THE GEOLOGY OF THE EQUINOX QUADRANGLE AND VICINITY, VERMONT

By

PHILIP C. HEWITT

With data on the Green Mountains
Section provided by Richard F. LaBrake

VERMONT GEOLOGICAL SURVEY

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ABSTRACT

The Equinox quadrangle and a small strip from its western boundary to the New York State line were mapped geologically. Three main sections were studied. From east to west they are the Green Mountains, Vermont Valley, and Taconic Range plus a small portion of the western low hills section. Formations studied range in age from pre-Cambrian to middle or upper Ordovician.

Gneisses and schists comprise the main part of the Green Mountain section. Lower Cambrian quartzites appear on its west-facing front. The remainder of the Cambrian section is in the Vermont Valley and is composed of interbedded dolomites and quartzites. Strata of the lower Ordovician are calcitic and dolomitic marbles. Middle and possibly upper Ordovician phyllites and marbles unconformably overlie the lower section. Although a purely western source has been postulated by other workers in the region, this does not appear to be necessary in view of the stratigraphic and sedimentologic conditions observed in most of the section. Some westerly derived sediments are, of course, likely. It is probable that several sources of sediments are needed to explain the thickening and coarsening of sediments and the great lateral lithologic variation.

Two episodes of metamorphism are indicated. The first episode involving only the pre-Cambrian rocks raised these to at least a medium grade. Later metamorphism of a low grade involved the Paleozoic strata also and caused retrogressive metamorphism in the pre-Cambrian section.

The major structural trend is N20°E. Two major fold systems, the Green Mountain anticlinorium and the Taconic synclinorium, are known.

Numerous folds of various magnitudes complicate the structural picture. Isoclinal and recumbent folding are common. Thrust faulting is present but, with a single exception, is difficult to map. Several cleavages and two directions of jointing are well known.

Several hypotheses are discussed and a new one proposed to explain the Taconic sequence. Evidence is presented that the "High Taconic" strata are the result of normal sequential deposition coupled with differential upwarp. It is suggested that the "High Taconics", Valley sequence and Green Mountains are thrust over a "Low Taconic" klippe. A complete discussion of the stratigraphy and the evidence which led to this hypothesis is given.

INTRODUCTION

Location

The Equinox quadrangle (longitude 73°00′ to 73°15′; latitude 43°00′ to 43°15′) in southwest Vermont constitutes the major area to be discussed in this report. The area east of the New York State line in the Cambridge, New York-Vermont quadrangle is also included. Figure 1 is an index map of the area.

Many good roads cross the area, the more important being Routes 7 (north-south) and 313 (east-west). In addition, excellent secondary and good dirt roads provide access to much of the region except that portion of the Green Mountains included in the Equinox quadrangle. One poor road crosses from East Arlington through these mountains to Wardsboro. Other than this no access roads are available.

Physiography

Physiographically, the Equinox quadrangle is composed of four distinctive zones. Three of these account for most of the area with the fourth involved only in a small portion of the northwest one-ninth.

The Green Mountains form the most easterly of the zones and covers about one-fourth of the quadrangle. Virtually all of the drainage in this portion of the Green Mountains is toward the Batten Kill River and, therefore, westward to the Hudson. Most streams rise in swamps or swampy ponds and, for at least part of their extent, they are heavily charged with organic debris. Heavy vegetative cover and few as well as poor roads makes access very difficult. Although relief within the Green Mountain portion is not over approximately 1,000 feet, dense vegetation creates difficult climbing conditions. Most of the hills have a maximum elevation close to or just over 3,000 feet with one, in the southeast, in Glastenbury township rising to over 3,440 feet.

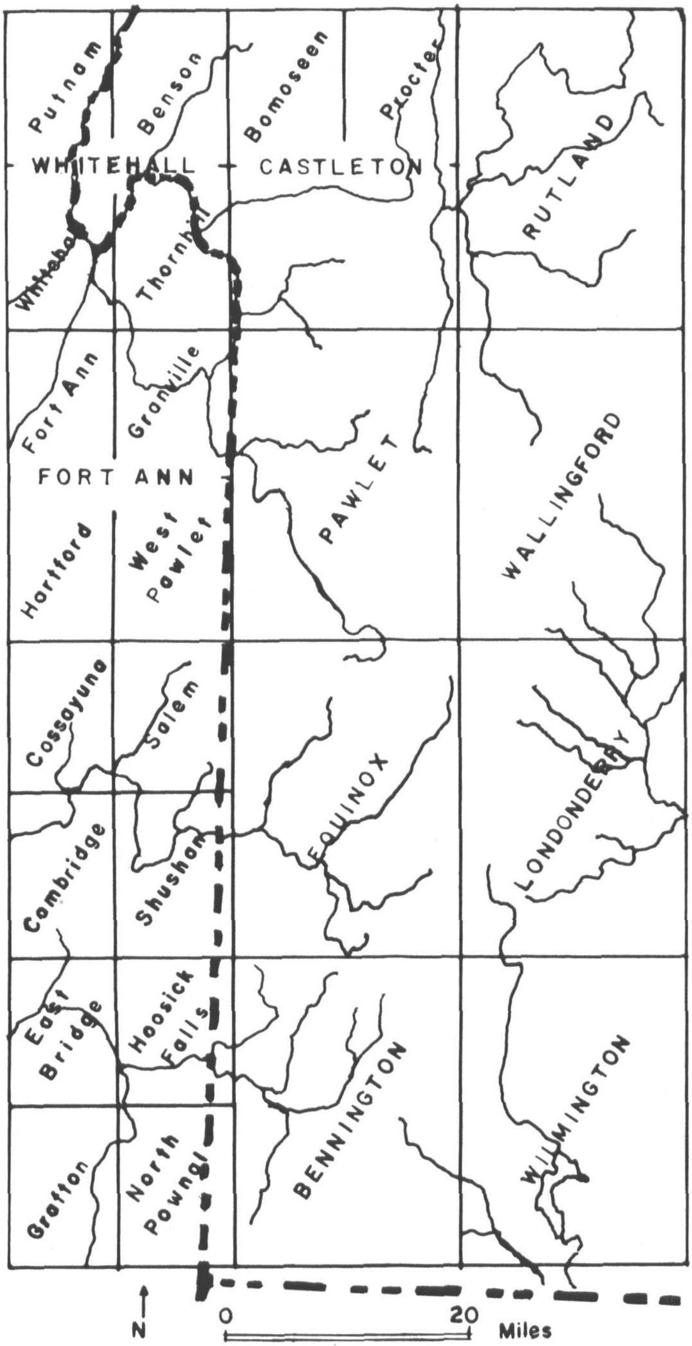


Figure 1. Index Map

The western front of these mountains forms a prominent scarp trending northeast and rising 1,500–2,000 feet above the floor of the Vermont Valley to the west. Fast flowing streams cut the scarp in many places, forming steep-walled valleys such as Downer Glen, Lye Brook Hollow, and valleys of Mill Brook and the Roaring Branch. The valleys and streams along the front are filled with large quartzite boulders, frequently the size of a large automobile. Small intermittent streams have begun headward erosion toward the east and strongly dissect the upper part of the west-facing front.

From a width of almost three miles at the south, the Vermont Valley, which is parallel to and west of the Green Mountain front, narrows to less than a mile in width at the north. In the vicinity of Arlington, the valley of the Batten Kill enters the Vermont Valley from the west. In the north the main valley appears to split with a broad branch of it turning northwest to Dorset. The Vermont Valley proper may be traced northward to the Champlain Valley. Elevations within the valley vary from 600 to 1,000 feet. In addition to the small hills dispersed throughout the valley, a persistent ridge trends parallel to and west of the Green Mountain front.

At the north end of the valley, between the Vermont Valley proper and the northwest trending branch which leads to Dorset, lies the first occurrence of the "High Taconics." Mt. Aeolus (Green Peak) and its associated hills appear as an anomalous elevated mass in an otherwise low lying area. West of the valley the major mass of the Taconic Mountains comprises the third physiographic zone. In this zone the relief is considerable. The highest elevation is that of Equinox Mountain (3,816 feet) with several other hills of well over 3,000 feet. With valley elevations at between 600 and 1,000 feet throughout these mountains, the relief is between 2,000 and 3,200 feet. Most of the drainage is toward the Batten Kill or its tributaries such as the Green River.

West of the Taconic Mountains lies a fourth zone, not easily separated from the third but of a somewhat different character. This is the low western hill topography similar to that of the Slate Belt. Elevations in this zone are only a few hundred feet above the valleys and produce a gently rolling topography. This is the area called the "Low Taconics."

Glaciation

The glacial geology of the Equinox area was not studied in detail. However, certain features should be mentioned since the glacial history is interesting and of considerable economic importance.

In both the Green Mountains and the Taconic Mountains the evidence of glaciation is primarily in the form of local erratics and small valley fill. Locally, along the flanks of the hills where marble was exposed to the action of the ice, long glacial grooving and striations may be observed. These are not seen in the higher portions of the Taconics since the hills are well vegetated and, in addition, the rocks at the highest elevations are phyllites which did not groove easily but were scraped evenly.

Several of the larger valleys in the mountain sections display plentiful evidence of glaciation. In the Green Mountains section large erratics are frequently found while in the valleys of the Taconics several excellent low level deltas may be observed. Generally, these are composed of poorly sorted material ranging in size from clay to cobble.

During deglaciation, the Vermont Valley was the site of a large proglacial lake. MacFadyen (1956) discussed the southern portion of the lake and commented on its origin. Such lakes, unable to drain southward due to morainal dams or other obstruction and prevented from northward drainage by the retreating ice, are not uncommon. Deltas formed by streams entering the lake are located on the lower flanks of the mountains which bordered the lake on the east and west of the valley. Several of the deltas are very well preserved and are over one hundred feet thick. The beds are well sorted and have been and are presently being used as sources of sand and gravel. Lenses of coarse material are interspersed through the exposed portion of several of these deltas.

A small well dissected kame terrace may be observed in the vicinity of the town of Manchester. Plate 2 is an overlay showing the location of the major glacial deposits in the Equinox area.

Purpose of Study

This study was undertaken primarily to produce a detailed geologic map of the Equinox quadrangle and the adjacent area west to the New York state line. In the process, structural and stratigraphic elements were studied carefully in order that any possible information regarding the "Taconic Problem" might be obtained.

Method of Study

The map (Plate 1) is the result of field study during the summers of 1957, 1958 and 1959. In an area as complex as the Equinox quadrangle, with all the problems involved in the single phrase the "Taconic Problem," five field seasons would have been preferred. Since this was not possible, a maximum time was spent on areas found to be critical to the problem.

The topographic map used as a base map for this study is the 15-

minute Equinox quadrangle sheet and that portion of the Cambridge, New York-Vermont map east of the state line. Both maps are on a scale of 1:62,500 and are highly inaccurate in certain localities. Several hills are totally missing and where certain valleys are shown on the map one finds no valley in evidence. Therefore aerial photographs were of inestimable assistance. Final formational boundaries and outcrop localities were located on the topographic map with great care for the geographic position regardless of the precise elevation shown on the map. In this way the data may later be transferred to the 7½ minute maps which are in the process of completion.

In the Green Mountain portion of the quadrangle the exposures away from the front were poor due to vegetative cover. Other parts of the area lacked exposure due to glacial deposits. However, sufficient control was available to map through in all cases. A transparent overlay has been provided (Plate 2) to show the areas of heavy glacial cover.

Regional Setting

The Equinox area is a complexly folded region in which three major divisions are obvious. In the east are the pre-Cambrian metamorphic rocks of the Green Mountains. Paleozoic quartzites and marbles lie on the west flank of these mountains and in the Vermont Valley. West of the valley is the Taconic Range composed of lower Paleozoic marbles and phyllites. Each of these is thoroughly discussed in this paper.

The Green Mountains pass northward beyond Burlington into Canada but the Taconic Range terminates in the vicinity of Brandon, Vermont. The Vermont Valley between the two mountain masses continues northward into the severely faulted Champlain Valley. West of the valley in the north, where the Taconic Range no longer can be observed, the lower Paleozoic sediments extend to the Adirondack mass. West of the Taconic Range in the south and central portions of the general area, lower Paleozoic sediments also may be traced to and around the southern flank of the Adirondack Mountains. East of the Green Mountains lie metamorphosed Cambro-Ordovician sediments.

An excellent, general discussion of the eastern New York-western New England region may be found in Billings, Thompson and Rodgers (1952).

Previous Work

The earliest reasonably detailed study of the geology of the area involved in this report was made by T. N. Dale (1912). Although on first inspection the scale of Dale's map appears wholly inadequate, the accuracy of much of the work is remarkable. Later studies by Gordon (1921, 1924) appear to be based on insufficient field examination and in some portions are quite erroneous. A more recent publication, though admittedly a reconnaissance study, was done by Billings, Thompson and Rodgers (1952) as a field guide. No other detailed studies of this region have been made.

Reports of workers in related areas have contributed to this investigation. Early comprehensive papers by Dale in 1892, 1894, 1899, 1904, and 1912 (above) provide much information of general interest. Emerson (1892) and Pumpelly, Wolff and Dale (1894) provided early study of the southern end of the Green Mountains. Prindle and Knopf (1932) added much data which included structural and stratigraphic studies of rocks directly south of the Equinox area, the northern part of which includes the present Bennington quadrangle. Their report included portions of the Green Mountains as well as the area to the west. More recently, and north of the area of this report, Brace (1953), Osberg (1959) and Thompson (1959) provided the latest information available.

Emmons (1842, 1844) proposed the term "Taconic System" to include certain strata in eastern New York, western Vermont and northwestern Massachusetts. Since that time, controversy has raged over these units. Dana (1877, 1887) and Walcott (1888) demonstrated that the use of the term as a system was invalid. This did not end the debate, since the origin, source and site of deposition of these rocks was in considerable doubt. An attempt was made by Keith (1912) to solve the problem of the seemingly anomalous position of the argillaceous rocks in contact with and in many localities overlying calcareous beds and, in other localities, in contact with other argillaceous strata of apparently similar character. He proposed that the north end of the Taconic Mountains were thrust in over the underlying beds. From this beginning the problem of the origin has swelled to immense proportions. Prindle and Knopf (1932) claimed that the anomalous rocks were part of a large thrust sheet. In this way the concept of the Taconic "klippe" was developed which required the use of the terms "autochthone" and "allochthone." This structural solution to a problem of sharply contrasting facies has been and is subject to serious question. Kay (1935, 1941), Knopf (1935) and others have extended the area covered by the supposed Taconic allochthone. Support for the concept of the thrust has been provided by investigations at the north end of the Taconic Range by Kaiser (1945), Cady (1945), and Fowler (1950). More recent studies by Shumaker (1959) and Zen (1959) utilize the idea of the klippe.

On the other hand, Bain (1938) and Balk (1953) rejected the over-thrust on the basis of structural evidence from widely separated areas. Bucher (1957), Craddock (1957) and Weaver (1957) completely reviewed the entire problem and discussed much of the literature. Results of their studies in New York indicated that gradational contacts and facies changes were in evidence in that region and they rejected the need for a thrust. MacFadyen (1956) in the Bennington quadrangle south of the Equinox area recognized an unconformity in certain localities between the carbonates and the argillaceous beds overlying them. In other localities he noted that the contact between these two units appeared to be gradational.

Keith (1932) and Cady (1945) studied the carbonates in the Champlain Valley and vicinity and provided the stratigraphic sequence which is closely followed in this paper.

Acknowledgments

The entire mapping project was financed by the Vermont Geological Survey headed by Dr. Charles G. Doll. For this and for his willingness to accompany me over rugged terrain to observe and discuss interesting phenomena, I am deeply grateful. My thanks are due also to Dr. James B. Thompson, Jr., who spent several days with me in the field in each of the summers involved in the study and with whom I mapped our mutual boundary at the northeast and north central part of the quadrangle. Robert C. Shumaker accompanied me in our early investigation and in mapping part of our mutual boundary in the northwest. Discussions with Shumaker, Dr. E-An Zen, Professor George Theokritoff and other workers in Vermont and adjacent areas in New York were most helpful. I want to express my gratitude to Dr. Joseph G. Davidson of Equinox Mountain who graciously gave me and my assistants full and free access to the mountain and who in many ways demonstrated his interest in the study. To Mr. Edwin L. Bigelow of Manchester, Vermont, goes a special word of thanks for leading me to particular localities of note and for his help throughout the three years.

I wish to express my appreciation to my field assistants John L. Fauth and Richard F. LaBrake. During the summer of 1959, John Fauth assisted me throughout the area and worked independently in parts of the southwest portion of the area. It is impossible to express fully my gratitude to Richard LaBrake who assisted me during the summers of 1958 and 1959 and independently mapped the Green Mountain portion of the Equinox quadrangle. His work was done in partial fulfillment of the requirements for the Master's degree at Rensselaer Polytechnic Institute.

In this paper, data for those sections involving the area of the Green Mountains were provided by Mr. LaBrake and a report was submitted by him to me. Data from this report have been incorporated into this paper. Full credit for this work is due him. His careful independent study contributed vitally to this report.

Several student assistants at Union College also helped in the project. Kenneth O. Hasson helped prepare some of the thin sections for study. Lawrence I. Benson prepared sections and helped with drafting and photography. M. Raymond Buyce also assisted me in some preliminary drafting.

Finally, to Dr. Leo M. Hall presently with the New York State Science Service and my future colleague at Union College, go my thanks for reading and commenting on arguments presented in this paper.

STRATIGRAPHY

General Statement

Four lithologic groupings may be observed in the Equinox area. These correspond to the topographic divisions discussed earlier. Figure 2 shows the probable correlation of the strata.

In the Green Mountains, pre-Cambrian basement rocks assigned to the Mount Holly complex (Whittle, 1894) are overlain to the west by formations of lower Cambrian age. No fossils were found and correlation must be based on evidence from other localities which have identifiable units of similar lithology. Fairly reliable reports of fossils from those localities adequately establish that the Cheshire formation is of lower Cambrian age. No evidence of the age of the Mendon formation is available and as many workers have included the Mendon with the pre-Cambrian as with the lower Cambrian. The apparent conformable relationship between the Cheshire quartzite and the Moosalamoo phyllite member of the Mendon formation suggests a lower Cambrian age.

West of the Green Mountains, in the Vermont Valley, is a thick section of Cambrian quartzites and dolomites and Ordovician dolomitic and calcitic marbles with interbedded gray and black phyllites. Fossils are rare and are found only high in the section. In only one case could a reasonable identification be made. Most of the paleontologic evidence has been destroyed by later metamorphism. Fossils are mainly highly fragmental and even the fragments are badly recrystallized. The best that can be said of the units involved in the Vermont Valley is that the higher ones are Ordovician and probably Trenton in age. No fossils have been found in the Equinox quadrangle in the lower part of the sequence. These units have, however, been traced from other areas where the paleontologic evidence is strong.

The greater part of the Taconic Range is composed of green, gray, and black phyllites. The age of these units cannot be demonstrated on paleontologic grounds. No fossils have been found in these strata nor is it likely that any will be found, with the possible exception being in the dark marbles which are located at or near the basal contact with the underlying Ordovician marbles. Other evidence of the probable age of the phyllites is available and will be presented in the appropriate section. The age of these rocks is of considerable importance since it is involved in the "Taconic Problem."

West of the Taconic Range, in the northwest part of the Equinox area, are olive and green slates with some occurrences of red and purple slates which are separated sharply from the phyllites to the east. These units may be closely correlated with lower Cambrian and lower (middle?) Ordovician units since fossils have been found in areas in the near vicinity. The formations may be traced easily from the fossil localities. It is the supposed similarity of the lower Cambrian rocks of this sequence with the argillaceous rocks of the Taconic Range that has created so much interest.

It is well accepted that a formation is a mappable unit. Several lithologies in the Equinox area can be traced only a short distance. Others become too thin to be displayed graphically. Also, the reappearance of the same material higher in the sequence demonstrates the danger of mapping only on the basis of lithologic similarity and without consideration of the stratigraphic sequence. In this study the units in the area were identified and mapped on both position in the sequence and on lithologic similarity. Correlations are based on fossil evidence where available, and in beds in which this has proved impossible, age assignments are made with reference to units of the same lithology and position in the sequence in the north where correlation is more certain. Table 1 lists the units studied.

Thicknesses of the various formations are given as closely as possible. There is, however, no certainty that they are more than reasonably accurate since the folding is intense and few key beds are available to assist the field worker in proper measurement. Isoclinal folding complicates the problem. Therefore, the thicknesses are compromise figures resulting from measured sections in part and calculations based on width of outcrop, topography and knowledge of the isoclinal nature of the folding.

TABLE 1

LIST OF FORMATIONS

Period	Formation	Thickness (in feet)
Middle Ordovician	Mount Anthony formation	600–800
	(May be unconformity within this unit)	
	(In NW; Poultney formation, 100^- feet)	
	Unconformity	
Lower Ordovician	Bascom-Beldens formations	400^+
	Shelburne formation	
	Columbian marble member	200^+
	Intermediate dolomite member	150
	Sutherland Falls member	100
Upper Cambrian	Danby-Clarendon Springs formations	300
Lower or Middle Cambrian	Winooski dolomite	300^+
Lower Cambrian	Monkton quartzite	$300^\pm$
	Dunham dolomite } ? Mettawee in NW	800–900
	Cheshire quartzite } ? $200^\pm$	800
	Mendon formation	
	Moosalamoo member	300
	Nickwacket member	200
	Unconformity	
pre-Cambrian	Mt. Holly Complex	Unknown

Pre-Cambrian Sequence

MT. HOLLY COMPLEX (Whittle, 1894)

Schists, gneisses, and quartzites of varying composition and thickness characterize the Mt. Holly Complex. A light gray and green banded actinolite schist is typical of the formation in most of the exposures observed. This lithology appears to grade into a uniformly gray, fine-banded quartz-biotite-chlorite schist which contains small grains or porphyroblasts of albite. The chlorite is present in minute bands which locally outline augen of larger albite masses. The biotite generally occurs in small grains. Occasional larger grains are segregated into lenses or bands several centimeters in width. This is believed due to local differences in the percentages of the original mineral constituents.

Quartzites of the Mount Holly are generally gray, massive, highly contorted rocks. Minor amounts of garnet, epidote, chlorite, muscovite, tourmaline and iron oxide (as an alteration product) are generally present. Small pegmatite veins cut the otherwise massive bedding of the quartzite along joints or other zones of weakness. Blue quartz beds up to one foot thick are present locally. Sheared blue-gray quartzite beds were observed which may have been derived from the massive blue quartzites in response to folding. The sheared unit contains some biotite, feldspar, and chlorite, but is primarily composed of quartz grains up to 2 millimeters in maximum dimension contained in a matrix which is chiefly finely crushed (?) quartz and feldspar.

Also typical of the Mount Holly is a unit composed of quartz and bands of pink microcline with biotite which represents the quartz-biotite-microcline gneiss reported to be a common rock type elsewhere in Vermont and well known from the Bennington quadrangle (MacFadyen, 1956; Prindle and Knopf, 1932). The bands vary in thickness but are generally several inches wide.

Light green talc-tremolite schist occurs within the quartzite outcrops along the Roaring Branch west of Kelly Stand. These may represent altered limestones within the massive quartzite. However, only one good exposure was observed. The origin is therefore difficult to determine.

Rocks belonging to the basement complex appear to be confined to the wide area east of the Green Mountain front. Good exposures of the Mount Holly may be observed along the courses of the main streams which drain the upland east of the escarpment. Scattered exposures indicate that all of the area north and south of Lye Brook Meadows, and the meadow area itself are underlain by crystalline rocks of the Mt. Holly Complex. The pre-Cambrian in the Equinox quadrangle reaches its maximum width in the township of Glastenbury. The western-most outcrop is located along the Roaring Branch in the township of Sunderland. The thickness is unknown but is probably considerable.

Lower Cambrian Sequence

MENDON FORMATION (Whittle 1894)

The Mendon formation overlies the pre-Cambrian unconformity and represents the first Cambrian deposits to be considered. Two members comprise this formation. These are the lower Nickwacket member and the overlying Moosalamoo member.

Nickwacket member: Conglomeratic quartz schist, gritty quartz-muscovite schist, chlorite schist and graywacke are found in the Nickwacket member which overlies the quartzites and gneisses of the pre-Cambrian. Deformation of the contact has produced a complicated relationship with the underlying rocks with which these strata easily may be confused. The mineralogy is essentially the same, which further adds to the complication. However, where the thick conglomerate unit is present, as in Lye Brook east of the front at elevation 1,600 feet, the contact may be determined fairly well.

The Nickwacket contains much more coarse material than is found in the overlying Moosalamoo phyllite. It is typically a light gray, gritty rock with thin conglomerate layers of blue quartz pebbles 2 to 3 millimeters in diameter. In the Nickwacket magnetite and pyrite are abundant locally and cause the gray and buff color on the fresh surface.

Moosalamoo member: The Moosalamoo is primarily a black, graphitic quartz-muscovite phyllite. In the upper part of the formation this member contains lenses of dark quartzite interbedded with the black phyllite. A peculiar golden brown weathering product was observed south of Mill Brook along the escarpment. Here the phyllite is predominantly dark gray or black and is interbedded with the overlying Cheshire quartzite through a fairly narrow transition zone.

Much of the area west of the pre-Cambrian along the Green Mountain front is underlain by the Nickwacket and Moosalamoo members of the Mendon formation. The Mendon is equivalent to the Dalton formation (Emerson, 1892) of Massachusetts. The Moosalamoo member is exposed in a narrow belt along the front and may also be seen above the Nickwacket member east of the front. The Nickwacket is usually observed in close proximity to the pre-Cambrian from which it is separated by an irregular, lens-like bed of coarse conglomerate.

The Mendon formation is about 500 feet thick with about 200 feet assigned to the Nickwacket and 300 feet to the Moosalamoo.

Cheshire Quartzite (Emerson, 1892)

The quartzite of the Cheshire is typically light gray to white, massive-bedded pure, recrystallized quartz sandstone. In the lower part of the formation feldspar and ankerite percentages increase and bedding is less massive. Individual grains are easier to recognize in the lower beds which, along the bedding planes, are schistose and pale green in color. Original sedimentary features are difficult to recognize due to recrystallization. However, some cross-bedding was observed in the upper part of the formation. Although no fossils were observed in this unit in the Equinox quadrangle, MacFadyen (1956, p. 21) reported *Scolithus* north of Bennington, Vermont, and listed *Olenellus, Hyolithes* and *Nothozoe* as observed by Walcott (1888, p. 288) and others.

Near the lower contact, the Cheshire is phyllitic and appears to be gradational with the underlying Moosalamoo. The best exposure of the contact is south of Mill Brook at an elevation of approximately 1,200 feet. Beds of dark quartzite may be seen several feet below the contact and within the phyllite, while directly above this zone is the typical white massive quartzite with minor amounts of phyllitic partings along the bedding which dips 70° west. The interbedded zone may be observed southward for about half a mile. The fold which brought the underlying phyllite into exposure along the front dies out southward where the contact is no longer exposed. A similar relationship exists north of Mill Brook. However, the outcrop is mainly Cheshire quartzite with minor beds of phyllite.

The transition of the Cheshire into the overlying lower Cambrian Dunham dolomite takes place through a zone of interbedded dolomites and white dolomitic quartzites. The contact is exposed in the valley at the foot of the escarpment adjacent to Lye Brook and along the Roaring Branch at the foot of "Catamount Cobble." At this locality only the rotten weathering dolomitic quartzites are exposed, whereas at the Lye Brook exposure the lower dark gray dolomite of the Dunham formation may be seen overlying the Cheshire formation. Elsewhere along the front the contact was not observed due to glacial and recent alluvial cover.

Dunham Dolomite (Clark, 1934)

In the Equinox area the Dunham dolomite is very similar in character to the same unit to the north and south. It is a highly variable formation consisting primarily of thick- to medium-bedded gray to cream or buff dolomites which characteristically weather to a yellow or orange color. The dolomites are sandy in the upper part of the Dunham and the Mallett member at the upper contact contains thick cross-bedded dolomitic sandstones or sandy dolomites up to ten feet thick. When weathered, the Mallett member is reddish-orange in color and is quite soft. Quartzite beds a few inches thick are found in the middle of the formation. These are generally gray and tan, mottled, dirty quartzites which are as much as a foot thick toward the top of the formation. In appearance these uppermost quartzites closely resemble the quartzites of the Monkton formation.

Although the contact of the Dunham with the overlying Monkton is gradational, and the lower Monkton contains some thick bedded dolomites similar to those of the Dunham, the Mallett member may be utilized to separate these units. Also the predominance of dolomites over quartzites in the Dunham is usually diagnostic.

Gray to gray-green phyllitic partings are common in the Dunham. This is far from being definitive since most of the Cambrian formations of the Vermont Valley have partings of the same type.

Cross-bedding in the Dunham sandy dolomites, particularly at the top of the formation in the Mallett member, may be utilized as a top and bottom criterion. These sand beds are far thicker than similar strata in the Winooski dolomite but the only safe means of differentiation is the relative position in the stratigraphic column as determined by the sequence.

No fossils were found in the Dunham of the Equinox area. However, in the vicinity of Rutland, Wolff (1891) and Foerste (1893) found early Cambrian fossils (*Salterella, Kutorgina*) and the formation may be traced to that area.

The Dunham is very well exposed in the Equinox area. New road cuts for the widening of U.S. Route 7 have provided fresh exposures. West of this well travelled road, in the northern part of the quadrangle, an excellent series of outcrops may be observed. In the central part of the area the best exposures are on the small hills immediately east of U.S. Route 7. In the south, the Dunham may be seen in the low hills east of the town of Shaftsbury.

Thicknesses reported for the Dunham are on the order of 1,000 feet. In the Equinox area it appears that no more than 800–900 feet can be attributed to this formation.

Monkton Quartzite (Keith, 1923)

The Monkton quartzite is composed of slightly greenish-gray quartzites in beds up to three feet thick interbedded with yellow or orange weathering gray or buff dolomites. Much of the dolomite is sandy. The weathered surface of these beds is often soft and of a deep red color. The quartzites are, in general, dolomitic and often show a mottling similar to that of the Dunham. A few clean quartzites a foot or two thick also may be found. Gray, greenish-gray and black phyllite partings are minor lithologic types in the Monkton. Although cross-bedding and ripple marks have been reported from the Monkton (Thompson, 1959, p. 76) these are rare in the Equinox area.

According to MacFadyen (1956, p. 22) the quartzites are much thinner in the Bennington area than they are to the north. He reported dolomitic sandstones as well as sandy dolomites. In mapping the northern part of the Maple Hill thrust in the south-central part of the quadrangle it was necessary to re-map a small portion of the summit of Maple Hill in the Bennington quadrangle. At that locality at least, the Monkton has maintained its lithology as predominantly a quartzite although the beds are not over 14 inches thick. They are, however, quite dirty and sandy, having lost the greenish-gray color which is characteristic a few miles to the north. The same statements are true for much of the Equinox area, since the color change is apparent though not consistent in the north-south direction. It is probable that the color is more variable in the southerly direction. The increase in the quantity of dolomite to the south is unquestioned. In many localities it becomes difficult to differentiate the Monkton from the dolomites above and below it. Fortunately, the Mallett member of the Dunham dolomite is an excellent marker throughout the quadrangle and a few distinctive quartzite beds in the Monkton made it possible to map this unit with a high degree of accuracy.

No fossils were found in the Monkton quartzite in the Equinox area. Plentiful evidence of the lower Cambrian age has been reported by Kindle and Tasch (1948) from an area more than 70 miles to the north. Long range correlation such as this is at best unsatisfactory. However, the unit may be traced from that locality and its stratigraphic position remains consistent over this wide area. It is reasonable to accept the lower Cambrian age of this formation.

In the Castleton area Fowler (1950, p. 20) reported a thickness of 250 feet in the north and stated that the formation thinned to the south and east. In a table of formations, Brace (1953, p. 29) indicated a thickness of between 400 and 800 feet. MacFadyen (1956, p. 23) found 1,000 feet of Monkton but this thickness seems excessive in view of the intense folding. Osberg (1959, p. 46) considered the thickness in the Coxe Mountain area to be 50 to 100 feet. Thompson (1959, p. 76) provided a figure of 300 feet for the thickness of the Monkton. In the Equinox area the precise thickness cannot be determined. The formation appears to decrease in thickness from about 300 feet in the north to about 200 feet in the south. The Monkton quartzite in the Equinox quadrangle is best exposed on the hills immediately west of U.S. Route 7 in the northern part of the area, on the several small hills east of U.S. Route 7 in the central part and in the south, extensive outcrops appear in the region east and northeast of Shaftsbury in the Shaftsbury anticline, and along the east side of the Maple Hill thrust.

METTAWEE SLATE (Cushing and Ruedemann, 1914)

The Mettawee is a light or olive green and purple slate. Quartzites are reported from other areas (Fowler, 1950, p. 47) but they are not found in the slates in the Equinox quadrangle. Limestone conglomerate or pinched-out limestone stringers occur in the lower part of the slates. The Mettawee is the same as division B of Dale's (1899) slate study.

In the Equinox area the green slate predominates although purple beds are not uncommon. The color change is quite abrupt both laterally and vertically with some specimens showing purple on one side and green on the other.

Characteristically, the Mettawee in this area weathers to small irregular chips and develops a thin clay soil. Bedding in this formation is difficult to detect.

Fossils were not observed in this unit. North of the boundary with the Pawlet quadrangle, in the Rupert area, lower Cambrian fossils have been reported by Dale (1899). Shumaker (oral communication) also reported probable lower Cambrian fossils from this area. This formation is probably equivalent in age to the Cheshire or Dunham in the east. The precise position is uncertain.

Fowler (1950, p. 49) reported 100 to 300 feet of the Mettawee in the Castleton area. Zen (1959, p. 1) did not include a thickness for the Mettawee member of his Bull formation. In the Equinox area not over 200 feet of the Mettawee is exposed. Erosion has probably removed much of the upper part since not all of the known lithologies are present in this area. Furthermore, the base of the unit was not observed.

The Mettawee is exposed in the northwest part of the quadrangle in and around the town of West Rupert.

Lower or Middle Cambrian

WINOOSKI DOLOMITE (Cady, 1945)

As used in this paper, the name Winooski refers to the revised description by Cady (1945) rather than the original definition by Hitchcock (1861). In the Equinox quadrangle the Winooski is a medium- to thin-bedded, gray to cream or pinkish dolomite which is orange to red on the weathered surface. The Winooski strongly resembles the Dunham except that the bedding of the Winooski is not as thick. Dolomitic quartzites which weather to a rusty color are intercalated between beds of dolomite. Toward the contact with the overlying Danby formation, the quartzites become cleaner and they resemble the quartzites of that unit. Both the upper contact with the Danby and the lower contact with the Monkton are gradational. Outcrops of Winooski dolomite are easily confused with the Dunham. The only certain distinction is in stratigraphic position. On this basis the Winooski lies above the distinctive quartzites of the Monkton which are easily identified by their position above the Mallett member of the Dunham dolomite. The upper boundary is placed at the first appearance of the clean, typical Danby quartzites.

The age of the Winooski dolomite is in some question. Fowler (1950, p. 21) and MacFadyen (1956, p. 23) have discussed the problem. No fossils have been found in this formation. The age may be either early or middle Cambrian but there is at present no means for properly assigning an age to this unit. It is completely possible that the Winooski includes the last event in the early Cambrian and all of the middle Cambrian as well. The lower contact with the Monkton is gradational, as is the upper contact with the Danby formation. If an unconformity exists in the Winooski itself, it is not evident in the Equinox area. Therefore, in this report the Winooski is considered to be questionably of lower or middle Cambrian age.

Various thicknesses have been given for this formation. Fowler (1950, p. 21) found the Winooski to be from 1,050 to 1,200 feet thick in the Castleton quadrangle. Brace (1953, p. 38) and MacFadyen (1956, p. 23) indicate the thickness to be 600 to 700 feet, respectively. The thickness in the Equinox quadrangle corresponds closely to that given by Thompson (1959, p. 76). Not over 400 feet are exposed in the area and this figure is probably high. It is suggested that a thickness of 300 feet is more nearly accurate.

Although the Winooski is well exposed elsewhere in the quadrangle, the best outcrops are on the several hills within the Vermont Valley and on the east flank of the Shaftsbury anticline.

Upper Cambrian

DANBY FORMATION (Keith, 1932; Cady, 1945)—CLARENDON SPRINGS DOLOMITE (Keith, 1932)

Although it is possible to distinquish the two formations in the Equinox quadrangle, the scale of the base map and the lack of sufficient thickness to the Danby formation prevents graphic representation of the individual units. Also, certain similarities between the two formations enable them to be discussed as a single mappable unit.

The lower part of this combined unit, the Danby formation, is distinguishable by clean, white to gray, vitreous quartzite beds three or four feet thick. These occur mainly near the base of the Danby. Interbedded with and above these quartzites are gray calcitic dolomites. In addition to the calcitic dolomites, sandy dolomites occur in the upper part of the Danby.

No fossils were found in the Danby in the Equinox area nor have any identifiable organic remains been found in this unit in Vermont.

The thickness of the Danby portion of the combined unit is not over 50 feet. MacFadyen (1956, p. 24) reported a thickness of less than 300 feet for the Danby in the Bennington quadrangle. According to Fowler (1950, p. 23) and others, this formation becomes thicker (700 feet) in the north. However, Thompson (1959, p. 76) published a thickness of between 50 to 100 feet.

The upper part of the combined unit, the Clarendon Springs formation, is composed of gray dolomite beds a foot or more thick which, in some localities, are calcitic. Near the base thin sandy dolomites grade into similar beds in the underlying Danby. Fowler (1950, p. 23) described the dolomites as massive and iron gray in color. This description seems quite usable also in the northern part of the Equinox quadrangle.

Knots and veins of milky quartz are common in the upper part of the Clarendon Springs. In addition, the upper part contains irregularly distributed dark chert. The dolomites weather to a medium to dark gray color. MacFadyen (1956, p. 24), in discussing the quartz and chert-bearing strata, stated, "These beds in weathered outcrop or float present a highly scoriaceous appearance due to the removal of the dolomite in solution." The feature is well exposed in the fields 1 to 2 miles south and west of Manchester.

MacFadyen (1956, p. 25) reported about 1,300 feet of this formation in the Bennington area. In the north the thickness of the Clarendon Springs appears to be 250 feet or less (Fowler, 1950, p. 24; Brace, 1953, p. 38; Thompson, 1959, p. 75) and this figure seems adequate in the Equinox area.

The age of the Danby-Clarendon Springs is probably late Cambrian. Correlation is difficult since no fossil evidence has been found in these beds in Vermont. However, on the basis of lithology and the tracing of these units into areas where evidence is stronger, Cady (1945, pp. 535–539) assigns these to the late Cambrian.

The Danby-Clarendon Springs outcrops on the west and east sides of U.S. Route 7 between Arlington and Manchester. In the central part of the quadrangle the Danby-Clarendon Springs is well exposed on the west side of the hill south of Mud Road, and on the north side of the hill and in the Roaring Branch northeast of the junction of routes U.S. 7 and 313 in Arlington.

Lower Ordovician

SHELBURNE FORMATION (Cady, 1945)

The Shelburne formation contains the lowest Ordovician strata in the area studied. Formerly considered to be of lower Cambrian age (Schuchert, 1933), the Shelburne was correlated with the Beekmantown B of Brainard and Seely (1890, pp. 2–3) by Cady (1945, p. 539).

The Shelburne formation was divided into three members (Bain, 1931) and these are easily recognized in the Equinox quadrangle. The members of this formation are, in ascending order:

Sutherland Falls member: The lowest member of the Shelburne formation is composed of beds of creamy to white calcite marble in beds from 1 to 3 or 4 feet thick. Chloritic and actinolitic streaks are common and, with occasional clusters of pyrite and hematite, the color variation within this unit is extremely attractive and therefore commercially important. Gray calcitic marble which is a very minor lithology in the north increases in quantity southward. Chainlike clusters of dolomite crystals, described by Thompson (1959, p. 75) as "dolomitic curdling" have been observed but are not common in the area. The thickness of this member is approximately 100 feet.

Intermediate dolomite member: The Intermediate dolomite resembles the Clarendon Springs in many respects except that its position between two white marbles is diagnostic. This member is a light to medium gray, thick bedded dolomite, with some milky quartz knots and a few sandy beds. In some localities white calcite marble occurs in patches as much as 10 feet thick within the mass of the dolomite. The Intermediate dolomite member is about 150 feet thick.

Columbian marble member: Clean white calcite marble characterizes this member. As in the Sutherland Falls member, streaks of chlorite, actinolite, pyrite and hematite are common. Beds are often over 6 feet thick. In addition to the white marble, a small quantity of gray marble occurs particularly near the top of the unit. The gray marble increases in quantity to the south, becoming more important than the white in the area northwest of Arlington. It is still distinguishable from the overlying blue-gray marbles, however, by its true gray color. On the weathered surface it is far less sandy than the overlying strata. The upper contact is not simple to map in the central and south part of the area since it is infolded with the overlying unit and either may contain beds of white calcite. The Columbian marble is approximately 200–250 feet thick.

The Shelburne formation is well recognized to the north (Fowler, 1950, pp. 24–27; Thompson, 1959, p. 75) although Fowler used the name Boardman formation for these strata. MacFadyen (1956, pp. 25, 26) combined all the units of the lower Ordovician and called them the Canadian limestone. These include considerably more than the Shelburne formation. Probably the explanation for MacFadyen's difficulty in separating the Canadian units lies in the fact that the marbles of the Shelburne become predominantly gray and dirty toward the southern boundary of the Equinox quadrangle. However, some white marble can be traced across the boundary into the Bennington quadrangle.

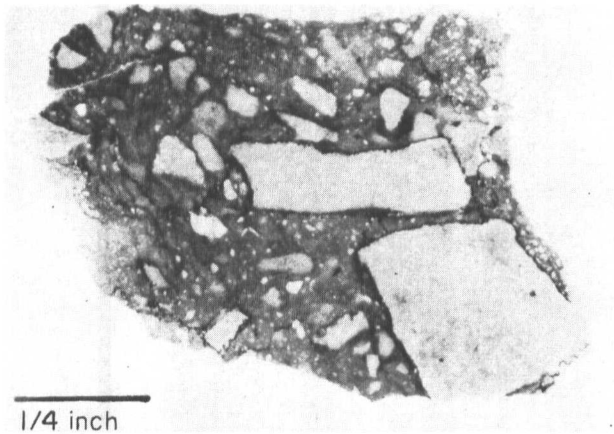
Paleontologic evidence provides only a weak correlation. Although no fossils were found in this formation in the Equinox area, Cady's correlation with the Beekmantown B horizon is accepted.

The Shelburne formation is well exposed from the north boundary of the quadrangle at Mt. Aeolus (Green Peak, Owl Head, etc.) to and along the east flank of the Taconic Mountains, and on the west side of a few of the hills occurring within the Vermont Valley. The best exposures are, of course, in the numerous quarries on and in the vicinity of Mt. Aeolus and South Dorset.

On the east side of Mt. Equinox, at an elevation of about 900 feet and located approximately half a mile north of the Sunderland town line, is a small quarry exposing a calcite marble breccia cemented by red, hematitic marble (Plate 3). Angular fragments of pinkish, blue-gray and gray marble make up most of the brecciated material. This is the location noted by Dale (1912, pp. 48, 49, 97–98) and is known as the Dyer Quarry. Dale also noted rare microcline in the breccia. The same material is seen at the southeast corner of Equinox Pond about 2 miles north of the Dyer Quarry. A further discussion of the Dyer Quarry breccia is reserved for the section on structural geology.

Bascom-Beldens Formations (Cady, 1945)

Although Cady (1945) distinguished several formations above the Shelburne and below the Trenton limestones, this is not possible in the Equinox area. In the present study it is impossible to utilize the



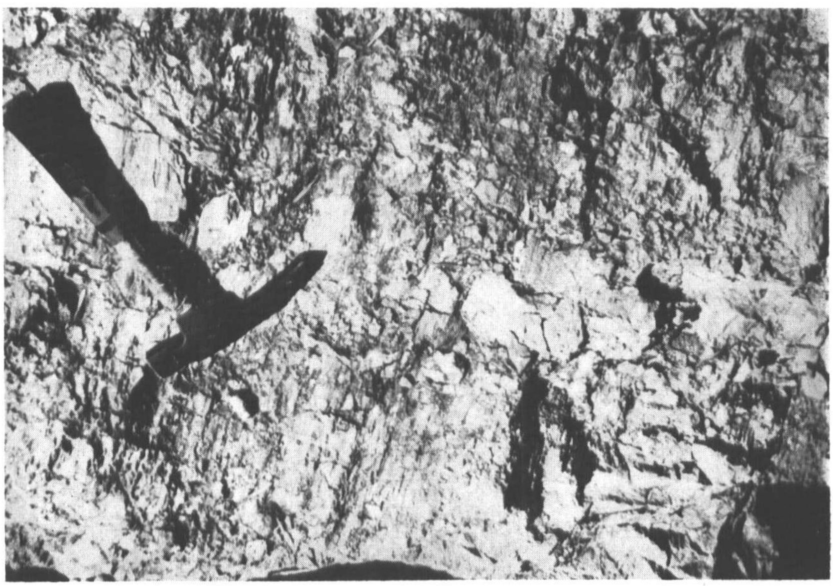


PLATE 3. Dyer Quarry Breccia.

Figure 1. Enlargement of small section.

Figure 2. Typical block of breccia.

criteria found in the north. Therefore, all lithologies from the Bascom through the Beldens formation are considered as a single unit. Although all of the rock types found in the north may be observed in the Equinox quadrangle, it is impossible to differentiate and map them as separate formations due to the extreme degree of folding and to the fact that several supposedly distinctive characteristics are found throughout the vertical extent of these strata.

The Bascom has been described primarily as a blue-gray calcite marble with interbedded white calcite marble. Banding is occasionally observed. Dolomite beds occur in the Bascom as do thin beds of dark gray or black phyllites. Some of the lower blue-gray marble beds are sandy.

The description of the Beldens formation is quite similar to that of the Bascom. In the Castleton quadrangle, Fowler (1950, pp. 29, 30) reported the Beldens, which is 200 feet thick, as a "cream-colored and white-weathering white and blue-gray marble streaked with green." In the Equinox area the green streaks are found in the white calcite marbles. Chlorite is the primary mineral causing the streaks with some sericitic material mixed with it. A few of the marble beds are sandy. Blue-gray dolomite beds a few feet thick weather to a tan, gray or orange color and frequently have weathered surfaces described as appearing like "thread-scored beeswax" or "chamois weathering" (see Cady, 1945, p. 550). Fowler (1950, p. 29) observed a similar occurrence.

In the Equinox quadrangle the dolomite with the "thread-scored beeswax" appearance is not confined to the higher beds but may be found at any position in the blue-gray and white marble sequence. In the absence of any good diagnostic criteria with which to separate the Bascom from the Beldens they are mapped as a unit.

The Burchards limestone (Kay and Cady, 1947) was reported by Fowler (1950, p. 28) as lying between the Bascom and the Beldens in the Castleton area. No means was found to distinguish this formation in the area studied. It is probable, however, that equivalent strata are present since similar lithologic types are found throughout the marble sequence studied.

The distinctions between the Bascom-Beldens and the upper part of the Shelburne appear to be a matter of quantity of white as opposed to blue-gray marble. Without large exposures of typical white Shelburne (Columbian) marble, it is not a simple matter to differentiate these formations. Therefore, the precise nature of the lower contact of the Bascom-Beldens is unknown. It appears likely, however, that the contact is gradational.

The upper contact of the combined Bascom-Beldens is equally difficult to place. In this case both the Bascom-Beldens and the marbles at the base of the Mount Anthony formation are similar. Distinctions are based on black phyllites, calcitic quartzites and at particular outcrops, fragmentary fossils which are found in the marbles of the lower Mount Anthony. A full consideration of this problem will be found in the section concerned with the Mount Anthony formation.

Since the contact of the Bascom-Beldens with the overlying marbles is not sharp or easily distinguished, it is possible that some of these marbles have been mapped with the Bascom-Beldens.

Further difficulty lies in the problem of correlation of these beds. The Bascom has been correlated with the upper Beekmantown (Cady, 1945, pp. 542–545) while the Beldens is considered to be equivalent to at least part of the Chazyan (Cady, 1945, pp. 550–552). Faunal evidence is entirely lacking from the Bascom lithology in the Equinox quadrangle. Fossils similar to those of the Ira formation are found in a few localities in marbles near the base of the Mount Anthony formation. These are probably of Trenton age and are younger than the assignment usually given to the Beldens. They are therefore mapped with the Mount Anthony formation as noted in the discussion of that unit.

The Bascom-Beldens is generally as much as 400 to 500 feet thick. Accurate measurements are not possible in these beds. The constant repetition of beds through strong recumbent folding in the absence of useful key beds makes it impossible to provide a more accurate figure for the thickness. In addition the unit thins and in one locality is completely missing, probably due to early or mid-Trenton erosion. North of this locality on Mt. Aeolus (Green Peak), the unit reappears and soon thickens to its usual dimensions.

If the total thickness of the Bascom-Beldens and the intervening Burchards is considered, the thickness is far greater in the north. Fowler (1950, pp. 28–30) reported about 850 feet for the thickness of these three units. Thompson (1959, p. 75) did not record the presence of the Burchards. However, his thickness for the Bascom and Beldens formation is a maximum of 450 feet. In the south no comparable figure is possible since MacFadyen (1956, pp. 25, 26) included these in the undifferentiated Canadian limestone.

Exposures of the Bascom-Beldens are found throughout the west side of the Vermont Valley and on the lower part of the eastern flank of the Taconic Range. With the exception of a small portion of the northeast part of Mt. Aeolus (Green Peak) these strata are continu-

PLATE 4. Folds in Bascom-Beldens formation.

Figure 1. Nearly recumbent fold between Arlington and West Arlington on Route 313.

Figure 2. Close view of same fold.

ously exposed in a broad strip from the north to the south boundary of the quadrangle. The Bascom-Beldens sequence, contorted into strong recumbent folds, may be observed in detail along Route 313 from about one mile west of Arlington to about one-third of a mile west of West Arlington (Plate 4, figures 1, 2).

Middle Ordovician

MOUNT ANTHONY FORMATION (MacFadyen, 1956)

MacFadyen (1956, pp. 28, 29) defined this unit as the gray to green "argillaceous-schistose rocks overlying the Walloomsac slate in the Bennington area." In addition he described the lithology as "altered argillite and sandy argillite" with lenses of dolomite and limestone. In his map explanation, MacFadyen also included black phyllite within the Mount Anthony although this is not mentioned in the text description of this formation. In the western part of the Bennington area the formation was described as a schist of sericite and chlorite with frequent occurrences of chloritoid, while to the east, chlorite-biotite schist predominates (MacFadyen, 1956, p. 28).

In the Equinox area, the name Mount Anthony formation is applied to the strata overlying the Bascom-Beldens sequence. It is composed primarily of black, gray and green phyllites. This formation was examined at the type locality at Mount Anthony in the Bennington quadrangle and traced directly from the northern part of that quadrangle into the Equinox quadrangle. A complete discussion of the stratigraphy of this formation is essential to later comments on the "Taconic Problem" and the structural discussion as well.

The term "Taconic Slate" (Emmons, 1842) has been applied to the argillaceous Taconic rocks. However, no slates whatever are included in this formation either at the type locality or in the area of this study. Slates are found to the west in the "Low Taconics."

Dale (1912) mapped the phyllite sequence in the Equinox quadrangle as the Berkshire schist (Dale, 1893) which is quite similar except for the presence of higher quantities of albite. MacFadyen (1956, p. 28) also reported albite but the quantity appears to decrease northward since it is less common in the Equinox quadrangle. Dale (1912) believed the Berkshire schist probably should be correlated with the Trenton. Thompson (1959, p. 77) applies the name Berkshire schist to the lower part of the phyllites which are primarily black with little gray-green and green, and a great variety of other lithologic types each of which

Table 2

APPLICABLE CAMBRIAN STRATIGRAPHY OF THE CASTLETON AREA

Adapted from Zen, 1959

Formation	Brief description
West Castleton formation	Gray siltstone, black fissile shale, rare quartzite, pebble conglomerate and rusty-weathering dolostone. Near base is Beebe limestone (black, discontinuous).
Bull formation	
Castleton Conglomerate member	Limestone-pebble, slate-matrix intraformational conglomerate.
Mudd Pond member	Medium-grained orthoquartzite (white, vitreous) rare dolomitic pods. Some green slate. Not always present.
Zion Hill member	Massive graywacke or subgraywacke (0–100 feet thick). Base may be pebble conglomerate with load-casting. Top may be mudstone. Graded bedding common.
Bomoseen Graywacke member	Olive-drab, massive graywacke (weathers gray to brick-red). A similar lithology may be lower and replace Biddie Knob or it may be thickened section of Bull formation.
Mettawee member	Purple and green slate, mudstone, phyllite. Lacks chloritoid.
Biddie Knob formation	Purple and green, chloritoid-bearing slate and phyllite. Subsidiary quartzite. Rare thin limestone beds.

is included in the lower part of the Mount Anthony formation in the Equinox quadrangle. In addition, Thompson uses the term Greylock schist for the main mass of the green, gray-green and black phyllite and associated lithologies above the Berkshire schist. No age should be implied by Thompson's use of the names Berkshire and Greylock schist since he indicates (1959, p. 77) that these formations are of uncertain age.

In the Equinox quadrangle all of these lithologies are included in the Mount Anthony formation. The differentiation is the same as that used by Thompson (1959) except that a single formational name is used. Lithologies included by Thompson in the Berkshire schist, however, are assigned to the lower Mount Anthony (Omal, on map. Plate 1) and wherever possible are mapped separately from the rest of the formation. Although this differentiation is possible in certain localities it is not consistent throughout the quadrangle. Therefore, all phyllites above the Bascom-Beldens are mapped as part of the Mount Anthony formation.

In the Castleton area, Zen (1959, pp. 1, 2) proposed the names Biddie Knob and Bull formation for a complex group of slates and phyllites of the "Taconic Sequence" (see Table 2). Fossils found in limestone beds in slate or limestone pebbles in slate matrix indicate an early Cambrian age. In every case fossils found are in limestone within a slate. Zen proposed (1959, pp. 3, 4) that the eastern phyllites capping the Taconic Range are in an inverted position and are equivalent to the Cambrian slate units to the west in the Slate Belt. According to this theory the phyllites of the Taconic Range are thrust in, up-side-down, above the carbonates and the right-side-up section is completely lacking. Certain facts must be considered in discussing this idea.

First, all carbonates in the eastern "Taconic Sequence" in the Equinox area are below the phyllites. Since the upper part of the Bull formation (Zen, 1959) has the carbonates (the Castleton member) it is necessary that the section be overturned everywhere in the "High Taconics" of the Equinox quadrangle. However, the Castleton member, a limestone-pebble, slate-matrix conglomerate does not occur in the appropriate position on the eastern front of the Taconic Mountains in the Equinox quadrangle, even if the section is considered to be inverted. In addition, in the area studied for this report, only in certain localities can anything resembling the description of the West Castleton formation (Zen, 1959, p. 2) be found and then the similarity is a superficial one drawing heavily upon a few analogous lithologies.

Second, none of the Mettawee member lithologies (purple and green slate) appear at the higher elevations in the east in the Taconic Range immediately below Zen's chloritoid-bearing Biddie Knob formation, as they should if the section is inverted.

Third, in the Mount Anthony formation is a conglomerate or graywacke which, according to Zen (oral communication), is similar to the Zion Hill member of the Bull formation. The description of this member (Zen, 1959, p. 1) is insufficient to be certain of identification without more data. At any rate, in the Equinox area the conglomerate

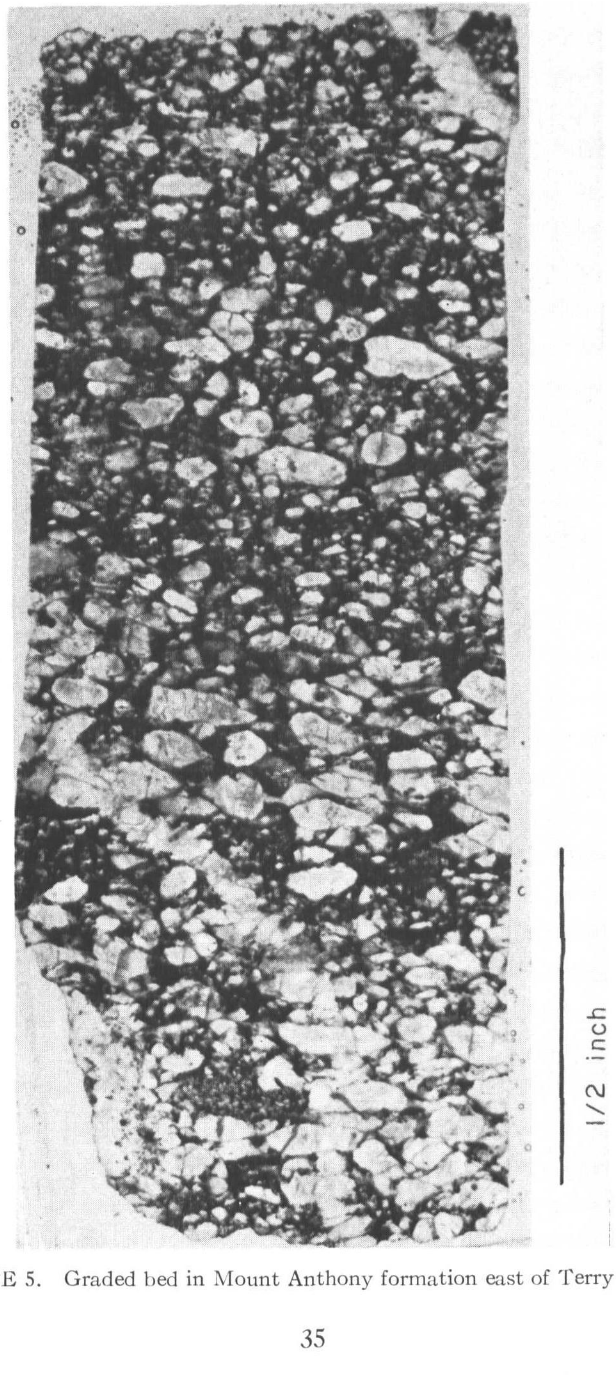


PLATE 5. Graded bed in Mount Anthony formation east of Terry Brook.

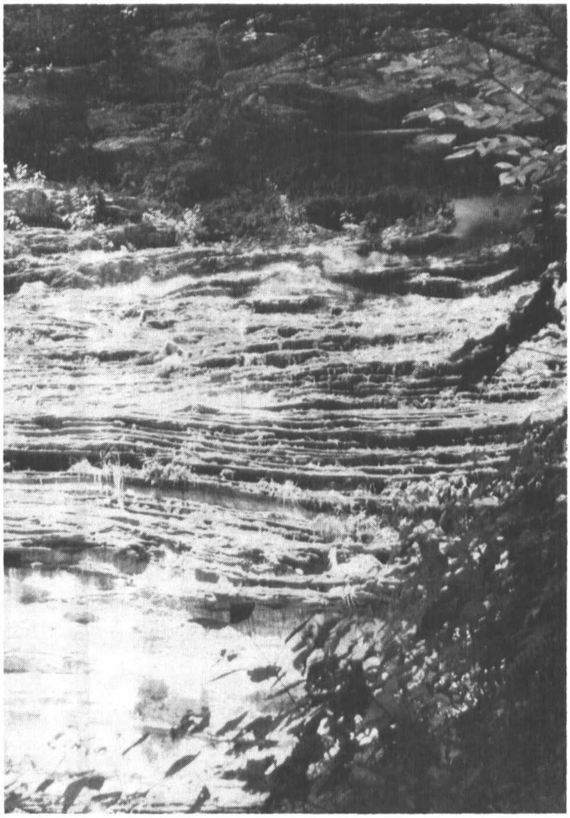


PLATE 6. Gradational contact at base of Mount Anthony formation at Cook Hollow.

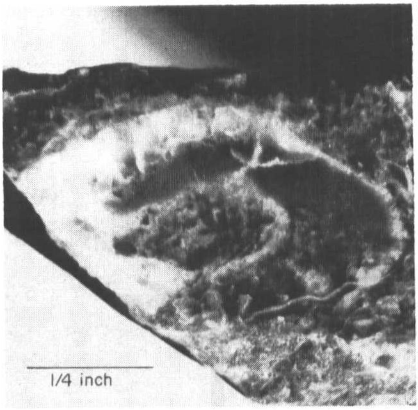
frequently contains graded beds (Plate 5) which indicate that the phyllites above and below it are not inverted. This distinctive unit crops out in many localities and is easily observed near the summit of the hills east of Terry Brook, on Egg Mountain, Minister Hill and in the streams incised into the hills north of Route 313, west of West Arlington. Although observed in many other localities in the area these exposures are not easily accessible.

Fourth, sandy marbles at the base of the Mount Anthony formation contain fossils which are certainly Ordovician and may indicate a correlation with rocks of Trenton age. Some of these marbles, well exposed on Mt. Equinox, are also cross-bedded and indicate that they are located stratigraphically below the phyllites. In certain localities the marbles grade upward into the phyllites by interbedding of green phyllite and marble, black phyllite and marble and by mixing of the phyllitic material within the marble (Plate 6).

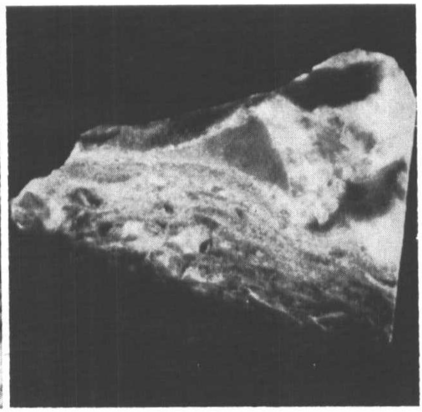
It is apparent from the above discussion that at least in the Equinox quadrangle, it is not possible to consider the western slates (Mettawee formation) as equivalent to the eastern phyllites.

A further discussion of the gradation and top-bottom criteria is reserved for the section on structure and the comments regarding the "Taconic Problem."

In general the description of the Mount Anthony formation in the Equinox quadrangle differs very little from that given by MacFadyen (1956, pp. 28, 29) in the Bennington quadrangle. The primary lithology in this formation is gray, green and black phyllite. At the bottom the contact is gradational with the underlying marbles in several localities but through much of the Equinox area the contact is not visible and in most other exposures the units appear to be separated by an unconformity. Starting at the base, blue-gray to black calcite marble with minor interbeds of creamy-white calcite marble are succeeded upward by black, graphitic phyllite. Gray sandy dolomites and gray dolomitic quartzites which weather deeply to a soft rusty sandstone occur occasionally. Some green phyllites are observed with the black phyllites and calcitic marbles. In some localities no black phylite is present and any of these lithologies may be lacking at a particular exposure. Several localities show a gradation from the marbles into the green phyllites. The black phyllites are higher in the section. This suggests sharp facies changes. In very severely folded zones where the lower horizons are exposed, the black phyllite has been highly oxidized and has become brick red. Some green phyllites and dark marbles have also been altered and the phyllites in these zones are also red. This may be observed easily at about 100 feet above Lake Madelaine (Spruce Swamp) or along the road west from Sandgate in the corkscrew turns at the first cross roads. Here both green and black phyllites have been altered, but some evidence of the original color remains. Calcitic beds may also be observed in this excellent section. The alteration is probably the result of oxidation of the included pyrite which, in less folded zones, is frequently altered to pseudomorphs of limonite. This portion of the formation is defined as the lower Mount Anthony and the mode of representation on the map has been discussed. An excellent exposure of the gradational contact may be seen between 1,800 and 2,100 feet at Cook Hollow south



a. Section across specimen toward posterior. Somewhat flattened.



b. Section at right angles to above, left. Not centered. Enlargement same as in a, left.

Figure 1. Probably *Endoceras Proteiforme* Hall.

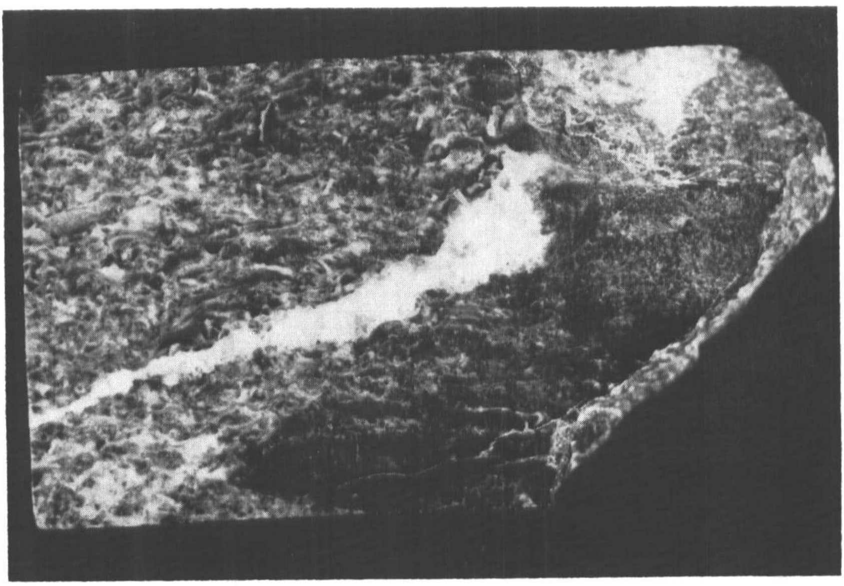


Figure 2. Portion of marble containing numerous fossil fragments.

PLATE 7. Fossils in lower Mount Anthony formation.

of Table Rock, south of Manchester Village. As suggested by Thompson (1959, p. 77) in his discussion* of the Berkshire schist, which is the same as this portion of the Mount Anthony formation, it is impossible at present to distinquish these strata from the Ira formation (a Trenton equivalent). It is probable that the Walloomsac formation as mapped by MacFadyen (1956) may be equivalent to the lower Mount Anthony.

Succeeding this heterogeneous material the phyllite increases in quantity and, although gray-green at the lower portion, it becomes deep green higher in the sequence. About 200 feet from the beginning of the main phyllites is a green conglomerate or graywacke composed of milky or blue quartz pebbles elongated in the direction of folding in a matrix of sericite and chlorite. Some limonite, pyrite and occasional rutile appear in minor quantities. Graded beds frequently occur in this unit and indicate the beds are in proper position. This unit strongly resembles the Zion Hill member of the Biddie Knob formation.

Green phyllite lies above the green conglomerate or graywacke and is uninterrupted for 100 or more feet. A black or gray phyllite which sometimes resembles the phyllites near the base of the formation, appears in this position. Above these the green phyllites become a deeper green and in many localities, particularly in the east where the higher portions of the formation are not eroded away, chloritoid rosettes increase in quantity. Some garnet is also present.

No fossils have been found in this formation except those in the calcitic beds at the bottom. These fossils include unidentifiable crinoid, gastropod and probable cystoid fragments. The Ordovician age is undoubted. The exact correlation is far from certain, though it is likely mid to late Trenton. A probable *Endoceras proteiforme* Hall has also been observed in the marbles immediately below the black phyllite. Photographs of this and the fossil fragments are found in Plate 7, figures 1 and 2. Since some of these marbles are interbedded with the overlying phyllites they are mapped with the Mount Anthony. MacFadyen (1956, p. 29) states, "The age of the Mount Anthony is unknown as no fossils have ever been found in it. The writer believes, however, that it is probably middle to late Ordovician, as it appears to overlie the Walloomsac in normal stratigraphic succession." The present study fully confirms these statements.

The thickness of this formation has been given as about 1,250 feet

*Thompson also noted that these may be the metamorphosed equivalent of Cambrian beds in the slate belt to the west.

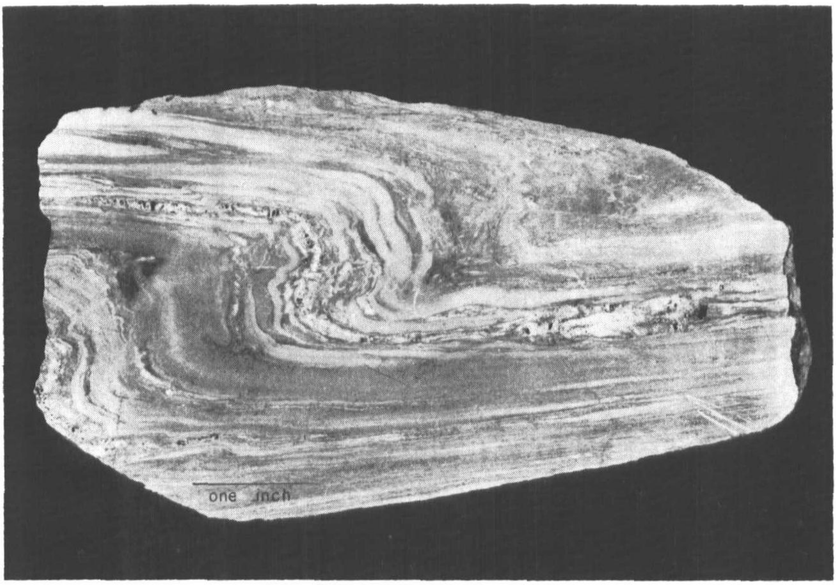


PLATE 8. Specimen of Mount Anthony formation showing effect of folding on thickness.

by MacFadyen (1956, p. 29). No figure of thickness has been published by Zen (1959) for units he believed to be equivalent though of Cambrian age. Thompson (1959, p. 77) reports a thickness of 400–600 feet for the Berkshire schist and over 1,000 feet for the Greylock schist. Although considerable material is exposed in this formation, structural considerations indicate the thickness to be much less than indicated elsewhere. In the Equinox area, excellent cross-sections of the column may be observed on Red Mountain and elsewhere. Doubling and even tripling of the thickness is easily observed in these areas (Plate 8). Therefore, a figure of 600–800 feet seems more likely for this formation.

The Mount Anthony formation is well exposed everywhere in the higher portions of the Taconic Range in the Equinox area.

Poultney Formation (Keith, 1932)

Little of this formation is exposed in the Equinox quadrangle. Far from being typical, the Poultney in this area closely resembles the Mettawee of the lower Cambrian. The primary lithology of the Poultney is fissile, light gray or light green to olive slate. Thin beds of dark gray limestone are occasionally intercalated in the slates. This is the primary distinction available to differentiate it from the Mettawee. In the Pawlet quadrangle Shumaker (oral communication) has traced this lithology into more typical Poultney and for this reason these beds are mapped with that formation. Lathy weathering of the slates in the Equinox area further distinguishes the two formations.

More typical Poultney formation lithology has been described by Theokritoff (1959, p. 56) as light gray slate or ". . . bluish-gray waxy-looking banded argillites, locally with indigo coloured patches replacing the banding." He also reported green and greenish weathering black argillites, brown sandstones, black shales, limestone-conglomerate and ribbon-limestones. Massive quartzite with angular limestone fragments also were observed by Theokritoff in this formation.

Zen (1959, p. 2) includes the Poultney slates as rock type 3 in the Poultney River Group. He reported the entire group as ranging from upper Cambrian to middle Ordovician though no fossils were listed to support this statement. None of these lithologies, except that of rock type 3, is found in the Equinox quadrangle. Theokritoff (1959, p. 56) indicated that lower Ordovician and Normanskill graptolites have been found in the Poultney slates and that the unit is correlated with the *Nemagraptus gracilis* (Hall) zone. Shumaker (1959, p. 68) reported *Glyptograptus teretiusculus* from Poultney beds in the Pawlet quadrangle. No fossils were found in the Equinox area. However, this unit is older than the Normanskill correlatives such as the Indian River formation which overlies the Poultney and is found west of the northwest corner of the Equinox quadrangle. It may be equivalent in age to at least part of the Mount Anthony formation.

In the Equinox area this formation is exposed in the vicinity of West Rupert. No reliable thickness can be given though certainly much less than 100 feet are exposed in the area.

The Poultney unconformably overlies the Mettawee. Zen (1959, p. 2) also noted this profound unconformity. About one-tenth of a mile east of the most easterly exposure of Poultney strata, the Mount Anthony formation also overlies the Mettawee. The close proximity is probably the result of westward thrusting of the Mount Anthony. An unconformity may also occur at this contact.

Dikes

North of the Equinox quadrangle many camptonite and olivine camptonite dikes are known. Only one of these dikes has been previously reported from the Equinox quadrangle. Hitchcock and Hager

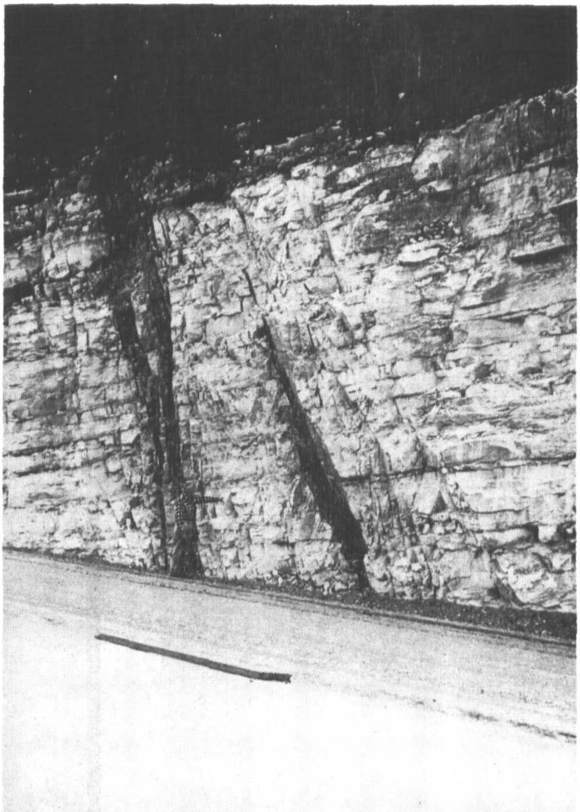


PLATE 9. Dikes at East Dorset.

(1861) described an olivine camptonite dike composed of olivine, augite, hornblende and plagioclase from Mt. Aeolus (Green Peak). Two similar dikes may be observed easily along the roadcut in East Dorset exposed in the widening of U.S. Route 7 (Plate 9). One of these is compound and cuts across the entire exposure of the Dunham at that locality, but the second pinches out vertically about 30 feet above the base of the outcrop. The sharp, clear-cut borders of the dikes and the lack of reaction with the country rock indicate that the magma was relatively cool during intrusion. None of the dikes appear to have been affected by orogeny and therefore are later than the Taconic folding of the late Ordovician.

No other dikes were found in the Equinox area although much float of the same material was observed in certain localities in the northern part of the quadrangle. Since the dikes are seen only in vertical section they do not appear on the map. The dikes strike about N25°E.

Dale (1912, pp. 72–74) discussed the dikes and their probable age. Since none of these were seen to cut the phyllites in the Equinox quadrangle, little evidence of their age can be added to Dale's statements which suggest an age of emplacement later than the Ordovician. Dale was no more definite than to consider them as post-Ordovician and pre-Triassic. Fowler (1950, pp. 58, 59) discussed the dikes in the Castleton quadrangle and made additional suggestions as to their age.

METAMORPHISM

General Statement

An area such as the Equinox quadrangle provides a complex metamorphic picture. Billings, Thompson, and Rodgers (1952, Plate 3, p. 6) showed three metamorphic zones in the area. These correspond closely to the Green Mountain section (Retrograde), Taconic Range and Vermont Valley (Biotite) and western low Taconics (Chlorite). As indicated by the above authors (*ibid.*, p. 7) the chlorite and biotite metamorphic zones are the same as the chlorite-muscovite and chlorite-biotite subfacies of the green schist facies, respectively.

A full discussion of the metamorphism is not within the scope of this paper. However, certain factors require some analysis of this important geologic feature.

It is apparent that at least two metamorphic episodes have affected the strata in the Equinox quadrangle. In the east, the Green Mountains section has undergone early, severe metamorphism with its resulting schists and gneisses. A later metamorphism involving the Paleozoic section to the west has caused probable retrogressive rather than progressive change in the Green Mountains. MacFadyen (1956, p. 32) discussed the retrograde metamorphism in the Bennington quadrangle in some detail. The argillaceous rocks of the Taconics were affected by low-grade metamorphism during the second episode. The carbonates and quartzites of the Vermont Valley are not in themselves indicators of any particular metamorphic zone.

Pre-Cambrian Rocks of the Green Mountains

The only unit under consideration in this section is the Mt. Holly complex. The Mt. Holly is primarily composed of quartz-biotite-microcline gneiss, quartz-biotite-chlorite schist and green banded actinolite schist. Other rock types are indicated in the full discussion of this unit. Since minerals of a medium metamorphic grade are also present and the major mass of the rock appears to be of a low grade, retrograde metamorphism is indicated.

These rocks were first metamorphosed to at least a medium grade in the course of an important orogeny during the pre-Cambrian. A major period of erosion during the late pre-Cambrian produced the profound unconformity between these rocks and the overlying Paleozoics. The Cambrian and Ordovician sediments west of the core of the Green Mountains were deposited on this erosion surface and, during the late Ordovician, a second orogeny affected the area. With this new metamorphic episode a lower grade was apparently imposed upon the old. Effectively, this results in a masking of the full effect of the earlier event.

The mineral suites of the Mt. Holly complex have already been fully discussed.

Cambrian and Ordovician Rocks

From the Mendon to the Mount Anthony formation, low-grade metamorphism is evident. Although the Mendon is a problematic unit, part of the reasoning for placing this unit in the Cambrian rather than pre-Cambrian is based on the distinction in grade of metamorphism.

Formations involved in the second orogenic episode alone range lithologically from quartzites to carbonates and phyllites. Mineral suites have been discussed previously. However, the phyllites frequently contain large quantities of graphite, muscovite, chlorite, sericite, biotite and in the Mount Anthony formation chloritoid rosettes are common at many horizons. In some of the more siliceous, sandy parts of the unit, garnets are not uncommon. Furthermore, as noted by MacFadyen (1956, p. 33) the quartz content increases and becomes more coarse to the east. This, however, is not the full picture of the quartz beds, since at the very easternmost exposures on Mt. Equinox the sediments become finer again, although the quantity is still large. It appears that these sandy beds in the Mount Anthony formation, which are numerous in all parts of the area, represent lateral sedimentological variations and are not due to metamorphic change. MacFadyen (1956, p. 33) noted a a mineralogic change from west to east in this formation and also considered it a primary variation.

MacFadyen (1956) believed that the black phyllite below the Mount Anthony represents the Walloomsac formation. In this study the same lithology is mapped as lower Mount Anthony to avoid confusion with studies to the north which use the term Ira or Hortonville (plus Whipple) to identify similar strata. MacFadyen (1956, p. 33) stated that there is little change in the Walloomsac from west to east. In the Equinox quadrangle, the equivalent beds vary rapidly, but not due to metamorphic change. The sediments show rapid lithologic change due probably to primary sedimentary facies. Metamorphic grade is quite consistent for this unit as for the others in the Paleozoic section.

A single change is noted in the fact that the Mettawee slates in the northwest part of the quadrangle lie below and west of the phyllites of the Mount Anthony formation and the Poultney slates. The lithology of the Poultney and Mettawee formations is quite similar, both containing similar slates and somewhat similar limestones. The Mount Anthony formation has no slate and is composed primarily of phyllites. Careful search along the contact of the Mettawee and the Mount Anthony reveals that the change across the boundary is quite abrupt with phyllite directly in contact with slate and no gradation between the two rock types. It is true that the distinction between a slate and phyllite, and a phyllite and schist is in some respects subjective. In this case, however, there is no question of subjectivity. At the contact, the Mettawee is a good slate and the Mount Anthony is an excellent phyllite. It is difficult to interpret the abrupt change in lithology other than by faulting over an unconformity developed here on the Mettawee formation. This matter is fully discussed in a later section. It is necessary, however, to note the metamorphic distinction in this discussion of the general metamorphism of the Paleozoic sediments. Certainly the dramatic change from slate to phyllite requires some discussion and an attempt to explain this is essential to this study. This is particularly true in view of the very close proximity of the Poultney slates to the Mount Anthony and with both units, one a slate and the other a phyllite, directly overlying an older slate. It is true that sedimentologic facies can be responsible for the change in a single formation from slate to phyllite in a short distance. However, abrupt as these changes may be, without some secondary event the two facies should grade laterally into each other. Billings, Thompson and Rodgers (1952, p. 5) stated that changes in metamorphic grade could greatly alter the description of the same unit from place to place. It is unlikely, however, that a change of this type would be as sharp as is the case between the Mettawee and the Mount Anthony. The hypothesis, rejected in this paper, that the Mettawee and the Mount Anthony formations are of the same age and differ only in metamorphic grade must in some way account for the abrupt change across the contact. Thrusting appears necessary to bring the two distinct rock types in contact abruptly whatever the theory advanced.

Most of the strata in the Equinox quadrangle are so severely metamorphosed that fossils, if present, have been crushed, fragmented or more frequently the hard parts are utterly destroyed. The high quantity of carbon deposits, particularly in the black graphitic phyllites suggests that many organisms lived in the seas in which these strata were deposited. In a few localities fossil fragments are found. These are, however, rarely identifiable. Usually evidence of a fauna is found at the nose of folds in a position of low stress.

It is almost impossible to ignore the immense quantity of vein quartz in the Mount Anthony formation. Undoubtedly the metamorphism is responsible for the veining. It is quite possible that much of the vein quartz is the result of the remobilization of previously existing bedded quartz sand. Boudinage is common, resulting from movement of the siliceous matter to positions of least stress. It is less likely that the quartz is the result of intrusion since the units underlying the Mount Anthony formation are less affected.

Boudins of lighter calcite appear in the dark, blue-gray marbles below the Mount Anthony in a few localities.

STRUCTURAL GEOLOGY

General Statement

In western Vermont two major structural features are well known and have been carefully studied. The Green Mountain anticlinorium and the Taconic synclinorium have been and still are the subject of numerous studies. East of the Vermont and Champlain Valleys lie the Green Mountains. To the west of the valley the Taconic Range extends from the central to southern part of the Bennington quadrangle northward through half of the Castleton quadrangle. These major structures dominate the Equinox quadrangle.

Three faults were mapped in the course of the field work in this quadrangle. None is in any sense referred to as the Taconic thrust. In the Equinox quadrangle no evidence of the "Taconic Klippe" as usually understood, could be found. No mappable faults can be found on the eastern front of the Taconics in the appropriate position. Since the presence or absence of an eastern thrust is essential to a discussion of

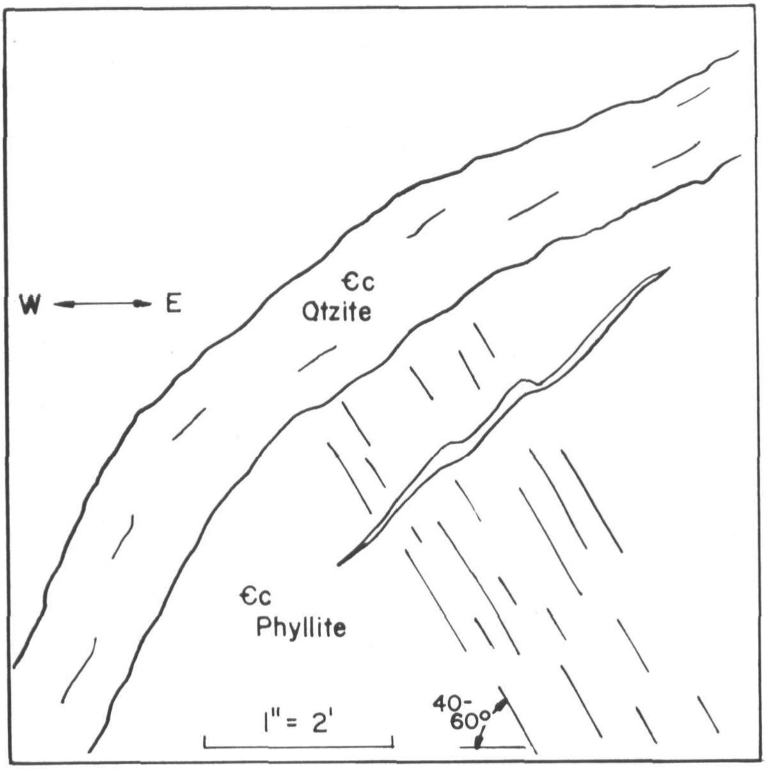


Figure 3. Cleavage-bedding relationship in Cheshire quartzite. South of Mill Brook.

the "Taconic Problem," evidence pro and con will be presented in the section devoted to that subject.

Isoclinal and recumbent folding is common throughout the area. Several large isoclinal folds and numerous minor ones are well exposed and easily studied.

Minor faulting is probably quite common though only a few faults may be discerned due to stratigraphic complexity. These are impossible to map since they are of limited geographic extent.

Other structures such as unconformities, jointing, cleavage and minor folding will be discussed fully since they are of importance in determining the total structure and in the problem of age relations. The location of these structures is indicated on the tectonic diagram (Plate 13) and the structure sections (Plate 14).

It is entirely possible that at least two episodes of folding have affected the area. Jointing and cleavage in a few localities appear to have been rotated following folding. If a second episode has occurred it has folded the strata parallel to the older plane of folding. The result of this is that the second episode is difficult to distinguish without the aid of rotated jointing and cleavage. The two (or more) possible episodes involve all strata and therefore are later than the deposition of the Mount Anthony formation or probably late Ordovician. This is in addition to the orogeny which affects only the pre-Cambrian rocks.

It is also possible that the Ordovician folding involved several phases. The results would have been identical.

Green Mountain Anticlinorium

The Green Mountains in the vicinity of the Equinox quadrangle are a part of the Green Mountain anticlinorium which extends from south of the Vermont-Massachusetts boundary northward for approximately two hundred miles. The general trend of the anticlinorium is slightly to the east of north. The western flank of this structure underlies the eastern portion of the Equinox quadrangle and forms a westward facing escarpment. Immediately west of the front is the synclinal Vermont Valley.

Major Structures

The major structural feature of the eastern part of the Equinox quadrangle is the western portion of the Green Mountain anticlinorium. Typically asymmetrical folds of varying magnitude were superimposed on the larger structure as a result of later episodes of tectonic activity. Movement of the beds which overlie the basement resulted in a series of tight folds overturned to the west, with a pronounced parallelism of strike.

Folding was accompanied by intense shearing movements which resulted in slip cleavage. The cleavage is best developed in the more incompetent strata such as the upper Mendon (Moosalamoo member) and the schists of the lower Mendon. Plastic deformation formed the asymmetrical folds in the Cheshire quartzite primarily by recrystallization.

The area known as "The Burning" is located on the main anticline of this region. The resistant Cheshire quartzite crops out on most of the structure and dips at low angles along the fold crest with steeper dips (locally 90° and overturned) on the west limb. On the western flank of the fold the Moosalamoo member of the Mendon formation crops out occasionally and further suggests the sharp attenuation of that limb. Several hundred feet of dark quartzite and phyllite were observed south of Mill Brook with the Cheshire above and below. This is interpreted to be the result of erosion of the quartzite (Cheshire) which exposes the underlying phyllite (Figure 3). Similar structures are exhibited elsewhere along the front north of the Equinox quadrangle (Thompson, 1959).

The Burning anticline plunges north beneath the valley in the vicinity of Lye Brook where the Dunham dolomite outcrops above the Cheshire quartzite. South of the Roaring Branch is another anticline of Cheshire identified on the map as the "Catamount Cobble." This structure also plunges north into and under the valley and is part of a larger anticlinal fold to the east which continues southward into the Bennington quadrangle.

With the exception of the exposure of the Dunham formation at the nose of the Lye Brook Anticline it is believed that the Dunham, which lies stratigraphically above the Cheshire quartzite, is buried at a relatively shallow depth along the valley wall in close proximity to the Cheshire exposures. Outcrops of the Cheshire-Dunham transition zone are not numerous. They are, however, observed in sufficient quantity to justify this interpretation. MacFadyen (1956) reported no occurrence of the transition in the Bennington quadrangle and believed that it is covered by glacial and recent material. At the contact with the Dunham formation the upper Cheshire is a deeply weathered, friable sandstone due to the removal of dolomitic cement. Although the massive dolomites of the Dunham are quite resistant, their absence at higher elevations along the front is probably due in part to the ease of weathering of this transition zone.

Folds along the western flank of the Green Mountains form a series of "steps" which are marked by an alternation of cliffs and narrow debris-covered slopes. Many minor folds and drag folds are superimposed on the major structure. Trends of the minor structural elements are for the most part consistent with those of the larger structures. The axial planes of most of the folds dip gently east. Bedding shows steep west dips which become vertical and overturned on the western limb.

Minor Structures

Bedding in the Cheshire quartzite is generally masked by recrystallization and may be difficult to recognize. However, relict sand grains in combination with micaceous partings and differential iron content are helpful in determining bedding attitudes. Pebble bands and distinct iron oxide traces define the original deposition planes but are not always present or distinct enough to be dependable. The same is true for the

PLATE 10. Bedding in Pre-Cambrian.

Figure 1. Bedding in Mt. Holly Complex. Note banding cross-cutting bedding.

Figure 2. Bedding in Mt. Holly Complex.

green or dark gray micaceous partings. Cross-bedding was observed at several outcrops but does not appear to be characteristic of the Cheshire.

The banded appearance of the Mount Holly formation indicates original compositional variations which have reacted differentially to several periods of metamorphic activity associated with uplift of the anticlinorium. Subsequent folding of the deformed rocks resulted in further complexities and masking of the original sedimentary features (Plate 10, figures 1, 2). According to Kaiser (1945) granitization is indicated in both the pre-Cambrian and lower Cambrian sequence of western New England. This is evidently subsequent to the folding of the area.

Cleavage

Slip cleavage is the predominant type and is well developed in the phyllites of the Mendon formation. The cleavage planes generally are orientated parallel to the axial planes of the folds and dip east approximately 45° (Plate 11). This type of cleavage represents the deformation of a relatively incompetent rock along numerous planes resulting from the orientation of platy minerals at an angle to the maximum stress direction.

The Taconic Synclinorium

This major structure lies west of the Green Mountain anticlinorium. The subject of repeated studies, it is a complexly folded and faulted area. In addition, the stratigraphy is difficult to understand and has been the source of confusion in regard to the solution of the structure as well. The trend of the axes of major structures is about N20°E with many smaller folds trending north-south or even to the northwest. The Taconic synclinorium is probably the southward extension of the Middlebury synclinorium (Cady, 1945, p. 562) of the Champlain Valley.

Typical of much of the Vermont Valley and the eastern part of the Taconic Range are the isoclinal folds in many cases completely recumbent. Outcrop patterns are broader than thicknesses would indicate as a result of the repeated overturned folding to the west. Excellent recumbent and isoclinal folds are easily observed along Route 313 from about one and one-half miles west of Arlington to the covered bridge in West Arlington. The most westerly of these is about one-half mile west of the covered bridge, but it is not easily observed. With some difficulty the minor isoclinal drag folds on larger nearly recumbent folds may be studied on Red Mountain. The south flank of this mountain has, at an

PLATE 11. Relation of cleavage, jointing and bedding in Mendon formation.

elevation of 1,100 to about 1,300 feet, a nearly vertical exposure one quarter to one-half mile long of interbedded and interfolded black phyllite and blue-gray marble (Plate 12, figures 1, 2). Higher in the exposure green phyllite is present. Both isoclinal and recumbent folds are easily seen here. This is only one example of many in the Equinox quadrangle.

Elements of the major structure to be discussed include the larger folds and faults and the several unconformities.

North Bennington Anticline

At the south-central boundary of the Equinox quadrangle is the northern extension of the North Bennington anticline (MacFadyen, 1956, pp. 41, 42). The town of Shaftsbury is located on the west flank of this major structure. MacFadyen (1956) was unable to map the structure through due to glacial cover. However, there is little doubt that this is the same anticline. The northeast flank is partially cut off by the northward continuation of the Maple Hill thrust (MacFadyen, 1956, p. 42).

The oldest unit exposed along the axis of the anticline is the Dunham

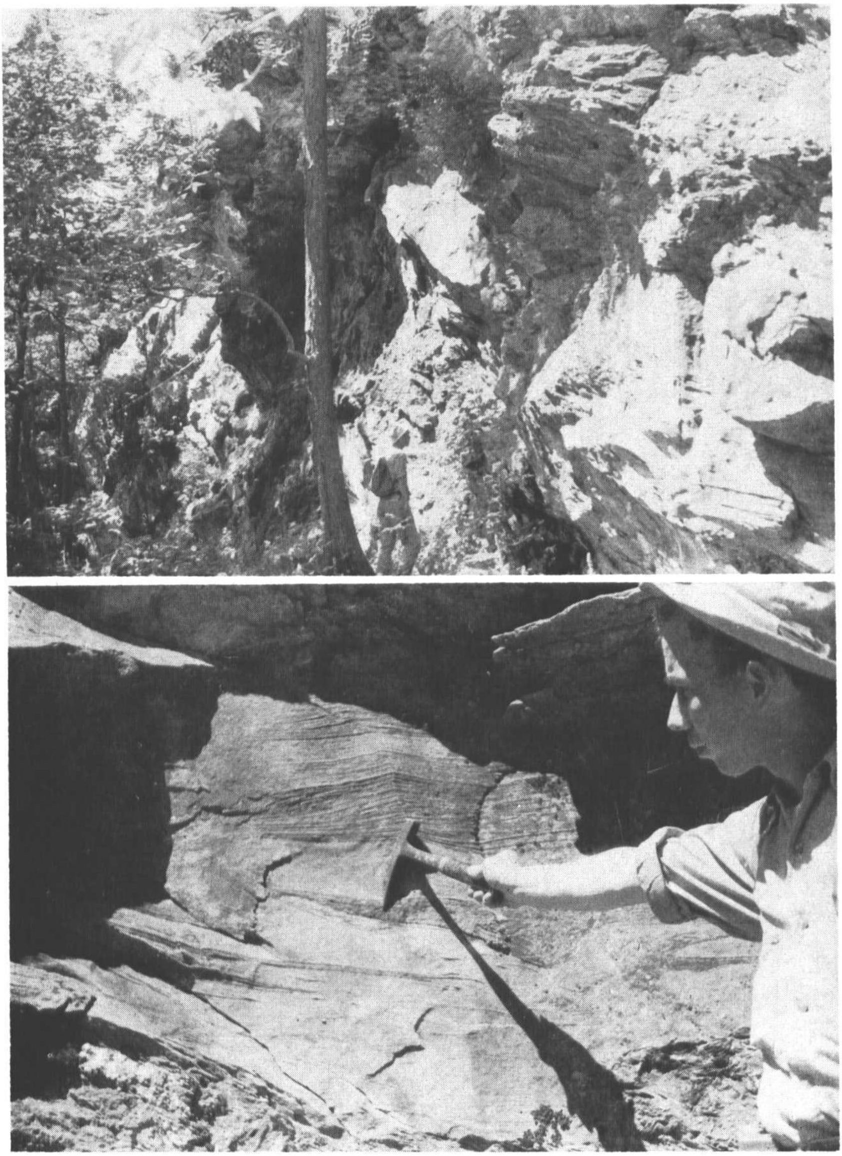


PLATE 12. Contorted black phyllite and marbles on Red Mountain.

Figure 1. Contorted interbedded phyllites and marbles.

Figure 2. Close view of smear folding.

dolomite. Excellent outcrops of the Mallett member on either side of the Dunham outline the crest of the fold. Although certain portions of the structure are covered, most of it is easily mapped in the field. The anticline plunges gently northward (less than 25°) with the Monkton formation wrapping around the nose as the fold dies out about one mile northeast of Shaftsbury. On the east flank, the Danby-Clarendon Springs, Winooski and the Monkton are cut out against the thrust. All of these units abut sharply against the Monkton quartzite which is faulted against the eastern flank of the anticline. Drag folds occur throughout but are best observed in the Monkton and Dunham where the quartzite beds are thrown into drags which may have an amplitude of a few inches or many feet. Axial plane cleavage is well developed through the entire anticline. The axial plane is nearly vertical, dipping steeply to the east. Some asymmetry is probable although it is difficult to demonstrate except by means of the very different width of outcrop of the formations with the topography on both limbs of the fold nearly the same.

Although in the Bennington quadrangle MacFadyen (1956, p. 41) noted the strike of the fold to be about N30°E, in the Equinox quadrangle this anticline has a gently curving axis with a general strike of N10°E to N20°E at the northern extremity.

The North Bennington anticline does not show the isoclinal or recumbent folding of the strata found in the Vermont Valley to the north in this area. In this structure bedding is excellent and generally fairly steep. The beds to the north are frequently nearly flat lying due to the extreme overturning to the west.

Maple Hill Thrust and Syncline

Named by MacFadyen (1956, p. 42) both structures extend into the Equinox quadrangle and are distinctive. The fault is quite extensive since Prindle and Knopf (1932) have traced it into New York State.

In the Bennington quadrangle the thrust is well exposed on Maple Hill immediately south of the boundary with the Equinox quadrangle. At that locality a thin portion of white marbles of the Shelburne formation (?) is in contact with the quartzites of the Monkton formation. A thin shear zone separates the two formations but the shearing appears only on the northernmost part of Maple Hill. No physical evidence of faulting other than stratigraphic omission can be observed in the Equinox quadrangle. The fault plane itself has not been seen in this area but the fault line is easily traced to its northward limit. The entire sequence from the Shelburne type marbles down to the Cambrian Monkton strikes sharply into the fault and against the Monkton on the upthrown or east side of the fault. About two miles north of the southern quadrangle boundary the fault passes into the Monkton so that this quartzite formation appears on both the eastern and western side. From this point northward the fault can no longer be mapped. The stratigraphic throw is approximately 1,000 feet. Since the amount of dip of the fault plane is unknown, neither the net slip nor any of its components can be determined.

In the Bennington quadrangle, the western limb of the Maple Hill syncline is thrust over the eastern limb of the North Bennington anticline (MacFadyen, 1956, p. 43). In the Equinox quadrangle the syncline is crossed by the thrust which strikes northwest (about N20°W). The eastern limb of the syncline has moved westward over the western limb. As the fault strikes toward the northwest, it passes across the North Bennington anticline. In this fashion the syncline has been faulted out of the section.

The eastern side of the fault is upthrown. MacFadyen (1956, p. 43) indicated that this is a high-angle reverse fault. However, this is difficult to substantiate in the Equinox area. It does not seem possible to be at all certain of the angle of dip of the fault since the plane itself has not been observed in the quadrangle. However, in this case the fault dies rapidly and the throw decreases markedly in a short distance northward. If the angle of the thrust were very high and the strike consistent it should still show disparity of formations for a greater distance northward. Of course some of the throw can be absorbed by the northwest strike of the fault in the Equinox quadrangle. The strike begins to swing to the northwest on the northwest flank of Maple Hill.

Immediately south of the Shaftsbury town line, the fault places Monkton against Monkton and shortly thereafter it can no longer be traced. Its exact extent within the Monkton is unknown. However, within half a mile north of its entry into the Monkton, all strikes are parallel and about N20°E. Therefore, it is believed that the fault is absent well south of Arlington.

West Mountain Syncline

The West Mountain syncline (MacFadyen, 1956, p. 42) in the Equinox quadrangle is the northern extension of the same structure in the Bennington quadrangle. In that area MacFadyen (1956, Plate 1, in pocket) indicated the presence of the Walloomsac formation, broadly exposed on the west flank of the mountain. Since no black phyllite or marble could be located near the southern boundary or north of it in the Equinox quadrangle, all of this has been mapped as part of the Mount Anthony formation. Furthermore, all exposures in the White Creek Valley and the stream west of it are green phyllite. The first outcrop of black phyllite occurs high on the hill east of the westernmost road in that locality. It is likely that this phyllite is much higher in the sequence and is the upper black unit within the Mount Anthony formation.

Overturned folds, generally isoclinal but not recumbent, are the minor folds in the major structure. The syncline, complicated by several sizes of minor and drag folds, is not an easily observed structure. Only by means of the minor folds is it possible to determine the continued overturning of the syncline and the gentle eastward dip of the axial plane. On first view it appears that deformation is not extreme in the structure as a whole. However, this is not the case and the shallow appearance of the syncline is due to the overturning of the subsidiary folds. The repetition of the upper black phyllite within the Mount Anthony formation in this area demonstrates the high degree of deformation.

In most outcrops bedding is difficult to discern. Extreme care must be exercised, since cleavage frequently resembles bedding. Flow banding is also common on the east side where black phyllite and dark calcite marbles are observed. In that area an anticline exposes a small quantity of black phyllite and dark gray marble which probably represents the lower Mount Anthony. None of this lithology is visible on the eastern flank at the contact of the Mount Anthony and the Bascom-Beldens. There green phyllites are in direct contact with the blue-gray marbles below. This small anticline is overturned strongly to the west and is one of the minor folds on the West Mountain syncline.

As reported by MacFadyen (1956, p. 42) this structure plunges gently to the southwest.

West Arlington Anticline

The West Arlington anticline is well exposed along both sides of the valley traversed by Route 313 from Arlington to West Arlington.

Little doubt of the recumbent and isoclinal nature of the folding can remain after study of the marbles along that route and the phyllites between 1,100 and 1,300 feet along the south face of Red Mountain. Many of the folds are easily observed. Others require careful examination of the exposures and tracing of particular pyritiferous strata.

The anticline itself is composed of a series of lesser structures strongly overturned to the west. The size of the folding may be from a few to many feet with a smearing of drag folds more evident in the phyllites.

Flowage and slippage is apparent in most of the section but some minute shear folding occurs particularly in the higher phyllites. Erosion by the Batten Kill River has cut through the core of the anticline almost at right angles to the strike or trend of the folding. This has provided excellent exposures of Taconic rocks for study.

It is possible in this section to observe the isoclinal and recumbent folding as well as the overall gentleness of the major structure. In addition, the thickening and thinning of the various units are easily seen, and the difficulty of measuring adequately the thickness of strata folded in this manner becomes obvious.

West of the covered bridge at West Arlington, green phyllite overlies the marbles, separated by the black phyllite and thin marbles of the lower Mount Anthony formation. The same green phyllite underlies (topographically) the marbles a few hundred feet west of the above exposure. The axis of the strongly overturned anticline lies here with a gently dipping or nearly flat axial plane. Two other folds are involved in the formation of the major structure. One has its axis east of the junction of Route 313 and the Sandgate Road. The synclinal axis lies immediately west of the junction but it is very shallow. The third overturned anticlinal structure is about halfway between Arlington and West Arlington. It is composed of small recumbent and isoclinal folds. This and the other two anticlines compose the major structure. It is impossible to discuss any single fold except in regard to the structure as a whole.

The whole structure appears as a series of minor drag folds upon larger drags which comprise the larger folds. Actually, the number of drag cycles is unknown since the amplitude of these may be only a few inches to several feet. This may be the result of more than one episode of folding with the stress occurring parallel to the earlier episode.

Plunges of the fold are northeast and southwest and are probably gentle. In all likelihood the plunge to the south is steeper that that to the north.

Spruce Swamp (Lake Madelaine) Anticline

As in the case of the West Arlington anticline this structure, southwest of the summit of Equinox Mountain, is composed of three distinct folds. In this structure the overturning is much less and no recumbent folds were observed although small isoclinal folds are plentiful. The structure plunges gently to the northeast and returns in that direction as the Beartown anticline.

The anticline is outlined by a thin exposure of the lower Mount

Anthony formation in most of its extent. In the north part of this fold black phyllite has been oxidized and is red from secondary hematite. This is not unusual and it is found in many localities particularly in the east part of the Terry Brook anticline. Pseudomorphs of limonite after pyrite are common in this zone.

The eastern part of the Spruce Swamp anticline is found on the northeast tip of Red Mountain. At this locality, errors in the topographic map do not enable proper mapping. Three small elevations are topped with Bascom-Beldens and rimmed with thin black phyllite and marble. These hills do not appear on the topographic map.

In these zones of intense folding it is difficult, if not impossible, to separate the Bascom-Beldens marbles from those in the lower Mount Anthony. Representation on the map is necessarily diagrammatic due to the interfolding of these units.

Spruce Swamp no longer exists as a swamp since it has been drained and cleaned and a dam has been built at the south end. This is now the site of Lake Madelaine. The core of the structure is about one mile south and west of the dam.

Beartown Anticline and the Bear Mountain Syncline

The Beartown anticline is probably a northward continuation of the structure south of Spruce Swamp. However, a minor syncline interrupts the fold with the anticline plunging out north of Spruce Swamp. Several small but complex folds have left remnants of the Mount Anthony formation isolated on the mass of the Bascom-Beldens.

Reference to the geologic map (Plate 1) demonstrates that in the Beartown anticline the top of the marbles is topographically higher than the same horizon in the Spruce Swamp anticline and therefore higher than its position in the West Arlington anticline. This, as well as the general northward plunge, would appear to indicate that the overall structure is higher to the north than in the south.

The Bear Mountain syncline exposes only the Mount Anthony formation. Little can be determined about the plunge beyond the fact that one mile west of Sandgate, lower beds are exposed and the syncline has plunged out north of Pruddy Brook.

Dorset Anticline

This structure is composed of many small isoclinal and recumbent folds. It extends from north of the northeast extremity of the Beartown anticline and may have the same relation to it that the Beartown anticline appears to have with the Spruce Swamp structure. The same anticline passes through the area to the northeast and out of the quadrangle.

Involved in the Dorset anticline are numerous isoclinal and recumbent folds. It is responsible in part for the repetition of the Columbian marbles in the quarries on Mt. Aeolus (Green Peak) and Owl's Head. Dale (1912, pp. 102–105; Plate XVI, figure 14) described and figured the intricate folds in these quarries. Folding of the same type is responsible for the very broad exposures of the Bascom-Beldens in the area west and northwest of South Dorset as well as those on the south, west and north flanks of Mt. Aeolus and the Owl's Head. Most of the beds are nearly flat lying.

On the east side of Mt. Aeolus, the Bascom-Beldens thins from the north and is missing for a short distance along the face of the mountain. The thinning and total absence of this unit is probably the result of deep erosion during the time of formation of the Trenton unconformity. Thompson (1959, Map, p. 86) indicated the presence of a fault in the Shelburne formation but evidence is weak or non-existent at this locality. Thompson (oral communication) postulated the fault on the basis of known faulting further north where pre-Cambrian rocks are in contact with Ordovician formations. It is not possible at present to trace that fault along the east as shown by Thompson (1959) although it is apparently well established on the west. In view of the obvious repetition of the Shelburne marbles by recumbent folding it seems unnecessary to resort to faulting to explain the section. Since there is no evidence to prove faulting none is mapped in the present study. Folding of the same type also occurs on the east side of Mother Myrick Mountain. The fault cannot be demonstrated there either.

Other smaller folds are associated with the Dorset anticline since it involves an area east across the Vermont Valley.

Terry Brook Anticline

In the area east and west of Terry Brook and the east side of Egg and Shatterack Mountains in the northwest one-ninth of the quadrangle is a wide expanse of black phyllite and dark blue-gray to black marble. This represents the lower Mount Anthony formation exposed in the core of a complex anticline. Folds are strongly overturned to the west but the familiar isoclinal and recumbent folding is much reduced. In several localities the folds are slightly asymmetrical with the axial plane very nearly vertical.

The sequence above to the east and west is as usual in the Mount Anthony formation with the graded beds of the conglomerate or graywacke (Zion Hill lithology?) mentioned earlier indicating that the strata are right-side-up. These beds may be observed easily on the hills east of the road parallel to Terry Brook and at the summit of Egg Mountain. The same unit may be observed on most of the hills in the same area. In each case the conglomerate or graywacke is at or near the summit.

On Egg and Shatterack mountains several long gently dipping isoclinal folds cause marbles and black phyllites to be repeated. Although the long limb indicates an easterly dip, the overall dip is to the west in these high areas.

The lithology of the strata at the core of the anticline is identical to that of the lower Mount Anthony formation elsewhere. The dolomitic quartzites are lacking. These beds may be buried. However, plentiful evidence of their presence is seen in the float.

In the south and central parts of the Terry Brook anticline, isoclinal folding is infrequent. Overturning to the west is still common, however.

Youlin Hollow Thrust

The Youlin Hollow thrust is somewhat problematic. Along the east side of Youlin Hollow and in a small area west of the Hollow the Mount Anthony formation (Ordovician) overlies directly the Mettawee formation (Cambrian). West of this area, the Poultney formation (Ordovician) also overlies the Mettawee. That an unconformity exists at the Poultney localities is undoubted. If it is true that the Mount Anthony formation is Ordovician in age, an unconformity may exist there also. Evidence for the age of the Mount Anthony is based on the gradational contact with the underlying Ordovician marbles.

The unconformity alone cannot explain the several phenomena. Unfortunately, the evidence of a thrust at Youlin Hollow is indirect in the Equinox area. Taken together with data provided by Shumaker (oral communication) in the Pawlet quadrangle the evidence is stronger. Shumaker observed that the green phyllites* are above younger (Ordovician) strata to the north along the strike of the fault. In the Equinox area it is noted that the same green phyllites overlie Cambrian rocks.

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*Shumaker (1959, p. 59) believed that these green phyllites (mapped as Ordovician in the Equinox quadrangle) may be of Cambrian age. Regardless of the age the evidence for a fault is consistent.

At the sharp contact of the Mount Anthony and the Mettawee in the Youlin Hollow area, intense quartz veining in the Mount Anthony is apparent. The beds are heavily slickensided but this is usual in the entire unit across the quadrangle. Quartz knots are also evident. Although no brecciation was observed at the Hollow some was observed elsewhere along the strike. The high degree of silicification at the contact may be positive evidence of faulting. In addition, the close contact of the phyllite and the Mettawee slates cannot be explained easily other than by a fault. None of the lower Mount Anthony formation is found at the contact. Green phyllites of the Mount Anthony are in direct contact with olive green slates of the Mettawee. No gradation exists between the two units. It is difficult to comprehend any possibility of two units in such close proximity being metamorphosed differently in the same locality without any gradation from the slate to the phyllite. Since the Mount Anthony has the more severely metamorphosed strata it is probable that these beds were farther east when metamorphosed. Faulting has thrust the Mount Anthony westward over the Mettawee and has placed two distinct lithologic types in direct contact.

It is apparent that younger beds have been thrust over older beds in the Equinox area along the Youlin Hollow fault. Billings (1933) has discussed this phenomenon at length. In the southwestern extremity of the fault zone, mapping is difficult because of rolling folds. As mapped the contact appears fairly straight since the scale of the map prevents tracing around the small hills which do not show on the topographic map.

West of the main mass of the fault a small klippe of the Mount Anthony overlies the Mettawee. Only a short distance (one-tenth of a mile) west (uphill) of this locality the Poultney overlies the Mettawee unconformably.

Dorset Mountain Thrust

Thompson (1959, p. 72) discussed the northern portions of the Dorset Mountain thrust. Evidence of the fault is excellent in that area. However, in the Equinox quadrangle the Dorset Mountain Thrust is not very apparent without knowledge of the section to the north.

The thrust nearly parallels Clark Hollow in the northwest one-ninth of the quadrangle. Recognition of the fault requires a traverse from the north at Dorset, along the north flank of Burnt Hill and southwest through Clark Hollow. In the Dorset area black phyllite, rusty weathering dolomitic quartzite and dark-gray to black marbles are in contact with, and apparently overlying, green phyllites which are west of the black phyllites. Beds on the east dip east. Across the northern part of Clark Hollow there are no westward dipping beds of comparable lithology. Instead, green phyllites are observed. It appears that the lower Mount Anthony is faulted over the higher green phyllites. If knowledge of the evidence of faulting to the north had not been available, an overturned fold with subsequent doubling of the section on the east would have explained this disparity. Small drag folds do show a small amount of doubling and the section is somewhat thicker than usual for this portion of the Mount Anthony formation in the Equinox quadrangle. The green phyllite would then overlie the black sequence which would have dipped below the green to the west. The contact is not seen in this northern part of the quadrangle.

However, in the face of Thompson's evidence (1959, p. 72) to the north, it is necessary to accept and map the thrust. If the criteria used are correct, the fault passes through Clark Hollow as indicated. At the southwest termination of the valley the fault separates two green units as the black phyllite exposures become thinner. Since the thrust from that locality southwestward faults green phyllite against green phyllite it is impossible to trace it further. Probably the fault dies out a short distance west of Haystack Mountain.

No positive criteria of faulting were found. Therefore evidence for mapping the thrust beyond the exposures of the black sequence is tenuous at best.

Evidence for the nature of the faulting is, of course, also lacking in the Equinox area. It is apparent, if the fault is accepted, that the east side is upthrown. However, the fact that the fault is a thrust is based on Thompson's evidence (1959, p. 72). The fault plane was not observed and its direction of dip could not be verified in the present study.

Dyer Quarry Thrust

Probably a near bedding plane fault within the Shelburne formation, this thrust is located between Manchester Village and Sunderland, west of Route 7. The evidence of faulting is based mainly on the presence of an excellent marble breccia. Fragments of the brecciated material are primarily the assorted lithologies found through the three members of the Shelburne formation. Details of this breccia have been discussed previously. The breccia has been observed only at the Dyer Quarry and near the southeast edge of Equinox Pond. Fragments of the same material have been found in the float in localities half a mile south of Dyer Quarry and between the quarry and Equinox Pond. It is apparent that the breccia extends between the two outcrops noted. However, there is no evidence of breccia in any other sections in the area.

The origin of the breccia is still in question. Although a fault is postulated it is possible that the breccia may represent an old talus slope occurring during a small uplift in the course of the deposition of the upper Shelburne strata. The breccia is in beds interfolded with the surrounding usual marble beds and the fault plane is intensely folded. There is no visible displacement of the beds but if the fault is near or in the plane of the bedding this is not unexpected. Dale (1912, p. 97) stated, "The brecciated bed is reported to have been core drilled to a vertical depth of 200 feet." It is doubtful that the breccia is as thick as this statement indicates since, in the same paragraph Dale points out the inconsistency between this report and the evidence of outcrops located in the near vicinity. This was also observed in the present study. However, as Dale noted, faulting may have altered the position and thickness of the breccia. If the thickness reported is accepted, the evidence for faulting is more positive than otherwise. Other evidence of faulting is involved in the tight folding of the breccia and the beds overlying it. Beds only a few feet higher are nearly flat lying (though recumbently folded) and the tight folding may represent a drag zone. If the drag is accepted the fault is a thrust with the east side upthrown. It is not, however, extensive.

Unconformities

The unconformities within the Taconic sequence, particularly in the higher parts of the column, are of extreme importance.

An unconformity may exist between the Winooski and the Danby formations. MacFadyen (1956, Table 1) indicated the possibility of a disconformity between the two units in assigning the Winooski to the lower Cambrian and the Danby to the upper Cambrian. In the present study, the Danby remains as upper Cambrian but the Winooski is indicated as possibly middle Cambrian as well as lower Cambrian. Therefore, no disconformity or unconformity is placed between these formations in this report. The basis for this decision is not firm. No fossil evidence is available to confirm or deny either hypothesis. However, the similarity of dolomites in the lower Danby to those in the upper Winooski and the similarity of the quartzites in the Danby to some found in the upper Winooski suggests a gradational contact. With no definite evidence to the contrary and without any indication of re-working of the upper Winooski during deposition of the lower Danby, it seems entirely possible that the middle Cambrian may be represented in the stratigraphic column.

MacFadyen (1956, Table 1) reported an unconformity between his Canadian limestone and the Walloomsac formation. Certainly a major unconformity is apparent everywhere in this area below this unit variously known as the Ira (Whipple-Hortonville), Walloomsac and the lower Mount Anthony formations. Thompson (1959, p. 72) also discussed this erosion surface and virtually all reports of the area indicate its presence. There is no doubt that the unconformity exists. The only question is the extent of erosion in the various localities. The faunal evidence is too weak to give definite opinions as to the age of several units. If the ages reported in other areas are applicable to the Equinox quadrangle, then erosion has truncated beds as old as the Cambrian and the later beds have been deposited on this surface (Thompson, 1959, p. 72). The Beldens, although generally considered to be Canadian in age, may be equivalent in part to the Chazyan (Cady, 1945, pp. 550–552). Prindle and Knopf (1932, p. 274) found the Chazyan limestones overlain by the Walloomsac. Fowler (1950, p. 35) reported the probable equivalent of this unit (Hortonville) overlying units from lower Cambrian to Trenton in age. No units which correlate with Black River beds have been reported in this general area, although Cady (1945, pp. 554, 555) has reported beds of this age from west-central Vermont. The Poultney formation has a range which should, at least in part, include Black River strata.

In the Equinox quadrangle, the lower Mount Anthony rests directly on the Shelburne on the east side of Mt. Aeolus (Green Peak). In many exposures along the east side of the Taconic Range, the black sequence, usually at the base of the Mount Anthony, is missing. In other localities, particularly along the east front of Equinox Mountain, the contact is completely gradational. An excellent example of the gradational contact may be studied in Cook Hollow, one mile south of Manchester. In the northwest part of the quadrangle green phyllites overlie the lower Cambrian Mettawee at the Youlin Hollow thrust. Faulting alone could be responsible for the lack of the black phyllites at the base. However, the Poultney also overlies the Mettawee and here confirms the unconformity. At any rate, in the West Rupert area, lower Cambrian beds are overlain by mid-Ordovician strata with a profound hiatus between them. The evidence is overwhelming in favor of an unconformity of major proportions either just prior to or early in the time of Trenton deposition.

A post-Walloomsac unconformity has been suggested by MacFadyen (1956, pp. 28, 29). His studies revealed the basal contact of the Mount Anthony formation is gradational in certain localities. Generally, however, MacFadyen believed that the Mount Anthony overlies the Walloomsac unconformably. The presence of this unconformity appears entirely possible from the studies of MacFadyen, and in the Equinox quadrangle similar evidence is readily apparent. Much of the eastern front of the Taconic Range, from the Sunderland area to Manchester, shows a gradational contact at the base of the Mount Anthony formation. Elsewhere the black phyllite, usually at the base, is lacking. However, at several exposures of the gradational contact the black phyllite appears 50–75 feet above the interbedded zone and the contact itself primarily involves green phyllite and marble. In other localities black phyllite takes part in the gradation. It is possible that an unconformity exists but a facies change is also possible. The fact that MacFadyen (1956, p. 29) reported Mount Anthony directly upon Canadian limestone with no intervening Walloomsac is good evidence for the unconformity. In the Equinox area the gradation is not always present. Therefore, the presence of the unconformity is probable. If this is the case, the lower units may have been re-worked as the basal Mount Anthony was deposited. However, it is more likely that after the lower Mount Anthony (Walloomsac?) was deposited re-working of parts of this lower portion stripped the black phyllites and marble from some localities and deposited them in others, leaving a relatively smooth surface on which the rest of the formation was deposited. Where the black phyllites and marbles are entirely lacking (by erosion?) and the green phyllites are in sharp contact with the Canadian marbles (MacFadyen, 1956, p. 29) the older marbles were not re-worked since they were probably consolidated by the time of deposition of the later rocks. Certainly the pre-Trenton unconformity and its accompanying uplift imply a passage of time during which such events were possible. A combination of unconformity and facies changes is suggested to explain the lower part of the Mount Anthony formation.

Folding

A few general statements to explain the structural elements in the Taconic Synclinorium are necessary.

Overturning of the folds to the west is the most prominent feature of the folding. Only in the northwest is it possible to demonstrate smaller folds which have a vertical or nearly vertical axial plane. Major structures, however, may not display the extreme overturning. These often appear as broad, nearly symmetrical structures. For example, the North Bennington anticline east of Shaftsbury is only slightly overturned to the west. In the Taconic Range the folds frequently appear as broad and gently dipping. In reality severe folding is encountered in all outcrops in the field. This seeming anomaly may be explained by noting the general flat-lying or gently dipping beds which appear strongly crenulated by drag folds of various magnitudes. The overall effect of gentle dip is evident in exposures of broad horizontal extent. Furthermore, the conglomerate or graywacke previously mentioned in the Mount Anthony formation can be demonstrated in the vicinity of Sandgate to have an overall dip of about 10° regardless of the severity of the numerous folds. Although a dip of 40° or more to the southeast may be measured in outcrops on hills west of Sandgate, this key horizon appears on successive hills in an easterly direction at elevations that indicate an overall dip of about 10°. Although more difficult of access the same statements may be made in regard to hills in a westward direction.

As indicated by Thompson (1959, p. 71), the structure in the eastern valley although complexly folded and overturned westward are actually dipping gently westward. In the Taconic Range the general dip is eastward as indicated by the increasing elevations at which lower strata of the Mount Anthony formation appear in the western part of the quadrangle.

The more competent beds show less drag folding as a rule than do the incompetent phyllites. The core of folds in the Taconic Range generally contain the more competent strata which are marbles primarily. These also show flowage folding rather than those of the drag type. The conglomerate or graywacke in the Mount Anthony formation displays the drag folding only in thin or polished sections. Quartz grains frequently are elongated to the southeast and fractures through the grains as seen in thin-section closely parallel a cleavage direction in several samples studied. This may represent the axial plane cleavage which is a prominent lineation in these beds.

Several folds too small to show individually on the map are of interest. The anticlinal structure in the corkscrew road west of Sandgate is typical of the intense folding. The lower portion in the core of the fold is oxidized to a brick red color. Along Route 313 west of Arlington several excellent recumbent and isoclinal folds may be observed easily. In the area east of the East Dorset Corners the Mallett member of the Dunham formation outlines a small syncline.

In the Vermont Valley several of the hills in the central part of the area show steeply dipping beds. Dips are generally to the west.

The main structural trend is N20°E. In most cases fold axes strike in that direction. On a local scale, however, the strike is extremely variable. The plunge of the entire structure is gentle and to the southwest. Broader exposures of the older beds appear in the northeast showing a general climb of the synclinorium in that direction.

Bedding

One of the most difficult problems in the Taconic Range is the certain distinction of bedding. Cleavage frequently simulates bedding and the two are difficult to distinguish in the phyllites. Fortunately, in the phyllite sections sandy, graywacke or conglomeratic zones as well as thin marbles assist in differentiation in many localities. Where the distinctive beds are not present it is not always possible to be certain of the bedding.

In the Ordovician marbles below the Mount Anthony formation bedding is more easily recognized. However, flow banding may resemble bedding locally by mineralogical segregation during metamorphism. Sandy horizons, cross-bedding and other identifiable zones are useful in these beds also. In the Cambrian beds below, where quartzites predominate or are interbedded with dolomites, bedding is not difficult to distinguish except in the Cheshire where jointing and bedding form blocks. Interbedded phyllites also are invaluable in outlining structural relations. Bedding is less certain in the pre-Cambrian.

Thickening and thinning of the phyllites is common, both through doubling in folding and by flowage of calcitic or quartzitic beds (Plate 8). This phenomenon provides misleading information as to the thickness of the more phyllitic units as well as of the more competent beds. In cases where the crests of tight overturned folds are eroded away it is often difficult to determine structural relations as all beds on both sides of the axial plane may dip in one direction, usually to the east. Some few key beds are useful in solving this puzzle.

Cleavage and Jointing

Several cleavages may be developed in the area. In general the strike of the cleavage is to the northeast, usually N10°E to N25°E, although some variability around individual folds was noted. Axial plane cleavage is well developed, particularly in the higher units. Dips are variable to the southeast. The most consistent dip of the cleavage is about 40°SE. Fracture cleavage is common in the more competent strata. In the higher portions of the Mount Anthony formation bedding plane and slip cleavage have completely obliterated any primary features. Bedding plane cleavage commonly is recognized where some readily identified bed is surrounded by phyllites. Platy minerals are oriented parallel with the bedding. Bedding and slip cleavage are the same in these exposures. Flowage also occurs. This has been discussed previously in regard to bedding.

Jointing is also common and is best displayed in the Cheshire and other quartzites. Two directions of jointing are found in this quadrangle, one at N20°E and the other at right angles to the first. Dips are steep and in much of the area are close to vertical. In the Cheshire quartzite it is not unusual to experience difficulty in distinguishing jointing from bedding. Only extreme care can prevent confusing the two features and, since the structure depends upon the distinction, caution is essential.

In the higher formations, particularly those primarily composed of phyllites, jointing is obscure. That it is present is undoubted but it is not sharp or distinct. Furthermore, fracture cleavage and jointing cannot be differentiated except by the spacing of the fractures. Jointing in the Ordovician marbles is locally well developed. In several localities on Route 313 at which the folds are recumbent, the jointing appears to wrap around the structure. These may be the result of folding later than the jointing. It is also possible that a single episode provided both phases. This would produce the same result.

THE TACONIC PROBLEM

Since the earliest study of the rocks in the Taconic area, the problem of the age, origin and structural relations of the "High Taconic" and "Low Taconic" strata has intrigued all those who have seriously considered them. The complexity of the structure and the lack of fossils has defied a positive solution and even the most likely hypothesis is not easily demonstrable. The "Problem" as originally considered involved Emmons' "Taconic System" (1842, 1844). Since Dana (1877, 1887) and Walcott (1888) provided evidence that the use of this term was invalid, this phase of "the problem" has been eliminated.

The Taconic Problem revolves around the supposed similarity of known Cambrian slates of the "Low Taconics" with the phyllites in the Taconic Range proper, the age of which cannot be demonstrated on paleontologic grounds. The problem has been discussed frequently, and recently many excellent studies have been made of the Taconic strata and its anomalous elements. A complete review of the subject would seem unnecessary and repetitious in view of the excellent summaries by Fowler (1950), MacFadyen (1956), Bucher (1957), Craddock (1957) and Weaver (1957).

Zen, *et al* (1959) added much new data also. Since so many excellent studies have been made recently, only a brief synopsis of the problem seems necessary. Following this a possible solution will be presented.

As noted earlier, the problem involves the age of certain argillaceous beds physically overlying and surrounded by Ordovician marbles and black phyllites which are probably mid-Trenton correlatives. The relationship of these argillaceous beds of the "High Taconics" to known Cambrian strata of the "Low Taconics" west of the Taconic Range, to which they bear some resemblance, is the basis of the confusion. The "Low Taconics," composed of Cambrian and Ordovician strata, are known to be thrust over an autochthonous sequence along "Logan's Line." The area east of the "High Taconics" is also believed to be autochthonous. The conflict lies in assigning an age to the phyllites of the "High Taconics." If these phyllites can be demonstrated to be the equivalent of the lower Cambrian olive, green and purple slates of the "Low Taconics" then obviously a klippe passes under the "High Taconics" with its eastern boundary at the contact of the Ordovician marbles and the overlying phyllites. The western boundary would then be "Logan's Line." If the phyllites of the "High Taconics" (Mount Anthony formation) are not equivalent to the Cambrian slates of the "Low Taconics" but instead are Ordovician in age then the klippe cannot pass under this mass.

In the eastern part of the Taconic Range the green phyllites are above known Ordovician strata in the Equinox area. Along the western flank of this range the same phyllites are in direct contact with and above known Cambrian beds. Between these two extreme easterly and westerly exposures the green phyllites overlie black phyllites and interbedded dark marble variously called the Ira formation (Whipple-Hortonville), the Walloomsac, the Berkshire schist and in this paper the lower part of the Mount Anthony formation. Thompson (1959, p. 86) has shown both Berkshire schist and Ira formation as differentiated on his map with both taking a position below the green phyllite. However, Thompson (1959, p. 77) stated in discussing the Berkshire schist, "This formation cannot be separated with any certainty from the Ira formation to which it may be in part or wholly equivalent." There appears to be little certainty of a need to distinguish these two units. Certainly the Walloomsac, Ira (Whipple-Hortonville) and lower Mount Anthony are so similar as to be indistinguishable and, although faunal evidence is weak they all appear to be Trenton equivalents. Weaver (1957, p. 746) noted the similarity of all these units also and reported, "Because of its relationship to the limestone at its base the Berkshire schist in the Copake quadrangle is regarded as of Trenton age." As is frequently the case, where fossils have been found the unit has been called Ira or Walloomsac (or lower Mount Anthony). With no fossils, the same lithology has been called the Berkshire schist. In an area such as this, confusion has been created by the multiplicity of formational names all meaning the same lithology. Whatever the precise age the above lithologies are under the green phyllites and, in the main, these are known to be in the Ordovician sequence and are probably best assigned as Trenton correlatives.

The supposed similarity of the eastern green phyllites with the known Cambrian slates is apparently based on the fact that both units are argillaceous and are associated with limestones or marbles. Another similar lithology is the supposed Zion Hill type discussed earlier. Actually, if one utilizes a klippe as usually conceived, the two sections must be demonstrated to be equivalent and, according to Zen (1959) and Shumaker (1959), the eastern green phyllites must be in an inverted position.

Careful examination of the section above the known Ordovician marbles indicates that in the Equinox quadrangle the green phyllites are not inverted. Graded beds in the conglomerate or graywacke within the green phyllites as well as cross-bedded, sandy marbles in the lower part of the Mount Anthony (in black phyllite) are correctly oriented. One example of the graded bedding is shown in Plate 5. More finely graded or more coarsely graded beds are also plentiful. There seems little reason for considering the green phyllite sequence to be inverted. If the Mount Anthony formation (the green phyllites) is not inverted, the supposed lithologic and stratigraphic similarity between these beds and the more western Cambrian slates becomes negligible. Furthermore, if (as is indicated by the evidence) the Mount Anthony strata are not inverted, the limestones and marbles at the base are in the proper position and not at the top of the formation as required to demonstrate close similarity (Zen, 1959, pp. 1, 2). Rather than being at the top, the marbles lie at the base. The supposed equivalence of the "High Taconics" to the "Low Taconics" is doubtful. One of the requirements of the theory of equivalence of the two sections is based on the similarity of lithologies and this is unacceptable in the face of the evidence in this area. Equivalence, therefore, must be based on fossils if possible. These are not available in the eastern green phyllite sequence. There seems little evidence that the two sections are the same.

In addition, no positive evidence of an eastern bounding fault has been found. In the west, the Youlin Hollow thrust can be demonstrated. However, it is essential to the usual concept of the klippe that a fault be demonstrated around the entire mass. At the present time this does not appear possible. Furthermore, evidence is available that if a fault exists on the east it is not at the base of the Mount Anthony formation. The origin of the klippe hypothesis is based on Keith's (1912) discussion. MacFadyen (1956, p. 58) noted that Keith probably was mistaken and in reality had observed the early or mid-Trenton unconformity rather than a fault.

Other hypotheses to explain the supposed anomalous position of the Taconic Range strata should be considered. These are based on stratigraphic or sedimentologic criteria.

One hypothesis by Weaver (1953) suggests that the Cambrian shales (in the Equinox area these are slates) are part of the autochthonous sequence and are an argillaceous facies of the Cambrian carbonates and sandstones. This theory involved a deep central trough into which the argillaceous sediments were deposited from the west after bypassing a more westerly sequence of carbonates. Carbonates also are east of the argillaceous beds. In the Equinox area this hypothesis would explain only the "Low Taconics" and is difficult to accept in view of the extreme bypassing required.

Later Bucher (1957, pp. 670–672) suggested an hypothesis involving deposition accompanied by differential uplift to account for the Cambrian argillites being located to the west of carbonates which, according to the usual concept, should be a further offshore facies. If an eastern source is assumed the muds should have been deposited east of the carbonates. According to the theory, the western muds (now present as Cambrian slates in the west) were first deposited in the east in the present site of the Cambrian dolomites and quartzites. Then after differential uplift at least some of the muds were eroded and transported westward to their present position. Later, the eastern area was downwarped and the Cambrian dolomite and sandstone was deposited in the area from which the muds were earlier removed. The theory also requires several later uplifts along the axis of the Taconic area, separating the two lithologies. It does not explain the autochthonous strata west of the "Low Taconics" or the supposedly anomalous phyllites of the "High Taconics." Bucher (1957, pp. 670–672) has listed an interesting series of events which, in part may be utilized in other theories but must be altered in the Equinox area.

Thus far the analysis has considered only the "Low Taconic" section. In his hypothesis Bucher (1957, p. 671) accounted for the later sequence by similar processes. Essentially, this is the same as the suggestion by MacFadyen (1956, pp. 61–64) who based his solution on the then unpublished data of Weaver and Craddock as well as evidence in his own area. MacFadyen, however, found none of the "Low Taconic" sequence in the Bennington area. His interpretations are based on unconformities above and below the mid-Trenton strata. Although none of his evidence is positive, he demonstrated that no evidence of a Taconic klippe is present in the Taconic ("High Taconics") section of the Bennington quadrangle. Evidence of thrusting is present in the west but not on the east flank of the Taconic Range. All beds are interfolded and suggest that diastrophism followed the deposition of the younger strata. None of the criteria usually associated with faulting have been observed between the carbonates and the "High Taconic" phyllites. Thus although the evidence is primarily negative in nature it does suggest agreement with areas in New York. Elam (oral communication)* in the Troy area in New York has also found no evidence of a klippe, and other workers in New York also reject the eastern fault.

In the Equinox area, however, positive evidence is available to demonstrate that between the carbonates and the green and/or black phyllites above, no fault is possible. If any fault is present it must either be well within the green phyllite sequence or far below the basal contact and within the marbles. In either case the fault would be unmappable and would include either more or less strata than are acceptable under the usual klippe hypothesis. In the second case, beds of Trenton age would be involved and on the face of it this is not possible unless the section were inverted. If the criterion of the graded beds within the green phyllite sequence is acceptable, the section cannot be inverted. As stated earlier, a complete gradation between the Ordovician marbles

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*Elam, Jack. In study for doctoral dissertation at Rensselaer Polytechnic Institute, 1960.

and the Mount Anthony formation may be easily studied at Cook Hollow and at other localities along the eastern and northeastern flanks of Equinox Mountain. Although the climb to the head of the Hollow is not easy, the section is a nearly vertical one and is easy to observe. Gordon (1924, p. 253) believed the precipitous exposures represented a nearly vertical fault plane. That this is not the case is obvious. Gordon did not observe the section at close range. Bedding is almost perfectly horizontal and interbedding and gradation are apparent (Plate 6).

The evidence indicates that an unconformity probably exists below the Mount Anthony formation. Re-working of the upper marbles during the deposition of the phyllites has produced a gradation between the marbles and the phyllites in some localities. It is also possible for facies changes to be involved in the numerous lithologies at the base of the Mount Anthony. No fault is postulated since the gradation and the lack of inversion of the section indicates that the Mount Anthony formation is in the normal sequence and is younger than the marbles below. No equivalence is required between the Cambrian slates and the Mount Anthony formation for they are of vastly different ages. As a result of mid-Trenton differential uplift and differential erosion, various formations across the area of the Taconics were exposed. An explanation such as this is not merely reasonable but likely. Deposition on the old erosion surface has produced the phyllites of the Taconic Range. This does not provide the answer but suggests that these phyllites lie in their normal position above the Ordovician marbles.

Zen (1959) indicated that at the north end of the Taconics the beds can be traced around the nose of the structure from the "High Taconics" to the "Low Taconics." In view of this at least in that area a fault is indicated. However, from the northern boundary of the Equinox quadrangle southward into New York, there has been no evidence reported of a fault along this eastern zone. These two interpretations of a fault in the one case as against the normal contact in the other appear to be diametrically opposed.

Although there is no general agreement regarding the supposed fault along the eastern front of the "High Taconics," virtually all students of the problem agree that a fault does exist along the western edge of this area. The same fault seems to be traceable from the west side of Stissing Mountain (Millbrook Quadrangle, New York) northeastward through New York State and into Vermont. Zen (1959) shows that the fault eventually bends eastward in the Castleton area. Adherents of the klippe hypothesis require that the fault turn southward and trend to the southwest roughly parallel to and eventually joining the westerly and generally accepted fault discussed above. Adherents of the normal sequential deposition theory do not accept the eastern fault since it is unlikely that the fault would occur at the contact between the marble sequence (Vermont Valley) and the overlying phyllites if that contact is gradational. It must be in some other position and this opposes the klippe hypothesis. They may agree that the western fault probably does arc to the east and south in the Castleton quadrangle. The fault cannot, however, continue its southward direction for any considerable distance in the view of these workers.

It would appear that the two hypotheses are unreconcilable. Yet Zen (1960) believes that such reconciliation is necessary in view of the conflicting data.

An interpretation by the present writer which may in fact reconcile both views, is suggested from the study of the Equinox area. Reference to Plate 15 will assist the reader in the following discussion. The theory assumes general agreement about the fault (Fault A) along the western edge of the "High Taconics." The "High Taconics" ("Slice A") has been thrust over the "Low Taconics" ("Slice B"). If the "High Taconics" is in its normal position relative to the marble sequence, then the entire mass, including those rocks east of Fault A (the Taconic Range, Marble Sequence and the Green Mountains) is part of the same "slice." These rocks have been thrust westward as a unit over the "Low Taconics" which was previously also faulted into its present site. Fault A then is on the eastern boundary of the "Low Taconics" and Fault B, which trends northeastward from the Troy area, is the western or leading edge of the klippe.

According to this hypothesis the area west of Fault B is the autochthone, "Slice B" the allochthone and "Slice A" (also allochthonous) is thrust over "Slice B." In this fashion the klippe is entirely exposed at the north end as Zen (1959) states. As one tries to follow the klippe southward it is buried on the east by the "High Taconics" ("Slice A") which has been thrust over the trailing or eastern side of the klippe. The eastern part of the klippe can no longer be observed for it is overlain by the "High Taconics" (Plate 16, Figure 1) and is cut off by the later fault (Fault A). The "High Taconics" is in its normal relationship to the strata east of it. Reference to an adaptation of Zen's cross-section (Plate 16, Figure 2) shows the klippe exposed on both east and west. Fault B is the major fault marking the western edge of the klippe. At its northern extremity it bends east then south and is covered in the rest of its southerly extent by Fault A which then becomes the major fault. The "Low Taconics" is allochthonous; the "High Taconics" a second, more easterly, thrust sheet.

The value of this interpretation is that it simplifies the highly complex structure and stratigraphy required by the usual klippe hypothesis. At the same time it avoids the unusual sedimentologic conditions required by the facies change concept since all of the elements (the autochthone, "Slice A" and "Slice B") were originally deposited separately in other areas and are not necessarily related sedimentologically.

Some evidence that the Green Mountains and marble sequence as well as the Taconic Range have been thrust in should be presented also. Diment (1956, p. 1688) indicated in his gravity studies of a portion of that area that a very high gravity exists in the region of the northern part of the Green Mountains and a very low gravity under the Taconic Range. He suggested faulting as one possible explanation for these gravity anomalies. In addition Fisher (personal communication) reports that several pre-Cambrian hills in the Schunemunk and Poughkeepsie quadrangles in New York are probably rootless. Offield (personal communication, 1961) believes that gravity measurements of Stissing Mountain in Dutchess County indicate that this pre-Cambrian is also separated from the basement, although he suggests that lateral movement was probably not great.

If pre-Cambrian rocks were formerly more extensive at the surface due to faulting, they would have been an excellent source area for later (Ordovician) sediments in the southern Taconics and may provide a source for such units as the Rensselaer graywacke in New York State. These would then not necessarily be of Cambrian age as presently suspected but possibly of later Ordovician age. A full discussion of the historical sequence is included in the appropriate section.

HISTORICAL GEOLOGY

Although the general geologic history of the region as a whole has been relatively well understood for many years, the details are frequently confused by the vexing problem of the Taconic sequence. Any discussion of the Paleozoic history depends upon the solution to the problem of origin and age. If the present hypothesis is accepted, a history must be interpreted that involves normal sequential deposition and thrusting. Since these are suggested by the evidence in the Equinox area the history of that part of the section is based on these factors.

Deposition of an unknown thickness of pre-Cambrian clastic sediments was followed by diastrophism during which these rocks were raised to a medium to high metamorphic grade. Pegmatitic intrusion along joints accompanied this activity. The area was raised and eroded forming the pre-Cambrian unconformity.

Following submergence the Paleozoic was initiated by the appearance of a coarse conglomerate, deposited in irregular lenses, upon the old erosion surface. Upon this surface, the variously textured clastics of the Cambrian Mendon formation were deposited. Muds as well as much coarser debris were spread across the area in the quite shallow sea. In the Vermont Valley section and westward, the muddy facies was probably well developed in the early Cambrian. Continued deposition in the area of the Green Mountains with slight fluctuations of the shoreline produced the interbeded contact of the Cheshire and the underlying Mendon. Uplift east of the Green Mountain area, as the Cheshire deposition began, provided the coarser sediments. The uplift may have been responsible for erosion of the muds from the region of the present Vermont Valley and their subsequent deposition toward the west. Winnowing of the fine sediments by wave action is entirely possible. This may have increased the westward transportation and produced the resultant cleanliness of the more easterly deposits particularly near the top. Probably a low-lying western source supplied the major part of the muds and occasional carbonates for the early Cambrian sequence in the "Low Taconics." A single basin however, is postulated with materials on the east coming from the east and those in the west primarily from that direction. Later the eastern area sank quietly and clean sands and dolomites were deposited. Occasional phyllite partings in the eastern quartzites and dolomites probably indicate warm, shallow water with removal of muds by wave action. Through the lower and middle Cambrian, deposition of the quartzites and dolomites continued in the valley area. Renewed and continued uplift in the east provided coarser sediments as the late Cambrian sandstones were deposited and interbedded with dolomites. As the eastern highlands were eroded dolomites became the predominant material. Shallowness is still indicated by clean deposits. Few, if any, areas lay below wave base since the fine muds have been cleaned out so well. The area to the east may have been quite precipitous and may have provided only coarse, clean material other than the sediments carried by solution. At the close of the Cambrian some muds were available and the resulting dolomites are far dirtier than the early Cambrian beds. The craton supplied clays and muds which were deposited east of the present foreland and became the Cambrian slates and their interbedded carbonates of the "Low Taconics." No lower or middle Cambrian deposits are known in the foreland indicating that the area was not negative during that time. Later in the Cambrian, the Adirondacks provided a source for the late Cambrian coarse clastics and dolomites of the foreland. In the course of this uplift any muds or clays deposited or formed in that area would have been transported eastward as the coarser clastics moved into that position.

As the Ordovician period began, carbonates with occasional clean quartz sand were spread westward into the Valley area. The source to the east was low and provided a poor traction or suspended load. More material was carried in solution by these weaker streams. Some muds were transported to produce the darker marbles. In the west, upwarp between the autochthone and the site of deposition of the Taconic strata resulted in erosion of small quantities of mud from the old Cambrian beds and produced a source for the early and middle Ordovician Taconic strata. This was a positive area but not high enough as yet to supply much material. Reworking was common. Continued deposition of a primarily chemical load in the east resulted in clean calcitic and dolomitic beds of the Shelburne formation and later, as mud content increased, the dark gray or blue-gray marbles of the Bascom-Beldens were laid down. In this interpretation two basins, probably connected at the north and becoming a single trough in that area, receive sediments from both east and west. The eastern basin sediments were transported both from the low land to the east (primarily a chemical load) and from the upwarped zone separating the two basins. Muds were available in that area. The western basin received muds from both the upwarped area and the more western craton. Carbonates were deposited between these mud facies. The Poultney and later strata were deposited on the east side of the western trough.

Probably faulting and uplift occurred following the deposition of these units. The Dyer Quarry breccia indicates at least minor movement during general deposition and the unconformity above the Bascom-Beldens, which is probably mid-Trenton in age, demonstrates the uplift and erosion of these beds. Differential uplift caused deep erosion in some areas, little or none in others. Subsequently, differential sinking of the region permitted deposition of the lower Mount Anthony with the area acting unstably. This caused some of the lower Mount Anthony to be eroded and redeposited in a gradational sequence in other localities. In the western part of the area, general sinking had occurred and the Poultney beds were deposited.

Many authors have postulated a western source for much of this material and probably both a western and eastern source should be combined to produce the results observed. In reality, local sources may be responsible for the numerous facies changes in parts of the sequence. A western source for the more westerly Cambrian slates is probable but an intermediate source is also required for the later strata. Conglomerates of the eastern Cambrian and some cross-beds in the Cambrian and Ordovician strata on the east indicate an eastern source. In the Trenton lower Mount Anthony formation, a northern or northeastern source for the quartzites is possible. No single factor has provided a definite answer to this problem.

No sediments younger than the Poultney or Mount Anthony are known in the Equinox area. The original thickness of these formations is not known nor is it known if any later sediments were deposited above them. Probably deposition ended during the Ordovician and, during the middle or late part of the period, diastrophism strongly folded the strata. Near the western margin along Logan's Line, faulting moved more easterly beds toward the west covering the section where Cambrian muds from the west mingled with Cambrian sands and dolomites from the east. Later faulting along the Youlin Hollow thrust moved the entire eastern area westward with the Mount Anthony faulting over the unconformity formed on the exposed and deeply eroded Cambrian strata in some localities, and over younger beds in other areas. According to this interpretation the entire eastern area has been moved westward as a unit so that the Taconic Range—Green Mountain region was not deposited in its present site but has been faulted into the present locality. In the process of this thrusting the intermediate source area which separated the two basins has been covered as have been all zones of interfingering of the various facies.

The only strata actually in place are those of the foreland. Both the "Low Taconics" and "High Taconics" are thrust into their present regions. The "Low Taconic" thrust sheet developed as a klippe with a very gently dipping fault plane. Later erosion may have dissected the eastern portion of this klippe. The second thrust, which brought in the "High Taconics," covered the eastern boundary of the earlier klippe. The remainder of the faulting resulted from overfolding to the west. Intense deformation produced isoclinal and recumbent folds. In the Green Mountain area the metamorphism was retrogressive and assumed the low grade of the entire area. Uplift and deep erosion followed by glaciation in the Pleistocene brings the history to the recent during which temporary lakes filled the valleys. The lakes emptied as lower outlets appeared and erosion has produced the present landscape.

ECONOMIC GEOLOGY

At the present time sand and gravel deposits are the only economic materials being worked in the Equinox quadrangle. In the past, however, the marble industry was quite active in the Manchester-Dorset-East Dorset area.

Dale (1912) has fully discussed the marbles and the exploitation of them during this early period. In the late 1800's and early 1900's many quarries were operated in the area. Several had been abandoned by the time of Dale's (1912) study. Those in operation at that time provided vast quantities of marble for building stone. None are in operation today although the quantity of high quality white and blue marble is far from depleted. Excellent marbles from the Shelburne formation are easily available in quarries in the north-central part of the quadrangle. The same marble outcrops in a belt southward. Blue marble is also plentiful. The Dyer Quarry breccia has never been exploited although an early attempt was made. Probably much more of this red marble breccia is available than was suspected at that time. However, the thickness probably is below that required for economical operation. One quarry in the Intermediate dolomite member was opened for dimension stone for use in building a local school.

On the southeast and south faces of Red Mountain, the black phyllite becomes so highly graphitic that crushed samples were used directly to lubricate locks on the field car. Some portions of the phyllite do show larger quantities of quartzose and calcareous impurities. The outcrop is quite large with a vertical exposure of well over 100 feet and a length of hundreds of feet. Lesser exposures of the same material have also been observed along the south face of Red Mountain. The graphite may be observed between 1,100–1,400 feet on Red Mountain as the beds tend to display an overall westerly dip. The intense folding shows most dips to the east but overturning causes a lowering of the section to the west in that area. An additional deposit though of poorer quality has been observed at the head of Terry Brook and on the east side of Egg Mountain.

Sands and gravels are well known in the Equinox quadrangle. Largely these deposits are from well sorted deltaic beds which were formed in the proglacial lake that filled the Vermont Valley. A few less well sorted proglacial deposits are also utilized. These sands and gravels are the main economic deposits worked in the Equinox area.

Iron was mined early, probably from bog iron deposits. Operations were abandoned after a short time. The precise location of the old workings is unknown but it is believed to have been on the northeast side of Lye Brook east of the Vermont Valley. Some hematitic deposits from the red, calcareous phyllites occasionally altered from black or green pyritiferous phyllites at the base of the Mount Anthony formation have been worked briefly as a pigment. No iron deposits have been commercially important.

Deposits of aluminum have been reported but the localities have never been verified. In one case the locality is definitely in error. Certainly highly aluminous clays from the weathering of the phyllites are plentiful but these are far from commercial in quality or quantity.

The single remaining possibility of economically valuable material is the quantity of quartzite, particularly the Cheshire, which breaks out in blocks since the jointing and bedding are sharp. These might be useful as dimension stone. At the present time it is not utilized.

In the near vicinity radioactive deposits are known from the Green Mountains. These have not been proven and have not been exploited.

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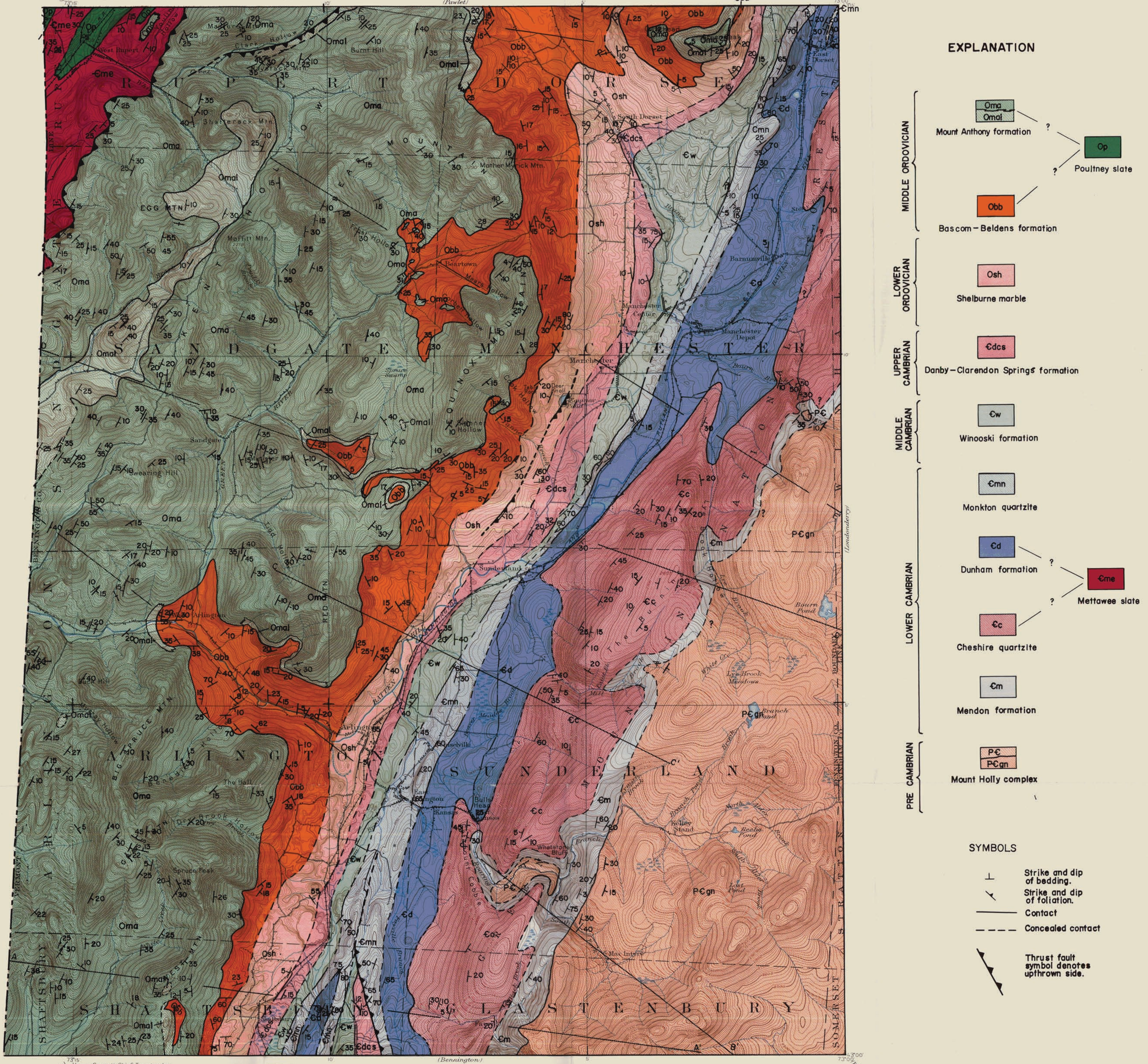
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PLATE I

VERMONT
EQUINOX SHEET



73°15′ 10′ 5′ 73°00′ 43°00′

Henry Gannett, Chief Topographer
H.M.Wilson, Chief Geographer in charge.
Triangulation by U.S.Coast and Geodetic Survey and G.T.Hawkins.
Topography by J.H.Jennings, G.E.Hyde and Jas. Mc.Cormick
Surveyed in 1894.

Hyde Jennings McCormick

SCALE 1:62500

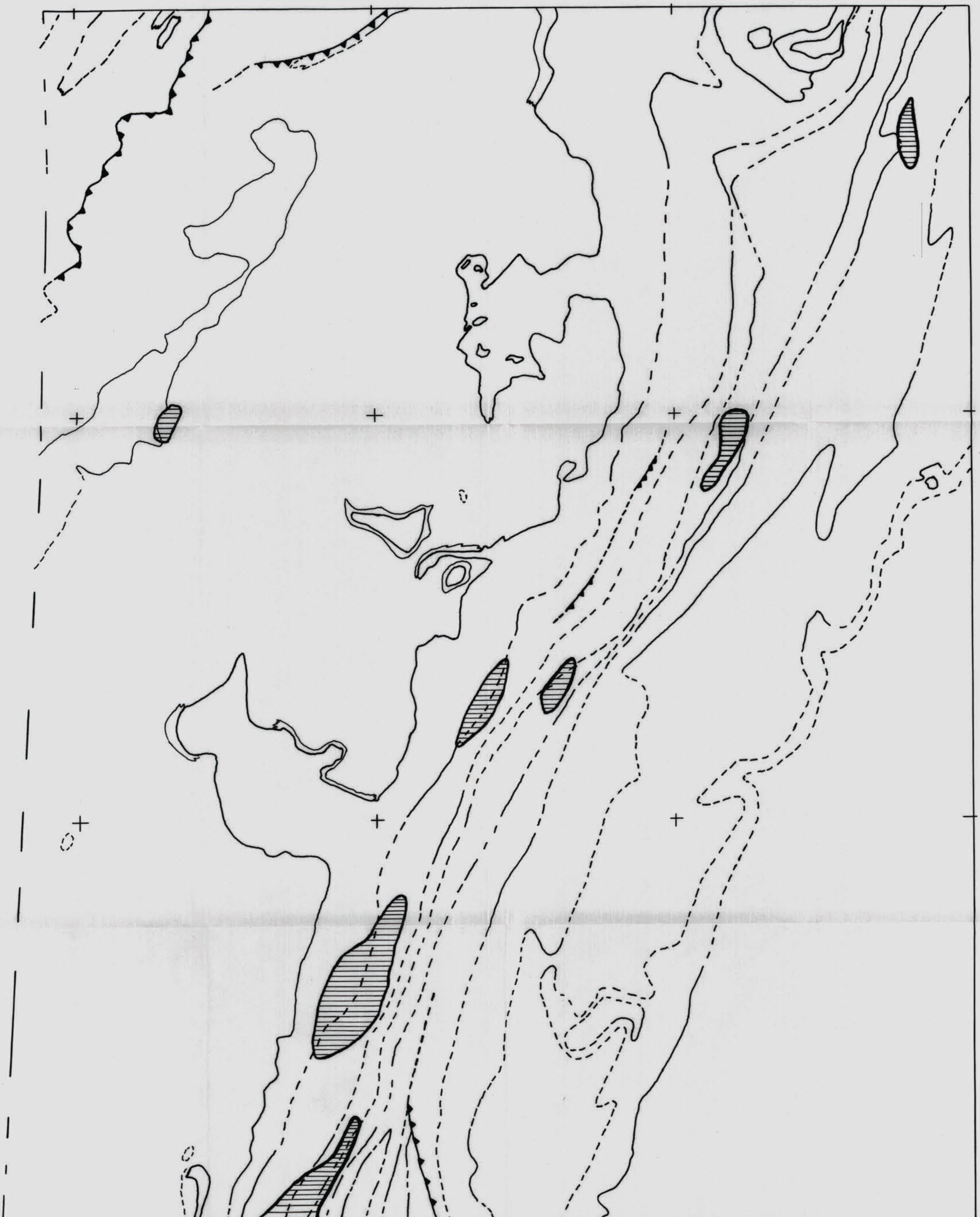
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

Edition of Nov.1900, reprinted 1946
Polyconic projection
Surveyed by reconnaissance methods

VT.
EQUINOX
N4300–W7300/15

VERMONT GEOLOGICAL SURVEY
Charles G. Doll, State Geologist
(Bulletin No. 18)

Geology By
Philip C. Hewitt and Richard F. LaBrake



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GLACIAL OVERLAY

(Includes only important glacial deposits.)

The rule-lined areas indicate location of moderately to well sorted glacial deposits.

PLATE 2

0 1 2 3 Miles

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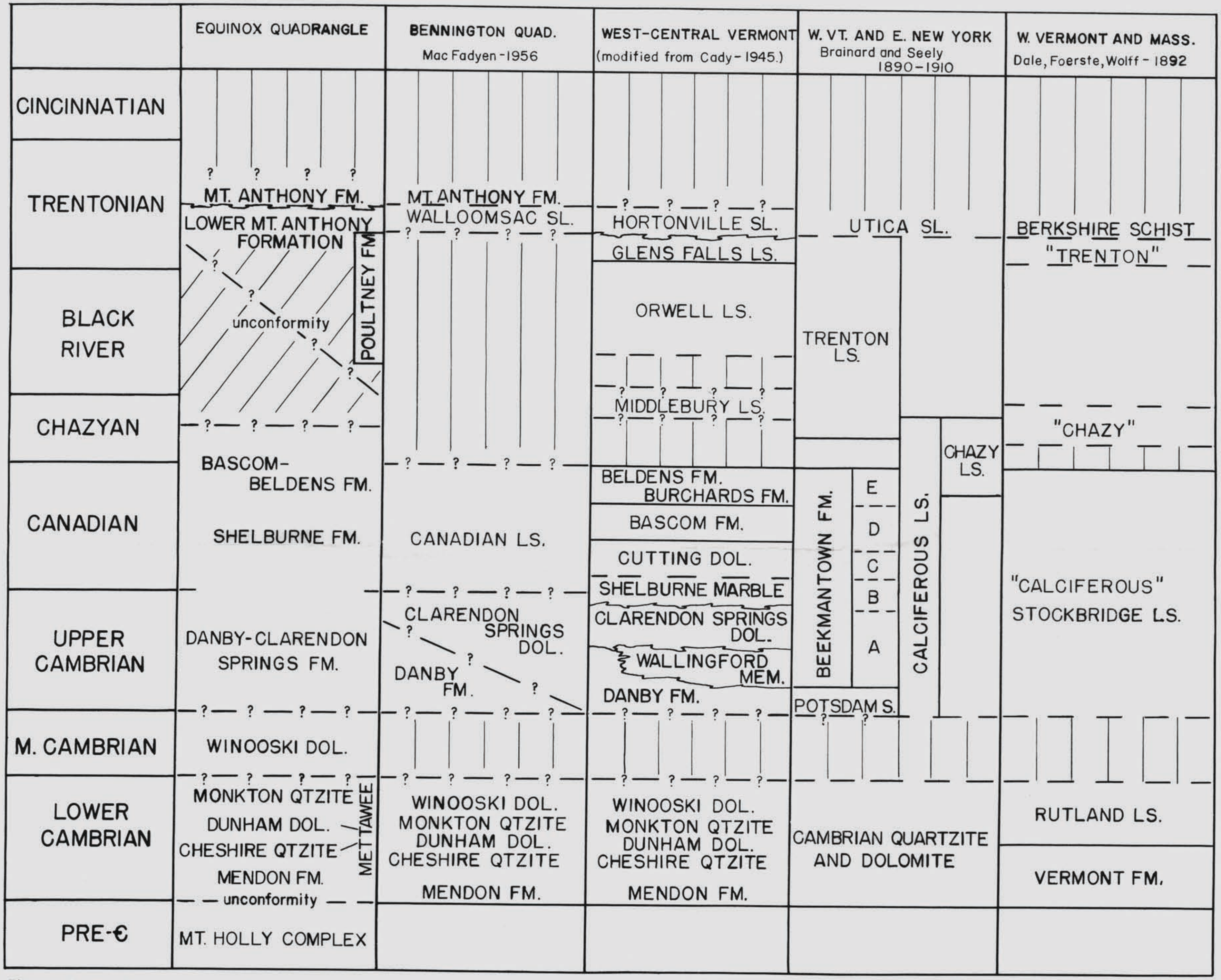

Figure 2 — Comparative Correlation Chart

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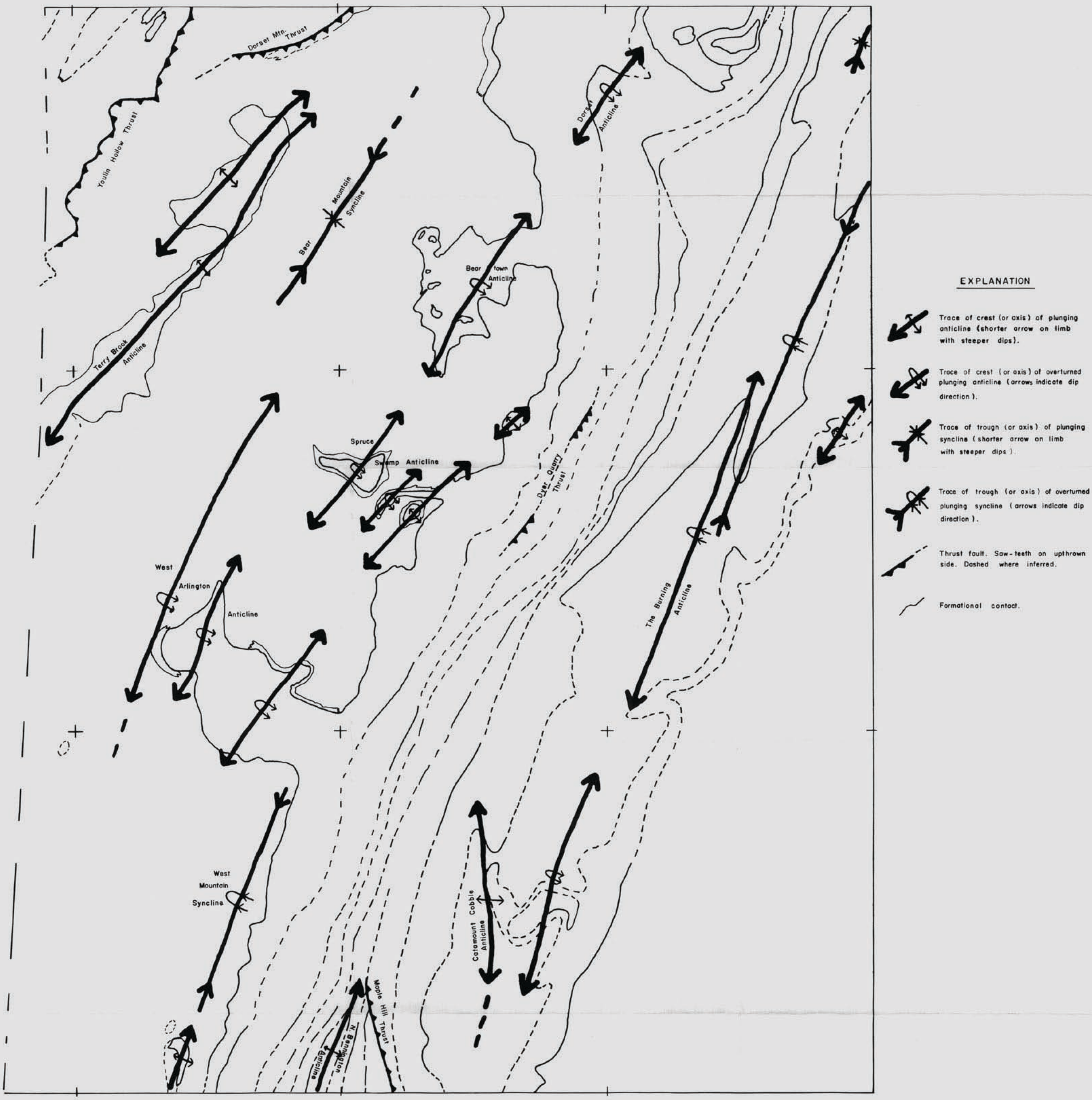

TECTONIC DIAGRAM

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PLATE 13

0 1 2 3 Miles

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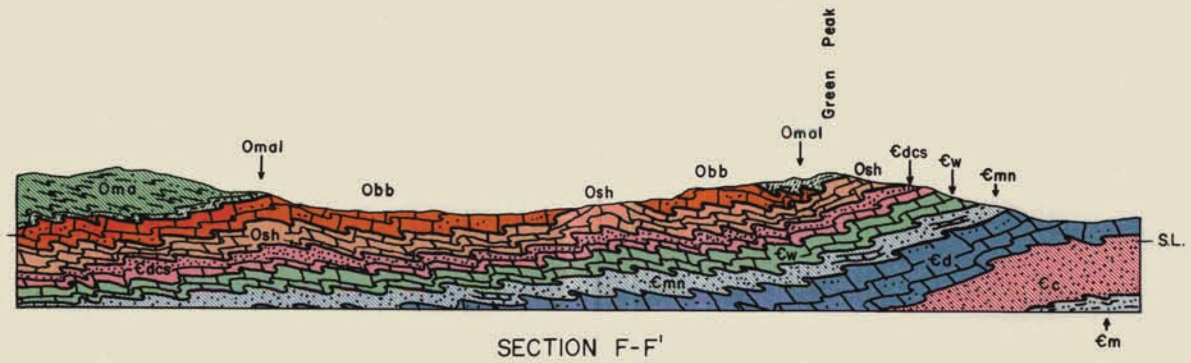
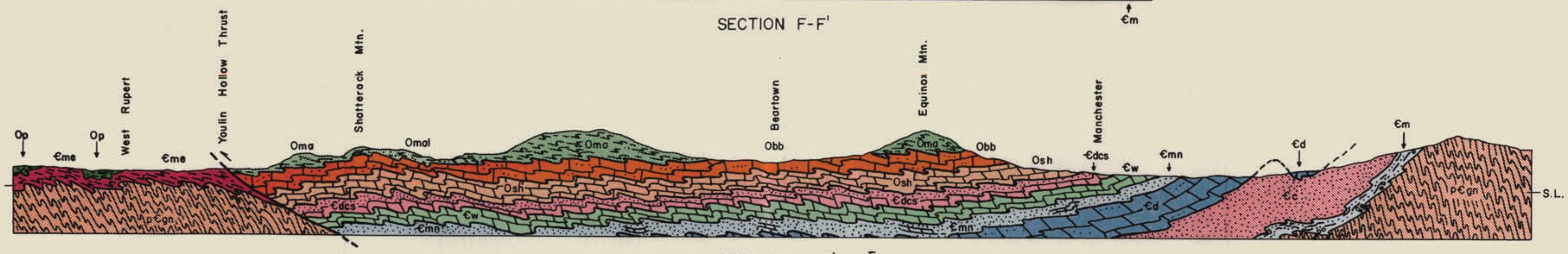


SECTION F-F'



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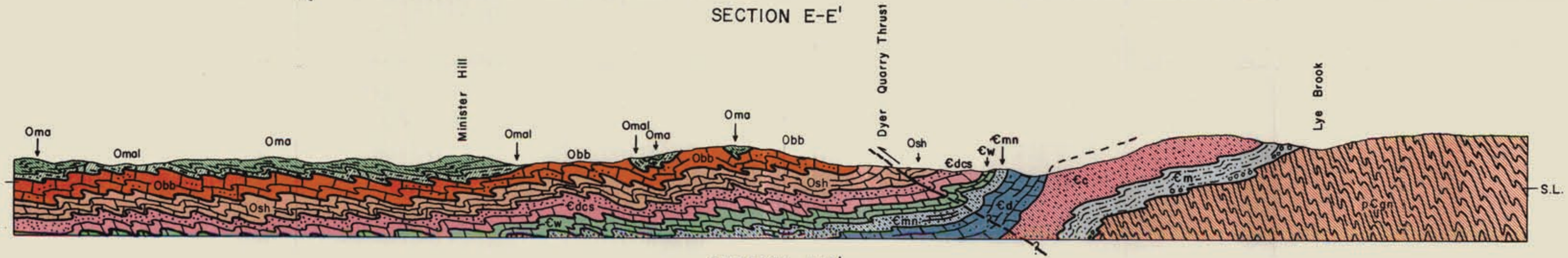

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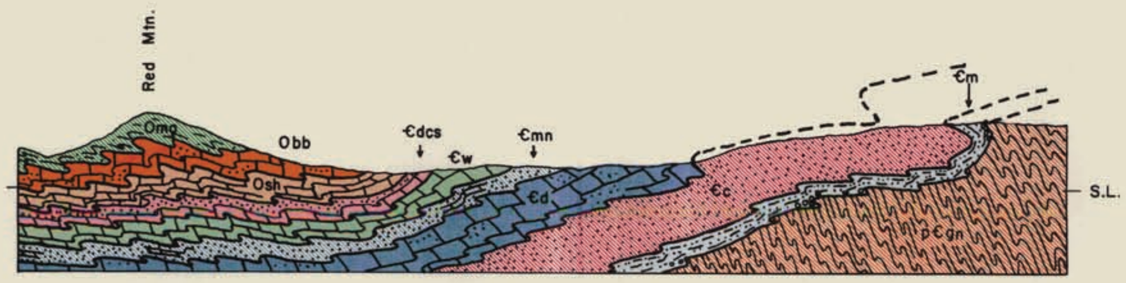

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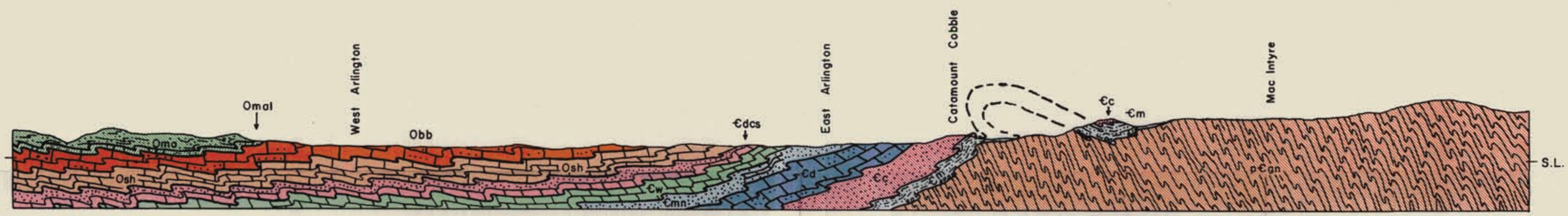

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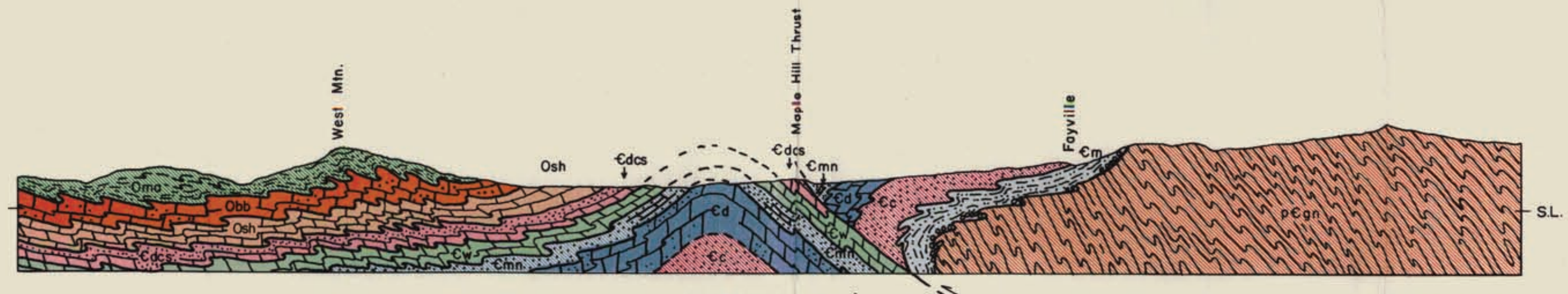

SECTION A-A'

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STRUCTURE SECTIONS OF THE EQUINOX QUADRANGLE, VERMONT

PLATE 14

0 1 2 3 Miles

All Profiles drawn to Natural Scale

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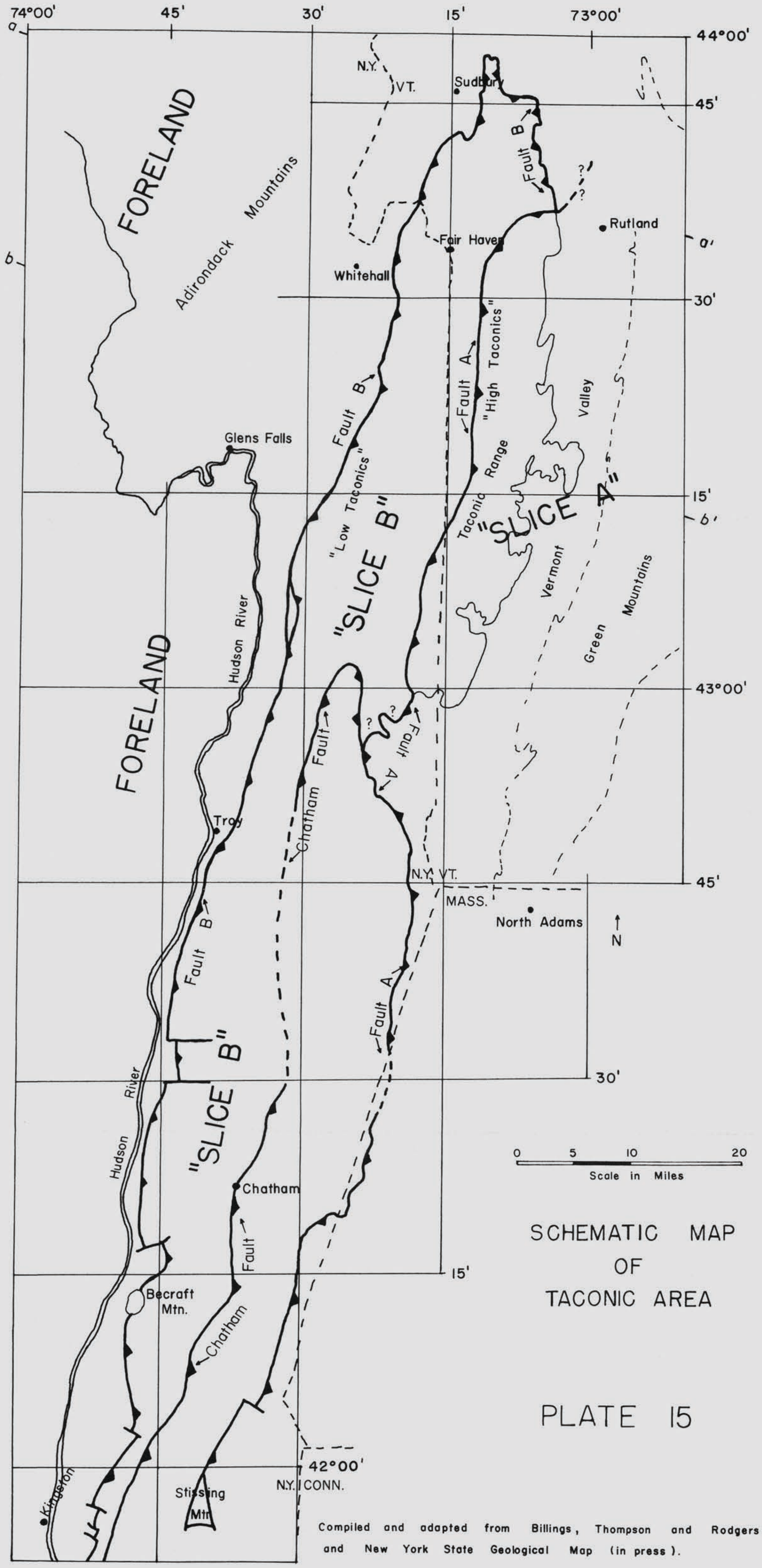

SCHEMATIC MAP
OF
TACONIC AREA

PLATE 15

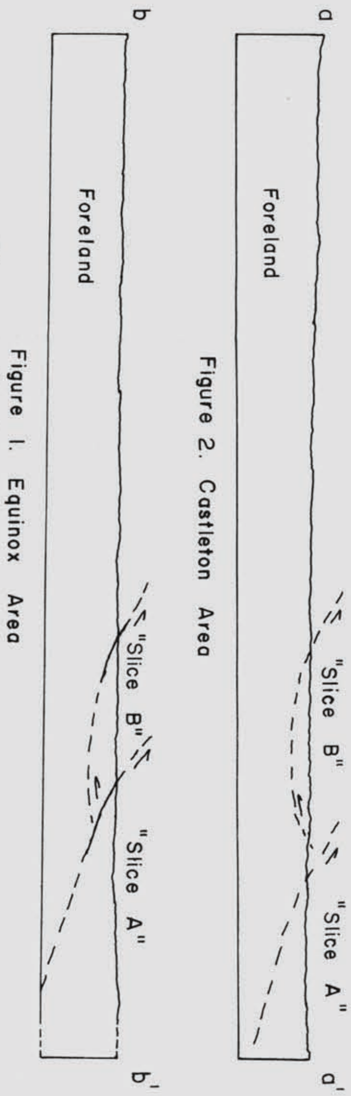

PLATE 16

Diagrammatic Cross-Sections of Taconic Area

Figure 1. Equinox Area

Figure 2. Castleton Area

Compiled and adapted from Billings, Thompson and Rodgers, 1952 and New York State Geological Map (in press).

Philip C. Hewitt

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