DE STRATORVM ORDINE, TERRAE GEOLOGICA FORMA, SEDIMENTORVM DEPOSITIONIS MODO ATQVE FOSSILIVM NATVRA IN PARTE AVSTRALIS REGIONIS TACONICAE IN NOVO EBORACO


MCMLXIII

STRATIGRAPHY, STRUCTURE, SEDIMENTATION AND PALEONTOLOGY OF THE SOUTHERN TACONIC REGION, EASTERN NEW YORK

Guidebook for
Field Trip Three
Geological Society of America
1963 Annual Meeting in New York City

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page 24, last line: of species
page 33, under Dale, 1923: delete 747, add 744, 71 p.
page 34, under Dzulynski: Kuenen, Ph. H., -- Carpathian
page 36, Rodgers, John: delete whole reference
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page 40, par. 2, line 7: heralded
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page 46, par. 5, line 4: change Early to Lower
page 47, Mileage: change 81.4 to 78.0
change 86.6 to 79.2
change 92.0 to 79.4
page 48, par. 1, line 1: change not noticeable to noticeably (delete not)
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INTRODUCTION

John M. Bird

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The belt of rocks geologically known as the Taconics extends from Sudbury, Vermont southward to the proximity of Poughkeepsie, New York, between the Hudson River Valley and the Adirondack Mountains on the west and the Green Mountains and Berkshire Mountains on the east (Plate 2). The Taconic Mountains are the range of high hills within this belt. The Taconic stratigraphic section is composed primarily of argillaceous and arenaceous rocks. It is herein referred to as the Taconic sequence to distinguish it from the carbonates and quartzites which more or less surround the Taconic belt. This carbonate and quartzite sequence is well exposed in the Middlebury synclinorium and is referred to as the synclinorium sequence in this guidebook.

The rocks in this belt have undergone at least two episodes of deformation and are severely deformed. Rock exposure is locally sparse in this glaciated region and fossils are uncommon. Stratigraphic differentiation is also difficult because of lithologic similarities between younger and older rocks.

Initial geologic investigations in the Taconics, which commenced with Chester Dewey's and Amos Eaton's work early in the 19th Century and culminated in the first "Taconic controversy" of the late 19th Century, have been summarized by Merrill (1924). The controversy was primarily the relative ages of the rocks of the region. Emmons (1842) proposed the Taconic System to include the clastic rocks of the Taconic belt and, because of his discovery of Olenellid trilobites (Elliptocephala asaphoides and Atops trilineatus) in black shale in Washington County (Emmons, 1849), maintained the system to be Early Cambrian and correlative with Sedwick's Early Cambrian of Great Britain. Walcott's (1888) discovery of Trenton fossils at Bald Mountain (fossils not within part of the Taconic sequence as used herein) finally resolved the controversy with the result that both Emmons and his opponents, notably Hall, Lyell and Dana, were both partially correct. The Taconic sequence does indeed contain both Cambrian and Ordocician rocks, as does the sequence in the Middlebury synclinorium.

A second Taconic controversy began when Ulrich (1902) proposed that the Taconic sequence clastic rocks and the surrounding synclinorium sequence of carbonates and quartzites were deposited in separate basins because of their pronounced lithologic differences and the supposed distinctness of their faunas (the Atlantic and Pacific faunal provinces respectively). The carbonates and quartzites were believed to have been deposited in the western Chazy trough, and the argillaceous and arenaceous Taconic sequence rocks to have been deposited in the eastern Levis trough. Ulrich (1911) suggested that the argillaceous rocks were thrust westward over the carbonate rocks, a theory apparently first proposed by Ruedemann (1909) although implied by Ulrich's (1902) two basin idea. Field evidence supporting this hypothesis was presented by Keith:

> "Inasmuch as the divisions of the Ordovician Stockbridge limestone in this area dip under the shales known to be Cambrian and these in

turn dip and pitch away from the limestones, and inasmuch as the limestones and slates are all unconformable with the general contact, an overthrust of the slates seems to be the only competent explanation of their relations." (Keith, 1913, p. 680).

This evidence was later found to be invalid (Cady, 1945, p. 569). Lochman's (1956) work on the faunas indicates their distribution to be ecologically controlled and not the result of separate basins of deposition.

Ulrich's original requirement of two basins of deposition was found to be unnecessary (Ruedemann, 1914, p. 114) since it was realized that shale and limestone can be deposited together but the concept of overthrusting of the Taconic sequence from the east has been adopted by most subsequent workers in the northern portion of the Taconics. The root zone of the proposed Taconic klippe has not been found. It has been variously proposed to be along the belt that includes and parallels the Green Mountain axis (Zen, 1961), in the western part of the Magog trough, or even in the eastern part of the Magog trough in the vicinity of Boston (Keith, 1932; Kay, 1940; Hawkes, 1941). Location of the root zone within the Green Mountains requires a considerable foreshortening of the root zone basement after the mid-Ordovician deformation of the Taconic rocks. That the root zone cannot be placed east of the Green Mountains in the Magog trough sediments is now generally realized because the rocks synchronous with the Taconic sequence are still in that region. Also, the Magog rocks include thick sections of volcanics not found in the Taconic sequence (although otherwise the rocks are quite similar).

Zen (1961), who has presented an excellent summary of possible structural interpretations for the northern Taconics, deduces an alpine-like nappe structure of Taconic sequence rocks resting on the authochthonous carbonates of the Middlebury synclinorium in the Castleton, Vermont area. He (Zen, 1961) has distinguished structural and lithologic terminology for the Taconic region by using Taconic sequence and synclinorium sequence as lithologic descriptions and indicating that these sequences are not everywhere allochthonous and autochthonous respectively. Apparently there are both autochthonous and allochthonous structural groups composed of Taconic sequence rocks and although most of the synclinorium sequence is known to be authochthonous,some structural groups of these rocks are known to be allochthonous.

In recent years geologists have become more concerned with the middle and southern portions of the Taconic belt (see Rodgers, in Rodgers, et al., 1952, who outlined the problems of this area). It is among these workers that opposition to the overthrust hypothesis has persisted (Bucher, 1957; Craddock, 1958; Balk, 1955; Lochman, 1956; MacFadyen, 1957; Elam, 1960, Ph.D. thesis, Rensselaer Polytechnic Institute). Basically, these workers have adopted either a hypothesis of facies change between the carbonate sequence and the Taconic clastic rocks, as proposed by Dale (1899, 1904), or a hypothesis of non-deposition from Early Cambrian to Early Ordovician that utilizes regionally unconformable stratigraphic relationships (Bucher, 1957; Craddock, 1957). Hewitt (1961) has deduced a geologic history for the region invoking both facies changes and overthrusting which assumes the phyllites of the "high Taconics" to be post-early Trenton in age.

All practicing Taconic geologists recognize the presence of large-scale thrust faulting in the Taconic sequence rocks and the lack of a need for two basins of deposition. Also, most of them concur that the Middlebury synclinorium carbonate sequence and the Taconic clastic sequence are exactly age equivalent. The main question is: are the eastern carbonates, those exposed along the western side of the Green Mountain anticlinorium, continuous under the Taconic section with the age equivalent carbonates on the west side of the Taconics, or are the Taconic clastic rocks facies equivalents of the carbonates, resting structurally more or less in place between the carbonates?

The Taconic problem, then, is to decipher the structural and stratigraphic relationships of the two sequences of rock. Stratigraphic correlations of the Middlebury synclinorium sequence lithologies have been extended well south of the Middlebury synclinorium and the major stratigraphic units within the Taconic sequence have been correlated throughout the Taconics (see Zen, 1961, p. 298).

If the Taconic klippe hypothesis is valid, the zone of facies change between the synclinorium sequence and the Taconic sequence must have occurred east of the carbonate belt that now parallels the west side of the Green Mountain anticlinorium. It must have been subsequently destroyed, possibly by erosion, during the overthrusting. The Taconic sequence, therefore, must have been deposited in a depression lying along what is now the Green Mountain anticlinorium. Those who oppose this reconstruction of the geologic history, notably Lochman (1956) and Elam (1960, Ph.D. thesis, Rensselaer Polytechnic Institute), maintain that the Taconic sequence constitutes an essentially elongate belt made up of deep water sediments, the lateral shelf facies of which are the synclinorium sequence of carbonates that surround the Taconic belt. This hypothesis requires a rapid facies change (a concept invoked by Dale, 1904) with extensive and repeated sediment by-passing of the Taconic sequence clastic sediments over the shelf carbonates and sands.

Since there is now major agreement on the stratigraphic correlations within the Taconic sequence and within the synclinorium sequence (see Zen, in press), investigations concerned with establishing the structural, paleontologic and facies relationships between these two lithologic sequences should lead to a solution of the Taconic problem.

This guidebook and the field trip are for the purpose of presenting some new data and interpretations of the geology of the southern Taconic region. Obviously, all aspects of the rocks of the region can not be demonstrated. Likewise, review of the considerable efforts of all those geologists who have worked in the Taconics is not possible.

Zen's contribution is a regional synthesis and geologic history in terms of the klippe hypothesis based on new interpretations of some major structures and exotic lithologies. Berry's recent paleontologic work with the Ordovician rocks is presented. His information is crucial for dating the sedimentologic and penecontemporaneous tectonic events concomitant with the Taconic deformation. Bird's article presents aspects and interpretations of sedimentary structures attributed to density current deposition and submarine slumping. These structures, interpreted in terms of recent advances in our concepts of sedimentation, are providing new insight concerning the geologic history of the region. Potter's article, received after this guidebook was prepared, is a summary of his extensive and detailed study of an area in the central portion of the Taconic belt.

Acknowledgements

Priestly Toulmin III, a Latin scholar who wanted to remain anonymous, and artist Barbara Sepenuk are hereby thanked for their contribution of the cover design. The State University of New York at Albany provided funds and services which appreciably reduced the cost for this trip. A. S. Warthin helped in many ways with the arrangements for stops 9 and 10.

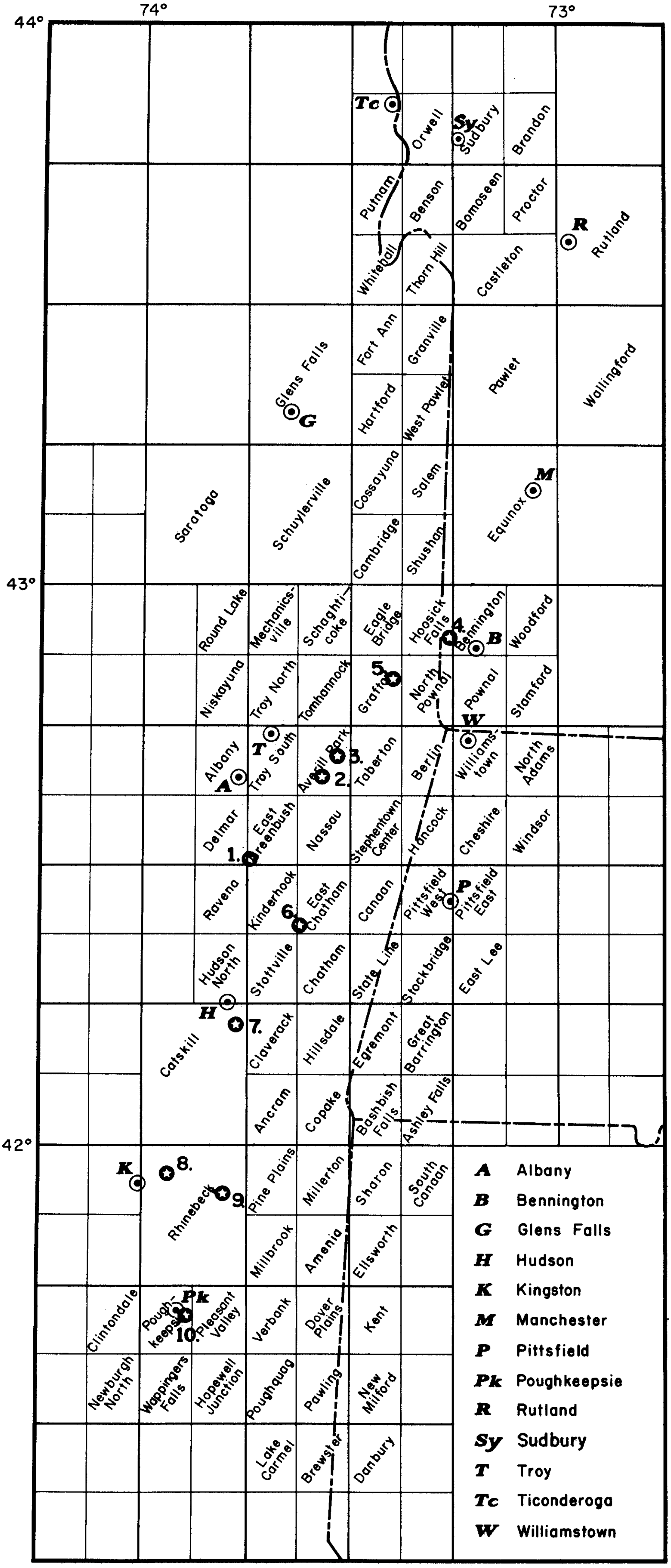

PLATE I

INDEX OF TOPOGRAPHIC QUADRANGLE MAPS
AND TRIP STOP LOCATIONS

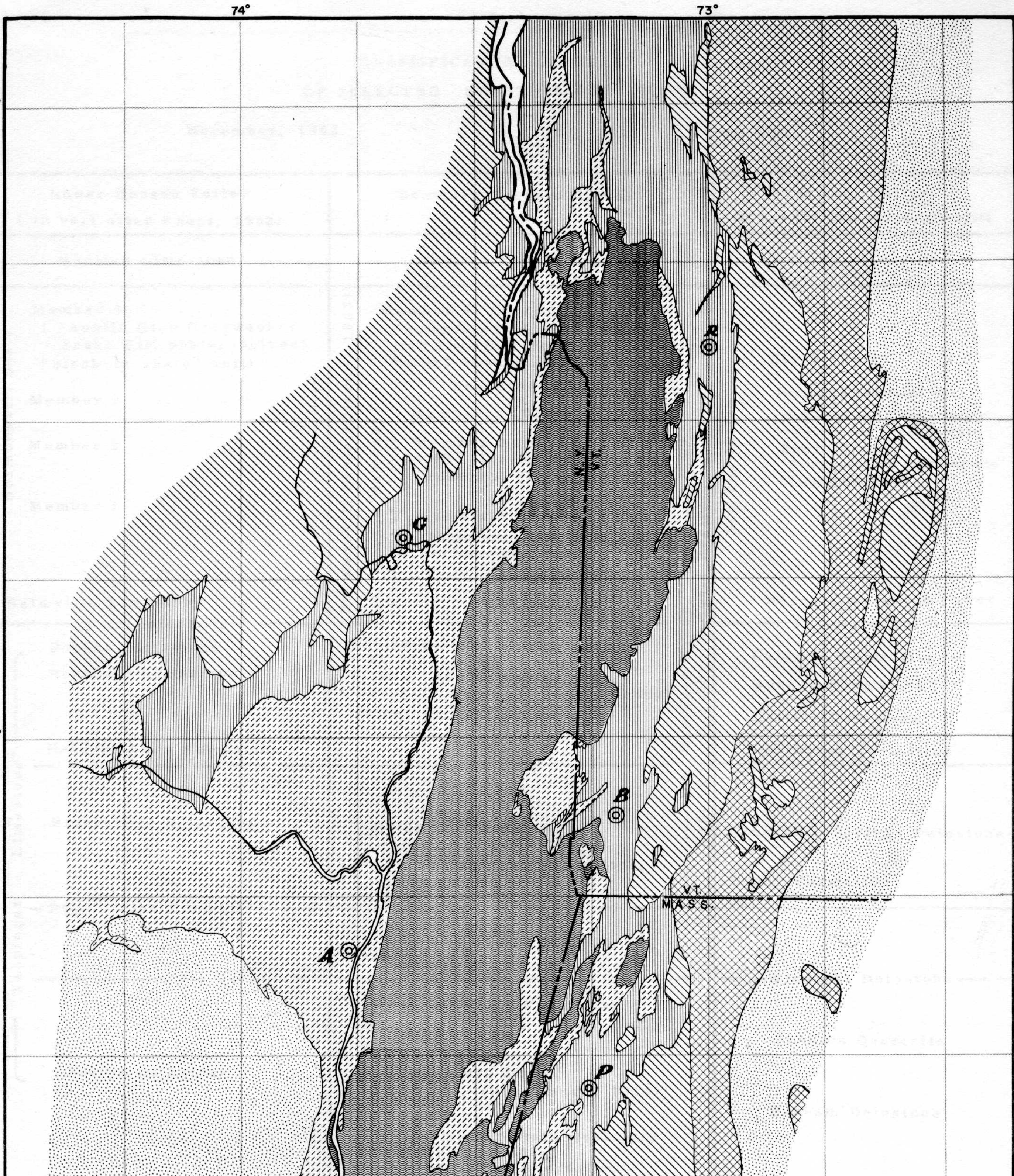

PLATE 2

Generalized Geologic Map of the Taconic Allochthone and Its Surrounding Area

Compiled by E-an Zen and J. M. Bird

November 1963

Plate 3

CLASSIFICATORY GLOSSARY OF SELECTED STRATIGRAPHIC NAMES

November, 1963 — E-an Zen

System	Series	Lower Hudson Valley (In part after Knopf, 1962)	Southern Taconic Region	Vermont Valley (In part after Doll and others, 1961)
Devonian		Manlius Limestone	Manlius Limestone	
Ordovician	Middle	Normanskill Shale Member 4 (=Austin Glen Greywacke; = Snake Hill Shale; includes "block-in-shale" unit) Member 3 Member 2 Member 1 Balmville Limestone	Normanskill Shale (Clarke, 1903) Member 4 (Berry, 1962; = Austin Glen Member, Ruedemann, 1942; Austin Glen Unit, Craddock, 1957; Pawlet Formation, Zen, 1961). Unconformity Member 3 (Berry, 1962; Mt. Merino Member (Ruedemann, 1942) Member 2 (Berry, 1962: = Mt. Merino Unit, Craddock 1957). Member 1 (Berry, 1962; =Indian River Slate, Keith, 1932; Red Slate Unit, Craddock, 1957.)	Ira Formation Black Shale (Upper part includes the Whipstock Hill Conglomerate, = Forbes Hill Conglomerate, Zen, 1961; "Wildflysch-like conglomerate" of this guidebook). Whipple Marble Member
		* Unconformity*		*Unconformity*
Ordovician	Early	Copake Limestone Rochdale Limestone Halcyon Lake Formation	Poultney Slate (Keith, 1932; = Stuyvesant Falls Formation, Fisher 1962b; includes the "Deepkill" and the "Schaghticoke" Slates). Mt. Hamilton Group, Zen, 1961, Northern Taconic Region	Chipman Formation Bascom Formation Cutting Dolostone Shelburne Formation
Cambrian	Late	"Wappinger Limestone" Briarcliffe Dolostone Pine Plains Formation	Hatch Hill Formation (Theokritoff, 1959; = Germantown Formation, Fisher, 1962a).	Clarendon Springs Dolostone Danby Formation
Cambrian	Middle		* ? Unconformity ? *	Winooski Dolostone
Cambrian	Early	Stissing Dolostone Poughquag Quartzite	Nassau Formation (Bird, 1962; = St. Catherine Formation, Doll & others, 1961; Bull + Biddie Knob Formations, Zen, 1961). West Castleton Formation (Zen. 1961) Mettawee Slate (Ruedemann, 1914) Curtis Mountain Quartzite (Fisher, 1962a; = Zion Hill Quartzite, Zen, 1961). Bomoseen Greywacke (Ruedemann, 1914) Rensselaer Greywacke (Prindle and Knopf, 1932).	Monkton Quartzite Dunham Dolostone Cheshire Quartzite Dalton Formation

Explanation:

— — — Formation boundary does not coincide with time surface.

——— Formation boundary does coincide with time surface.

STRUCTURAL RELATIONS IN THE SOUTHERN TACONIC REGION: An Interpretation[1]

E-an Zen

U. S. Geological Survey, Washington 25, D. C.

The geology of the Taconic sequence of rocks in western Vermont, western Massachusetts, and eastern New York is classical in the literature because of the many baffling problems it presents. These rocks are of Cambrian and Ordovician age, and consist of argillite, with subsidiary strata of greywacke, quartzite, and carbonate. In sedimentary facies and even in many stratigraphic details, these rocks recall the age-equivalent eugeosynclinal sequence of eastern Vermont, with which, however, they are not directly connected on the ground. Recent detailed mapping at the north end of this belt (Zen, 1961; Theokritoff, 1959; Shumaker, 1962) demonstrates a stratigraphic sequence which apparently continues as far south as the latitude of Catskill, New York, without any significant structural break, as is clear from the works of Potter (unpublished), Bird (1962), J. G. Elam (Ph.D. thesis, Rensselaer Polytechnic Institute, 1960) and T. W. Talmadge (written communication, 1961). Zen (1961) showed that the Taconic sequence at the north end is made up of a series of nested low-angle thrust slices. Taken as a whole, however, the Taconic sequence here lies in the center of the southern continuation of the relatively open Middlebury synclinorium (Cady, 1945). The Middlebury synclinorium is south-plunging and overturned to the west, and is the structural complement of the Green Mountain anticlinorium (Cady, 1945). The two limbs of the synclinorium correspond closely in their stratigraphy, and consist of carbonate and orthoquartzite, typical of the miogeosynclinal facies of sedimentation. These rocks, called the synclinorium sequence by Zen (1961), are Early Cambrian to Middle Ordovician in age, exactly the age of the Taconic facies which is found in the center of the synclinorium, surrounded by the quartzite-carbonate rocks.

The Taconic sequence of rocks, thus, presents a stratigraphical, sedimentological, and structural anomaly; its explanation has caused much controversy. The problem of the decipherment of Taconic geology is compounded by the recent discovery (for instance, Zen, 1961) that the Taconic rocks clearly have undergone at least two generations of folding, of which the earliest is the most intense, while only the latest episodes are observed in the rocks of the synclinorium sequence. Since 1945, three main theses have been advocated to explain the time and space relations of the Taconic rocks; these are briefly summarized here.

The hypothesis of Bucher (1957) and Craddock (1957) assumes that the Taconic rocks are basal Early Cambrian and post-Chazy Ordovician in age, with a depositional gap in between. This hypothesis, designed to avoid the problem of the facies contrast, may be discarded now because of the finding of fossils of all intermediate ages except the Middle Cambrian (Berry, 1959). The most probable correlations with the early Paleozoic sections of northern and eastern

[1]Publication authorized by the Director, U. S. Geological Survey.

Vermont (Lochman, 1956; Zen, 1961; Doll and others, 1961) show also that the Early Cambrian Taconic rocks are at least in part younger than the age demanded by Bucher's hypothesis.

The hypothesis of Dale (1899, 1904) and Lochman (1956), followed by Weaver (1957) and J. G. Elam (Ph.D. thesis, Rensselaer Polytechnic Institute, 1960), invokes a facies contrast. The Taconic rocks are supposed to occupy a region of uplift, possibly an anticlinorium, at least the north end of which is nested in the Middlebury synclinorium. The Taconic sediments possibly were derived locally; the similarity with the eugeosynclinal eastern Vermont section is considered fortuitous; and the presence of thin carbonate and quartzite beds in the Taconic sequence are taken as evidence for the required marginal facies change. The Taconic rocks thus are supposed to rest directly on the Precambrian basement.

The third hypothesis is that originally proposed by Keith (1912), later modified by Cady (1945), Fowler, (1950), and Zen (1961). The Taconic rocks are considered to be allochthonous, and according to Zen (1961) thrust in, and entirely separated from their site at deposition, as submarine gravity slides in late Trenton time from a site of deposition coincident with the present Green Mountain anticlinorium. Acording to this idea, the Taconic rocks are truly the geometrically highest strata of the Middlebury synclinorium, whose structural evolution continued after the emplacement of the Taconic thrust sheets. The facies contrast between these rocks and the surrounding, age-correlative carbonate and quartzite is thus the result of structural dislocations, and the synclinorium sequence is supposed to intervene between the Taconic rocks and the Precambrian basement at depth. This allochthonous hypothesis is most probable for the origin of the northern portion of the Taconic sequence, and in the ensuing discussion will be so assumed for that area.

A distinctly different stratigraphic and structural picture, meanwhile, has been formulated by Warthin in the Poughkeepsie and Rhinebeck quadrangles, at the extreme south end of the Taconic rock sequence (A. S. Warthin, New York Museum Open File Reports, 1949, 1953). According to Warthin, all the Taconic rocks in these two quadrangles, with the exception of a narrow, north-northeast-trending belt that extends southward from the Copake quadrangle as far as Schultz Mountain in the Rhinebeck quadrangle, and an isolated outcrop near Poughkeepsie, are the Normanskill Shale, and according to Berry (1962) belong to Zones 12 and 13 (Climacograptus bicornis and Orthograptus truncatus var. intermedius Zones, respectively) of his graptolite succession. These rocks are lithically identical with the Normanskill Shale of the region to the north, but stratigraphically different in that they rest, with apparent conformity, above the Lower and Middle Ordovician carbonate rocks characteristic of the synclinorium sequence. As pointed out by numerous field workers, there is no basis for considering these Normanskill Shale beds to be allochthonous. The problem, then is to resolve the conflicting interpretations for the north and south ends of the Taconic sequence.

The writer (1960) suggested that the apparent contradiction may be composed by admitting the possibility that the southern terminus of the Taconic thrust sheet may be within the Normanskill Shale. The Taconic rocks that extend northward, approximately from Schultz Mountain to Sudbury, Vermont (Plate 2), which include all the pre-Normanskill strata of this sequence, are supposed to be allochthonous. The Normanskill Shale south of the latitude of Schultz Mountain, autochthonous on the basis of Warthin's compelling field evidence, is a record of a general flooding of the erstwhile miogeosynclinal area by clastic, Taconic-type sediments derived from an easterly source (stop 9; see also McBride, 1962). The flooding of clastics in the miogeosynclinal area in Black River to Trenton time (upper Porterfield and lower Wilderness stages of Cooper, 1956) is one of the most significant Middle Ordovician events in this entire area. This sudden and lasting change in the sedimentary regime is believed to reflect the uplifting and related diastrophic activities to the east, in the area of the present Green Mountains-Berkshire Highlands, which culminated in the emplacement of the Taconic allochthone. This scheme of tectonic history for the Taconic belt is consistent with the sequence of events evidenced by the graptolite faunas in the pertinent rock units, as recently studied by Berry (1959, 1962), and discussed by him in this guidebook.

One aim of this field trip is to contrast and compare the nature of the Taconic sequence approximately north and south of the latitude of Schultz Mountain, and to show the differences in the structural relations of these rocks with the surrounding rocks of the synclinorium sequence. Potter's work (stop 4) showed that the eastern contact of the Taconic sequence with the Walloomsac Slate and older Ordovician carbonate rocks of the Middlebury synclinorium is locally sharp, with the Late Cambrian and Early Ordovician Taconic rocks overlying the Early and Middle Ordovician; this finding is contrary to the common assumption that this contact is everywhere gradational, an assumption taken by some as evidence of lack of a thrust. Fossils in the Walloosac Slate near Whipstock Hill (stop 4) belong to Zone 12 of Berry's (1960) nomenclature, and thus occupy approximately the time zone of the basal Normanskill Shale, both within and outside the Taconic allochthone as presently interpreted. The fossiliferous beds are succeeded by a conglomerate called by Potter the Whipstock Member of the Walloomsac Slate. This rock is very similar to the congomerate at Moordener Kill (stop 1; Ruedemann, 1901), the Forbes Hill Conglomerate of Zen (1961), and the "block-in-shale" unit of Berry (1962), both in lithology and in its stratigraphic-structural position relative to the Taconic allochthone. This type of conglomerate was interpreted by Zen (1959, 1961) as submarine landslide deposits derived from a nearby, advancing Taconic allochthone. If this interpretation is correct, then the outcrop at Whipstock Hill (stop 4) dates the event of the Taconic thrust at Zone 12 time (Black River; = Wilderness) or slightly younger. The fact that the conglomerate at Whipstock Hill is located on the east side of the Taconic belt shows that the lithically similar outcrop at Moordener Kill and the Forbes Hill Conglomerate, both of which occur west of the Taconic belt, probably were not deposits related merely to marginal thrusts.

Stops 2, 3, 6, and 7, all within the Taconic belt, show rock types and stratigraphic successions which, even in detail, agree with those of the synchronous rocks in the northern Taconic region, as worked out by Zen (1961), Theokritoff (1959, also written communication, 1962), R. C. Shumaker (Ph.D. thesis, Cornell University, 1960), L. B. Platt (Ph.D.thesis, Yale University, 1960), and others. The numerous sedimentary features that indicate significant turbidity transport accord with the concept of an environment of deposition in relatively deep water, and are consonant with a location between the miogeosynclinal belt and the eugeosynclinal belt of east Vermont and west-central Massachusetts (Zen, 1960, 1961). Stop 1, at Moordener Kill, shows a rock which is nearly identical with the outcrop at Rysedorph Hill, and so correlated by Ruedemann (1901). The rock is like that at Whipstock Hill, and believed to have the same tectonic-sedimentary origin. Graptolites in the matrix of the conglomerate at this locality fix the age as within the Canajoharie Shale

(Zone 13; Berry, 1962; also oral communication, 1963), and thus is consistent with the other chronological data, cited above, for the event of Taconic thrusting. The time span of the thrusting corresponds to the time of deposition of the greywacke of the Austin Glen (Member of the Normanskill Shale; Ruedemann, 1942; Berry, 1962). Ruedemann's Austin Glen may have been deposited during the movement of the thrust slices, with locally derived material; with the progress of time, however, this facies extended farther west as the "source" area itself moved (Zen, unpublished data). This interpretation is consistent with the graptolite data of Berry (1962).

Stop 8 at Long Pond shows, in contrast, the conformable contact between the lower members of the Normanskill Shale and the underlying limestone ("Balmville Limestone" of Holzwasser, 1926) south of the latitude of Schultz Mountain. The limestone is unconformably above the pre-Middle Ordovician carbonate and quartzite units of the miogeosynclinal suite. According to the writer's interpretation, this contact depicts the beginning of clastic flooding of the sinking shelf area by Taconic-type sediments. According to Berry (1962), the basal Normanskill is in his Zone 12, so that the biostratigraphic data support the time-and-space relationships of these rock units as here proposed.

One classical view on Taconic geology that is probably untenable is that there exists a sharp lithic, faunal, and structural contrast between rocks of the Normanskill Shale and the Snake Hill Shale (= Canajoharie Shale; see Kay, 1937). One consequence of this assumption is the idea that all the Normanskill Shale must be thrust in; on the merits of this argument much of the modern Taconic controversy revolves. Worthin's work, as seen at Long Pond and near the Vassar Campus (stops 9 and 10), removes much of the stratigraphic and structural ground for this assumption; Berry's work removes the chronologic need for it, and the writer (1960) and Berry (1962) furnished at least one possible alternative interpretation of the regional relations. At stop 8, and, time permitting, also at stop 10, the occurrence of a typical Snake Hill fauna in the Normanskill Shale, discovered by Warthin, will be seen. Because these two faunal as well as rock types apparently interdigitate, an indigenous origin for the surrounding Normanskill Shale is indicated. In fact, Berry (1963) shows that the type Snake Hill Shale, at Lake Saratoga, is lithically like the Austin Glen (a fact first mentioned by Ruedemann, 1914), but there the beds do carry the shelly fauna.

SEDIMENTARY STRUCTURES IN THE TACONIC SEQUENCE ROCKS OF THE SOUTHERN TACONIC REGION

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One of the purposes of this field trip is to show some of the turbidite features of the Taconic sequence. Sedimentary structures and lithologies attributed to submarine slumping, density current deposition and large scale, tectonically induced submarine slumping and sliding will be described and seen in the field.

The Taconic sequence in the southern Taconic region, a thick section of shale with interbedded greywacke, quartzite and minor carbonates, has been divided into Lower Cambrian, Upper Cambrian-Lower Ordovician and Middle and Upper Ordovician lithostratigraphic units (see Plate 3). Middle Cambrian rocks have not yet been recognized. These lithostratigraphic units are much alike in gross aspects, but in detail are quite dissimilar in composition and associated sedimentary structures. The Lower Cambrian is composed mostly of green argillite with extensive quartzite and greywacke. The Upper Cambrian-Lower Ordovician (= part of the Mount Hamilton Group of Zen, 1961; see Plate 3) is predominantly shale and thin limestone and quartzite. The Middle and Upper Ordovician is mostly black shale with some red and green shale and extensive greywacke.

Most of the arenaceous rocks of this predominately argillaceous section are turbidites; and Taconic section, in general terms, corresponds to "flysch" as defined by Dzulynski, et al. (1959, p. 1089):

"thick series of regularly bedded marine geosynclinal sedimentary rocks showing alternation of shales or marls with dark sandstones (greywacke-like rocks), usually poor in fossils but rich in organic and inorganic sole markings (= hieroglyphs)."

The structure of the Taconic region is complex and stratigraphic differentiation at both large and small scales in many areas remains unsolved. It is apparent that study of the sedimentary structures can lead to a great deal more factual geologic history for the Taconic region. However, present interpretations of sedimentary structures in this structurally complex and relatively unfossiliferous region may be burdened with considerable speculation. The usefulness of sedimentary structures in the Taconic region is also hampered by the eastwardly increased metamorphism which has obliterated all but the coarsest of the structures in the eastern area.

As yet no definitive studies of current directions have been made in the Taconic region. Until more is known of the regional structure, particularly the amount of lateral rotation of the various major thrust plates before and during their metamorphism, current directions obtained from the sedimentary structures are most difficult to interpret. The regional geology shows definitely that the Taconic sequence was deposited in a north-south trending, elongate basin. However, analysis of current direction data might refine this overall picture, and verify postulated sediment sources, as well as explain the northward currents indicated by the features of some of the turbidites.

Types of Sedimentary Structures

Practically all of the clastic strata in the Taconic sequence (Plate 2) display some feature or group of features attributable to turbidity currents or submarine slumping. The bulk of the arenaceous rocks belong to the greywacke of the Austin Glen in the Middle Ordovician Normanskill Shale and the Rensselaer Greywacke in the Lower Cambrian Nassau Formation (Bird, 1962). Thinner, subsidiary strata of greywacke, quartzite and limestone conglomerates also constitute portions of the Upper Cambrian to Middle Ordovician rocks (Mount Hamilton Group of Zen, 1961).

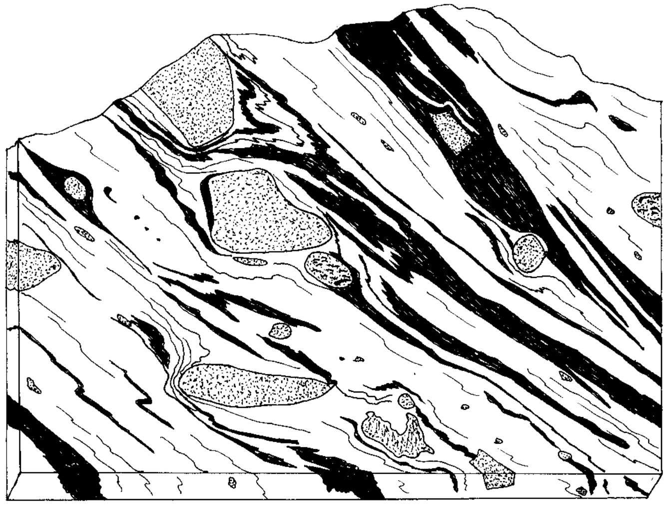
Slump deposits, fluxoturbidites, turbidites and Wildflysch-like conglomerates have been recognized in the southern Taconic region.

Slump deposits and fluxoturbidites. Slump-origin deposits are usually a chaotically arranged, heterogeneous mixture of phenoplasts and phenoclasts usually within an argillaceous matrix. These are thought to be the result of deposition of unconsolidated sediment, often containing poorly to well consolidated layers, which has moved from its original site of deposition. Fluxoturbidites (Dzulynski *et al.*, 1959, p. 1095) are deposits having a mixture of the characteristics of both slump deposits and turbidites (to be described); deposits transitional between those resulting from slumping and those resulting from density currents.

Rocks of postulated slump origin have been found in Lower Cambrian green argillite and black shale in Rensselaer and Columbia Counties, mostly along the east side of the Hudson River.

Figure 1 shows a rock thought to have been formed by slumping of poorly and well consolidated sediment. Rounded to angular fragments of four different limestone lithologies, one containing fossil fragments of the *Elliptocephala asaphoides* fauna (Lochman, 1956), are set in a matrix of green argillite and black shale. The arrangement of the limestone fragments and the deformed laminations within the argillite and black shale suggest that the sediment moved from its site of deposition as a hydroplastic or somewhat thixotropic mass. Paper-thin, wispy black shale and silty laminations are stretched and bent around the limestone fragments as if the fragments rotated during movement. Some of the black shale and silty laminations are curved and streaked out along what appear to be flow lines. In three dimensions, the axes of the folds of argillite around the fragments and of the folds of shale and silt within the geeen argillite are all approximately parallel throughout the specimen. This parallelism, unrelated to the structural axes of the area, also suggests that the sediment moved as a mass. Thin beds of silt in argillite next to the sample horizon are essentially undeformed.

This specimen is from one of the areas described by Lowman (1961). Generally, the stratigraphic section in this area is the Mettawee Slate (light green to olive argillite), equivalent to that in the Bull Formation of Zen (1961) in the northern Taconic region, overlain by black shale and thin limestone strata believed to be partially equivalent to Zen's (1961) West Castleton Formation. The specimen shown in Figure 1 is from the contact between the argillite and black shale unit which is a zone up to approximately 20 feet thick of interbedded black shale and green argillite. Much of the black shale and limestone unit appears to have been deformed while partially consolidated because the thin continuous limestone strata are folded, boudinaged and stretched, all in about the same direction within relatively undeformed strata.



1 inch

Figure 1. Drawing of a sawed slab of a conglomerate believed to have originated by slumping. Stippled = limestone; stippled with black lines = limestone with fossil fragments of the Elliptocephala asaphoides fauna; black streaked = black shale; white areas = olive argillite, thin lines are very fine silt laminations. Sample from Lower Cambrian Mettawee Slate just north of the Troy High School playing field, Troy, New York.

Rock saw clab-cuts of other specimens from this locality indicate that some of the conglomeratic rock within the stratigraphic horizon of the specimen shown in Figure 1 resulted from actual flow of a suspension of sediment because these conglomerates lie across stratification of the green argillite and black shale and have a faint grading of large limestone fragments. These rocks may be fluxoturbidites in the sense that their transport may have partially involved density current transport. They occur more or less on strike with postulated slumped sediment. Such lithologies may reasonably be expected to have formed in the vicinity of slumped sediments, but results of work in this locality are as yet inconclusive concerning fluxoturbidites.

It is also possible, however, that the limestone fragments within the specimen shown in Figure 1 were derived from an area that was undergoing some sort of mechanical alteration, and slid into the environment receiving the alternating green argillite and black shale sediment, before the slumping took place. Indeed, the large exposures of the black shale and thin limestone strata which overlie, nearby, the rock from which the specimen was taken, may have also slumped into the argillite and shale sediment and caused the deformation of the specimen.

The fossil fragments of the Early Cambrian Elliptocephala asaphoides fauna in some of the limestone fragments of the specimen constitute a derived fauna but there is no reason to consider them part of a remanie fauna (fossils derived from older rock). There are graded, silty turbidite strata, up to several inches thick and not folded, in the green argillite at this locality which contain these same fossil fragments directly imbedded in the argillite at the upper contact of the turbidites. Apparently the silt and fossil fragments were derived from the same general source as the limestone fragments.

Approximately fifty feet stratigraphically below the horizon from which the specimen shown in Figure 1 was taken, there is a polymict conglomerate, approximately 12 feet thick, in Mettawee Slate (green argillite). Figure 2 is a sawed slab of a specimen taken from the middle of this conglomerate. The conglomerate has a round quartz grain matrix with black argillaceous material which is, upward, progressively more sandy. The matrix of the specimen in Figure 2 contains less than 2% argillaceous material. The conglomerate contains angular fragments, pebbles and boulders of limestone and black shale up to at least 2 x 4 x 1 feet. The fragments include black shale and silty black shale, green argillite, and at least four varieties of limestone. There is a faint grading of the various inclusions. The basal surface of the conglomerate, resting on essentially undeformed Mettawee argillite, is penetrated by what apparently were injections of the argillite sediment, several inches long, due to loading (flame structure). There are no strata in the vicinity that would compositionally correspond to either the sand matrix or most of the limestone inclusions of the conglomerate. Because of the contact relations and the faint grading of the inclusions, this conglomerate seems to be the result of density current transport. However, the large size of some of the inclusions suggests that the conglomerate may actually be a fluxoturbidite, that is the result of an event intermediate between a slump and an actual turbidity current.

At Nutten Hook on the east shore of the Hudson River, approximately eight miles due north of Hudson, New York, there is an abandoned rock excavation, which contains examples of similar conglomerates. These rocks, probably Upper Cambrian, are a series of quartzites, black and grey shales, siltstones and limestones, with various conglomerates.

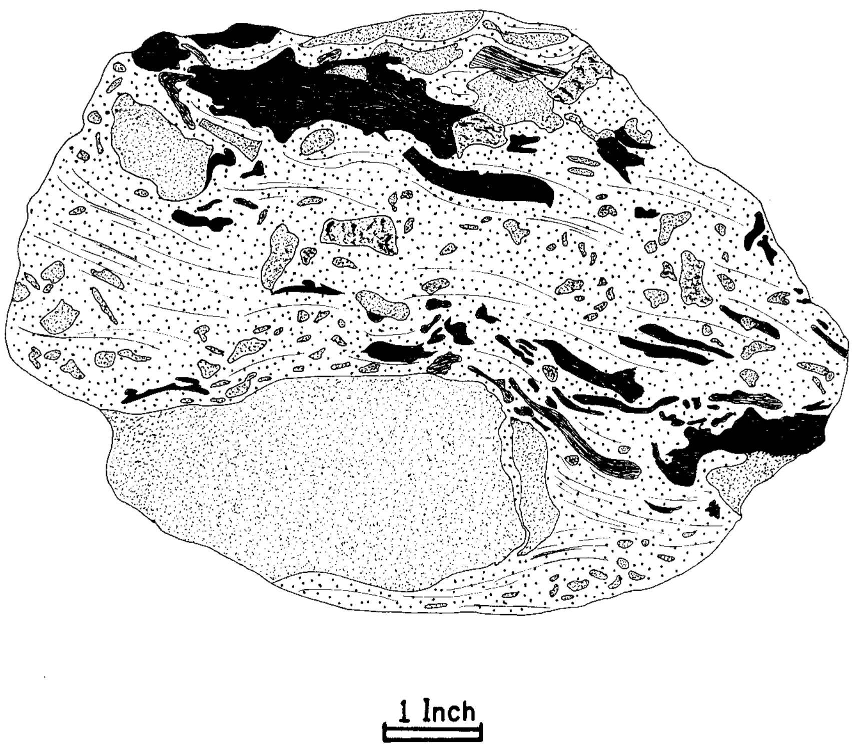


Figure 2. Drawing of a sawed slab of a conglomeratic turbidite or fluxo-turbidite (?). Stippled = limestone; stippled with black lines = limestone with fossil fragments of the Elliptocephala asaphoides fauna; black streaked = black shale; lined = green argillite; dotted = round quartz grain matrix, thin lines are very thin, discontinuous argillaceous laminations. Sample locality same as for Figure 1.

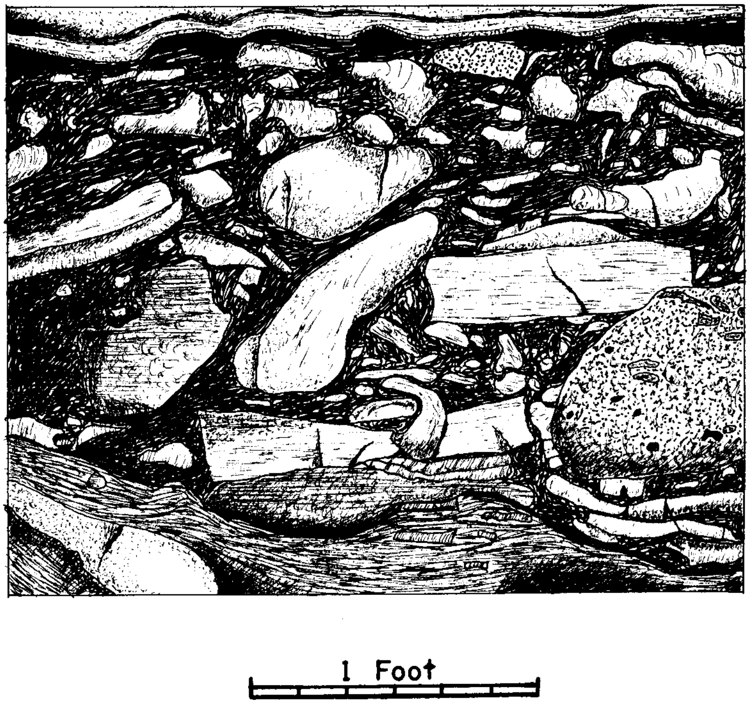


Figure 3. Drawing from a photograph of a fluxoturbidite (?) exposed approximately 8 miles north of Hudson, New York at Nutten Hook, on the east shore of the Hudson River. This rock may be the result of an event intermediate between slumping and density current transport. The conglomerate rests on black shale containing a few pebbles and boulders of quartzite and limestone, shown at the bottom of the drawing. It is overlain by thin beds of black shale and laminated fine-grained quartzite and black shale shown at the top of the drawing. The conglomerate is composed of several varieties of limestone and quartzite set in a matrix of black shaley material and silt. Approximately 1/8X.

The conglomerates, though lithically dissimilar, are otherwise much like those described. Figure 3 is of one of these conglomerates and shows the not uncommon, large size of the inclusions. The faint grading of the fragments suggests partial density current transport. The conglomerate may be a fluxoturbidite.

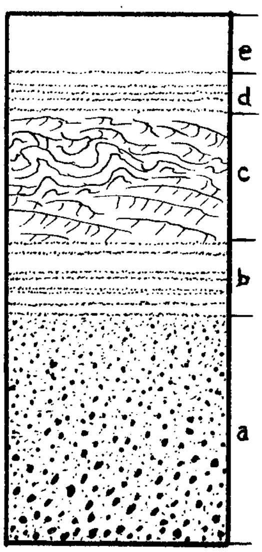
Conglomerates similar to those described can be found throughout the Taconic sequence along the east side of the Hudson Valley. Variations of internal structures, lithologies and stratigraphic positions of the conglomerates are great and their descriptions are very meager in the literature. However, their abundance in the Lower Cambrian and Upper Cambrian-Lower Ordovician lithostratigraphic units suggest prolonged instability of the basin slope and shelf areas.

Turbidites. Turbidites are deposits resulting from turbidity or density current transport of sediment. A turbidity current or density current is a turbulent mass of sediment and water which flows, usually along the floor of a body of water, because its greater density than the surrounding water.

The structures of sediments attributed to turbidity current deposition occur both within strata and on the bedding surfaces of strata.

Internal structures of turbidites

Bouma (1962) has shown that, within a turbidite there is a fixed succession of sedimentary structures, characteristic of a turbidity current deposit. A layer having the complete succession is divided into five intervals, each of which is characterized by the dominance of one type of sedimentary structure, the boundaries of which may be either transitional or abrupt.



e. pelitic interval

d. upper interval of parallel lamination

c. interval of current ripple lamination

b. lower interval of parallel lamination

a. graded interval

(from Bouma, 1962, p. 49)

Briefly, the characteristics of each interval according to Bouma (1962) are:

a) Graded interval. Only if the material of this interval is well sorted, of uniform size, is graded bedding absent or indistinct. The grading may range from pebbles to sand.

b) Lower interval of parallel lamination. Alternating laminae of clayey sand predominate over grading (if present). The contact between a and b is usually gradational.

c) Interval of current ripple lamination. Consists of current ripple laminations, usually less than 5 cm. high and 20 cm. long, with distinct fore-set lamination visible. Ripples may be more or less convolute. Contact between b and c is usually distinct.

d) Upper interval of parallel lamination. Usually very fine, sandy to silty pelite with indistinct parallel lamination. Weathering or tectonism may obscure the laminae. May have an upward decrease of sand. Contact between c and d is usually distinct.

e) Pelitic interval. No visible sedimentary structures except a slight upward decrease in grain size may be present. May have a rapid upward increase in lime. Sometimes overlain by clay or marl, presumably pelagic.

Bouma's (1962) notations for possible turbidite (T) combinations are:

Complete Sequence	Base-cut Sequences	Truncated Sequences	Truncated Base-cut Sequences
T_{a-e}	T_{b-e}	T_a	T_b
	T_{c-e}	T_{a-b}	T_{b-c}
	T_{d-e}	T_{a-c}	T_c
		T_{a-d}	T_{c-d}
			T_d

Field work by the writer indicates that various truncated, base-cut, and truncated base-cut sequences are common in the Taconic rocks. The sequences T_a, T_{a-b}, T_{a-c}, T_{a-d}, T_{a-e}, T_{b-c} and various combinations such as T_a overlain by T_{a-b} are common and may be seen at stop 8 (Rhinecliff Bridge). Bouma (1962) gives a long discussion, based on the composition of source materials and characteristics of turbidity currents, to explain partial sequences and truncated sequences. Preliminary work indicates these explanations may be applicable to turbidites in the Taconic rocks.

Graded bedding (T_a) is very common in the greywacke of the Austin Glen in the Normanskill Shale, the Rensselaer Greywacke of the Nassau Formation, as well as in the numerous subsidiary quartzite strata of the Upper Cambrian-Lower Ordovician lithostratigraphic units. Grain sizes in the Austin Glen commonly range from sand to silt. Pebbles as much as 20 mm across are not uncommon in some of the graded beds. Unusually coarse Austin Glen is exposed in a road cut at the east edge of Defreestville, 0.4 miles west of the intersection of Routes 40 and 43 in the Troy 15 minute quadrangle. The Rensselaer Greywacke commonly has distinct graded bedding, which may be very coarse in the western area of the

Rensselaer Plateau. In the Rensselaer Greywacke exposed on the west side of the Rensselaer Plateau, particularly that just east of Hoag Corners, approximately 14 miles southeast of Troy, grading ranges, in strata four to six feet thick, from cobbles 6 to 8 inches in longest dimension to silt size grains, much like the Zion Hill Quartzite in southwestern Vermont (Zen, 1961). Boulders of granitic gneiss up to approximately 14 inches in longest dimension have been found in the Rensselaer Greywacke of the Austerlitz area (Balk, 1953). The cobble and boulder size in graded beds is unusual and indicates very vigorous density current transport.

Graded bedding must be used with care as a top-bottom criterion in the Taconics. Definitely reversed (or negative) graded bedding has been found in the Rensselaer Greywacke and the greywacke of the Austin Glen Member of the Normanskill Shale. The top sense of beds determined by graded bedding alone sometimes conflicts with other criteria such as load casts and cross-laminations in a single outcrop.

Sawed slabs of the Rensselaer Greywacke have revealed some unusual turbidite structures. Figure 4 is a sawed slab of a graded Rensselaer Greywacke bed exposed at stop 3 (Barberville Falls). The dark streaks are phenoplasts of red argillite, compositionally the same as the red argillite that underlies the sample horizon. The phenoplasts are set in a matrix of greywacke graded from 1 mm size grains at the base to silt at the top of the graded interval. The top of the graded interval, which is faintly cross-laminated, is truncated and overlain by a $\frac{1}{4}$ inch layer of red argillite, probably of pelagic origin. This argillite layer is overlain by cross-laminated silt with a layer of silty argillite, the whole of which is interval T_c and part of sequence T_{c-e} apparently present at the same locality but not collected with this sample.

Sea-floor erosion by a turbidity current can occur if the current is underloaded with sediment (Kuenen and Migliorini, 1950). Apparently, the turbidity current which transported this sediment was underloaded during part of its flow and incorporated within itself soft fragments of the sediment from the ocean floor. The grading of thequartz and feldspar grains of the greywacke matrix indicates that density current flow rather than slumping took place. The thin continuous argillite layer between this interval and the overlying T_{c-e} interval probably resulted from the settling of fine argillaceous material after deposition of the interval T_a. The interval T_{c-e} might be interpreted as the result of later, weaker currents depositing fine material derived from the T_a interval closer to the basin slope or sediment source. Rocks like that of Figure 4 are not uncommon in the Rensselaer Greywacke along the western side of the Rensselaer Plateau.

Excellent examples of graded conglomerates in the Rensselaer Greywacke may be seen in an abandoned quarry, approximately $\frac{1}{4}$ mile southwest of the village of East Nassau in the southeastern corner of the Nassau $7\frac{1}{2}$ minute quadrangle, and in Fitzgerald Brothers quarry, near Quackenkill, approximately 10 miles east of Troy on Route 2.

The other intervals of Bouma's classification are also easily recognizable in the western Taconic region. For example, T_c (the interval of current ripple lamination) occurs as one to twelve inch thick, well-sorted, fine-grained quartzite strata within the extensive area of Mettawee Slate in the western half of Rensselaer County. It is thought that some of these quartzites may have been deposited from the "dilute tails" of the turbidity currents

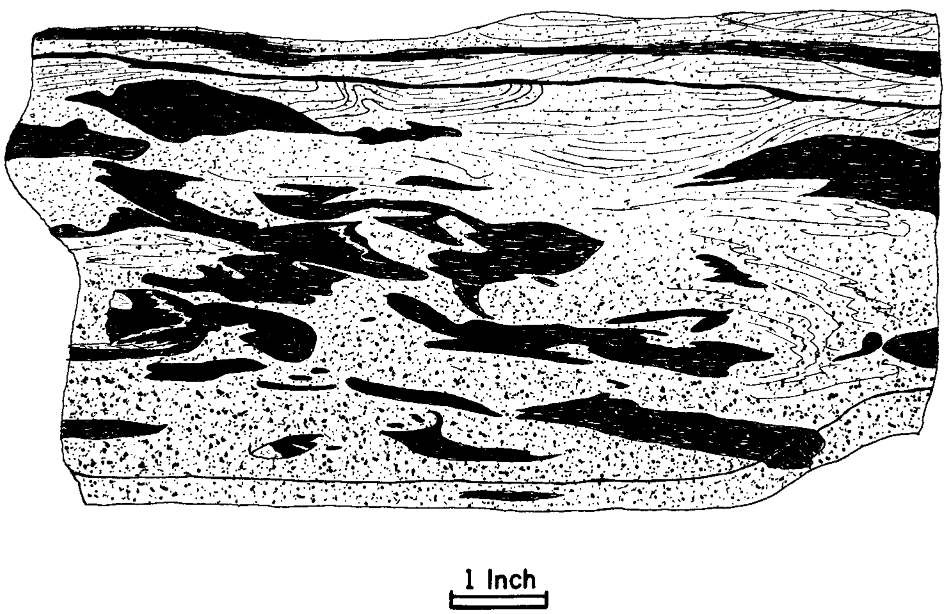


Figure 4. Drawing of a sawed slab of Rensselaer Greywacke exposed at stop 4, Barberville Falls, two miles east of the village of Poestenkill (Averill Park quadrangle). Black = very fine grained to silty, red-maroon argillite; stippled = chloritic, hematitic, feldspathic quartzite graded from 1 mm grains at bottom to silt at top; black lines = discontinuous laminations of red argillite and silt. The argillite fragments are believed to have been phenoplasts of bottom sediment incorporated into the greywacke matrix because the density current transporting the matrix sediment was underloaded and capable of eroding the sea floor. The fragment-bearing portion of the specimen (Bouman's T_a interval) is overlain by a continuous, thin, red argillite layer, believed to have settled on the turbidite just after deposition of the turbidite. This is overlain by cross-laminated silt and argillite (Bouma's T_c interval).

that transported the Rensselaer Greywacke sediment (Bird, Ph.D. thesis, Rensselaer Polytechnic Institute, 1962).

Preliminary work indicates that the most frequent occurrences of various base-cut and truncated base-cut sequences are in the Upper Cambrian-Lower Ordovician lithostratigraphic units (Mount Hamilton Group of Zen, 1961; Germantown and Stuyvesant Falls Formations of Fisher 1962a and 1962b). Exposures along the east side of the Hudson River, particularly from Castleton-on-Hudson to Nutten Hook provide excellent examples. They can be observed at stop 8 (Rhinecliff Bridge).

Sole surface structures of turbidites

The structures on the sole surfaces of turbidites are usually casts of structures caused by sediment bearing currents or differential loading and compaction. These structures are common in the Taconic sequence.

A practically ubiquitous bedding surface feature of the extensive greywacke and quartzite turbidites is an undulatory, wavy base projecting into shale or argillite. These structures, called load casts by Kuenen (1957a) and load folds (for the upward projecting underlying sediment) by Sullwold (1960), are produced by differential settling and compaction of the turbidite after deposition. They vary in shape and size. Usually they are downward projecting rounded bumps but may be oval or elongate ridges or clusters of ridges. Under a particular turbidite strata the load casts or load folds are of quite uniform size. Generally, the thicker the turbidite the larger the load casts. On one to two feet thick Rensselaer Greywacke beds in Rensselaer County, the load casts are usually 3 to 6 inches in diameter (or longest dimension). Load casts shaped like a canoe and about 6 to 8 feet long have been found under a 20 to 30 feet thick quartzite unit in the Nassau Quadrangle (Bird, Ph.D. thesis, Rensselaer Polytechnic Institute, 1962).

Load casts, particularly in the greywacke of the Austin Glen Member of the Normanskill Shale, are commonly superimposed on other structures attributed to a current origin. These current-formed or induced structures have recently been studied quite extensively, particularly in Europe (see Bouma, 1962, for an excellent reference list and glossary).

In the Taconic region these various structures are apparently most common in the Austin Glen Member. They will be seen at stop 8 (Rhinecliff Bridge). The following is a list of sole markings found by the writer, but is not meant to be complete.

Scour and fill structure

Lenses of sand to pebble conglomerates, several inches to several feet wide and with a downward projecting bottom and a flat top, are believed to be the result of the filling of current scoured channels or grooves. Well exposed examples of these structures occur on the northwest edge of the elongate crest of Curtis Mountain in the Nassau quadrangle, within the Curtis Mountain Quartzite. Here, lenses of pebble conglomerates two to six feet wide and up to three feet thick, in Mettawee Slate, are covered by beds of the quartzite and were definitely deposited before the quartzite, in a pre-existing depression probably formed by current scour.

Flute casts

Oblong and usually parallel protrusions from the sole of a turbidite with a roughly tear-drop outline. The tail of the "tear drop" points in the down-current direction. (For examples, see Crowell (1955) and Hsu (1960), who have described flute casts in the Prealpine Flysch of Switzerland). Flute casts form when a turbidite is deposited on scoured bottom sediment. The turbidite material fills the scours and a cast of the scour shape results. Flute casts are present in the Rensselaer Greywacke but are most readily observed in the Austin Glen Member of the Normanskill Shale (stop 8, Rhinecliff Bridge).

Groove casts

Sole markings of turbidites formed by the deposition of a turbidite into grooves cut into underlying mud by a current or rock fragment transported by a current. The filling of the grooves forms a cast on the base of the turbidite. Groove casts are similar in origin to flute casts but are elongate and parallel with straight sides. They are parallel to the current direction. Well developed groove casts approximately an inch wide and at least three feet long may be seen at stop 8 in the greywacke of the Austin Glen at the east end of the Rhinecliff Bridge, near Rhinebeck, New York.

Short, narrow groove casts, common in the greywacke of the Austin Glen, parallel to other large groove casts, may have been formed by objects within a density current grazing the bottom muds as the current proceeded. These marks, called bounce casts, fade out at both ends and, where seen in the Austin Glen are usually less than three inches long. They are present at stop 8 (Rhinecliff Bridge).

Tracks and burrows

Animals moving on the bottom sediment leave marks which, when covered by a turbidite, may be cast into the base of the turbidite. Also, animals moving through the bottom sediment leave holes, the impressions of which may be preserved. Casts of worm tracks are common on the bases of the numerous one inch to two feet thick quartzite strata in the Mettawee Slate of the western half of Rensselaer County. These are usually sinuous, tubular projections of the quartzite base, two to six inches long and 1/8 to 1/2 inch in diameter.

Also, sawed slabs of argillite from directly under some of these quartzite strata show tubular inclusions of silt which are probably the remnants of worm burrows.

Ripple marks

Translation ripples, some sets of which show current interference effects, commonly occur on the tops of the quartzites mentioned above as well as on other thin clastic strata throughout the Taconic sequence.

Wildflysch-like Conglomerate

Wildflysch is a name applied to shales with broken and contorted bedding and with lenses of sandstone and mudstone, in the Ultrahelvetic nappes of western Switzerland. The prefix "wild" refers to the very chaotic bedding of the shale. The Wildflysch in the Alps is commonly polymict, containing boulders of granite, schist, and various sedimentary rocks including sandstone, limestone and shale, poorly sorted and chaotically arranged in the shale. The overall texture, composition, and stratigraphic position of the Wildflysch strongly suggest that the lithology was the result of submarine slumping and sliding on the slope of a rising tectonic element, synchronous with deposition of the Wildflysch shale matrix.

Conglomerates similar to the Swiss Wildflysch, in the Taconic sequence, are believed to have originated by shedding of rocks from an active tectonic element onto a muddy ocean floor (Zen 1959, 1961). These conglomerates, for example Berry's (1962) "block-in-shale" unit, and the Forbes Hill Conglomerate of Zen (1961) are characteristically composed of a severely contorted Trenton black shale matrix containing blocks and chips of greywacke, quartzite, shale and limestone. In the southern Taconic region, the Wildflysch-like conglomerates are predominantly along a north-south belt both on the east and west banks of the Hudson River, within the autochthonous Normanskill Shale and west of overlying, predominantly Lower Cambrian and presumably allochthonous rocks. They also occur in the eastern area of the Taconics (stop 4, Whipstock Hill).

Ruedemann (1901) described a conglomerate at Rysedorph Hill, approximately two miles southeast of Rensselaer, New York from which he derived the name Rysedorph Conglomerate. Ruedemann (1914) later used this name for a similar conglomerate found at Bald Mountain near Schuylerville, New York. Elam (Ph.D. thesis, Rensselaer Polytechnic Institute, 1960) has indicated the conglomerate at Rysedorph Hill is incorporated as blocks with various other blocks in Normanskill Shale (containing graptolites as also found in the Canajoharie Shale) of the western part of the Troy 15 minute quadrangle. Berry (1962) described an outcrop in the village of Schodack Landing having blocks and cobbles of Rysedorph Conglomerate, quartzite, limestone and Austin Glen Greywacke in a black shale matrix. This same exposure has also been cited by Ford (1884), Ruedemann (1930) and Goldring (1943).

Ruedemann (1901) found 84 species of fossils in limestone pebbles, ranging from Early Cambrian to Middle Ordovician, in the conglomerate at Rysedorph Hill. The origin of this limestone pebble conglomerate is enigmatic in terms of its fauna and lithic aspects. Ruedemann (1942, p. 120) thought the Rysedorph Conglomerate may have been .... "produced on an extensive scale on submarine slopes by periods of violent earthquakes." However, the occurrence of this conglomerate as blocks with other blocks of Taconic sequence rocks, including turbidites presumably deposited in deep water, indicates the various blocks originated from the same mechanism, which involved more than slumping of synchronous slope and shelf sediments.

"Rysedorph Conglomerate" at Bald Mountain has been proposed as a Trenton basal conglomerate by Platt (1962) and Sanders, Platt and Powers (1961). The regional association of other blocks of Taconic sequence rocks, including deep water turbidites, with the Rysedorph Conglomerate as described by Ruedemann (1901) does not permit a basal conglomerate interpretation of the Rysedorph

Conglomerate. Also, elsewhere the Rysedorph blocks occur much above the base of the Trenton black shale. Likewise, apparently the name Rysedorph Conglomerate should not be used for the Wildflysch-like conglomerate since it is not certain that Ruedemann realized that the conglomerate at Rysedorph Hill is a conglomerate within a conglomerate.

Either Wildflysch-like conglomerate or Berry's (1962) "block-in-shale unit" are preferable names for this lithic unit in the Normanskill Shale. In the southern Taconic region, excellent exposures are at the Cohoes Falls in the Mohawk River just north of Cohoes, New York, in a large road cut on Route 151, two miles east of Rensselaer, New York and in the gorge of the Moordener Kill at Castleton-on-Hudson, New York (stop 1). All of these exposures are characterized by the presence of "exotic" blocks, usually greywacke of the Austin Glen member of the Normanskill Shale but including limestone, quartzite, greywacke and shale lithically equivalent to rocks found throughout the Taconic sequence, in a severely deformed matrix of silty, black to grey shale lithically equivalent to the Normanskill Shale. Lithic counterparts of the exotic blocks (except the Rysedorph Conglomerate) occur as nearby strata in the underlying greywacke of the Austin Glen in the autochthonous portion of the Normanskill Shale and in the Taconic allochthone to the east. Taken as a whole, the Wildflysch-like conglomerate may be considered a mega-sedimentary structure of slump and turbidity current origin.

Zen (1959, 1961) proposed that the Forbes Hill Conglomerate, composed of blocks of Taconic sequence rocks ranging from Early Cambrian, in autochthonous Trenton black slate, resulted from westward moving submarine gravity slides of rock shedding blocks into synchronously deposited Trenton black mud, and indicated the possible equivalence of the similar conglomerates in the Hudson Valley area. It is significant that Potter has found a similar conglomerate that he has named the Whipstock Member of the Walloomsac Slate (stop 4), on the eastern side of the Taconic belt which is in the supposedly autochthonous Walloomsac black slate of Trenton age.

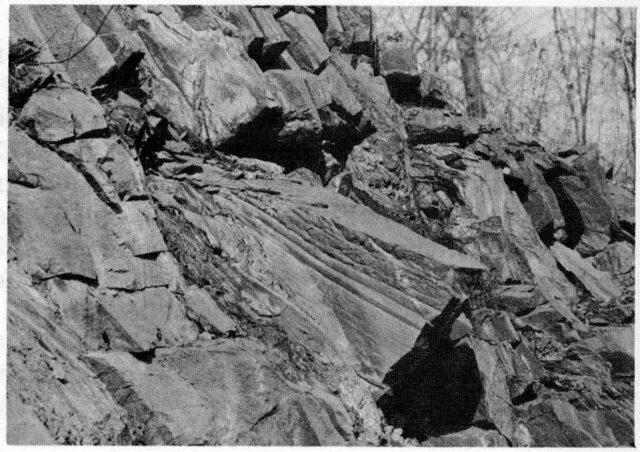
The time range of the fossils found by Ruedemann (1901, 1930) in the Rysedorph Conglomerate, from Early Cambrian to Middle Ordovician, indicate a rock source for the conglomerate and therefore a remanie fauna.

The writer, Zen and Theokritoff also found, at the lower falls of the exposure on the Moordener Kill (stop 1), fragments of trilobite fossils of the <u>Elliptocephala asaphoides</u> fauna (identified by Theokritoff) in a block of limestone pebble conglomerate lithically similar to the Rysedorph Conglomerate at Rysedorph Hill. There are also blocks of Taconic sequence rocks from Lower Cambrian to Middle Ordovician, including blocks of black shale lithically the same as Normanskill Shale, at the Moordener Kill exposure. The source of the blocks, then, must have been more than an area of synchronously deposited shelf sediments as has been invoked by the writer for the Cambrian conglomerates. It must have been composed of both Cambrian and Ordovician Taconic sequence rocks lying east of the Wildflysch-like conglomerate. Also, the blocks of greywacke of the Austin Glen are of turbidites that must have been deposited down-slope (and presumably in deep water) from a sedimentary rock terrain as evidenced by the sedimentary rock fragments common in the greywacke.

The eastward thickening and coarsening of individual strata and of the total greywacke section (Austin Glen Member), from the Schenectady, New York area, in the definitely autochthonous Normanskill Shale, indicates an eastern source for the greywacke turbidites. The most plausible eastern source during Trenton time would be a sedimentary rock terrain composed of Taconic sequence rocks. Therefore, the occurence of the Wildflysch-like conglomerate, with its various exotic blocks, above interbedded greywacke and black shale of the Normanskill along the periphery of the great mass of predominantly pre-Trenton age rocks (allochthonous Taconic sequence, Plate 2) strongly suggests the emplacement of a submarine gravity slide (or slides) as visualized by Zen (1961).

Figure 5. Examples of some turbidite structures.

A. Flute casts with superimposed load casts.



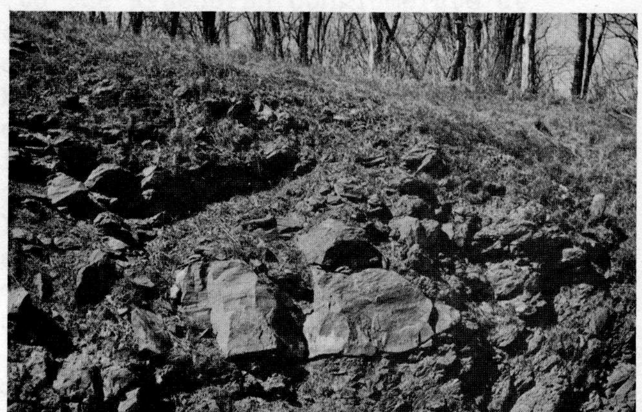
B. Groove casts, some with superimposed load casts.

C. Load casts. Layer at top center has groove and bounce casts.

D. Current ripple laminations in greywacke. Bouma's T_c interval.

A through D are from the large exposure of the greywacke of the Austin Glen Member at the east end of the Rhinecliff Bridge.

E. Load casts in the Curtis Mountain Quartzite, Curtis Mountain, Nassau quadrangle.



F. Wildflysch-like conglomerate of blocks of limestone, quartzite and the greywacke of the Austin Glen Member, in Normanskill Shale. Road cut on Route 151, two miles east of Rensselaer, New York.

STAGES	GRAPTOLITE ZONES	BLACK RIVER VALLEY	NORTHERN PART OF TACONICS	SOUTHERN PART OF TACONICS	NORTHERN MARGIN OF TACONICS (W)	NORTHERN MARGIN OF TACONICS (E)	EAST-CENTRAL TACONIC MARGIN (W Taconics)	EAST-CENTRAL TACONIC MARGIN (E Margin)	WESTERN MARGIN OF TACONICS	SOUTHERN MARGIN OF TACONICS
TRENTON	13 (Orthograptus truncatus var. intermedius)	Atwater Creek Sh Deer River Sh Cobourg Ls Sherman Falls Ls: Denmark Ls, Shoreham Ls	Pawlet Fm	Normanskill Formation: Austin Glen. Mem.	Horton-ville Fm Glens Falls Ls	Ira Formation			Schenectady Ss Siltstone unit Blocks in shale	Normanskill Fm: Austin Glen Mem.
WILDERNESS (Black River in part)	12 (Climacograptus bicornis)	Hull Ls Rockland Ls Chaumont Ls Lowville Ls Pamelia Ls	Indian River Slate	Mem. 3 Mem. 2 Mem. 1 ? ?	Orwell Ls	Whipple Marble Member	Normanskill Formation: Austin Glen Mem. M. 3 M. 2 M. 1 ?	Walloomsac Slate ?	Normanskill Fm: Austin Glen Mem. Mem. 3 (Only these members of Normanskill Fm exposed - limestone beneath ?	M. 3 M. 2 M. 1 Balmville Ls ?
PORTERFIELD	11 (Nemagraptus gracilis)							carbo-nate		
ASHBY	10 (Glyptograptus teretiusculus)		Poultney Slate	Stuyvesant Falls Formation	Middle-bury Ls		Poultney Slate	?		
MARMOR (Chazy)	9 (Hallograptus etheridgei)					?				
WHITEROCK	8 (Isograptus) 7 (Didymograptus bifidus)				?					

Table 1 -- Middle Ordovician correlations in the Taconics and areas adjacent to them.

ORDOVICIAN CORRELATIONS IN THE TACONIC AND ADJACENT REGIONS

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INTRODUCTION

The earliest recognition of the Taconic group of rocks as a distinctive entity may be credited to Professor Chester Dewey of Williams College who, in a series of publications (1819, 1820, 1824 a, b), observed the general arrangement of the strata and constructed the first geologic map (1824 a) of the area in which they were found - western Massachusetts, western Vermont, and eastern New York. He applied the name Taconic to the general terrain.

Not long after Dewey's initial observations, Ebenezer Emmons plunged the Taconic rocks into the midst of controversy which has continued, although in varying forms, to the present day. The Taconic controversy or problem remains as the most long-standing in American geological annals. Emmons initiated the controversy in 1841 and 1842 when he presented the results of his investigations in eastern New York for the then relatively newly-formed New York Geological Survey. He applied the name Taconic System to the deformed slates, shales, limestones, and quartzites exposed in New York east of the Hudson River. The validity of the Taconic System as a distinctive System was attacked from Emmon's earliest report on it and even in the face of mounting evidence against it, Emmons' almost stubborn and persistent advocacy of the System enlarged and perpetuated the controversy that grew from and around the question of its validity.

Emmons considered the Taconic System to be a group of rocks bearing the oldest record of the history of life on earth, and that it, at least in part, lay stratigraphically beneath the Cambrian. The first fossil collections from the rocks included in the Taconic System tended to support this view. In fact, the noted paleontologist Barrande (1860) concluded that trilobites he thought came from rocks of the Taconic System, were "Primordial in age" and characterized the System. Not long after Barrande's pronouncement, fossil finds by Dale and Ford, and later Walcott demonstrated that the Taconic rocks included strata that were Early and Middle Ordovician in age as well as Cambrian. Some of the fossils, including those first found by Emmons and also those reviewed by Barrande, were indeed Early Cambrian in age and thus at least some of the Taconic rocks did include strata that bore some of the earliest of records of earth's life history. As Dana (1888) pointed out in his comprehensive review of the Taconic problem, once the Taconic rocks were recognized to include strata of Cambrian and Ordovician age and not strata of an age older than that of the Cambrian, the "Taconic System" was gradually abandoned.

As the "Taconic System" was being slowly submerged during the last decade of the 1800's, mapping by T. N. Dale began to reveal another aspect of the Taconic problem. Of particular significance are Dale's reports (1912, 1923) on the marble belt on the east side of the Taconic group of rocks. His work and studies made by a number of later investigators among whom Cady (1945), Cushing and Ruedemann (1914), Gordon (1911), Hewitt (1962), Knopf (1927, 1946, 1962), MacFadyen (1956), Prindle and Knopf (1932), Thompson (1959), Weaver (1957), and Zen (1961) may be considered the more prominent, demonstrated that quartzite and carbonate of Early Cambrian age, carbonate of Late Cambrian to Early Ordovician age, and some carbonate of early Middle Ordovician age lie in a nearly continuous belt along the east side of the Taconic pelitic rocks, on their northern margin, and also on their western margin at least as far south as the vicinity of Saratoga Lake, New York. The southern and southwestern margins of the Taconic rocks have not been studied in detail, but as illustrated by Fisher (1962) and Kay (1937), carbonate rocks of Late Cambrian, and Early and Middle Ordovician age are present west of the Taconic rocks.

Cady (1945) showed that the northern portion of the Taconic rocks are approximately in the center of the southward continuation of the relatively open, southerly plunging Middlebury synclinorium. The stratigraphic section of the two limbs of the synclinorium is similar.

The Taconic rocks thus are strangely "out-of-place" inasmuch as they are dominantly pelitic and are essentially surrounded by carbonates and quartzites, which are the same age and which are folded into a broad syncline. The Taconic controversy as it has developed since the turn of the century has been primarily concerned with the explanation of how the pelitic rocks achieved their present position.

Until relatively recently, precise stratigraphic and faunal analysis has been lacking in the Taconic sequence. Thus, using to some extent meagre, and in some respects erroneous information, many working hypotheses have been proposed as answers to the controversy over the past half-century. Fisher (1961) summarized most of these in brief fashion and Zen (in this guidebook) has also reviewed them. As noted by both Fisher and Zen, the two most prominent hypotheses are those of facies contrast and of thrusting. The facies contrast hypothesis demands that the Late Cambrian and Ordovician sediments of the Taconics, which include coarse clastics, either be locally derived or the result of marked sedimentary by-passing and that the similarity of the Taconic succession with that of the same age in eastern Vermont (Doll, et al., 1961; Zen, 1961) is remarkably fortuitous. The thrusting hypothesis has stood in opposition to the facies hypothesis and in terms of general regional stratigraphy and paleogeography, particularly late Middle Ordovician paleogeography, seems the more plausible when all facts are considered. The hypothesis was apparently originally conceived by Ruedemann (1909), discussed by Keith (1912), and later elaborated upon by Cady (1945) and Zen (1961). Zen's (1961) work demonstrated that thrust faults do bound the northern margin of the Taconic rocks. Uncertainty has long prevailed over the position of thrust contacts, if indeed they are present, on other margins of the Taconic area. Potter (unpublished) has mapped a thrust contact between Taconic rocks and strata adjacent to them on the east in the east central part of the Taconic area. Ruedemann (in Cushing and Ruedemann, 1914) indicated that the western margin of the Taconic rocks, and therefore the thrust on the western border, must lie at the western limit of the truly pelitic rocks of Middle Ordovician age. He thus included all of the Normanskill Formation and what he termed the Snake Hill Shale within the Taconic area. The author (1962), in a study of the Normanskill Formation and of the rock units that overlie it (Berry, 1963), suggested that the western margin of the Taconic area is essentially delimited by the Hudson River, at least from Schuylerville, New York on the north to at least the Columbia-Rensselaer County line on the south. The western margin may parallel the Hudson

River as far south as Schultz Mountain in the Rhinebeck quadrangle or perhaps to Hyde Park, New York. If the border does parallel the Hudson River for a considerable distance, then a part of the Normanskill Formation and the rocks mapped by Ruedemann (in Cushing and Ruedemann, 1914) as Snake Hill Shale lie outside of the Taconic area and are, if thrusting did take place, autochthonous.

Warthin (oral communication, 1955), in the course of mapping the Rhinebeck and Poughkeepsie quadrangles, has demonstrated that the Normanskill Formation lies comformably above the Middle Ordovician Balmville Limestone. The base of the Normanskill Formation in these quadrangles includes some lenses of limestone and the upper part of the Balmville Limestone may intergrade laterally with the basal part of the Normanskill Formation. On the basis of this evidence, the conclusion that the southern margin of the Taconic area lies north of most of the terrain mapped by Warthin (but not north of Schultz Mountain, Zen this guidebook) is plausible. Further, the southern margin, like the western margin, probably lies within that terrain in which the Normanskill Formation crops out. These conclusions have been noted by Zen (1960, 1961, and this guidebook).

ZONES

Until recently, zonal evidence for precise dating of the several formations of the Taconic sequence and for correlation of them with the carbonate succession has not been available. This has been particularly true of the Ordovician strata, but now, through the use of graptolite zones, some detailed correlations are possible and these correlations have been investigated by the author.

The most precise correlations of Ordovician graptolite-bearing pelitic rocks may be accomplished by the use of zones. Graptolite zones, as have been discussed by the author (1960, 1962), are Oppelian in character. In the study of North American graptolite-bearing strata, partial or complete sequences of Ordovician graptolite zones have been recognized in west Texas (Berry, 1960), western Newfoundland (Kindle and Whittington, 1958), and the northern Yukon (Jackson and Lenz, 1962). These zonal successions were delimited after the ranges of many graptolite species through the strata under study had been analyzed. When the ranges of the several species were known, the joint association or congregation of several were noted to typify certain bodies of strata. Such strata, typified by a diagnostic joint association or congregation, are Zones. Many species may range through several Zones, some may be confined to one Zone, others may begin in one Zone and continue to range into younger beds, and yet other species may range into a Zone from underlying beds. Zones are not based on merely observed assemmblages of species found occurring one above another in a given area. They are based upon a study of the ranges of all of the species in an area under investigation worked out by careful sampling from many measured stratigraphic sections. After the ranges of all species have been determined in many measured sections, the ranges of several will be noted to overlap. A certain association of species which occurs in a thickness of rock thus results from the overlapping ranges of the several species found. Such associations differ from others above and below. The limits of the strata bearing them, which are zone boundaries, are chosen at the incoming of several new species, commonly those pertaining to new phylogenetic lineages. A diagnostic joint association or congregation or species may thus be interpreted to have a time significance. The strata bearing the association or congregation interpreted to be time-significant are considered to constitute a Zone, in the Oppelian usage of that word.

One species occurring in the strata that constitute the Zone is commonly chosen, essentially on personal bias, to give its name to the Zone. The name-giver has no special significance and may or may not be limited to the Zone. Further, it may or may not occur commonly in the strata included in the Zone to which its name is given.

The three North American Ordovician graptolite zonal sequences mentioned above are closely similar, but only the succession in west Texas appears to represent the entire Ordovician. For that reason the zonal terminology discussed by the author (1960) in that area has been used on the correlation chart (Table 1) and will be employed in this discussion. As noted by the author (1962), graptolite assemblages found in the New York Ordovician graptolite-bearing strata are so similar to those in west Texas, that they may be interpreted to be the same as the diagnostic congregations of species that characterize the west Texas Zones.

Graptolite-bearing strata seldom include other kinds of fossils, thus correlation of them with non-graptolitic, shelly-fossil bearing strata is difficult. The author (1960) discussed correlation of the Texas graptolite Zones with the Series and Stages of the Ordovician in North America based upon shelly fossils. That study and additional graptolite finds in primarily shelly-fauna bearing strata suggests the Middle Ordovician correlations as shown on Table 1.

THE CORRELATIONS

Cambrian - Early Ordovician

Early Cambrian age strata are well developed in the Taconics as dominantly pelitic rocks and as dominantly quartzites and carbonates in adjacent areas to the east and south. Demonstrable Middle Cambrian rocks have not been found either in the Taconics or in the areas adjacent to them. The depositional pattern that continued into the Early Ordovician began both in the area where the Taconic rocks were deposited as well as in the areas presently adjacent to them, in the Late Cambrian.

<u>The Taconics</u> - Deposits of probable Late Cambrian age in the Taconic area include quartzites and shales grouped in the Hatch Hill Formation by Theokritoff (1959), quartzites included in the Eagle Bridge Quartzite by Prindle and Knopf (1932), and thin siltstones, ribbon limestones, and shales termed the Germantown Formation by Fisher (1961 b). The Hatch Hill and Germantown Formations have yielded dendroid graptolites which the author considers to be most similar to denroids figured by Ruedemann (1947, pl. 18, 19) from Late Cambrian strata. The strata of both the Hatch Hill and Germantown Formations that bear the graptolites demonstrably underlie strata bearing Early Ordovician graptolites.

The Hatch Hill Formation is conformably overlain by the Poultney Slate. It bears the diagnostic Early Ordovician graptolites <u>Dictyonema</u> <u>flabelliforme</u> and <u>Staurograptus</u> <u>dichotomous</u> in its basal beds exposed near North Granville and Middle Granville, New York and one-half mile south of South Hartford, New York. The writer (1961) identified graptolites typical of Texas graptolites Zones 2, 3, and 4 collected from the Poultney Slate two miles southwest of Hampton, New York.

A group of graptolites diagnostic of Zone 4 have also been identified by the author in collections from the Poultney Slate exposed at the summit of Mt. Tom in the Hoosick Falls quadrangle submitted by Dr. D. B. Potter. Further, the author noted (1961) that the dependent didymograptid D. protobifidus had been collected by Walcott and Prindle from rocks probably assignable to the middle part of the formation 6 miles southwest of Hampton, New York. This species is known to occur only in the zone to which it gives it name (Zone 6) and that Zone is probably latest Early Ordovician in age. The only other graptolites collected from the Poultney Slate are from its stratigraphically highest beds exposed 2 miles south of Hampton, New York. The assemblage collected there was noted (Berry, 1961) to be probably indicative of the Nemagraptus gracilis Zone (Zone 11) which is herein considered to be a correlative of the Middle Ordovician Ashby Stage. Thus, faunal evidence obtained to date suggests that the Poultney Slate is surely Zone 1 through Zone 6, or Canadian, age, and that its uppermost part is of Middle Ordovician, probably Ashby, age. Fossils indicative of an early Middle Ordovician age have not been found in the Poultney Slate as Fisher (1962 b) pointed out. No fossils have been collected from the upper part of the formation except the one collection from the stratigraphically highest beds. Further, the strata comprising the formation appear to be comformable throughout and they have been so mapped by Zen (1961), Theokritoff (oral communication, 1959), Platt (Ph.D thesis, Yale University), and Potter (this guidebook) in the northern part of the Taconic area. From this evidence, the author suggested (1961) that the Poultney Slate does include strata of early Middle Ordovician age and the deposition was continuous in at least a part of the area of the present Taconic rocks from the Late Cambrian throughout the Early and Middle Ordovician.

The Poultney Slate or its lithic equivalent can be recognized from the northern part of the Taconic area south to the northern part of Rensselaer County. Fisher (1961, 1962 b) gave the name Stuyvesant Falls Formation to green shales, green siltstones, siliceous argillites, and some thin black shales which conformably overlie the Germantown Formation in Columbia County. The author indicated (1962, p. 709) that this unit could be recognized at Snyder's Lake (5.5 miles southeast of Troy) in Rensselaer County. Thus, the formation may be widespread in the southern part of the Taconic area. As noted by the author (1962), the formation yielded Early Ordovician graptolites from a locality 4.5 miles east of Albany (Ruedemann, 1947), a collection of Zone 5 graptolites from 3.8 miles south of Hudson, New York (this locality is stop 6 of the trip), collections of Zone 6 graptolites from Stuyvesant, New York, and Zone 9 graptolites from the east side of Mount Merino (Ruedemann's (1908) Ashhill Quarry) and a locality southeast of it. The Stuyvesant Falls Formation apparently spans the entire Early Ordovician and includes at least some Middle Ordovician strata. It has not been mapped in sufficient detail to ascertain if unconformities are present in it or not, but it may, like the Poultney Slate, represent continuous deposition from the Early Ordovician into the Middle Ordovician (into approximately Porterfield age). Its contact with the overlying Normanskill Formation appears to be conformable in the few exposures examined.

Two other formations of Early and early Middle Ordovician age have been recognized within the Taconic area, the Schaghticoke and Deepkill Shales. The Schaghticoke Shale is identical in lithologic aspect and fauna to the basal part of the Poultney Slate. Only one exposure of it is known and that lies close to the western margin of the Taconic rocks. The Deepkill Shale, as discussed by the author (1962), is latest Early Ordovician and early Middle Ordovician in age. Its lithology, in part, resembles that of the Poultney Slate, but it also includes a considerable amount of limestone. Exposures of the Deepkill Shale are restricted to the vicinity of the Deep Kill gorge near Melrose, New York.

Areas adjacent to the Taconics - The Late Cambrian - Early Ordovician rock succession in areas adjacent to that presently occupied by the Taconic rocks includes quartzose sandstone at the base followed by primarily carbonates. Deposition of carbonate in areas adjacent to that now occupied by the Taconic rocks continued uninterruptedly into the Early Ordovician. It may have continued without cessation into the Middle Ordovician, locally within the terrain of the northern part of the Middlebury synclinorium. South from that terrain, a regional unconformity separates the Late Cambrian - Early Ordovician carbonates from those of the Middle Ordovician. The correlations suggested by Fisher (1962 b) indicate that this unconformity may have developed slightly earlier in the Rhinebeck-Poughkeepsie area than it did north of there.

If the Poultney Slate and Stuyvesant Falls Formation and the formations under them do represent continuous deposition which began in the Late Cambrian and continued uninterruptedly throughout the entire Early Ordovician and early part of the Middle Ordovician, then the area of the present Taconic rocks did not undergo a period of hiatus in the early part of the Middle Ordovician as did the carbonates in the present areas west, south, and east of them. Depositional history of the Taconic rocks and that in the areas presently adjacent to them is, in this interpretation, dissimilar. This dissimilarity in depositional history would mitigate against the validity of the facies hypothesis as the explanation for the anomalous present position of the Taconic rocks. An early Middle Ordovician unconformity might reasonably be expected in the Taconic rocks if they were in their present position at the same time that an unconformity was being developed in areas adjacent to them.

MIDDLE ORDOVICIAN

The Taconics - Within the area of the Taconic rocks, the Normanskill Formation succeeds the Poultney and Stuyvesant Falls Formations conformably. The details of the stratigraphy and fauna of the formation have been discussed by the author (1962). Four members may be recognized within the formation and all of these, with the exception of the upper part of the stratigraphically highest member, bear graptolites diagnostic of Zone 12 (*Climacograptus bicornis* Zone). The upper part of the highest member of the formation bears graptolites indicative of Zone 13 (*Orthograptus truncatus* var. *intermedius*). This stratigraphically highest member (Austin Glen) rests unconformably on lower parts of the formation and on older strata locally in the northern and central parts of the Taconic area (Zen, 1961; Potter, unpublished). On the east-central margin of the Taconic area, Potter has noted that rocks lithologically similar to those in the upper part of the Normanskill Formation occur as lenses in the upper part of the Walloomsac Slate. This relationship suggests that the sediments of the Walloomsac and upper part of the Normanskill formations intergraded laterally during the time they were deposited.

Areas adjacent to the Taconics - Early Part of the Middle Ordovician - Following the early Middle Ordovician hiatus in the areas of carbonate deposition, carbonate deposition once again took place. West of the present position of the Taconics, the well known Black River limestones were deposited (Fisher, 1962 b).

South of the Taconics, Warthin (oral communication, 1959) has mapped the Balmville Limestone as lying unconformably above the Late Cambrian - Early Ordovician carbonates and beneath the Normanskill Formation. Lists of fossils from the Balmville Limestone have been examined by Cooper who suggested (in a report to Zen dated February, 1960) that fossils listed by Dwight (1879) and Knopf (1927) from a railroad cut at Pleasant Valley, New York indicate a Wilderness age (correlation with the Lowville Formation) for the stratigraphically lower collection and an early Trenton age (an approximate correlation with the Ion Formation of the midwest which is a correlative of the lower part of the Sherman Fall Formation) for the stratigraphically higher collection. According to Cooper's report, the fossils listed by Dwight (1879) and Knopf (1927) from the Balmville Formation exposed at Rochdale, New York also suggest correlation with the Ion Formation and an early Trenton age.

A number of geologists have found Porterfield age carbonates east of the Taconic rocks, showing that the Late Cambrian - Early Ordovician age carbonates are unconformably overlain by these Middle Ordovician carbonates. Weaver (1957) indicated in his mapping of the Copake quadrangle that in the area east of the Taconic rocks, limestone of Black River or possibly early Trenton (in the sense of Kay, 1937) age (rocks of Wilderness age) unconformably overlies Early Ordovician limestone.

Geologists working at the north end of the Taconic belt, including for example Cady (1945) and Zen (1961), have shown that the carbonate rocks of the Middlebury synclinorium occur both east and west as well as north of the Taconic rocks. Zen (1961) has referred to rocks in the Middlebury synclinorium as those of the "synclinorium sequence". From the discussions of the Early and Middle Ordovician carbonates presented by both Zen (1961) and Cady (1945), the latest Early Ordovician carbonates may, in a few places, grade conformably upward into those of Middle Ordovician age. The Middle Ordovician carbonates appear to represent a conformable sequence, containing fossils indicative of probably Marmor and post-Marmor age. Carbonate deposition may have been continuous throughout Early and much of Middle Ordovician time, without hiatus, very locally within the area of the northern part of what is now the Middlebury synclinorium.

Areas adjacent to the Taconics - Latter part of the Middle Ordovician - Black shale commonly overlies Middle Ordovician carbonate in areas adjacent to the Taconics. To the east of the central Taconic area, the Walloomsac Slate overlies the Porterfield age carbonates. It bears Zone 12 (*Climacograptus bicornis* Zone) graptolites in its upper part. The basal part of the Walloomsac Slate is probably Wilderness in age, but it may be as old as Porterfield. Exotic blocks have been found by Potter (see article in this guidebook) in the slates comprising the stratigraphically uppermost part of the Walloomsac Slate. The blocks-in-slate unit will be seen at Whipstock

Hill (stop 4). It may be Wilderness in age or possibly as young as Early Trenton (in the sense of Cooper, 1956).

North of the Taconic rocks, the youngest carbonate unit, the Glens Falls Limestone is, in its stratigraphically uppermost part, a correlative of the Shoreham Limestone (Early Trenton in age in the sense of Cooper, 1956), at least in its more easterly exposures. The shales of the Hortonville Formation conformably overlie it on the west side of the Middlebury synclinorium, and those of the Ira Formation succeed conformably the Whipple Marble Member of that formation on the east side of the synclinorium. The carbonate units intergrade on both sides of the synclinorium axis. The lower part of the Hortonville Formation near Hortonville, Vermont has yielded orthid brachiopods (Kay, 1959). Zen (written communication, 1963) indicated that Cooper had examined some of the brachiopods at his request and had noted that they suggested a questionable correlation with the Ion Formation (Early Trenton age). Zen (1961) mapped the Forbes Hill Conglomerate at several places within the Hortonville Formation on the northern margin of the Taconic rocks. The cobbles and pebbles of the conglomerate include several rock types common among those of the Taconics.

South of the Taconic rocks, Warthin (oral communication, 1959) has mapped the Normanskill Formation as lying conformably above the Balmville Limestone, and perhaps the two formations in part intergrade. Silty beds within the mudstone-shale succession that comprises the middle part of the Normanskill Formation in the Rhinebeck and Poughkeepsie quadrangles have yielded brachiopods, some of which have been examined by Cooper. In a report to Zen (dated 1960), Cooper noted that these were probably Early Trenton in age - approximately the age of the Ion Formation. Graptolites from the same part of thr formation, yet from different places than those in which the brachiopods were obtained, are diagnostic of the _Climacograptus bicornis_ Zone (Zone 12).

A few brachiopods have also been collected from the Austin Glen member of the Normanskill Formation by Warthin and these are also considered by Cooper to be of probable Early Trenton age. The brachiopods from the sandstones in the Normanskill Formation are the same species as those obtained from the upper beds of the Balmville Limestone.

The upper part of the Normanskill Formation (Member 3 and the Austin Glen Graywacke) crops out immediately west of what the author considers the present Taconic area, on the west short of the Hudson River. _Climacograptus bicornis_ Zone (Zone 12) graptolites have been collected from Member 3 and the lower part of the Austin Glen Graywacke, and _Orthograptus truncatus_ var. _intermedius_ Zone (Zone 13) graptolites have been collected from the upper part of the Austin Glen Graywacke in this area (Berry, 1962). A significant fossil locality in the exposures of the Normanskill Formation immediately west of the Taconic rocks is that at Snake Hill on the east shore of Lake Saratoga. As discussed by the author (1963), strata comprising the upper part of the Normanskill Formation (a part of Member 3 and the Austin Glen Graywacke Member) form the only formation exposed in the area which Ruedemann (in Cushing and Ruedemann, 1914) designated as the type for the Snake Hill Shale. The graptolite fauna from that part of the Normanskill Formation exposed at Snake Hill is diagnostic of the _Orthograptus truncatus_ var. _intermedius_ Zone (Zone 13). The shelly fauna, which occurs with graptolites in both Member 3 and the Austin Glen Graywacke Member, includes Cryptolithus tesselatus and orthid brachiopods which indicate a correlation of the beds bearing them with the lower part of the Sherman Fall Limestone, the Shoreham Limestone. The brachiopods in the fauna are the same species that occur in lenses in the upper part of the Normanskill Formation in the Poughkeepsie and Rhinebeck quadrangles.

East and northeast of Snake Hill, a unit composed of cobbles and pebbles of graywacke, chert, and mudstone in a shale matrix overlies the Normanskill Formation. In areas west of Snake Hill, a unit of thin-bedded siltstone and silty black shale overlies the Normanskill Formation. The two units appear to grade laterally into each other. The siltstone unit may be a more silty eastward facies of at least part of the Canajoharie Shale as it bears a graptolite fauna closely similar to that of the upper or Fairfield Member of that formation. The fauna is indicative of the Orthograptus truncatus var. intermedius Zone (Zone 13).

The pebbles and cobbles in shale unit exposed east of Snake Hill crops out on both the east and west banks of the Hudson River from Schuylerville, New York on the north to at least the Rensselaer - Columbia County line on the south. The unit has also been mapped immediately east of the Hudson River in the vicinity of Troy by Elam (1960, Geology of Troy South and East Greenbush Quadrangles, New York, Ph.D.Thesis, Rensselaer Polytechnic Institute). Shales forming the matrix of the unit have yielded Zone 13 (Orthograptus truncatus var. intermedius) graptolites. Some limestone blocks in the unit have yielded brachiopods, the youngest of which indicate correlation with the Hull Limestone (Cooper, 1956). Such blocks must have been incorporated within the shale matrix at the same time or after the deposition of the Hull Limestone occurred.

South from Snake Hill on the west side of the Hudson River, the upper part of the Normanskill Formation is well exposed and it has yielded Zone 12 (Climacograptus bicornis Zone) graptolites from several localities. Its stratigraphically highest beds bear a Zone 13 graptolite fauna. The siltstone unit, similar to that exposed near Snake Hill, or a silty black shale overlies the Normanskill Formation west of the Hudson River. The siltstone unit apparently grades laterally westward into the shales of the Canajoharie Shale which in turn, as shown by Kay (1937), grade westward through the Dolgeville facies into the Sherman Fall Limestone.

From this evidence, the general conclusion may be reached that during Wilderness time, black shale deposition began in the area east of the present position of the Taconic rocks and that this type of deposition spread westerly during Wilderness and Trenton time. Coarse grained sandstone deposition (the Austin Glen Graywacke Member of the Normanskill Formation) followed it westward. Then, shale deposition again took place east of, and to some extent later than that of the Austin Glen Graywacke Member. In many places, this shale forms the matrix of the cobbles and pebbles in shale unit, the shales forming the matrix of the Forbes Hill Conglomerate, and the matrix of the conglomerate exposed at Whipstock Hill. If the blocks, cobbles, and pebbles of this unit were dropped from the margins of large sheets of previously formed rock being thrust or sliding westward, they dropped into an area of black shale deposition. Because large blocks of the Austin Glen Graywacke are locally common in the blocks-in-shale unit, the unit must have formed after at least some of the sediments that now comprise the Normanskill Formation had been deposited and lithified, at least in a part of the area of the Taconic rocks. The upper part of the Normanskill Formation may well have been being deposited at the same time in the area that is now adjacent to the present south margin of the Taconic rocks. The formation of the blocks-in-shale unit, and thrusting or sliding, which probably indeed did occur, took place during the time of deposition of the upper part of the Sherman Fall Limestone or during the early part of the Trenton (in the sense of Cooper, 1956).

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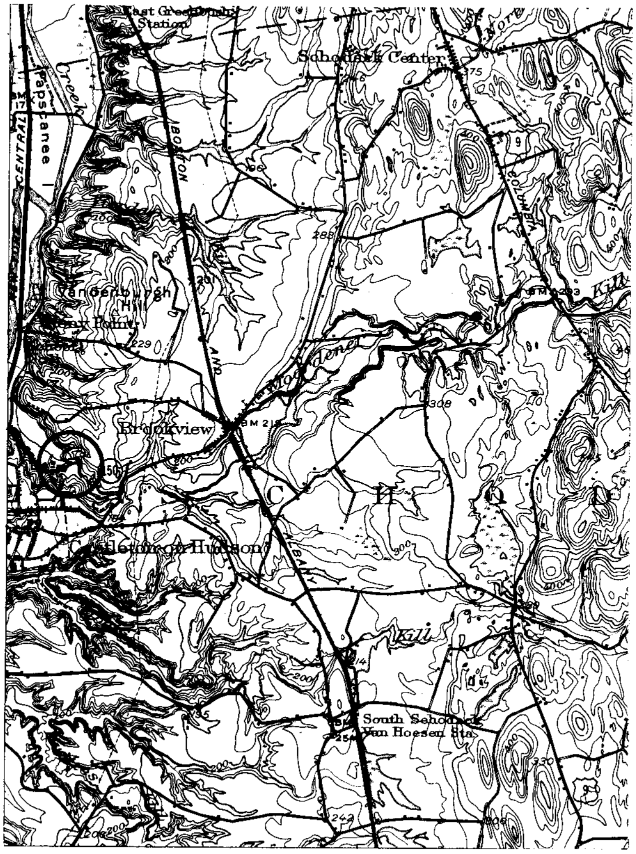
LOCATION MAPS FOR TRIP STOPS

One inch equals 1.5 miles

Stop 1



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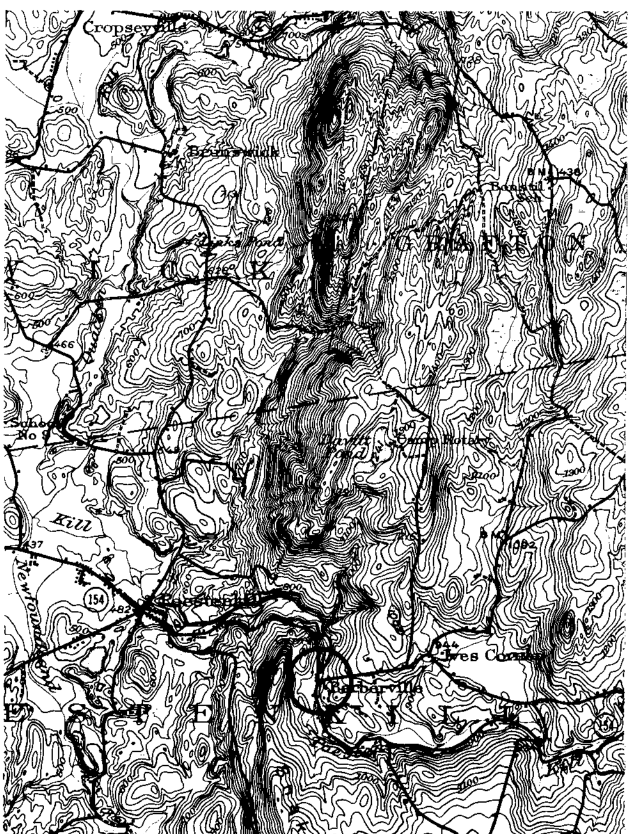

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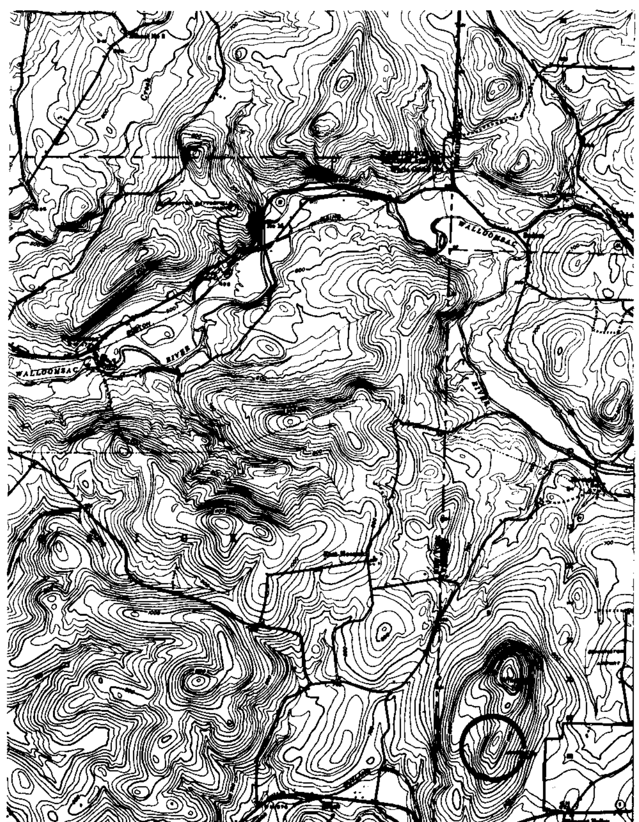

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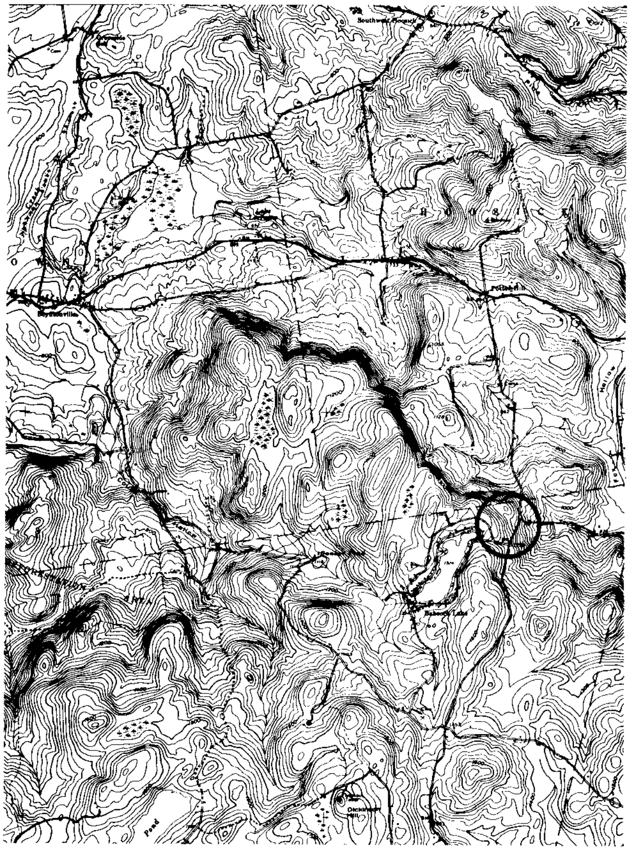

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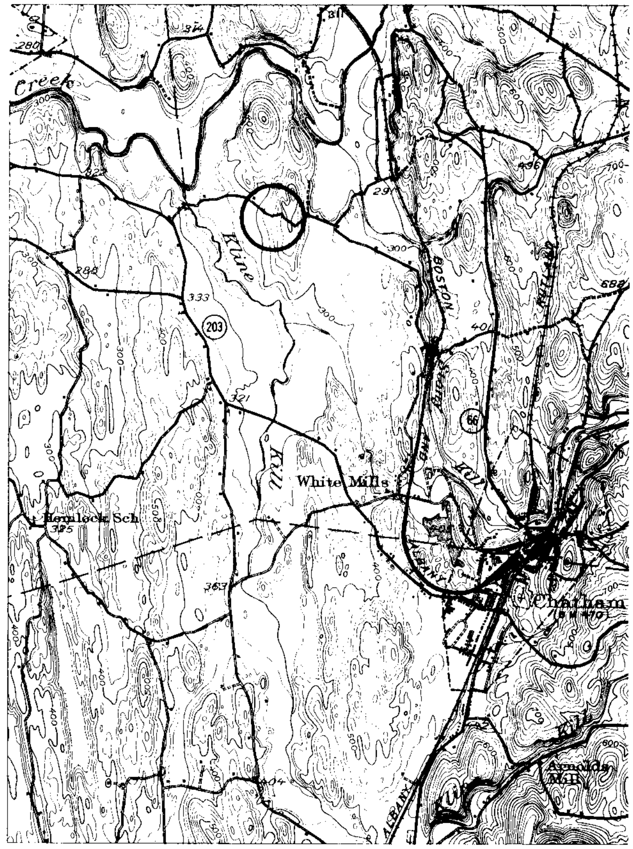

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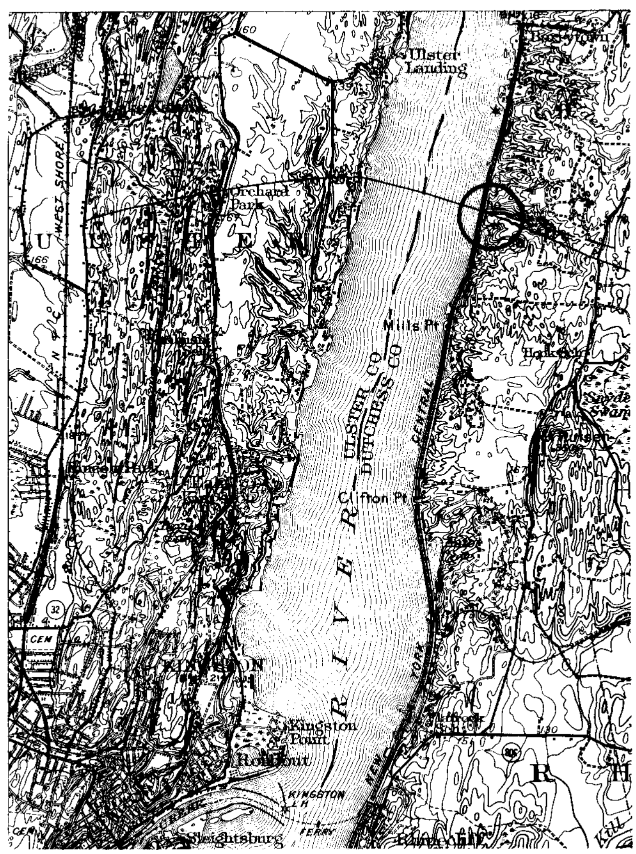
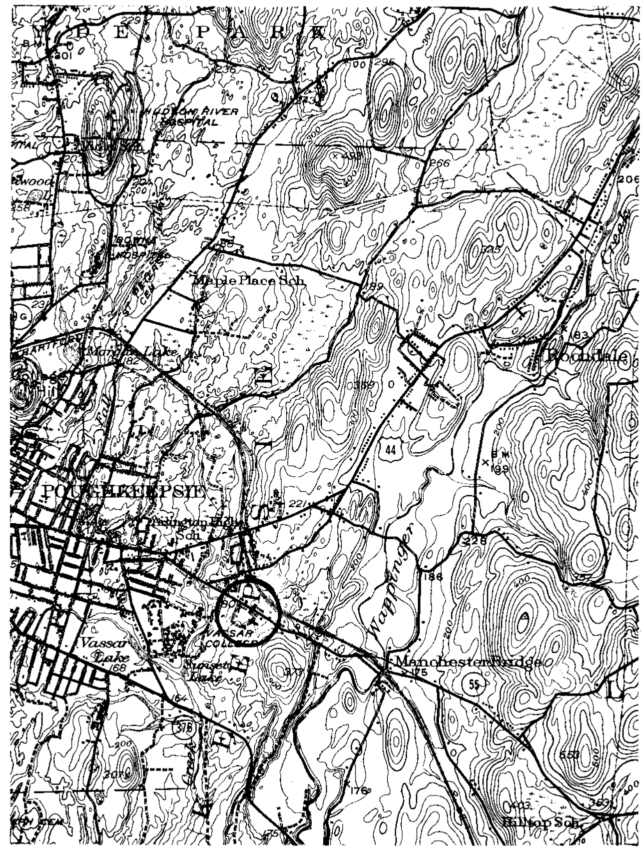


STOP 9

STOP 10



ROAD LOG

by E-an Zen and J. M. Bird*

First Day

Mileage	
0.0	Start of log at junction of Routes 34 and U. S. 9 and 20, east portal of the Dunn Memorial Bridge, Rensselaer, N. Y. Follow Routes 9 and 20 east.
1.0	Junction with Route 9J. Turn right (south) on 9J.
6.5	Hudson River tidal flats to the right (west) of the road.
8.0	Turn left at private road of the Fort Orange Paper Co. plant. Road is marked "Oak Grove Mills". Proceed 0.2 miles to parking lot.
8.3	STOP 1. Moordener Kill

Walk east from the plant of the Fort Orange Paper Company into the gorge of the Moordener Kill. Follow foot path on the south side of the creek upstream to the base of the lower water fall.

The dominant rock in the gorge is a silty black slate which has yielded graptolites to J. G. Elam. The graptolites are characteristic of Zone 13 of the Marathon succession (Berry, 1960); the slate, therefore, is correlative with the Canajoharie Shale. Within the black slate, beginning below the lip of the lower falls, are "exotic" blocks, that is, rocks not in a sedimentary sequence with the black slate, which range in size from a fraction of a foot to twenty feet or more. The blocks include (1) a limestone conglomerate with brown-weathering limy matrix, typical of the conglomerate at Rysedorph Hill (Ruedemann, 1901, 1930); (2) green and grey chert; (3) green slate with brown, silty laminae; (4) brown weathering, dolomitic siltstone; (5) green subgreywacke; and (6) greywacke of the Austin Glen Member of the Normanskill Shale, among other rocks. Type (2) may be of the Mount Merino Chert of the Normanskill Shale, whereas types (3), (4), and (5) recall, respectively, the Poultney Slate, the Hatch Hill Formation, and the Zion Hill subgreywacke (equivalent to the Curtis Mountain Quartzite of Fisher, 1962), all of which are in the allochthonous Taconic sequence exposed a short distance to the east.

The faunal content of the limestone blocks from type (1) blocks has been described by Ruedemann (1901, 1930). In the summer of 1962, Bird, Theokritoff, and Zen discovered trilobite fragments, identified by Theokritoff as of the Early Cambrian *Elliptocephala asaphoides* fauna, in the conglomeratic block on the north bank of the stream at the lip of the lower falls.

*With the assistance of D. B. Potter from stop 3 to the end of road log for the first day.

Note that the various "exotic" blocks are randomly distributed in the black slate matrix. Notice, also, that the black slate shows only vestigial bedding and the cleavage is greatly contorted. The rock unit, as a whole, is herein referred to as the Wildflysch-like conglomerate, after a similar rock unit in the Swiss Alps. Berry (1962) named this the "block-in-shale" unit of the Normanskill Shale.

Zen (1961) interpreted the lithically similar Forbes Hill Conglomerate at the north end of the Taconic allochthone as being composed of blocks that, spalling from the advancing Taconic allochthone, slumped or slid onto a sea-floor receiving the Mid-Orodovician (Canajoharie-correlative and equivalent) black mud sediment. If Zen's interpretation of the Forbes Hill Conglomerate is correct and can be applied to this outcrop, then the deposition of this rock unit heraled the early phase of the Taconic thrusting in this part of the Taconic region.

Turn around and return to Route 9J.

8.5 Turn left (south) onto 9J.

10.0 Turn left at traffic light in Castleton-on-Hudson onto New York Route 150.

11.3 Road crosses Moordener Kill.

11.7 Road cut in the upper Normanskill Shale.

13.3 Bear right with Route 150.

15.4 Junction with Routes 9 and 20. Turn right.

15.5 Turn left; follow Route 150. Stay on 150 for the next 8.5 miles.

18.2 Village of East Schodack; bear left on Route 150.

18.9 Begin road cut exposures of the Mettawee Slate (Nassau Formation); purple and green slates.

20.4 Junction with Route 151; continue on 150.

21.8 Junction with Route 152; continue on 150.

23.5 End road cuts in Mettawee Slate

24.9 Village of West Sand Lake. Turn right onto Route 43 at stop light.

27.4 STOP 2. Road cut on the north side of New York Route 43, 0.6 mile northwest of the village of Averill Park.

The rocks of this exposure, all part of the pre-*Elliptocephala* Early Cambrian section of the allochthonous Taconic sequence, consist of the Rensselaer Greywacke, the Bomoseen Greywacke, and the purple and green Mettawee Slate. These three lithic types are part of the Nassau Formation as redefined by Bird (1962). They are here seen to be interbedded, thus demonstrating their partial contemporaneity. This point is pertinent, because the age of the Rensselaer Greywacke has long been moot (see Zen, in press); the relations of the strata at this outcrop and at stop 3 show that this rock is a part of the Taconic sequence, conformably underlying rocks bearing the Early Cambrian Elliptocephala asaphoides fauna.

Note that the Rensselaer Greywacke strata are graded and have loadcast features; these indicate that the top of the section is to the northwest, and that the outcrop is slightly overturned.

The Bomoseen Greywacke thickens and coarsens to the southwest of this outcrop. Despite the interbedding, the regional distribution as well as local structural relations show that, as a whole, the Bomoseen is slightly younger than the Rensselaer Greywacke, and is very likely a western facies of the Rensselaer Greywacke.

The bulk of the Rensselaer Greywacke occurs in the Rensselaer Plateau, some two miles east of this outcrop, where it is also interbedded with purple and green Mettawee Slate strata and subsidiary strata of the Bomoseen Greywacke. The Rensselaer Plateau is separated from the area to its west by a major thrust fault, the Rensselaer thrust (Zen, in press), which at places is a zone of imbrication. With the exception of the Tackawasick Limestone, which contains Trenton fossils (see Ruedemann, 1930), the thrust fault(s) separates rocks of Early Cambrian age on both sides; the Tackawasick Limestone must have been brought to its present position from an easterly source as a tectonic silver along the sole of the Rensselaer thrust. Lithically, the Tackawasick Limestone, and several areas of Early and Middle Ordovician dolostone and limestone on line with it, are typical of units in the synclinorium sequence. Bucher (1957) and Craddock (1957) explain these carbonate rocks as being autochthonous and unconformably overlying the Lower Cambrian Taconic sequence rocks. Because all these carbonate outcrops, including the Tackawasick Limestone, are along the trace of a major thrust fault, called the Chatham thrust by Craddock (1957), the autochthonous explanation does not seem tenable. Detailed field work in these areas, in part by T. W. Talmadge (oral communication to Zen 1961-1962), also failed to substantiate the synclinal structure attributed to the carbonate rocks by Bucher (1957).

On the northeast and east side of the Rensselaer Plateau also, along the valley of the Little Hoosic River, the Rensselaer Greywacke in part overlies Ordovician carbonate and black slate (the Walloomsac) of the autochthonous sequence. The contact is well exposed just south of Buck Rock, about two miles west of Cherryplain. These relations will also be demonstrated at stop 5 (Babcock Lake). The relations with the carbonates indicate that the Rensselaer Plateau must be severed on all sides from its root zone.

Continue on Route 43 to the southeast.

28.3 Turn left onto Route 66 (go north).

30.9 Turn right off Route 66 onto Round Top Road, which is Rensselaer County Road 127. Road cuts in Mettawee Slate at corner.

31.4 The buses will stop momentarily by a road cut of purple Mettawee Slate. The wooded hills to the right and ahead define the western limit of the Rensselaer Plateau.

33.1 Turn right onto Rensselaer County Road 3 in the village of Poestenkill.

33.4 Purple Mettawee Slate on right (south) side of the road.

34.0 Purple Mettawee Slate on right (south) side of road.

34.2 Quarry in the Rensselaer Greywacke and Mettawee Slate to the right (south) of the road.

35.0 Turn left onto Rensselaer County Road 30; cross bridge to the east side of the brook. Leave Bus.

STOP 3. Barberville Falls exposure. Walk 300 feet northward along path from the east side of the bridge over the Poesten Kill. Outcrop is to the left (west) in the stream bed.

The interbedding of the Bomoseen Greywacke, the Rensselaer Greywacke and the green and purple Mettawee Slate seen at stop 2 is also demonstrated at this stop which is, however, within the Rensselaer Plateau. Here the Rensselaer Greywacke strata are much thicker and the Bomoseen very minor. The green and purple Mettawee Slate is the same as seen on the northwest side of Round Top Road, (mileage 31.4, 1.5 miles south of the village of Poestenkill) which is almost a mile west of the western edge of the Rensselaer Plateau.

Due west of this stop, one can see the crest of Snake Hill, part of the western edge of the Plateau, composed of massive Rensselaer Greywacke strata.

The crest of the Barberville Falls is along the axis of a north-south trending anticline. The eastern limb of the fold has been eroded to a small cliff, exposing the termination of a Rensselaer Greywacke bed in the Mettawee Slate and various other thinner and finer grained turbidites which are continuous over the whole length of the exposure. The termination of the greywacke bed is therefore not a fault feature, but is the result of "lensing-out" of the graded greywacke in the slate.

Close examination of the thin greywacke strata shows turbidite features such as load casts and some of Bouma's various turbidite intervals. The sample shown in Figure 4 of Bird's article is from the southern edge of the outcrop area, near the stone wall. Coarse graded bedding is visible in the thicker greywacke strata. Note that some of the thin greywacke strata have a reddish matrix rather than the usual green. This is attributed to incorporation of the red sea-floor muds into the greywacke sediment during density-current transport.

The greywacke bed termination is significant, because detailed mapping in the area has shown that it is not possible to trace individual beds of greywacke any great distance north-south. The greywacke strata occur as wedges within a thick section of the Mettawee Slate; these wedges rapidly thin to the west and apparently terminate to the north (or south) as seen here.

The coarsest Rensselaer Greywacke strata occur along the western side of the Rensselaer Plateau. Balk (1953, p. 826 and p. 859) invoked a western source for the greywacke because of this fact. On the west side of the Plateau, rocks tectonically underlying the coarse greywacke are the thinner, finer grained greywacke, as seen at stop 2. The greywacke becomes much finer grained eastward, within the upper Rensselaer Plateau Slice, and also within the Mount Anthony-like rocks east of the Berlin Valley (see Potter, this guidebook).

35.1 Continue on County Road 30 northeastward.

35.9 Road junction by white frame house; turn right onto Rensselaer County Road 89.

37.4 Stop sign. Bear left to rejoin County Road 3 at the village of East Poestenkill.

39.1 Rensselaer Greywacke on the right.

41.4 Bear left onto Rensselaer County Road 15.

44.2 Descend the east edge of the Rensselaer Plateau.

46.3 Entering the village of Berlin. In July, 1962, a wandering propane tank-truck overturned at the foot of the hill along this road and exploded, killing 11 people and destroying a substantial part of the village. The remains of the fire and blast damage may be seen along the road.

46.4 Center of the village; go past the bronze statue and bear left by the fire hydrant. Proceed 300 feet to a stop sign.

46.5 Stop sign, junction with Route 22. Turn left (north) onto Route 22 which follows the valley of the Little Hoosic River.

50.6 Road cut in purple and green slates of the Mettawee Slate for the next 0.4 mile.

51.5 Village of Petersburg; junction with U. S. Route 2. Continue north on Route 22 AFTER LUNCH STOP.

51.7 Roadcuts to the left comprised of plunging folds in the Bomoseen Greywacke, the Mettawee Slate, the Hatch Hill Formation, and the Poultney Slate.

52.1 Steep, wooded hill to the right is Moon Hill, first described by Prindle and Knopf (1932). Recent restudy of this hill indicates that the stratigraphic section is inverted. The rocks at the base of the hill are part of the Normanskill Shale (Middle Ordovician). This is followed uphill by the Poultney Slate (Middle and Lower Ordovician), the Hatch Hill Formation (Upper Cambrian), the West Castleton Formation (Lower Cambrian), the Bomoseen Greywacke and the Mettawee Slate of the Nassau Formation (Lower Cambrian and Cambrian?);the hill is capped by the Rensselaer Greywacke of the Nassau

Formation (Cambrian?). Prindle and Knopf (1932) reported a Lower Cambrian fossil from the west side of this hill.

The roadcut to the left is in the Hatch Hill Formation.

54.1 Top of the hill ahead is capped by the Rensselaer Greywacke, belonging to the Rensselaer Plateau Slice. The greywacke is thrust over younger Lower Cambrian slates of the Nassau Formation, with an intervening zone of Ordovician carbonates which are part of the synclinorium sequence and apparently occurring as tectonic slivers (as at stop 5).

The thrust surface underlying the Rensselaer Plateau Slice is exposed in the hills on both sides of the road. Outcrops along the road are the Mettawee Slate and the Bomoseen Greywacke, tectonically underlying the Rensselaer Plateau Slice. These rocks are, in turn, thrust over Ordovician carbonates of the autochthonous synclinorium sequence. This lower slice is probably the same as the Giddings Brook Slice of Zen, 1961.

54.5 Road cuts in the Mettawee Slate and the Bomoseen Greywacke.

56.4 Ordovician limestone and dolostone along the road. These rocks, possibly belonging to the Beldens Member of the Chipman Formation (Cady and Zen, 1960), are part of the autochthonous synclinorium sequence.

57.2 Village of North Petersburg, junction with Route 346. About 200 feet above the level of the valley floor, on the steep east flank of the wooded hills to the left (west) of the road, the thrust contact between the autochthonous Beldens(?) Member and the Cambrian and Ordovician rocks of the allochthonous Taconic sequence is exposed. The Taconic rocks are much contorted and sheared along the contact. This contact is significant because of its location on the east side of the Taconic allochthone, where the structural relations between the two sequences have hitherto remained much in doubt. It is unfeasible to lead a large group to this outcrop. Those interested can reach the outcrop by leaving the road at the transformer station a short distance north, along Route 22, and go straight up-hill to the base of a line of cliffs. The cliffs are in the allochthone; at the base of the cliffs the autochthonous carbonates crop out sporadically.

Turn right at road junction onto Route 346 going east.

57.9 Turn left in front of grey barn onto Rensselaer County Road 11.

58.2 Bear left after crossing bridge.

58.4 Road cuts are in Lower and Middle Ordovician dolostone and limestone, part of the autochthone exposed in the Hoosick Falls re-entrant of the Taconic allochthone.

58.5 Middle Ordovician Walloomsac Slate, here involuted with the carbonates. The Walloomsac, as well as the Middle Ordovician carbonates

(= the Whipple Marble Member of the Ira Formation; Zen, 1961), rest above the older rocks of the synclinorium sequence with a profound unconformity; this is the same unconformity that will be visited at stop 9 on the second day.

59.2 Sharp turn to the right, follow Rensselaer County Road 20. Hills ahead with power line are underlain by interbedded Bomoseen and Rensselaer Greywackes of the allochthone.

59.8 Lower Ordovician Poultney Slate along the road.

60.1 Valley to the right is Breeze Hollow, underlain by carbonates of the autochthonous synclinorium sequence.

61.5 High peak to the right in the middle distance is Mount Anthony, the type locality of the Mount Anthony Formation (MacFadyen, 1956). The rock is a green-grey chloritoid-bearing schist, part of the so-called "high Taconic" section. This rock section overlies the autochthonous synclinorium sequence ("low Taconic" section) that has concerned us so far. The relationship between the "high Taconic" section and the two underlying sections is very controversial. Dale (1912), MacFadyen (1956) and Hewitt (1961) believe that the "high Taconic" section rests unconformably above the two underlying sections, and is late Middle Ordovician in age. Prindle and Knopf (1932), Doll and others (1961), as well as the leaders of the trip, however, consider the "high Taconic" section to be largely Cambrian in age, correlative with the Nassau Formation at least in part, and thrust over the two underlying sections as part of the Taconic allochthone.

61.6 Walloomsac Slate along the road.

62.2 Bare knob ahead is Whipstock Hill.

63.4 Stop sign. Carbonates of the synclinorium sequence along the road; part of the autochthone. Turn right sharply onto New York Route 7.

64.0 Entering State of Vermont.

64.7 Transistor Electronics Plant to the left (north).

64.9 Turn left at dirt road in front of a white house. Go north along the dirt road immediately west of the house.

65.7 STOP 4, at bend in dirt road. Whipstock Hill

Walk west, approximately 600 yards in open fields to the crest of the hill.

The Whipstock Conglomerate unit of the Walloomsac Slate (Wilderness-Trenton) is exposed.

The clasts or inclusions are commonly only a few inches long, and consist dominantly of fine-grained sericitic sandstone and siltstone, and greenish slate. The conglomerate has a streaked appearance caused by the linear alignment, and possible tectonic stretching, of the clasts. Two exotic blocks of subgreywacke can be seen in the rock at the crest of the hill; one block is about 6 inches by 14 inches, and the other is about 4 feet across. Lithically, both blocks resemble the Lower Cambrian Zion Hill Greywacke and Quartzite (Member of the Bull formation, Zen, 1961) of the Taconic sequence.

The conglomerate rests on, and is apparently infolded with, a unit mapped as the Lower Cambrian Bomoseen Greywacke; locally the latter is intensely sheared to a flaser structure. This Bomoseen may be a gigantic exotic block; alternatively it might be a sliver tectonically wedged between two plates of the parautochthonous Walloomsac Slate.

The Middle Ordovician age of the Whipstock Conglomerate is established as follows: at the west base of Whipstock Hill, the conglomerate is underlain by a pyritic and cherty black slate which locally has yielded Climacograptus and other graptolites of Berry's Zone 12 (identification by W. B. N. Berry). In addition, thin lenses of the conglomerate occur at a dozen other places in the Walloomsac Slate west of this stop; these lenses are interlayered with black slate and, locally, with greywacke of the Austin Glen (upper member of the Normanskill Shale).

The conglomerate is inferred to be a submarine slide accumulation that was contemporaenous with the Taconic thrust. This notion is consistent with the age of the matrix slate, the presence of exotic blocks of rocks of the Taconic allochthone, and the fact that, northwest of Whipstock Hill, the conglomerate has been found to underlie major thrust faults which are genetically associated with the Taconic thrust. It is significant that this conglomerate, lithically comparable with many exposures of such rocks west of the Taconic allochthone, including that at Moordener Kill (stop 1) and the Forbes Hill Conglomerate of Zen (1961), is east of the Taconic sequence, for the genesis of this conglomerate must be related to a Trenton diastrophic event which also involved rocks of the Taconic sequence. Because these Taconic rocks now overlie the Walloomsac Slate to the west of Whipstock Hill, it might be argued that the Whipstock Conglomerate was related merely to a marginal thrust fault with west-over-east movement sense. In this construction, the Taconic rocks were spalled off, to an easterly direction, into a Trenton sea, and thus need not be allochthonous on a regional scale. This concept, however, is contradicted by the dominant east-over-west movement sense that is everywhere present in the Taconic rocks circum-located about the Hoosick Falls re-entrant. The autochthonous hypothesis for the Taconic rocks, as we have seen, is also incompatible with the geometry of the rock units in the valley of the Little Hoosic River. The leaders, therefore, subscribe to the alternative interpretation, that the Whipstock Conglomerate was formed while the Taconic allochthone was still east of the hill and moving west. Therefore, existence of this conglomerate exposure is an important clue for the understanding of the regional relations of the Taconic allochthone, and of the timing of the several diastrophic events related to the Taconic thrust.

The steep front of the Green Mountains is visible east of Whipstock Hill. The Precambrian gneisses of the Mount Holly Complex are exposed along the crest of the range. The large rock exposures visible on the mountain front are dip-slopes of the Early Cambrian Cheshire Quartzite, which rests on the Precambrian with a profound unconformity. The Cheshire is here at the base of the synclinorium sequence which consists dominantly of miogeosynclinal carbonates of Early Cambrian to Middle Ordovician age. These rocks underlie the broad valley between the Green Mountain front and Whipstock Hill, as well as the low ground east, north, and west of this hill. The Taconic allochthone, being intermediate in facies between that of East Vermont (eugeosynclinal) and the miogeosynclinal facies, therefore presumably came from an area east of the exposures of the Cheshire Quartzite. Zen (1961) suggested the Green Mountain core as a possible site.

The prominent hill to the southeast is Mount Anthony.

Turn around, retrace dirt road to Route 7.

66.4 Route 7 (same corner as mileage 64.9. Turn right (west) onto Route 7.

72.1 Junction of Routes 7 and 22. Follow Route 7 west.

72.4 Crossing the Taconic thrust; Lower Cambrian slates ahead are over Ordovician carbonates of the synclinorium sequence.

73.9-74.1 Lower Cambrian Bomoseen Greywacke on right (north) side of road.

77.6 Turn left (south) off Route 7, onto County Road 33, at sign for "Babcock Lake".

81.4 North edge of Rensselaer Plateau visible ahead (south)

86.6 Outcrops of Lower Cambrian Mettawee Slate (green) on left (east) side of road.

92.0 Stop on road 100 yards south of intersection with dirt road from the east.

STOP 5. Thrust fault and tectonic slivers at the base of the Rensselaer Plateau slice.

Walk west about 200 yards in semi-open field.

Some of the features of one of the major thrust faults can be observed at this stop. The Lower Cambrian Rensselaer Greywacke, to the left (south) at the base of the steep slope, has been thrust westward along a gently eastward dipping surface over green and purple Mettawee Slate. Both the greywacke and slate are of the Nassau Formation. The slate is exposed beneath a block, approximately 1000 feet long and 200 feet wide, of Lower Ordovician limestone and dolostone (Chipman Formation of the synclinorium sequence). This thrust surface is paved with such tectonic slivers of carbonate rock along much of the north and east base of the Rensselaer Plateau. The carbonate slivers apparently were dragged along the sole of the thrust from an area at least five miles to the east where the greywacke is thrust over a downwardly continuous section of carbonate rock.

Here, the Rensselaer Greywacke is not noticeable sheared. Locally, the foliation of the contorted slate, compared with that in the carbonate, is discordant. Locally, the dolostone of the limestone and dolostone beds is brecciated.

(Busses turn around one hundred yards south of debarking point for stop 5.)

Return to Route 7.

99.3 Turn left on Route 7 and proceed southwest to Troy and Albany.

Second Day

Mileage

0.0 Start of log at junction of Routes 34 and U. S. 9 and 20, east portal of the Dunn Memorial Bridge, Rensselaer, N. Y. Follow Routes 9 and 20 east.

1.0 Junction with 9J. Continue on U. S. 9 and 20.

8.1 Junction Routes 9 and 20. Bear right, follow Route 9 south.

17.9 Junction with 9H. Continue on Route 9.

19.1 Village of Valatie; junction with Route 203, turn left onto 203.

19.5 Turn right, follow sign for Route 203, east bound (Chatham Street). Cross bridge. Follow Route 203.

22.0 Route 203 turns right in front of a large white house ("Knollwood Manor"). Keep left, follow dirt road going east immediately in front of the house.

22.9 STOP 6. Shale strata in the lower Normanskill Shale, southwest of Chatham Center, New York. Leave bus at the foot of a steep grade.

Members 1 and 2 of the Normanskill Shale according to the terminology of Berry (1962) are exposed. Along the south side of the road and in the pasture beyond is Member 1, which consists of red shale with interbedded thin green shale and green quartzite layers ("Red Shale Unit" of Craddock, 1957). The beds dip east here. The next outcrop to the east, on the steep slope south of the road, consists of grey and green siltstone and chert, with interbedded red slate near the base, and local beds of a jet black, fine-grained, and rusty-weathering shale which is commonly graptoliferous. This is Member 2 of Berry, or the Mount Merino Unit of Craddock (the two units, plus Berry's Member 3, together constitute the Mount Merino Member of Ruedemann, (1942), and is, as such, the lower member of the Normanskill Shale). The last outcrop, at the north side of the road, consists of grey chert and grey silty shale, and also a thick bed of black shale which is richly fossiliferous (Berry's 1962 Normanskill fossil locality 11, for which a detailed list of graptolites was given). The outcrops are on the west limb of a syncline whose axis trends nearly north-south. The syncline is defined by the red shales of Member 1, and its axial region is occupied by Member 2.

The red shale of Member 1 is found throughout the Taconic allochthone as well as in the authochthone. In western Vermont and in the Washington County, New York it is called the Indian River Slate which includes some minor chert and green slate. The lithic counterpart of Member 2 is very minor at the north end of the Taconic sequence, however, and Member 3 is a local unit totally absent in the northern Taconic region. As a result, in the northern Taconic region Berry's Member 4, which is there called the Pawlet Formation, rests directly on the red shale. In the Chatham area, however, Member 4, known as the Austin Glen Member (shale and greywacke), rests on Member 3 of the Normanskill Shale. The base of the Austin Glen, therefore, is locally an unconformity, but the existence of an unconformity is not everywhere demonstrable.

Members 1, 2, and 3 of the Normanskill belong to the Climacograptus bicornis zone (Zone 12 of Berry, 1960) as does the base of Member 4. The top of Member 4 is in Berry's Zone 13 (Orthograptus truncatus var. intermedius zone). Therefore, it appears that the pre-Austin Glen unconformity does not span a significant time interval. Significantly, Members 1 and 2 have not been found west of the Hudson River. It would seem that the Normanskill Shale progressively overlapped westward and became areally more extensive in the younger Trenton time. The trip leaders believe that the overlap of the Normanskill reflects increasing tectonic activity to the east, with augmentation of the clastic sediments derived from the older Taconic rocks and with increase, also, of turbidite components in the sedimentary section. The massive turbidity deposits in the Austin Glen (stop 8), and in the Wildflysch-like conglomerates in the shales of the Austin Glen, as seen at Moordener Kill and Whipstock Hill (stops 1 and 4) were the culmination of the tectonic activity.

The type locality of the Mount Merino of Ruedemann (1942) consists only of Berry's Member 2. Large road-cuts of Member 1 occur along the Taconic Parkway in the Rhinebeck and Poughkeepsie quadrangles. According to A. S. Warthin, a lens of black slate was exposed near Hibernia during the excavation for the parkway. This lens contained graptolite forms belonging to Zone 11 (Nemagraptus gracilis zone) or Zone 12 of Berry, thus proving the age of this lowest member of the Normanskill. This fossil locality is now buried under the roadway.

The four members of the Normanskill have not been formally designated by Berry. This stop, however, is within Craddock's map area, where he first separated the red shale unit; it may be taken as characteristic of the red shale unit (Member 1). Lithically, the outcrops at the top of the steep grade are typical Member 2, which is Craddock's modified Mount Merino.

Busses will proceed to turn around and pick up the group at the top of the steep portion of the road, in front of the house. Roadlog resumes at the point of debussing, mileage 22.9.

Retrace route into the village of Valatie.

26.6 Junction, Routes 9 and 203 (same as mileage 19.1). Turn left onto Route 9.

27.4 Clover leaf. Turn right after overpass, circle onto Route 9H, southbound.

29.2 Road cut of grey-green slate, interbedded with thin quartzite strata. Cross-lamination of quartzite strata indicates that the section is normal, topping east. The rock is lithically equivalent to the Poultney Slate, of Early Ordovician age.

38.4 Traffic light; intersection with Route 66. Continue south on 9H.

42.2 Junction with Route 23B; continue on 9H.

45.2 Route 9H bears left (south). Continue straight ahead on secondary paved road.

45.5 Bear Right at intersection.

45.6 Bear left at cross-roads.

46.2 Stop sign. Turn right (north) onto Routes 9-23.

47.2 STOP 7. Road cut on U. S. 9, south of Becraft Mountain. Lower Ordovician rocks of the allochthonous Taconic sequence.

The road-cut consists of ribbon-like, interbedded, thin black limestone and grey silty slate, as well as a carbonate-matrix, limestone pebble conglomerate. The slate is locally greyish green, with conspicuous colour lamination. Graded bedding and channel fills, visible on the weathered surfaces of some of the silty limestone beds, indicate that the section is not inverted (tops east).

Numerous features of soft-rock deformation, apparently penecontemporaneous with sedimentation, may be found in the exposure. The beds dip east under a unit of grey to olive, silty shale that crops out in the pasture to the east. The latter rock characteristically weathers to a dull white, and contains thin beds of silty quartzite.

The rock units in the road cut and in the pasture constitute part (upper?) of the Germantown Formation of Fisher (1961, 1962a). The lithic assemblage in the road cut is characteristic of the Schaghticoke Shale, which bears the *Dictyonema flabelliforme* fauna and is thus of Tremadoc age (lowest Lower Ordovician). The same lithic units farther north in the Taconic allochthone comprise the basal member of the Poultney Slate. The rock unit in the pasture is the second, or intermediate member of the Poultney Slate in areas to the north. The outcrops at this stop, as well as another 0.5 mile south, were called Lower Cambrian by Ruedemann (1942). Craddock (1957) reported that R. H. Flower found Deepkill fossils (*Triograptus* sp.) in one of these road cuts. Lately Berry (1962) reported Late Cambrian *Callograptus* and *Dendrograptus* from this stop, and graptolites belonging to Zone 5 (*Tetragraptus fruticosus*, 3 and 4 branch forms) from the outcrop 0.5 mile to the south. These two exposures, therefore, are correlative respectively with the upper part of the Hatch Hill Formation and the lower part of the Poultney Slate farther north; the latter is also a probable correlative of the oldest part of the section in the Deepkill gorge. Faunally as well as lithically, therefore, outcrops at this stop and at the roadcut 0.5 mile south correspond closely with the upper part of the Hatch Hill, the lower two members of the Poultney Slate, and the Schaghticoke Shale, in the Taconic allochthone. The lower part of the Germantown Formation, not exposed here, consists of massive calcareous quartzite interbedded with black shale. This combination corresponds to the lithology of the lower Hatch Hill Formation, which is below the fossil-bearing beds in this unit. In terms of the discussions for stops 2, 3, and 6, there appears to exist a complete litho- and bio-stratigraphic identity, from the Early Cambrian into the Middle Ordovician, throughout the entire Taconic allochthone, at least west of the main range of the Taconic Mountains. Because there is no known large cross-break between the area of this stop and western Vermont and Washington County, New York, any acceptable regional structural interpretation postulated for one end of the Taconic sequence must be equally applicable to the other end.

West of Route 9 there occur outcrops of the Normanskill Shale, here considered to be part of the autochthone. This north-striking contact disappears under the deformed Siluro-Devonian rocks of the Becraft Mountain mass which rests unconformably across the trace of the Taconic thrust.

Continue north on Route 9.

48.1 Wooded hill ahead is Becraft Mountain. Road cut to the right (east) is the Manlius Limestone, the base of the Siluro-Devonian sequence of Becraft Mountain that rests above the allochthonous and autochthonous Taconic sequence with a profound angular unconformity. The unconformity is exposed in several quarries in the Devonian limestone, as has been described for example by Schuchert and Longwell (1932), and, for the comparable relations at the nearby Mount Ida, by Craddock (1957). Although the Devonian rocks are themselves strongly folded and faulted, the contact relations exposed in the quarries clearly show that these younger rocks bevel across the isoclinally folded rocks of the Taconic sequence. This earlier episode of isoclinal, recumbent folding is believed by the trip leaders to have been contemporaneous with the late Trenton emplacement of the Taconic allochthone. This relative chronology is consistent with the present interpretation that the Siluro-Devonian rocks of Becraft Mountain cover the leading edge of the Taconic thrust.

Turn around and continue southward on Route 9.

49.5 Road cut in black slate contains graptolites of Berry's Zone 5 Tetragraptus fruticosus, 3 and 4 branch forms); this corresponds to the oldest beds of the Deepkill Shale.

66.9 Village of Red Hook; turn right at traffic light onto Route 199, going west.

68.4 Begin road cuts in the greywacke of the Austin Glen (uppermost member of the Normanskill Shale). The rock unit is of late Trenton age, belonging to Zones 12 and 13 of Berry's (1960) Marathon, Texas, graptolite succession. The Austin Glen (or at least the lower part of it) is correlative with at least the higher strata of the Walloomsac Slate, seen during Day 1 of the trip. The rock unit occurs both in the autochthone and the allochthone and spans the time interval of the emplacement of the allochthone. The rock unit, therefore, both underlies the allochthone and buries detached slices of the latter.

68.8 Stop sign; turn left on 9G and 199.

70.7 Turn right with Route 199, follow signs for the Rhonecliff Bridge.

71.9 STOP 8. Large road cuts on New York State Route 199, just east of the east portal of the Rhinecliff Bridge.

The exposures are composed of the greywacke (with interbedded shale) of the Austin Glen Member of the Normanskill Shale (Berry, 1962). The west end of the large outcrop on the north side of the road is faulted and folded, and partially overturned. However, the bulk of the outcrop is right-side-up, dipping east.

Numerous turbidite features are present, some of which are illustrated on Figure 5 of Bird's article. Flute casts, groove casts, load casts and the complete and various partial turbidite sequences of Bouma (1962, p. 49) are readily observable. Currents, approximately from east to west and from south to north, are indicated by flute and groove casts. Note the inclusions of green and black shale in the graded interval (T_a) of some of the turbidites. These are much like that shown in Figure 4 of Bird's article in this guidebook. These and other turbidite features are also well exposed in a spectacular road cut at the west portal of the Mid-Hudson Bridge at Poughkeepsie, New York.

Blocks of greywacke, lithically the same as that exposed here, are common in the Wildflysch-like conglomerate as seen at stop 1.

The greywacke, which extends westward into the Mohawk Valley at least as far as Schenectady, becomes coarser and thicker eastward. Because of its composition, its source must have been an eastern terrain of Taconic sequence rocks. The greywacke of the Austin Glen Member of the Normanskill Shale, then, may be considered a synorgenic "flysch" facies. The occurence of the greywacke as blocks in the Wildflysch-like conglomerate indicates this facies was in part also involved in westward tectonic transport, concomitant with the deposition of its autochthonous correlatives to the west of the Taconic allochthone.

These exposures are evidence of the extensive and predominant density current activity in the basin during Trenton time.

The black shale interbeds resulted from the accumulation, apparently at a slow rate, of pelagic sediment in a presumably euxinic, deep-water environment. The pelagic mud deposition was periodically interupted by the relatively instantaneous deposition of each turbidite. Some of the flute casts are of scours caused by currents perhaps unrelated to a particular overlying turbidite. This is indicated because of the two current directions evidenced by both the flute and groove casts. Apparently there were currents both transverse and parallel to the basin axis, the transverse currents being primarily the density currents transporting the arenaceous sediment. Likewise, it is possible that these transverse currents turned parallel to the north-south basin axis during or after deposition of the sediment load.

The greywacke usually contains fairly well sorted and rounded quartz, feldspar and rock fragments typical of the Taconic sequence. It is likely that this sediment first accumulated on a shelf (or shelves) along the western shore line of the rising eastern land-mass. The shelf became periodically oversteepend causing slumping that generated the density currents which transported the greywacke sediment into deeper water. As the orogenic activity progressed, the land-mass moved (slid) westward and the greywacke facies extended westward. More eastern and older portions of the greywacke became involved in this westward tectonic transport, as evidenced by the Wildflysch-like conglomerates, synchronously with further and more westward greywacke deposition (Schenectady area). Apparently, at least part of the site of deposition of the Austin Glen Member was subsiding synchronously with the eastern orogenic activity.

Turn around, follow Route 199 east.

73.3 Junction with Route 9G. Turn right onto 9G, southbound.

74.7 Junction with Route 9 at traffic light. Turn right (south) onto Route 9.

76.5 Enter village of Rhinebeck. LUNCH STOP.

77.2 Traffic light in center of the village, intersection with Route 308. Turn left (east) onto 308.

78.7 Turn right (south) onto Violet Hill Road.

79.4 Stop sign. Turn right onto Route 9G, southbound.

79.6 Road cut in the Austin Glen.

80.6 Turn left at the "Slate Quarry Hill" sign.

81.2 Quartz sand (rounded)-and-limestone-matrix limestone conglomerate and also interbedded limestone and grey shale. Lithically, this section could be either part of the Lower Ordovician Taconic sequence or part at the lower Normanskill Shale.

81.8 Road junction at White School. Bear right.

82.3 Road cuts in black slate and calcareous siltstone that have been severely folded and contorted. Lithically, these rocks resemble the lower parts of the Poultney Slate (Lower Ordovician) of the allochthonous Taconic sequence. This road cut is the beginning of a series along this road, in rocks resembling various units in the pre-Normanskill Taconic sequence, including the Lower Cambrian Nassau Formation; they are herein so designated. This area is believed by the leaders to be at the southern end of the Taconic allochthone; the last known outcrop of the pre-Normanskill Taconic rocks is some three miles south of here, with the exception of a single anomalous outcrop near Hyde Park that is surrounded by an extensive area of the Austin Glen. On the other hand, this area of the pre-Normanskill Taconic sequence may be traced continually northward into the main belt of the Taconic allochthone east of the Chatham Thrust (see text for stop 2).

83.4 Road cut in green slate resembling the Lower Cambrian Mettawee Slate.

84.5 Turn right at 410' road corner onto dirt road, Lake Drive Road, marked by a sign for Long Pond. According to A. S. Warthin, the area is underlain by the lower Normanskill Shale of the autochthone. Directly east along the paved road, however, carbonates of the "Wappinger Limestone" are exposed.

85.7 Intersection with Long Pond Road. Debus, beginning of STOP 9. Busses will proceed eastward (turn left) on Long Pond Road for 0.2 mile, to pick up the group at the end of the stop.

STOP 9. Long Pond, town of Clinton, Rhinebeck Quadrangle.
Leave bus at the intersection of Long Pond Road and Lake Drive Road. Walk west along Long Pond Road for 200 feet.

Ledges south of the road are interbedded grey chert and silty shale, typical of the Mount Merino (Member 2 of Berry, 1962). The beds here strike northeast and dip southeast. Walk east along Long Pond Road for 0.2 mile to sharp bend in road. Proceed north along foot path for about 600 feet to a point where open pastures are on both sides of the path. En route, the ledges in the woods east of the path are massive dolostone beds that belong to the upper part of the "Wappinger Limestone", comparable with the Copake and Rochdale Limestones of Knopf (1962), or the Providence Island Dolostone of Billings and others (1952). This same dolostone, well exposed in the pasture east of the path where it is seen to exhibit the "thread-scored beeswax" texture on the weathered surface, is pale grey and fine grained, and typical of the Lower Ordovician dolostone units of the Vermont valley. The bedding is nearly horizontal.

Exposed in the footpath is a very fossiliferous, light grey limestone consisting of fragments of echinoderms, trilobites and ribbed brachiopods. The limestone is of Middle Ordovician age, presumably correlative with the Balmville Limestone of Holzwasser (1926). It is probably no more than 20 feet thick here. Although the contact with the dolostone is not exposed, relationships elsewhere in the circum-Taconic belt make it likely that the contact marks a major unconformity. The older dolostone may have been rotated back to near-horizontality by subsequent deformation.

The pasture west of the footpath contains large, glacially polished outcrops of a silty to slightly cherty green and grey slate that weathers white. Bedding is difficult to ascertain owing to the strong development of cleavage banding. However, according to A. S. Warthin, brachiopods typical of the Snake Hill fauna have been collected here, and the orientation of the fossils indicate that bedding and cleavage are locally parallel. Strata that contain the Snake Hill fauna are generally conceded to be younger than the Balmville Limestone. This conformable succession, verified by numerous exposures of the contact between the same two units peripheral to the entire Taconic belt is demonstrated at the site of a removed stone fence along the western limit of the footpath. The rocks therefore appear to be on the east limb of a syncline, a point confirmed by the fact that the dolostone east of the footpath is succeeded to the east by other, older carbonate formations which are directly comparable with units of Knopf's (1962) Pine Plains succession. The shale beds west of the pasture, however, can be traced into the chert beds seen near the road intersection (upon debussing). The cherty rocks are characteristic of the Mount Merino; therefore it appears that the Normanskill Shale is younger than the Balmville Limestone in a conformable sequence. There is no reason to suppose that the Normanskill Shale here is not autochthonous. If the Normanskill Shale which is associated with Balmville and older carbonate units is removed from the Taconic allochthone, then the allochthone would be drastically reduced in size. The dating of the Taconic thrust, namely in late Trenton time (see stops 1, 4 and 6), is entirely consistent with this interpretation; the thickness of the Normanskill Shale below the horizon of the thrust is taken to represent the time interval between the inception of the orogenic events to the east, which resulted in the shift in sedimentary regime at the site of the former shelf area, and the time of arrival of the allochthone itself, which locally rests on the isofacial Normanskill Shale, rendering the contact relations obscure. As a matter of fact, the wooded hills west of the pasture are underlain by rocks which may well be of the Nassau Formation; these rocks are at the southern extremity of the allochthone, here resting upon a substrate of the autochthonous Normanskill Shale.

85.9 Sharp corner on Long Pond Road by grey shingle house; enter busses, proceed southeastward on Long Pond Road.

87.1 Turn left, cross bridge, go up hill.

87.3 Hamlet of Schultzville. Turn right onto Centre Road.

93.5 Village of Salt Point. Road intersection; turn right (south) onto major secondary road.

94.1 Road fork; follow left branch with sign for Pleasant Valley.

97.9 Road intersection. Bear slightly left and proceed straight ahead.

98.8 Village of Pleasant Valley, junction with Route 44. Turn right onto Route 44. Road follows a belt of the "Wappinger Limestone".

103.1 Bear left, leaving Route 44 at Shell gas station. Follow Overock Road.

103.3 Stop sign; go straight ahead.

103.6 Bear right at intersection.

104.1 Crossing tracks of the New York, New Haven, Hartford Railroad.

104.2 Turn left onto Marshall Road.

104.4 Route 55. Turn left (east) onto Route 55.

104.6 Vassar View Road to the right; turn right, proceed for 200 feet to outcrop to the left.

STOP 10. Route 55 and Vassar View Road, Poughkeepsie, New York.

Three outcrops exhibit the same features here: one is on Vassar View Road, and two on the two sides of Route 55 at the road corner. The rocks are silty, grey shale, without any noticeable slaty cleavage. In detail, the rocks are much deformed, as may be seen by studying the geometry of the interbedded quartzose layers. These layers are no more than a few inches thick each and lithically recall the silty beds in much of the Austin Glen Member of the Normanskill Shale. The shale beds, too, resemble the bulk of the shale and slate in the Austin Glen and were in fact mapped as part of the Austin Glen by A. S. Warthin.

The outcrops contain brachiopods typical of the Snake Hill fauna. Some samples of the brachiopods have been marked by yellow paint; additional samples may be found by diligent searching. The relations here, therefore, once again lead to the conclusion that the Snake Hill is actually a shelly-fauna facies of the Normanskill (see Berry, 1963). At stop 9, the Snake Hill fauna is in rocks lithically corresponding to the "lower and/or middle" Normanskill; here it is in rocks lithically part of the upper Normanskill. There appears to be no evidence that the Normanskill everywhere underlies the Snake Hill Shale, as has been assumed in much of the geologic literature. Such an assumption led to the dilemma that either any Normanskill Shale must be part of the Taconic thrust mass, or that a Taconic allochthone cannot exist because some Normanskill Shale outcrops are demonstrably autochthonous. The probability does exist, however, that rocks containing the Snake Hill fauna may have become progressively more important with time, at the expense of rocks containing the graptolite fauna commonly associated with the Normanskill Shale.

Continue on Vassar View Road, loop around to Locust Road, which returns to Route 55. Turn left on Route 55 to Poughkeepsie, and thence to New York City. End of log.

STRATIGRAPHY AND STRUCTURE OF THE HOOSICK FALLS AREA

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Introduction

The Hoosick Falls area, constituting the Eagle Bridge, Hoosick Falls, Grafton, and North Pownal $7\frac{1}{2}$-minute Quadrangles, is situated about mid-way between the north and south ends of the Taconic belt (Plates 1 and 2). The Taconic belt (see articles in this guidebook by Zen, and by Bird) is underlain by two lithologically dissimilar but age-equivalent rock sequences: the Taconic sequence consisting largely of argillite, slate and graywacke, and the Middlebury synclinorium sequence (herein called the synclinorium sequence) consisting of carbonate rocks and slate. The importance of this area stems from the fact that practically all of the formations of the Taconic sequence and most of the formations of the synclinorium sequence are exposed. The overall distribution of these two sequences is shown in the inset of Figure 1.

Previous work in this area:

T. N. Dale (1893) included the Hoosick Falls area in his reconnaissance studies of the Rensselaer Plateau. Prindle and Knopf (1932) contributed additional faunal evidence for the ages of the formations, and a geologic map of a large area in the central Taconic region; they distinguished between "allochthonous" and "autochthonous" formations and postulated thrusts to explain the position of the "allochthonous" rocks. Bonham (Ph.D. thesis, Univ. of Chicago, 1950) assessed the thrusting thesis by a study of small-scale structures. Balk (1953) studied the Rensselaer Graywacke and presented an abbreviated geologic map of part of the four quadrangles. Lochman (1956) included fossils from this area in her extensive study of Early Cambrian fauna. MacFadyen (1956) included the eastern margin of this area in his study of the adjacent Bennington Quadrangle.

Present Study:

The present detailed mapping of four $7\frac{1}{2}$-minute quadrangles has been under way for eight field seasons and is about three-fourths complete. The work has been generously supported by the New York State Geological Survey, The Geological Society of America, and The National Science Foundation. The aim of this work is four quadrangle maps delineating areas of outcrop from areas of cover, in addition to detailed description and interpretation of stratigraphy,

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Editor's Note: There was insufficient time to incorporate Potter's article into the general format of this guidebook and establish consistency with details of terminology. Potter's stratigraphic nomenclature is his preferred usage.

paleontology, and structure.

While fossils indicate the relative ages of the major litho-stratigraphic units, the detailed stratigraphic succession is difficult to determine. Many of the distinctive mapping units, such as the Normanskill Graywacke, black lithic sandstone, thin quartzites, and limestone lenses are poorly exposed. A pervasive slatey cleavage, not related genetically to the folds, is exhibited by most of the rocks and, hence, bedding-cleavage relationships are rarely of any value. In many instances it is difficult to determine the attitude of the bedding, much less find primary sedimentary structures that would indicate tops and bottoms. The problem of determining stratigraphic succession is particularly acute in the synclinorium sequence. In the Taconic sequence, however, graded bedding is occasionally exhibited by the Rensselaer and Normanskill Graywackes and in the sandstones of the Hatch Hill Formation; crossbedding is seen in the later. The succession is determined, hence, by these rare primary structures, by the relation of beds to apparent large structures, and by association: the finding of a lithologic unit whose age is unknown, several times near, or in contact with another unit is taken as evidence that the two are in depositional contact.

Stratigraphic Characteristics and Problems

Figure 1 shows the general stratigraphic succession of some 40 map units. Regardless of one's interpretation of the overall structure in this area, there are present here two lithologically dissimilar stratigraphic sequence that are, in part, age-equivalent.

The synclinorium sequence in this area consists of Lower and Middle Ordovician carbonate rocks, overlain by the Middle Ordovician Walloomsac Slate. The carbonate rocks in this sequence are underlain, in the area immediately east (MacFadyen, 1956), by a sequence of orthoquartzite-limestone-dolomite rocks of Late and Early Cambrian age.

The Taconic sequence here consists of Lower and Upper Cambrian, Lower and Middle Ordovician argillites, slates, and graywackes. Thus, in the area of these four quadrangles, the striking contrast in lithic types and in depositional environments between the Taconic and synclinorium sequences is shown only by the formations of Early and Medial Orodvician age: the Lower Cambrian Taconic sequence has no age-equivalent synclinorium formations exposed here; the Middle Ordovician Normanskill formation of the Taconic sequence resembles in several ways, and probably interfingers with, the Walloomsac Slate of the synclinorium sequence.

Paleontological control

Fossils have been found in seven litho-stratigraphic units of the Taconic sequence and in four units of the synclinorium sequence (marked in Figure 1).

Synclinorium sequence: the Lower and Middle Ordovician limestones, unlike carbonates in the Taconic sequence, display fossils on the weathered surface: gastropods, cephalopods, brachiopods, and trilobites are most easily seen in that order, but they are generally fragmented and identification is difficult. D. W. Fisher (personal communication, 1959) assigns a Canadian age

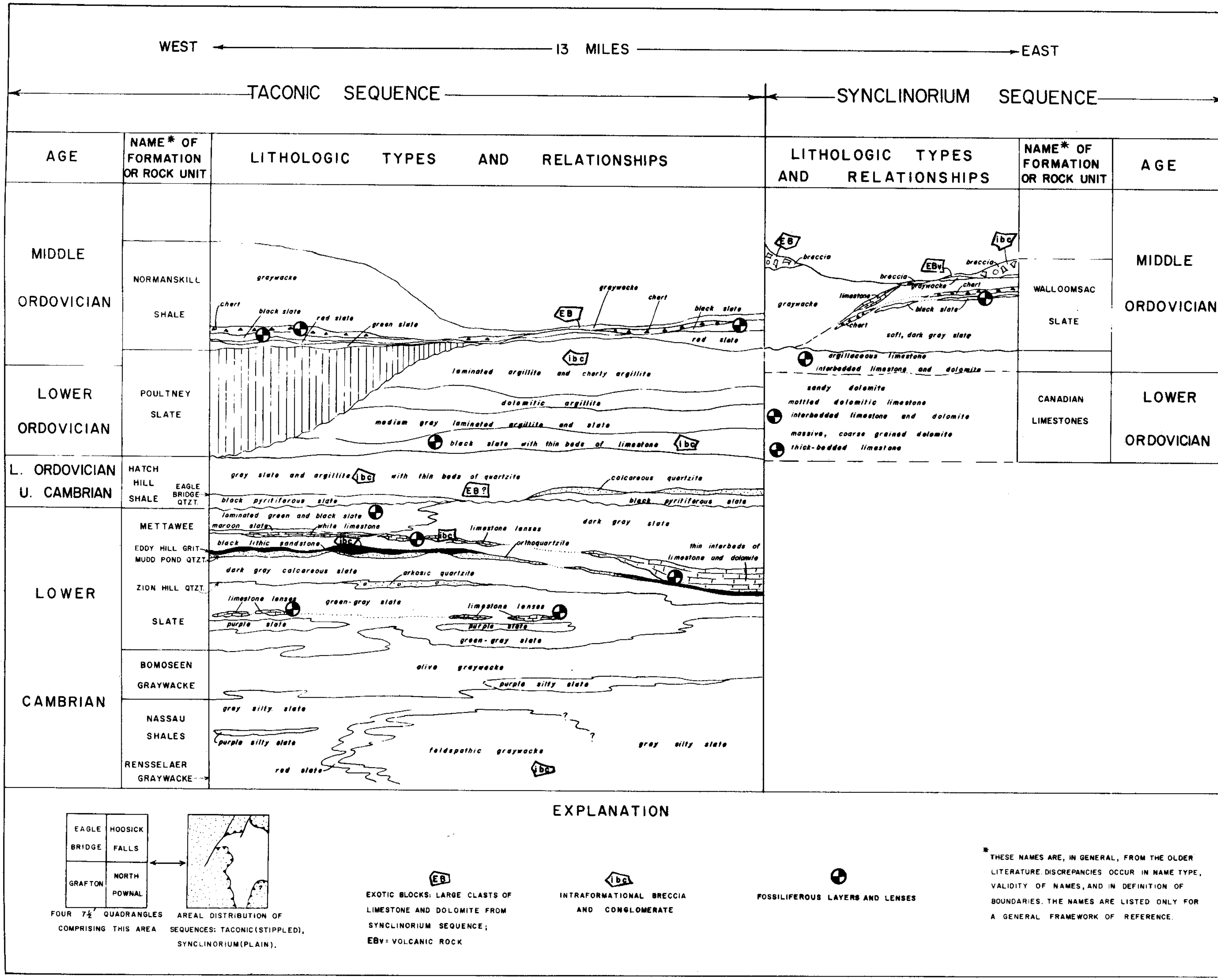

FIGURE I. STRATIGRAPHY OF THE HOOSICK FALLS AREA, N. Y.

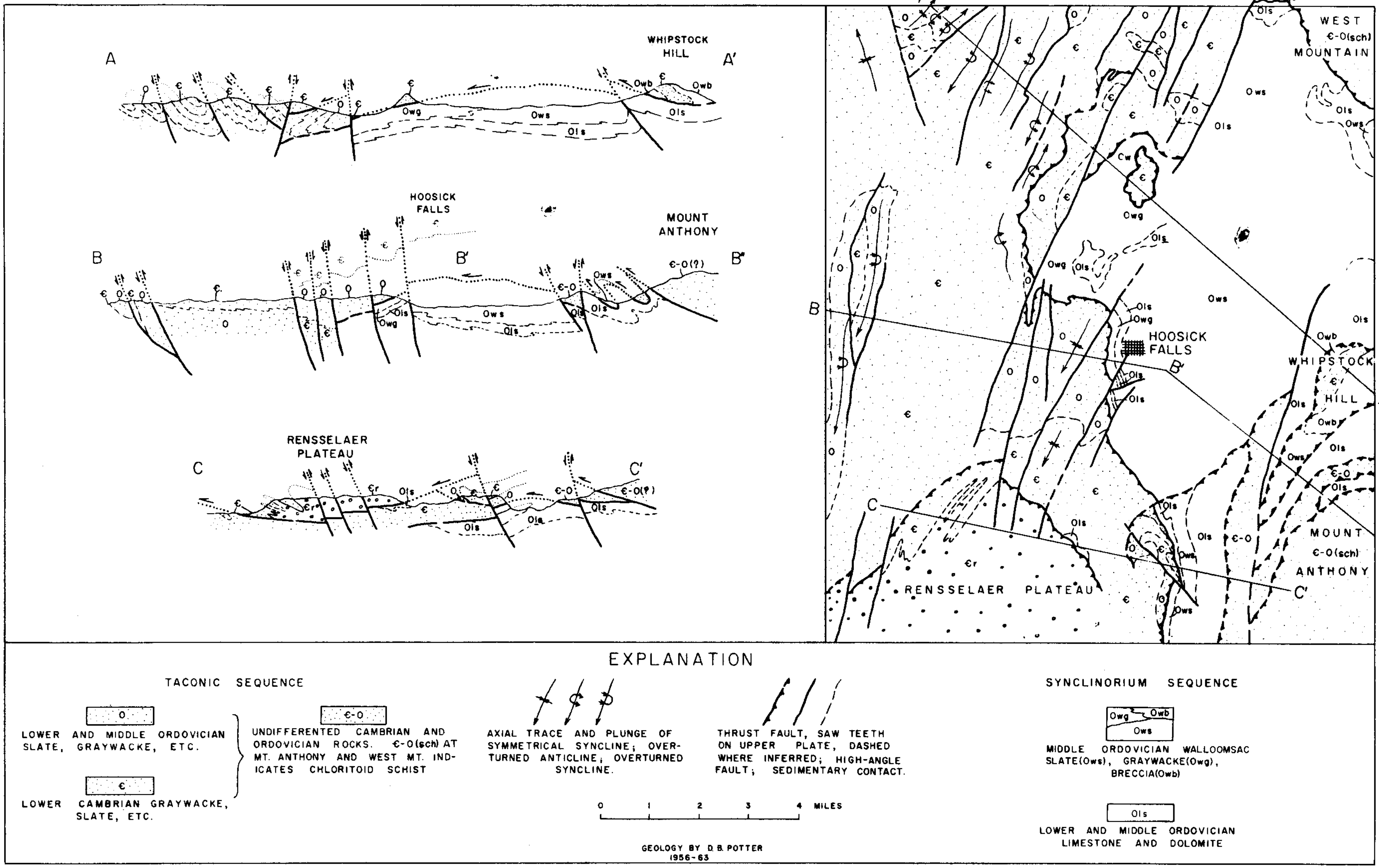

FIGURE 2. GEOLOGIC SKETCH MAP AND STRUCTURE SECTIONS OF THE HOOSICK FALLS AREA, NEW YORK

to some of the limestones on the basis of the presence of the gastropod, Gasconadia, and the nautiloid, Protocycloceras; a Medial Ordovician age (Fisher, ibid.) is indicated for other limestones by the presence of the ostracod, Leperditia, and also orthid brachiopods. These age assignments agree, in general, with those presented by Prindle and Knopf (1932) and by Bonham (Ph.D. thesis, Univ. of Chicago, 1950).

Graptolites of the Climacograptus bicornis Zone (Zone 12 of Berry, 1961) were found in black slate at one locality in the Walloomsac Slate (identification by W. B. N. Berry, personal communication, 1960). This agrees with Prindle and Knopf's (1932) "Normanskill age" assignment for the Walloomsac Slate based on the graptolite, Diplograptus foliaceous.

Taconic sequence: the principal fossiliferous units of Early Cambrian age are limestone lenses occurring directly above purple slate, and lenses occurring in black slate above the black lithic sandstone. Such lenses are generally conglomeratic and the fossils, primarily trilobite fragments of the Elliptocephla asaphoides fauna (Lochman, 1956), are found on the freshly broken surfaces of calcarenite pebbles. Also, locally, black slates in the laminated green and black slate unit near the top of the Lower Cambrian sequence yield the brachiopod Botsfordia caelata (identification by R. Ramsdell).

The only fossils found in the Ordovician formations of this sequence are graptolites from jet-black slates: graptolites of the Tetragraptus fruticosus Zones (Zones 4 and 5 of Berry, 1961) were found at one locality in black slate within the Poultney Slate. Graptolites of the Climacograptus bicornis Zone are easily found at many localities in the black slate immediately beneath the Normanskill Graywacke.

Lithologic and stratigraphic characteristics

Synclinorium sequence: the Lower and Middle Ordovician rocks of this sequence are medium to thick bedded limestones, medium to thick bedded dolomite, sandy limestone, and limestones exhibiting various degrees of dolomitization. These units are underlain, in the area east of the four quadrangles under discussion, by a thick sequence of older orthoquartzites and carbonate rocks (MacFadyen, 1956). The overall aspect of these sedimentary rocks suggests a stable, shallow water environment.

The overlying Walloomsac Slate is dominantly a thick, homogeneous dark gray slate, probably of deep-water origin. The upper (?) part of the Walloomsac Slate contains bedded chert, black graptoliferous slate, some thin lenses of graywacke (identical to the Normanskill Graywacke) and breccia. The last consists of rounded to angular clasts of sericitic sandstone and minor limestone in a dark gray slate matrix. Rare, exotic blocks of amygdaloidal volcanic rock, (?) cherty dolomite, sandy dolomite (of the synclinorium sequence), and quartzite (of the Taconic sequence) up to fifty feet in length have been found in this breccia within a 12 sq. mile region in the east central part of the area. Near North Petersburg a large block of dolomite occurs in dark gray slate matrix immediately below a thrust which brings formations of the Taconic sequence over the Walloomsac Slate and carbonate formations of the synclinorium sequence. The breccia is inferred to be of combined tectonic-sedimentary origin, and may have been formed as thrust sheets advanced into the basin in which the Walloomsac Slate (mud) was being deposited. The breccia is well exposed at Whipstock Hill (stop 4).

Taconic sequence: The stratigraphic units of this sequence are dominatly pelitic (shale, argillite, slate) and graywacke, with minor quartzite and limestone. The textural and compositional aspects of these rocks indicate generally deep water deposition, and unstable bottom conditions with slump and turbidite-type accumulations. Delicately laminated argillite and thin bedded chert (Poultney and Normanskill formations) indicate a deep water environment; euxinic conditions are suggested by pyritiferous black slate (Early Cambrian, Late Cambrian, Medial Ordovician) and associated chert; graded bedding in graywacke, and intraformational breccias and conglomerates ("ibic" on Stratigraphic Chart, Figure 1; Figure 3) indicate unstable bottom conditions and turbidite-type transportation and accumulation. Exotic blocks ("EB" on Stratigraphic Chart) of carbonate rocks in the Normanskill Graywacke and in the breccia of the Walloomsac Slate, and questionable exotic blocks of dolomite in the black slate of Late Cambrian age again suggest submarine slumping, triggered perhaps by submarine thrusting.

All of the Taconic units are noticeably lenticular within the area of the four quadrangles under study and this characteristic is particularly obvious in the Rensselaer and Normanskill Graywackes. The Rensselaer Graywacke is perhaps several hundred or a thousand feet thick in the southwestern part of the area, yet four miles to the north of this point the graywacke is only half as thick and it interfingers with red and purple slate. The Normanskill Graywacke is several hundred to one thousand feet thick in the western part of the area, yet thins eastward to a thickness of from three to ten feet; still farther east, where it is mapped as part of the synclinorium sequence near Hoosick Falls, the graywacke is again many hundreds of feet thick. The distinctive Lower Cambrian marker units (purple slate, limestone, orthoquartzite, black lithic sandstone, maroon slate) are, to the dismay of the field worker, lenticular, and range from zero to 30 feet in thickness. The Poultney Slate (argillite, slate, cherty argillite) is several hundred feet thick in the central and north-central part of the area and absent at the west margin of the area. In the Normanskill shale units the red slate is markedly lenticular, ranging from zero to 50 feet in thickness.

Unconformities occur between the Upper Cambrian-Lower Ordovician Hatch Hill Formation and the Lower Cambrian pelitic sequence (Middle Cambrian rocks apparently missing); at the base of the Normanskill Formation (Poultney Slate absent in west part of the area); and at the base of the Normanskill Graywacke (the thin, distinctive red slate, black graptoliferous slate, and bedded chert are absent in parts of the area and the graywacke rests on the next older unit).

Metamorphism

Regional metamorphism has affected all the rocks in the area with a general increase in rank from west to east. A flow cleavage has been impressed on all the rocks: the pelitic rocks range from poorly cleaved to perfectly cleaved slates through most of the area, and along the east border of the area the pelitic rocks are phyllites and schists. The maximum rank of metamorphism in the eastern part of the area is in the greenschist facies.

Structure

The highly complex and baffling structure (see Geologic map and sections, Figure 2) in this area is divided into three geographic-structural zones for the purpose of description: the western zone of Taconic formations, the eastern zone of synclinorium formations, and the zone of thrust faulting between the two sequences.

1. Structure of the Taconic formations in the western zone: the structure here is dominantly one of asymmetrical and westward-overturned and faulted folds, as shown in the northwest parts of structure sections A-A' and B-B'. In the north-central part of the area, formations are recumbently folded (fold axes trend north-south) and thrust faulted.

The Rensselaer Graywacke, in the southwestern part of the area, lies entirely within this western zone of Taconic rocks. That the entire mass of graywacke has been thrust into its present position is suggested by the structural discordance and local intense shearing and crushing along the north and northeast contact with the underlying Lower Cambrian pelitic formations, and by the presence of large, apparently isolated, blocks of Ordovician limestone of the synclinorium sequence at this contact between the graywacke and the underlying Cambrian formations. (These features will be seen at stop 5). The thrust is not obvious along the northwest part of the graywacke mass, for here the graywacke interfingers with red and purple slate and apparently terminates. The thrust here must lie between the red slates and the underlying Lower Cambrian pelitic formations.

2. Structure of eastern zone of synclinorium formations: the structures here have not been studied in as great detail as those to the west. The oldest formations exposed here, the Lower and Middle Ordovician carbonate rocks, are in sedimentary contact with the overlying Walloomsac Slate. Both are folded into westward-overturned folds, and cut by reverse faults and thrust faults (east side up). The magnitude of these structures is not great in the central part of this zone for the Walloomsac Slate crops out over a broad expanse here.

The breccia unit in the Walloomsac slate, shown in the eastern part of section A-A', is described under "Stratigraphy." It is probably a submarine slide accumulation, although its relation to possible submarine thrusting is not as obvious at Whipstock Hill (stop 4) as at the locality described below.

3. Zone of thrust faulting between the two sequences: in general, the Taconic formations have been recumbently folded on a large scale and thrust along gently dipping fault planes over the synclinorium sequence. These thrust planes are folded and cut by numerous steeply-dipping, northeast-trending reverse faults.

The thrust faults in the central and south-central part of the area are shown in the central part of structure sections A-A', B-B', and C-C'. This thrust (or thrusts) is best established three miles north of Hoosick Falls (Structure section A-A') where fossiliferous Lower Cambrian rocks cap an isolated hill and are structurally discordant with the tightly folded Middle Ordovician graywacke below. The correlation of the thrust beneath this small klippe with other thrusts farther west in section A-A' is not well established but it is likely that a single thrust plane or several planes passes completely beneath the superficial structures shown in the western half of structure section A-A'.

Structure sections B-B' and C-C' show Taconic formations thrust over the Walloomsac Slate and carbonate formations of the synclinorium sequence. The pelitic rocks immediately above the thrust plane are locally silicified, sheared, and crushed. The graywacke beneath the thrust is locally sheared. Near North Petersburg the dark gray Walloomsac Slate (Breccia unit) immediately beneath the thrust holds an isolated block of Canadian dolomite (of the synclinorium sequence), the size of a small automobile. The pelitic formations in the overthrust block just west of Hoosick Falls (Structure section B-B') and in the central part of Structure section C-C' are upside down, indicating that large recumbent folds were developed during tectonic transport. Such large recumbent folds have not been found in the Taconic sequence more than two miles west of the thrust exposure.

Chloritoid schist and associated low rank schists cap West Mountain and Mount Anthony in the northeastern and southeastern parts of the area respectively. The schists are underlain by carbonate rocks of the synclinorium sequence. MacFadyen (1956) named these schists the Mount Anthony Formation; he, and Hewitt (1961), who mapped the Equinox Quadrangle to the northeast, have interpreted this pelitic sequence as Medial Ordovician in age, and have considered it to rest with stratigraphic unconformity on the other carbonate rocks. In studying that portion of West Mountain shown in Figure 2, the author has found within this pelitic sequence five distinctive lithologic units typical of the Poultney and Hatch Hill formations of the Taconic sequence. The structural discordance between these pelitic units and the underlying carbonates is thus interpreted to be a thrust which has brought Upper Cambrian and Lower Ordovician pelitic formations of the Taconic sequence over Lower Ordovician and perhaps Middle Ordovician carbonate formations of the synclinorium sequence.

South of Mount Anthony, at Poplar Hill (south of area of Figure 2), green and purple chloritoid schist occurs interbedded with Rensselaer Graywacke. This relation is identical to that west of the Rensselaer Plateau where the graywacke interfingers with purple and green slate of the Lower Cambrian Nassau formation. Thus, at least some, and probably all the chloritoid schist in the Mount Anthony area is of Early Cambrian age and the schist is thrust over the underlying carbonate rocks.

Summary comments:

At the present stage of work in this area the evidence here strongly supports the thrust thesis to explain the position of the Taconic sequence. The evidence, briefly, is marked lithologic contrast between the older units of the Taconic and synclinorium sequences, lack of any interfingering of the two (except the youngest units in each), and the fact that the two sequences are, in part, the same age. Further, gently-dipping thrust faults in this area separate the recumbently folded pelitic Taconic sequence from the underlying carbonate and pelitic rocks of the synclinorium sequence.

A significant stratigraphic characteristic here is that while there is a marked lithologic contrast between the older units of the two sequences, there is a similarity between the youngest and age-equivalent formations (Normanskill Shale of the Taconic sequence and Walloomsac Slate of the synclinorium sequence): both are dominantly argillaceous, both contain bedded chert above graptoliferous black slate, and graywacke is common to both. These facts can be interpreted satisfactorily by a submarine thrusting hypothesis (Zen, this guidebook): in this area, deposition of what is now the Walloomsac Slate and chert would have been the last recorded event prior to thrusting; graywacke deposition, initiated in the basin of deposition of the pelitic formations to the east, continued in front of the submarine thrusts as they advanced into this area; the breccia in the Walloomsac Slate formed as part of this episode of submarine disturbance; finally the thrust sheets moved in over what are now carbonate rocks, slate, graywacke, and breccia.

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