Stratigraphy and Structure of the Hoosick Falls Area, New York-Vermont, East-Central Taconics

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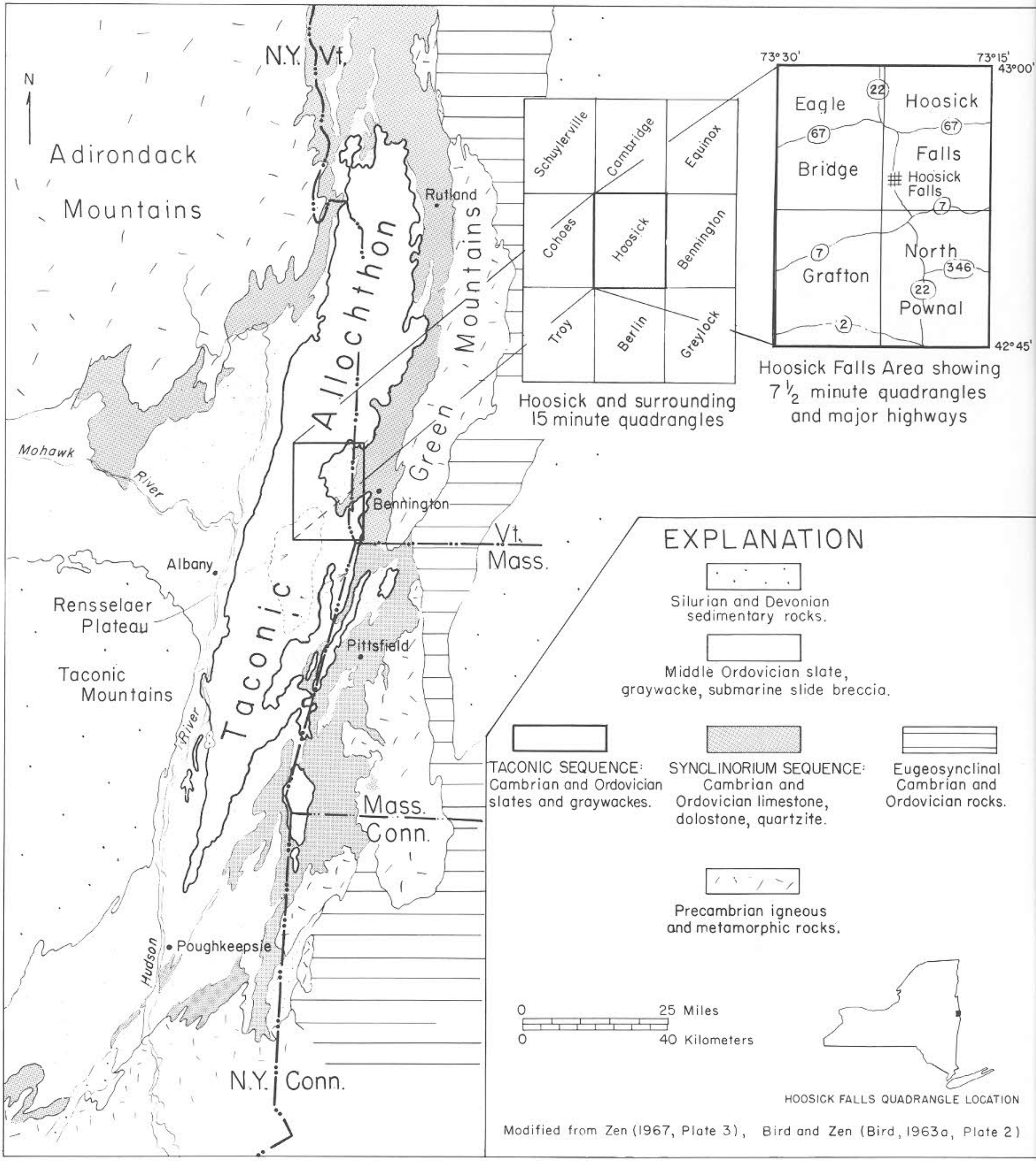

FIGURE 1. Geologic setting of the Taconic Allochthon and location of the Hoosick Falls area.

Stratigraphy and Structure of the Hoosick Falls Area, New York-Vermont, East-Central Taconics[1]

by Donald B. Potter[2]

ABSTRACT

This is a detailed account of the stratigraphy and structure in the Eagle Bridge, Grafton, Hoosick Falls, and North Pownal 7½-minute quadrangles which comprise the old Hoosick quadrangle in eastern New York and southwestern Vermont. It is based on surface mapping of the bedrock at a scale of 1:24,000 and provides abundant evidence for the concept of emplacement of the Taconic Sequence of rocks along thrust faults, thus substantiating other recent studies in the Taconic region.

Two partially synchronous, yet lithologically dissimilar rock sequences are exposed in the Hoosick Falls area: in the Taconic allochthon is the Taconic Sequence of slates, graywackes, cherts, minor quartzites, and limestones; beneath and immediately east of the allochthon is the Synclinorium Sequence of limestones, dolostones, slate, and graywacke.

The Taconic Sequence is perhaps 1,220 meters (4,000 feet) thick and consists of turbidites and pelitic rocks suggesting deposition in deep water with unstable bottom conditions. The major stratigraphic units are the Lower Cambrian Nassau Formation consisting of these members or facies: Rensselaer Graywacke, Mettawee Slates, Bomoseen Graywacke, Mudd Pond Quartzite; Lower Cambrian West Castleton Formation of dark-gray slates and limestone lenses; Upper Cambrian Hatch Hill Formation of dark slate and thin quartzites with Eagle Bridge Quartzite Member; Lower and Middle Ordovician Poultney Formation consisting of White Creek (new name) dark slate, thin limestones, and quartzites, and Owl Kill (new name) cherty slate and argillite; Middle Ordovician Normanskill Formation consisting of Indian River red slate, Mount Merino chert, Austin Glen Graywacke. Fossils are found in all formations except the Hatch Hill.

The Synclinorium Sequence is approximately 610 meters (2,000 feet) thick and consists of carbonate rocks that attest to a shallow water shelf environment, overlain by a slate-graywacke-submarine slide breccia that marks the period of thrusting. The sequence includes the Upper Cambrian Clarendon Springs Dolomite, Lower and Middle Ordovician limestones and dolostones, and Middle Ordovician Walloomsac Formation. Fossils are found in all but the Clarendon Springs. The Walloomsac is dominantly slate, but also contains the Whipstock (new name) submarine slide breccia and Austin Glen Graywacke. The graywacke is thus common to both major rock sequences.

The allochthon consists of two sheets, one above the other, that have been thrust westward onto the Synclinorium Sequence. Evidence for thrusting includes lithologic contrasts of synchronous formations above and below the thrusts; structural discordance; slices of carbonate rock from the Synclinorium Sequence between the two thrust sheets; and crushing, shearing, and mineralization at the thrust zones. The lower (North Petersburg) thrust sheet includes all the rocks of the Taconic Sequence except the Rensselaer Graywacke; recumbent folds are extensively developed in the lower 305 meters (1,000 feet) of the sheet which consists of younger formations than the upper part of the sheet. The North Petersburg sheet is thus a huge recumbent anticline or nappe. The upper (Rensselaer Plateau) thrust sheet is perhaps the eastern core of the North Petersburg nappe which was thrust westward onto the inverted limb of the nappe. Eight formations or members of the Taconic Sequence, ranging from Early Cambrian to Middle Ordovician, constitute the Rensselaer Plateau sheet on Mount Anthony in the Taconic Mountains. Identification of these stratigraphic units rules out MacFadyen's (1956) conclusion that the schists and related rocks here, which he called the "Mount Anthony Formation," are Middle Ordovician and autochthonous.

Beneath the North Petersburg thrust is the Middle Ordovician (Wilderness) Whipstock submarine slide

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breccia, consisting of clasts of the Taconic Sequence and some giant blocks of carbonate rock from the Synclinorium Sequence. It is inferred that thrusting was a Middle Ordovician submarine phenomenon; that Austin Glen Graywacke was deposited on both sequences at the early stages of orogeny; that as the thrust sheets moved into this area from the east, blocks of limestone and dolostone up to 2.9 kilometers (1.8 miles) long and 213 meters (700 feet) thick (from the shelf environment), and Taconic Sequence rocks (from the advancing thrust sheets), slid westward into the mud in the deeper parts of the basin to form the Whipstock. Unconsolidated breccia, graywacke, and mud were overridden by the North Petersburg sheet.

Both major thrust planes and thrust sheets have been refolded by a second deformation that produced a pervasive slaty cleavage-foliation. High-angle reverse and normal faults, striking north-northeast, cut the two thrust sheets and the autochthonous rocks beneath.

All the rocks in the area have undergone regional metamorphism. Increase in rank from west to east is shown by recrystallization of limestones and dolostones and by metamorphism of argillites and slates to phyllites and schists containing chlorite, sericite, chloritoid, and albite.

Introduction

The term " Taconic allochthon " is used to describe the plate of deformed and metamorphosed Early Cambrian to Middle Ordovician slates and graywackes which comprise the Taconic Sequence (Kaiser, 1945, p. 1083) in eastern New York, western Vermont, and western Massachusetts (figure 1). The rocks beneath and around the allochthon are dominantly orthoquartzite-carbonate-shale facies, Early Cambrian to Middle Ordovician in age, and are called the " Synclinorium Sequence " (Zen, 1961, p. 296) from their occurrence in the Middlebury Synclinorium north of the allochthon. The present study, at the east edge of the allochthon, involves both rock sequences and the stratigraphic and structural relations between them.

The allochthon has been deeply weathered and dissected to the extent that the topography reflects subtle differences in lithology and structure. The western two-thirds of the allochthon consists of low, rounded hills, quite extensively farmed, and the relief is no more than a few hundred feet. Hewitt (1961a) called this terrain the " Low Taconics." The Rensselaer Plateau stands 215–245 meters (700 to 800 feet) above this low ground in the central part of the allochthon. At the eastern edge of the allochthon is a wooded range of mountains, the Taconic Mountains or " High Taconics " with as much as 2,500 feet of relief. Carbonate formations of the Synclinorium Sequence between the east edge of the allochthon and the Precambrian terrain of the Green Mountains have been deeply weathered and eroded into a long, narrow depression called the " Vermont Valley." The Hoosic[3] River and its tributary, the Walloomsac River, have dissected the allochthon, exposing the underlying Synclinorium Sequence in a major indentation or reentrant of the east edge of the allochthon centered at Hoosick Falls, New York. The name Hoosick Falls reentrant is used for this structural-topographic feature.

ACKNOWLEDGMENTS

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I owe particular debt to the following men for identification of fossils: W. B. N. Berry, G. Arthur Cooper, Donald W. Fisher, Rousseau H. Flower, Robert C. Ramsdell, George Theokritoff, and Ellis L. Yochelson.

My field assistants have been: the late Brian T. C. Davis (2 years), William H. Harris, N. Timothy Hall, John C. Lawrence, John J. Thomas, Michael A. Lane (2 years), Jay D. Murray, and W. Scott Baldridge. I wish to thank all for their able help and especially for the tedious job of factfinding when the overall structural picture was not known.

My debt to E-an Zen will be obvious to all who have read the recent literature on the Taconic problem. I have received valuable aid from Zen, in working out the stratigraphy, and have placed the structural history of this area in the framework of submarine thrusting that he has postulated. Others who have helped me through discussion or through field visits in this area or in the areas where they have mapped are: W. B. N. Berry, John M. Bird, Jack G. Elam, Philip C. Hewitt, John A. MacFadyen, Jr., Lucian B. Platt, Nicholas M. Ratcliffe, George Theokritoff, and John D. Weaver.

Donald W. Fisher and E-an Zen have carefully reviewed the manuscript, and I am grateful for their suggestions and criticisms.

GEOLOGIC STUDIES OF THE TACONIC PROBLEM

Geologic study of the Taconics[4] spans more than 120 years, starting with the reconnaissance work of Dewey and Eaton in the early 1800's (Merrill, 1924, pp. 594–614). During the latter half of the 19th century a controversy arose as to the age of the rocks that constitute the " Taconic Sequence,"[5] with Emmons (1849) holding

[3] Note spelling variants: Hoosic (river); Hoosick (city, town, quadrangle); Hoosac (school, mountain range southeast of Green Mountains).

[4] Informal name used in this report meaning region of the Taconic allochthon.

[5] Quotes in this paragraph denote modern terminology of rock sequences. These names were not used or precisely defined by the earlier workers.

that all the formations here were Early Cambrian, while Dana (1888) and Walcott (1888) showed these formations were, in part, Ordovician. After Dale's (1893, 1898, 1904) comprehensive work on the stratigraphy and structure of the Taconics the major controversy arose as to the stratigraphic and structural relations between the "Taconic" and "Synclinorium" sequences. Dale postulated that the "Taconic Sequence" represented a facies of the "Synclinorium Sequence," while Ruedemann (1909), Ulrich (1911), Keith (1913), and later, Prindle and Knopf (1932) argued that the "Taconic Sequence" had been thrust to its present position. During the last two decades a number of geologists, working mainly in the central and southern Taconics, have argued against the thrusting hypothesis, stating that the relations could be explained by facies change, or by unconformity (Balk, 1953; Lochman, 1956; MacFadyen, 1956; Bucher, 1957; Craddock, 1957; Weaver, 1957; Elam, 1960; Hewitt, 1961). At about the same time, other geologists, working mainly in the northern Taconics and independent of one another, postulated the allochthonous theory (Kay, 1942; Cady, 1945; Kaiser, 1945; Fowler, 1950; Zen, 1956, 1959, 1960b, 1961, 1964a, 1967; Platt, 1960; Ratcliffe, 1966; Bird, 1963). For a more detailed account of the problems and the history of their investigations the reader is referred to Merrill (1924, pp. 594–614), Bird (1963, Intro.), Zen (1957, pp. i-ii; 1967, pp. 3–7, app. 1), Craddock (1957, pp. 678–679, 706–718), and Fisher (1961).

PREVIOUS WORK IN THE EAST-CENTRAL TACONICS

The first definitive map showing the general geology and some fossil localities in the Hoosick Falls area was compiled by Walcott (1888). Dale (1893) included this area in his study of the Rensselaer Plateau and he mapped south to the northern border of the Hoosick Quadrangle in his (Dale, 1899) classic work on the slate belt of eastern New York and western Vermont. A large section of the allochthon west of the Hoosick Quadrangle was studied by Dale (1904), and later by Ruedemann (1930) in his report on the Capital District.

Prindle and Knopf (1932) first recognized and described the great structural complexity of the Hoosick Falls area, and their contributions in identifying stratigraphic units, locating critical fossil sites, and in showing the correct position of some of the major faults should be underscored.

Bonham (1950), mapping largely in the Hoosick Falls 7½-Minute Quadrangle, attempted to assess the thrusting hypothesis by a study of small-scale structures; he concluded that "the movement picture involves west-northwest tectonic transport, and thus is compatible with the hypothesis of overthrust." Balk (1953) made a detailed study of the structures of the Rensselaer Plateau and Taconic Range (Taconic Mountains), but he was not able to establish sufficient stratigraphic control to formulate a picture of the overall structure. Lochman (1956) made a detailed study of the Early Cambrian fauna in this area, reexamining much of Prindle's original collections which are now stored in the U.S. National Museum.

MacFadyen (1956) and Hewitt (1961) mapped the Bennington and Equinox Quadrangles immediately east and northeast, respectively, of the area. They concluded that the pelitic schists (Mount Anthony Formation) forming the Taconic Mountains are autochthonous, Middle Ordovician or younger in age, and rest with stratigraphic unconformity on the autochthonous formations below. Evidence from the present study denies this interpretation.

PRESENT STUDY

Fieldwork was started in the summer of 1955 and continued through 1964 with the exception of the summer of 1961. The intent was to work out the stratigraphic succession in as great detail as possible, and then use this stratigraphy to work out the major structural relations. The detailed stratigraphic approach is, of course, pinned on all the paleontologic evidence at hand. While tedious and time consuming, it is a most fruitful way to study the geology of an area where primary sedimentary criteria for tops and bottoms are rarely encountered, where metamorphism has destroyed the distinctive lithologic characteristics of many of the marker beds, and where multiple deformations make such criteria as bedding and cleavage useless in telling tops and bottoms. Most of the stratigraphic succession was worked out in the western part of the area where deformation was less complex than in the east.

Mapping was done on topographic maps, at 1:31,680 and 1:24,000 scales, using Brunton compass and pocket altimeter. Great care was taken in plotting outcrops by resection, or by single shot altimeter method. Several fossil localities or critical outcrops in wooded terrain were plotted by taking Brunton readings from the tops of trees. Perhaps half of the area is covered by surficial deposits, and because of the critical nature of many outcrops and the wish to present field data objectively, limits of outcrop areas are shown on Plate I.

Stratigraphy

The stratigraphic succession, paleontologic control, and lithologic character of the rock units in the Hoosick Falls area are summarized in figure 2. Thirty-seven of the 49 mappable units belong to the Taconic Sequence of slates, graywackes, and cherts, with minor quartzites and limestones spanning Early Cambrian to Middle Ordovician time, and having a total estimated average thickness of about 1,220 meters (4,000 feet). The Synclinorium Sequence consists of limestones, dolostones, slate, graywacke, and submarine breccia. Average thickness of this sequence is perhaps 610 meters (2,000 feet).

TACONIC SEQUENCE

INTRODUCTION

The Taconic Sequence (see fig. 3 for areal distribution) presents a classic example of a deepwater depositional environment in which thousands of feet of pelitic sediments accumulated and in which turbidity currents, submarine slumping, and unstable bottom conditions played a major role. Delicately laminated argillite and thin-bedded chert (Poultney and Normanskill Formations) suggest deep, quiet water conditions; euxinic conditions are suggested by pyritiferous black slate, with and without graptolites (West Castleton, Hatch Hill, Poultney, and Normanskill Formations); transportation and deposition by turbidity currents is indicated by the lithologic character, graded bedding, and sole markings in the two main accumulations of graywacke (Rensselaer and Austin Glen); unstable bottom conditions and submarine slumping is indicated by intraformational breccias (Rensselaer Graywacke, graywacke phase of Mudd Pond, Poultney Formation) and by exotic blocks of carbonate rock in the Poultney and Normanskill.

All of the units of the Taconic Sequence, and particularly the graywackes and quartzites, are lenticular within the map area. The Rensselaer Graywacke is perhaps less than 30 meters (100 feet) thick in the northwest corner of the Rensselaer Plateau, but thickens to more than 305 meters (1,000 feet) in the central part of the plateau. The Austin Glen is locally 305 meters (1,000 feet), thick along the west edge of the area, but 10 miles to the southeast, it is only 0.9 to 3 meters (5 to 10 feet) thick. In general, stratigraphic units within the Taconic Sequence show great continuity north and south, and exhibit maximum change in thickness and lithologic character across strike from east to west. Thus, practically every unit shown in figure 2 can also be identified 97 kilometers (60 miles) north, at the north end of the allochthon. The east-west variations, though relatively slight as compared to the lithologic contrasts between the two major sequences, are accentuated by the telescoping of the facies within the allochthon. One of the structural interpretations of this study explains this telescoping — the North Petersburg thrust sheet is probably a nappe and the formations exposed in the northwestern part of the area are the upper limb of this nappe; the formations in the central and eastern part of the area are the inverted limb. In the original basin of deposition, those lithologies which are now farthest west were east of, and probably farther away from, those presently exposed in the central part of the sheet. Such telescoping of facies is taken as the explanation for the presence of maroon slate, thin-bedded limestone, and laminated slate in the West Castleton Formation in the northwestern part of the area, and their very slight development or absence elsewhere in the North Petersburg sheet. West Castleton limestone in the inverted limb of the nappe is locally much thicker than in the normal limb, indicating a westward thickening of Early Cambrian limestone in the area of deposition.

Unconformities within the Taconic Sequence are very difficult to recognize because of lenticularity of units and faulting. Four possible unconformities are suggested: 1. Between the West Castleton and Hatch Hill (no Middle Cambrian fossils have yet been found in this area, but they have been found elsewhere [Rasetti, 1967] in the central Taconics); 2. at the base of the Poultney (West Castleton and Hatch Hill absent in western part of area); 3. at the base of the Normanskill (Owl Kill Member of the Poultney absent in the western part of the area); and 4. at the base of the Austin Glen Member of the Normanskill (locally, the Indian River and Mount Merino are absent and the Austin Glen rests on older formations).

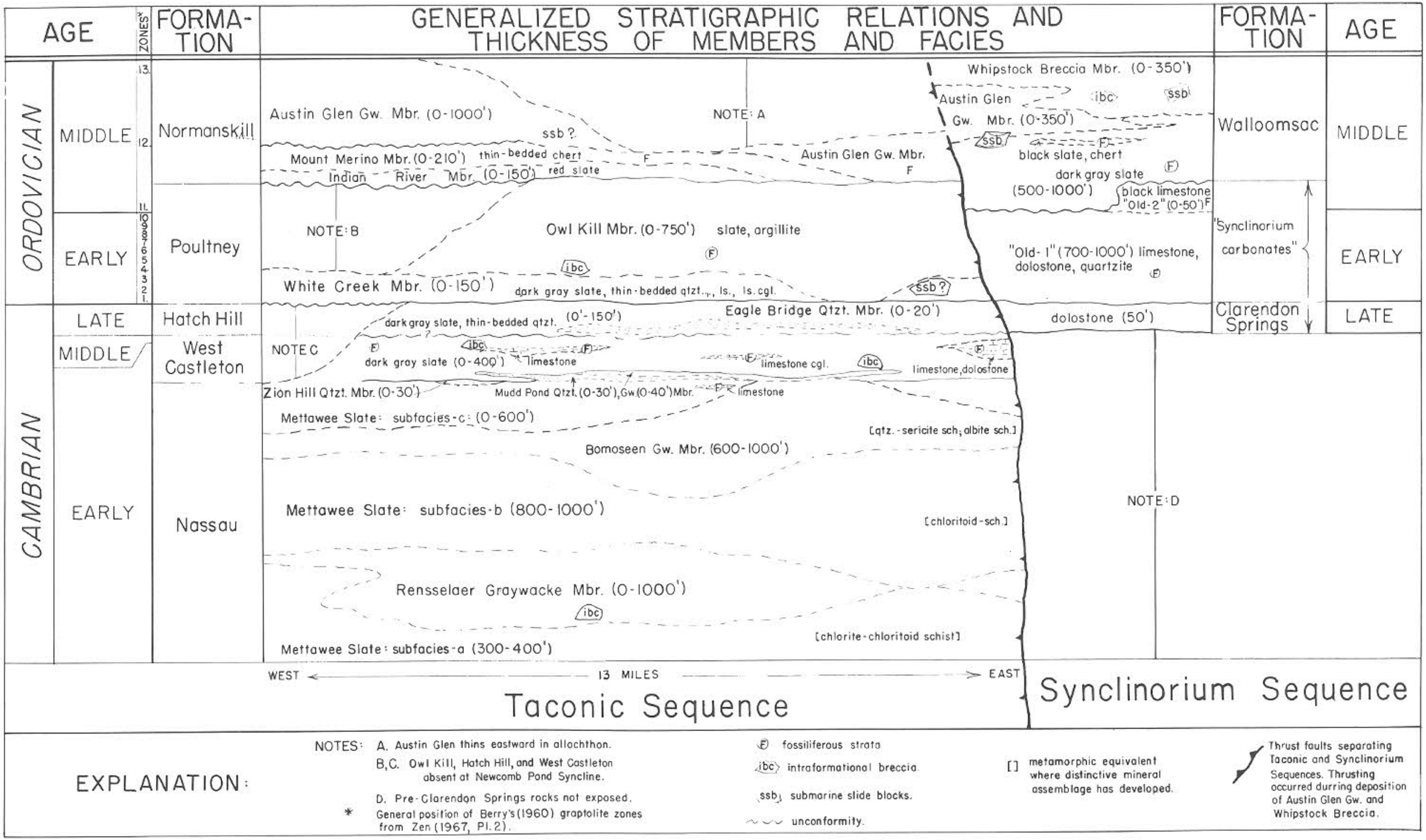


Figure 2. Stratigraphy of the Hoosick Falls Area

NASSAU FORMATION

The Nassau Formation (Bird, 1962; 1963b) includes all rocks of Early Cambrian age except the West Castleton Formation. It is thus equivalent to Zen's (1961) Bull and Biddie Knob Formations. Stratigraphic continuity and lack of facies change from north to south is indicated by the fact that five members' or facies' names used in this paper were defined some 80 kilometers (50 miles) to the north. Early Cambrian fossils occur in limestone lenses at the top of the formation which is interlayered with the fossiliferous lower Cambrian West Castleton Formation.

The dominant lithology in the Nassau is a monotonous sequence of green, gray, purple, and red argillite, silty argillite, and siltstone with variable but generally pronounced development of slaty cleavage. Following Zen's (1961, p. 300) interpretation of the Bull Formation in the northern Taconics, these slates are the Mettawee Slate Facies (of the Nassau). Three subfacies of the Mettawee are recognized in this study, and together they constitute the matrix for the Rensselaer Graywacke, Bomoseen Graywacke and, locally, the Mudd Pond Quartzite.

Mettawee Slate Facies

Lower, middle, and upper subfacies of the Mettawee are distinguished as follows:

a. The lower Mettawee subfacies (Ꞓmn-a) lies beneath and interfingers with the Rensselaer Graywacke at the northwest edge of the plateau (Plate I: A, B, C-11, 12, 13[6]; Plate II, sections H-H' and I-I'). The dominant lithology is a fine-grained dusky-red slate or argillite with thin beds of fine-grained quartzite and thin lenses of Rensselaer Graywacke; other lithologies are green and purple slate, and thin lenses of Bomoseen Graywacke. Fine-grained texture and numerous thin quartzites distinguish the lower Mettawee from the middle and upper subfacies. Subfacies (a) is as much as 91 to 122 meters (300 to 400 feet) thick in the tributary to Couch Hollow (C-12, D-12).

b. The middle Mettawee subfacies (Ꞓnm-b), lying between the Rensselaer and Bomoseen, constitutes the thickest slate unit in the Nassau and is exposed over broad areas north and east of the Rensselaer Plateau.

The dominant lithology is a poorly cleaved, soft, green, gray, or purple silty argillite forming low outcrops. All gradations from soft, thinly cleaved slate to crudely cleaved siltstone are found. The green slate may display an olive-green cast near the weathered surface, a feature shown also in the Bomoseen. Cleavage planes generally have a black-weathering stain. Bedding is generally not seen but may be defined in certain outcrops by thin color laminations. Broken surfaces of the slate commonly display spangles of clastic mica. Purple silty slate and silty argillite are abundant in this part of the Mettawee, but they do not constitute dependable map units because of the close resemblance of purple beds or zones at different stratigraphic positions. Dale (1898, p. 205) further noted that the change from green slate to purple or red slate did not necessarily follow bedding planes. Fine-grained quartzite, in beds from 2.5 to 45 cm (1 to 18 inches) thick, occurs sparingly in the middle Mettawee subfacies. The quartzite is slightly calcitic or dolomitic and weathers white, but appears spotted with light brown limonite specks on broken surface; some beds have a black manganiferous stain on the outer surface.

A minimum thickness of 244 to 305 meters (800 to 1,000 feet) is estimated for the middle Mettawee subfacies along the east edge of the Plateau, from Church Hollow (H-14) to Petersburg (H-17), where it is overturned and lies above the Bomoseen and younger formations in the inverted limb of the North Petersburg nappe (plate II, sections H-H', I-I'). The largest area of exposure of the middle Mettawee subfacies is from Nipmoose Hill (B-6 to D-8) south through the low ground to the Rensselaer Plateau and east to Fox Hollow (G-12, G-13) where the slates presumably represent the core of the nappe (plate II, sections F-F', G-G'). Stratigraphic position of subfacies (b) beneath the Bomoseen is seen at the core of the Buskirk anticline (plate II, section A-A').

c. The upper Mettawee subfacies (Ꞓnm-c), lying generally above the Bomoseen and below or interbedded with the West Castleton, is lithologically similar to the middle subfacies. The two subfacies are distinguished on these bases: 1. Most slate in the upper subfacies is finer grained, more perfectly cleaved, and occurs as smoothly weathered outcrops. Note that the Cambrian Roofing Slates of Dale (1809, opp. p. 178), named the Mettawee Slate by Ruedemann (Cushing and Ruedemann, 1914, p. 69), were known to lie *above* the olive grit (Bomoseen Graywacke). There has been no quarrying of Mettawee slates in the area under study, but those in the upper subfacies are clearly the best quality of any in the Nassau Formation. 2. Thin quartzites are more abundant in the middle than in the upper subfacies. 3. Upper subfacies slates more commonly dis-

[6] Letters and arabic numbers refer to a map grid system on Plate I and Figure 3 to aid the reader in locating places referred to in text.

EXPLANATION

Taconic Sequence

Undifferentiated Upper Cambrian, Lower and Middle Ordovician formations: Hatch Hill, Poultney, Normanskill.

Undifferentiated Lower Cambrian formations: Nassau and West Castleton. Dotted pattern is Rensselaer Graywacke Member of Nassau.

Synclinorium Sequence

Middle Ordovician Walloomsac Formation. Wide-spaced diagonals: dark gray slate and Whipstock Breccia. Close-spaced diagonals: Austin Glen Graywacke. Numbers denote submarine slide blocks described in app. 2.

Upper Cambrian, Lower and Middle Ordovician limestones and dolostones. (Synclinorium carbonates)

RP — Rensselaer Plateau Thrust Fault, saw teeth on upper plate.

NP — North Petersburg Thrust Fault, saw teeth on upper plate.

D/U — High-angle reverse and normal faults. D-down, U-up

Minor thrust fault; saw teeth show direction of dip; movement up on saw tooth side unless otherwise noted.

Sedimentary contact

Outline of submarine slide block.

a. axis of symmetrical anticline plunging southwest.
b. axis of symmetrical syncline plunging southwest.
c. axis of anticline overturned to northwest, plunging southwest.
d. axis of syncline overturned to northwest, plunging southwest.
e. trace of axial plane of recumbent syncline open to northwest.

f. ra-2; g. rs-1

f., g. traces of axial planes of recumbent anticline (ra-2), recumbent syncline (rs-1). Numbers give relative position (lower folds have lower numbers) of recumbent folds in terrain west of White Creek, and in terrain west of North Petersburg. No correlation of folds between two terrains is implied. Axial trace of some numbered recumbent folds omitted where shown by map pattern of stratigraphic units.

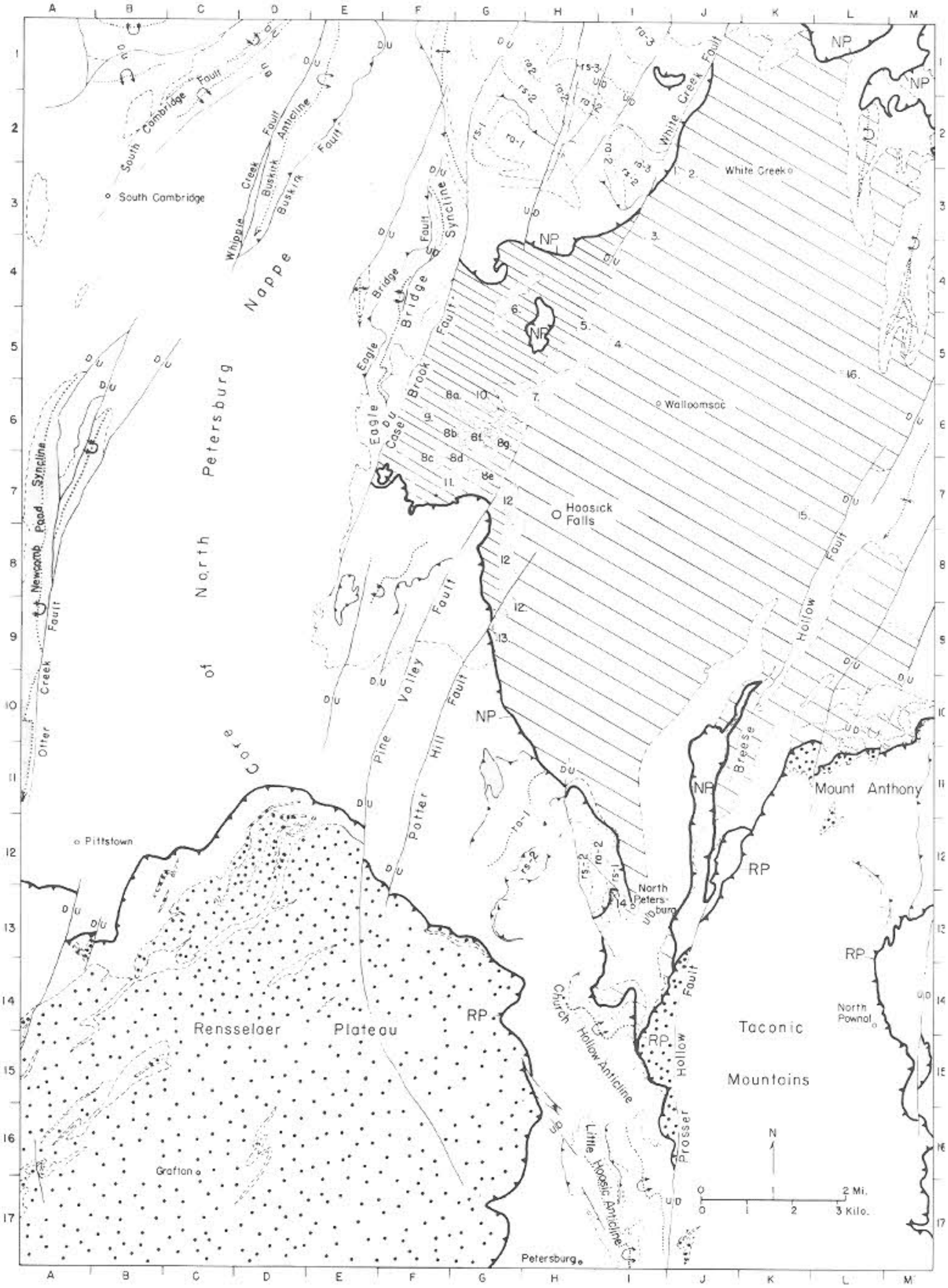


Figure 3. Tectonic and generalized geologic map of the Hoosick Falls Area, New York-Vermont

play rusty-weathering cleavage surfaces than do those in the middle subfacies. 4. Slates of the upper subfacies grade upward into black slate of the West Castleton Formation and, locally, the upper subfacies slates form the matrix for Mudd Pond Quartzite and fossiliferous limestone lenses. No such marker beds occur in the middle subfacies.

Thickness and stratigraphic position of the upper Mettawee slates can be determined from elevation 800 to 880 feet on the west side of Whipple Brook (D-1) where approximately 183 meters (600 feet) of upper Mettawee slates separate the Bomoseen from the overlying West Castleton. However, at other localities, the Bomoseen lies directly beneath the West Castleton with no upper Mettawee present. This relation may represent a facies change in the rocks beneath the West Castleton, or an unconformity.

Metamorphism of Mettawee: The Mettawee slates exhibit subtle mineralogical changes reflecting increase in metamorphic rank from west to east. Recrystallization first becomes apparent in the hills west of the Little Hoosic River and east of the Rensselaer thrust trace. The slates in these areas are more highly sheared and have a higher luster than those to the west. The slate is traversed locally by irregularly spaced sericite films. Farther east, on West Mountain, Mount Anthony, and the Taconic Mountains, the Mettawee is metamorphosed first to a phyllite, then to chloritoid schists or quartz-sericite-chlorite schist.

Rensselaer Graywacke Member

Lithology: The Rensselaer Graywacke is a typical turbidite. It occurs as tough, hard beds from 1.3 to 36 cm (0.5 inch to 12 feet) thick (figure 4). Outcrops weather brownish gray and are studded with quartz grains ranging from 1 to 4 mm. in diameter. The coarsest modes of individual beds vary from pebble conglomerate to medium sand and are composed dominantly of quartz with subsidiary feldspar (plagioclase and microcline), muscovite, dark cherty argillite, and other rock clasts including graphitic quartzite. The matrix is typically dark green, gray or red, and of silt or fine sand size; quartz, again, is dominant and feldspar, chlorite, and micas occur in small amounts (figures 5, 6). Most thin sections indicate the Rensselaer to be a feldspathic graywacke, and more rarely a lithic graywacke (classification of Pettijohn, 1957, p. 291). Other minor types found interbedded with these are arkosic and lithic sandstone, orthoquartzite, and an intraformational breccia of large, flat, and bent argillite clasts in a typical coarse-grained graywacke matrix (figure 4). Bird (1963, p. 13) called special attention to such coarse breccias and attributed them to a combination of turbid flow and slumping. Other more common structures attributed to turbidity current deposition include graded bedding, sole markings such as load casts and linear grooves, cut and fill, clasts of medium-grained graywacke in conglomeratic graywacke beds, and small-scale normal faults within a given bed. Orientation of linear grooves at the soles of the beds, and direction of crossbedding at one exposure suggest that depositing currents came from the northwest. The coarsest beds occur in the western half of the plateau and on Poplar Hill (J-17). On the basis of sediment coarsening, Balk (1953, p. 846), and Bird (1963a) assumed a westward source, but some speculation on large-scale structures should at least leave this an open question.

Figure 4. Rensselaer Graywacke on north side of N.Y. Route 2, 0.3 mile west of East Grafton (E-17), showing graded bedding and large intraformational clasts of dark silty argillite near top (left side) of bed.

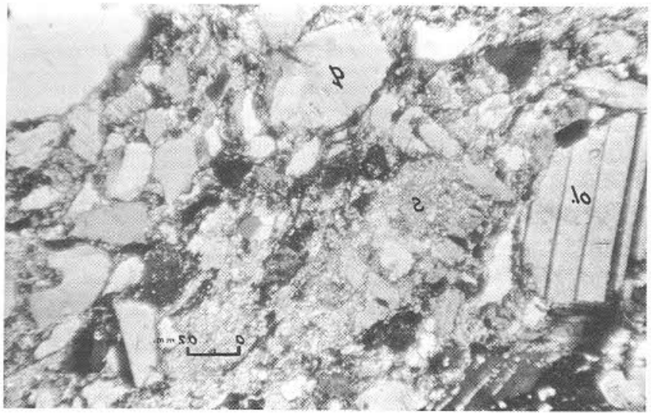


Figure 5. Photomicrograph of Rensselaer Graywacke, from Ward Hollow (C-14). Clasts of oligoclase (ol) and quartz (q) in matrix of sericite, clay, calcite, and fine grained quartz. Plagioclase at (s) is partially sericitized.

Graded bedding in the Rensselaer is generally manifest by the decrease in size of the coarsest fraction from bottom to top, but also by decrease in amount of coarse clasts of a single size from bottom to top. Many beds exhibit no discernable grading; others are coarsest in the middle or some intermediate part of the bed. Interbedding of graywacke with delicately laminated red and green argillite and silt suggest deposition in deep, quiet water. Such interbedding is common in the western half of the plateau and on the west slopes of the Taconic Mountains; elsewhere, graywacke appears to be in massive beds up to 15 meters (50 feet) thick, but careful examination generally reveals that in such areas the beds are from 0.6 to 3 meters (2 to 10 feet) thick, the

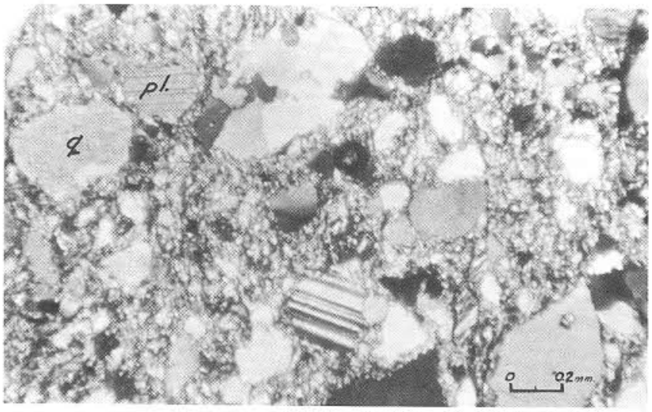


Figure 6. Photomicrograph of slide block of Rensselaer Graywacke in Whipstock Breccia at elevation 1,000 (K-9). Quartz (q), plagioclase (pl) in fine-grained matrix of clay, quartz, sericite, chlorite.

massiveness being an illusion produced by pervasive sandy texture and lack of slate interbeds. For detailed accounts of lithology, genesis, and chemistry, see Dale (1893), Balk (1953, pp. 813–833), Bird (1963a, p. 117; 1963c, pp. 5–20), and Ondrick and Griffiths (1969). The lithology and field occurrence of the Rensselaer Graywacke, Austin Glen Graywacke, and the graywacke phase of the Mudd Pond Quartzite are summarized in appendix 1.

Metamorphism of Rensselaer: Recrystallization of graywacke is most obvious in the thrust zones where crushing and shearing have apparently made the rock susceptible to regional metamorphism. The graywacke in these zones shows a west to east progression from a cataclasite to a flaser gneiss to a highly foliated gneiss with contorted folia of quartz (figure 8). In this gneiss, grain boundaries of quartz are sutured, quartz within the grains is recrystallized, and feldspar is less abundant and finer grained than in the unmetamorphosed graywacke. The matrix of the gneiss is quartz, chlorite, sericite, and chloritoid (figure 9).

Thickness: On the west face of the plateau (A-14), 2 miles south of South District School and immediately south of a large, steep talus slope (probably Slide Mountain of Dale, 1893, p. 308 and loc. 40 on Geologic Map), a continuous, overturned section of graywacke, with only minor slate interbeds, extends from elevation 900 feet to 1,360 feet. A minimum thickness of 274 meters (900 feet) is indicated here. A continuous right-side-up sequence, one mile southeast of Boyntonville, is also about 274 meters (900 feet) thick. It seems safe to round out these figures and conclude that the thickness of graywacke along the west edge of the plateau is about 305 meters (1,000 feet). It may be much thicker in the central part of the plateau (plate II, section I–I′).

At the base of the Rensselaer Plateau thrust sheet east of the Little Hoosic River (I–14–15), the highly sheared and folded graywacke appears to be several hundreds of feet thick; a lens of graywacke on the west shoulder of Mount Anthony (K-11, L-11) has a probable thickness of a few hundred feet. The graywacke at Poplar Hill (J-17) occurs as two lenses each about 107 meters (350 feet) thick.

In summary, Dale's estimate (1893, p. 328) of a maximum thickness of 365 to 396 meters (1,200 to 1,300 feet) seems reasonable. The interfingering of slates and graywacke at the western edge of the plateau suggests an abrupt westward thinning of graywacke, and thus the present margin of the plateau may mark the approximate original limit of the graywacke lens.

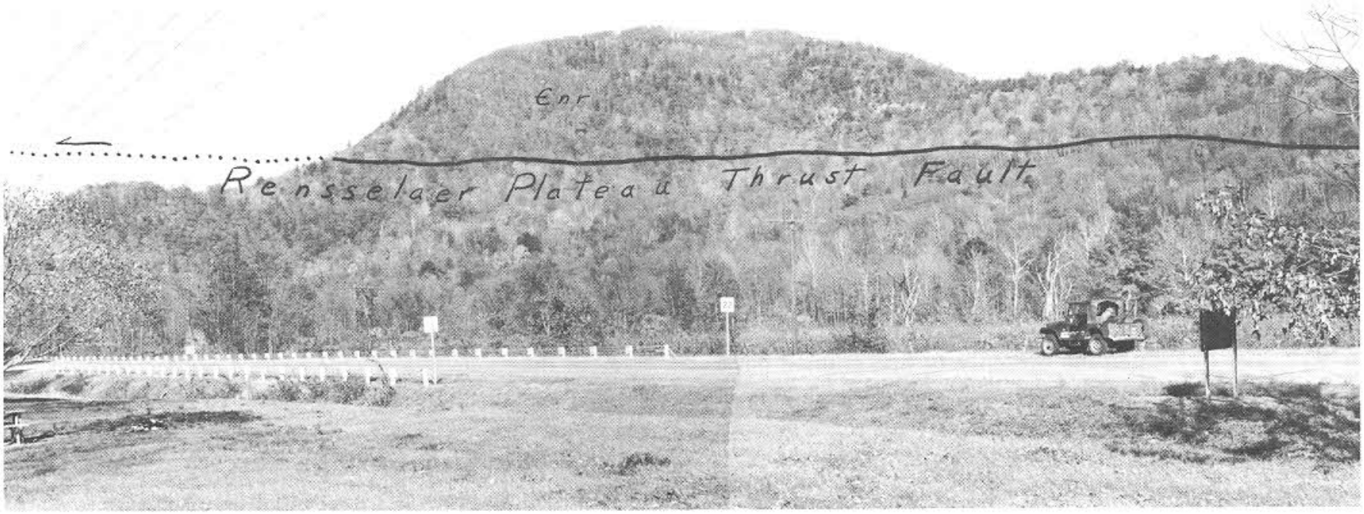


Figure 7. View of Rensselaer Plateau thrust fault on east side of Little Hoosic River (I-15). Looking northeast from N. Y. Route 22, 2.5 miles south of North Petersburg. Above thrust is sheared Rensselaer Graywacke; beneath is Hatch Hill Formation underlain by Nassau Formation in the North Petersburg thrust sheet.

Age and stratigraphic relations: Rensselaer Graywacke is interpreted to lie almost entirely within the upper (Rensselaer Plateau) thrust sheet. At the north and northwest faces of the plateau (plate I: C, D-12–13), the graywacke is interbedded with fine-grained red, maroon, green, and olive slates and argillites — the lower subfacies of the Mettawee. Similarly, the graywacke is gradational with underlying red and maroon slates and thin-bedded, fine-grained quartzites, as seen from elevation 620 to 800 feet in a west-flowing stream (C-12, D-12) 1.6 kilometers (1 mile) southeast of Boyntonville.

At Poplar Hill (J-17), thick beds of coarse- and medium-grained graywacke are right-side-up beneath Mettawee purple and green slate, phyllite, and chloritoid schist. North from Poplar Hill to the Hoosic River, a thick and sheared sequence of graywacke lies at the base of the Rensselaer Plateau thrust sheet (figure 7), but a high-angle fault separates the graywacke from schists to the east. On Mount Anthony (K, L, M-10, 11, 12), graywacke again lies at the base of the thrust

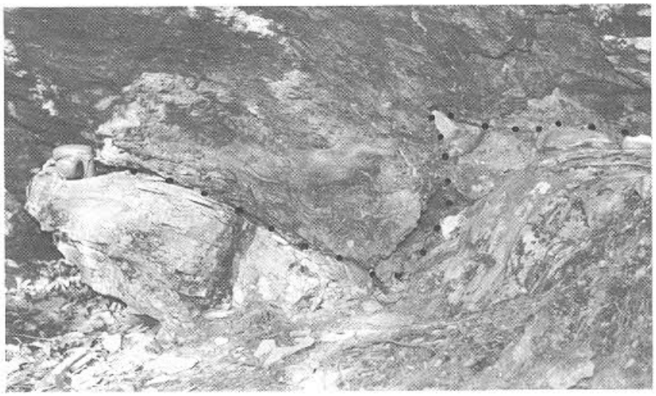


Figure 8. Looking north at folded Rensselaer Plateau thrust fault (dotted), on west shoulder of Mount Anthony, elevation 1,520 (L-11), one mile S 60° E from intersection 802 in Breese Hollow. Below thrust is thinly foliated limestone; above thrust is contorted and sheared Rensselaer Graywacke.

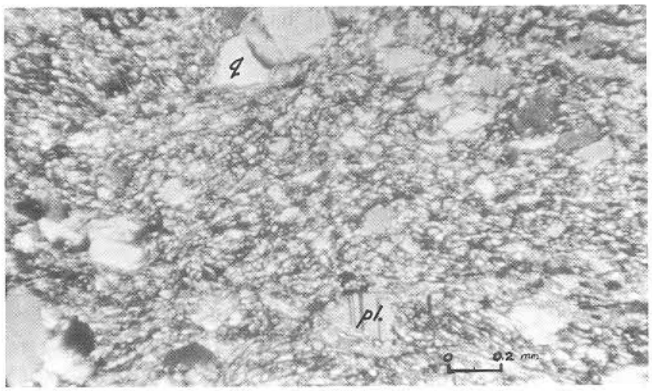


Figure 9. Photomicrograph of sheared and metamorphosed Rensselaer Graywacke, from west shoulder of Mount Anthony (K-11). Clasts of quartz (q) and plagioclase (pl) in foliated matrix of fine-grained quartz, chlorite, sericite, and chloritoid.

sheet, with chloritoid schist (Mettawee), Bomoseen, and other units above in apparent normal stratigraphic succession. Thus, the Rensselaer lies beneath the bulk of the Mettawee slates, near the base of the Lower Cambrian Nassau Formation. A similar stratigraphic position for the Rensselaer is indicated by Bird (1962; 1963b) and Craddock (1957, p. 644) in their work in the southern and southwestern part of the Rensselaer Plateau.

Associated igneous rocks: Dale (1893, p. 310), Prindle and Knopf (1932, p. 282), and Balk (1953, p. 827, loc. 15) noted the presence of fine-grained basic igneous rocks within the graywacke sequence west of Babcock Lake. The present study reveals three igneous occurrences; a lens of pillow lava, lamprophyre dike, and highly sheared volcanic rocks at the thrust zone on the east side of the Rensselaer Plateau.

The lens of pillow lava, 12 meters (40 feet) thick and perhaps 180 meters (600 feet) long, occurs on the north slope of Hill 1280 (D-13), 0.9 kilometer (0.6 mile) west of Banker Pond. The rock is hard, dark green to greenish gray, and aphanitic, and is crisscrossed with veins of epidote and bright-red hematite. Zen (1971) records pumpellyite from this rock. Pillow structure is well developed (figure 10), and small amygdules occur throughout the lens. Spherulitic structure is seen in thin section. The lens is conformable in a right-side-up sequence of medium-grained graywacke, yet amygdules may be more abundant in the lower part of the lens. If this is so, the lens may be a large inverted clast in graywacke. Numerous large loose blocks occur south of the main outcrop.

A lamprophyre dike, 2.4 to 7.6 meters (8 to 25 feet) thick and 45.7 meters (150 feet) long, occurs at the crest of hill 1300 (C-14), 1 mile southwest of the pillow lava lens. This rock is a very hard, massive green-gray to dark gray aphanite with phenocrysts of pyroxene. The contacts with the graywacke are irregular, and the margins of the dike are chilled as much as 7.6 centimeters (3 inches) from the contact. Graywacke exhibits textural and color changes at the contact.

Both dike and pillow lava have a crude foliation developed within them that is parallel to slaty cleavage in the graywacke. It seems probable that both are related to a period of Early Cambrian submarine volcanism.

Sheared volcanic rocks occur with graywacke in the Rensselaer Plateau thrust zone on the east side of the plateau. The best exposure is at elevation 1,330 feet, 0.8 kilometer (0.5 mile) south of Stillham (G-17). The rock is very fine-grained, hard, greenish gray, and foliated. In thin section, it is seen to consist of quartz, calcite, epidote, chlorite, albite, and hematite (?). Calcite occurs as large poikiloblastic rhombs; quartz is very fine-grained and anhedral; chlorite is dispersed throughout. Albite makes up only a small part of the rock and is seen to be partially replaced by other minerals. One thin section shows clearly the random orientation to albite laths (figure 11), suggesting a spherulitic or diabasic texture. While Balk (1953, p. 821, plate 8, figure 2) concluded this rock was a lens of tuff, the random orientation of the feldspar and the mineralogy of the rock suggest that this is an altered basic

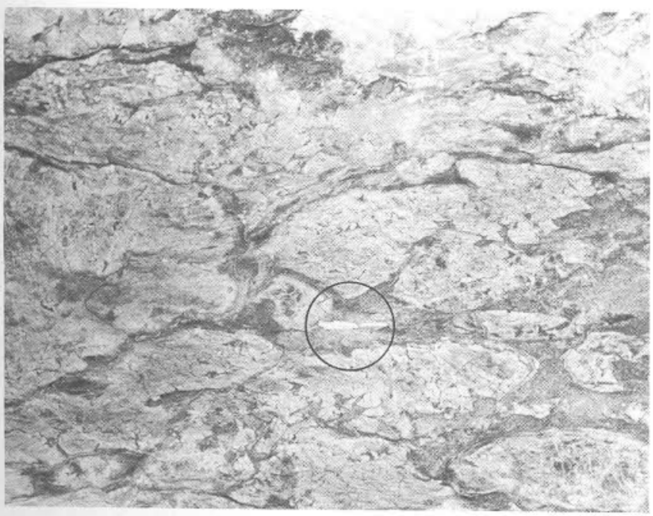


Figure 10. Pillow lava in Rensselaer Graywacke $\frac{1}{2}$ mile west of Banker Pond (D-13). Large float block near outcrop. Knife is 5 inches long.

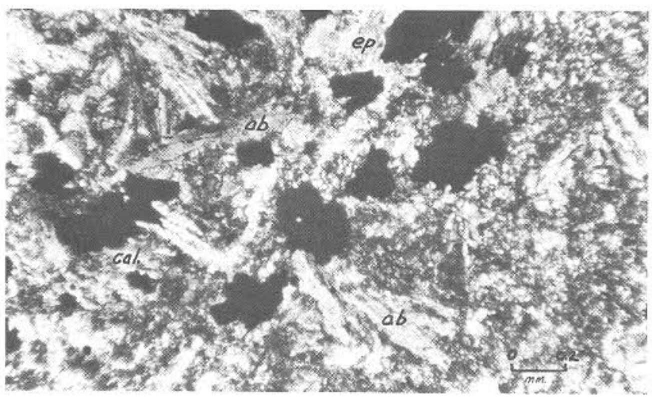


Figure 11. Photomicrograph of sheared volcanic rock in Rensselaer Plateau thrust zone, elevation 1,330, $\frac{1}{2}$ mile southwest of Stillham (G-17). Albite (ab) in spherulitic aggregates, partially replaced by epidote (ep) and calcite (cal). Opaque is probably hematite.

eruptive, perhaps a lava flow. Its occurrence in the thrust zone suggests volcanism during thrusting, or alternatively, it may be related to the period of Early Cambrian volcanism suggested previously.

Bomoseen Graywacke Member

Bomoseen is the name given by Ruedemann (Cushing and Ruedemann, 1914, p. 69) for Dale's (1898, p. 179) "olive grit," and more recently defined by Zen (1961, p. 299) as a member of the Bull Formation. Its designation as a member of the Nassau follows Bird's (1963) usage.

Lithology: The Bomoseen is a hard, massive to crudely foliated, silt-, and fine sand-textured graywacke consisting mainly of quartz, feldspar, and minor amounts of detrital muscovite (figure 12). The unweathered rock is gray or dark green; near the weathered surface it is characteristically olive green and the weathered surface is reddish. The Bomoseen forms bold outcrops in the woods and roche moutonnée crops out in the fields. Bedding is difficult to see, but certain weathered outcrops suggest cyclic beds of graywacke 2.5–7.6 centimeters (1 to 3 inches) thick separated by partings of argillite or slate; one exposure shows a 50-centimeter (20 inch) bed of graywacke.

Lithologic variations of the massive, silt-textured graywacke include gray siltstone with thin, wispy laminations of dark gray argillite, gray siltstone with tightly folded, light gray silty bands, and slaty siltstone and gray-green slate. Fine-grained, white-weathering quartzites, generally about 1.3 centimeters (0.5 inch) thick, are commonly interbedded with the graywacke.

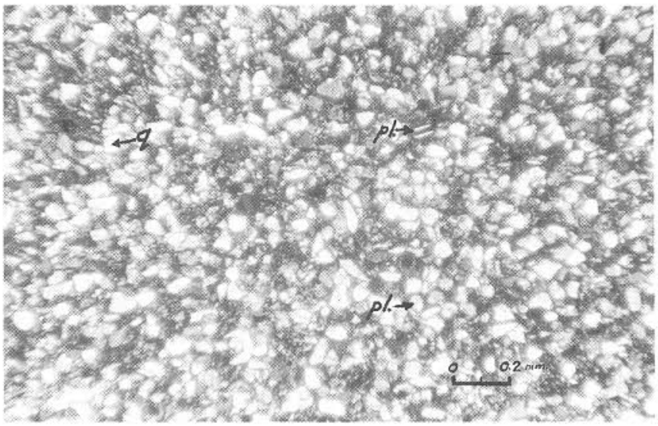


Figure 12. Photomicrograph of Bomoseen Graywacke, from outcrop (F-4) 0.3 mile southwest of Eagle Bridge. Small, angular grains of quartz, (q), plagioclase (pl) in matrix of fine grained quartz, clay, and sericite.

Metamorphism of the Bomoseen: Incipient recrystallization of the Bomoseen, seen between the east edge of the Rensselaer Plateau and the Little Hoosic River, is marked by scattered sericite flakes whose basal cleavage is at a high angle to the slaty cleavage. Farther east, the Bomoseen is a hard quartz-sericite schist containing bands of white granular quartz parallel to the foliation planes. This rock encloses some large lenses of porphyroblastic albite schist (figure 13).

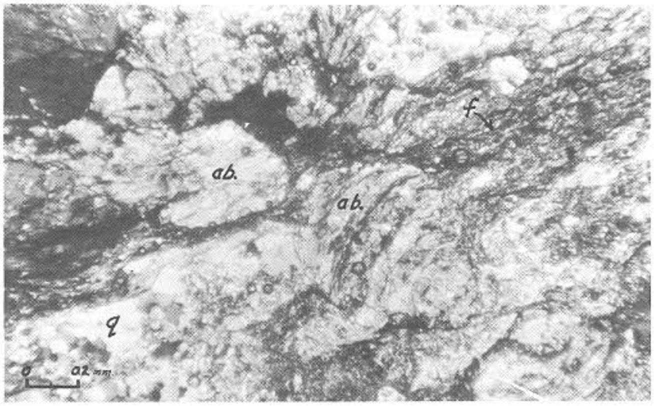


Figure 13. Photomicrograph of porphyroblastic albite schist which is interbedded with metamorphosed Bomoseen, from outcrop at elevation 1,240, west of Potter Hollow (L-13). Clastic quartz (q), porphyroblastic albite (ab), and folia of fine grained quartz, sericite, and chlorite.

Thickness: The main body of the Bomoseen is lenticular within the Hoosick Falls area and has a thickness of about 183 to 305 meters (600 to 1,000 feet). A similar estimate is given by Zen (1961). On the west shoulder of Poplar Hill (I-17), the Bomoseen has a minimum thickness of about 183 meters (600 feet), for its inverted upper contact with the Poultney Formation is an unconformity or thrust fault. At hill 920 west of Whipple Brook (D-1), the base of the Bomoseen is faulted against the Normanskill Formation, but its top is clearly shown and a minimum thickness of 183 meters (600 feet) is indicated. From Thurber Pond (F-1) south to West Hoosick (D-7), no measurements were made because of structural complexity, but it seems safe, judging from outcrop width, to estimate a maximum thickness between 152 to 305 meters (500 and 1,000 feet).

Stratigraphic relations: Dale (1899) assigned the olive grit (Bomoseen) to the base of the Lower Cambrian sequence, and Zen (1961, p. 297) indicated, in the northern Taconics, that the Bomoseen is a time-transgressive facies in the lower two-thirds of the Bull Formation. In the Hoosick Falls area, the Bomoseen occurs mainly as a homogeneous lithology in the upper part of the Nassau. The graywacke is found immediately below the Mudd Pond or West Castleton at these locations: in the fields (F-3) 0.8 kilometer (0.5 mile) north of Eagle Bridge; on the crest and east slope of hill 977 and hills to the south (E-5, E-6), 2.4 kilometers (1.5 miles) southwest of Eagle Bridge; at elevation 700–800 feet in the small east-flowing stream at School No. 3 (H-16). The graywacke may be separated from the overlying West Castleton by as much as 183 meters (600 feet) of upper Mettawee Slate, a relationship shown at D-1 and discussed under upper Mettawee subfacies. While the bulk of the Bomoseen is assigned to the upper part of the Nassau Formation, there are also lenses of Bomoseen in the middle Mettawee subfacies and thin beds of Bomoseen interbedded with Rensselaer Graywacke.

Zion Hill Quartzite Member

The name Zion Hill Quartzite was given by Ruedemann (Cushing and Ruedemann, 1914, p. 70) for Dale's (1899, p. 183) " Ferruginous Quartzite and Sandstone." The problems of identity and correlation of this and other quartzites in the Taconics are great and have been summarized by Zen (1964b, p. 87).

In the Hoosick Falls area, the Zion Hill Quartzite is treated as a member of the Nassau Formation. Mappable exposures are limited to the North Hoosick Klippe (H-4, H-5); hill 580 (G-4), 1.6 kilometers (1 mile) northwest of the klippe; and the west shoulder of West Mountain (M-1). The quartzite is highly lenticular.

Lithology: The Zion Hill Quartzite commonly occurs as a sequence of thick-bedded conglomerates and coarse-grained quartzites overlain by interbeds of fine-to medium-grained quartzite and gray slate. The conglomeratic quartzite weathers light gray. Pebbles range up to about 2.5 centimeters (1 inch) in maximum dimension and consist of subrounded white, gray, or bluish quartz, chalky-weathering feldspar, and dark-gray silty argillite. The light green-gray matrix consists of silt-to sand-sized particles of quartz, chlorite, and feldspar with or without dolomite and siderite. Pyrite is a common minor constituent. Gradations exist from pebble conglomerate through granule conglomerate to the most abundant lithology, a medium- to very coarse-grained inequigranular quartzite. This rock weathers light gray but, on broken surfaces, shows numerous brown specks, apparently weathered carbonate. Chert oolites are seen in some thin sections of this rock. A detailed petrographic description of the Zion Hill Quartzite at the North Hoosick Klippe is given by Harris (1961, pp. 39–59).

Thickness and stratigraphic relations: At the North Hoosick Klippe (Hill 1000), the Zion Hill is from 0.6–9 meters (2 to 30 feet) thick along the west slope of the hill. Graded bedding indicates the quartzite is right-side-up above a sequence of very thinly cleaved, soft, medium gray slate, medium to dark gray slate spangled with mica, and minor poorly foliated siltstone, all typical of the middle Mettawee subfacies. Sparse lenses of graywacke, identical to the graywackes phase of the Mudd Pond Quartzite, occur at the upper contact of the Zion Hill Quartzite which is overlain by a complexly folded sequence of West Castleton.

Mudd Pond Quartzite Member

Mudd Pond Quartzite was defined by Zen (1961, p. 303) as a member near the top of the Bull Formation in the northern Taconics. The Mudd Pond is probably equivalent to the Diamond Rock Quartzite of the Troy area (Zen, 1964b, p. 31; Fisher, 1962).

The dominant lithology is an orthoquartzite. At the type locality (Zen, 1961, p. 303) and in the Hoosick Falls area, the orthoquartzite is commonly overlain by, or gradational along strike with, a black graywacke phase. These two lithologies are mapped separately in the Hoosick Falls area and, though discontinuous and highly lenticular, are excellent marker beds at the top of the Nassau Formation. They are commonly infolded in the overlying West Castleton Formation.

Lithology of the orthoquartzite: The Mudd Pond Quartzite is typically a hard, massive, light gray-weathering orthoquartzite cut by fractures and joints and criss-crossed sparingly by veins of white quartz. Individual lenses range from 0.9 to 9 meters (3 to 30 feet) thick; most are 3 to 4.5 meters (10 to 15 feet) thick and less than 91 meters (300 feet) long. Typically, the outcrops are rounded and free of vegetation. The broken surface of the orthoquartzite is conchoidal and glassy; quartz grains are inequigranular, generally less than 1 mm in diameter, and tightly interlocking. Interstitial dolomite occurs in only small amounts. Small pockets or encrustations of quartz crystals are common.

Lithologic variations include a dolomitic quartzite with rounded, smoky quartz grains set in a light gray or tan colored dolomitic matrix. The outer few inches of this rock weathers to a punk, reddish brown, highly porous, low-density rock without interstitial cement. Outcrops of this rock are found: 1. Beneath the graywacke phase of Mudd Pond, at elevation 800 feet, just north of the crest of hill 820 (F-5), 1.9 kilometers (1.2 miles) southeast of Eagle Bridge; 2. associated with the graywacke phase of the Mudd Pond on hill 1220 (H-12), 2.2 kilometers (1.4 miles) northwest of North Petersburg. Unfortunately, this dolomitic facies of the Mudd Pond bears a close resemblance to the younger Eagle Bridge Quartzite, a similarity noted also by Zen (1961, p. 307) in the northern Taconics. Adding to the problem, the Mudd Pond Quartzite lies only a few feet stratigraphically below the Eagle Bridge Quartzite at many localities in the Hoosick Falls area.

A rare variety of the orthoquartzite is a dolomitic (and sideritic) conglomerate with pebbles of quartz, hematitic chert, and black slate. The rounded chert pebbles are slightly dolomitic and silty gray when fresh and deep brown to bright red when weathered. The matrix is a poorly sorted mixture of quartz and clay. This rock is in contact with the graywacke phase of the Mudd Pond on the crest of Hill 920 (C-12) 1.2 kilometers (0.8 mile) southeast of Center Cambridge, and is interbedded with the graywacke at elevation 640 feet and 1,000 feet in the North Hoosick Klippe (H-5).

Lithology of the graywacke phase of the Mudd Pond Quartzite: Outcrops of this graywacke are small and highly weathered, and the rock commonly occurs as somewhat rusty weathering, blocky float capping small topographic knobs. Maximum thickness of graywacke lenses is 12 meters (40 feet), but usual thickness is less than 1.5 meters (5 feet). Typically, the graywacke consists of a black argillaceous matrix, making up more than 50 percent of the rock, studded with rounded and frosted grains of quartz between 1–2 mm. in diameter (figures 14, 15). Other clasts include subrounded feldspar and angular clasts of chert up to 7.6 centimeters (3 inches) in length, black laminated dolomitic siltstone, and thin fragments of black slate which are commonly smeared in the plane of foliation. This lithology is described in detail by Dale (1898, pp. 181–182) and by Harris (1961, pp. 59–66. (See appendix 1 for a comparison of this graywacke with other graywackes in the Taconic Sequence.)

The intraformational nature of the graywacke, together with the rounded and frosted quartz grains in a black slate matrix, suggest slumping and a dual source of sediment; presumably the orthoquartzite represents an accumulation of clean sand, in relatively deep water, under stable conditions. At the same time, sands accumulating on the shelf areas were being rounded and frosted; orthoquartzite deposition was brought to a halt when these shelf sands and black muds slumped to deeper waters as a black muddy slurry. Two facts indicate slumping of shelf sands several times; similar graywacke occurs as lenses overlying the Zion Hill Quartzite, and rounded quartz grains occur locally in the Bomoseen.

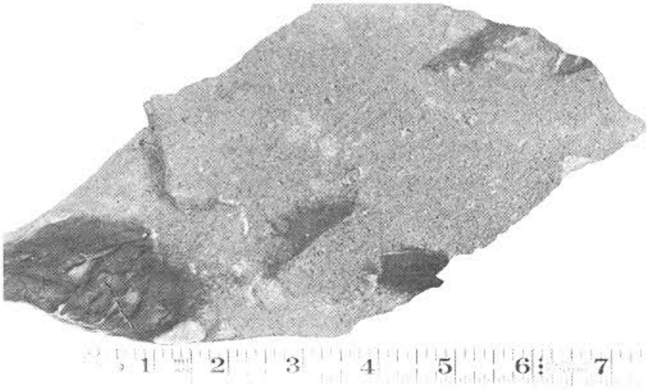


Figure 14. Hand specimen of graywacke phase of Mudd Pond Quartzite from crest of hill 820 (F-5), 1.2 miles S 8° E from Eagle Bridge. Note intraformational clasts of black slate and siltstone.

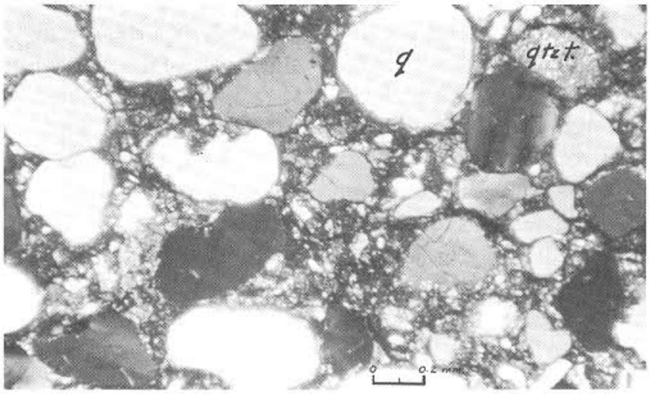


Figure 15. Photomicrograph of graywacke phase of Mudd Pond Quartzite, from Hill 966 (E-2). Clasts are quartz (q) and quartzite (qtzt) in matrix of clay, sericite, and fine grained quartz.

Stratigraphic relations: The graywacke phase of the Mudd Pond commonly lies directly on top of, or along strike from lenses of the orthoquartzite at the top of the Nassau Formation. The contact between the orthoquartzite and overlying graywacke can be seen in a small abandoned quarry on the north side of the dirt road, 0.4 kilometer (0.3 mile) southwest of intersection 892 (E-10); and at elevation 720 feet (D-1), west of Whipple Brook, 4.5 kilometers (2.8 miles) north of Buskirk. Throughout much of the latter area, however, no quartzite is found near the graywacke.

West Castleton Formation

The West Castleton Formation is a dominantly dark gray to black slate sequence which forms the matrix for the bulk of the *Elliptocephala asaphoides* (trilobite) — bearing limestone beds and lenses. The West Castleton was defined as a formation by Zen (1961, p. 304) in the northern Taconics; Bird (1962) and Theokritoff (1964) have followed this designation.

Lithology: The dominant lithology is a dark gray to black calcareous silty slate or siltstone, weathering white or light gray, with a ribbed appearance due to differential weathering of bedding laminae. Texturally, some of this rock is similar to, and grades into, the Bomoseen Graywacke. It forms more prominent outcrops than other slates in the Taconic Sequence. Closely associated with this lithology are: soft, black slate; black to medium gray slate with rusty weathering, closely spaced calcareous quartzite beds from 0.6 to 7.6 centimeters (0.25 to 3 inches) thick; maroon slate; black, tough, fissile, cherty slate weathering bluish gray and rusty on cleavage planes; thin beds or lenses of black chert. Lenses and beds of Mudd Pond Quartzite and graywacke occur at the base of the black slate. Thinly laminated, green-gray and black slate occurs with olive green and maroon slate in the upper part of the West Castleton in the northwest part of the area, and some of the green-gray slate here contains small chips or lenses of black slate that closely resemble lithology (d) of the Owl Kill Member of the Poultney. However, the West Castleton black slates carry the Early Cambrian brachiopod, *Botsfordia caelata* (appendix 4, station 284).

Limestone occurs in the West Castleton in the following forms: (a) Thin beds of unfossiliferous white-weathering limestone in a medium-gray slate sequence up to 6 meters (20 feet) thick, underlying maroon slate in the northwest part of the area. (b) beds and lenses of limestone conglomerate up to 0.9 meter (3 feet) thick in black or medium gray slate. The matrix of this conglomerate is brown or gray weathering, fine- to medium-grained limestone; the pebbles are dark argillaceous limestone, buff or tan calcilutite, calcarenite, dolostone, and slate, generally less than a few inches in diameter, and subrounded. A few exposures of this conglomerate exhibit a " swiss cheese " appearance due to deep weathering of small limestone pebbles with respect to matrix. Early Cambrian fossils occur in matrix and pebbles of limestone conglomerate and are most easily found on fresh surfaces of calcarenite pebbles. (c) Isolated lenses and beds up to 15 centimeters (6 inches) thick of fossiliferous, bluish gray weathering, dark gray argillaceous limestone with shaly partings. Types (b) and (c) are generally found stratigraphically within 6 to 9 meters (20 to 30 feet) of the Mudd Pond Quartzite or its graywacke phase. (d) Thick sequence of interbedded limestone and dolostone in the lowest

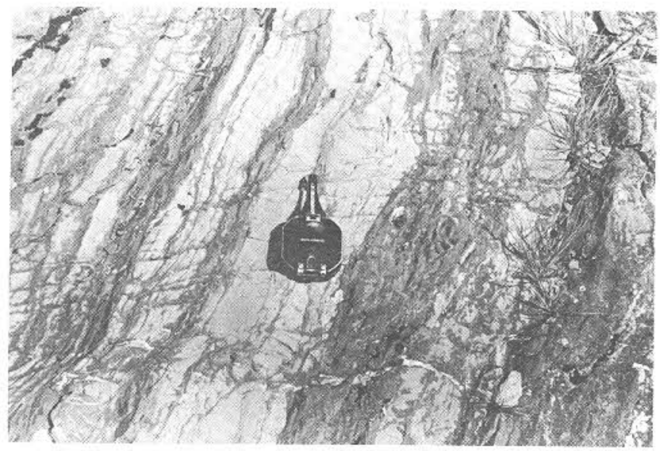


Figure 16. Thin-bedded limestone (light gray) and dolostone of the West Castleton Formation. At crest of Hill 760 (I-3), 0.8 miles S. 65° E from intersection 528 at Post Corners.

recumbent anticlines of the Post Corners (G-2, H-2) and North Petersburg (I-12) areas. This rock is remarkably thicker, and of different character, than the lenses and thin beds noted above. Limestone and dolostone attain a maximum thickness of about 91 meters (300 feet) in the Post Corners area and the general section, from the oldest to youngest is — Bomoseen Graywacke, West Castleton dark calcareous siltstone grading up into dark-gray calcarenite, interbedded limestone 10-centimeter (4 inch) beds and shaly dolostone 5-centimeter (2 inch) beds (figure 16), brown-weathering dolostone and shaly dolostone. The *Elliptocephala asaphoides* fauna occurs in the 4 inch limestone beds (appendix 4, stations 15, 60, 62). The significance of this thick carbonate sequence is discussed under " Structure of the North Petersburg Thrust Sheet."

Metamorphism of the West Castleton: The West Castleton black slates grade eastward into black siliceous phyllites and to black schists with bands of white-weathering granular quartz as on the west shoulder of West Mountain.

Thickness, stratigraphic relations, and age: The West Castleton is from 6 to 122 meters (20 to about 400 feet) thick in the Hoosick Falls area. It is underlain by either the Bomoseen Graywacke, as in the fields (F-3) 1.3 kilometers (0.8 mile) northeast of Eagle Bridge, or by the Mettawee slates; it is overlain by the Hatch Hill Formation (as at elevation 780 feet in the creek immediately west of School No. 3 (H-16). The lower contact is not always sharp, for locally the West Castleton grades down into the Bomoseen Graywacke or interfingering of Mettawee and West Castleton occurs. Locally, the West Castleton is absent and the Hatch Hill and Ordovician formations rest directly on the Bomoseen. The West Castleton is clearly lenticular within the Hoosick Falls area; its absence locally in the section may be due to pre-Hatch Hill erosion.

Abundant faunal evidence (appendix 4, West Castleton and Nassau Formations; all stations except 15, 60, 62) in the Hoosick Falls area indicates the bulk of the West Castleton to be Early Cambrian. It is possible, however, (see figure 2) that some of the rocks included in this formation are Middle Cambrian, a relation suggested by the work of Rasetti (1967), and Bird and Rasetti (1968).

HATCH HILL FORMATION

Defined by Theokritoff (1959, p. 55) in the northern Taconics, the Hatch Hill's dominant lithology is black slate with interbedded dolomitic sandstones, and its age is established by graptolites as Late Cambrian.

Lithology: The Hatch Hill in the Hoosick Falls area consists of three main rock types: (a) black cherty slate; (b) Eagle Bridge Quartzite Member; and (c) thin quartzites in dark gray slate.

(a) The oldest unit in the Hatch Hill is jet black, pyritiferous, cherty slate, weathering rusty or bluish gray on cleavage surfaces. It weathers into chunky, tabular slabs. No graptolites have been found in this facies. About 3 meters (10 feet) of this black slate underlies the Eagle Bridge Quartzite on the Owl Kill (see description of the Eagle Bridge Quartzite). Lenses of this black slate underlie the Eagle Bridge and overlie dark gray slate of the West Castleton in the hills north of Post Corners (G-1, 2; H-1 and 2). The cherty black slate is lenticular and often absent from the section, due in part to pre-Eagle Bridge erosion because pebbles and slabs of the slate occur in Eagle Bridge Quartzite.

A 15 meter (50 feet) sequence of black slate with several beds of dark gray to black limestone is exposed in a small glen (C-1) 0.8 kilometer (0.5 mile) east of Center Cambridge, and is mapped as Hatch Hill. It is equally probable that this is the White Creek Member of the Poultney.

(b) **Eagle Bridge Quartzite Member**

The name " Eagle Bridge Quartzite " was given by Prindle and Knopf (1932, p. 278) for the " quartzite . . . well exposed in the vicinity of the village of Eagle Bridge on Hoosic River in New York "; they also note (p. 277) that it is exposed in " a quarry 1.5 miles northeast of Eagle Bridge." No quartzite could be found along the Hoosic River in this vicinity and Prindle and Knopf were likely locating the village, not the outcrops of quartzite. There are excellent exposures of Eagle Bridge Quartzite on the Owl Kill beneath a bridge 0.2 kilometer (0.1 mile) north of B.M. 403, and in the small abandoned quarry 91 meters (300 feet) northwest of the bridge (G-3). This quarry, 1.6 kilometers (1 mile) northeast of the village, is undoubtedly the one referred to by Prindle and Knopf, and is here considered the type locality. The sequence exposed in the quarry and on the bank of the Owl Kill is shown in figure 17.

Lithology: The Eagle Bridge is typically a dolomitic quartzite with rounded quartz grains in the 1–2 mm range. Pyrite is a common minor constituent. Smears, patches, and stylolitic stringers of black carbonaceous material are common in the quartzite, perhaps arising from black mud that was forced up into the sand before consolidation. The Eagle Bridge has a distinctive weathered appearance — the outer few inches are cavernous, rusty, and porous, with sand grains and numerous crisscrossing veins of white quartz standing in relief above the weathered matrix (figure 18). The rock rarely forms good outcrops and is generally found as float blocks capping small topographic knobs.

Variations of the dolomitic quartzite in this area are:
1. Coarse conglomeratic dolomitic quartzite with angular to subrounded clasts of black slate, fine-grained quartzite, coarse-grained dolostone, and chert — all clasts are typical of the lithologies immediately below the Eagle Bridge and suggest an intrabasinal origin; 2. medium to dark bluish-gray orthoquartzite having the same grain size as the dolomitic quartzite but without

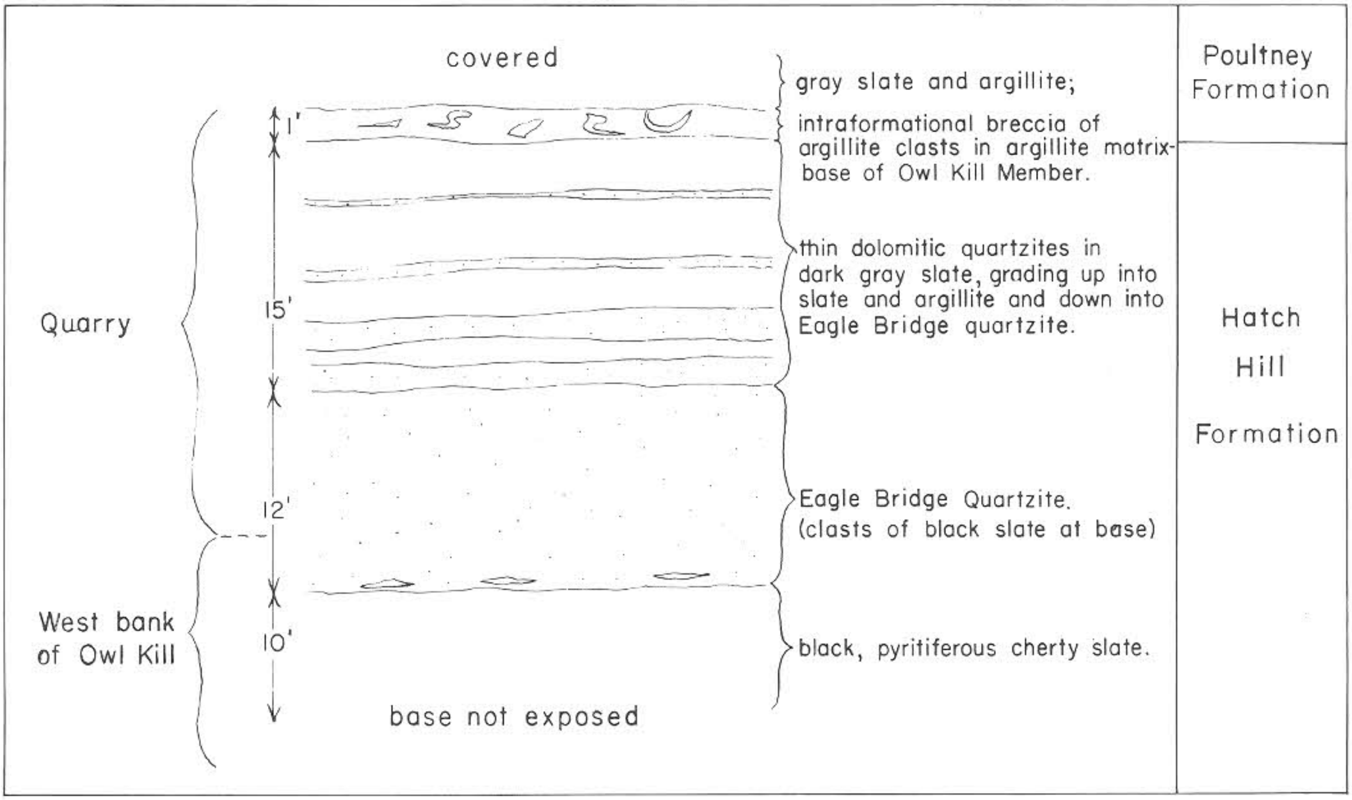


Figure 17 Stratigraphic relations of the Eagle Bridge Quartzite at its type locality one mile northeast of the village of Eagle Bridge

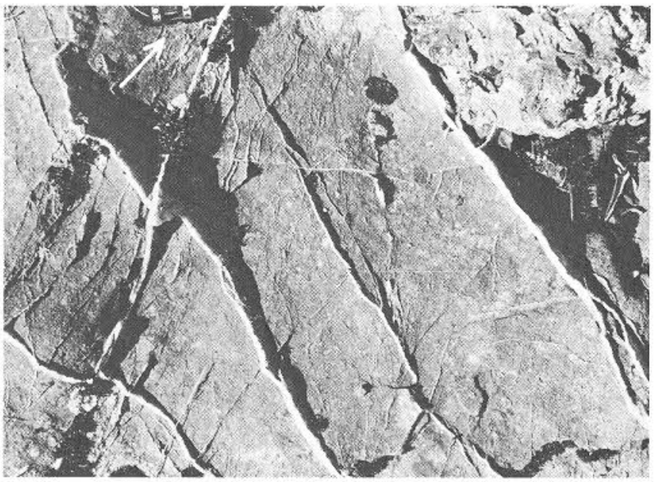


Figure 18. Eagle Bridge Quartzite at elevation 1,020 (G-9) on spur 0.6 mile S 30° W from School No. 14. Note differential weathering of quartz veins and dolomitic quartzite, and block of porous, punk quartzite in upper right corner.

dolomite cement; 3. cherty quartzite with sparse rounded grains of quartz set in a matrix of dark bluish gray chert; 4. sandy dolostone and brown weathering, dark gray, coarse grained dolostone. All these lithologies occur as vertical and lateral variants of the dolomitic quartzite.

The Eagle Bridge Quartzite attains a maximum thickness of about 6 meters (20 feet) in the hills 2 kilometers (1.25 miles) east of Post Corners (I-2, I-3), but is generally less than 3 meters (10 feet) thick and is lenticular due to depositional variations and flowage during folding.

Age and stratigraphic relations: The Eagle Bridge was considered to be Early Cambrian by Prindle and Knopf (1932, p. 277). In the area north of Post Corners (H-1) Bonham (1950, p. 14) found crinoid stems in sandy limestone, and erroneously correlated this lithology with the Eagle Bridge. On this basis, Bonham suggested an Ordovician age, and Lochman (1956, p. 1336) an " Upper Cambrian, probably a Lower Ordovician age " for the Eagle Bridge. Although this may well be the age of limestones overlying the Eagle Bridge in this area it is significant that the Eagle Bridge is nowhere a sandy limestone. Therefore, this evidence is not valid. Fisher (1956) indicated the Eagle Bridge to be Ordovician and intimately associated with Middle Ordovician slates above it, but he later (Fisher, 1962) modified this view to indicate that the Eagle Bridge lay within the Upper Cambrian Hatch Hill Formation. The present assignment of the Eagle Bridge to the Hatch Hill Formation is based on lithologic similarities of the quartzite, at Eagle Bridge, New York, to that at the type locality of the Hatch Hill Formation; the similar stratigraphic position of quartzite in the two areas; and the gradational contact of the Hatch Hill with the overlying Poultney Formation in the quarry at Eagle Bridge, New York.

(c) Thin-bedded quartzites in dark gray slate diagnostic of the Hatch Hill (Theokritoff, 1964, p. 178), are seen (at the type locality of the Eagle Bridge Quartzite) to be gradational between the Eagle Bridge and the overlying Poultney slates. The Eagle Bridge thins along strike to beds 0.3 meter (1 foot) thick or less, and becomes indistinguishable in this thin-bedded quartzite sequence. Locally, the Eagle Bridge and its associated thin-bedded quartzites pinch out, and only dark gray slate is present in the section.

Individual quartzites in this sequence generally range from 0.5 to 5 centimeters (.25 to 3.0 inches) thick and are separated a few inches by thinly cleaved, black, gray, or olive-green slate. The quartzites are characterized by paper-thin partings of black shale and a combination of cross bedding and graded bedding. Grain size ranges from very fine to medium sand, and the rock is tightly cemented by dolomite, calcite, and silica. Quartzite beds have a rusty and punk outer surface and weather more readily than the slate intercalations.

Total thickness of the thin-bedded quartzite sequence ranges from about 4.5 meters (15 feet) at the Eagle Bridge quarry, to more than 15 meters (50 feet) in the road cut and cliffs (I-12) 0.8 kilometer (0.5 mile) northwest of North Petersburg.

POULTNEY FORMATION

The name "Poultney Slate" was given by Keith (1932, p. 403) to white-weathering gray slates and cherts of Early Ordovician age in the northern Taconics. Theokritoff (1964, pp. 179–182) redefined Keith's Poultney Slate, assigned the oldest lithologies to the Hatch Hill, and described three members. Berry (1961) made a thorough study of the graptolite fauna of the Poultney, as defined by Theokritoff, and determined its age as Early and Middle Ordovician. The present study reveals a thick sequence of Poultney, with Early Ordovician graptolites at one locality. The formation is distributed widely in the North Petersburg thrust sheet and appears to be thickest in the northern part of the area. It is exposed locally in the Rensselaer Plateau thrust sheet on Mount Anthony (L-2).

The Poultney is here called a formation and two members are distinguished: (1) White Creek Member — dark gray slate with intercalations of limestone and quartzite, (2) Owl Creek Member — laminated argillite and slate.

White Creek Member (new name)

The White Creek Member is generally a dark gray to black slate containing ribbon limestone, thin-bedded limestone and dolostone, thin-bedded quartzites, and flat-pebble limestone conglomerate. The White Creek is equivalent to Theokritoff's (1964, p. 179) Member A, and is difficult to distinguish from the underlying Hatch Hill. The type area of this member is in the fields and low hills (G-2) from 0.8 to 1.6 kilometers (0.5 to 1 mile) northeast of Center White Creek.

In the area between the Center White Creek-Post Corners road and the base of the steep hills 1.6 kilometers (1 mile) north, there is exposed a large recumbent anticline (ra-1) with Early Cambrian units in the core and Eagle Bridge Quartzite and Poultney lithologies on the limbs. The White Creek Member lies directly beneath the Eagle Bridge Quartzite on the inverted limb of the anticline; the locality is at elevation 540, (1,600 feet) N 20° E of the church at Center White Creek; the outcrops occur near the tops of small hillocks about 200 feet west of the edge of the woods. From oldest to youngest (northeast to southwest) the stratigraphic sequence in the overturned structure is: fossiliferous Lower Cambrian ribbon limestone in dark gray argillaceous dolostone (West Castleton); Eagle Bridge Quartzite; White Creek Member of the Poultney consisting of ribbon limestone in dark gray slate (about 10 feet thick), thin-bedded limestone and pale brown-weathering dolostone. Cherty slates of the Owl Creek Member occur west and south of this ribbon and thin-bedded limestone.

In general, the ribbon limestone is fine-grained, dark gray to black, and weathers light bluish gray or buff. Individual beds are about 1.3 centimeters (0.5 inch) thick and are separated by less than an inch of dark gray slate. In some areas the limestone is a calcarenite and occurs in beds as much as 0.6 meter (2 feet) thick. In the Center Cambridge area (C-1), sparse, thin argillaceous limestone beds are characterized by solution tubes or wormholes perpendicular to the bedding. Maximum thickness of this ribbon limestone, or limestone-black slate unit, is about 6 meters (20 feet), but commonly it is 2.4 to 3 meters (8 to 10 feet).

Thin-bedded calcareous quartzites in dark gray slate separate the ribbon limestones from the overlying slates of the Owl Kill Member at a few localities. Generally, the superposition cannot be established, and sparse limestone beds or lenses are interbedded with thin quartzites. It is difficult to distinguish these thin-bedded quartzites from those assigned to the Hatch Hill, and formational assignment is made on the basis of stratigraphic succession or stratigraphic association, not on lithologic identity. The succession of ribbon limestones and thin-bedded quartzites is compatible with Theokritoff's (1964, p. 179) stratigraphic interpretation in the northern Taconics and agrees with his (pp. 181–182) evaluation of the Schaghticoke Shale section in the gorge at Schaghticoke, N.Y.; *viz.*, the ribbon limestone and overlying thin-bedded quartzites are lowermost Ordovician and rest on the Hatch Hill.

Thin-bedded, fine-grained, calcareous quartzites in gray, olive green, and black slate matrix attain a total thickness of 46 meters (150 feet) on the limbs of the Newcomb Pond syncline. The best exposure is on the creek bank, 0.6 kilometer (0.4 mile) southwest of intersection 533 (A-7). These quartzites lie unconformably on the Mettawee slates, are overlain by the Normanskill, and are assigned to the White Creek Member.

A distinctive lithology of the White Creek Member is flat-pebble limestone conglomerate which occurs in a matrix of black slate or dark gray, cherty slate, together with thin quartzite beds. The conglomerate occurs as beds up to 25 cm (10 inches) thick, or as isolated lenses. The conglomerate's matrix is a silty, pyritic limestone, weathering bluish gray, with a gritty surface. The clasts are tabular, rounded to subangular, dark gray limestone, brown-weathering dolostone, calcareous sandstone, and dark gray chert. An intraformational origin is suggested by the shape of limestone pebbles and by the similarity between the clasts and the lithologies of the lower Poultney. At the railroad cut (F-4) 0.8 kilometer (0.5 mile) east of B. M. 414 at Eagle Bridge, three beds of this limestone conglomerate occur in cherty gray slate with sparse think quartzite beds. (figs. 19, 20). Underlying beds are not exposed, but the overlying lithologies are Owl Kill cherty slate and argillite. Another exposure is on a small knob, elevation 1,060 feet, on the south slope of hill 1080 (F-7), 1.5 miles west of Hoosick Falls. Here, lenses of limestone conglomerate occur in dark gray, laminated slate

Figure 19. Folded cherty slate with beds of limestone conglomerate (at pick). White Creek Member of Poultney Formation in railroad cut 0.4 mile east of station at Eagle Bridge (F-4).

with thin calcareous quartzite beds. Finally, conglomerate lenses occur in cherty gray slate on the normal limb of recumbent anticline (ra-1) at elevation 700 feet (G-2), 0.9 mile N 25° E from Center White Creek. This limestone conglomerate in the Hoosick Falls area is correlated with a similar lithology in Theokritoff's (1964, p. 180) A Member.

Limestone in the White Creek Member south of the road (F-3), 0.5 mile southwest of Center White Creek, may be indigenous to the member, or may be a submarine slide block from the Synclinorium Sequence.

Owl Kill Member (new name)

The Owl Kill Member forms the bulk of the Poultney Formation and is dominantly argillite, siliceous argillite, and very fine-grained hard slate. The member is named for exposures in the stream and hills on the west side of the Owl Kill (F-3, F-4). The best exposures in the stream are from about 1,000 to 1,400 feet upstream from the confluence of the Owl Kill (stream) with the Hoosic River. The lower part of the member is exposed in the upper few feet of the quarry at the Eagle Bridge Quartzite type locality. Good exposures occur on hill 560 (F-3) 0.9 mile north of School No. 3 and 1,400 feet west of the Owl Kill stream. Here the Normanskill Formation occurs below 540 feet on the west slope, the Owl Kill Member at the crest, and other slopes down to about 470 feet.

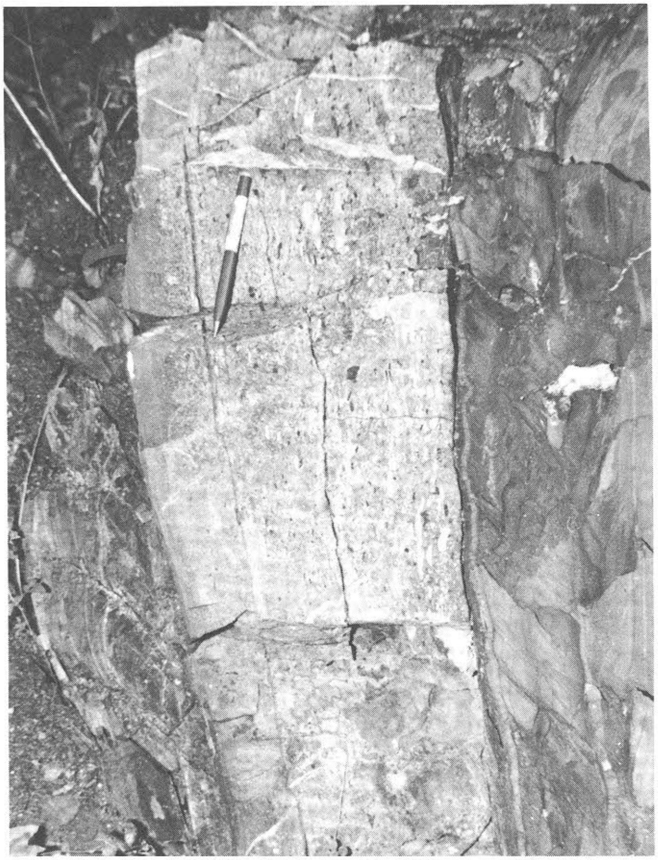


Figure 20. Detail of limestone conglomerate bed shown in fig. 19. Note graded bedding. Light colored pebbles are limestone, dark ones are dolostone and chert. Pencil is 5 inches long.

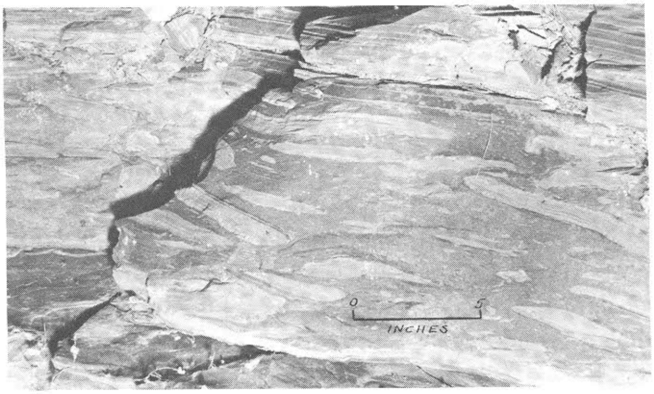


Figure 21. Intraformational breccia of green-gray argillite in black argillite: base of Owl Kill Member of Poultney Formation in quarry (G-3), 1 mile northeast of Eagle Bridge.

The Owl Kill Member is correlated with Theokritoff's (1964, pp. 180–181) B and C Members on the basis of lithologic similarity and fossils. The only graptolites found in the Poultney (see app. 4, station 26) in the Hoosick Falls area belong to Berry's (1961) Zone 4 (Early Ordovician). These graptolites occur in black slate associated with typical Owl Kill lithologies. This fauna was also found by Theokritoff (p. 180) in the lower part of his B Member.

Lithologies: The lithologic sequence within the Owl Kill is difficult to determine, and the following list, from oldest to youngest, gives only an approximation of stratigraphic order:

(a) Intraformational breccia of argillite: At the quarry 1 mile northeast of Eagle Bridge, a breccia bed, about 1 foot thick is exposed 8 feet above the Eagle Bridge Quartzite. The dark gray argillite matrix of the breccia holds tabular clasts of light gray and green-gray argillite, similar to the rocks above and below (fig. 21). Some clasts are bent or folded and have blunt ends as if they had been moved when soft; some clasts are simply slightly segmented beds. These features suggest the breccia was formed by slumping of partially consolidated muds. This breccia layer is taken as the base of the Owl Kill Member, and the thin-bedded quartzites beneath it are assigned to the Hatch Hill. The absence of the White Creek Member may be due to slumping that produced the breccia. A similar breccia, lying close to the underlying Hatch Hill, is exposed in the northwest part of the area (B-2) on the west side of the road, 0.8 mile south of intersection 699, and also just above the North Petersburg thrust fault at elevation 650 feet (I-12), 1.0 mile N 15° W from North Petersburg.

(b) Ribbon quartzite: This rock type consists of silty- and fine sand-textured quartzites, each bed from (0.25 to 3 inches) thick and separated by thin partings of hard, medium gray argillite or slate. It forms rounded massive outcrops which exhibit differential weathering of the white-weathering quartzites and slate interbeds. The thinner quartzite beds have a novaculite appearance; the coarser beds are vitreous. Flow-folding of the quartzite ribbons is common. This lithology is found in the lower Owl Kill and attains a maximum thickness of about 30 feet. It resembles, but is finer grained than, certain banded silty slates in the upper Mettawee.

(c) Siliceous argillite or slate and bedded chert: These rocks weather white or light gray. The chert beds are medium gray or green gray and generally less than 1 inch thick. By contrast, the Mount Merino cherts are black, gray, green, and red; individual beds are thicker than these in the Owl Kill. The siliceous slate commonly displays dark and light gray laminations as described in the next lithology, and is harder and more resonant than other slate in the Taconic Sequence in this area. Typical of the lower two-thirds of the Owl Kill, this lithology may be as much as 100 to 200 feet thick.

(d) Laminated and chip-textured argillite and slate: Laminated argillite or slate is the most distinctive lithology of the Poultney Formation. Laminations consist of dark gray bands in a light or medium gray argillite matrix, the whole having a striped appearance (fig. 22). Chip texture is a term used in this report for thin tabular chips, patches, or smears of dark gray argillite in a matrix of light or medium gray argillite (fig. 23). The chips are generally less than 1 mm thick and 1 cm long. These chips, lying at various angles to the slaty cleavage are not genetically related to cleavage development; when lying in the plane of cleavage they are more highly flattened or elongated than in other orientations. The chips are probably bedding laminae segmented by minor slumping during deposition. Laminated and chip-textured argillite and slate is found throughout the Owl Kill and its maximum thickness is perhaps 200 to 300 feet. Chip texture is also exhibited by some olive-green

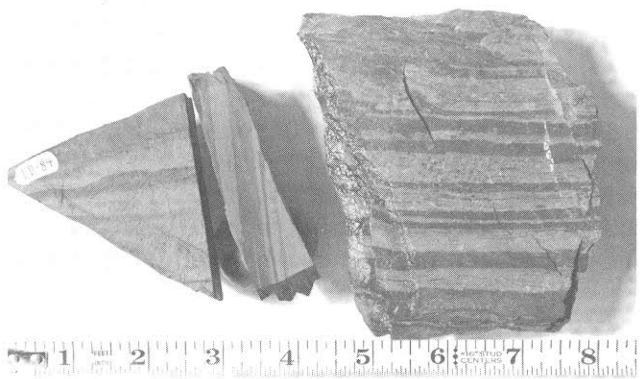


Figure 22. Laminated argillite and phyllite of Owl Kill Member of Poultney Formation. Two samples on left are from east slope of hill 560 (F-3), 1.2 miles northeast of Eagle Bridge. Sample at right is phyllite from West Mountain, elevation 1,200, 0.8 mile S 60° E from Bouplon Corner.

Figure 23. Chip-textured slate, Owl Kill Member of the Poultney Formation, elevation 840 (F-7), 1.54 miles N 64° E from intersection 530 at West Hoosick.

and green silty slates in the upper part of the West Castleton Formation, but as a minor type, slightly siltier than the Owl Kill rock.

(e) Black graptoliferous slate: One 3-foot bed, containing graptolites, was found in the north-central part of the area, associated with dark gray to brownish-gray, laminated and chip-textured slate, and with 3-inch beds of coarse grained dolostone (app. 4, station 26). The associated lithologies are typical of the Owl Kill, yet black slate is not common in this member.

(f) Dolomitic argillite: A medium to light gray, laminated, dolomitic argillite with chip texture and a distinctive rusty orange weathered surface. Coarse granular quartzite pebbles rarely occur in this argillite which has a maximum thickness of several tens of feet.

(g) Thin beds or lenses of graywacke: This is a minor lithology in the Owl Kill. Graywacke beds are generally less than a few inches thick and are of two types — a dark gray, fine-grained shale-fragment graywacke resembling the Austin Glen; and a gritty graywacke consisting of coarse, rounded, quartz grains in a dark gray, silty, and argillaceous matrix.

(h) Pale-red argillite or slate; thinly ribboned, red and green argillite (minor lithologies in the Owl Kill): These are difficult to distinguish from the Indian River red slate and the distinction is made on the basis of the associated rocks.

(i) Medium gray to light gray, soft argillite or slaty argillite with sparse, thin, dolomitic argillite laminae: This lithology may be as much as several hundred feet thick and is probably one of the youngest units of the Poultney.

As noted above, some of the Owl Kill rocks resemble the Mettawee slates but can be generally distinguished from them. The Mettawee slates are siltier, and commonly weather to an olive-green color within a few centimeters of the outer surface which is stained black. The Poulteney slates, by contrast, exhibit weathering discoloration only to a depth of a few millimeters and, in general, weather white or light gray. Dale (1899, p. 185) called this lithology the "White Beds." Owl Kill slates and argillites exhibit color laminations and, in general, are harder than the Mettawee.

Metamorphism of the Poultney: Slates of the Owl Kill Member are metamorphosed to phyllites and schists at West Mountain and at Mount Anthony, but extensive recrystallization of these rocks was apparently precluded by their very fine-grained nature. Thus, the ribbon appearance of flaminated medium and dark gray Owl Kill argillite is well preserved, yet the rock is a very fine grained silky-lustered schist or phyllite (fig. 22). The laminated argillite also exhibits widely spaced shear planes coated with sericite. The chert appears as thin, white-weathering beds, generally contorted and cut by a shear cleavage to the extent that cleavage banding (Dale, 1898, p. 214) is more pronounced than the delicate sedimentary laminae.

NORMANSKILL FORMATION

"Normanskill" is a widely used rock name or rock-stratigraphic name in the central and southern Taconics. The type locality is at Normans Kill, 25 miles southwest of the Hoosick Falls area (Ruedemann, 1930, p. 97; 1942, p. 88). Berry, (1962, pp. 709–714) called the unit the Normanskill shale and recognized four members. Three members of the Normanskill Formation are recognized in the present study: Indian River Member of red and green slate or argillite, Mount Merino Member of thin bedded chert and black slate, and Austin Glen Graywacke Member. Graptolites of the *Climacograptus bicornis* zone have been found in the Mount Merino and Austin Glen members in the Hoosick Falls area, and because the Indian River interfingers with the Mount Merino cherts and because a *C. bicornis* fauna has been reported from the Indian River in the northern Taconics (Berry, 1959, pp. 61–62), it appears safe to assign the entire formation, in this area, to Berry's (1960) *Climacograptus bicornis* zone.

Distribution, thickness, stratigraphic relations: The Normanskill is widely distributed within the North Petersburg thrust sheet but is absent from the structurally younger Rensselaer Plateau sheet. It is recumbently folded with the Poultney Formation along the east edge of the North Petersburg sheet. The largest and best defined exposure of the Normanskill is in the Newcomb Pond syncline along the west edge of the area (A-6, B-6, to A-11).

The Normanskill is highly lenticular, apparently due to variations in depositional thickness. Maximum thickness is estimated at 1,400 feet in the western part of the area, but elsewhere it is less than about 400 feet and, locally, may be only a few tens of feet thick.

An unconformity of unknown geographic extent occurs beneath the lowest units of the Normanskill in the western part of the area for the Normanskill rests directly on the Nassau; for in the Newcomb Pond syncline, the Normanskill rests on the White Creek Member of the Poultney Formation. Elsewhere in the area the Normanskill is conformably underlain by the Owl Kill Member of the Poultney, a relationship emphasized by Berry (1961, p. 224; 1962, pp. 711–712) although he did not use the name "Owl Kill." Fisher (1961, p. D9) also noted that the Normanskill rests unconformably on rocks of varying ages within the Taconic Sequence

Indian River Member

The Indian River red slates (Keith, 1932, p. 403) are widely recognized at the northern end of the Taconics (Zen, 1964, p. 24; Theokritoff, 1964, p. 182; Doll, et al., 1961) and in the central and southern Taconics (Craddock, 1957, pp. 687–688; Prindle and Knopf, 1932, p. 279; Elam, 1960, p. 61).

The Indian River, one of the more distinctive slates in the Taconic Sequence, is a bright "brick red," brighter than any of the red slates in the Poultney or Nassau. Slaty cleavage is variably developed, but the rock generally is a thinly cleaved silty argillite or argillite. Interbeds and interlaminations of light green to greenish-gray argillite are common and, in places, green slate or argillite constitutes half the member. Locally, the rock is a thinly ribboned or pinstriped, red and green argillite. Thin beds of purple slate occur locally with the red.

In the Hoosick Falls area, the Indian River is as much as 150 feet thick (E-7, 8, 9; F-4, 5, 6) but is highly lenticular and absent at many localities where other members of the formation are thick, as in the southern part of the Newcomb Pond syncline (A-8 to A-11), and in the valley of the Little Hoosic River (H-16, 17 to I-16, 17).

Stratigraphic position of the Indian River Member beneath the Mount Merino thin-bedded cherts can be established on the west limb of the Newcomb Pond syncline, 400 feet east of intersection 388 (A-6), and on the road about 1.5 miles south of Eagle Bridge and 350 feet east of intersection 721 where the beds are overturned. However, the red and green slate does not always lie beneath the thin-bedded cherts of the Mount Merino Member, for at the latter locality red slate is also interbedded with the cherts. Locally, on the east limb of the Newcomb Pond syncline, red slate lies above thin-bedded chert and beneath the Austin Glen Graywacke.

Mount Merino Member

The name " Mount Merino " is used here for interfingering black slate and bedded chert which, locally, can be mapped as separate units. Ruedemann (1942, pp. 90–101) defined the " Mount Merino chert and shale " as a unit within the Normanskill Formation, but also included the red slate that is here mapped as the Indian River Member.

Black slate: Black graptoliferous slate is interbedded with chert on the east limb of the Newcomb Pond syncline (A-7), and lies above the bedded chert at the north end of the syncline (A-6). The fresh slate is sooty black and ranges from a hard, crudely cleaved argillite to soft, thinly cleaved slate with silky luster. A yellow, rusty-weathering surface is common and bedding is not generally seen except where thin, white-weathering quartzite beds exist. The black slate unit is as much as 90 feet thick. Graptolites are well preserved and fossil localities are easily found in the black slate or in black slate interbeds with chert. (app. 4, stations 111, 159, 248, 260-P, 297, 298)

Thin-bedded chert: More persistent along strike than the black slate, the thin-bedded cherts occur in a matrix of black, gray, red, or olive-green slate or argillite. Individual beds, 0.25 to 3 inches thick, are black, gray, or green on fresh surface, and light gray or white on weathered surface. These bedded cherts form resistant outcrops, underlying the crests of hills or small hillocks in open country. Chert float is common in lieu of outcrops. In thin section, the chert from the Newcomb Pond syncline appears as a " a pinpoint-birefringent aggregate of microcrystalline quartz " (Harris, 1961, p. 108). Harris noted radiolaria which had received earlier attention by Ruedemann and Wilson (1936). The Mount Merino cherts are thicker and more sharply defined in the slate matrix than those of the Owl Kill which grade into siliceous slate. Maximum thickness of the thin-bedded chert unit is 120 feet.

Austin Glen Graywacke Member

This unit, named by Ruedemann (1942) in the Catskill area about 55 miles southwest of the Hoosick Falls area, is the Pawlet Formation of the northern Taconics (Zen, 1961, p. 307). Potter (1959) referred to it as the Normanskill Graywacke. In the Hoosick Falls area it occurs within the allochthonous Normanskill Formation, as described here, and also in the autochthonous Walloomsac Formation.

Lithology: The Austin Glen is a distinctive light gray to brown weathering, soft, gritty rock, generally showing slaty cleavage. In general, it forms poor outcrops because of abundant shale or slate interbeds, and the soft nature of the graywacke. Chunky pieces of float or low rubbly outcrops are commonly the only surface expression of the graywacke beds. The massive hard beds of coarse graywacke in the Newcomb Pond syncline are exceptions.

In this syncline, the graywacke forms beds from 3 inches to 10 feet thick, interbedded with thin beds of brown-weathering silty slate spangled with small flakes of mica. Graywacke/slate ratio here is about 3/1 by volume. Elsewhere, the slate interbeds are bluish weathering, dark gray, silky slate or sooty black, graptoliferous slate, graywacke beds are 2 inches to 2 feet thick, generally fine-grained, and the graywacke/slate ratio is lower.

Following Pettijohn's classification (1956, p. 291), this rock is a lithic graywacke with a dark gray, soft, calcareous matrix of chlorite and micas; the clasts are quartz, dark gray or green shale, and feldspar. Quartz

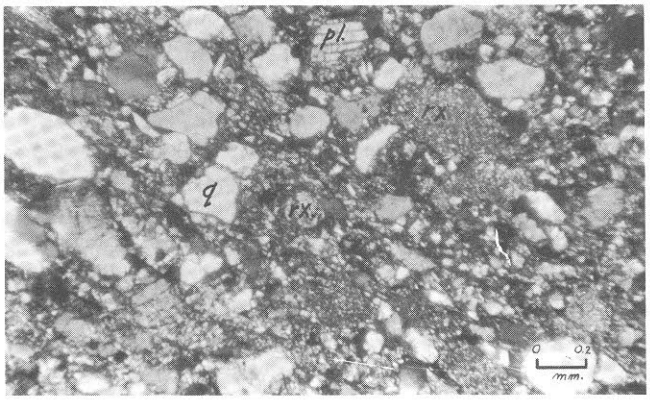


Figure 24. Photomicrograph of Austin Glen Graywacke Member of Normanskill Formation, from Newcomb Pond Syncline (A-9). Clasts are quartz (q), plagioclase (pl), and silty argillite (rx), in matrix of clay, sericite, and calcite.

grains are generally clear, but also milky or blue; they range from subangular to rounded, but most appear to be subrounded and are generally less than 2 mm in diameter (fig. 24). Very thin shale clasts often appear as mere skins on the broken surface of the graywacke, and measure 5 mm or less in maximum dimension.

Graded bedding is well developed at the Newcomb Pond syncline where the largest quartz grains, in beds 3 to 4 feet thick, are about 2 mm in diameter at the base and less than 0.5 mm in diameter at the top. Elsewhere in the area, bedding, and especially graded bedding, is difficult to see because of poor outcrops.

A possible submarine slide block of limestone (Synclinorium carbonates) occurs in the Austin Glen in the core of the recumbent syncline (E-9), elevation 950 feet, 0.75 mile north of Southwest Hoosick.

Stratigraphic relations, age, and thickness: The Austin Glen is the youngest unit in the Normanskill Formation and, hence, in the Taconic Sequence in this area. Its position above the Mount Merino and Indian River is best established along the west limb of the Newcomb Pond syncline (A-6, 7, 8) where graded bedding in the graywacke, and crossbedding in the White Creek quartzites beneath the Mount Merino and Indian River indicate a right-side-up section. Elsewhere in the area the graywacke occurs structurally above the Mount Merino Member but, because of poor outcrops, the stratigraphic top of the section cannot be proven.

The age of the Austin Glen in this area is Late Middle Ordovician (Wilderness or Trenton stages). This assignment is based on graptolites found in black slate interbedded, or in contact, with graywacke (app. 4, stations 19, 76).

The Austin Glen graywacke is lenticular and generally less than about 350 feet thick. At many localities it may be but a few tens of feet thick, while in the western part of the area it is more than 1,000 feet thick. This limited evidence supports Berry's (1962, p. 713) statement that the Austin Glen thickens rapidly westward from the northeast part of the allochthon, and it is in general agreement with his estimate of 400–500 feet for the graywacke in Rensselaer County.

SYNCLINORIUM SEQUENCE

INTRODUCTION

The Synclinorium Sequence (fig. 2) presents fewer stratigraphic details than the Taconic Sequence. The oldest rocks, referred to here informally as the Synclinorium carbonates, include Late Cambrian, and Early and Middle Ordovician fossiliferous limestone, dolostone, and minor quartzite. Three map units are distinguished: Clarendon Springs Dolomite (Ccs), Lower Ordovician limestones and dolostones (Old-1), and Middle Ordovician limestones and dolostones (Old-2). These rocks are underlain east of the Hoosick Falls area by a thick and continuous sequence of older quartzites and carbonate rocks (MacFadyen, 1956). The overall aspects of this part of the Synclinorium Sequence suggest a stable, shallow-water, shelf environment.

The overlying Middle Ordovician Walloomsac Formation is dominantly a thick, homogeneous, dark gray slate, probably of deepwater origin, containing in its upper part, thin beds of black graptoliferous slate and bedded chert, and lenses of Austin Glen Graywacke. Associated with the graywacke are lenses and poorly defined masses of Whipstock Breccia, a submarine slide accumulation containing some large clasts of rocks from the Taconic and Synclinorium Sequences. The graywacke was deposited on the youngest formations of both the Synclinorium and Taconic Sequences prior to or during thrusting; the Whipstock Breccia formed when shelf rocks and rocks of the advancing thrust sheets slumped into the deepwater muds.

SYNCLINORIUM CARBONATES

Clarendon Springs Dolomite

The Clarendon Springs (Keith, 1932) forms large outcrops east and northeast of the Hoosick Falls area (MacFadyen, 1956; Hewitt, 1961), but its only occurrence in the area is on the low hills (M-6) at the east edge of the Hoosick Falls quadrangle where the upper 50 feet of the formation is exposed. The rock is a light tan dolostone and siliceous dolostone with irregular knots and veins of chert and quartz. Differential weathering is highly developed. Following earlier workers, the formation is assigned to the Late Cambrian. It is overlain by white to blue-gray marble and by medium- and dark gray dolostone assumed to be Early Ordovician.

Lower and Middle Ordovician limestone and dolostones

Definitive work on limestones and dolostones of Early and Middle Ordovician age has been done in west-central Vermont (see Cady, 1945; Cady and Zen, 1960, and their references to earlier work). Hewitt (1961b) mapped two stratigraphic units, Shelburne and Bascom-Beldens, in the Equinox Quadrangle to the northeast. In the Bennington Quadrangle to the east, MacFadyen (1956) lumped all Early Ordovician carbonates into one map unit and considered the Middle Ordovician carbonates to be part of the Walloomsac. The present study shows a continuous sequence of dolostones and limestones ranging in age from Early Canadian or perhaps Late Cambrian, through Middle Ordovician (Trenton). The great bulk of this sequence (Old-1) is Early Ordovician; Middle Ordovician fossils occur at a few localities and here the carbonates are designated Old-2.

The stratigraphic succession of Old-1 is best seen in the east-central part of the area, from Hill 840 (M-6) southwest through Riverside School (M-7) where a normal sequence is indicated by broad stratigraphic succession and by a few primary structures. Lying on the Clarendon Springs is light to medium-gray weathering, coarse-grained dolostones that could be correlated with the Lower Ordovician Shelburne Formation. Above this, with an aggregate thickness of 700 to 1,000 feet, are the following lithologic types: coarse grained limestone with thin, dark gray shale partings; thin bedded dolomitic sandstone and quartzite; interbedded fossiliferous calcarenite and sandy dolostone; massive, coarse grained fetid dolostone; light blue-gray-weathering limestone or white marble; blue-gray limestone with chert zones up to 2 feet thick; creamy white to brown-weathering, medium-bedded dolostone; blue-gray fossiliferous limestone; limestone with thin ribbons of sandy dolostone; limestone with blebs or curdles of dolomite; interbedded blue-gray limestone or white marble and heavily creased white, buff, brown, orange, tan, medium to thick-bedded dolostone. In general, sandstone, quartzite, massive dolostone, and the minor cherty beds are common in the lower part of this section, and limestone becomes dominant towards the top. Fossils (app. 4, stations 7, 10, 66, 89) and lithologic characteristics of the bulk of this sequence suggest a correlation with the Lower Ordovician Bascom and Chipman Formations. One trilobite indicates that, locally (station 10), part of the sequence may be Late Cambrian.

Overlying Old-1 and widely distributed through the area, are Middle Ordovician (app. 4, stations 7, 10, 84, 90, 93) limestones and dolostones having many of the lithic characteristics of Old-1. The most distinctive lithology in this younger sequence is a dark gray to black argillaceous crinoidal limestone 15 to 50 feet thick. This rock is exposed at the north slope of Whipstock Hill, and at the north end of the road cut (I-13) on New York Route 22, 0.7 mile south of North Petersburg. Fossils occur in this rock in submarine slide block No. 8c (fig. 3; app. 4, station 93). The best exposure is in submarine slide block No. 4 in Little White Creek (I-5).

SPECIAL OCCURRENCES OF THE SYNCLINORIUM CARBONATES

North Pownal Village: The large tongue of limestone and dolostone east and northeast of North Pownal (M-13, 14, 15) has been variously interpreted as a lens in the Middle Ordovician Walloomsac Slate (MacFadyen, 1946), or as part of the continuous Early to Middle Ordovician carbonate sequence (Prindle and Knopf, 1932). The present study favors the latter hypothesis because the north part of the tongue has blue-gray marbles, sandy marble with shaly partings, punk-weathering and thinly laminated dolomitic quartzites, white calcitic marble, and ribbon dolostone in limestone — all typical of the Lower Ordovician Bascom Formation.

East of the village are two prominent cliffs and hilly terrain with abandoned quarries at the north and south ends. This terrain is underlain by blue-gray, gray, and white marble with interbeds of massive creamy-white to pale-brown dolostone (fig. 25) and one or two 4-foot black shale beds. This sequence is apparently overturned, for discontinuous slivers of the Walloomsac Formation, up to 40 feet thick and 2,000 feet long (fig. 26) occur beneath it and above the inverted Rensselaer Plateau thrust. The only carbonate rocks within the Walloomsac Slate are distinctive, thin, dark gray,

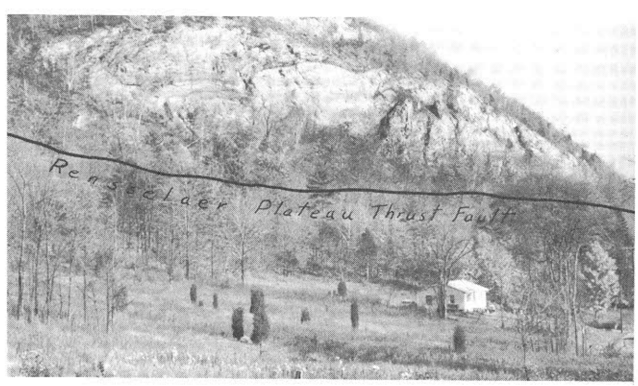


Figure 25. Folded limestones and dolostones (darker beds) of the Synclinorium carbonates above inverted Rensselaer Plateau thrust fault on cliff, 1,200 feet southeast of that shown in figure 26.

chocolate brown-weathering limestone and dolostone beds, lithologically different from those in the carbonate sequence above. The main limestone-dolostone mass in these hills resembles the Bascom and Chipman lithologies but may be correlated with the older Shelburne Marble which contains massive dolostone beds. In addition, there is some blue-gray marble with shredded, thin, sandy dolomitic laminae which appear to be deformed dolomite blebs. Locally, the limestone of the main mass at its inverted contact with the Walloomsac is dark gray to black, suggesting a correlation with the Old-2. In summary, the limestone and dolostone lithology in the entire tongue suggests an Early and Middle Ordovician age; the sequence is complexly folded and overturned, for the Walloomsac Formation occurs beneath it.

The structural continuity of the thrust beneath the tongue at North Pownal with the thrust south of the

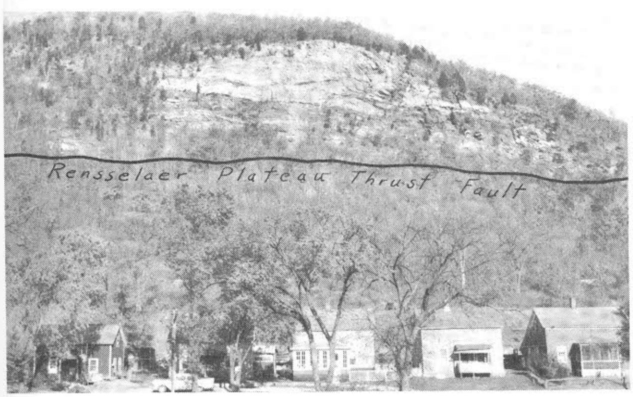


Figure 26. View of inverted Rensselaer Plateau thrust fault on cliff (M-14, 15) east of North Pownal. Looking northeast from roof of tannery. Chloritoid schists (Mettawee) exposed in wooded slope beneath thrust; sequence above thrust is inverted, with Walloomsac phyllite and interbedded limestones just above thrust, and Synclinorium carbonates (light gray) in upper part of cliff.

Quadrangle is shown on plate 1. South of the river, carbonate lithologies are white marble, mottled dark and light gray marble, blebby dolomite in limestone, blue-gray limestone with medium-bedded creamy- and brown-weathering dolostone, white to pale-red marble, and dark gray argillaceous limestone with dark gray shaly partings, again indicating similarity with the Lower Ordovician Bascom and Chipman Formations.

West Shoulder Mount Anthony: MacFadyen (1956) showed the upper carbonate zone, at elevation 1,200 to 1,300 feet, as a lens in the Walloomsac Slate and correlated it with marble in the tongue east of North Pownal (fig. 27). Prindle and Knopf (1932) mapped this upper carbonate zone as part of the main carbonate sequence; Balk's map (1953, pl. I) suggests a similar relation. The present study (fig. 27) suggests that this upper carbonate zone is the synclinorium carbonates in the inverted limb of a large recumbent syncline directly below the Rensselaer Plateau thrust fault. There is a marked discordance between the synclinorium carbonate-Walloomsac contact and the trace of the thrust fault. Above the thrust fault is the Lower Cambrian Rensselaer Graywacke and other formations of the Taconic Sequence, *not* the Walloomsac Slate as shown by MacFadyen.

This upper carbonate zone consists of interbedded limestone and dolostone, the latter being more abundant. Again, these lithologies closely resemble those of the Synclinorium Sequence.

Hill 560 near Petersburg Junction: Limestone and dolostone are exposed on the east side of the Boston and Maine Railroad, 0.9 mile north of Petersburg Junction (I-11), and their structural complexity and age range warrants this separate description.

A massive, coarse-grained, fetid, medium gray dolostone, 15 to 25 feet thick, forms a cliff above the tracks on the west side of Hill 560. Beneath the dolostone, near track level, is a 10-foot sequence of light gray calcilutite carrying Middle Ordovician fossils (app. 4, station 10, NP-9). Massive dolostone occurs again beneath the calcilutite at track level. Above the main mass of dolostone is a 50-foot sequence of irregularly dolomitized limestone with irregular beds of blue-gray chert, interbedded limestone and dolostone, and thin-bedded quartzites with cross bedding indicating a right-side-up section. A possible Late Cambrian fossil (station 10, NP-51) was found in the lower part of this sequence, and the rocks are lithologically similar to those in the synclinorium carbonates. Although no thrust faults were seen, it seems likely that most of the sequence above the massive dolostone is thrust over it and that the dolostone may be folded into a recumbent syncline open to the west with Middle Ordovician calcilutite at the core.

Further complications are obvious along the south slope of Hill 560 in the woods east of the tracks. Two high angle normal faults, about 100 to 150 feet apart, strike northeast across the crest of the hill. Between these faults which perhaps are related to solution collapse, the layers are segmented, highly contorted and faulted.

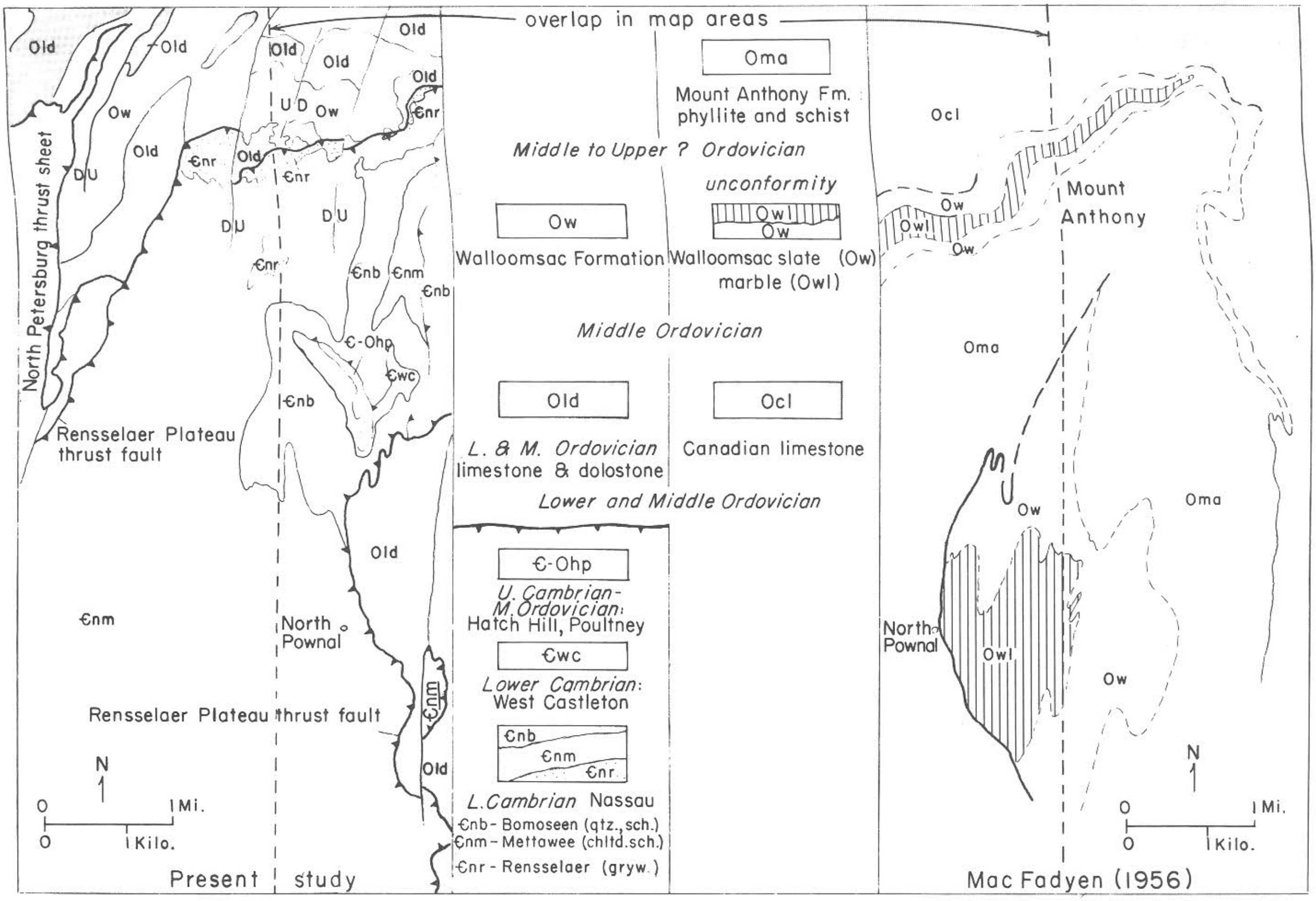


Figure 27. MacFadyen's interpretation of structure at Mount Anthony compared to interpretation of present study

Early Ordovician fossils at station 10 (NP-49L) come from calcarenite interbedded with dolostone, sandy dolostone, and intraformational breccia at the level of the tracks about 600 feet north of Hill 560. These beds are in fault contact with the massive dolostone, and are correlated with the layers that lie above the dolostone on the hill.

WALLOOMSAC FORMATION

The name "Walloomsac slate" was first used by Prindle and Knopf (1932, pp. 274–275) for "dark smooth shales and soft slates . . . in the valley of the Walloomsac River west and northwest of Bennington." This places the type locality in the northeast part of the Hoosick Falls area along the river between North Hoosick (I-6) and Riverside School (M-7), for slate is not exposed along the river in the Bennington Quadrangle. Bonham (1950, p. 36) and Harris (1962, pp. 124–136) have subsequently described and mapped the Walloomsac in this area. Zen (1966) defined the Walloomsac as a formation.

In the northern Taconics, a similar Middle Ordovician black slate (Ira), lying beneath the allochthon at its east edge, was mapped by Keith (1932), and by Zen (1961, pp. 310–313); the Ira's western equivalent in the northern Taconics is the Hortonville Slate (Keith, 1932, p. 369; Zen, 1961, pp. 310–313; 1964, pp. 44–45, 47–48), and this unit contains the Forbes Hill Breccia Member which is very similar to the Whipstock Breccia of the Walloomsac. In the southern Taconics the Walloomsac is the "Trenton or Trentonian black shale" along the east edge of the allochthon in the Kinderhook (Craddock, 1957, pl. I) and Copake (Weaver, 1957, pl. I) quadrangles. Zen (1966) indicates that the

Walloomsac can be mapped continuously from its type locality to southwestern Massachusetts and Connecticut.

The dominant lithology of the Walloomsac in the Hoosick Falls area is dark gray slate. In this are mappable lenticular units of (a) fossiliferous black slate and chert, (b) Austin Glen Graywacke, and (c) Whipstock Breccia.

Distribution: The Walloomsac underlies approximately 30 square miles of low ground in the Hoosick Falls reentrant (fig. 3). The formation extends eastward into the Bennington Quadrangle (MacFadyen, 1956); to the north, south, and west, it is bounded by the Taconic Sequence which has been thrust over it or otherwise faulted against it.

Age: Prindle and Knopf (1932, p. 274) noted the occurrence of the graptolite *Diplograptus foliaceus* from the Walloomsac " in the old slate quarry ¾ mile north of Hoosick " (I-9), and also reported two additional localities south of White Creek (K-3) where graptolites indicated a " Normanskill age." No graptolites were found in the present study at any of these localities, but Berry (personal communication, November 28, 1960) kindly examined some of the original slabs from the Hoosick slate quarry loaned by Williams College. He referred them to his *Orthograptus truncatus* var. *intermedius* Zone, which is Trenton or upper Middle Ordovician (app. 4, sample 30). Two new graptolite localities were found in black slate lenses in the eastern part of the area (app. 4, stations 318, 319) and this fauna is of the *Climacograptus bicornis* Zone. Thus the sum of the graptolite evidence indicates that the Walloomsac is Wilderness and Trenton in age, and that the Walloomsac and Normanskill Formations are essentially age equivalent (Berry, 1963, p. 21).

Stratigraphic relations: The stratigraphic relations between the Walloomsac and the synclinorium carbonates in the reentrant are very difficult to establish for although the contact is exposed at several localities, top and bottom criteria are lacking and the Walloomsac is found structurally beneath the carbonates as many times as above them. The presence of either Old-1 or Old-2 immediately beneath the Walloomsac supports the observations of Zen (1967, pp. 40–44), MacFadyen (1956, p. 27), and others that this is an unconformable contact. In the eastern part of the reentrant, the Walloomsac is recumbently and isoclinally folded with the carbonate formations. In the western part, the distribution and structural position of many of the carbonate masses (fig. 3) within the Walloomsac suggests that they are probably large submarine slide blocks (see Whipstock Breccia).

Lithology of the Walloomsac Formation: The dominant rock of the Walloomsac is dark gray, soft, thinly cleaved, fine grained slate with silky luster on cleavage planes. Variations are dark gray argillite with widely spaced slaty cleavage, dark gray to black calcareous silty argillite, medium gray argillite beds ½- to 1-inch thick in dark gray slate, dark gray slate or argillite with thin, white sandstone or quartzite laminae. The last lithology is closely associated with the Whipstock Breccia. Foliation is commonly crumpled and crinkled, and the slate contains numerous veins and pods of white quartz. The slate commonly weathers light or bluish gray in an irregular, streaked pattern. Outcrops are small and generally do not rise more than a few feet above the surface. Two exposures of the typical dark gray slate are at the slate quarry, 0.86 mile north and west of the village of Hoosick (I-9), and in the road cut on New York Route 7, 0.2 mile east of the entrance to Bennington Battlefield Park (K-5).

There are thin beds and lenses of brown-weathering dark gray limestone in the Walloomsac Slate at several localities but in general this is a minor lithology. The best exposure is at elevation 800 feet near the base of the steep cliff at North Pownal (M-14, 15) where pyritic, dark gray to black phyllite is interbedded with thin beds of brown-weathering dark gray limestone.

Total thickness of the dark gray slate phase of the Walloomsac is very difficult to estimate because bedding can rarely be seen and the rock is highly folded and crumpled. If essentially flat-lying, it has a minimum thickness of about 800 feet. Just north of the west shoulder of Mount Anthony (L, M, 10, 11) a minimum thickness of about 400 feet is indicated by the fold pattern. In summary, this rock type is of the order of 500 to 1,000 feet thick in the Hoosick Falls area.

Metamorphism of Walloomsac Slate: In the eastern part of the area where metamorphic rank is highest, the Walloomsac is a hard, black, pyritic phyllite containing white silt laminae and numerous quartz veins.

Black slate and gray chert: This is a lenticular unit as much as 100 feet thick consisting of jet black slate and dark gray chert. The two main exposures are: (1) on the west side of the New York-Vermont State line (L-6) southwest of Sodom. Here, black slate, black cherty slate, and some chert occur as a lens about 0.6 mile long and 400 feet wide within the Walloomsac Slate. Graptolites are found about midway in this lens (app. 4, station 329); (2) on the southwest slope of Whipstock Hill where graptoliferous black slate (app. 4, station 318) and black chert occur in a lens, 2,000 feet long, structurally beneath the Whipstock Breccia.

The chert is typically dark gray to black and contains many thin partings of black slate or phyllite. On weathered surfaces, it is dark bluish-gray and exhibits small solution pits from which carbonate minerals have been dissolved. The slate is jet black, thinly cleaved, and has a silky luster on cleavage surfaces. Seams of coarse granular quartzite, up to 3 mm. thick, occur sparingly in this slate. Thin lenticular solution pits, coated with a black sooty residue and containing bundles or radiating aggregates of fibrous white quartz, are common in the black slate. These pits are commonly drawn out in a marked lineation so that the slate has numerous parallel solution chains.

Austin Glen Graywacke member

This name is widely used in the central and southern Taconics for the graywacke in the Normanskill Formation. In the Hoosick Falls area, the graywacke also occurs in lenses a few feet thick within the Walloomsac Slate, and it is generally closely associated with the lenses of black slate and chert and with the Whipstock Breccia. The graywacke is identical to the Austin Glen of the Normanskill — grain size varies from very coarse to fine sand; the dominant clasts are angular grains of quartz, shale fragments, and plagioclase; the matrix consists of a very fine paste of chlorite, sericite, and quartz.

Thin lenses of Austin Glen Graywacke occur at these widely distributed localities in the Walloomsac terrain:

1. At the north end of the East Hoosick volcanic block; and in the stream cut 0.4 mile southwest of East Hoosick (K-7).
2. Stream cut north of St. Mary's Cemetery (H-8) and at elevation 680 feet in the same stream.
3. At elevation 800 feet, 1.4 miles S 80° W from White Creek (K-4).
4. At elevation 840 feet, 1,400 feet northeast of the State line marker No. 29 (L-4).
5. Walloomsac River, about 0.8 mile downstream from village of Walloomsac (I-6).
6. Hoosic River, 0.7 mile upstream from Hoosick Junction (H-6).
7. Elevation 520 feet in Shingle Hollow (H-11).
8. Elevation 680 feet in stream cut 1.1 miles due east of Hoosick (J-10).
9. Elevation 1,000 feet in gully 1,800 feet N 80° W from State line marker No. 18 (K-10).

Thick sequences of Austin Glen Graywacke occur at two localities, and these are of considerable importance in the reconstruction of the tectonic-sedimentary history of this region. The first is assigned to the Normanskill, and the second to the Walloomsac Formation.

1. On the west side of Indian Hill (J-10, J-11) and extending 1 mile south to the Breese Hollow road, an overturned sequence of Austin Glen, 100 to 350 feet thick, occurs beneath the Poultney Formation. The North Petersburg thrust separates the Austin Glen from the underlying carbonate formations. Graded bedding indicates the graywacke to be overturned and this suggests it was deposited on the Poultney as a part of the Taconic Sequence. However, at the northwest shoulder of Indian Hill (elevation 800 feet, 0.3 mile northwest of the 1091 crest), this graywacke appears to interfinger with slate and breccia of the Walloomsac Formation. A likely inference from this relation is that graywacke was deposited on the thrust sheet just prior to, or during, its westward movement, and that overturning of the advancing thrust sheet brought the unconsolidated Austin Glen into contact with the underlying mud and unconsolidated breccia. Thus the apparent interfingering is perhaps due to melding of unconsolidated sediments beneath the overriding thrust sheet.

2. A continuous sequence of Austin Glen Graywacke with measured minimum thickness of 250 feet occurs in the low ground around the North Hoosick Klippe (G, H-4, 5), in the valley of Case Brook (F, G-5, 6, 7), and along the east slope of hills (G-7, 8, 9) from 1 to 2 miles west and southwest of Hoosick Falls. Prindle and Knopf (1932, fig. 2) assigned this graywacke to the Walloomsac; the present study verifies this and further suggests the graywacke lies stratigraphically above the bulk of the Walloomsac Slate. A significant feature of this terrain is that the contact between the graywacke and the underlying Walloomsac Slate is marked by lenses, or blocks of the Synclinorium carbonates inferred to be giant submarine slide blocks. (See Whipstock Breccia.)

Whipstock Breccia member (new name)

The type locality is Whipstock Hill (L, M-8, 9), (especially Hill 1180) west of Kingsley Cemetery. Prindle and Knopf (1932, fig. 2) mapped this as Normanskill Shale; MacFadyen (1956, pl. I) indicated it as Walloomsac Slate.

The Whipstock is a distinctive breccia containing small intraformational silt-textured fragments, and large clasts derived from the Taconic and Synclinorium Sequences, and some unknown volcanic source. It occurs as lenses and beds closely associated with the Austin Glen Graywacke in the Walloomsac terrain, and it is widely distributed beneath the North Petersburg thrust. It is thus an integral part of the Walloomsac Formation, and its age is Wilderness or post-Wilderness for the breccia is underlain on the west slope of Whipstock Hill by a black slate containing graptolites of the *Climacograptus bicornis* Zone.

Thickness: Whipstock occurs as lenses or beds ranging from 2 to 50 feet thick and with an aggregate maximum thickness of about 100 to 200 feet. The thickest single accumulation of breccia is in a belt extending from Whipstock Hill (L, M-8) southwest to Indian Hill (J-11) and Hill 1027 (J-12). Here the breccia, estimated to be 350 feet thick, lies beneath the folded North Petersburg thrust fault.

Lithology: The Whipstock Breccia matrix is a dark gray silty argillite or slate, irregularly cleaved because of the breccia fragments. Clasts are angular to subangular and commonly range from 1 mm. to 3 or 4 cm. in maximum dimensions; some of the larger clasts are several tens of feet long, and one measures about 100 by 50 feet. In addition, there are giant clasts over a mile in length related to this period of submarine slumping.

The typical breccia has an irregular pitted weathered surface due to differential weathering of matrix and clasts. The dark gray slate matrix is stained with limonite on cleavage surfaces and the sandy clasts have a porous, rusty appearance on freshly broken surfaces. The clasts may lie in the foliation plane and display a prominent lineation (fig. 28) or occur as angular and bent fragments with little preferred orientation (fig. 29). The smaller clasts — less than about 5 cm.

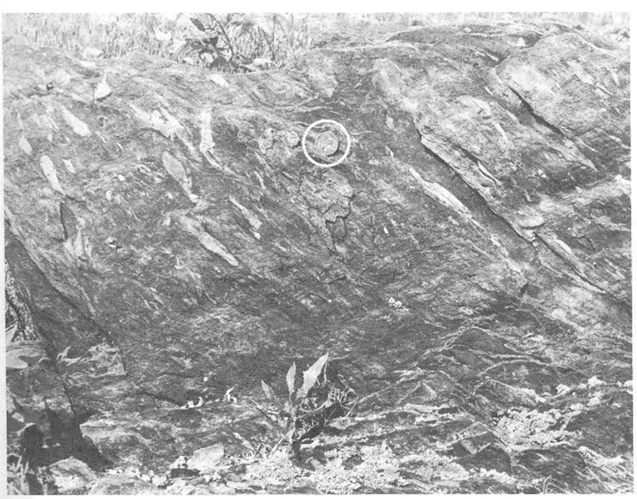


Figure 28. Whipstock Breccia Member of the Walloomsac Formation at crest 1180 on Whipstock Hill (1-8). Matrix is dark gray slate; lineated clasts are siltstone and argillite. Coin is 0.8 inches in diameter.

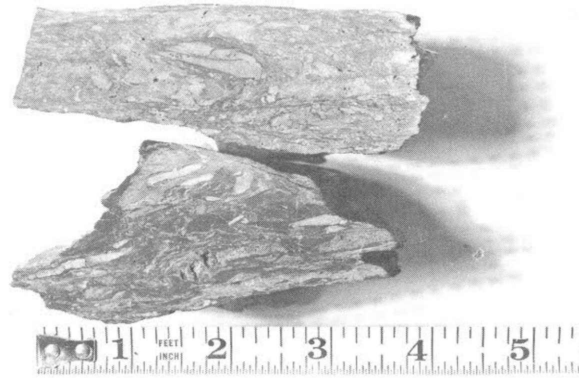


Figure 29. Hand specimens of Whipstock Breccia from Hoosick Falls area.

in maximum dimension — consist of these lithic types in order of decreasing frequency of occurrence: fine grained sericitic sandstone or siltstone weathering white or rusty pale brown; green or green-gray argillite or slate; quartzite consisting of coarse, subangular to rounded smoky quartz grains in a dark gray fine grained quartzose matrix; brown-weathering dark gray, silt- or fine sand-textured limestone; dark gray silt; fine grained dolomitic quartzite having a blotchy medium and light gray appearance on broken surface. The fine grained sandstone and siltstone clasts are identical to the thin sand laminae in the Walloomsac Slate, and much of the Whipstock appears to be simply segmented thin sandy laminae in dark slate. The brown-weathering dark gray limestone clasts are identical to beds of this lithology in the Walloomsac Slate. These similarities and lack of any great diversity in rock types that make up the smaller clasts suggest an intrabasinal origin for the bulk of the breccia. But the Whipstock (Potter, 1967) also contains large submarine slide blocks that were derived from: (a) the Taconic Sequence; (b) a volcanic source; and (c) the Synclinorium carbonates. These blocks are imbedded in various matrices — Whipstock Breccia, Austin Glen Graywacke, or simply dark gray Walloomsac Slate. The inference here is that during the episode of sliding, the large blocks came to rest in various lithologies of the Walloomsac Formation.

Submarine slide blocks. (app. 2; fig. 3.)

(a) Slide blocks of the Taconic Sequence: Several blocks of Lower Cambrian Nassau Formation have been found in the breccia on Whipstock Hill and Indian Hill. Two clasts of quartzitic variety of the Rensselaer Graywacke, or Zion Hill Quartzite, are exposed on the

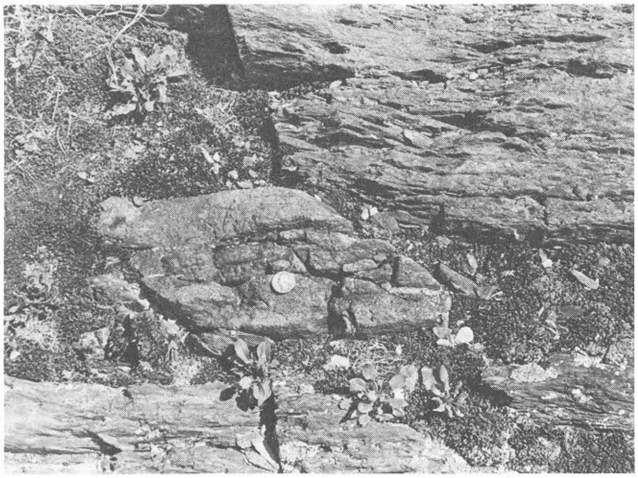


Figure 30. Slide block (under coin) of Rensselaer Graywacke in Whipstock Breccia at crest 1180, Whipstock Hill (L-8). Other rocks exposed are slate matrix of breccia. Coin 0.9 inches in diameter.

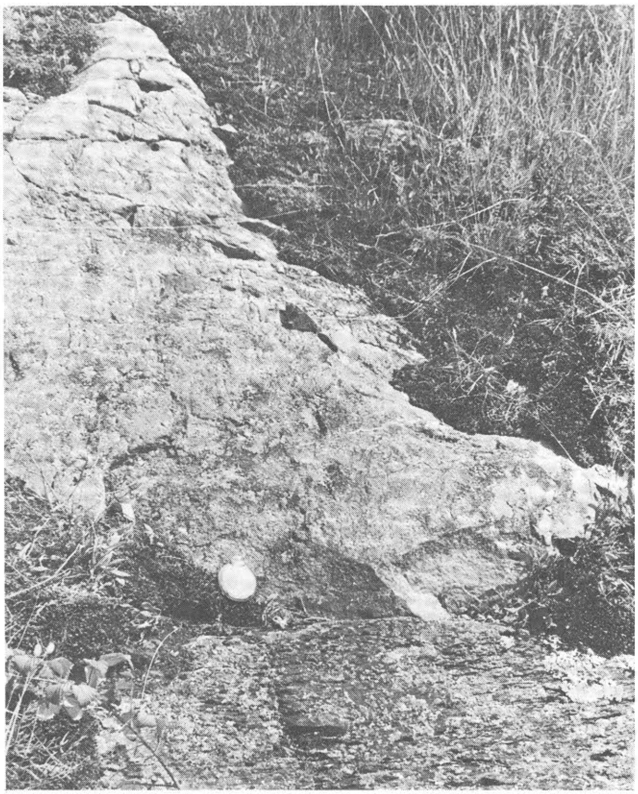


Figure 31. Slide block of Mudd Pond Quartzite in Whipstock Breccia, same locality as figure 30. Clast is about 4 feet long and 4 feet wide; its base is in contact with slate matrix of breccia just below watch.

unwooded 1180 crest of Whipstock Hill (L-8). One clast, 16 inches in maximum dimension (fig. 30), is a conglomeratic quartzite with grains of subrounded quartz, quartzite, and oligoclase in a matrix of fine-grained quartz, white mica, and chlorite. Another angular block (fig. 31), about 4 x 4 feet, is inequigranular pyritic quartzite resembling the Mudd Pond Quartzite. A 3 x 6 foot block of coarse-grained Rensselaer Graywacke (fig. 6) occurs in the breccia at elevation 1,000 feet, 1,400 feet N 10° W from intersection 784 (K-9). Larger clasts consist of Hatch Hill and Poultney Formations (fig. 3, nos. 9, 10), and Mettawee Slate (fig. 3, no. 11).

Figure 32. Slide block of amygdaloidal volcanic rock in Whipstock Breccia 200 feet east of intersection at East Hoosick (K-7). Coin is 0.9 inch in diameter.

(b) Slide block of volcanic rock of unknown source: a block of altered volcanic rock (fig. 3, No. 15), about 100 feet long and 50 feet wide, is exposed at East Hoosick (Bonham, 1950, pp. 47–50).

The dominant lithology surrounding the block is Whipstock Breccia; thin lenses or thin beds of black slate and chert and Austin Glen Graywacke are interbedded with the breccia. The volcanic is a soft, light, to medium gray, crudely foliated rock containing numerous spherical or irregularly shaped aggregates of coarse-grained white calcite and chalcedony. On weathered surfaces, the calcite aggregates have been dissolved and the rock as a vesicular appearance (fig. 32). Bonham (1950, p. 47) and Potter (1963, p. 62) earlier concluded that the calcite aggregates (fig. 33) were amygdules, but many of the smaller aggregates show some degree of idiomorphism; they are equant

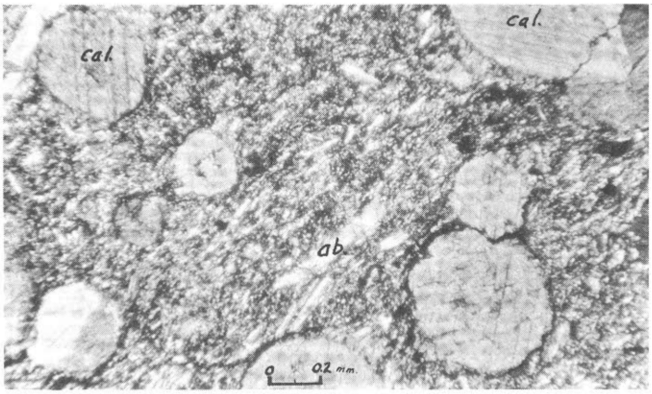


Figure 33. Photomicrograph of slide block of volcanic rock in Whipstock Breccia, knob 900, at East Hoosick (K-7). Calcite (cal) amygdule or pseudomorph after leucite, etc., in felty groundmass of albite (ab).

and display six, eight, or ten straight edges. These may be leucite or analcite phenocrysts pseudomorphically replaced by calcite. The groundmass consists of a felty aggregate of albite, chlorite, sericite, and opaques. In addition, there are a few large anhedral phenocrysts of albite partially replaced by calcite. Some calcite aggregates are sheathed in fresh albite; calcite from some of the aggregates partially replaces the groundmass.

The high albite content in the matrix (rare broken phenocrysts and rims about calcite amygdules) and the high content of replacement calcite strongly suggest that this is an albitized volcanic, a spilite, or an altered leucite basalt.

The source of this volcanic is quite uncertain. Possibly it was derived from the Taconic Sequence or from limited volcanism during thrusting. The sheared albitic volcanic in the Rensselaer Plateau thrust zone presents a similar problem.

(c) Slide blocks of the Synclinorium carbonates: a typical block is No. 16 (app. 2; fig. 3), a 25 x 25 foot block of gray brown-weathering, dark gray dolomitic limestone imbedded in dark gray slate. The limestone is finely brecciated and contains thin lenses or beds of cavernous-weathering calcareous quartzite; it resembles lithologies in the lower part of the Synclinorium carbonates. The structural setting of many of the carbonate blocks is shown by No. 14 which is orange- and buff-weathering dolostone lying in dark gray slate about 10 feet below the North Petersburg thrust fault.

Numerous other lenses or blocks of dolostone and limestone from the Synclinorium Sequence occur in the Whipstock Breccia and in Walloomsac Slate beneath the folded North Petersburg thrust fault from the north end of Indian Hill (K-9) south of Hill 1027 (J-12). Individual blocks are as much as 400 feet long and 30 feet wide. All lie in the plane of foliation which is parallel to the fold axes and high angle faults. Several blocks occur at the contact between Whipstock Breccia and other stratigraphic units and may be slivers dragged upward along reverse faults. Such a slice, 0.5 mile long and 150 feet wide, is on the east side of the Breese Hollow fault, 0.25 mile east of the crest of Indian Hill. However, many carbonate blocks, occurring within the breccia or dark gray slate, show no evidence of shearing or displacement along faults and are interpreted as submarine slump blocks.

The largest carbonate masses (Nos. 1–8, 12, 13), inferred to be submarine slide blocks, are found in the western part of the reentrant. This is an area of rather poor exposures; hence, the size and shape of the carbonate masses cannot be established unequivocally. Several blocks are more than 1,000 feet in length; the largest being 1.8 miles long and 700 feet thick. Recumbent and isoclinal folding and reverse faulting are common within the carbonate blocks, and minor faults, slip cleavage, and shearing characterize the slate immediately above some blocks.

That these carbonate masses are slide blocks and not isolated outcrops of a continuous carbonate stratum is suggested by the following: (1) An apparent structural discordance occurs between some blocks in the valley of Case Brook; (2) blocks of the Taconic Sequence (Nos. 9, 10, 11) occur in the same terrain; and (3) limestones at five localities (app. 4, stations 66, 84, 89, 90, 93) carry fossils of Early and Middle Ordovician ages, yet these carbonate masses are surrounded by Middle Ordovician breccia, graywacke, or slate, or occur at the contact between graywacke and slate. The presence of many of the carbonate masses at the contact between slate and graywacke suggests that submarine sliding occurred after a thick accumulation of mud (Walloomsac Slate) and at the onset of deposition of the Austin Glen Graywacke. It seems likely that the carbonate clasts slid from a nearby shelf environment. Such sliding may have occurred down a steep slope as the North Petersburg thrust sheet rode onto the shelf.

While the large size (1.8 miles long, 700 feet thick) of block No. 12 seemingly casts some doubt on its submarine slide origin, the following facts support it: An Early Ordovician age for the limestones and dolostones making up the block is indicated by fossils (app. 4, station 66) and by lithologic similarity with the Canadian Bascom and Chipman Formations. Cross-bedding at the south end of the block indicates that at least at its base the block is right-side-up. The block is underlain by Walloomsac Slate and is overlain by Austin Glen Graywacke. At one locality this graywacke is right-side-up but elsewhere it is too highly cleaved to obtain top and bottom criteria. Thus, the carbonate block appears to be right-side-up and sandwiched between two facies of a younger formation. The details of the upper contact of the carbonate block add greater complexity to the structure but can be interpreted by the submarine slide mechanism. Locally, Poultney slates lie between the carbonate block and the overlying graywacke. At elevation 560 to 600 feet in a small stream (G-8, 9) 0.4 mile S 45° W from School No. 14, a slice or clast of Poultney, about 25 feet thick, is separated from the carbonate block by Whipstock Breccia and it is overlain by graywacke. While this huge carbonate block could be a tectonic sliver between thrust faults, its position between two facies of the Walloomsac Formation suggests the following interpretation: The carbonate block slid from a shelf environment into muds (Walloomsac Slate) in the deeper part of the basin. As the North Petersburg thrust sheet entered the basin from the east, clasts and blocks of the Taconic Sequence broke off the leading edge of the sheet and cascaded down on top of the carbonate block. The locus of graywacke deposition shifted to this deeper part of the basin, or perhaps the unconsolidated graywacke already deposited on the thrust sheet was decanted and redeposited in the deep basin in front of the thrust sheet. Austin Glen Graywacke deposition or redeposition continued until the North Petersburg thrust sheet advanced over it.

Problematic rocks in the Whipstock: Large masses of fine grained phyllitic siltstone, recrystallized radiolarian chert, and associated pelitic rocks with high quartz content are exposed in the breccia terrain and may be beds in the breccia, large intraformational clasts, or clasts of the Taconic Sequence. The major outcrops (Owu) are: (1) On the crests and north slopes of Hill 1100 (M-3) 1.5 miles east of White Creek; (2) on the north slope, crest, and along the west slope of Whipstock Hill to the south end; and (3) at the north end of Indian Hill (K-9) between intersection 746 and the 1000 crest. In addition, numerous small lenses of these lithologies are in the breccia and also in the Walloomsac slate in the eastern part of the area.

The dominant lithology is a light to medium gray, bluish gray, or dark greenish gray siltstone with closely spaced phyllitic partings which, locally, is a very fine grained quartz-sericite-chlorite schist. This rock contains more than 95 percent quartz, but, unlike fine grained graywacke such as the Bomoseen, lacks feldspar. The siltstone could be recrystallized radiolarian chert (to be described) or possibly some rock from the Taconic Sequence. One small lens of recrystallized limestone occurs in the siltstone at elevation 860 feet in the gully at the south end of Whipstock Hill.

Hard, white- or gray-weathering recrystallized radiolarian chert is exposed at several places: crest of Hill 1100 (M-3); south end of Whipstock Hill at elevation 1,090 feet (L-9); elevation 930 feet, 400 feet northwest of intersection 897, East Hoosick (K-7); elevation 870 feet, 500 feet northwest of intersection 746, north end of Indian Hill (K-9). This rock has the appearance of a very fine grained siltstone or porcellanite. In thin section, it is seen to consist of microcrystalline quartz and minor amounts of sericite and chlorite with some scattered dolomite euhedra. The radiolaria appear as circular or elliptical aggregates of quartz from about 0.1 to 0.2 mm. in diameter; in plane-polarized light these appear as clear windows in the recrystallized chert matrix; quartz in the matrix is about 0.01 to 0.02 mm. in diameter but slightly larger in the radiolaria. These radiolaria closely resemble those in the Owl Kill Member of the Poultney and in the Mount Merino chert, and are very similar to those described by Ruedemann and Wilson (1946) in the Deepkill and Normanskill strata. However, in the field, this rock lacks the thin, evenly bedded nature of the Mount Merino chert, and it is likewise more massive than the siliceous Owl Kill beds. As no positive formational assignment can be made, this lithology is lumped with the phyllitic siltstone in a separate map unit (Owu).

Both the siltstone and radiolarian chert exhibit cleavage banding in the form of phyllitic or schistose partings. Many outcrops show a well developed lineation and, locally, flaser structure. However, structural deformation indicates little about the origin of these problematic lithologies for lineation and cleavage banding are also well developed in the Whipstock.

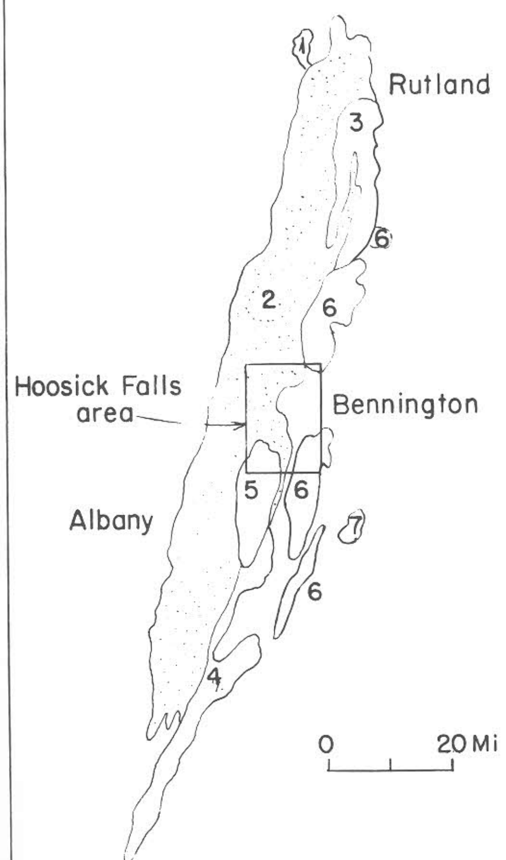
STRUCTURAL GEOLOGY

Introduction: The major structural elements in the Hoosick Falls area (fig. 3) are two low-angle thrust faults along which thick sheets of rocks of the Taconic Sequence were emplaced over the Synclinorium Sequence (Potter and Lane, 1969). The lower, or North

Petersburg thrust fault, can be thought of as "The Taconic Thrust" for immediately beneath it lie carbonate and slate-graywacke formations of the Synclinorium Sequence. The North Petersburg thrust sheet is correlated with Zen's (1967, p. 9) Giddings Brook Slice (fig. 34) and in this area includes all the formations of the Taconic Sequence. Thrusting was submarine as indicated by the Middle Ordovician Whipstock Breccia immediately below the thrust. The upper, Rensselaer Plateau thrust fault has brought a thick sheet of Rensselaer Graywacke, slate, and pelitic schists of the Taconic Sequence over the Synclinorium Sequence, but this upper thrust sheet is also nested, in large part, on top of the North Petersburg sheet.

The North Petersburg thrust sheet (pl. I; fig. 3) presents the greatest structural complexities in the area. In general, younger formations occur near the base of the sheet and older formations lie above, indicating a gross overturning or nappe structure. The core of the nappe is marked by the broad expanse of middle Mettawee slates (Cnm-b). The formations exposed in the northwest part of the area are the normal limb, and the recumbently folded rocks east of the core, near the trace of the North Petersburg thrust, comprise the inverted limb.

The Rensselaer Plateau thrust sheet consists mainly of two massive rock units — Rensselaer Graywacke and Mettawee slates and schists. The Rensselaer sheet may



Thrust slices in the Taconic Allochthon (abridged from Zen, 1967, Fig.2)

Zen's thrust slices (1967) (in order of relative age of emplacement oldest at bottom)	Hoosick Falls thrust sheets (this report)
6. Dorset Mtn. and Greylock slices	Rensselaer Plateau sheet
5. Rensselaer Plateau slice	
4. Chatham slice	
3. Bird Mountain slice	
2. Giddings Brook slice	North Petersburg sheet
1. Sunset Lake slice	

NOTE: Zen's slice 6 in southeastern part of Hoosick Falls area is interpreted to be eastern half of Rensselaer Plateau sheet; in northeast corner of area slice 6 is mapped North Petersburg sheet.

Figure 34. Correlation of North Petersburg and Rensselaer Plateau thrusts sheets with Zen's (1967) slices

also be a nappe, but stratigraphic succession indicates, largely, a right-side-up sequence.

The interpretation of this study (fig. 35) is that the two thrust sheets were initially a single sheet or slice which moved from an eastern source into the Middle Ordovician seas in this area as a huge recumbent anticline or nappe. The North Petersburg sheet is thought to be the western part of this nappe; the Rensselaer sheet is the core and normal limb of the eastern half of the original nappe.

A broad arching of both thrust sheets and subsequent erosion has exposed the underlying Synclinorium Sequence in the Hoosick Falls reentrant. The outline of the reentrant (fig. 3) is mainly the trace of the North Petersburg thrust, but in the western part it is bounded by high-angle faults, and in the southeast by the trace of the Rensselaer Plateau thrust. Small klippen of the North Petersburg sheet occur at H-5 and M-2, and a window in the sheet is at I-1.

The Synclinorium Sequence is isoclinally and recumbently folded (fig. 3) and, in general, older formations of this sequence occur along the east edge of the area and younger formations lie to the west, suggesting a synclinorial structure.

A second period of deformation, following Mid-Ordovician thrusting and recumbent folding, was superimposed on all older structures. This deformation manifests itself by small-scale folding, and by a pervasive slaty cleavage-foliation. Lane (1970) has analyzed the evolution of small scale structures in this area. High-angle faults, mostly reverse, with east side up, cut all the structures in the area.

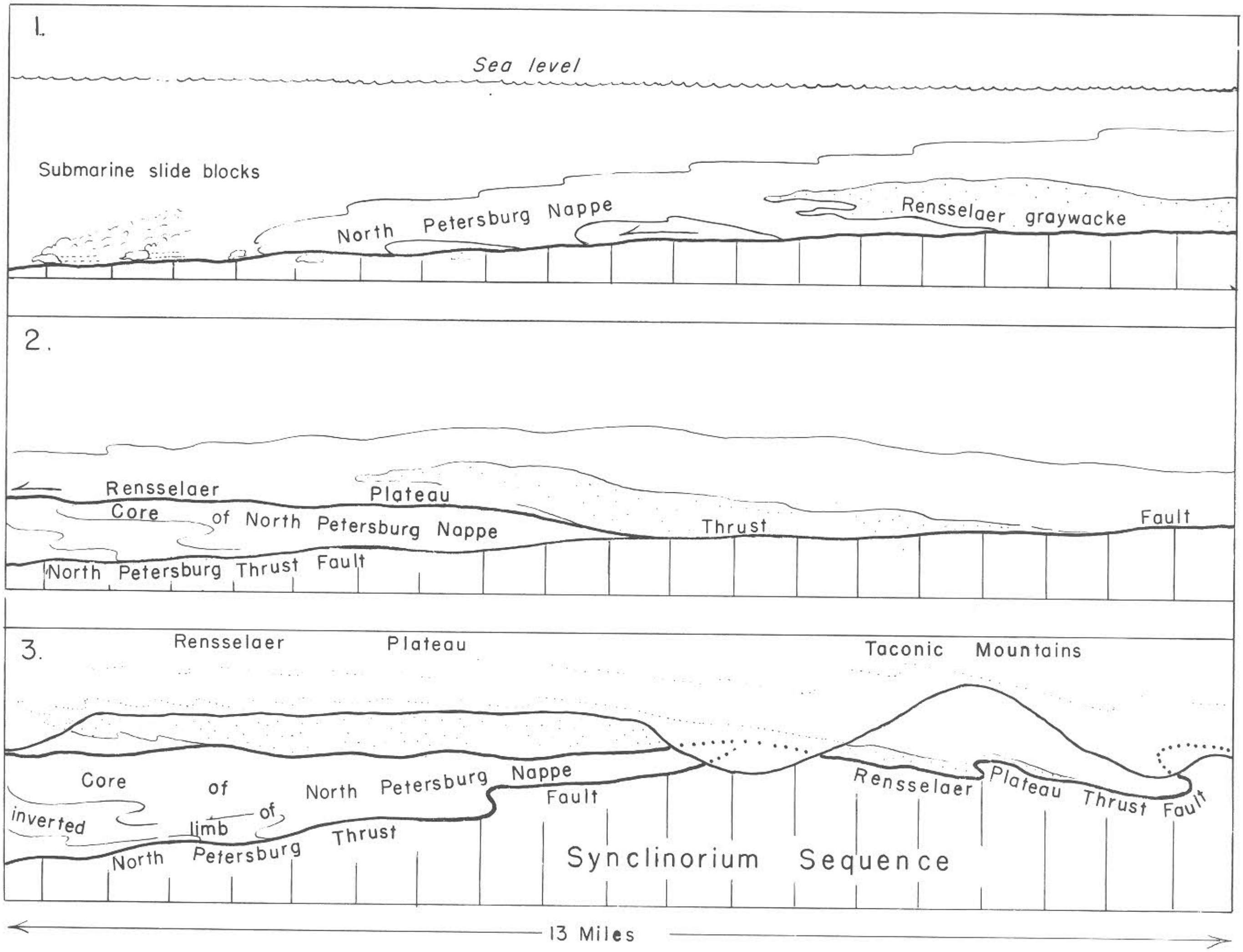


Figure 35. Schematic sections showing emplacement of thrust sheets

STRUCTURE OF THE SYNCLINORIUM SEQUENCE

The formations of the Synclinorium Sequence can be traced northeastward and southeastward from the Hoosick Falls reentrant into the main belt of the Synclinorium Sequence. Their distribution within the reentrant (fig. 3) gives a clue to the broad structure of the autochthonous rocks at the allochthon's east edge: Late Cambrian through Middle Ordovician carbonates occur mainly at the east edge of the reentrant, especially beneath the major thrust faults. In the central and western parts of the reentrant the younger Middle Ordovician Walloomsac Formation is extensively exposed. Thus, although these formations are complexly folded and faulted, their gross distribution indicates a broad synclinorium whose axis is somewhere west of the west edge of the reentrant.

In general, recumbent and isoclinal folds in the Synclinorium Sequence have a structural motif similar to folds in the thrust sheets, and probably developed during the period of Mid-Ordovician thrusting. East of North Pownal (L, M-14, 15), the Synclinorium carbonates are recumbently folded with the Rensselaer Plateau thrust fault so that an inverted section of Walloomsac below the cabonates is exposed above the thrust (pl. II, section H-H'; fig. 26). In the area north and south of Petersburg Junction (I, J-11, 12), westward-overturned folds, thrust faults, and high-angle reverse faults are seen in the carbonate rocks, and recumbent folds are inferred (see Special Occurrences of Synclinorium Carbonates). North of the Rensselaer Plateau thrust trace, on the west shoulder of Mount Anthony (L,M-10), the outcrop pattern of the Walloomsac and Synclinorium carbonates suggests a refolded recumbent syncline with carbonate formations at the limbs and the Walloomsac at the core of the fold. Between Whipstock Hill (L-8) and the Walloomsac River (M-2), the Synclinorium carbonates seem to be folded into a simple south-plunging syncline but large recumbent folds cannot be ruled out here. The folding of the Walloomsac and Synclinorium carbonates between Sodom (L-5) and West Mountain (M-2) is probably more complex than appears on the map, for the Walloomsac occurs above and below the carbonates, and tight recumbent folds are likely present that have been refolded in a north-trending isoclinal system.

The limestone and dolostone beds within the submarine slide blocks in the western part of the reentrant are recumbently and isoclinally folded, perhaps in part due to soft rock deformation during slumping in Mid-Ordovician time. In general, the attitudes of folds and foliation in these blocks is concordant with that in the surrounding slate and breccia.

The Walloomsac Slate throughout the reentrant is thinly cleaved and the cleavage planes are folded and crumpled. Commonly this slaty cleavage is cut by shear cleavage planes a few inches to 2 feet apart. Movement on these shear surfaces has deformed the slaty cleavage into chevron folds.

NORTH PETERSBURG THRUST FAULT

The lower major thrust at the base of the Taconic allochthon in the area is exposed in several localities in the Hoosic River Valley and its tributaries. It is named for excellent exposures on the steep hillsides 0.5 mile west of the village of North Petersburg (fig. 36). Details and exposures are given in appendix 3.

Evidence for the North Petersburg thrust fault: The prime evidence for this major thrust fault, and hence for the allochthonous nature of the Taconic Sequence, is the contrast in lithology between approximately synchronous rock sequences above and below the fault and the structural discordance at the fault (fig. 3). The formations within the North Petersburg sheet are slates, graywackes, argillites, and cherts, and minor quartzites and limestones (Taconic Sequence) that range from Early Cambrian through Middle Ordovician. The formations below the thrust are limestones, dolo-

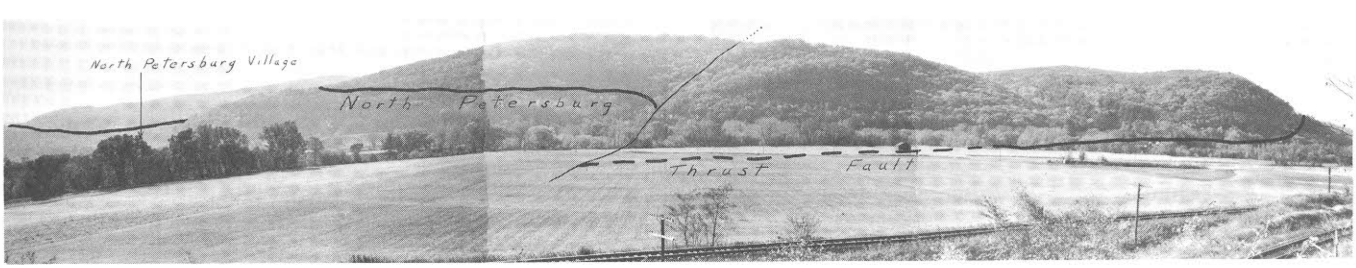


Figure 36. Panoramic view of hills west of North Petersburg showing trace of North Petersburg thrust fault. Looking west from road ½ mile south of Petersburg Junction.

stones, slates, and graywacke (Synclinorium Sequence), range from Late Cambrian through Mid-Ordovician.

Formations of the North Petersburg thrust sheet are grouped into two map units in figure 3; those of Early Cambrian age, and those of Late Cambrian through Middle Ordovician age. These two broad units of the Taconic Sequence are markedly discordant to the trace of the North Petersburg thrust, and to the map units of the Synclinorium Sequence beneath. The discordance of the Synclinorium Sequence units to the trace of the North Petersburg thrust (fig. 3) precludes the possibility this contact is an overturned unconformity.

Further evidence for thrusting is the discordance of foliation and/or bedding above and below the fault plane, at the mouth of Shingle Hollow (pl. I: H-11).

The thrust contact is generally a zone from 1 to a few tens of feet thick in which the more competent rocks are crushed, sheared and somewhat bleached; slates in this thrust zone are typically very thinly cleaved and have a phyllitic appearance. Quartz veins and silicified zones up to 8 feet thick are fairly common at the thrust zone, especially where graywacke or slate of the Walloomsac Formation lies beneath the thrust.

Movement direction: While some rotation of structural elements has occurred since the emplacement of both thrust sheets, it appears that certain linear elements give a generally consistent indication of movement from the southeast. Slickensides were recorded at only a few localities and indicate a movement axis trending east-southeast; a few overturned and silicified folds (fig. 37) in the thrust zone could be considered true drag folds, and these indicate movement from the east-southeast; at Indian Hill (J-11) the section is overturned to the west at the base of the North Petersburg sheet and this is consistent with movement from the east; streaking and penciling in limestone and slate beneath the North Petersburg thrust, and in slate and graywacke just above the thrust, is far more pronounced than in rocks far removed from the thrust. Bonham (1950, pp. 88–89) likewise attributed east-southeast-trending "a" lineation to thrusting in this area.

Figure 37. Quartz veins defining drag folds — upper plate has moved from east (right) to west — in North Petersburg thrust zone, elevation 800 (G-9) in small stream 1.5 miles southwest of Hoosick Falls.

Topographic expression and sink holes: The North Petersburg thrust is almost invariably exposed near the base of steep hills (fig. 36) because rocks of the Taconic Sequence in the sheet are more resistant to weathering and erosion than are the carbonate rocks and soft slate and graywacke of the Synclinorium Sequence below. Commonly the thrust is marked by a small bench on the steep hillsides.

A surprising feature of the thrust contact is the scores of small sink holes, or solution depressions, which occur in the carbonate rocks at the trace of the thrust (pl. I, special symbol). Some depressions are possibly old prospects but the bulk is apparently due to solution. These depressions are generally never more than about 400 feet horizontally from the trace of the thrust; they are circular in outline and are as much as 20 feet in diameter and 10 feet deep. In addition to these depressions, small channels and caves are locally developed, and springs are common at the thrust. Sink holes and caves are not conspicuous in the major carbonate terrain of reentrant, nor do they occur at the contact between the carbonate formations and the Walloomsac Formation. However, the extensive glacial drift in the carbonate terrain makes any generalization about solution phenomena here very uncertain. The sink holes are almost certainly not an expression of a pre-Walloomsac (Mid-Ordovician) unconformity but have formed since the period of thrusting, for they are well developed in the slivers of carbonate rock between the Rensselaer Plateau and North Petersburg thrust sheets. It seems likely that these sinks developed during the period of extensive weathering before the Pleistocene; that they may be the surface expression of rather extensive solution of carbonate rocks beneath the thrusts, such solution being hastened by the low carbonate content of groundwater moving through the thrust sheet; and that they escaped glacial erosion and infilling because of their proximity to steep slopes where there is no significant accumulation of drift. Many of the depressions seem to be deeply filled with forest litter while others, especially on the east side of Breese Hollow (J, K-11, 12) are active solution channels that may feed two important springs near the center of the valley.

Deformation of the North Petersburg Thrust Fault: Folding and faulting of the thrust plane during and after emplacement of the thrust sheet has resulted in as much as 500 feet of structural relief in the southern part of the area and 700 feet in the northeast. In the western half of the reentrant, the fault trace is fairly regular and there is little obvious folding but the thrust is cut here by a few high-angle faults, generally reverse and with east side up. At the North Hoosick Klippe (fig. 38), the fault plane dips south at about 5 to 8 degrees.

On the south spur of West Mountain (M-2), the thrust sheet is preserved as a thin erosional remnant. On the shoulder extending southwest towards White Creek, from elevation 900 to 1,300 feet, the thrust plane is apparently isoclinally folded, with axial planes dipping 15 to 30 degrees east (pl. II, section A-A′).

In the southeast part of the area, the fault plane and thrust sheet are more complexly folded and faulted, especially at Indian Hill and in the area to the south (pl. II, section F-F″). At Indian Hill, the fault plane is folded into an overturned synform whose axial plane dips east. The thrust is cut by the Breese Hollow reverse fault which has a long and intensely sheared slice of carbonate rock on its hanging wall, 1,000 feet east of the crest of Indian Hill. South of Breese Hollow, and extending through crest 1027 (J-12), there is a long, narrow exposure of Whipstock Breccia flanked by the Taconic Sequence (pl. II, section G-G′). The breccia contains several lenses of Austin Glen Graywacke, and slivers or blocks of the Synclinorium carbonates. These slivers occurring within 20 feet of the thrust contact at crest 1027, are sheared and highly foliated. Although this exposure of Whipstock could represent an anticline in the North Petersburg thrust, it might also represent an intrusive wedge of unconsolidated Whipstock graywacke and mud into the base of the overriding thrust sheet. It is postulated that unconsolidated muds beneath the thrust sheet were forced upwards into the sheet, wedging it apart. An anticline in the thrust plane could have initiated such an intrusion.

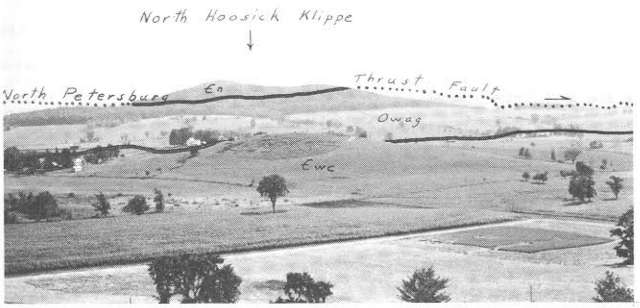


Figure 38. Looking south to North Hoosick Klippe from Hill 760 (I-3), Lower Cambrian terrain of the North Petersburg thrust sheet is in the foreground and at klippe; beneath thrust in middle background is Austin Glen Graywacke Member of the Walloomsac Formation.

STRUCTURE OF THE NORTH PETERSBURG THRUST SHEET

The gross structure of the sheet is postulated to be a nappe or large recumbent anticline with arch bend to the west. The following evidence or arguments support this view: Younger formations of the Taconic Sequence are recumbently folded in the lower 1,000 feet of the thrust sheet just west of the trace of the thrust (fig. 3); older formations (especially middle Mettawee slates, Єnm-b) are found higher in the sheet, in the central and western part of the area and just beneath the Rensselaer Plateau thrust on the east and northeast edge of the plateau; younger formations dip beneath older formations as shown in plate II, section E-E′ (immediately west of Case Brook fault) and section J-J′ (vicinity of Pine Valley). This suggests that the terrain of younger formations about the Hoosick Falls reentrant is the inverted limb of the nappe, and that the core is the vast exposure of middle Mettawee slates in the west-central part of the area. The normal limb of the nappe, less deformed than the inverted limb, includes the Newcomb Pond syncline and the terrain of overturned folds and reverse faults in the northwest part of the area. The nappe structure also explains some stratigraphic relations, for the terrain here proposed as representing the normal limb displays unconformities and facies not seen in the inverted limb. Thus, at the Newcomb Pond syncline, the West Castleton, Hatch Hill, and upper member of the Poultney are missing, while they are generally well developed on the inverted limb. In the area northwest of Buskirk, the West Castleton contains several distinctive lithologies which are absent or developed to only a minor degree in the inverted limb. These include maroon slate, thin-bedded light gray limestone and slate, and laminated green and black slate. Unconformities and east-west facies change are certainly common in the Taconic Sequence but the apparent short distance through which these occur in the field today may be due to the telescoping effect of the nappe.

Granting the nappe structure, the normal limb is composed of sedimentary rocks deposited farther east than those in the inverted limb. The thick sequence of West Castleton limestone and dolostone in the inverted limb at Post Corners and at North Petersburg thus represents a westward thickening of Early Cambrian carbonate rocks. This reasoning supports the theory (Zen, 1961, p. 330) that the root zone of the Taconic Sequence was the present site of the Green Mountains, just east of the Synclinorium Sequence with its thick Early Cambrian carbonates.

A second stage of deformation, following formation of the nappe and its associated smaller recumbent folds, resulted in a broad flexure of the nappe about an east-west axis in the area west of Eagle Bridge, and the development of secondary folds, slaty cleavage-foliation, and high-angle reverse and normal faults throughout the thrust sheet.

Details of the structures of the North Petersburg thrust sheet are considered by terrains which represent the postulated normal limb, core, and inverted limb of the nappe.

1. Structure of normal limb of nappe: Second stage simple folds and high-angle faults characterize the normal limb. The Newcomb Pond syncline is the largest simple structure in the Hoosick Falls area, extending south from the mouth of Nipmoose Brook for about 5.5 miles along the western boundary of the area (pl. I and fig. 3: A-6 to A-12). The syncline (pl. II), sections E-E′, F-F″, G-G′) is overturned to the west about 30 to 40 degrees past the vertical, and plunges gently south. There are excellent exposures of all the members of the Normanskill Formation in this syncline and the rocks are less sheared and tectonically disturbed here than anywhere else in the area. Conformably beneath the Normanskill and lying directly on the upper Mettawee slates, is a sequence of thin-bedded quartzites in gray slate, assigned to the White Creek Member of the Poultney.

Most of the overturned east limb of the syncline is cut out by the Otter Creek reverse fault which brings middle Mettawee Slate up against various members of the Normanskill. At the north end of the syncline, another reverse fault cuts the trough of the syncline and faults up Bomoseen and Mettawee against Normanskill.

The Normanskill Formation is also exposed at scattered localities north of the Hoosic River, especially 0.7 mile northwest of Lee (A-3). Ruedemann (1930, Geologic Map) shows vast areas covered by Normanskill in the area west of the Newcomb Pond syncline. The Normanskill is apparently downfolded in rather shallow synclines in this terrain.

A Cambrian and Ordovician terrain of asymmetrical and overturned folds, and reverse and normal faults, marks the normal limb of the nappe north of the Hoosic River and west of Oak Hill (E-3). The formations here, along with the core and part of the inverted limb of the nappe, were apparently thrust down to their present position along the Eagle Bridge thrust fault (pl. II, sections A-A′, C-C″, D-D′). This thrust fault may be thought of as a secondary feeder during the emplacement of the nappe. The relatively simple folding in this terrain is typified by the Buskirk anticline — a narrow, south-plunging, nearly symmetrical fold in the hills north of Buskirk (D-3). The anticline at its south end is defined by three lithologies of the West Castleton; black slate, thin-bedded limestone in gray slate, and maroon slate. Proceeding north, the core of the anticline is marked successively by upper Mettawee Slate, Bomoseen Graywacke, and middle Mettawee Slate. Thus, at the quadrangle boundary, the core of the nappe is exposed in the core of the secondary Buskirk anticline (section A-A′). The west limb of the anticline is cut out by the Whipple Brook reverse fault whose dip-slip component is about 1,000 feet. Several asymmetrical folds with faulted limbs occur to the northwest (sections A-A′ and C-C″).

The south-plunging structures of the normal limb of the nappe just described, must be reversed south of Buskirk where the core of the nappe (Ꞓnm-b) is postulated. The following structural evolution is suggested: emplacement of the nappe with arch bend trending approximately north-south; broad refolding of nappe about an east-west axis coinciding approximately with the Hoosic River so that secondary folds north of Buskirk plunge south while those south of Buskirk plunge north. The secondary folds — Buskirk anticline, etc. — may have developed during this broad refolding of the nappe.

2. Structure of core of nappe: Middle Mettawee slates (Ꞓnm-b) presumably mark the core of the nappe (pl. II, all sections; fig. 3). The main exposure of the core starts at the Thurber Pond outlet (F-1) and continues south through Oak Hill (F-3) to East Buskirk (D-4); south of this the exposure of middle Mettawee slates flares out and forms a broad, monotonous terrain across Nipmoose Hill (B-6 to D-7) to the trace of the Rensselaer Plateau thrust. The east edge of this terrain is the broad band of Bomoseen Graywacke which presumably marks the trace of the inverted limb of the nappe. Secondary isoclinal folds in the core of the

nappe are poorly defined by outcrop patterns of purple slate, and by Bomoseen Graywacke. Fold axes trend north or northeast, axial planes dip east. Slaty cleavage is developed pervasively and likewise strikes north or northeast and dips east in marked discordance to the attitude of foliation in the Rensselaer Plateau to the south.

3. Structure of inverted limb of nappe: The formations within about 2 miles of the trace of the North Petersburg thrust about the Hoosick Falls reentrant are near the base of the thrust sheet and presumably mark the inverted limb of the nappe. This terrain is characterized by recumbent and isoclinal folds which presumably formed during emplacement of the nappe, and by a later stage of folds with generally steep axial planes. From point of stratigraphic detail and structural complexity this is by far the most complex area mapped. Seven stratigraphic-structural localities are discussed, starting at West Mountain and going counter-clockwise about the Hoosick Falls reentrant.

West Mountain: Several units of the Taconic Sequence can be distinguished in the phyllite and schist terrain on the west spur of West Mountain (L, M-1, 2). These units include West Castleton dark gray phyllite with lenses of limestone, Mudd Pond Quartzite, Hatch Hill quartzite in dark phyllite, Eagle Bridge Quartzite, and the Poultney Formation (fig. 22). The identification of these units is significant, for MacFadyen (1955, pl. I) mapped the formations above the carbonate rocks of the Synclinorium Sequence on West Mountain as the autochthonous Middle Ordovician Walloomsac and Middle to Upper (?) Ordovician Mount Anthony Formations. Hewitt (1961) likewise considered the phyllites and schists on West Mountain immediately east of the quadrangle to be the autochthonous Mount Anthony Formation.

Formations in the thrust sheet on the west spur of West Mountain are recumbently and isoclinally folded with the thrust fault (section A-A′) and axial planes dip east and southeast. Thus, on the west slope, from elevation 952 (L-1) eastward to the fault contact with the Hatch Hill-Poultney, there are several lenses of Mudd Pond Quartzite, probably repeated by folding; foliation here strikes north and dips about 15 to 35 degrees to the east, and a marked southeast-plunging " a " lineation is defined by penciling in the phyllites.

Post Corners Area: The area north and east of Post Corners (H-3) includes the best defined recumbent folds in the North Petersburg sheet (pl. II, sections A-A′, B-B′). This recumbent folding was also noted by Prindle and Knopf (1932, p. 293). The topography in this area has greatly facilitated the identification of the structures, for the edges of cores and shells of recumbent folds are exposed on the south slopes of hills which rise some 800 feet above the low ground at Center White Creek and Post Corners. Structural study is further aided by several distinctive map units, particularly the Bomoseen, graywacke phase of the Mudd Pond, fossiliferous limestone of the West Castleton, Eagle Bridge Quartzite, and several units of the Poultney and Normanskill Formations. The attitudes of recumbent folds are variable, but, in general, fold axes plunge southeast and axial planes dip gently to the southeast. At a road cut 1.5 miles south of the quadrangle boundary, on N.Y. Route 22 (fig. 39), axial planes of recumbent folds strike between N 25° E and N 80° E and dip from 13° to 23° southeast; axes plunge east-southeast from 3 to 20 degrees; recumbent anticlines open to the northeast. All recumbent folds in the Post Corners area are to some degree refolded by a second fold system whose axial planes strike northeast and dip steeply southeast. In addition, the recumbent folds are chopped by northeast-trending reverse and normal faults.

Six recumbent folds are well defined in the low ground and hills north of Center White Creek and Post Corners. The core of the lowest recumbent anticline (ra-1), exposed on the low ground south of the hills, is composed of Bomoseen, West Castleton black slate, and an unusually thick sequence of fossiliferous limestone and dolostone (fig. 16). The normal limb, nose, and a small part of the inverted limb of this anticline are well marked by Eagle Bridge Quartzite. The underlying recumbent syncline (rs-1) has Poultney on the normal and inverted limbs and Normanskill at the core (fig. 39). The normal limb of ra-1 (section A-A′) is cut out by a thrust fault which brings rs-2, containing Poultney and Normanskill, against ra-1 and rs-1. Above rs-2 is an impressive tight recumbent anticline (ra-2) whose core rocks are Bomoseen, graywacke phase of Mudd Pond, and West Castleton slate and fossiliferous limestone. Eagle Bridge Quartzite occurs on both normal and inverted limbs. The core of this recumbent anticline is exposed at elevation 1,000, on the west slope of the spur (G-1), two miles northeast of Center White Creek; core and shell can be traced southwest to the top of this spur, and thence southeast along the south face of the hills to another spur 1 mile north of Post Corners where it is offset by two high-angle faults. Above ra-2 is a less well defined recumbent syncline (rs-3) marked by the extensive exposures of Poultney. The core of this fold is at the exposure of Normanskill, elevation 1,000 to 1,100 feet, 1.5 miles due north of

Figure 39. Recumbent anticline, Normanskill Formation, at core of lowest recumbent syncline (rs-1) in Post Corners area. Graded beds of Austin Glen Graywacke (thicker layers) are interbedded with slate and dolomitic siltstone exhibiting crossbedding. Looking east on N.Y. Route 22 (G-2), (1.5 miles) south of north edge of Eagle Bridge Quadrangle.

Post Corners; the several lenses of Eagle Bridge Quartzite and Hatch Hill in the Poultney terrain probably represent digitations in rs-3. The inverted limb of the next higher recumbent anticline (ra-3) is marked by Eagle Bridge and Hatch Hill on the spur (I-1) 2 miles north-northeast of Post Corners. This inverted limb can be traced northwest to the quadrangle boundary where it bends to the northeast. Bomoseen is exposed in the core of ra-3 at the quadrangle boundary, about 1.5 miles northeast of Post Corners.

Some of the recumbent folds just described are also exposed in the area east of Post Corners and south of White Creek (stream) (I-2, 3) (see section B-B′). The lowest anticline is isoclinal with axial plane dipping northeast. Bomoseen and Mettawee are exposed at the core north of intersection 623 (I-3), and the thick sequence of West Castleton limestone and dolostone forms the limbs. A bedding-plane thrust fault separates this anticline from two recumbent anticlines and an intervening syncline above. The Nassau Formation defines the core of ra-2 which, on the map, forms an irregular collar about the Ordovician map units. Above ra-2 and in fault contact along the northeast side of the hills, is recumbent syncline rs-3, with Eagle Bridge on both normal and inverted limbs, and Poultney in the core. On the high ground, just west of the White Creek fault, is the highest recumbent anticline (ra-3) with Bomoseen in the core.

The second stage of folding is clearly indicated in the Post Corners area by the folding of the secondary thrust faults and by the sharp " V " puckers in the limbs and cores of the recumbent folds. These can be seen in the map patterns (pl. I) on the ridge northeast of intersection 623 (I-3). Smaller folds, not obvious from outcrop pattern, are also superimposed on the recumbent structures. The axial planes of these puckers strike northeast and dip southeast; axes plunge 15 to 50 degrees northeast.

Thurber Pond to Pine Valley: The complex of structures considered here forms a strip along the west edge of the reentrant from the vicinity of Thurber Pond (F-1) south to Pine Valley (E-10, F-10). The folded Eagle Bridge thrust fault is a major structural element in this terrain, for it brings the inverted limb, core, and normal limb of the nappe, on west side of thrust, in contact with the recumbently folded inverted limb (pl. II, sections A-A′ through D-D′). Thus, between the Eagle Bridge thrust and the Case Brook fault, the Cambrian and Ordovician formations are the westward continuation of ra-1 and rs-1 and 2 in the Post Corners area. These recumbent folds are refolded by a simple anticline along the Owl Kill (see sections A-A′ and B-B′) and by the overturned or isoclinal Eagle Bridge syncline (see sections C-C′, D-D′) farther south. The sequence of the normal limb of the Eagle Bridge syncline, proceeding west from the Owl Kill (see section C-C′), is Hatch Hill, Eagle Bridge, Poultney, and Normanskill, all right-side-up dipping west, yet bedding-cleavage relations indicate the section to be inverted. A bedding-plane fault, parallel to the trace of the Eagle Bridge thrust, brings up Poultney west of the syncline axis.

South of the Hoosic River there is additional complexity, for a folded thrust fault at the Eagle Bridge syncline axis (see section C-C′) faults the core and west limb of the syncline down on its west side. The structural complexity is well represented in the railway cut 0.6 mile east of the station at Eagle Bridge. Here, in the east limb of the Eagle Bridge syncline are exposed Mettawee, West Castleton, Mudd Pond, and Hatch Hill. The Hatch Hill dips west right-side-up; 200 feet to the east the Mettawee is brought up along a reverse fault; between the fault and the Hatch Hill is a disharmonically folded and faulted sequence of Mudd Pond and West Castleton. Thus, the broad stratigraphic sequence is preserved but the detailed structures greatly confuse the picture.

The outcrop pattern of Bomoseen, West Castleton, Hatch Hill, and Poultney north and east of hill 935 (E-7) suggest that the younger formations lie conformably beneath the Nassau in the inverted limb of the nappe (see section E-E′).

At the head of Nipmoose Brook, one mile southeast of Southwest Hoosick (E-9, E-10), the outcrop pattern of Bomoseen, Mudd Pond, Hatch Hill, and Poultney (fig. 3) defines a sharp bend in the trace of the inverted limb of the nappe. East of the bend the succession dips south and is overturned (see section J-J′). Several tight recumbent folds are well displayed by the outcrop pattern of Poultney and Normanskill on the hills (E, F, G-8, 9) north of the head of Pine Valley (see section F-F″). The inverted limbs of some recumbent anticlines are cut out by thrust faults, and at Hill 965 (E-9), the inverted limb of a recumbent anticline is thrust over older formations, and refolded. Poultney is exposed beneath the thrust around the base of this hill, and above the thrust is an inverted sequence of Normanskill, all tightly refolded. A second stage of folding in this area is also indicated by the dextral flexure pattern in the recumbent fold (plate I) east of Hill 965.

North Hoosick Klippe: Hill 1,000 (H-5), 1 mile northwest of North Hoosick, is capped by an erosional remnant of the North Petersburg thrust sheet (fig. 38). The formations in the klippe are Early Cambrian and include Mettawee, West Castleton (with fossiliferous limestone lenses), Mudd Pond, and a 30 foot thick lenticular body of Zion Hill Quartzite, all isoclinally folded (see section D-D′). The proximity of the klippe to probable submarine slide blocks in the Austin Glen terrain (fig. 3) leads to the interesting speculation that the " klippe " itself may be a giant slide block.

Pine Valley to Petersburg: This is a wooded area of steep slopes and rugged hills rising to 900 feet above the flood plain of the Hoosic River and its tributary, the Little Hoosic River (fig. 36). Recumbent folds are well developed above the sole of the thrust, and many are bounded by thrust faults. A second stage of folding has been superimposed on these earlier structures.

Between the head of Pine Valley (F-9) and Potter Hill (F-11), bedding and foliation dip south, younger formations beneath older. Thus, from Potter Hill north we find, successively, middle Mettawee, Bomoseen, upper Mettawee, Mudd Pond, and West Castleton which collectively constitute the core and inverted limb of the North Petersburg nappe (see section J-J′). A small thrust on the north side of Shingle Hollow (G-11) brings Bomoseen and Hatch Hill-Poultney over the south-dipping sequence just mentioned.

Between Shingle Hollow and North Petersburg (I-13) there is a well defined nest of recumbent folds (see section G-G′) in the lower 800 feet of the North Petersburg sheet. In general, axial planes of these folds strike northwest and dip about 15° to southwest; axes plunge about 10° to the southwest. Thrust faults are more common at the fold limbs than indicated on plate I, but are omitted so as to emphasize the stratigraphic details of the folds. Structural complexity within each fold is great and the folds are best understood if one considers the distribution of two major units, the Nassau and the Hatch Hill-Poultney. Immediately above the North Petersburg thrust, south of the mouth of Shingle Hollow, the Bomoseen marks the core of the lowest recumbent anticline (ra-1).[7] Above this is a recumbent syncline (rs-1) with Poultney-Hatch Hill in the core and Eagle Bridge locally on the limbs. Above rs-1 is a well-defined recumbent anticline (ra-2) open to the southeast, and marked by Bomoseen, West Castleton, and Mettawee. A digitation on the inverted limb of ra-2, at elevation 800 feet, 0.6 mile west of Petersburg Junction, accounts for the greatly thickened West Castleton limestone. Fossils (app. 4, station 56K) in this limestone resemble those seen in the core of the lowest recumbent anticline in the Post Corners area. Above ra-2, 0.7 mile northwest of North Petersburg, an exposure of Poultney and Hatch Hill marks the highest recumbent syncline (rs-2). West of the high-angle reverse fault, rs-2 is bounded by thrust faults and becomes highly attenuated to the southwest. Prindle and Knopf (1932, p. 279) recognized the essence of the recumbent folds in this area for they found graptolites which they assigned to the Deepkill Shale in what is herein mapped as Poultney-Hatch Hill, and also noted the Lower Cambrian rocks above.

At the mouth of Church Hollow (I-14), an anticline superimposed on the inverted limb of the nappe (section H-H′) has Normanskill and Poultney at the core, and Hatch Hill, West Castleton, and Bomoseen on the limbs. The Hatch Hill is cut out on the western limb by a reverse fault. Formation contacts north and south of Church Hollow suggest many digitations in the secondary anticline whose axial plane strikes northwest and dips northeast.

The Little Hoosic anticline (section I-I′) is centered along the Little Hoosic River south of School No. 3 (H-16). Again, Normanskill and Poultney mark the core of a secondary anticline, while Hatch Hill, West Castleton, and Bomoseen define the limbs. A reverse fault at the western limb of the anticline has cut out the Hatch Hill north and south of Dill Creek. The east-

[7] Numbers refer to relative position of recumbent folds in this area only and do not signify a correlation with recumbent folds in the Post Corners area.

ern limb is likewise cut by thrust faults along the steep faces of Odell Hill and Moon Hill (I-16, 17). The distribution of beds from the west face of Odell Hill east to the trace of the Rensselaer Plateau thrust suggests either simple anticlines and synclines overturned to the west, or anticlinal folding of an inverted sequence (section I-I′). The latter interpretation is preferred, for again it is postulated that the formations are in the inverted limb of the North Petersburg nappe. Two small lenses of Rensselaer Graywacke occur in middle Mettawee on Moon Hill, west of the trace of the Rensselaer Plateau thrust. Thrust faults are doubtless common between various formations on the west face of Moon Hill but, essentially, the pattern here is due to digitations on the east limb of the Little Hoosic anticline.

Indian Hill: The North Petersburg thrust sheet at Indian Hill (J-10) is folded, and the formations in the lower part of the sheet are, again, inverted. Normanskill occurs at the sole of the thrust on the west slope of Indian Hill (J-11, J-12), and is overlain by Poultney and Bomoseen. A finger of the North Petersburg sheet, consisting mainly of Bomoseen, extends 1 mile northeast from the crest of Indian Hill. The inverted structure can be traced south to the hills south of Breese Hollow.

RENSSELAER PLATEAU THRUST FAULT

The Rensselaer Plateau thrust sheet is nested on rocks of the Synclinorium Sequence and on the North Petersburg sheet in the southern half of the area where it comprises the major highland masses, the Rensselaer Plateau and Taconic Mountains. The Rensselaer Plateau thrust fault, at the base of this sheet, is named for its exposure on the northeast and east side of the Rensselaer Plateau (pl. I: E-12 to G-17). At the northwest base of the plateau, the thrust is not exposed but is inferred from stratigraphic evidence and structural discordance. The thrust is well exposed east of the Little Hoosic River on spurs of the Taconic Mountains (I-14 to I-16) (fig. 7) and can be traced north of the Hoosic River to the shoulder of Mount Anthony (M-10). On the east side of the Taconic Mountains, it is exposed in the low ground west of the Hoosic River (M-16, 17) at the base of cliffs east of North Pownal (M-14, 15) and near the mouth of Potter Hollow (M-13).

Evidence for the Rensselaer Plateau Thrust Fault: (a) The contrast between the rocks in the Rensselaer Plateau sheet and those of the underlying North Petersburg sheet, and between the Rensselaer Plateau sheet and those in the underlying Synclinorium Sequence constitutes prime evidence for the thrust. On the Rensselaer Plateau, the rocks of the sheet are Lower Cambrian Rensselaer Graywacke, and red and green slate of the lower Mettawee subfacies (Nassau Formation), while only minor exposures of lower Mettawee and Rensselaer Graywacke are found in the North Petersburg sheet. In the Taconic Mountains, the Rensselaer Plateau sheet consists dominantly of chloritoid schist which here interfingers with and overlies Rensselaer Graywacke. In addition, other younger stratigraphic units of the Taconic Sequence are exposed on the west shoulder of Mount Anthony (L, M-11, 12, 13). Rocks of the Synclinorium Sequence beneath the Rensselaer Plateau thrust present an even greater age and lithologic contrast to those in the Rensselaer Plateau sheet: the autochthonous rocks are Lower and Middle Ordovician carbonates and Middle Ordovician Walloomsac phyllite, while schists, graywacke, and other units of the Rensselaer Plateau sheet range from Early Cambrian to Middle Ordovician.

(b) Structural discordance between rocks in the Rensselaer Plateau and North Petersburg sheets is emphasized by equal area plots of the attitudes of bedding, foliation, and lineation (fig. 40) prepared by M. A. Lane. Discordance of map units in the North Petersburg sheet to the Rensselaer Plateau thrust fault is clearly seen east of the Little Hoosic River. From the spur south of Lewis Hollow (J-16) north to the Hoosic River (J-13), the following map units and structures occur immediately beneath the sole of the thrust: Mettawee, Bomoseen, West Castleton, Hatch Hill, inverted North Petersburg thrust plane, Synclinorium carbonates, and Whipstock. Structural discordance is most pronounced west of the crest of Mount Anthony (K-11 to M-10) where lenticular masses of Rensselaer Gray-

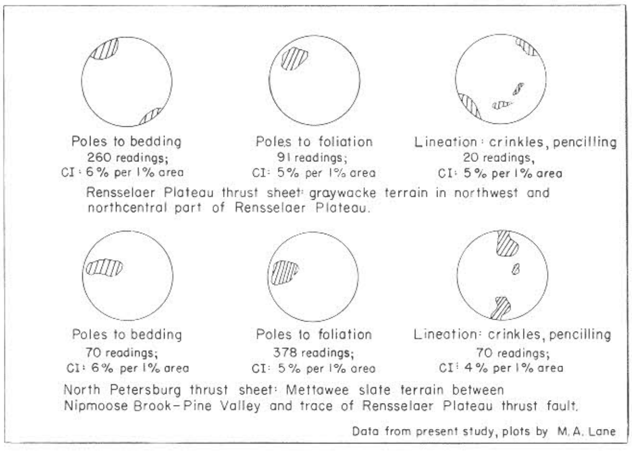


Figure 40. Subfabric diagrams showing local contrast in orientation of structures in North Petersburg and Rensselaer Plateau thrust sheets

wacke are extensively exposed at the base of the sheet. Beneath the fault plane, Synclinorium carbonates and the Walloomsac slate-phyllite are complexly folded, and the contacts between these two map units is noticeably discordant to the trace of the fault plane.

(c) The plane of the North Petersburg thrust is discordant to the Rensselaer Plateau thrust. This is indicated by the truncation of the trace of the former by the latter on the east side of Breese Hollow (K-12), elevaion 950 feet, 1.88 miles N 80° E. of Petersburg Junction, and at elevation 1,000 feet (I-15), 2.06 miles due south of B.M. 483 at North Petersburg.

(d) Beneath the Rensselaer Plateau thrust plane, where it rests on the North Petersburg sheet, there are some 20 slices of limestone and dolostone of the Synclinorium carbonates. These slices are widely distributed in space, occurring at the sole of the thrust along the northeast and east side of the Rensselaer Plateau, east of the Little Hoosic River and north of Prosser Hollow (I-15), and from the Hoosic River northeast to the saddle east of crest 1294 (J-12). Several rock types of the Synclinorium carbonates are represented: creamy-weathering dolostone, brown-weathering dolostone, blue-gray-weathering limestone with blebs of dolomite, blue-gray to light gray limestone, limestone with irregular patches of bluish-gray chert. The smaller slices are about 3 feet long and 3 inches thick; the larger are 600 feet long and 100 feet wide (just north of Babcock Lake, F-13); and 0.4 mile long and 200 feet wide (south from crest 1294, J-12). Limestone slices are generally thinly foliated, penciled, and folded, while dolostone slices are fractured (fig. 41) and brecciated. Recrystallization and silicification of the carbonate slices is seen locally. The slices are generally lenticular (fig. 42) and lie with their long axes parallel to the foliation planes of the enclosing rock, but at the Babcock Lake locality foliation and bedding (?) in the slice is discordant to the foliation in the slates below. On the northeast and east sides of the Rensselaer Plateau, the slices occur either immediately beneath the intensely sheared graywacke, or lie some 15 feet below the graywacke enclosed in middle Mettawee green and purple slate or phyllite. In many cases, the graywacke is so intensely sheared in the thrust zone it is difficult to distinguish from slate, and the carbonate slices provide the main clue to the position of the sole of the thrust. Many slices appear to have been kneaded into the underlying slates. Whether the slices are truly tectonic and have been dragged along the sole of the thrust or are submarine slide blocks cannot be proven, but a tectonic origin seems most likely for the slices

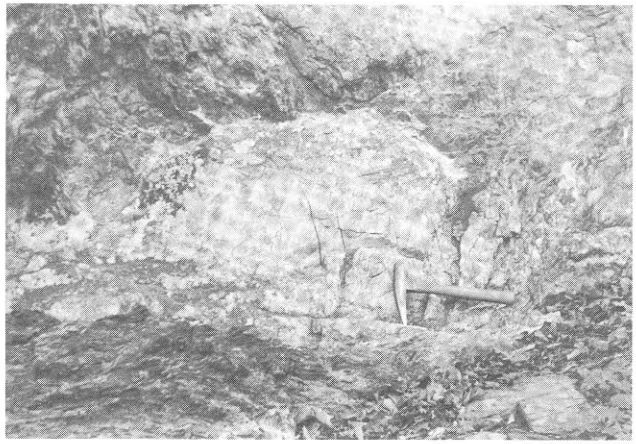


Figure 41. Dolostone slice at sole of Rensselaer Plateau thrust on west side of Taconic Mountains, elevation 1,080 (I-15), 2.1 miles due south from B.M. 483 at North Petersburg. Above slice is sheared Rensselaer Graywacke; slice is highly fractured; below slice is Hatch Hill Formation.

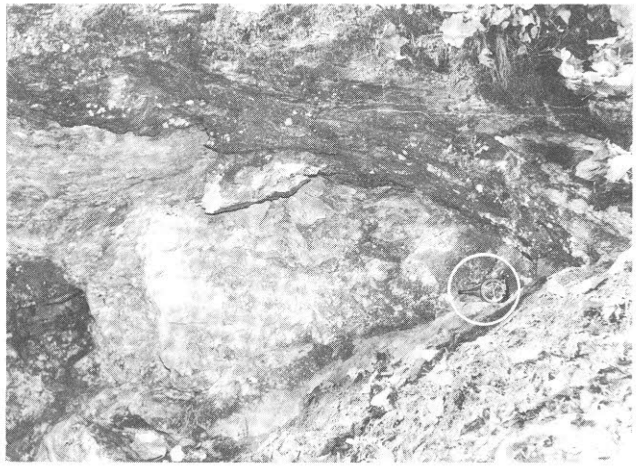


Figure 42. Limestone slice in Rensselaer Plateau thrust zone, elevation 1,260 (G-14), 2.1 miles S 62° W from B.M. 483 at North Petersburg. Compass is at right end of lenticular slice (lighter rock), 15 feet long and 4 feet thick. Darker rock above slice is sheared Mettawee slate, dark green volcanic rock, and Rensselaer Graywacke.

are intensely sheared and fractured, and there is no Whipstock Breccia or other Walloomsac members surrounding them. Their presence between the two thrust sheets is extremely important evidence for thrusting (Zen, 1967, p. 31), especially in the metamorphic terrain of the Taconic Mountains where identification of stratigraphic units is difficult.

(e) A significant feature of the Rensselaer Plateau thrust is the intense shearing and crushing of Rensselaer Graywacke at the sole and through a zone up to 300 feet thick above it. Argillaceous rocks in this zone are commonly phyllitic or schistose. The graywacke in the sheared zone is highly foliated (figs. 8, 9) and appears as a hard gritty schist with sparse small grains of quartz; thin white quartz laminae, parallel to the foliation and spaced about ½ inch apart, are typical of this sheared graywacke. Slickensides are developed sparingly (see below) but the dominant lineation is defined by pencils of quartz, chlorite, or other mineral aggregates. Flaser structure is commonly seen in thin section, and in the eastern part of the area the sheared graywacke is a quartz-muscovite-chlorite-epidote schist showing only a few relic quartz clasts. Quartz grains survive mechanical breakdown better than plagioclase grains. Epidote, calcite, and quartz occur as veins and irregular replacement masses in the sheared graywacke. Some epidote-rich rocks may be metavolcanics (see Rensselaer Graywacke).

Movement direction: A few readings from slickensides developed in or near the thrust zone present a consistent picture of a northwest-southeast movement direction, although the degree to which these slickensides have been rotated by later deformation is not known. The few drag folds observed at the thrust zone indicate movement of the thrust sheet from an easterly direction. On the west shoulder of Mount Anthony (fig. 8), the fault plane is folded and these folds, as well as the small folds in the sheared graywacke above, suggest an overthrust from the east, but this evidence is not unequivocal for these folds may be due to a later deformation.

Deformation of the fault plane: The Rensselaer Plateau thrust fault, like the North Petersburg, is isoclinally folded and cut by high-angle faults. Deformation of the thrust plane is most intense in the southeastern part of the area where chloritoid schists constitute the bulk of the thrust sheet, and least where the thick and competent Rensselaer Graywacke makes up the sheet.

Isoclinal folding of the thrust plane occurs on a small scale on Mount Anthony (see above), and such deformation reaches its major development in the overturned thrust on the cliff east of North Pownal (M-14, 15). (figs. 25 and 26; pl. II, section H-H′) The Synclinorium Sequence is inverted here above the thrust, the Walloomsac occurring sporadically beneath the Synclinorium carbonates. The inverted thrust plane dips perhaps 15–20 degrees east but, locally, it is much steeper. North of the village, near the mouth of Potter Hollow (M-13, 14), the thrust fault trace and one fault plane exposure indicate that the thrust plane has been folded into south-plunging isoclinal folds. South of the village, along the west side of the Hoosic River through a distance of about 2 miles, the fault plane continues to be inverted and dips east. The projection of the carbonate formations westward up Frost Hollow (M-17) and the wedge of schists exposed below them in the channel of the stream may represent an isoclinal fold of the thrust.

High-angle reverse faults are well developed at the north edge of the Rensselaer Plateau (pl. I: E, F-12, 13) and on the west shoulder of Mount Anthony (K-11 to M-10). Maximum throw on these faults is about 400 feet. The Prosser Hollow fault (J-14 to J-17) is a high-angle normal fault, east side down perhaps several hundred feet.

Shearing and reverse faulting of the thrust plane have produced highly irregular and complicated contacts in several areas. There are all gradations from a relatively undisturbed fault plane, through an isoclinally folded fault plane, to a chopped-up fault plane where carbonate rocks of the Synclinorium Sequence occur intercalated with sheared graywacke at the thrust zone. This is particularly well shown at elevation 1,540 feet, 0.4 mile S 22° W of State line Monument No. 18 (L-11), where limestone and dolostone slices have been faulted up 15 to 20 feet into the thrust sheet and are now conformable with the foliation of the sheared graywacke. The complex nature of the fault trace, 1.5 miles north of Stillham on the east side of the plateau (H-15), is similarly due to faulting and perhaps folding of the thrust.

Near the base of the thrust sheet, two cleavages are commonly seen in the rocks. The pervasive slaty cleavage is cut by a slip cleavage or a set of minor faults spaced 2 to 6 inches apart. The slip cleavage planes have a steeper dip than the slaty cleavage, and the slaty cleavage has been bent into " S " curves by small displacements on the slip planes. The slip cleavage planes generally strike north or northeast, but the movement along slip planes presents no consistent picture. This feature is also common in the lower part of the North Petersburg sheet and may be due to differential vertical movement near the thrust soles during thrusting, thus predating the later more pervasive slip-cleavage development.

STRUCTURE OF THE RENSSELAER PLATEAU THRUST SHEET

In general, the Rensselaer Plateau sheet presents a much simpler structural picture than does the North Petersburg sheet. This is due to the competent nature of the Rensselaer Graywacke, and the absence of distinctive marker beds in the schist terrain of the Taconic Mountains. The structure of the Rensselaer Plateau sheet is considered in two areas — the Rensselaer Plateau and the Taconic Mountains.

Rensselaer Plateau: The Rensselaer Plateau sheet, up to 1,500 feet thick, consists of graywacke and interbedded lower Mettawee slates. The western and eastern halves of the plateau present a contrast in stratigraphy and deformational pattern, and these terrains are separated, at least at the north end of the plateau, by the Pine Valley reverse fault (E-12, 13).

The base of the Rensselaer Graywacke is exposed at the northwest edge of the plateau (pl. II, sections H-H′ and I-I″) where the graywacke interfingers with, and is underlain by, lower Mettawee slates. Mettawee Slate and graywacke are repeated throughout the western half of the plateau in a consistent pattern of folding: fold axes trend northeast-southwest, and plunge gently, generally to the southwest; the folds are overturned to the northwest or are isoclinal with axial planes dipping southeast. The width of slate bands in this terrain (pl. I) is probably not a true indication of stratigraphic thickness for it is obvious that there is considerable thinning on limbs of folds and thickening at the crests and troughs. Slickensides and shearing are common at the contacts between slate and graywacke, and it appears that some of the massive sequences of graywacke have moved like giant boudins in the more pliable slate. This is suggested by the outcrop pattern in the vicinity of Ward Hollow (B, C-13, 14). Slate intercalations may be more numerous than the map indicates for the topography is well adjusted to lithology on the plateau and slate generally occupies low ground where exposures are poor.

The eastern half of the plateau contains only one mappable intercalation of green-gray slate, interpreted to be middle Mettawee. It strikes west-northwest and lies above the thrust zone 1 mile east of Babcock Lake (F-13). Fold axes from Babcock Lake southeast to Stillham (G-17) generally trend east-west; the folds are overturned to the north or isoclinal, and axial planes dip 20 to 50 degrees south.

The overall structure of the Rensselaer Plateau sheet is interpreted to be a right-side-up sequence. Possibly the sheet has a recumbent anticlinal, or nappe structure but there is little evidence to support this. The nappe structure could explain the contrasting structures and lithologies east and west of the Pine Valley fault, with the terrain west of this fault representing down-thrown normal limb of the nappe, and the terrain east of the fault the core or inverted limb. An interesting conjecture follows from this speculation and from Balk's (1953, p. 846) and Bird's (1963a) observation that the Rensselaer Graywacke is coarsest at the west edge of the plateau. When the limbs of this conjectured nappe are restored to their original position in the basin of deposition, the coarsest beds would then lie to the east and suggest an eastern sediment source.

Taconic Mountains: The dominant lithologies here are Mettawee chloritoid schist and Rensselaer Graywacke; younger Taconic Sequence formations are exposed between Mount Anthony and the Hoosic River.

Rensselaer Graywacke occurs generally at the base of the thrust sheet with green and purple chloritoid schist (middle Mettawee) above. The principal occurrences of graywacke on the west side of the mountains are from Poplar Hill (J-17) north to the Hoosic River, and on the west shoulder of Mount Anthony (K-11 to M-10); on the east side of the mountains, thin graywacke lenses were found above the thrust at Frost Hollow (M-17) and Lincoln Hollow (M-16). At Poplar Hill, stratigraphic succession is established by graded bedding in graywacke which is underlain by green and purple (lower or middle) Mettawee slates and overlain by green and purple phyllite and chloritoid schist (middle Mettawee).

North of the Hoosic River, gross distribution of map units again suggests a normal stratigraphic sequence dipping east: Rensselaer Graywacke at the base of the sheet on the west shoulder of Mount Anthony is overlain to the southeast by middle Mettawee chloritoid schist containing a lens of Rensselaer, and by successively younger units of the Taconic Sequence: Bomoseen, West Castleton, Hatch Hill, and Poultney (pl. II, section G-G′).[8] Within the West Castleton, on the spur (L-12) west of Potter Hollow, there are two small lenses of Mudd Pond Quartzite. The Hatch Hill in the streambed consists of highly folded and sheared black and green-gray phyllite with a few interbeds of calcareous marble, cherty limestone, and Eagle Bridge Quartzite.

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[8] E-an Zen, in reviewing the manuscript of this report, suggests that the younger units of the Taconic Sequence are not part of the Rensselaer Plateau sheet, but rather a thrust slice of the underlying North Petersburg sheet.

MacFadyen (1956) named the schists on Mount Anthony the "Mount Anthony Formation" and considered them to be autochthonous Middle to Upper (?) Ordovician, though separated from the underlying Walloomsac by an unconformity (fig. 27). The presence of mappable units of the Taconic Sequence in this terrain makes his conclusion untenable; the name "Mount Anthony Formation" should be abandoned.

A nappe structure for the Rensselaer sheet in the Taconic Mountains is not indicated by the present study but it is not incompatible with the map pattern. Thus, on the west shoulder of Mount Anthony, Rensselaer Graywacke at the base of the sheet could be the inverted limb of the nappe; chloritoid schists (€nm) could be correlated with the *lower* Mettawee slates and mark the core; and the upper limb would be the lens of graywacke at the State line (L-12) and the younger formations of the Taconic Sequence near Potter Hollow. South of the Hoosic River, the intensely sheared graywacke at the base of the sheet would again mark the inverted limb, and chloritoid schist, the core of the nappe. If the entire mass of chloritoid schist is correlated with the *lower* Mettawee slates, it would be necessary to postulate a fault between the graywacke on Poplar Hill and the schists to the east.

REVERSE AND NORMAL FAULTS

More than a score of high-angle reverse faults, and a few normal faults cut the major thrust faults, thrust sheets, and formations of the Synclinorium Sequence in the Hoosick Falls area (fig. 3; pl. I, II). In general, these faults strike north-northeast, dip steeply east, and have vertical displacements from 50 to more than 1,000 feet.

Reverse faults having greatest vertical displacement are in the western and northwestern part of the area, and include the Otter Creek fault (maximum vertical displacement, 1,000 feet) at the east limb of the Newcomb Pond syncline, Whipple Brook fault (about 1,000 feet), and South Cambridge fault (about 1,000 feet). About the reentrant, the Case Brook (400 feet), White Creek (200 feet), Pine Valley (400 feet), and Potter Hill (100 feet) reverse faults offset the trace of the North Petersburg thrust. The Pine Valley and Potter Hill faults extend into the Rensselaer Plateau sheet which is also cut by smaller reverse faults on the plateau and on Mount Anthony.

The reverse and normal faults clearly postdate the emplacement of the thrust sheets, and probably developed during the second period of deformation. Meager evidence suggests that metamorphism probably postdates the development of one of these faults for the chloritoid isograd is not offset by the Prosser Hollow normal fault (pl. I; J-17).

The Pine Valley and White Creek faults may mark a Mid-Ordovician submarine scarp, for west of a line connecting these two faults (fig. 3) is a thick sequence of Austin Glen Graywacke, while Walloomsac slate is to the east. Perhaps the thick sequence of graywacke was deposited in deeper water west of the scarp.

Metamorphism

A regional metamorphism, postdating thrusting and possibly some slaty cleavage development, is superimposed on all formations. The highest rank — greenschist facies — is displayed by the rocks in the eastern third of the area. Details of lithologic changes produced by increased rank of metamorphism appear under formation descriptions (see Stratigraphy).

Pelitic rocks are particularly sensitive indicators of metamorphic rank: in the western half of the area these are argillites and slates; to the east they become more highly sheared, take on a silky luster and become phyllites; farther east sericite is developed with its basal plane at a high angle to the foliation; the highest rank of metamorphism is recorded in the Taconic Mountains, Mount Anthony, and West Mountain where pelitic rocks, exhibiting a pronounced foliation, are chlorite-sericite schists, commonly containing chloritoid and, rarely, albite. Bulk chemistry of the pelitic rocks has been a determining factor in the development of chloritoid. Original rock texture seems to have played a major role in its recrystallization, for very fine-grained argillites and cherty argillite (Poultney Formation) are less recrystallized than siltier and more quartz-rich slates (Mettawee) in the vicinity of West Mountain. Quartz veins are common in schist in the eastern part of the area.

Arenaceous sediments, graywacke and quartzite, exhibit considerable recrystallization in the green schist facies. Grain boundaries are sutured, grains of quartz are flattened and exhibit strain shadows and internal recrystallization. Feldspar appears to be less abundant than in the unmetamorphosed rock, perhaps because of mechanical breakdown to submicroscopic-sized particles. The matrix of metamorphosed graywackes consists of recrystallized quartz, muscovite, chlorite, and chloritoid.

Synclinorium Sequence limestones and dolostones are recrystallized to marble with an increase in grain size. Complex folds, flowage of limestone, and boudinage of some thin competent dolostone and quartzite beds are common. The Walloomsac Slate becomes markedly phyllitic and carries numerous quartz veins in the eastern part of the reentrant.

Summary of Paleozoic History in the Hoosick Falls Area

Early Cambrian to Middle Ordovician: Deposition of the Taconic Sequence in a deep marine basin at the present site of the Green Mountains or farther east: sediments are mainly pelites and turbidites with minor carbonates and clean sands; minor scattered eruptions of basic volcanics occur in this basin; synchronous deposition of clean sands and carbonates of the Synclinorium Sequence in a shelf environment west of the Green Mountains and in the area now occupied by the Taconic Allochthon.

Middle Ordovician:

(a) Carbonate deposition continues on shelf.

(b) Area occupied today by the allochthon is deeply depressed and receives a thick accumulation of dark mud (Walloomsac slate), at the time that Indian River (red slate) and Mount Merino (chert) are deposited to the east.

(c) Tectonic activity increases as Austin Glen Graywacke is deposited on the Taconic Sequence and also on top of the (Walloomsac) muds in the area now occupied by the allochthon.

(d) Area or deposition of the Taconic Sequence rises and thrust sheet peels off from the root zone; as sheet slides westerly along the sea bottom, overriding the shelf rocks of the Synclinorium Sequence (fig. 35), it develops a recumbent anticlinal (nappe) form and numerous smaller recumbent folds (first deformation); clasts of the Taconic Sequence from the leading edge of the thrust sheet, as well as giant blocks of carbonate rock from the shelf, break off and slide west into the unconsolidated mud (Walloomsac), graywacke (Austin Glen), and breccia (Whipstock); graywacke continues to be deposited in front of the advancing thrust sheet, or perhaps unconsolidated graywacke from the thrust sheets is decanted into the basin and redeposited.

(e) Leading edge of the North Petersburg thrust sheet rides westward onto the unconsolidated Walloomsac, and inverted limb of nappe locally brings unconsolidated Austin Glen of the Taconic Sequence into contact with the underlying unconsolidated Walloomsac Formation giving rise to a melded contact; recumbent folds develop extensively in lower 1,000 feet of nappe, while folding in normal limb is less intensive.

(f) East-dipping thrust fault develops in the North Petersburg nappe at the western edge of the Rensselaer Graywacke (fig. 35); the Rensselaer Plateau thrust is thus generated as the eastern half of the nappe slides westward onto the western half; as this movement takes place, slices of carbonate rock from the Synclinorium Sequence are dragged westward at the sole of the Rensselaer Plateau thrust; perhaps minor scattered volcanism accompanies thrusting.

(g) All rocks are deeply depressed and refolded (second deformation); all existing structures, including recumbent folds and thrust faults, are folded under a new stress pattern that generates northeast-trending isoclinal and westward-overturned folds; a pervasive slaty cleavage-foliation develops parallel to axial planes of the secondary folds; steeply dipping slip cleavage develops locally, during or after a regional metamorphism which is superimposed on all rocks in the area; high-angle, northeast-trending reverse and normal faults cut all the structures in the area.

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Appendix 1

FIELD CRITERIA FOR DISTINGUISHING GRAYWACKES

	AUSTIN GLEN	GRAYWACKE PHASE OF MUDD POND QUARTZITE	RENSSELAER
Matrix	soft, dark gray chloritic and micaceous	black, argillaceous	dark green, hard, quartz-rich
Cleavage development	crudely cleaved to closely cleaved	massive to crudely cleaved	generally massive; closely cleaved above thrust faults
Conspicuous clasts	sand-sized quartz, shale fragments	coarse, rounded and frosted quartz; thin, angular black shale fragments	milky quartz, feldspar, dark gray silty argillite fragments
Weathered surface	brownish or tan, slaty, fine grained gritty texture	dark gray, gritty surface with large fragments of black shale conspicuous	gray or brown, massive, hard, and gritty
Outcrop habit	low outcrops; often occurs only as float on hillside or capping on small hillocks	low outcrops; often occurs as meager float on hillside or capping on small hillocks	forms bold outcrops and major topographic features (Rensselaer Plateau)

Appendix 2

SUBMARINE SLIDE BLOCKS IN THE WALLOOMSAC FORMATION

Block No. (see Figure 3)	Rock Type and Age Where Known From Fossils	Location on Figure 3 and Plate I	Length & Width of Clast (in feet unless otherwise noted)	Structural Relations
1.	limestone, minor dolostone (Synclinorium Sequence)	J-2; el. 1,000–1,020; 1.8 miles N 88° E of Post Corners	300 X 200	Immediately below North Petersburg thrust, and surrounded by Whipstock Breccia; 15-foot deep cave in limestone
2.	limestone and dolostone (Synclinorium Sequence)	900 feet SE of above location	2,000(?) X 200	Surrounded by Walloomsac slate; block is parallel to foliation in slate
3.	limestone (Synclinorium Sequence)	I-3; el. 660; south side of road, 0.18 mile east of intersection 705	less than 10 X 10	Small outcrop of limestone in contact with Whipstock Breccia
4.	limestone and dolostone (Synclinorium Sequence)	I-5; el. 460; bed of Little White Creek	400 X 200	Infolded with Whipstock Breccia; contacts exposed
5.	limestone (Synclinorium Sequence)	H-5; el. 680; east slope of Hill 1000, 0.8 mile northwest of North Hoosick	1.5 wide	Thin plate of foliated limestone at contact between Walloomsac slate and Austin Glen Graywacke; included in tabulation to emphasize setting
6.	limestone and dolostone (Synclinorium Sequence)	G-4; el. 500; east side of Rt. 22 at County Line	200 X 400	Overlain by Walloomsac slate; underlain by Austin Glen Graywacke
7.	Early Ordovician limestone-dolostone (Synclinorium Sequence)	G, H-5, 6; extending NE from 780 crest through Hoosic Jct. to Hoosic River	1.5 miles long, 600–700 feet thick	Complexly folded, overlain by Walloomsac slate, underlain by Austin Glen Graywacke and slate
8.	(8a-8g) seven blocks of limestone and dolostone; 8a, probably Middle Ordovician; 8c, Trenton; 8g, Middle Ordovician (Synclinorium Sequence)	F, G-6, 7; valley of Case Brook, 1.5 miles NW of Hoosick Falls	up to about 1,800 X 800 irregular	Blocks surrounded by Austin Glen Graywacke or at contact between graywacke and Walloomsac slate; contacts between blocks and matrix poorly exposed
9.	Poultney Fm. (Taconic Sequence)	F-6; el. 560–600; bed of small tributary to Case Brook; 1.2 miles S 85° W of B.M. 406	400 X 200	Limits of clast poorly defined; overlain by Austin Glen Graywacke

Block No. (see Figure 3)	Rock Type and Age Where Known From Fossils	Location on Figure 3 and Plate I	Length & Width of Clast (in feet unless otherwise noted)	Structural Relations
10.	Eagle Bridge Qtzt., Hatch Hill, and Poultney Fms. (Taconic Sequence)	G-6; crest and south slope Hill 840, 0.4 mile SW of B.M. 406	1,400 X 500	Limits of clast poorly defined; completely surrounded by Austin Glen Graywacke
11.	Mettawee Slate (Taconic Sequence)	G-7; elevation 660–680, south side of road, 0.3 mile east of intersection 728	200 X 400 ?	Poorly defined mass of olive-green and gray slate in Austin Glen Graywacke; contacts not exposed
12.	Early Ordovician limestone and dolostone (Synclinorium Sequence)	G, H-7, 8, 9; el. 500–800; 0.5 mile west of Hoosick Falls	1.8 miles long, 700 feet thick	Underlain by Walloomsac slate, overlain by thin slices or clasts of Taconic Sequence and by Austin Glen Graywacke; contacts between plate and matrix exposed locally; isoclinal folding in block
13.	Limestone and dolostone (Synclinorium Sequence)	G-9, el. 820 to 850 on east slope; 0.9 mile S 25° W from Sch. No. 14	two lenses up to 80′ thick, over distance of 0.4 mile	Poorly defined platy blocks; underlain by Whipstock Breccia, overlain by Austin Glen Graywacke; 0–40′ below North Petersburg thrust
14.	Dolostone (Synclinorium Sequence)	I-13; el. 800; 0.41 mile N 63° W from B.M. 483, North Petersburg	7 X 10 X 15	Well defined block in Walloomsac slate immediately beneath North Petersburg thrust
15.	Volcanic rock (Taconic Sequence) ?	K-7; el. 900; 200 feet northeast of intersection 897	100 X 50	Surrounded by Whipstock Breccia which contains lenses of black slate and Austin Glen Graywacke
16.	Dolomitic limestone (Synclinorium Sequence)	L-5; el. 760; 100 feet northwest of state line monument No. 26	25 X 25	Surrounded by Walloomsac slate

Appendix 3

SELECTED LOCALITIES WHERE NORTH PETERSBURG THRUST FAULT AND RENSSELAER PLATEAU THRUST FAULT ARE WELL EXPOSED

Exposures of the North Petersburg Thrust

1. North Petersburg: (I-13), at elevation 800 feet on steep wooded slope, 2,000 feet N 60° W from intersection of N.Y. Routes 22 and 346. About 10 feet below thrust on talus-covered slope is Walloomsac slate enclosing a large submarine slide block (no. 14) of dolostone from Synclinorium Sequence; slates immediately above the thrust are sheared and mylonitized; lower 50 feet of thrust sheet consists, in descending order, of thin quartzites in dark slate (Hatch Hill), ribbon limestone and thin-bedded quartzite (White Creek Member of Poultney), laminated slates (Owl Kill Member of Poultney).

2. North Petersburg: (I-12), at elevation 600 to 700 feet, 1 mile N 14° W from intersection of N.Y. Routes 22 and 346. On steep slope, Synclinorium carbonates exposed immediately beneath thrust with Walloomsac slate structurally beneath the carbonates near road level; above thrust are Poultney and Hatch Hill Formations in core of recumbent syncline (rs-1).

3. Indian Hill: (J-11), at elevation 700 to 800 feet, about 1.2 miles N 25° E from Petersburg Junction. Below thrust are Synclinorium carbonates; above thrust is inverted section of Normanskill and Poultney Formations.

4. Hoosick Falls: (G-8, 9), at elevation 800 feet in small streambed, 0.6 miles S 50° W from School 14. Below thrust is Austin Glen Graywacke Member of Walloomsac; thrust zone is silicified, and drag folds (fig. 37) suggest east over west movement; above thrust is Poultney Formation.

Exposures of the Rensselaer Plateau Thrust

1. Babcock Lake: (F-13), elevation 1,200 feet, 1.4 miles south of Potter Hill and about 1,000 feet northwest of road. Below thrust in semi-open terrain are two large slices of limestone and dolostone of Synclinorium carbonates which rest on purple and green middle Mettawee slate; locally in this slate there are small boudins or slices of Rensselaer Graywacke. Thrust contact is at base of steep slope south of carbonate slices; fault plane not exposed, but graywacke on steep slope is sheared and its foliation is discordant to general trace of thrust.

2. Head of Church Hollow: (H-14), elevation 1,420 feet, 1.8 miles S 55° W from North Petersburg. This locality is reached most easily by dirt road along spur from the north. Thrust plane is marked by numerous slices of dolostone and limestone of the Synclinorium carbonates, some of which have apparently been kneaded into underlying slates; above thrust plane is highly sheared graywacke, and purple and green phyllite of the middle Mettawee; epidote is fairly common in the thrust zone; minor thrust faults in the lower part of the Rensselaer Plateau sheet dip gently northwest, and drag folds indicate movement on them has been an overthrust from the east-southeast. This is Balk's (1953, p. 820) Locality 9.

3. Spur north of Prosser Hollow: (I-15), elevation 1,070 feet, 2.06 miles due south of B. M. 483 at North Petersburg: this point is just south of the truncation of the trace of the inverted North Petersburg thrust by the Rensselaer Plateau thrust. The Rensselaer Plateau thrust plane, at the base of the steep slope, is marked by slices (fig. 41) of brecciated dolostone as much as 8 feet long and 2 feet thick. Above the sole of the thrust, through a vertical distance of 300 feet, the graywacke is intensely sheared and highly foliated. Beneath the thrust the dark gray-black slates may be the Hatch Hill in the North Petersburg sheet or Whipstock Breccia.

4. Spur southeast of North Petersburg: (I-14), elevation 1,100 feet, 1.1 miles S 22° E from B. M. 483 at North Petersburg. This locality is 600 to 800 feet south of the truncation of the trace of the North Petersburg thrust by the Rensselaer Plateau thrust. The sole of the Rensselaer Plateau thrust is marked by thin slices of Synclinorium carbonates, one of which is 3 feet long and 3 inches thick. The graywacke above the thrust has been sheared through a vertical distance of more than 100 feet. Below the thrust, on the talus-covered slope, is Whipstock Breccia enclosing clasts of carbonate rock; elevation 1,030 feet marks the top of a continuous sequence of the Synclinorium carbonates.

5. West Shoulder of Mount Anthony: (L-11), elevation 1,520 feet, 0.96 miles S 61° E from intersection 802 on west side of Breese Hollow. Locality is accessible by farm road, pasture, and log road from farm in center of valley. Thrust is exposed on south slope of spur extending west from main shoulder of mountain. The thrust fault is clearly exposed and exhibits several overturned or isoclinal folds (fig. 8). Below thrust plane is a thick sequence of Synclinorium carbonates, thinly cleaved near the contact. Above the thrust is dark gray, sheared, and foliated graywacke with thin seams of granular quartz. This is Balk's (1953, p. 244) Locality 25. Four hundred feet northeast of the thrust contact just described, limestone and dolostone slices are faulted up into the thrust sheet along faults parallel to the foliation.

Appendix 4

FOSSIL LOCALITIES IN THE HOOSICK FALLS AREA

Localities from which identifiable collections were made are shown on plate I with an Ⓕ and the station number. Where fossils have been found but not identified, the locality is simply denoted by an Ⓕ. Station and specimen numbers are given in the following tabulations to aid further study of this material which is stored in the New York State Museum, Albany, New York.

FOSSILS FROM THE WEST CASTLETON AND NASSAU FORMATIONS (EARLY CAMBRIAN)

Early Cambrian fossils come from the West Castleton Formation and from the upper Mettawee slates in the Nassau Formation and, with the exception of the brachiopods (Sample EB-125), all fossils come from lenses or beds of limestone. Generally, fossils are not seen on weathered surfaces, and the limestone must be broken to expose them. George Theokritoff (Personal communication, August 3, 1965) has provisionally identified all the following collections with the exception of EB-125 which was identified by Robert C. Ramsdell (Personal communication, August 9, 1959).

Station Number	Specimen number and fauna	Location, geologic setting, remarks
1	EB–145: *Hyolithellus* sp.? *Kootenia* sp.? eodiscid *Serrodiscus* aff. *bellimarginatus* *Fordaspis*? sp. This is also Bonham's (1950, p. 104) Locality F from which he reports: *Discinella* fragments of *Olenellus* calcareous algae	(G-1), 200 feet south of north edge of Eagle Bridge Quad., 150 feet east of Rt. 22: West Castleton here includes about 50 feet of medium and dark gray slate with beds and lenses of lms. cgl. and lms. of various colors and textures. Fossils from dark gray lms. lenses.
14	HF–36: *Serrodiscus* sp. This is the area of two of Prindle's localities (Lochman, 1956, p. 1342): Locality 10P59, No. 453, "about 1½ miles north of Center White Creek and 350 feet east of road": Hexactinellid sponge spicules *Fordaspis nana* (Ford) *Calodiscus lobatus* (Hall) *Serrodiscus speciosus* (Ford) *Hyolithellus micans* (Billings) The second Prindle locality is: 10P51 No. 418, "east side of slate pond about 1½ miles north of Center White Creek": *Elliptocephala* sp. *Hyolithellus micans* (Billings) *Helcionella subruqosa* (d'Orbigny) *Fordilla troyensis* (Walcott) *Botsfordia caelata* (Hall) *Calodiscus lobatus* (Hall)	(G-1), elevation 550 feet, 1.5 miles north of Center White Creek, 1,000 feet east of Rt. 22: sample from dark gray lms. lens in West Castleton dark gray slate. Same setting as Station 1.

Station Number		Specimen number and fauna	Location, geologic setting, remarks
15	HF–37A:	*Serrodiscus* ? sp. ident.	(G-2), elevation 570 feet, 0.34 mile N 26° E from church at Center White Creek: from lms. in thick sequence of ribbon lms. and dolostone in core of recumbent anticline (ra-1).
56–K	NP–68:	*Kootenia* or *Bonnia*?	(I-12), elevation 740 feet, on steep wooded slope 0.94 mile N 22° W from B.M. 483 at North Petersburg: at west edge of poorly defined mass of lms. and dark gray slate (West Castleton), a digitation in inverted limb of recumbent anticline (ra-2); fossils from calcarenite.
60	HF–67:	*Serrodiscus* cf. *speciosus* olenellid fragments	(I-3), Hill 760, 0.8 mile S 64° E from intersection 528 at Post Corners: 250 ft. section of shaly limestone, interbedded dolostone and lms., lms. with dolostone partings resting on Bomoseen and dipping north right-side-up.

This is also Bonham's (1950, p. 104) Locality A from which he reports:

Olenellus
Eodiscus (*Serrodiscus*) *speciosus* (Ford)
Eodiscus (*Eodiscus*) *lobatus* (Hall)
brachiopods
? gastropod

This is also Prindle's (Lochman, 1956, p. 1342) " Hill southeast of Post Corners ":

Serrodiscus speciosus (Ford)
Obolella sp.
Hyolithellus micans (Billings)

Lochman (p. 1339) made two collections from Station 60:

Y–6: *Botsfordia caelata* (Hall)
Hyolithellus micans (Billings)
Hexactinellid sponge spicules
Indiana dermatoides (Walcott)
Helcionella subruqosa (d'Orbigny)
Elliptocephala asaphoides (Emmons)
Serrodiscus speciosus (Ford)
Calodiscus lobatus (Hall)

Station Number		Specimen number and fauna	Location, geologic setting, remarks
60 (contd.)	Y–9:	cf. *Ptychoparella* sp. *Hyolithellus micans* (Billings) *Elliptocephala asaphoides* (Emmons) *Serrodiscus speciosus* (Ford)	
62	HF–69:	olenellid fragments This is probably Prindle's (Lochman 1956, p. 1342) locality 10P55 No. 429½, " 1.5 miles southeast of Post Corners ": *Serrodiscus speciosus* (Ford) *Hyolithellus micans* (Billings) *Elliptocephala* sp.	(I-4), elevation 700 feet, wooded hill 1.4 miles S 40° E from intersection 528 at Post Corners; fossils from dark gray argillaceous calcarenite associated with dolostone in Mettawee slate.
66	HF–78: HF–81:	*Hyolithes* sp. *Helcionella* sp. olenellid fragments This hill is Prindle's (Lochman p. 1342) locality P7 No. 67 " hill 1 mile northwest of North Hoosick ": *Elliptocephala asaphoides* (Emmons) *Calodiscus lobatus* (Hall) *Helcionella subruqosa* (d'Orbigny) *Hyolithellus micans* (Billings) *Obolella crassa* (Hall) cf. *Scenella retusa* (Ford)	(H-5), Hill 1000, 1.1 miles N 35° W from North Hoosick, at North Hoosick Klippe: fossiliferous limestone lenses in medium and dark gray calcareous slate of the West Castleton, which also contains lenses of graywacke phase of Mudd Pond; HF-78 from elevation 690 feet on south slope; HF-81 from elevation 940 feet, south of crest.
107	EB–18A: EB–18B:	olenellid frag. *Hyolithes* sp. olenellid frag. cephalon *Calodiscus* sp. This is undoubtedly Prindle's station 12P100 (Lochman, 1956, p. 1342), "half a mile southeast of Eagle Bridge": cf. *Ptychoparella* sp. *Elliptocephala* sp. *Helcionella subruqosa* (d'Orbigny)	(F-5), crest of 720 hill, 0.7 mile S 41° E from B. M. 414 at Eagle Bridge: fossils from lms. cgl. in gray slate which is interbedded with graywacke phase of Mudd Pond and calcareous quartzite just above upper Mettawee on east limb of Eagle Bridge syncline. Lms. cgl. consists of medium gray lms. pebbles in a dark gray lms. matrix. EB-18A comes from top of hill at closed 720 contour; EB-18B comes from same bed 100 feet down slope to northwest.
117	EB–23:	*Hyolithes* sp. olenellid frag. with reticulate ornament *Pelagiella* cf. *primaeva*	(E-5), elevation 840 feet on slope in field, 1.3 miles S 20° W from B.M. 414 at Eagle Bridge: lenses of dark gray fine grained lms. and calcarenite in gray siltstone of the West Castleton. Fossils from bluish-gray calcarenite.

Station Number		Specimen number and fauna	Location, geologic setting, remarks
122	EB–27:	*Serrodiscus speciosus* *Fordaspis* sp. *Calodiscus lobatus* olenellid frag.	(E-5), elevation 860 feet, 1.2 miles S 27° W from B.M. 414 at Eagle Bridge: dip slope of lms. cgl. (West Castleton) consisting of pebbles of fine-grained lms., dolostone, chert, and slate, in calcarenite matrix. Fossils from matrix.
124	HF–139A:	olenellid fragments with reticulate pattern	(H-2), elevation 1,030 feet, on wooded spur, 0.86 mile N 16° E from intersection 528 at Post Corners: fossils from lenses of lms. in punk, black dolomitic slate (West Castleton) underlying Bomoseen which marks core of recumbent anticline (ra-2).

Two other fossil localities have been found by Prindle (Lochman, p. 1342), and one by Bonham (1950, p. 105) in this recumbent anticline. Prindle's localities are: 10P No. 414 " about 1.25 miles north of Post Corners ":

Fordaspis nana (Ford)

10P47 No. 402 " about 1 mile northeast of Post Corners ":

Elliptecephala asaphoides (Emmons)

Bonham's Locality I is " 1.2 miles N 5° W from Post Corners ":

Discniella
Eodiscus
Olenellid fragment

Station Number		Specimen number and fauna	Location, geologic setting, remarks
126 and 127	EB–28: EB–29:	*Kootenia* or *Bonnia*? *Kootenia* sp.	(D-6), Station 126 (EB-28) is in a field at elevation 590 feet, 1.76 miles N 4° W from intersection 530 at West Hoosick. Station 127 (EB-29) is 400 feet northeast along strike from Station 126: fossils from calcarenite lenses associated with lenses of fine-grained lms. in medium gray slate. Purple slate (upper Mettawee), and dark gray slate (West Castleton) underlie fossiliferous horizon. Dark gray slates are dominant above; this is interpreted to be an interfingering of upper Mettawee and West Castleton, the latter being dominant.
128	EB–30:	*Kootenia* or *Bonnia* sp. pelecypod ?	(E-6), elevation 690 feet, in field 300 feet south of road, 1.64 miles N 24° E from intersection 530 at West Hoosick: fossils from dark gray lms. pebbles of a lms. cgl. which occurs in greenish gray silty (upper Mettawee) slate; Mettawee appears to be interfingering with West Castleton.

Station Number	Specimen number and fauna	Location, geologic setting, remarks
133	EB–31: *Serrodiscus* sp.	(E-6), elevation 720 feet, 200 feet north of road in field, 1.9 miles S 20° W from B.M. 414 at Eagle Bridge. Lenses of dark gray, fine-grained lms. in dark gray slate of the West Castleton.
136	G–3: olenellid cephalon (fragment) *Serrodiscus speciosus* *Serrodiscus* was also reported by Lochman (p. 1342) from Prindle's locality 10P9 No. 134 " about $2\frac{1}{2}$ miles southwest of Hoosick Falls, New York." This is probably the same locality as Station 136.	(F-9), elevation 1,120 feet, 0.94 mile S 81° E from intersection 840 at Southwest Hoosick: fossils from thin-bedded, lenticular, light gray to buff-weathering lms. in West Castleton dark gray calcareous slate; closely associated with maroon slate and Mudd Pond Quartzite.
179	EB–44: *Hyolithes* sp.	(E-7), elevation 920 feet, 100 feet southwest of crest of hill 935, 1.26 miles N 42° E from intersection 530 at West Hoosick: 1-foot lenses of fine grained lms. containing fossiliferous calcarenite zones; lms. set in greenish gray silty argillite and closely associated with purple slate (all upper Mettawee) which is interbedded with graywacke phase of Mudd Pond, and West Castleton.
284	EB–125: *Botsfordia caelata*	(C-1), elevation 720 feet, low outcrops on northeast side of road, 0.52 mile S 48° E from intersection 601 at Center Cambridge: brachiopods from black slate interlaminated with greenish-gray slate which underlies graywacke phase of Mudd Pond, and lms. lenses on inverted limb of anticline. All slate lithologies are West Castleton.
289	This is the area of Prindle's locality 10P44 No. 376 " about $\frac{3}{4}$ mile west of Center Cambridge, New York." Lochman (1956, p. 1342) reports the following: *Obolella crassa* (Hall) *Hyolithellus micans* (Billings) *Acrotreta taconica* (Walcott)	(B-1), elevation 680 feet, on small knob 0.66 mile S 85° W from intersection 601 at Center Cambridge: rocks here are West Castleton medium gray argillite containing beds of calcarenite and graywacke; brachiopods are seen on weathered surface of the calcarenite.

Four of Prindle's localities (Lochman, p. 1342), not located in the present study, are here noted and discussed: (1) 10P90 No. 60 " about three quarters of a mile north of Eagle Bridge." This is an area of limestone lenses in dark gray slate associated with graywacke phase of Mudd Pond and it is very likely that thorough search here would yield fossils. (2) 10P80 No. 552 " about $2\frac{1}{3}$ miles northeast of Post Corners." The graywacke phase of Mudd Pond in dark gray slate occurs on a spur (J-1) at this general locality and it seems likely that fossiliferous limestone lenses might also occur here. (3) P-13 " about half a mile northwest of Petersburg, New York." Exposed here are middle Mettawee slates and it seems unlikely there is a fossil locality on this hill. It seems more likely that fossils were found 0.5 mile northwest of North Petersburg on the spur southeast of crest 1123. (4) " West side of Moon Hill, about 1 mile north of Petersburg, New York " — also Lochman's locality Y7. West Castleton dark gray slate and limestone lenses were found on the lower slopes of Moon Hill and Odell Hill in the present study and it is regrettable that the author was not able to pinpoint Prindle's important locality.

Several fossil localities from which identifiable collections were not made are shown by an F on plate I. These may warrant further examination: (G-10) elevation 1,140 feet south of Pine Valley and 1.8 miles S 75° W from Hoosick, N.Y.: green to medium gray and purple slate (upper Mettawee) with lenses up to 5 inches long of limestone conglomerate: fossils from pebbles in limestone.

(E-5), elevation 600 feet in small stream cut 0.8 mile S 42° W from B.M. 414 at Eagle Bridge: lenses and thin beds of fossiliferous dark gray fine grained limestone in soft black slate (West Castleton).

(E-4), elevation 460 feet, 0.5 mile S 57° W from B.M. 414 at Eagle Bridge: numerous float blocks of fossiliferous bluish gray-weathering limestone in area of West Castleton slate and graywacke phase of Mudd Pond.

(E-1), elevation 680 feet, in woods 150 feet east of powerline, 0.6 mile N 58° W from west end of Thurber Pond: fossils from float of brownish-weathering limestone; bedrock is West Castleton gray slate and graywacke phase of Mudd Pond.

(F-1), elevation 690 feet, at north edge of Eagle Bridge Quadrangle and 0.2 mile west of road: abundant limestone lenses in medium gray slate of the West Castleton; fossils most abundant in calcarenite.

POULTNEY AND NORMANSKILL FORMATIONS

The only fossils found in these formations in the present study were graptolites and these occur almost exclusively in black slate. Identifications and age assignments have been made by William B. N. Berry (Personal communication, November 28, 1960), and the zone names and numbers are after Berry (1960, 1961, 1962, 1963).

FOSSILS OF THE POULTNEY FORMATION (EARLY ORDOVICIAN)

Station Number	Specimen number, fauna, age		Location, geologic setting, remarks
26	HF–44:	*Didymograptus extensus* (Hall) ? *Tetragraptus fruticosus* (4-branched form) (Hall) T. *pendens* (Elles)	(H-1), crest of Hill 1520, 1.8 miles N 20° E of intersection 528 at Post Corners: exposures made by excavation for radar site; graptolites from 3-foot black pyritiferous slate which is interbedded with laminated medium and dark gray slate, green-gray slate with chip texture, 3-foot bed of dolostone, and dark gray laminated slate; bulk of these lithologies is typical of the Owl Kill Member of the Poultney. Specimen No. HF-44A comes from exposure 25′ west and 10 feet south of location for HF-44.
	Age:	Probably zone 4 — *Tetragraptus fruticosus* (4 branch form)	
	HF–44A:	*Clonograptus* sp. *Didymograptus extensus* (Hall) *D. nicholsoni planus* Elles and Wood *D. patulus* (Hall) *Tetragraptus pendens* Elles *T. quadribrachiatus* (Hall)	
	Age:	Zone 4 — *Tetragraptus fruticosus* (4-branched form)	

FOSSILS FROM THE NORMANSKILL FORMATION (MIDDLE ORDOVICIAN)

Station Number	Specimen number, fauna, age		Location, geologic setting, remarks
19	HF–38:	*Amplexograptus perexcavatus* (Lapworth)? *Climacograptus bicornis* (Hall) *C. modestus* Ruedemann *C. phyllophorus Gurley* *Corynoides* sp. *Dicellograptus gurleyi* Lapworth? *D. sextans perexilis* Ruedemann *Dicranograptus ramosus* (Hall) *Didymograptus sagitticaulis* Gurley *Glyptograptus teretiusculus* (Hisinger) *Nemagraptus exilis linearus* Ruedemann *N. gracilis* (Hall)	(G-2), elevation 560 feet at edge of woods, 1.18 miles N 42° W of intersection 528 at Post Corners: from 10 foot black slate bed lying immediately west of vertically-dipping Austin Glen Graywacke at the core of recumbent syncline (rs-1).
	Age:	Zone 12 — *Climacograptus bicornis*	
	This is Bonham's (1950, p. 104) Locality D from which he records:	*Nemagraptus gracilis* *Dicranograptus furcatus* (Hall) *D. furcatus exilis,* cf. *D. ramosus* (Hall) ? *D. nicholsoni* *Climacograptus* sp. *Diplograptus* sp. *Dicellograptus sextans* (Hall)	
76	HF–90:	*Climacograptus bicornis* (Hall) *C. modestus Ruedemann* ? *C. phyllophorus* Gurley *Dicellograptus* sp. *Dicranograptus furcatus* (Hall) *D. nicholsoni diapson* Gurley ? *D. ramosus* (Hall) *Didymograptus sagitticaulis* Gurley *Glyptograptus teretiusculus* (Hisinger)? *Orthograptus calcaratus,* var.	(H-2), elevation 740 feet, large outcrop in field 0.66 mile N 7° W from intersection 528 at Post Corners: graptolites from black pyritiferous slate which overlies thin-bedded chert (Mount Merino) and Austin Glen Graywacke in inverted section at core of recumbent syncline (rs-2).
	Age:	Zone 12 — *Climacograptus bicornis*	
111	EB–19:	*Climacograptus phyllophorus* Gurley *Cryptograptus tricornis* (Carruthers) *Dicellograptus sextans* (Hall) *Dicranograptus furcatus* (Hall) *D. contortus* Ruedemann *D. ramosus* (Hall) *Didymograptus sagitticaulis* Gurley *Glyptograptus teretiusculus* (Hisinger)	(F-5), elevation 540 feet, in woods about 150 feet west of road, 0.4 mile south of B.M. 414 at Eagle Bridge: graptolites from a small outcrop of black slate on slope below exposure of Indian River red slate.

Station Number	Specimen number, fauna, age		Location, geologic setting, remarks	
		Nemagraptus exilis (Lapworth) ? *Orthograptus calcaratus acutus* (Lapworth)		
	Age:	Zone 12 — *Climacograptus bicornis*		
159	EB–42:	*Climacograptus bicornis* (Hall) *C. eximius* Ruedemann *C. modestus* Ruedemann *C. phyllophorus* Gurley *Cryptograptus* ? sp. *Dicellograptus intortus* Lapworth ? *D. divaricatus salopiensis* *D. sextans* (Hall) *Dicranograptus ramosus* (Hall) *Didymograptus sagitticaulis* Gurley *Glyptograptus teretiusculus* (Hisinger) *Hallograptus bimucronatus* (Nicholson) *Nemagraptus exilis linearis* Ruedemann *Orthograptus calcaratus acutus* (Lapworth)	(E-7),	elevation 880 feet, on steep slope 200 feet west of road, 1.12 miles N 85° E of intersection 530 at West Hoosick: graptolites from sooty-black slate which lies on strike with Indian River red slate to the south and Mount Merino chert to the north. Austin Glen Graywacke lies beneath black slate, indicating an inverted sequence.
	Age:	Zone 12 — *Climacograptus bicornis*		
248	EB–69:	*Climacograptus bicornis* (Hall) *C. eximius* Ruedemann *C. phyllophorus* Gurley *Dicellograptus divaricatus* (Hall) *D. divaricatus salopiensis* Elles & Wood *D. sextans exilis* Elles & Wood *Dicranograptus furcatus* (Hall) *D. nicholsoni* var. *diapson* Gurley *D. ramosus* (Hall) *Didymograptus sagitticaulis* Gurley *Glyptograptus teretiusculus* (Hisinger) *Hallograptus bimucronatus* (Nicholson) *Nemagraptus exilis* (Lapworth) *Orthograptus calcaratus acutus* (Lapworth) *O. calcaratus incisus* (Lapworth)? worth) ? *Syndyograptus* ? sp.	(A-6),	1.60 miles N 38° W of East Pittstown, in field, south of road, at elevations 540 feet and 580 feet: graptolites from low outcrops of black rusty-weathering slate underlain by bedded chert (Mount Merino) and overlain by Austin Glen Graywacke; Newcomb Pond syncline.
	Age:	Zone 12 — *Climacograptus bicornis*		
260-P	B–J:	*Dicranograptus* sp. *Glyptograptus teretiusculus* (Hisinger) *Orthograptus calcaratus* ?	(F-3),	elevation 460 feet, 10 feet east of road, 1.34 miles N 19° E of B.M. 414 at Eagle Bridge: graptolites from black slate beneath Mount Merino chert at trough of Eagle Bridge syncline.
	Age:	Probably Zone 12 — *Climacograptus bicornis*		

Station Number	Specimen number, fauna, age	Location, geologic setting, remarks
	This is Bonham's (1950, p. 105) Locality J from which he described the following graptolites: *Dicranograptus furcatus* (Hall) *Climacograptus* *Dicellograptus mensurans* Ruedemann *D. foliaceous*	
297	EB–134: *Climacograptus phyllophorus* Gurley *C. scharenbergi* Lapworth *Cryptograptus tricornis* (Carruthers) *Dicellograptus divaricatus* (Hall) ? *D. gurleyi* Lapworth *D. sextans* (Hall) *Didymograptus sagitticaulis* Gurley *Glossograptus ciliatus* Emmons *G. hincksii* (Hopkinson) *Glyptograptus teretiusculus* (Hisinger) *Nemagraptus exilis* (Lapworth) *Retiograptus geinitzianus* Hall Age: Zone 12 — *Climacograptus bicornis*	(A-3), elevation 550 feet, in field, 0.88 mile S 88° W from South Cambridge: graptolites from black slate overlain by Mount Merino chert, and underlain by Austin Glen Graywacke. Sequence dips east and is inverted.
298	EB–135: *Climacograptus bicornis* (Hall) *C. eximius* Ruedemann *C. phyllophorus* Gurley *C. scharenbergi* Lapworth *Corynoides calicularis* Nicholson *Corynoides incurvus* Hadding *Cryptograptus tricornis* Ruedemann *Dicellograptus sextans* (Hall) *D. sextans exilis* Elles & Wood *Didymograptus sagitticaulis* Gurley *Dicranograptus ramosus* (Hall) *Glossograptus hincksii* (Hopkinson) *Glyptograptus teretiusculus* (Hisinger) *G. euglyphus pygmaeus* (Ruedemann) *Hallograptus bimucronatus* (Nicholson) *H. mucronatus* (Hall) *Nemagraptus exilis linearis* Ruedemann *Orthograptus* ? sp. Age: Zone 12 — *Climacograptus bicornis*	(A-3), in woods 500 feet southeast of Station 297; same geologic setting: well preserved graptolites from heavy float of black slate.

Additional localities from which graptolites have been collected but not identified are marked by an Ⓕ on the Geologic Map and described below to aid future work.
(A-10), 0.41 and 0.76 mile north of intersection 567 and 200 feet west of road: associated with Mount Merino chert: graptolites poorly preserved in black slate.
(A-8), 0.42 mile west of the west end of Newcomb Pond and 800 feet north of outlet: heavy float of graptoliferous black slate and thin-bedded quartzite on west limb of Newcomb Pond syncline.
(A-7), 1.1 miles west of East Pittstown, 0.1 mile southwest of road, on small knob in field: graptolites in black slate interbeds in inverted section of Mount Merino chert. This is Bonham's (1950, p. 104) Locality E.
(A-7), two localities in same area as above, but north of road: one is a small knob in field 1,000 feet northeast of the road, the other about 2,000 feet northeast of the road at a small brook.
(A-6), 1.1 miles N 50° W from East Pittstown: poor outcrops of rusty-weathering black graptoliferous slate near base of hill on west side of draw.
(A-6), 1.52 miles N 36° W from East Pittstown: elevation 540 feet in field southeast of house.
(E-8), 1 mile northwest of Southwest Hoosick: on north (elevation 760 feet and 790 feet) and northeast (elevation 920 feet) slopes of Hill 965: in black slate closely associated with Mount Merino Chert and Indian River red slate. Entire section is inverted and in thrust contact with Poultney beneath.

SYNCLINORIUM CARBONATES

The material collected from these rocks is poorly preserved and, in many cases, not sufficiently diagnostic for stage assignments. Fossils are generally best seen on weathered surfaces of limestone. Identifications are made by G. A. Cooper, R. H. Flower, E. L. Yochelson (Personal communication from Cooper, December 1966, and by D. W. Fisher (Personal communication, October, 1959). Initials indicate person who made identification and age assignment. J. J. Thomas (1961) has added to the original collections from these stations and his material is incorporated in this report.

FOSSILS FROM THE SYNCLINORIUM CARBONATES (LATE CAMBRIAN, EARLY AND MIDDLE ORDOVICIAN)

Station Number		Specimen number, fauna, age	Location, geologic setting, remarks
7	NP–3:	Brachiopods cf. *Paurorthis sp.* Orthacean brachiopods Ostracods cf. *Leperditia* sp. Trilobites fragments Bryozoa trepostomatous bryozoan	(J-12), elevation 500 feet, at base of slope in field, 1,280 feet N 50° E from B.M. 473 at North Petersburg: low ledge of calcarenite in isoclinally folded section of limestone and dolostone.
	Age:	Post-Canadian (by D. W. F.)	
	NP–27:	Brachiopods *Nanorthis* or *Finkelnburgia*	At elevation 580 feet, 280 feet N 8° E from Station 7; fossils from a calcarenite bed.
	Age:	Early Ordovician (by G. A. C.)	

Station Number	Specimen number, fauna, age	Location, geologic setting, remarks
10	NP–49L: Brachiopods *Finkelnburgia* Gastropods Trilobites Age: Early Ordovician, possible Tribes Hill (by G. A. C.)	(I-11), east side of B & M railway tracks about 1 mile north of Petersburg Junction: undifferentiated sequence of massive dolostone, various types of limestone, and thin quartzites. NP-49L comes from calcarenite interbedded with sandy dolostone and intraformational limestone breccia, 0.98 mile north of B.M. 469. Prindle and Knopf (1932, p. 273) report trilobites from limestone at the approximate location of NP-49L, and assign these, provisionally, to Division B of Beekmantown.
	NP–9: Gastropods cf. *Helicotoma* Cephalopods *Michelinoceras* Age: Middle Ordovician (by E. L. Y. and R. H. F.)	NP-9 comes from a light gray calcilutite infolded with massive dolostone at base of cliff, 0.84 mile north of B.M. 469.
	NP–51: Brachiopod cf. *Lingulepsis acuminata* Age: Late Cambrian (by G. A. C.)	NP-51 comes from calcarenite bed at elevation 510 feet, 400 feet east of track on south slope of hill.
66	HF–49: Brachiopods Trilobites asaphid trilobite Age: Early Ordovician (by G. A. C.)	(G-9), abandoned quarry southwest of Hoosick Falls, in woods on west side of road 0.5 mile southwest of School No. 14: normal sequence of sandy limestone, calcareous quartzite, limestone, massive fetid dolostone, and limestone with blebs of dolostone. Fossils from base and top of section in quarry. Bonham (1950, p. 105, Locality M) dates these rocks as Beekmantown. Prindle and Knopf (1932, p. 273) assign trilobites in a " limestone quarry one mile south of Hoosick Falls " to the Division B of the Beekmantown. Carbonate rocks at this locality interpreted to be part of giant submarine slide block (No. 12).

Station Number	Specimen number, fauna, age	Location, geologic setting, remarks
84	HF–23: Gastropods *Helicotoma* Cephalopods *Michelinoceras* Brachiopods and Bryozoan Age: Middle Ordovician (by E. L. Y. and R. H. F.)	(G-6), elevation 780 feet, 300 feet northwest of closed 800 contour, 0.62 mile S 29° W from B.M. 406 at Hoosick Junction: interbedded orange-brown-weathering and buff-weathering dolostone and fossiliferous blue-gray-weathering lms., complexly folded and faulted; probably a giant submarine slide block (No. 8g). Station 84 is in the vicinity of Bonham's (1950, p. 106) Locality P, " 1.4 miles N 45° W from Hoosick Falls. Near northwest tip of 780-foot contour line, east of road . . . Ordovician (may be Middle Ordovician)."
89	HF–18: Brachiopods *Finkelnburgia* Age: Early Ordovician (by G. A. C.)	(G-6), elevation 770 feet, 0.34 mile S 44° W from B.M. 406 at Hoosick Junction: creamy-weathering dolostone and fossiliferous blue-gray limestone. Possible submarine slide block (No. 7).
90	EB–6: Gastropods *Gasconadia* or *Lophospira* Age: Probably Middle Ordovician (by E. L. Y.)	(G-6), small knob on south side of road, 0.7 mile S 72° W from B.M. 406 at Hoosick Junction: fossils from blue-gray limestone interbedded with thin beds of fine grained, dark gray dolostone. Whole mass is possibly a submarine slide block (No. 8a).
93	HF–27: Bryozoa *Pachydictya* *Hallopora* Brachiopods *Dinorthis* Age: Middle Ordovician (Trenton) (by G. A. C.)	(F-7), elevation 780 feet, 1.34 miles S 52° W from B.M. 406 at Hoosick Junction: fossils from low outcrop of dark gray argillaceous lms. in field at south edge of woods; and in field at east edge of woods, 1,400 feet N 25 E from intersection 728; interbedded with lms. is cream-weathering dark gray dolostone and blue-gray-weathering lms. with dark gray chert. Possible submarine slide block (No. 8c).

In addition to the localities noted above in the Hoosick Falls reentrant, there are two localities cited by Bonham (1950, p. 105) from which collections were not made in the present study. These localities are located by an F on plate I and quoted below to aid further study.

Bonham's locality K: (L-7), " 0.6 mile S 70° E from East Hoosick. In limestone west of road. Poor material. Ordovician (probably Middle Canadian). Identified by R. H. Flower."

Bonham's locality L: (M-7), " 1.5 miles S 82° E from East Hoosick. Knoll capped by 780-foot contour circle. In limestone. Ordovician (Upper Canadian-Fort Cassin). Cephalopods, crinoids. Identified by R. H. Flower."

FOSSILS FROM THE WALLOOMSAC FORMATION (MIDDLE ORDOVICIAN)

Station Number	Specimen number, fauna, age	Location, geologic setting, remarks
318	HF–16: *Climacograptus* ? sp. *Dicellograptus intortus* Lapworth *Glossograptus* ? sp. *Glyptograptus euglyphus* var. *pygmaeus* (Ruedemann) *Hallograptus* ? sp. Age: Probably zone 12 — *Climacograptus bicornis* (by W.B.N.B.)	(L-8), elevation 880 feet, on west slope of Whipstock Hill, 0.4 mile south of State line monument No. 21; graptolites from poorly exposed black slate which underlies a 10 to 30 foot section of gray chert. Chert is overlain by Whipstock Breccia.
329	HF–28: *Climacograptus bicornis* (Hall) *C.* sp. *Didymograptus sagitticaulis* Gurley *Glyptograptus* sp. Age: Zone 12 — *Climacograptus bicornis* (by W.B.N.B.)	(L-6), elevation 620 feet, in field, west bank of Walloomsac River, 1.6 miles N 18° E of intersection at East Hoosick: graptolites from black slate lense within dark gray Walloomsac slate.

Sample No. 30: (I–9), elevation 720 feet, abandoned quarry 0.85 mile N 7° W from Hoosick. This specimen was not collected in the present study but was loaned by the Department of Geology at Williams College so that Berry could examine the fauna which formerly had been called *Diplograptus foliaceous* (Prindle and Knopf, 1932, p. 274). Berry (Personal communication, November 28, 1960) reports the following: " Orthograptids of the *truncatus* and *calcaratus* groups. Probably *Orthograptus truncatus* var. *intermedius* (Elles and Wood) and *Orthograptus calcaratus* var. *acutus* (Lapworth) are present. The assemblage surely is that of the zone of *O. truncatus* var. *intermedius* and is Trenton in age."

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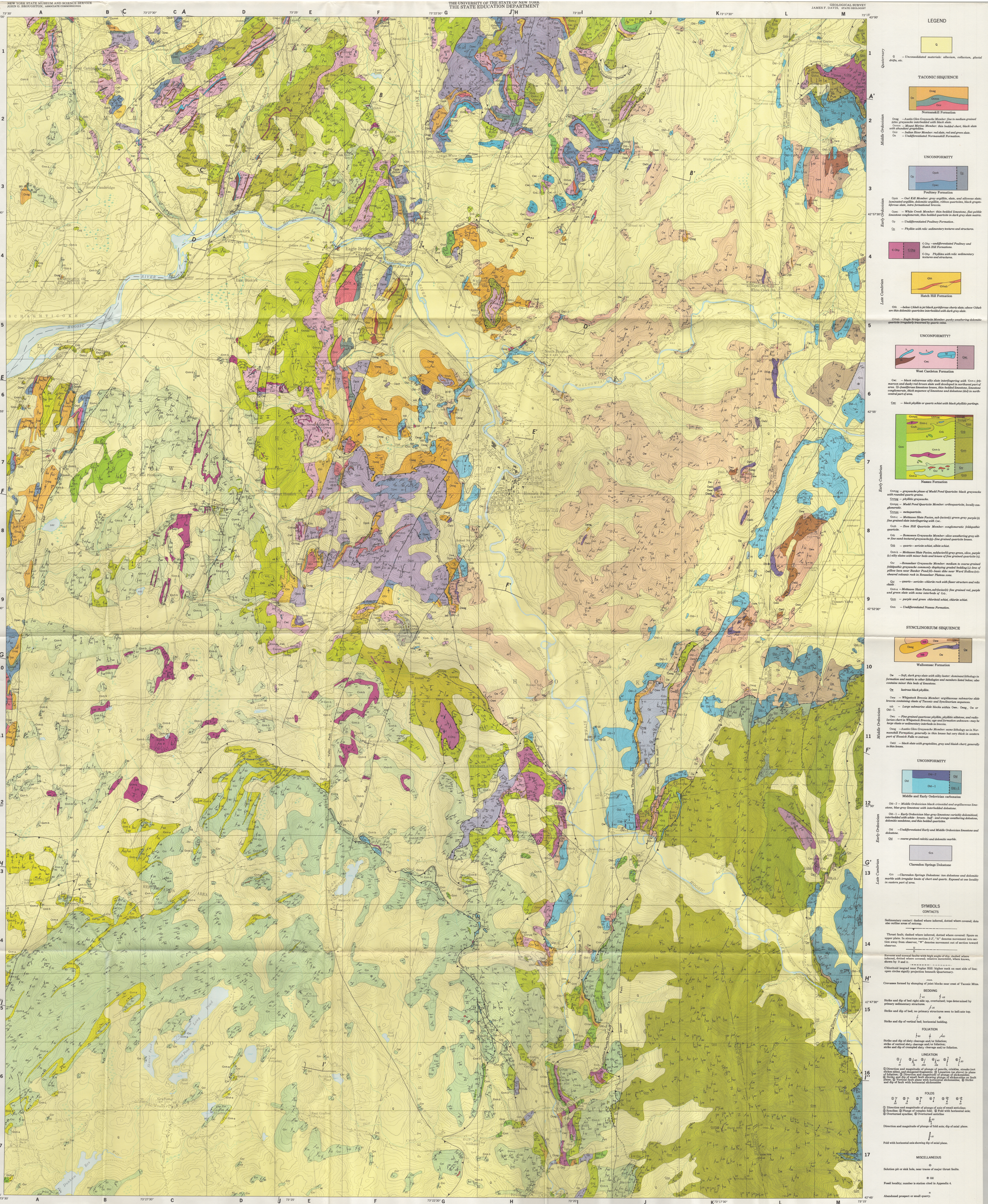

BEDROCK GEOLOGY OF THE HOOSICK FALLS AREA, NEW YORK AND VERMONT

By: Donald B. Potter

SCALE 1:24000

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

UTM GRID AND 1954 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

Mapped, edited, and published by the Geological Survey
Control by USGS and USC & GS
Topography from aerial photographs by multiplex methods
Aerial photographs taken 1942. Field Check 1943
Revised by planetable surveys 1954
Polyconic projection. 1927 North American datum

INDEX MAP: Eagle Bridge, Hoosick Falls, Grafton, North Pownal

New York State Museum and Science Service
Geological Survey, Map and Chart Series: No. 19
(1971)

Prepared by The National Survey, Chester, Vermont

NEW YORK
QUADRANGLE LOCATION

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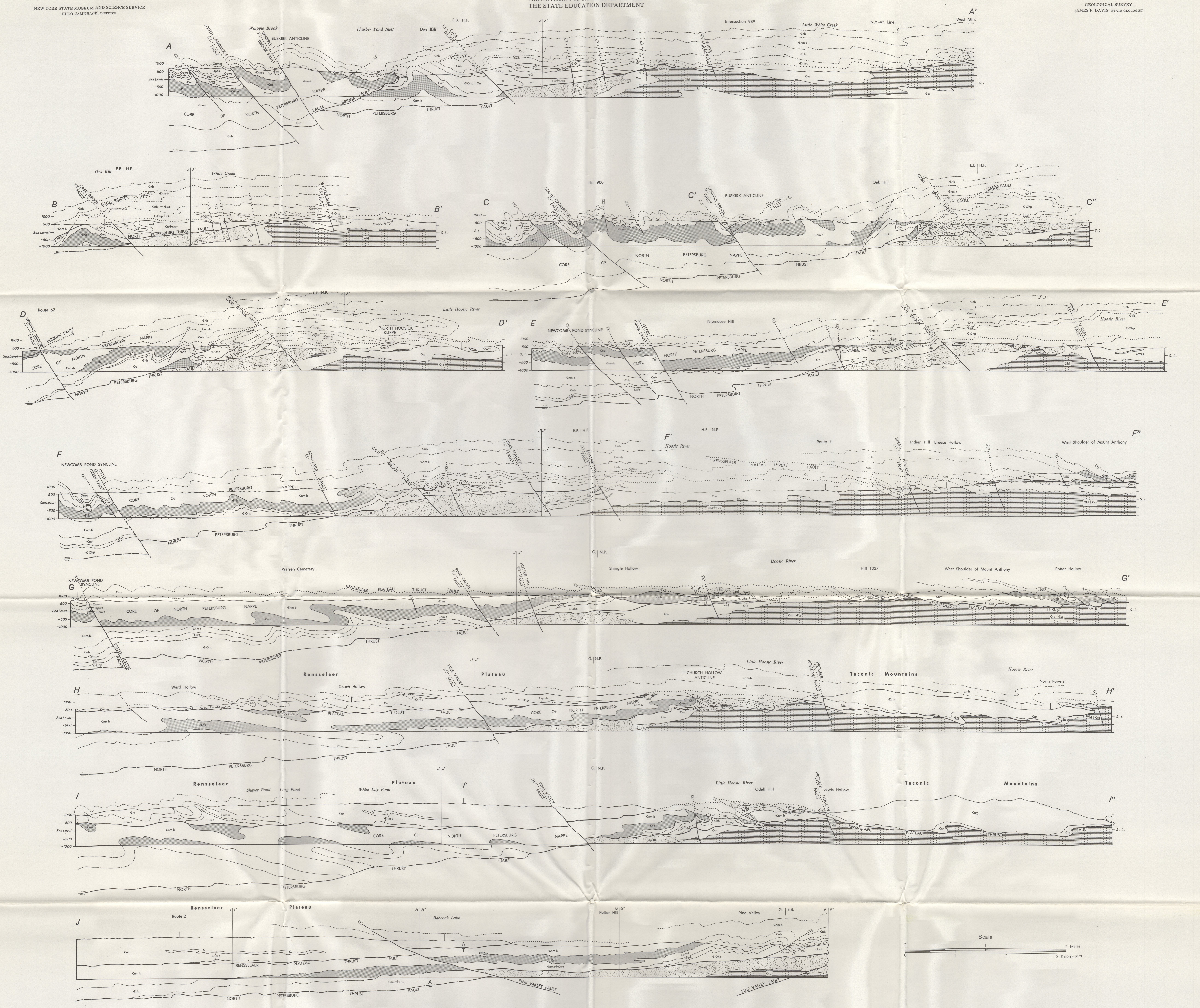

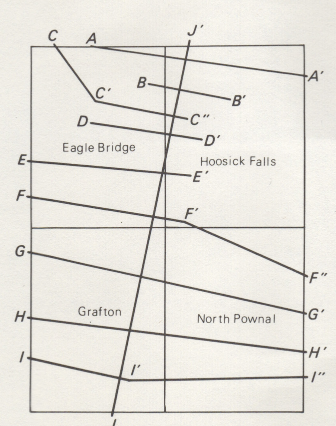
Location of cross-sections

Legend

A Relative movement away from observer
T Relative movement toward observer

QUADRANGLE ABBREVIATIONS
H.F. Hoosick Falls
E.B. Eagle Bridge
N.P. North Pownal
G. Grafton

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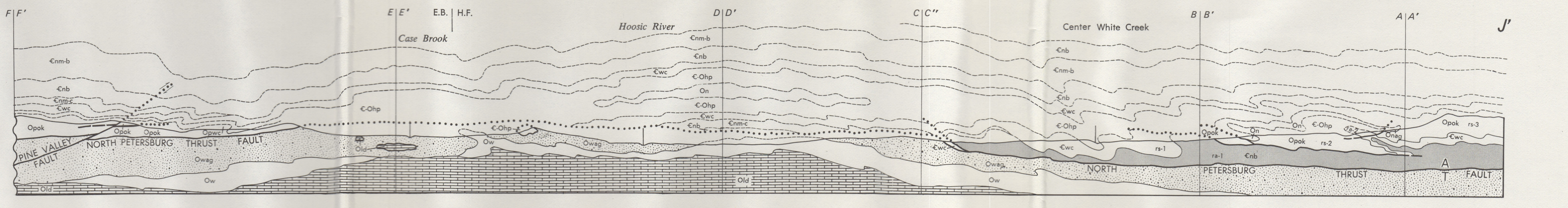

PLATE 2. STRUCTURAL CROSS-SECTIONS OF THE HOOSICK FALLS AREA, NEW YORK AND VERMONT

Donald B. Potter