DETAILED STRATIGRAPHIC AND STRUCTURAL FEATURES OF THE GIDDINGS BROOK SLICE OF THE TACONIC ALLOCHTHON IN THE GRANVILLE AREA

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SUMMARY

The trip will visit localities in the "Giddings Brook Slice" of the lower Taconic allochthon in the vicinity of Middle Granville, New York. Eight localities will be visited, at each the stratigraphy and structure of the lower Taconic allochthon will be described and investigated in detail. Stratigraphically, the stops will emphasize our recognition of a more detailed stratigraphy than previously defined, specifically, the presence of two Cambrian black-green lithologic boundaries, abundant sedimentologic evidence for deep water North American continental rise depositional environment and the need for a Taconic reference section with well defined stratigraphy and known stratigraphic contacts. Structurally, the trips will focus on the nature of the continental rise sediments at the time of emplacement on the continental shelf and the nature of the deformation associated with emplacement. Particular emphasis will be placed on evidence suggesting that the low Taconics were emplaced as coherent tectonic slices and not as soupy soft sediment slides as all previous tectonic interpretations have suggested.

INTRODUCTION

The allochthonous, predominantly deep water argillaceous and subsidiary arenaceous and calcareous rocks of Cambrian(?), Cambrian to Middle Ordovician (Late Caradocian) age of the Taconic Allochthon crop out in an elongate belt approximately 200 km long, from the vicinity of Sudbury, Vermont to Poughkeepsie, New York. The Allochthon extends laterally 20-30 km and approximately parallels contiguous sections of the New York, Vermont, Massachusetts and Connecticut state borders. Taconic rocks, now primarily slates, commonly show evidence of at least two phases of deformation and have undergone low grade regional metamorphism (chlorite to biotite). Structurally, the Allochthon consists of a series of imbricate and partially nested thrust slices with complex internal deformation. Six major thrust slices are recognized in the Taconics by Zen (1967); they are, from structurally lowest (west) to highest (east), the Sunset Lake Slice, Giddings Brook Slice, Bird Mountain-Chatham Slice, Rensselaer Plateau Slice, Dorset Mountain-Everett Slice and Greylock Slice. See Figure 1a. In general, deformation and metamorphism increases from west to east within the Allochthon. The Taconic Allochthon tectonically overlies and is surrounded by an autochthonous to parautochthonous, coeval sequence of dominantly shallow marine carbonates and clastics of the

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Champlain Valley and Vermont Valley Sequences (Shumaker, 1967). Facies, thickness, sedimentary structures and paleontologic considerations suggest that the coeval carbonate-clastic and argillite-clastic sequences represent a carbonate shelf "starved" continental rise pair of the east-facing Atlantic-type North American continental margin during the Early Paleozoic (Bird and Dewey, 1970; Rodgers, 1968, 1970). The Taconic Allochthon was emplaced onto the carbonate shelf during the Middle Ordovician (Late Trenton-Caradocian) "Taconic" orogeny. A discussion of the "Taconic" orogeny will be deferred until later.

The field trip will be conducted through a part of the Giddings Brook Slice in the northern Taconics, near Granville, New York (Figure 1a). Recent detailed mapping in contiguous portions of the Granville, Thorn Hill, Wells and Poultney 7 1/2 minutes quadrangles (Figure 1b-d) by Jacobi (1977), D.B. Rowley (1979) and regional work by W.S.F. Kidd (1974-1979) while running the SUNY/Albany field course provide us with a more detailed stratigraphic (Figure 2) and structural picture of the northern Giddings Brook Slice than previously available. Our mapping, during more than ten months of field work, encompasses approximately 100 square kilometers, from the allochthon-autochthon boundary on the west to the approximate base of the Bird Mountain Thrust on the east. The map shown in Figure 1b is a compilation of outcrop maps done at a scale of 1:12,000 by Jacobi (1977) and Rowley (1979).

Previous mapping in this and adjacent areas by Dale (1889), Zen (Castleton 15 minutes Quadrangle, 1961, 1964a), Theokritoff (Granville and Thorn Hill 7 1/2 Quadrangles, 1964) and Shumaker (Western Portion of the Pawlet 15 minutes Quadrangle, 1960, 1967) and the work of Potter (Hoosick Falls 15 minutes Quadrangle, 1972) provided an initial stratigraphic and structural framework. The more paleontologically oriented work of Theokritoff (1964), Berry (1962) and others provided a time-stratigraphic framework with which to compare our lithostratigraphy. Our work has yielded a number of interesting stratigraphic and structural observations that have significant implications for Taconic litho- and time-stratigraphy and the emplacement history of the Taconic Allochthon. These implications will be detailed below.

The purpose of this field trip is three-fold:

(1) We will describe and examine a detailed conformable litho-stratigraphic section from basal Bomoseen wackes to upper Pawlet flysch. (We will also describe variations in litho-stratigraphy across the Giddings Brook Slice.) Attention will be focused on a) the presence of two Cambrian black-green lithologic boundaries; b) problems of litho- and time-stratigraphic correlations and c) possible depositional environment as indicated by composition and sedimentary structures.

(2) We will describe and examine both mesoscopic and macroscopic structural evidence that provide insight into the nature of the Giddings Brook Slice at the time of emplacement and structural complexities produced during allochthon emplacement.

(3) We will outline an actualistic plate tectonic corollary model for the evolution of the North American continental margin during the Early Paleozoic and the emplacement of the Taconic Allochthon. The implications of this model for the regional geology of western New England will be discussed during the field trip and in a separate paper (Rowley and Kidd, in prep.).

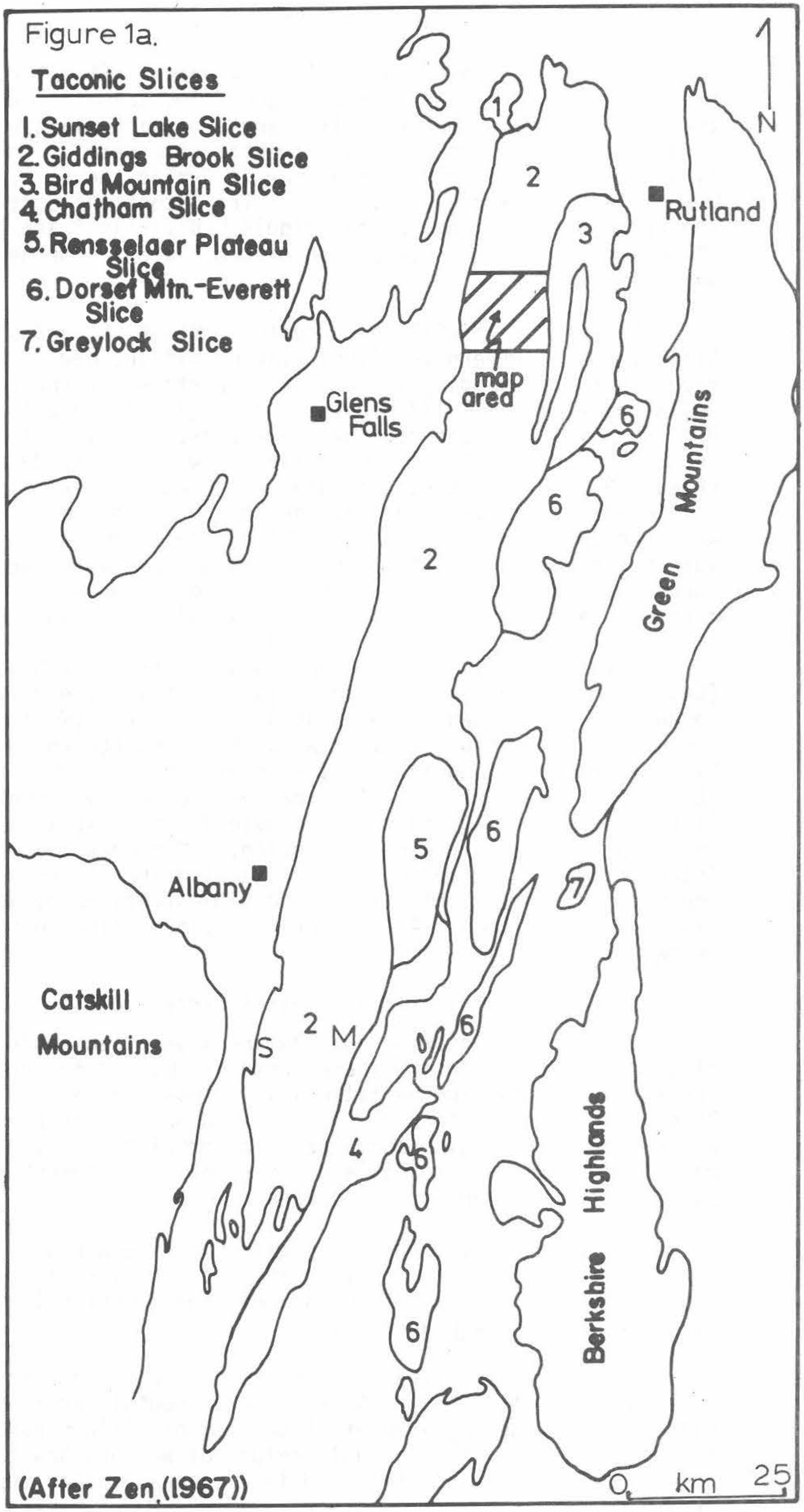


Figure 1a. Structural slices of the Taconic Allochthon after Zen (1967). Numbers refer to slices. S - Schodack Landing, M - Malden Bridge.

Figure 1b.

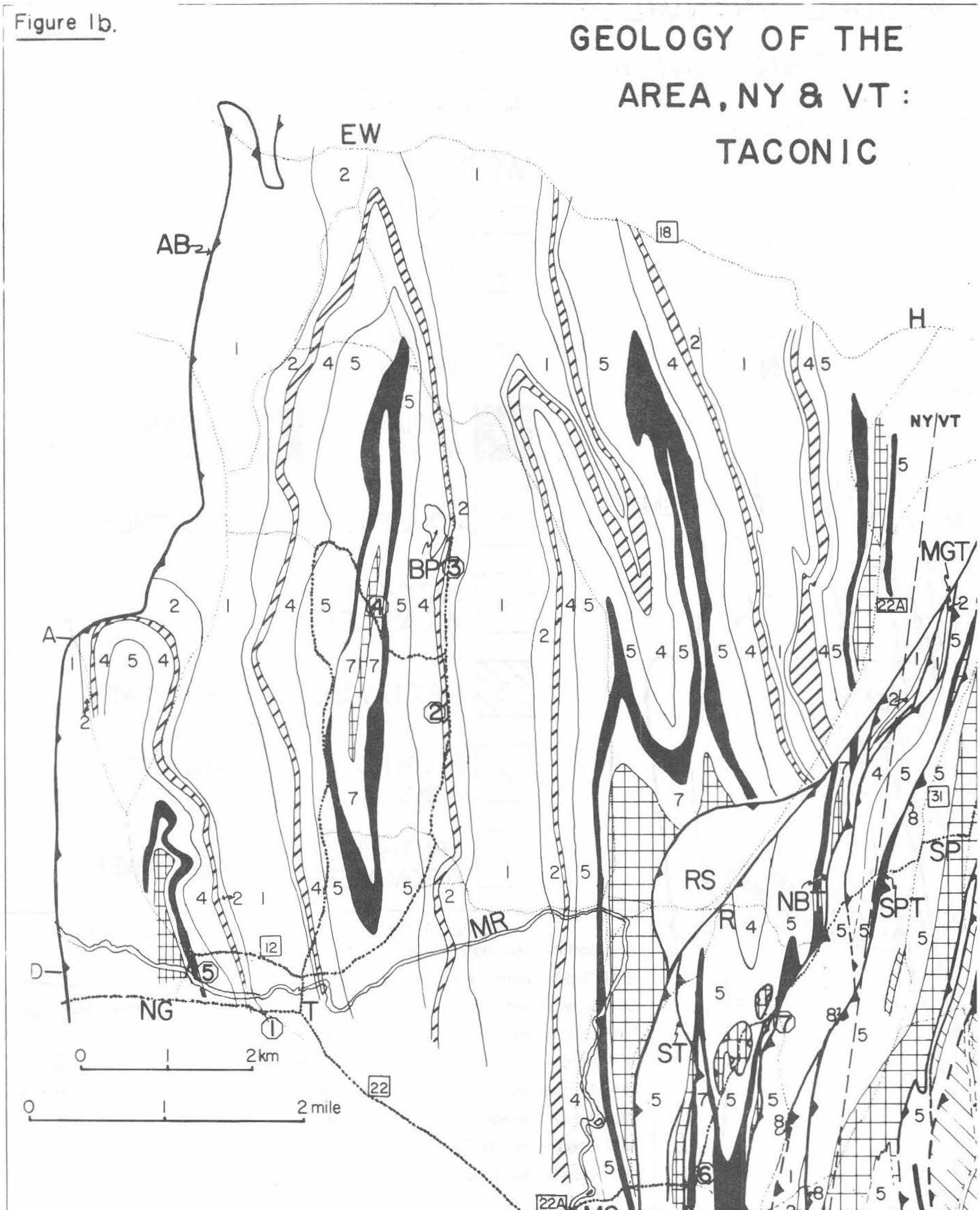
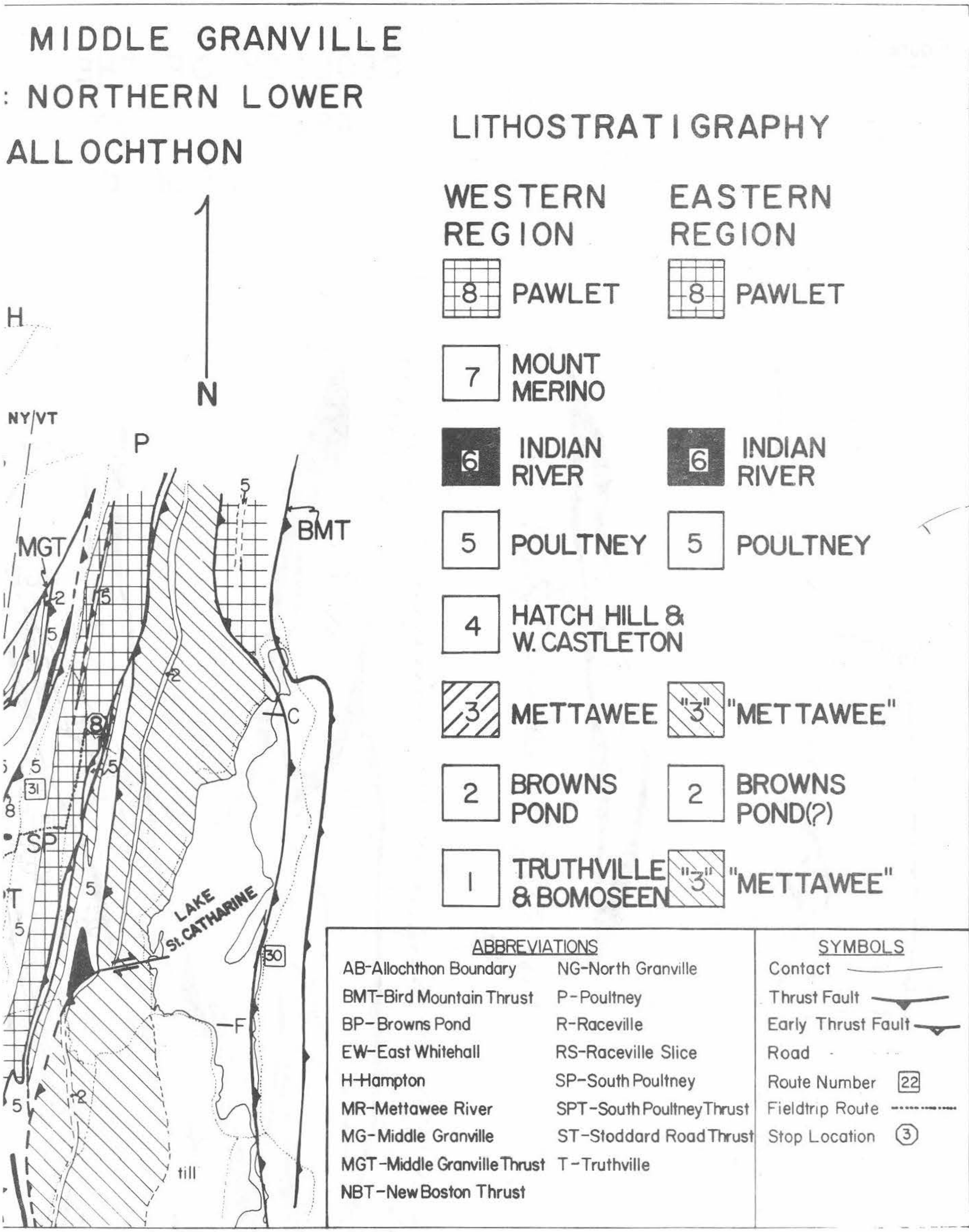


Figure 1b. Geologic map of field trip area. Compiled from outcrop maps (scale 1:12,000) of Jacobi (1977) and Rowley (1979). Stops and route are shown.


MIDDLE GRANVILLE
: NORTHERN LOWER
ALLOCHTHON
LITHOSTRATIGRAPHY
WESTERN REGION
EASTERN REGION
8 PAWLET
8 PAWLET
7 MOUNT MERINO
6 INDIAN RIVER
6 INDIAN RIVER
5 POULTNEY
5 POULTNEY
4 HATCH HILL & W. CASTLETON
3 METTAWEE
"3" "METTAWEE"
2 BROWNS POND
2 BROWNS POND(?)
1 TRUTHVILLE & BOMOSEEN
"3" "METTAWEE"
N
H
NY/VT
P
MGT
BMT
C
SP
T
F
LAKE St. CATHARINE
till
31
30
ABBREVIATIONS
AB-Allochthon Boundary
BMT-Bird Mountain Thrust
BP-Browns Pond
EW-East Whitehall
H-Hampton
MR-Mettawee River
MG-Middle Granville
MGT-Middle Granville Thrust
NBT-New Boston Thrust
NG-North Granville
P-Poultney
R-Raceville
RS-Raceville Slice
SP-South Poultney
SPT-South Poultney Thrust
ST-Stoddard Road Thrust
T-Truthville
SYMBOLS
Contact
Thrust Fault
Early Thrust Fault
Road
Route Number 22
Fieldtrip Route
Stop Location 3

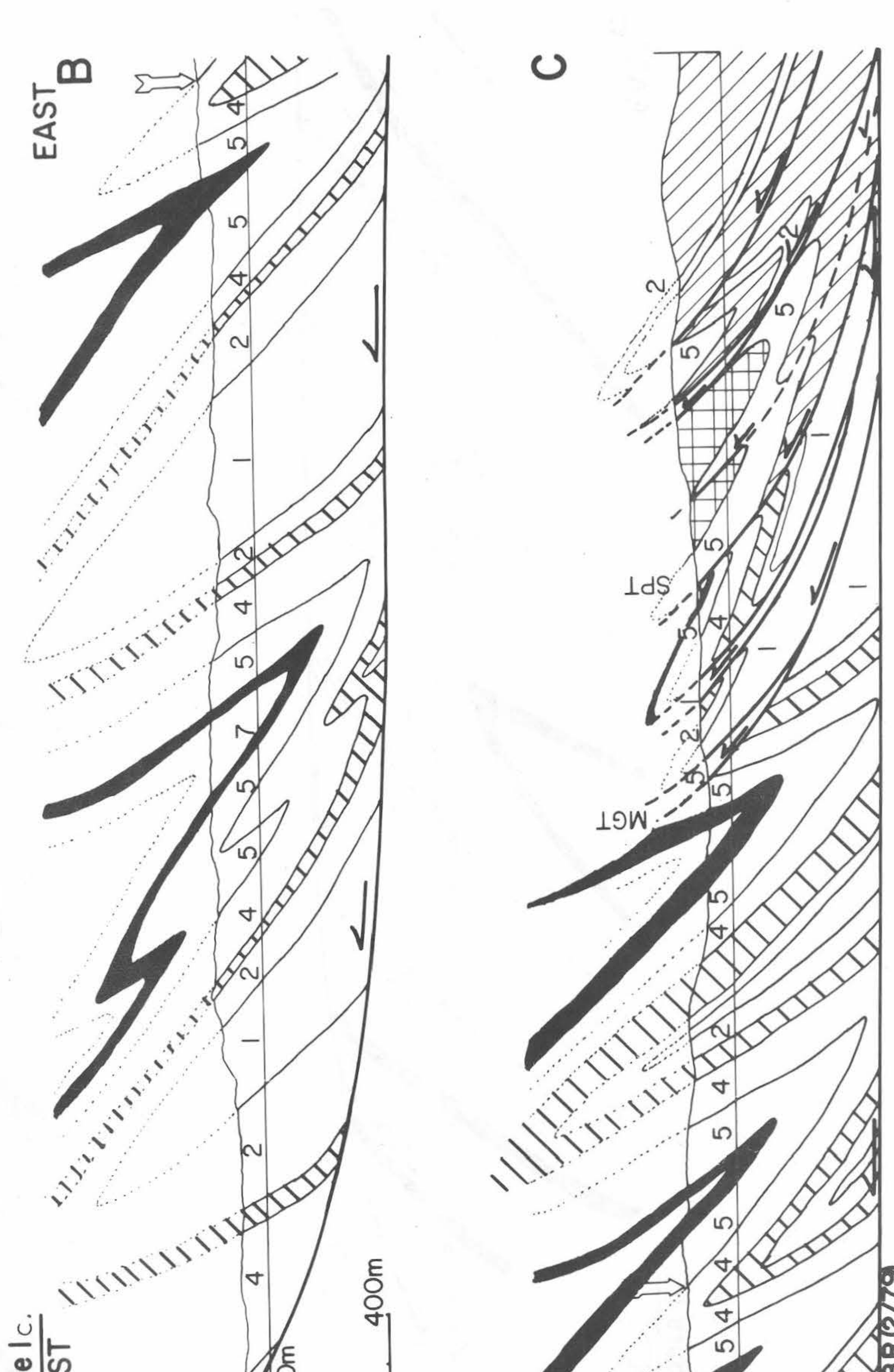


Figure 1c and 1d. Cross sections A-C and D-F from map (Figure 1b). Depth of basal decollement inferred from gravity data of Rickard (1973) and regional relations at the north end of the Allochthon.

Figure Id.

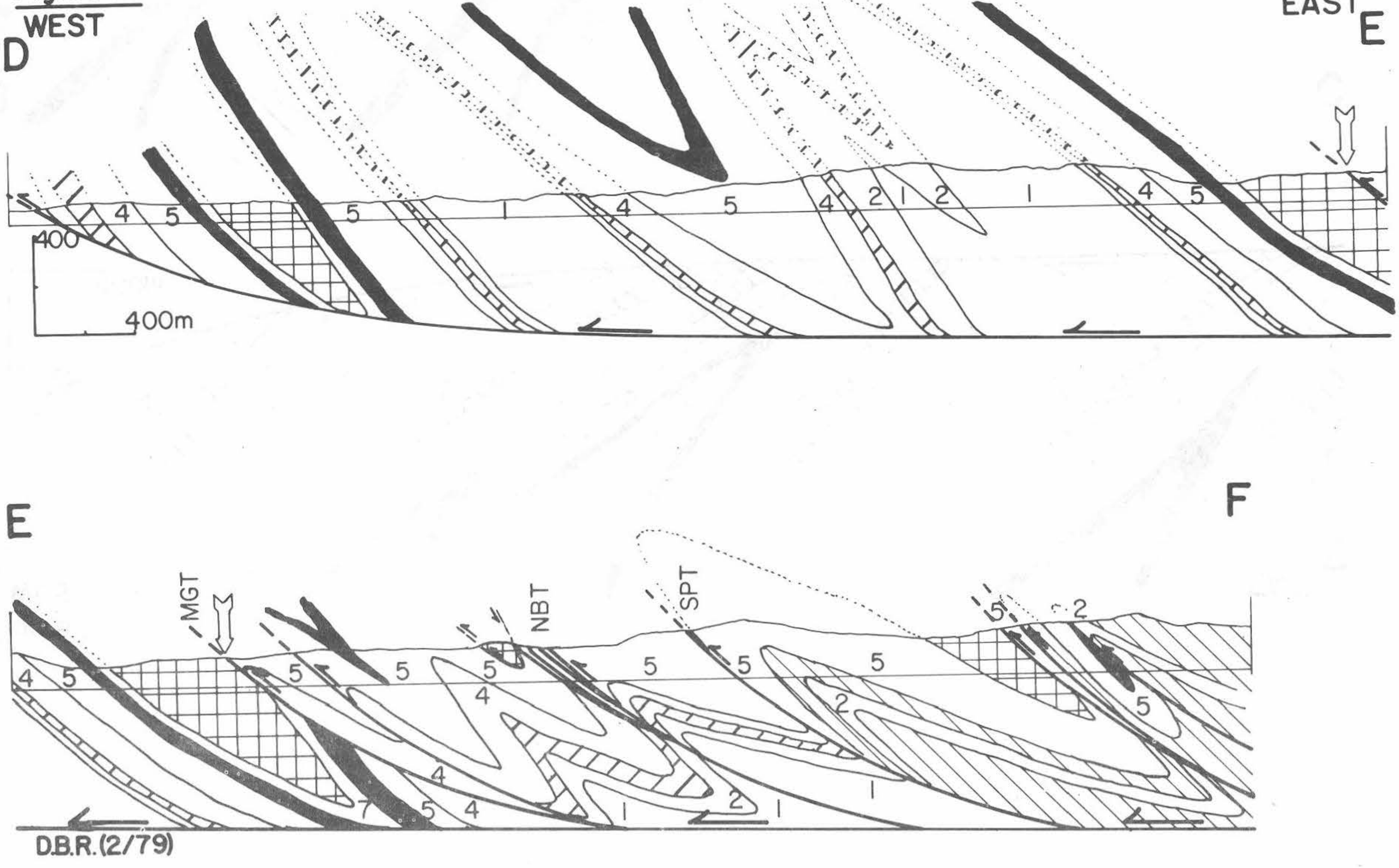


Figure 2

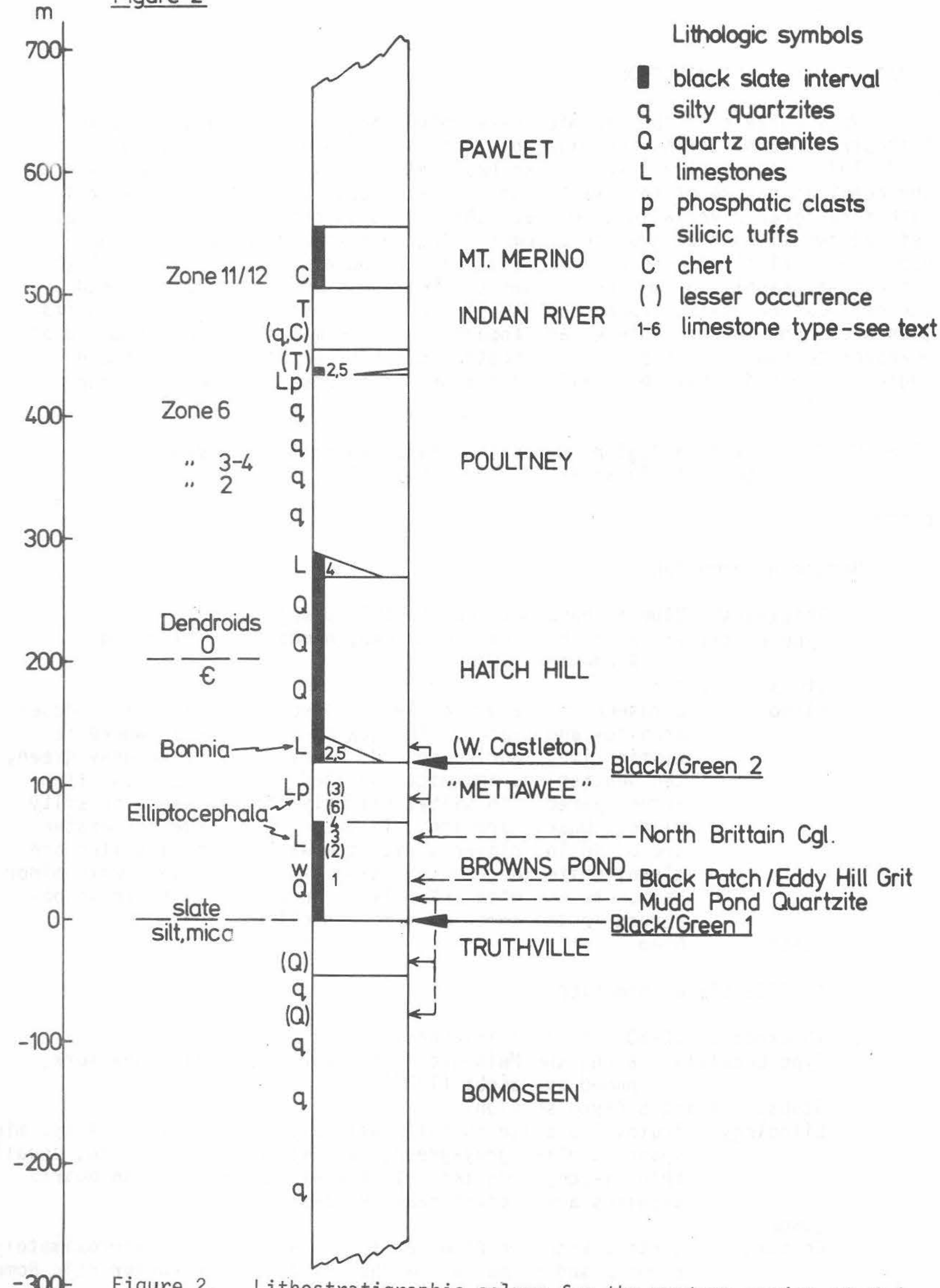


Figure 2. Lithostratigraphic column for the western region of the Granville area.
Typical post-deformation thicknesses are given. Unstrained thicknesses are probably three times post-deformation thicknesses. Graptolite zones after Berry (1962). See Fisher (1977) for correlation with Riva (1974).

STRATIGRAPHY: INTRODUCTION

Many workers in the Taconics have noted large lateral variations in lithostratigraphy across the Giddings Brook Slice (e.g. Zen, 1961, 1964a, 1967, 1972; Potter, 1972) yet no one has specifically addressed themselves to the detailed nature of this variation. We also observe a striking lateral lithostratigrahic variation, and feel that it is so significant that we have defined two lithostratigraphic columns. The western and eastern sections apply respectively to the west and east of the South Poultney Thrust. The lithostratigraphic column for the western region is very well constrained and defines the maximum number of easily and consistently recognizable units. This area contains a complete, and apparently conformable sequence from basal Bomoseen to Pawlet flysch. The lithostratigraphic column for the eastern region is considerably less well constrained as a result of complex structure.

STRATIGRAPHY: Western Region, Allochthon-Autochthon boundary east to South Poultney Thrust (Figure 2).

CAMBRIAN(?)

Bomoseen Formation

Thickness: 240m + (base not seen in this area)
Type Locality: west shore Lake Bomoseen, named by Cushing and Ruedemann (1914)
Stops: 1 and 5
Lithology: Bomoseen is predominantly composed of wackes, with lesser arenites and slates. The quartz-rich type of wacke is distinctive, poorly cleaved, hard, dull, olive gray-green, tan weathering, and mica spangled. This wacke is often interlayered with silty, slightly softer, wacke or silty slate. Quartz arenites, 1-100cm thick, usually massive, are often interlayered with the wacke. The arenites are clean, white to greenish, silty to coarse sand, with minor carbonate and mica. Rarely, a purple silty slate is observed in the cores of some anticlines.
Fossils: None

Truthville Slate Formation

Thickness: 20-60m, typical thickness 45m
Type Locality: along the Mettawee River near Truthville, New York, named by Jacobi (1977)
Stops: 1 and 5 (type section)
Lithology: Truthville slate is soft, well cleaved, fissile, silty, mica spangled olive gray-green, tan weathering with rare, usually thin (1-2cm) arenites. In places, thicker, clean quartz arenites are present near the base.
Lower Contact: Contact with the Bomoseen is gradational over approximately a meter and is marked by the absence of characteristic Bomoseen wacke.
Fossils: None

Cambrian

Browns Pond Formation

Thickness: variable, 25-130m, typical thickness 80m

Type Locality: near Browns Pond along Holcombville Road, at the Granville-Thorn Hill 7-1/2" quadrangle boundary. Named by Jacobi (1977).

Stops: 2 and 3 (type locality), 5

Lithology: The Browns Pond Formation is a heterogeneous assemblage of lithologic types all lying within a predominantly black slate matrix. The slate is predominantly black with lesser dark gray, intermittently calcareous, finely cleaved, rather fissile, and forms the matrix of the formation. Other lithologic types include limestones, limestone conglomerates and breccias, black calcareous quartz wacke, thin dolomitic calc-arenites, and one or two thick clean quartz arenites.

Limestones: are compact, light gray weathering, dark gray micrites, calcisiltites, or calcarenites, sometimes finely laminated, and usually occur as thin (2-3cm) beds or intraformationally slumped horizons.

Limestone Conglomerate: jumbled blocks of carbonates, with lesser amounts of slate, arenites, and calcareous quartz wacke in a black or dark gray slate matrix. The matrix often displays tight, irregular intrafolial folds, and flow structures around larger blocks.

Limestone Breccia: closely packed breccia of dove gray weathering limestone in a slaty to sandy dolomitic matrix. The matrix often constitutes less than about 10% of this lithology. The limestone clasts show little size and type variation. Locally, intraclasts of slate are present.

Calcareous Quartz Wacke: This is a very distinctive lithology. The wacke contains medium to coarse, rounded to subrounded quartz grains set in a black to very dark gray slaty wacke matrix. Lithic clasts within this wacke are predominantly black slate, however, locally clean and rusty-weathering medium grained arenites, blocks of bedded dark gray to black argillite and thin arenites, and black phosphatic pebbles are observed.

Thin Dolomitic calc-arenites: These are locally present and are often finely parallel and cross-laminated.

Thick Quartz Arenites: One or two hard, white to light gray weathering, clean vitreous, medium to coarse grained, locally faintly rust speckled, massive or locally finely laminated quartz arenites are present. Bed thicknesses vary from 1-10 m and are often associated with a calcareous quartz wacke.

All of these lithologies form demonstrably lensing, intermittently present horizons within this formation. Generally the calcareous quartz wacke and thick, clean quartz arenites occur in the lower to middle part, while the closely packed limestone breccia is only known to occur at the top.

Lower Contact: Contact is sharp and marked by distinct color change from gray-green to black.

Fossils: The late Early Cambrian *Elliptocephala asaphoides* fauna has been collected from some of the limestones and the closely packed limestone breccia at the top. (See Theokritoff (1964) for details.)

Mettawee Slate Formation (sensu stricto)

Thickness: 15 to 95 m, typical thickness 50 m
Type Locality: Quarries along the west side of the Mettawee River, north of Middle Granville, New York. Named by Cushing and Ruedemann (1914).

Stops 2, 3, 5:

Lithology: Mettawee slate is one of two extensively quarried slates in this region. The slate is well cleaved, non-fissile, commonly buff weathering, purple, green and near the top gray with black bioturbated laminae. Thin (1 cm), green micritic limestone may occur, and in places, lenses of micritic and arenaceous limestone are present near the base of this formation. Black phosphate pebble-bearing calcarenite and dolomitic matrix micrite breccia are rarely found in middle part.

Lower Contact: The contact with the Browns Pond is usually gradual, over 1-2 m, and marked by color and hardness change, or sharp where limestone is present.

Fossils: The limestone conglomerates within the lower and middle part of the Mettawee also contain the late Early Cambrian *Elliptocephala asaphoides* fauna.

West Castleton Formation

Thickness: 0 to 20 m (best included with Hatch Hill Fm in this area).

Type Locality: near West Castleton, Vermont in the Castleton Quadrangle named by Zen (1961).

Stops 3 and 5:

Lithology: West Castleton Fm is demonstrably lensing, often poorly exposed, and only a marginally mappable unit in this area. It is characterized by interbedded black, fissile, well cleaved, often pyritiferous slate and medium to dark gray limestones (calcarenites and calcisiltites). Dolomitic quartz arenites are also present, making the distinction from Hatch Hill marginal.

Lower Contact: Contact is sharp and marked by color change from gray or green to black. This is the second Cambrian black-green boundary.

Fossils: Trilobites of the Paedeumias-Bonnia, Pagetia connexia, and Pagetides elegans faunules have been reported. These are slightly younger than the Elliptocephala asaphoides fauna found in the Browns Pond and Mettawee Formations (Theokritoff and Thompson, 1969).

Hatch Hill Formation

Thickness: 35 to 205 m - typical thickness 150 m

Type Locality: on Hatch Hill in the Thorn Hill Quadrangle. Named by Theokritoff (1964).

Stops 2, 4 and 5:

Lithology: Hatch Hill is also characterized by rusty, black, fissile, well cleaved, slightly silty slate. Interbedded with the black slate are thin (2-10 cm) to thick (30-400 cm), medium to coarse grained, dolomitic sub-quartz arenites. The arenites are massive, sometimes finely parallel-laminated, and only rarely are cross-laminated or affected by soft sediment deformation. Extensively developed quartz and calcite veins characterized the thicker arenite beds. A closely packed arenite breccia is locally observed near the top of the unit in the thickest beds.

Comment: Distinguishing Hatch Hill from West Castleton is often not possible, particularly where the West Castleton is thin and contains dolomitic quartz arenites. We suggest that the West Castleton may be better regarded as a facies of the Hatch Hill, possibly an overbank deposit of Hatch Hill distributory fan channels.

Lower Contact: The West Castleton-Hatch Hill contact is placed at the first substantial dolomitic quartz arenite bed. Where Hatch Hill is in contact with Mettawee the contact is sharp. No conclusive evidence for the presence of an unconformity below the Hatch Hill is observed, however, a local disconformity may be present.

Fossils: Dendroid graptolites from near the top of the Hatch Hill have been found by Theokritoff (1964) and identified by Berry as of probable Tremadocian age (latest Cambrian in North America; earliest Ordovician in Europe).

ORDOVICIAN

Poultney Formation

Thickness: 70-210 m, typical thickness 185 m
Type Locality: along the Poultney River, west of Poultney, Vermont. Named by Keith (1932), but included the Hatch Hill Fm.
Stops: 4,6,7
Lithology: Poultney Formation is divisible into two members, informally called the Dunbar Road Member (lower) and Crossroad Member (upper). These members are similar to Potter's (1972) White Creek and Owl Kill members, respectively, in the Hoosick Falls area.

Dunbar Road Member is known to be lenticular, and is composed of fissile, thinly cleaved, dark gray to black slate with interbedded thin (3 cm), micritic, and sometimes silty limestones. Crossroad Member crops out extensively, and is characterized by hard, often chalky weathering, nonfissile, moderately to well cleaved slate. Color of the slates varies considerably, but is predominantly medium gray, with lesser, light gray to green, and black, and rare maroon, purple and red slates present. Finely color laminated slates are common and often show prominent bioturbation features. Commonly interlayered with the slates are: Thin (1 mm - 1 cm), clean, white, (some with fine black laminae) often 'ribboned' silty quartzites and quartz arenites. Also seen are: much less common, thicker (~30 cm) medium-grained quartz arenites; chalky weathering gray chert, only very close to the top; disrupted, non-transported, recemented limestone or quartz arenite conglomerate horizons; rounded limestone and/or black phosphate pebble conglomerate and associated laminated calcarenites/siltites.

Lower Contact: Where the Dunbar Road Member is present the contact is placed at the first limestone bed above the dolomitic arenites. The Crossroad-Hatch Hill contact is sharp and marked by both color and hardness changes.

Fossils: Graptolites from Berry's (1962) zones 2,3,4,6 in this area and 7 and 9 in other areas. According to the graptolite classification of Riva (1974). Poultney extends at least as high as Glyptograptus dentatus (Upper Canadian or upper Arenigan and possibly into Climacograptus angustatus or lowest Nemagraptus gracilis (Whiterockian, lowest Champlainian-Llanvirnian to lowest Llandeilian (Fisher, 1977), though no graptolites of this period have been reported, possibly because of unsuitable host rocks.

Indian River Formation

Thickness: 25-55 m, typical thickness 50 m
Type Locality: Quarries close to Indian River, south of Granville, New York. Named by Keith (1932).
Stops: 4,6,7

Lithology: Indian River slates are the second of the extensively quarried slates in this region of the slate belt. The slate is strong, well cleaved, non-fissile, red, green to blue-green, and locally gray at the top. Locally present in the slates are red and green chert layers and rare narrow, white, fine grained, silty quartzites. Distinctive, white to yellowish weathering, pale grey flinty horizons, interpreted to be silicic tuff beds, are present in the middle to upper Indian River. Small rounded to ellipsoidal, poly-crystalline quartz grains, presumably radiolaria, are often seen on slaty cleavage surfaces.

Lower Contact: The nature of the contact depends on the color of the lowest Indian River; if red, the contact is sharp, if green the contact is gradational over 1-2 m from gray to green.

Fossils: No datable fossils have been reported from within the Indian River.

Mount Merino Formation

Thickness: 25-70 m, typical thickness 50 m.

Type Locality: Mount Merino, west of the town of Hudson in the Southern Taconics. Named by Cushing and Ruedemann (1914).

Stops: 4,6,7

Lithology: Mount Merino is divisible into two distinctive members. A lower banded chert member and an upper black slate member, informally called the Stoddard Road Member.

Lower Chert Member: Composed of chalky white weathering predominantly black with lesser dark green, 3-5 cm thick, banded cherts with minor interlayered black slates. Both cherts and slates are often pyritiferous.

Stoddard Road Member: A very distinctive, coal black, rusty weathering, well cleaved, slightly silty graptoliferous slate.

Lower Contact: This is probably the best exposed contact in this area, due to the extensive quarrying of the Indian River. The contact is very sharp, marked by both color and hardness changes.

Fossils: Graptolites of Berry's zones 11 and 12 (N. gracilis to Climacograptus biconis, or Rivas N. Gracilis zone. (Llandeilian to lowest Caradocian)

Pawlet Formation

Thickness: greater than 150 m, the top is never observed.

Type Locality: Pawlet, Vermont, in the Pawlet Quadrangle. Named by Zen (1967) after usage by Shumaker (1960, 1967).

Stops: 5,6,7

Lithology: Pawlet is characterized by easterly-derived deep-water turbidite flysch sequence of interbedded brownish to gray weathering, medium to dark gray, variably calcareous, fine to coarse grained, quartz-rich lithic greywackes and fine to finely silty, well cleaved, often fissile grey slates. The greywackes vary from fine grained, sometimes silty, often finely parallel or cross-laminated, moderately clean 3-10 cm beds, to medium to coarse grained, commonly grading to silty, 10-300 cm thick, lithic wackes. Lithic fragments are almost exclusively slate rip-up clasts, although some possible chert fragments have been observed.

Lower Contact: The Pawlet is conformable in this area on the Mount Merino and its base is marked by the incoming of greywackes.

Fossils: Graptolites of Berry's zones 12 and 13 are reported (*C. bicornis* and *Orthograptus truncatus*, var. *intermedius*). Riva's zones are upper N. gracilis, *Diplograptus multidens*, and *Corynoides americanus* and possibly *Orthograptus ruedemanni*. (Middle to upper Caradocian). The latter may only occur in parautochthonous or neoautochthonous Pawlet - Austin Glen.

STRATIGRAPHY: Eastern Region, South Poultney Thrust to Bird Mountain Thrust

CAMBRIAN(?)-CAMBRIAN

"Mettawee Slate" (*sensu lato*)

Thickness: unknown, greater than 30 m

Stop: 8

Lithology: Primarily purple, green and gray, with minor black, red, and maroon, non-fissile, well cleaved, extensively quarried slate. Often interlayered with the quarried slates are thin (1-2 cm) green micritic limestones, called 'rubber beds' by quarry workers in this area. Also present are purple, green, and less commonly gray, fine silty to silty moderately to coarsely cleaved slates and argillites. Interlayered with the silty argillites are thin (1-2cm) fine to silty clean, often finely laminated greenish to white quartz arenites. Rarely, 30-100 cm thick, vitreous, medium to coarse grained quartz arenite beds are observed.

Fossils: None

Browns Pond Formation (?)

Thickness: less than 10-30 m, average 15.

Lithology: Lying within the Mettawee Slates (*sensu lato*) are pale to medium gray, and locally dark gray, fine, fissile well cleaved, slates with interlayered medium to coarse clastic horizons, including:

(1) Calcareous quartz wacke with medium to coarse, rounded to sub-rounded quartz grains within a dark gray to black slaty matrix.

(2) Associated with(1) is an argillaceous quartz arenite, 5-15 cm thick, of medium to coarse arenite with minor interstitial clay.

(3) Medium grained, well rounded thoroughly rotten-weathering quartz arenite.

(4) Thick, 20-60 cm, vitreous, medium to coarse grained, clean, hard white to light gray weathering, rarely, faintly rust speckled quartz arenite.

(5) White weathering, black phosphate(?) pebbles to discontinuous 0.5-1.0 cm thick layers in a dark gray slate.

Note: all lithologies described above are lensing, and may grade into one another either along strike or vertically.

Fossils: None

West Castleton-Hatch Hill-lower Poultney

These lithostratigraphic units are unrecognized in this area. The reasons for this missing section are unclear. Four hypotheses may be suggested, but none is entirely satisfactory.

(1) An unconformity below the Poultney, possibly due to scouring by bottom currents.
However, this seems improbable because the medium to coarse sand character of the Hatch Hill is not easily transported, and one would expect that winnowing would have left this sand fraction behind. Evidence for strong bottom currents is not observed to the west, and the presence of Hatch Hill and West Castleton to the east and west also argues against such a hypothesis.

(2) Large-scale down slope slumping, resulting in local removal of these units in this locality, similar to that discovered by DSDP drilling off the coast of Africa (Leg 47, Geotimes, 1976). This model requires that somewhere to the east extremely large thicknesses of black slates, limestones, and dolomitic quartz arenites should have been present originally, presumably in a chaotic, olistostrome-like deposit. Data from areas to the east do not allow us to test this, as most of the black slates and phyllites have been mapped as Undifferentiated Cambrian-Ordovician black slates by Shumaker (1967).

(3) These units have been systematically removed tectonically during emplacement of the allochthon in the Middle Ordovician. This requires either tectonic excisions along all Mettawee-Poultney boundaries after early F_1 folding or pre-folding thrust removal of these units in this area. The first mechanism appears to be highly improbable. There is no field evidence to support large-scale pre-folding thrusts, but this possibility cannot be entirely ruled out.

(4) There was a facies change from black slates with interbedded limestones and dolomitic arenites to the west to purple, green and gray slates with thin interbedded micritic limestones to the east. This hypothesis does not explain the lack of arenites to the east, even though they were probably confined to channels, or the presence of Hatch Hill and West Castleton farther to the east in the Edgarton Half-Window, as mapped by Shumaker (1967).

ORDOVICIAN

Poultney Formation

Stop: 8

Lithology: Predominantly medium gray, often interlayered with gray, dark gray, black, and locally green, in some places silty, moderately to well-cleaved slates and argillites. Argillites tend to be hard, sometimes siliceous, white weathering with only a spaced cleavage developed in them. Thin (2 cm) white weathering, silty to fine grained, clean, often finely laminated quartz arenites characterize the Poultney of this area. Thicker (2-10 cm) white weathering, silty to medium grained, clean, parallel and irregularly cross-laminated quartz arenites are also observed. Rare, thin (1 cm) white weathering black cherty layers in a dark gray silty argillite are sometimes observed near the lower contact of this unit.

Indian River Formation (Rare)

Lithology: Red, green to blue-green, with minor maroon well cleaved, non-fissile slate. Thin (1 cm) silty to fine grained, parallel and irregularly cross-laminated quartz arenites are often present near to lower contact with the Poultney. This contact appears to be gradational over about a meter, from predominantly medium gray to red. Rare, flinty green, silicic tuff bands are present.

Mount Merino Formation (Very Rare)

Lithology: Only very poorly exposed in this area and only as demonstrably tectonically-bounded thrust slivers. Both members, black cherts and sooty black, locally graptoliferous slates have been observed.

Pawlet Formation

Stop: 8

Lithology: Medium to dark gray, fine to slightly silty, well cleaved fissile, slates interbedded with very distinctive silty to coarse grained lithic greywackes. The greywackes are often graded, with locally observed current lineations, and other sole markings. Internal structures within the greywackes are very rarely observed and usually consist of fine cross-liminations at the tops of some beds. Bed thicknesses range from 3-300 cm ; locally evidence of composite beds are observed. Average bed thickness is 30-40 cm. Very locally, Poultney-like medium gray silty argillites and thin silty quartz arenites are interbedded with greywackes. These lenses do not appear to be intraclasts, however, this origin cannot be entirely ruled out.

Lower Contact: Zen (1961, 1964a, 1967) Shumaker (1967), Potter (1972) and others suggest that the Pawlet unconformably overlies lithostratigraphic units as old as the Mettawee (Cambrian-(?)-Cambrian). Shumaker (1967) suggests that the unconformity is at least locally angular. In this area Pawlet does appear to rest with depositional contact on Poultney, but nowhere is it unequivocably in depositional contact with rocks any older, in fact depositional contacts cannot be unequivocably demonstrated anywhere in this area. The nature of the basal contact is extremely difficult to pin down. Locally a thin 5-20 cm thick dark gray argillite is present between undisputable Poultney and Pawlet, however, nowhere is a basal breccia, conglomerate or rafts of older units observed that would support an unconformable or at least angular unconformable relation.

DISCUSSION

The great stratigraphic advantage of the western area, besides better outcrop, over most other areas of the Giddings Brook Slice, is that the lithostratigraphy of the early Cambrian and possibly older rocks is divisible into clearly distinguishable formations. Instead of finding large thicknesses of purple and green slates below one (or no) black-green boundary as in the eastern area mapped by Rowley, here there is a well defined unit with black to dark slate (Browns Pond Formation) below a thin purple and green slate (Metawee Slate Formation (ss)) and, in addition, there is the easily defined green wacke and quartzite of the Bomoseen Formation separated from the Browns Pond by a silty micaceous green slate (Truthville Formation). The boundaries between these readily mappable formations provide a framework to define, more precisely than has been previously possible, the positions of occurrence of distinctive lithologic members in this part of the succession. This precision is not possible where only undistinguishable green and purple slates and silts occur below one black-green boundary, as is the case in much of the Giddings Brook slice. These members have been very extensively used in mapping in many areas of the Taconics mostly because they are more resistant than the surrounding slates and hence outcrop preferentially. Knowledge of their constancy (or lack of it) in lithostratigraphic position will therefore allow improvement of existing maps of other areas that show these members. Three lithologies are of concern 1) a clean medium to coarse grained thick-bedded quartzite (Mudd Pond Quartzite) 2) a highly distinctive grey to black cleaved silty wacke containing dispersed coarse well-rounded quartz grains and dark slate rip-up clasts (Black Patch Grit or Eddy Hill Grit) and 3) limestones, especially varieties of limestone conglomerate and breccia (North Brittain conglomerate, Ashley Hill conglomerate, Beebe limestone).

In the western map area, the Mudd Pond Quartzite lithology is most commonly found, when present, in the lower half of the Browns Pond Formation as one, or two, thick (to 10 m) multiply bedded, lenticular units that most probably occupy channels. They are clearly associated with the Black Patch/ Eddy Hill Grit lithology in this position (Stop 3), although one may often be present in any section without the other (Stop 5). Unlike the Black Patch Grit lithology, which <u>only</u> occurs in this position low in, but not at, the base of the Browns Pond Fm., less prominent (in this area) occurrences of the Mudd Pond Quartzite lithology are found in the lower and upper part of the Truthville Slate (seen at Stop 5), and in the upper part of the Bomoseen Formation. As lithostratigraphic markers, therefore, we regard the Black Patch Grit lithology as a much more reliable indicator of stratigraphic position than the Mudd Pond Quartzite lithology, which may appear at several places within a range of about 130 m of section (15% of the exposed thickness of the pre-Pawlet Greywacke section).

In this area, limestones in the two units above and below the Metawee Slate (s.s.), and within it, are usually distinguishable from one another when taken as assemblages of lithologies. Individual lithologies, for example, laminated calc-arenites are, however, common to more than one of these units, so distinction of units cannot be made on the basis of single limestone lithologies. Limestone lithologies occurring in this area and their position in the stratigraphy are as follows (numbers keyed to Fig. 2) This listing may be of assistance in identifying lithostratigraphic position in the absence of two black-green slate boundaries, etc.

1) Blocks and pebbles of calcarenite to micrite, which may or may not be dolomitic, widely dispersed in a dark calcareous wacke (Black Patch Grit lithology) or dark calcareous slate showing evidence of debris flow and slumping. This occurrence is restricted to the lower and middle parts of the Browns Pond Formation (Stops 3, 5).

2) Thin-bedded (1-10 cm), parallel-laminated (lesser cross-laminated), calcarenites and calcisiltites; lesser micrites. Occurs locally near the top of the Browns Pond Formation (Stop 3); otherwise seen at the base of the Hatch Hill Formation (West Castleton "Fm") (Stop 3) and in an uncommon carbonate horizon high in the Poultney Formation. Although calcarenites do occur in the carbonate horizon of the basal Poultney Formation (Dunbar member), this tends to be dominated by micrites (see below). Rare thick (20-100 cm) individual beds of laminated calcarenite occur at the Browns Pond-Metawee Formation contact, and within the latter. F m. (Stop 2)

3) Limestone breccia with mainly grey micrite in compact but irregularly shaped pebbles and cobbles; less common calcarenite clasts; orangy-weathering arenaceous dolomite matrix. Clasts are closely-packed. Lithology is restricted to the topmost Browns Pond Fm. (Stop 3), except for rare occurrences of a single bed less than 50 cm thick in the middle of the Metawee Slate Formation.

4) Nodular grey micrites mostly 1-5 cm thick. These may occur as very disconnected nodules if diagenetic dissolution was intense. They occur up to a few metres on either side of the Browns Pond Formation-Metawee Slate formation (s.s.) contact (Stop 2). The layers in the green Metawee Slate are characteristically more nodular and the nodules more widely separated. Micrites are also dominant where carbonates occur in the lower Poultney Formation (Dunbar Member).

5) Limestone conglomerate/breccia with up to 1 cm pebbles of micrite and lesser calcarenite. Uncommon lithology which occurs in base of Hatch Hill Fm. (West Castleton) (Stop 3), and in the carbonate horizon found high in Poultney Fm.

6) Limestone breccias other than those of 1), 3) and 5), typically with relatively closely packed clasts dominantly of micrite in a shaly matrix. These are uncommon in the map area, occurring mostly in the lower part of the Metawee Slate Fm. (s.s.).

The use of these data on Taconic carbonates in lithostratigraphic correlation may be illustrated by using two well known central-southern Taconic sections, that have been studied by the authors, at Schodack Landing and Malden Bridge. The latter section consists dominantly of calc-arenites in black slate, above purple slate. We suggest that the purple slate correlates with the Mettawee Slate Formation (s.s.) and that the calcarenites are equivalent to basal Hatch Hill Formation (West Castleton).

The Schodack Landing section described by Bird and Rasetti (1968), Bird and Dewey (1975), Keith and Friedman (1977) and Friedman (this guidebook) and our observations consists of nodular, bedded micrites overlain by a lenticular micrite/shale matrix breccia and highly nodular micrites in green shale, lie below black shales with dolomitic arenites and quartzites identical to the Hatch Hill Formation. We correlate these micrites with those straddling the Browns Pond-Mettawee Slate Fm (s.s.) contact. The single black-green boundary seen at both localities is lithostratigraphically correlated with the upper one in the Granville area; faunal collections from them and other Taconic sections (Bird and Rasetti, 1968) and in the Granville area (Theokritoff, 1964) support the proposal that this upper black-green boundary is essentially isochronous. We suggest that it is likely to be so, when properly identified throughout the Taconic region.

Phosphatic clasts have been proposed (J.M. Bird, pers. comm.) to be characteristic only of the Cambrian part of Taconic stratigraphy. While they are prominent in some calcarenites and breccias in the Mettawee Slate Fm. (s.s.) and the carbonates of the basal Hatch Hill (West Castleton) Fm., they also occur in the upper Poultney Fm. carbonates.

SEDIMENTARY FEATURES AND ENVIRONMENT OF DEPOSITION

The present stratigraphic thickness in this area of the section from the top of the Bomoseen Fm. to the base of the Pawlet Fm. ranges from 380 to 840 meters. Most estimates are in the range from 450 to 650 meters with a typical value of 610 meters. This variability probably results from both sedimentary and tectonic causes. Channelized deposition, non-deposition and/or scouring by bottom currents may account for some of the thickness variation. Small faults, probably thrusts, minor folds and inhomogeneous strain, particularly during D_1, may also produce some part of the observed variability. At present it is not possible to estimate the relative contribution of these effects.

Paleontological evidence indicates that this stratigraphic section of about 600 meters represents the time from late early Cambrian to late medial Ordovician (Caradocian), a period of perhaps 110 m.y. (560-450 m.y.). An approximate average rate of deposition can be obtained, once the present thickness has been corrected for tectonic thinning during D_1 folding and cleavage development. Wood (1973, 1974) estimated 75% shortening perpendicular to slaty cleavage, using deformed reduction spots in purple slates from near this area. Taking into account the effects of strain variation in different lithologies we estimate an original thickness of approximately 2000 meters. An average deposition rate of about 20 m/m.y. (or 20 mm/1000 yr.) results. This very slow overall rate supports the suggestion of Elam (1960) and Bird and Rasetti (1968) that the environment was "starved." Bird and Dewey (1970) pointed to the continental rise off a carbonate shelf as the specific "starved" depositional environment of Taconic rocks.

Sedimentary structures and facies seen within Taconic stratigraphy are wholly compatible with deposition in deep water on a continental rise prism (Jacobi, 1977; Keith and Friedman, 1977). In the framework of mudrocks, the silty arenaceous and coarser beds are either channelized debris flows and traction grain flows*, turbidites, or contourites*. Evidence of soft-sediment disruption (incipient slumping), mud injection structures and sedimentary (clastic) dikes**, some of large size, are seen in good outcrops. Burrowing is prominent in non-black mud units. No autochthonous carbonate can be proven and much is demonstrably transported. The only fossil types seen in mudrocks are graptolites and poorly preserved radiolaria, both pelagic forms.

The arenaceous and coarser detritus in units from the Browns Pond to the Indian River Formations must be originally derived from the carbonate platform and environments landward of it where quartz silt and sand were being supplied. Possible sedimentary environments for parts of the Cambrian section have been described by Keith and Friedman (1977). Prior to deposition of the Browns Pond Formation, the 'framework' sediment is silty, with a prominent detrital mica component, suggesting active erosion of exposed crystalline basement. The rocks of the Truthville and Bomoseen Formations, however, still show some evidence of deep-water deposition and no evidence of shallow water structures. The schematic evolution of this source as a newly rifted continental margin evolving into a subsiding carbonate platform is well known (Bird and Dewey, 1970).

The uppermost unit, the easterly derived Pawlet Formation (a flysch) is interpreted as heralding the convergent tectonics of the Taconic orogeny (Bird and Dewey, 1970). The mineralogic and lithic composition of Pawlet greywackes, suggests that they were, at least in part, derived from erosion of Taconic or Taconic-like rocks. This suggests that these greywackes might best be thought of as the products of erosion of material already incorporated in an accretionary prism, and transported as turbidites down into and along the morphologic trench at the front of the moving prism.

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*Best displayed in two large contiguous outcrops of the Hatch Hill and Poultney Formations on the west bank of the Poultney River, northwest of Fair Haven. If you visit these outcrops, please do not vandalize them by attempting to collect specimens. Please take nothing but photographs.

**Small clastic dikes are well exposed in the Poultney River outcrops described above. Large clastic dikes are exposed in an outcrop of Poultney Formation, with unusually thick, fine-grained quartzite beds in it, on the west side of Rt. 22A, 1.3 miles north of Middle Granville, directly opposite a dirt parking area on the other side of the road.

Reference Section for Taconic Lithostratigraphy

A plethora of stratigraphic names, both lithostratigraphically and biostratigraphically defined have been used in the Taconics. Zen (1964b) provided a great service for Taconic geology by compiling and systematizing Taconic stratigraphic names, descriptions and synonomies. Without Zen's compendium Taconic stratigraphy would be in chaos. Even so, many lithostratigraphic units remain poorly and inadequately described, particularly with respect to lithologic assemblages and stratigraphic relationships. This results in part from poorly chosen and described type-localities, as well as generally mediocre outcrop in many parts of the Taconics. We suspect that much confusion and misidentification of lithostratigraphic units results from this situation. In order to help rectify this situation we propose the western part of the Granville area to the west of the Middle Granville Thrust, as a lithostratigraphic reference area for the low Taconic Giddings Brook Slice. The following attributes of this western area support this proposal: 1) good outcrop, with excellent, easily accessible exposures; 2) well described stratigraphy and stratigraphic relationships for a complete, regionally conformable lithostratigraphic section from Bomoseen to Pawlet Flysch. 3) Presence of four to ten lithostratigraphic unit type localities within this area. 4) Simple, coherent, well defined structure. We feel that a well mapped, well exposed reference area should help in the correlation of Taconic lithostratigraphy, at least in the Giddings Brook Slice, and provide a standard lithostratigraphic column upon which to refine biostratigraphic work.

STRUCTURE

The deformation history of this region involves syn-depositional, soft-sediment slumping and slump folding (D_0), and two north-trending, essentially coaxial tectonic deformations. Structures associated with the first tectonic deformation (D_1) are responsible for the map geometry of the lithostratigraphy. D_1 deformation primarily involves large-scale overturned folds that are progressively dismembered to the east by mid- to late syn-D_1 east over west thrusting. This tectonic dismemberment, associated with D_1, results in a macroscopic, west to east pattern of increasing deformation and structural complexity. Second generation structures (D_2) result in only minor redistribution of earlier structures and are of distinctly secondary importance. Mesoscopically, the D_2 related crenulation cleavage (S_2) becomes more pronounced to the east. Zen (1961, 1964, 1967), Wright (1970), Potter (1972) and others have noted a similar mesoscopic pattern for S_2.

D_0 Pre-regional Deformation

Syndepositional slumping (Stop 1, 3, Stop 5) is observed in many units, and is particularly well developed in the Bomoseen, Browns Pond, Mettawee Slate (s.s.) and Poultney Formations. D_0 deformation usually involves dismemberment, or folding of one or several beds. Slump folds are often demonstrably intrafolial and tend to be tight to isoclinal, locally involving transposition. Individual soft-sediment related structures never affect more than a few beds, and never influence the macroscopic outcrop distribution of lithostratigraphy. It is more important to realize that all D_0 structures have been significantly modified by later, tectonic deformation. Unless folding is demonstrably intrafolial, or S_1 cuts both limbs of the fold (Wright, 1970), the distinction between mesoscopic F_0 and F_1 is very difficult.

In order to better appreciate structural variation, the map area has been divided into three contiguous regions, each with similar structural style, and separated by tectonic boundaries.

Tectonic Structures - Western Area

The westernmost region extends from the allochthon-autochthon boundary on the west to the Middle Granville Thrust on the east. The structural style of this region is characterized by large, coherent, west-facing, overturned, tight to isoclinal, gently plunging folds (F_1) and an associated moderately dipping, penetrative, axial surface slaty and locally spaced cleavage (S_1). The map pattern of this region reflects this structural style. Local thrusting along some limbs of these folds may explain some of the large variations in lithostratigraphic thickness, but nowhere do these thrusts grossly disrupt the map pattern. Second generation structures, generally involving open to angular upright to asymmetric folds (F_2) and associated upright to steeply east dipping crenulation cleavage (S_2) are only locally observed. Small, steep late schuppen are locally present, but the offset associated with these is never more than a few meters.

Central Area

The central region extends from the Middle Granville Thrust to the New Boston Road Thrust. This small region is intermediate in structural style between regions to the west and east. This region is characterized by large, tight to isoclinal, gently plunging overturned F_1 folds with well developed axial surface slaty and locally spaced cleavage (S_1). Slides (Bailey, 1910, p. 593, Dennis, 1963) occur along the short limbs or in the hinges of some of the F_1 folds, best seen in the Stoddard Road Thrust (Stop 6). Thrusting is believed to be associated with D_1; micro- and mesoscopic evidence suggests that a late D_1 timing is probable (see description of mesoscopic structures associated with thrust faults below). D_2 structures include open to angular folds (F_2) and associated steeply east-dipping axial surface crenulation cleavage (S_2). Late, syn-D_2 to post D_2 schuppen and granulated vein quartz with angular clasts of slate are locally observed, but neither demonstrably offsets stratigraphy. The time of emplacement of the small klippe of Pawlet greywackes in to the hinge region of the large F_1 fold to the west of Stoddard Road is not clear. Outcrop density is not sufficient to determine if the klippe thrust is or is not folded with the underlying Poultney. The wackes of the klippe are tightly folded and may indicate that they were in their present position at the time of F_1 folding, but this need not be so. At the present time we are biased towards a pre-F_1, early to pre-D_1 age, but this cannot be conclusively demonstrated.

Eastern Area

Farther to the east, from the New Boston Road Thrust to the Bird Mountain Thrust, large scale sliding and slicing pervades the structural pattern giving rise to linear outcrop belts. Macroscopic F_1 hinges are poorly defined, for example, the Indian River-Poultney contact in the central eastern part of this area. Mesoscopic F_1 folds are tight to isoclinal of similar-type, with well developed slaty cleavage axial surface to them. Locally, polyclinal folds are well developed, particularly in Poultney, thin quartz arenites. Bedding and cleavage tend to be parallel supporting the inference that folding is regionally tight to isoclinal. Mesoscopic pre- to syn-S_1 thrust faults are recognized and tend to dip slightly less steeply east than S_1, and locally they are demonstrably openly folded by F_1. Macroscopic, large scale tectonic slides have clipped off primarily hinges and short limbs of the major F_1 folds. Thrusting occurred syn-to late D_1 (see below). Mesoscopic D_2 structures are common, but always distinctly secondary to D_1. F_2 folds are open to angular, gently plunging, low amplitude (less than 1 m), short wavelength (less than 2-3 m) with an associated steeply east-dipping, spaced crenulation cleavage. Conjugate crenulation cleavages are observed, but only rarely. Brecciated and granulated zones are present, but do not seem to be significant structures. Late, small northwest trending steep kink zones are the last deformation observed in this area.

EVIDENCE FOR THRUSTING

As a result of the poor outcrop characteristics of thrust fault related rocks in this and most regions of the Taconics, the presence of thrust faults is inferred and supported by the following observations. The most conclusive are presented first.

1) Pawlet greywackes younging directly into older lithostratigraphic units without an intervening oppositely facing limb.

2) Thin, discontinuously exposed unbedded Pawlet greywackes often only a few meters wide, surrounded by older lithostratigraphic units.

3) Complexly interdigitated, distinctive lithologies from two or more lithostratigraphic units, in a zone from two to approximately ten meters thick.

4) Along strike loss of a limb of a large structure.

5) Along strike loss of lithostratigraphic units.

6) Extreme thickness variations and loss of units across repeating sequences.

MESOSCOPIC CHARACTER OF THRUST FAULTS

Thrust zones vary in thickness from 10 to greater than 400 cm and are characterized by an argillite matrix within which slivers, often with a 'shredded' appearance, of greywackes or quartz arenite can be found (Stop 6). The matrix argillites possess a moderately to well developed slaty cleavage, often with a more phyllitic appearance than surrounding slates. The slaty cleavage within the fault zones tends to be parallel or slightly less steeply east-dipping than the regional slaty cleavage. The slivers of greywacke and quartz arenite occur as disrupted and probably transposed lensoid layers with a distinct planar preferred orientation parallel to the slaty cleavage of the matrix. In some instances a preferred linear orientation can be demonstrated that plunges down the dip of the cleavage. No reclined folds have been observed that are unequivocably associated with thrusting. It is important to note that the mesoscopic evidence for thrusting does not involve brittle-looking fault breccias or mineralized zones, the lack of which are commonly cited as evidence against large-scale thrusting within the lower Taconics. All mesoscopic and macroscopic evidence points to a 'hard rock' not soft rock origin of these thrust faults.

MESOSCOPIC AND MICROSCOPIC FABRIC ELEMENTS

The primary meso- and microscopic tectonic fabric element in these rocks is the S_1 slaty and spaced cleavage. The nature of this S_1 foliation varies continuously from a very fine, well developed slaty cleavage in fine argillites, such as the Mettawee, Indian River and slates of the Pawlet, to a spaced cleavage in silty argillites Poultney Bomoseen and finer grained wackes of the Bomoseen and Pawlet Formations. S_1 is not demonstrable in most of the medium to coarse grained quartz arenites, although strained quartz is often observed. Cleavage refraction is well developed where suitable grain size and compositional variations occur. The S_1 foliation is defined by the planar preferred orientation of clay minerals, chlorites, white micas and elongate quartz and carbonate grains. The development of the chlorites within the S_1 foliation suggests that low grade metamorphism occurred synchronously with D_1 as has been suggested by others (Zen, 1961, 1960; Potter, 1972).

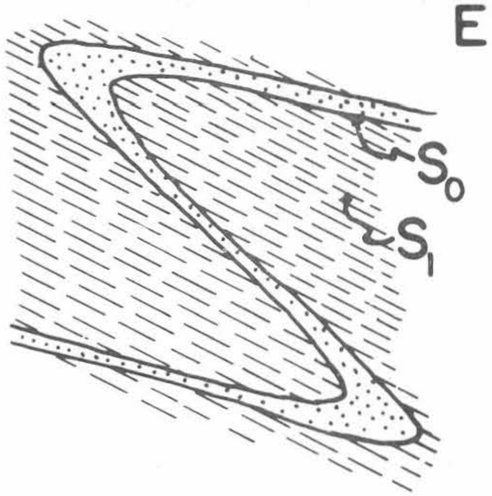
Wood (1973, 1974) has done finite strain analysis in fine grained, quarried purple slates of the Taconics using ellipsoidal reduction spots as finite strain markers. His analysis indicates that the slates have enjoyed approximately 75% shortening perpendicular to slaty cleavage (Z or λ_3 direction), and simultaneously, approximately 150% and 50% extension approximately perpendicular and parallel to F_1 hinge lines (X or λ_1 and Y or λ_2) within the plane of S_1. Slaty cleavage was found to lie precisely within the plane of maximum finite shortening. The down-dip lineation, commonly referred to as the "grain" was found to be parallel to the direction of maximum finite extension (Wood, 1973, 1974; Wright, 1970).

The crenulation cleavage (S_2) axial surface to F_2 folds is a spaced, locally developed fabric. The spacing of the crenulation cleavage appears to be correlated with two factors, one, the tightness of F_2 folds and secondly, with the grain size of the affected rocks. Spacing varies from 1 to 10 mm. No new minerals appear to be associated with the crenulation cleavage, though our observations are not detailed enough to state this unequivocably. It is important to recognize that the presence of a second, crenulation cleavage is not necessarily associated with or indicative of a second, wholly separate and later, in this case, Acadian deformation. This is well demonstrated in other regions where a second tectonic event is unrecognized, yet a second cleavage, often coaxially associated with the first is observed. These 'second' generation structures appear to be relatively late readjustments of the rocks, with slaty cleavage to continuing progressive deformation and strain (W.D. Means, 1979, pers. comm.).

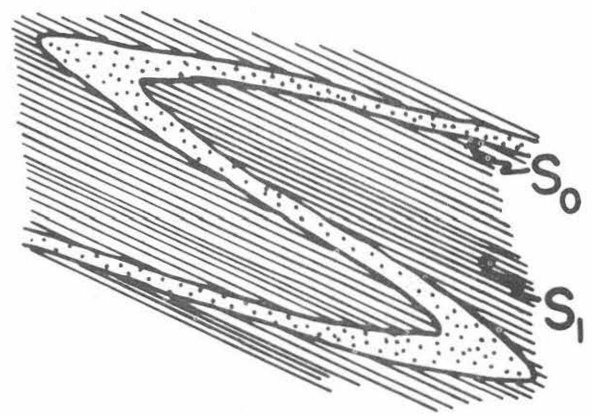
Figure 3 diagramatically illustrates the envisioned structural evolution.

Figure 3.

SCHEMATIC STRUCTURAL EVOLUTION

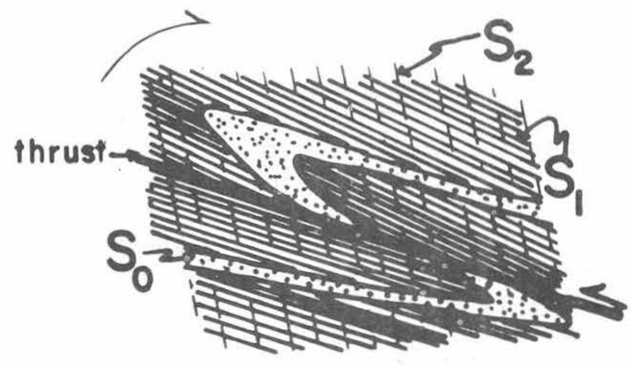


INITIAL ASYMMETRIC FOLDING (F_1) OF BEDDING (S_0). INCIPIENT AXIAL SURFACE CLEAVAGE (S_1) DEVELOPMENT.



TIGHTENING OF F_1 FOLDS.

S_1 SLATY CLEAVAGE WELL DEVELOPED.



ROTATION OF F_1 AND S_1, THRUSTING OCCURS ON SHORT LIMBS AND IN HINGE REGIONS OF F_1 FOLDS. DEVELOPMENT OF SMALL F_2 FOLDS WITH SPACED AXIAL SURFACE CRENULATION CLEAVAGE (S_2).

D.B.R. (2/79)

TECTONICS

Plate tectonic corollary models for the emplacement of the allochthonous continental rise (Taconics) sediments onto the autochthonous and parautochthonous continental shelf ("synclinorium") sequence are of two varieties. The earliest model, proposed by Bird and Dewey (1970, 1975) and reiterated by others suggests that the initiation of a west-dipping subduction zone led to the following related events.

(1) Development of an Andean-type volcanic arc in the outer continental rise region (Ammonoosuc volcanics), (2) uplift of the continental rise terrain to the west of the volcanic arc, (3) collapse of the continental shelf and development of the 'Normanskill Exogeosyncline,' (4) soft-sediment gravity sliding of the low Taconics in the Middle Ordovician and (5) progressive emplacement of the high Taconics by 'hard-rock' thrusting during late Middle and Late Ordovician. According to this model the Taconics were assembled in their present location and subsequently folded with the underlying shelf sequence in the Middlebury Synclinorium, as first suggested by Zen (1961).

Chapple (1973, 1979) and Rowley and Delano (1979) proposed a second type of plate tectonic corollary model. They suggest that the emplacement of the Taconic Allochthon resulted from partial subduction of the Atlantic-type North American continental margin in an east-dipping subduction zone. Chapple (1973) argued that the post-Chazy history of the continental shelf, involving uplift, erosion and development of a karst surface, followed by block faulting and rapid subsidence, accords well with the trajectory of crust entering subduction zones. Chapple (1973) followed previous models by suggesting that the low Taconics were emplaced as soft-sediment gravity slides prior to emplacement of the high Taconics slices by subduction accretion 'hard-rock' thrusts. Rowley and Delano (1979), however, argued that structural evidence from within the low Taconics does not support a soft-sediment gravity slide origin, but instead indicates emplacement by 'hard-rock' thrusts. Rowley and Delano (1979) and Chapple (1979) propose that most of the deformation associated with D_1 occurred during subduction accretion tectonics as the accretionary prism of the island arc overrode the continental rise. The allochthonous continental rise sediments were therefore already assembled as a series of thrust packages prior to overriding of the outer continental shelf edge. Independently, Rowley and Kidd (in prep.) and Chapple (1979) proposed that continuing convergence between the two lithospheric plates resulted in: (1) overriding of the shelf edge by the Allochthon, as a composite thrust sheet, not as a detached slide block (a suggestion first made by J. Sakes (1971)), incorporation of carbonates slices occurred along the base of the Allochthon (e.g., Dorset Mountain); (2) thin-skinned shortening, by folding and thrusting within the carbonates (i.e., Sudbury Nappe and early folding of the Middlebury 'Synclinorium' (Voight, 1965, 1972)), (3) late imbrication and open folding (D_2) of the Taconic Allochthon to form the presently defined major slice boundaries, as demonstrated by the presence of thin carbonate slivers and locally Grenville basement (e.g., Ghent Block, Ratcliffe and Bahrami, 1976) along all major slice boundaries, and (4) westward-directed thrusting involving crystalline basement, of the Berkshire Massif (Ratcliffe, 1965, 1969, 1977) and the Green Mountains (maps of Hewitt, 1961; and MacFayden, 1956); these thrusts progressed outward to the Champlain Thrust and other thrusts of the shelf carbonate sequence in front of and along-strike with the edge of the Allochthon (Coney, <u>et al</u>., 1972; Fisher in Rodgers and Fisher, 1969).

A major difference between the models of Bird and Dewey (1970, 1975) and Chapple (1973, 1979) and Rowley and Kidd (this publ. and in prep.) is the presence or absence of a suture between the volcanic arc (Ammonoosuc) and the eastern edge of the Atlantic-type North American continental margin. Bird and Dewey accepted the 'dogma' that a continuous Cambrian(?) to Medial Ordovician, time-stratigraphic, "eugeosynclinal" sequence is present in the Eastern Vermont sequence, equivalent to the Taconic sequence and thus did not place a suture between the arc and continental margin. The second model requires a suture within the Eastern Vermont sequence. We prefer to place the suture along the Vermont Ultramafic belt, probably to the east of the Chester Dome in the Connecticut River "Synclinorium." This requires that at least in parts of the Eastern Vermont sequence where ultramafics are present, a continuous time-stratigraphic sequence does not (Gregg, 1975; Nisbet, 1976) and cannot exist (as pointed out in Burke, Dewey and Kidd, 1976).

The model proposed here requires that the initial stacking sequence of Taconic rocks progress from east (oldest-structurally highest) to west (youngest-structurally lowest). This is opposite to that commonly described for the Taconics (Zen, 1967, 1972). Palinspastic reconstructions of litho-tectonic assemblages in mountain belts (Dewey, 1976, in press); foreland fold-thrust belts (Elliot, 1976, Chapple, 1978) and accretionary prisms (Seeley, et al., 1974) indicate that the stacking sequence suggested here is most common. Examples where the opposite stacking sequence, i.e., the one commonly attributed to the Taconics are rare or do not exist (Dewey, 1979, pers. comm.).

Figure 4 illustrates a schematic evolutionary for the emplacement of the Allochthon as described above.

FIGURE CAPTION FOR FIGURE 4 . Schematic Evolution of the Taconic Orogeny

Lithologies:

(1) Oceanic crust and mantle. Ophiolite.
(2) Continental crust. Everything shown is Grenville age.
(3) Accretionary prism proper. Pelitic rocks associated with polyphase deformed, tectonized pelitic rocks with associated wackes, and exotic lenses of amphibolite, pillow basalts, gabbros, and serpentinized ultramafics.
(4) Taconic rocks. Continental rise-slope sediments.
(5) Shelf sequence. Basal clastics, both arkosic sediments and sheet sands and overlying thick predominantly carbonate sequence.
(6) Black argillites, shales and slates deposited on the shelf. Correlative and equivalent black slates are present within the Taconic sequence, but are not differentiated on the figure. Black argillites are younger than medial N. gracilis zone.

Sections:

(A) Atlantic-type continental margin of eastern North America during early N. gracilis time, the first evidence of a volcanic arc to the east is seen in thin tuff bands in the Indian River Fm. and then volcanogenic cherts (Mount Merino Fm.).

(B) Trajectory of oceanic lithosphere entering a subduction zone. Possibly also applicable to continental lithosphere. On the bulge and to the east crust is in an extensional regime. If this trajectory is applicable it could explain the sub-Balmville unconformity and the so-called Tinmouth orogeny (Chapple, 1973)

(C) Taconic rocks already incorporated in accretionary wedge due to eastward subduction of the Atlantic-type continental margin. Deposition of black argillites on the rapidly subsiding eastern and central parts of the continental shelf. Continued carbonate deposition to the west. Approximately medial to late N. gracilis time.

(D) Continued subduction, now involving underthrusting of continental basement and shelf. Peeling of cover sequence from basement along deeper parts of the overthrusting wedge (Sudbury Nappe, base of Dorset Mountain). Folding of early thrust surfaces as active thrust surface migrates westward and considerably less rapidly downward. Approximately late N. gracilus zone time.

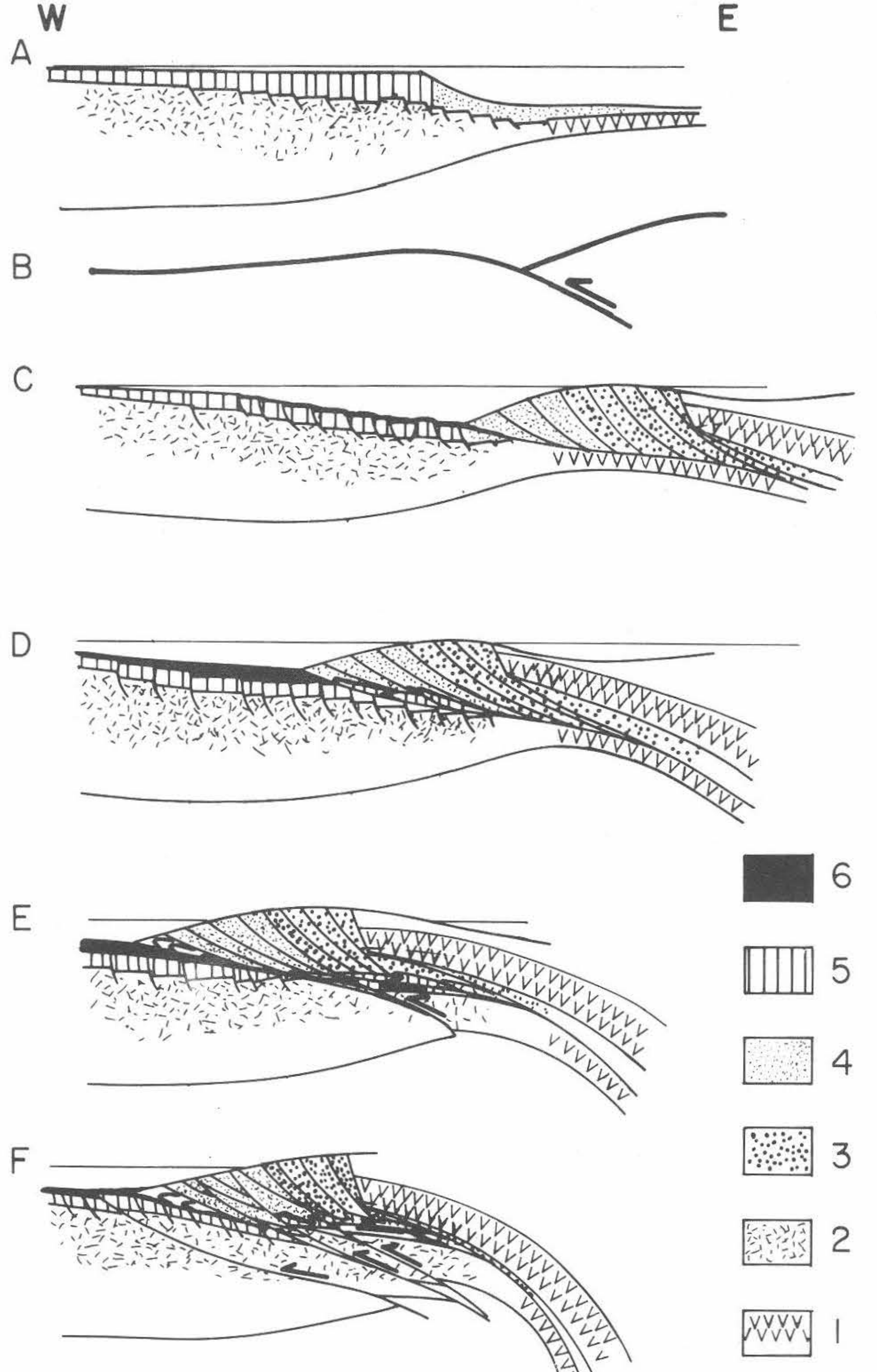
(E) Continued convergence of lithospheric plates, shortening within the continental crust (due to bouyancy effect of attempting to subduct light. bouyant continental crust) gives rise to initial imbrication of the continental crust. Subduction rates lessens as more continental crust is underthrust. Melanging of parautochthonous Austin Glen in front of advancing composite thrust wedge. Approximately C. americanus zone time.

(F) Progressive westward imbrication of the basement along listric thrust surfaces. Imbrication of the basement results in late imbrication of the overlying shelf and allochthonous Taconic sequences. Final emplacement of the Allochthon. Approximately O. ruedemanni zone time. Basement thrusts correspond to the Hoosic Thrust (Norton, 1967, 1976), Beartown Mountain Thrust Ratcliffe (1969), Champlain and/or Orwell Thrust (Coney, et al., 1972; Zen, 1972) in front of and to the north of the Allocthon.

Presently defined Taconic slice boundaries result from thrusting illustrated in sections D through F of Figure 4.

Figure 4.

Schematic Tectonic Evolution of the Taconic Orogeny



D.B.R. (5/79)

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Instructions to Participants

Participants must bring their own pack lunch. There will be no opportunity to obtain it during the trip. This trip involves 1 1/4 hours travel before the first stop but compensates for that by having little distance between stops in the field area. Good outcrops in the Taconics are rare -- PLEASE DO NOT HAMMER OR DEFACE OR OTHERWISE DESTROY OUTCROPS -- Please take samples only if you will be doing bona fide research with them.

ROAD LOG

Mileage cumulative	interval	
0.0		RPI Houston Field House. Go north on Burdett Avenue.
	(0.4)	
0.4		Turn left at light. Proceed W on Route 7 and follow signs for Rte. 40N through 2 lights.
	(0.5)	
0.9		At third light turn right on 40N and stay on it to its end 54 miles away where it meets Route 22.
	(3.4)	
4.3		Sharp right at light followed by sharp left at next light. Stay on 40 N. Route 40 follows closely the western edge of the Taconic Allochthon Lowlands to the west are mostly underlain by autochthonous and parautochthonous shales and lesser greywackes (Normanskill/Snake Hill).
24-25		Road cuts on right of deformed (shelf) carbonates that are at the sole of the Taconic allochthon.
27.4		Turn right following 40N and 29E combined through Middle Falls.
	(1.0)	
28.4		Turn left following 40 N. Road runs within the Taconic allochthon for the next 9 miles
	(9.6)	
38.0		Take sharp right in Argyle. Remain on 40 N.
	(10.3)	
48.3		Passing the village of Hartford and junction with Rte. 149.
	(7.0)	
55.3		End of Rte. 40. Junction with Rte. 22.

**Optional stops: (a) 1.5 to 2.5 miles west of the junction of 22 and 40--Road cuts show gently east-dipping autochthonous carbonates whose unfolded, undeformed structural condition contrasts markedly with that of rocks in the Taconic Allochthon only 2 miles to the east.

(b) 1.2 miles north of the junction - go straight across 22 from Rte. 40 and follow dirt road to dirt parking area on right above Metawee River.

Go over stile and follow path down slope to river. Gently east-dipping (10-15°) carbonates (autochthonous or parautochthonous) extend ot north along west bank of river and also illustrate little deformed nature of platform rocks, in this case less than 1/2 mile from the western edge of the Allochthon. Dark shales on east bank have lenticular cleavage and may be part of mélange terrane bordering Taconic Allochthon.

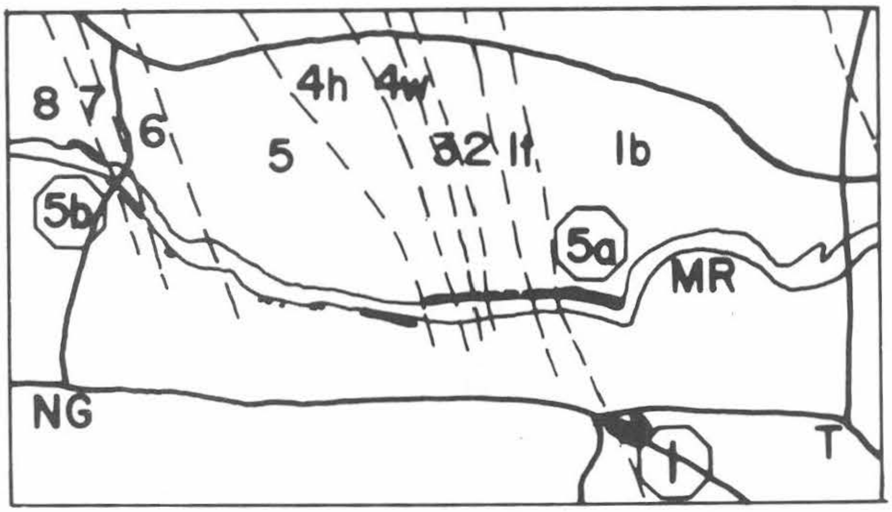
Mileage

cumulative	interval	
55.3		Junction of 40 and 22. Turn right onto Rte. 22E. Pass through the village of North Granville. Immediately after next large bend, to right.
	(1.8)	
57.1		Take left fork off Rte. 22 onto County route 12 and stop. Park at roadside. Walk east along Rte. 22 (N side) past road cut and angle left down to stream at east end of cut. PLEASE DO NOT WANDER IN THE ROAD OR OBSTRUCT TRAFFIC - IT TRAVELS AT LETHAL SPEEDS HERE.
		<u>Stop 1</u> - Bomoseen Formation and part of Truthville slate. The lowest lithounits exposed in the area. The glacially-polished outcrop by the stream and the roadcut expose typical lithology in atypically good outcrop.
57.1		Continue on county route 12.
	(0.3)	
57.4		Turn left in hamlet of Truthville
	(0.2)	
57.6		Cross Mettawee River and go straight across at crossroads onto Truthville Road.
	(1.1)	
58.7		Turn right onto DeKalb Road.
	(0.8)	
59.5		Turn left onto Holcombville Road (dirt)
	(0.7)	
60.2		Entrance to quarry on left - pull in and stop.
		<u>Stop 2</u> - Mettawee Slate Formation
	(0.6)	
60.8		Tanner Hill Road on left - continue straight.
	(0.6-0.8)	
61.4-61.6		Browns Pond area (pond is visible from road at site). Turn around and park at side of road.

Mileage		
cumulative	interval	
		Stop 3 - Browns Pond Formation and Metawee Slate Formation.
61.6		Drive south on Holcombville Road, back the way you have just come.
	(0.8)	
62.4		Turn right onto Tanner Hill Road.
	(0.3)	
62.7		Stop 4 - Roadcut on right on hill is the beginning of Stop 4. This stop involves walking along the road for 1.1 miles on the bus-transported trip. For trips with cars, it is better to park first at the top of the hill and walk back; the remainder of the outcrops can be seen in stages moving the vehicles part of the way each time.
	(0.2)	
62.9		Contact of green Poultney Formation with red Indian River Formation. Road runs N-S.
	(0.2)	
63.1		Road curves to left - outcrop of Mt. Merino cherts on right.
	(0.2)	
63.3		Road curves to right - outcrop of Mt. Merino cherts on right at top of hill
	(0.1)	
63.4		Road runs N-S. Indian River red slates exposed on left.
	(0.2)	
63.6		Road turns to W - Poultney Formation outcrop on left reported fossiliferous.
	(0.2)	
63.8		Junction with Truthville Road (dirt). Turn left and drive south on it.
	(1.0)	
64.8		Pass dirt track to left which leads to **old Indian River slate quarries (permission required). Follow track, taking left fork when choice encountered. After fork, park when track turns sharply S after tall ridge outcrop (of Mt. Merino cherts) in trees on right (south). Head NE from track; south end of quarry should be encountered after 30 metres. Tight F_1 folds well-displayed in south wall of quarry are prominent because of pale-weathering siliceous tuff beds (meta-bentonites) up to 10 cm thick. DO NOT HAMMER, PLEASE.
65.9		Junction with DeKalb Road - continue south - road becomes paved.
	(1.1)	
67.0		Junction at stop sign with Middleton Road. Turn right.
	(0.8)	
67.8		Junction with road to North Granville. Turn left.

Mileage cumulative	interval	
	(0.1)	
67.9		Turn left on dirt track just before old bridge. On bus-transported trip, we will get out here and walk the 0.35 mile to the parking lot. Cars can drive in unless it is very muddy.
	(0.35)	
68.25		Parking lot by Mettawee River. Walk on foot path directly to falls at eastern end of this section. LUNCH STOP. Examine section after lunch.
		Stop 5 - Mettawee River section - Bomoseen through Hatch Hill Formations.
	(0.35)	Return to road by old bridge.
68.6		Turn left, cross bridge (on foot with bus trip; small parking lot for cars on left on south side of bridge). Find foot path down to river on right (west) side of road.
		Stop 5b - Mettawee River section - Indian River through Pawlet Formations.
		Either (in cars) - go south 0.2 mile from bridge, turn left on 22 in North Granville; follow 22 east for ~3 miles to flashing yellow light at intersection with 22A and rejoin road log there.
	(0.1)	
68.7		Or (in bus) - go north to junction with county road 12. Turn right.
	(0.9)	
69.6		Turn right at crossroads. Cross Mettawee River bridge to Truthville.
	(0.2)	
69.8		T-junction, turn left.
	(0.3)	
70.1		Stop sign at junction with 22. Turn left.
	(2.2)	
72.3		Turn left at junction onto Rte. 22A at flashing yellow light.
	(0.4)	
72.7		Turn right across green bridge.
	(0.05)	
72.75		Turn left onto Fox Road.
	(0.25)	
73.0		Cross D&H railroad.
	(0.5)	
73.5		Turn left onto Stoddard Road. Park on left just before pond. ASK PERMISSION at farmhouse on corner.
		Stop 6 - Thrust contact between Poultney and Pawlet Formations.
	-(1.3)	Continue north on Stoddard Road.
74.8		Stop just beyond white house on right at top of hill. Ask permission at white house. See sketch map of outcrops in stop description.

Mileage cumulative	interval	
		Stop 7 - Complex geology due to thrusting involving Poultney through Pawlet Formations - this stop may be omitted if time is short.
	(0.2)	
75.0		Intersection with New Boston Road. Turn left
	(1.5)	
76.5		Intersection with Vermont State Route 31. Turn left
	(0.1)	
76.6		Turn right on minor paved road.
	(0.3)	
76.9		Turn left at T junction.
	(0.7)	
77.6		Stop just before white house on left. Park at roadside. Dirt track making 150° angle with road on right. Stop 8 - Walk up this dirt track for ~0.3 mile past outcrops of Pawlet Fm. to contact with Poultney Fm. Follow contact north into woods for ~0.1 mile. Return to vehicle(s).
	(0.5)	
78.1		Junction with Vt. Route 31. If going to Vermont, New Hampshire, etc., turn right and go north on Vt. Rte. 31 to Poultney, follow signs for Rte. 22A, follow this to Fair Haven and junction with Route 4. If returning to Capital District or points W, S and SE - Turn left. Go south on Vt. Rte. 31.
	(3.9)	
82.0		Turn right onto Fox Road at Vermont-NY border (this intersection is easily missed - if you do, go on into Granville and follow signs or ask for Rte. 22. Go N + W on 22 to rejoin the road log).
	(1.7)	
83.7		Cross D&H railroad.
	(0.2)	
83.9		Stop sign - turn right - cross bridge over Metawee River.
	(0.1)	
84.0		Turn left at stop sign onto 22A
	(0.4)	
84.4		Turn right onto Route 22
	(4.5)	
88.9		Turn left at junction with Route 40 and follow it back to Troy. (For those wishing to return to anywhere but Troy, continue west on 22 to its junction with Rte. 4. Turn left and go south about 4 miles on Rte. 4 into Fort Ann. Turn right in Fort Ann onto Rte. 149 and follow it to Rte. 9 in Lake George. Turn left on Rte. 9 and follow signs for Interstate 87 (North for Quebec, south for everywhere else.)



[Stop maps 1,2,3,5, 6, approximate scale 1:12,000, Stop 4; approximately 1:14,000. North at top, except for Stop 8. Black spots are known outcrop locations (not all of which will be visited.)]

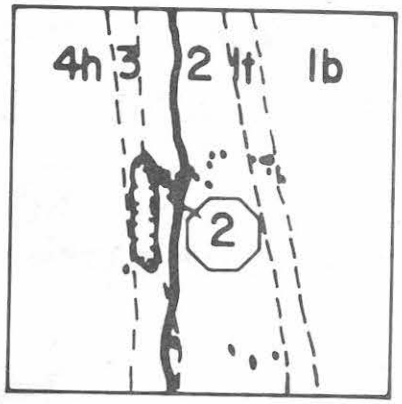
STOP 1: Roadcut and stream outcrop on NY Rte. 22 near Truthville - parts of Bomoseen and Truthville Formations. BEWARE OF TRAFFIC!

This outcrop shows typical Bomoseen lithologies in atypically clean outcrop. The dominant rock type is a poorly and lenticularly-cleaved green silty wacke. Where a polished surface is seen, as in the stream outcrop, this lithology is in part internally finely laminated and bedded, although it is not possible to detect this in the road cut or weathered outcrops. A subordinate lithology, which is almost always present in outcrops of Bomoseen, consists of rather diffusely bounded thin (cm) beds of fine sandy green quartzite. These always contain narrow extension gashes perpendicular to bedding.

The etched polished surface of the stream outcrop shows the fine bedding and some cross-lamination in the wacke, disturbed in places by sediment loading/ injection structures. Folds in this outcrop are probably due originally to soft sediment deformation and slumping, as is the disruption of the quartzites seen here and locally in the northern roadcut.

At the western end of both roadcuts, about 2 meters of thicker and well-defined planar-bedded green medium-grained quartzites from a contrasting member, which would be identified as "Zion Hill quartzite." It is not common in this area. The Bomoseen is structurally underlain and stratigraphically overlain at the western end of the outcrop by green silty micaceous slates of the Truthville Formation.

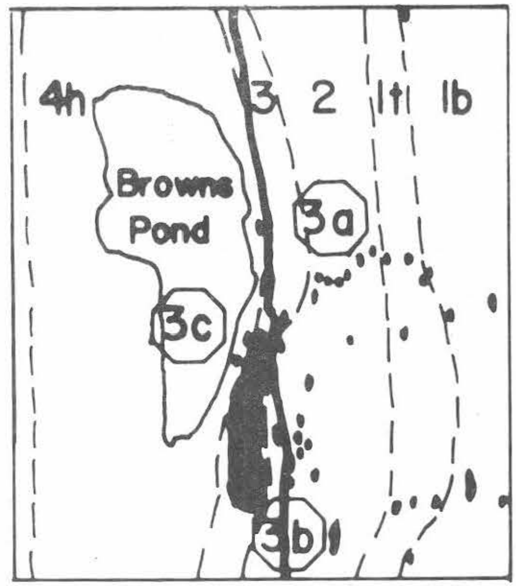
The gently to moderately east-dipping bedding and near-parallel slaty cleavage are characteristic of almost all outcrops in the Giddings Brook Slice, and imply the presence of very tight folds. A mesoscopic, tight antiformal fold with a gently south-plunging hinge is seen in the center of the northern cut. Although this example may owe its existence to disorientation of layering during soft-sediment deformation, its geometry and orientation are representative of the larger-scale folds. Bedding/cleavage orientations at the Truthville Slate-Bomoseen contact in the southern cut imply (correctly) that the succession is inverted in this outcrop. Many post-cleavage, slickensided faults with small offsets are seen.



STOP 2: Quarry adjacent to Holcombville Road - Mettawee Slate Formation and contacts.

The basal contact of the Mettawee Slate Formation is exposed on the east side of this quarry (the strata are inverted) next to the track leading to the waters' edge (bear slightly left past the ruined shed). The stratigraphically lowest beds exposed consist of 1 to 5 cm nodular micritic limestones in dark grey slate, assigned to the top of the Browns Pond Formation, as is the single 30 cm bed of laminated calcarenite, which can be seen in the northwall of the quarry in a thicker development. The rest of the rocks exposed in the quarry, stratigraphically above this calcarenite are assigned to the Mettawee Slate Formation (sensu stricto - see stratigraphic discussion). Some diagenetically dissolved nodular micritic limestones occur in the basal few meters of green slate, together with a limestone breccia less than a meter thick which is only exposed along the base of the east wall of the quarry (water level usually prevents easy access to this bed). Several meters of purple slate with diffuse boundaries occur within green slate on the north wall of the quarry (we will not examine this; purple slate may be seen in loose pieces near the quarry). The rock then turns from green to shades of grey slate, exposed on the west wall.

Fissile, sooty, black, pyritiferous slate of the basal Hatch Hill Formation lie not more than 5 meters, stratigraphically above (structurally below) this porcellanous gray slate. At least two beds of coarse dolomitic arenite occur not more than 10 m above the slate in the west wall of the quarry. These exposures which will not be visited on the formal field trip,** may be found by walking south on Holcombville Road from the quarry entrance to the dirt-track that runs around the south end of the quarry. Follow this track until it comes to an open space in front of a large slate heap. Outcrops are in the track and to the west in the bushes.



STOP 3: Browns Pond Formation and Mettawee Slate Formation at Browns Pond

Stop at or before the place where Browns Pond comes closest to the road. At this point a dirt track can be found leading east from Holcombville Road. Turn vehicles around, park at side of road, and follow the trace for:

STOP 3A: - Lower part of Browns Pond Formation in the type area.

10 m from road along track there is a small outcrop of buff-weathering green Mettawee Slate in the bed of the track. Track turns left and up slope. In bushes on right, thin bedded calcarenites and black slates outcrop that are much better exposed in Stop 3b (below). Track turns right; passing by cabin small outcrops also of dark calcareous slate and thin-bedded limestone are seen. Track passes small pond/swamp on left and turns right (to S). At bend in track is outcrop and loose pieces of distinctive grey-black wacke (Black Patch Grit lithology) containing large rounded quartz grains, and dark slate rip-up clasts. Track turns left (to E) and after 20 m. a low ridge occurs. To left (N) of track, exposure of about 7 m thick homogenous pale-weathering coarse quartzite (Mudd Pond Quartzite lithology). Grey-black quartz wacke found at base of outcrop. Rejoin track, finding more wacke in outcrop west of the track just north of where it turns from NE to N-trending opposite a cabin down the slope. North of the cabin, below the track, another thick quartzite is exposed. Black slate can be found in poor exposures stratigraphically below this second quartzite which we will not visit. Beyond the slope is a swamp-filled narrow valley on both sides of which Truthville slate is exposed and beyond which Bomoseen Formation is encountered. Return to Holcombville Road.

Mudd Pond Quartzite lithology may occur in 2 large beds (here-rare), one (e.g., Stop 5), or, more commonly, is not present. These highly lenticular discontinuous quartzites probably occupy channels.

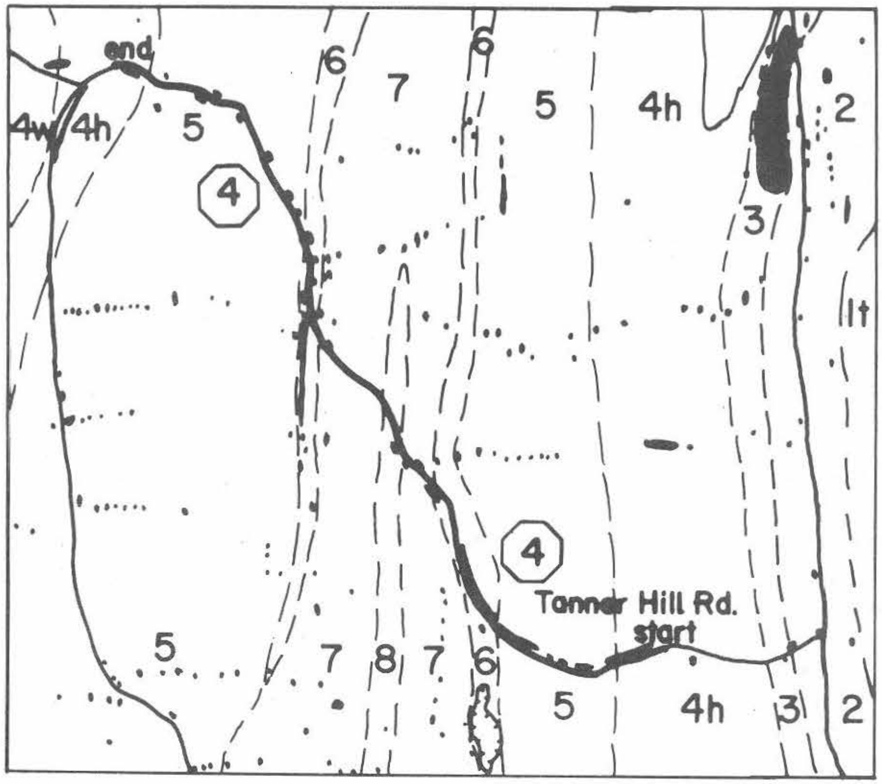
Black Patch Grit lithology is more often present than Mudd Pond, and is a better lithostratigraphic marker (see Stratigraphic discussion). Its extreme mixture of grain sizes, rip-up clasts and, locally, included pebbles and boulders, suggest a slump to debris flow origin.

STOP 3B: - Upper part of Browns Pond Formation in the type area.

From dirt track, walk south along Holcombville Road to first roadcut on left (east) side of road on small rise. Thin-bedded, dolomitic, laminated and cross-laminated, dolomitic calcarenite and calcisiltite are interbedded with black calcareous slate. Cross-lamination demonstrates inversion of these beds. This lithologic assemblage, although prominent in this local area, is not common in the Browns Pond Formation.

Walk north on the road to the roadcut on the western side. This mostly consists of a distinctive limestone breccia with close-pakced homogenous grey limestone clasts of irregular but compact shape, set in an orange weathering dolomite-rich matrix, containing some quartz grains, that occupies a small proportion of the whole rock. Probable crack-injection relationships between matrix and clasts can be seen in places. Contacts of this breccia with areas of dark fine-grained thin bedded limestone and calcareous slate are seen, with the bedding truncated and no convincing signs of faulting. At the north end of the outcrop a possible block of breccia 2 m. across rests within bedded material. In other places the bedded material seems to be in large clasts within or perhaps forming a matrix to large blocks of the breccia. Thus there seems to be evidence of mutual breakup of breccia and bedded limestones; however, there is no evidence that the breccia itself was formed in situ. Instead we suggest that it was deposited as consolidated blocks. Theokritoff (1964) reports fossils from this outcrop. This distinctive breccia is only seen, when it occurs, very close to the top of the Browns Pond Formation. A rather similar breccia, seen rarely in the overlying Mettawee Slate Fm. is in a much thinner bed and has a significantly larger proportion of matrix. Debris flow deposits with carbonate blocks and slaty matrix are more common than this type in the Browns Pond Formation and will be seen at Stop 5.

STOP 3C: - Go through gate in fence on the western side of the road, north of the roadcut just examined. Walk west to shore of pond across outcrops of distinctively buff-weathering green slate of the Mettawee Slate Formation. These are stratigraphically above the carbonates of the Browns Pond Formation, just seen. At the pond shore, a ledge-like outcrop exposes sooty black pyritiferous slate and some beds of laminated calcarenite and calcisiltite. Inverted cross-lamination can be seen. At the north end of the ledge, a 10 cm bed of pebbly limestone breccia is seen containing a minor amount of dark phosphatic pebbles. This green-black slate change is the upper of the two black-green boundaries in the area and correlates with the one seen in other areas of the Taconics. The locally developed limestone and black slate assemblage can be mapped as West Castleton; however, it is perhaps more easily mapped as a basal member of the Hatch Hill Formation. The limestones in this outcrop, and in 3b are probably turbidites, mostly representing the D and E horizons.



STOP 4: - Hatch Hill, Poultney, Indian River, Mt. Merino and Pawlet Formations repeated across syncline-Tanner Hill Road.

This stop entails walking for 1.1 miles west along Tanner Hill Road. Start at roadcut on north side on slope of hill. Thin to thick (1cm-3 m) bedded dolomitic sandstone and quartzite beds; distinctive orange deep weathering rottenstones, interbedded with fissile black pyritiferous slate. Thickest beds are internally massive, very close sandstones and contain rip-ups of finer dolomitic sandstone. Thinner beds are finer grained, parallel laminated, uncommonly cross-laminated and only some show grading. In this outcrop, one side of a channel (proving inversion of this section) can be seen at the base of the thickest bed. The dolomite in these sands (10-50%) was originally clastic although now recrystallized.

The thick beds are either grain flow deposits or traction deposits at the base of large turbidity flows; in either case they fill channels. The thinner laminated beds are more problematic; those showing grading are probably turbidites, but the laminated beds with sharp tops and bottoms are harder to interpret. They are probably too coarse to represent deposits on levées of submarine turbidite channels.

The top of the Hatch Hill Formation at this locality, proceeding up the hill, consists mostly of black slate with a few very rotten weathering sandstones. If limestones occurred in this black slate, as they do in places, they are traditionally (Theokritoff, 1964; Potter, 1972) placed as a basal member of the Poultney -- another instance where the lithostratigraphy might usefully be changed. However, the resulting confusion might be worse than the existing kind.

Just west of the small borrow pit on the north side of the road, the low outcrop shows a rapid gradation from black to green slate with thin subordinate dark slate laminae. This is the base of the Poultney Formation. Opposite the quarry entrance, thin (mm) silty quartzite laminar beds are seen; these are characteristic of the Poultney and may be seen in the low, more or less continuous outcrop on the north side of the road, in varying abundance, throughout this formation. Their universally silty grain size, fine parallel and lesser cross laminations, the absence of associated coarser quartz-rich sands and the abundant indications of burrowing in the associated slightly silty slates, (particularly well shown near the top of this section), are suggestive evidence that these silty quartzites were deposited by deep contour currents and that they are contourites.

By a track leading off the road to the north a 1 m. section of maroon slate is exposed and two more sections containing maroon slate, one 5 m thick, are exposed to the west, up the hill. This maroon horizon can be traced locally to the north but is not found elsewhere in the area and is regarded as rare. The color of the slate is somewhat different and moderately distinguishable from the purplish Mettawee slate below and the red Indian River slate above.

In the whole of the section thus far up to the Indian River Formation contact, bedding is sensibly parallel with cleavage, reflecting the tightness of the large-scale folds.

The Indian River Slate Formation follows across a 5 m thick zone of interlayered red and green slate. The sea (blue) green porcellanous slate of the interlayered zone contrasts with the olive-green and silty nature of the Poultney slate and sea-green slate of this type is always placed with the Indian River, since red slates within the Indian River can be seen elsewhere to alter to this type. A good illustration of this may be seen at the western contact (top) of the Indian River exposed on the west side of the road about 0.2 mile north of the contact with the Poultney Fm., where relic patches of red slate may be seen diffusing into the sea-green slate. Elsewhere the Indian River may in places be altered to this green slate across its entire thickness.

Rare silty quartzite laminae identical to those in the Poultney occur within the lower part of the Indian River. Pale buff-weathering laminae or layers, pale greyish-white on a fresh surface, are siliceous but well-cleaved and interpreted to have been silicic ash beds, now tuffs. These are slightly better developed in the second occurrence of Indian River, 0.5 mile along the road, but the thickest beds (10-15 cm) can only be seen in exposures not readily shown to large groups. The spotty appearance of many cleavage surfaces in the Indian River, as if coarse sand grains are scattered through it, is due to ellipsoidal, microcrystalline quartz aggregates, probably recrystallized radiolaria.

Beddrug-cleavage obliquities reflecting mesoscopic folds are seen locally within this belt of Indian River Fm.

The source of this notably red clay is proposed (Bird & Dewey, 1970) to be terra rossa soils developed on the karst surface that cuts the sub-Black River and Trenton platform carbonates. The soils provided the clays transported out to the continental rise; the rocks do not seem to provide clues to their last agent of transport, which may have been contour currents.

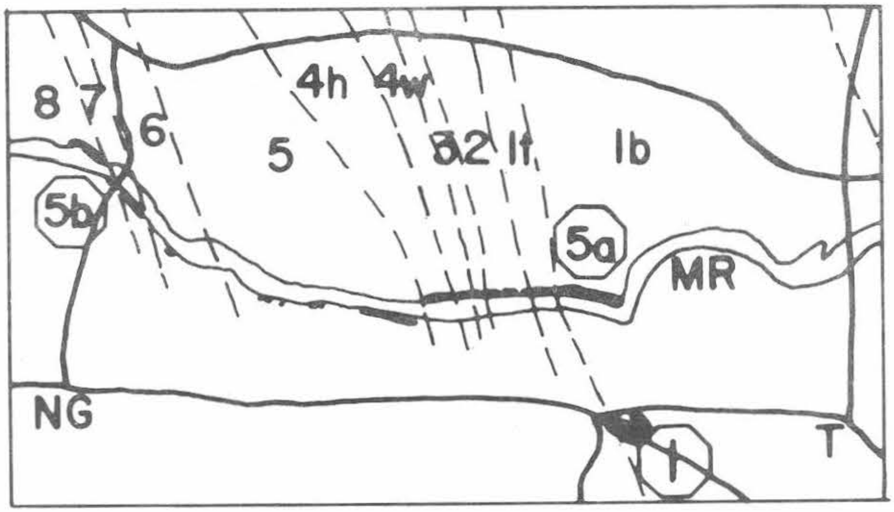
From the north-south road segment along which Indian River is exposed, the road turns west. On the southwest side there is a small outcrop of greyish cherty slates transitional to the Mt. Merino Formation, whose lower member is seen in a cut on the northeast side of the road. Chalky-weathering dark cherts 1-5 cm thick are interbedded with dark grey and black slates and cherty slates. The upper member of the Mt. Merino Fm. is not seen here or elsewhere on this trip; it consists of a sooty black slate that is commonly graptolite-bearing (Zones 11 and 12 of Berry). The two members can be shown to be a facies of one another, with the variable being the abundance or lack of chert.

To the west of this outcrop, where the road turns back to the north, a small excavated outcrop to the west and southwest of the road exposes fine silty greywackes of the basal Pawlet Formation. A fine development of a spaced cleavage oblique to bedding and bedding-parallel parting produces a well developed pencil-slate.

North and west along the road, the major synclinal axis is crossed and then the stratigraphy is repeated in reverse order. At the top of a gentle hill, an outcrop of the cherts of the Mt. Merino Fm. is seen on the right, followed by red slates of the Indian River down the slope on the left. At the north end of this outcrop the contact with the Poultney Fm. is exposed. Intermittent outcrop of Poultney Fm. occurs as the road turns from N-S to about E-W. Just around this bend, a larger outcrop of Poultney on the left has been reported by Theokritoff (1964) to contain graptolites of Berry's Zone 6. The next outcrop on the left contains black slate and lesser dolomitic arenites of the upper Hatch Hill Formation; Theokritoff (1964) reports dendroid graptolites of Tremadocian age from this cut. More Hatch Hill Fm. outcrop occurs at and south of the intersection with Truthville Road.

All along this road, except locally near the core of the syncline, bedding and cleavage are sensibly parallel and dip 20-40° east. We emphasize that this requires the large-scale folds to be near isoclinal in geometry with axial surfaces dipping at the same attitude as the slaty cleavage.

End of Stop 4.



STOP 5: - Mettawee River section by North Granville - Bomoseen To Pawlet

STOP 5A: - Starting at waterfall where Mettawee River bends sharply north and smaller stream joins it from SE. Get to top of falls by going up the bank and around behind the small cliff, in the woods. Typical Bomoseen lithology of green silty wacke and cm. thick diffusely bounded, green fine-grained quartzites seen beside falls and in cliff. An M-style fold of D_1 generation may be seen at the base of the cliff. Where the cliff curves away from the river into the earth bank, the contact with the Truthville Slate Formation is exposed.

This consists of typical silty mica-spangled olive-green slate: very close to its contact with the Bomoseen, there is a 20 cm thick bed of clean medium-grained quartzite, of Mudd Pond type. Thicker occurrences of Mudd Pond Quartzite in this stratigraphic position exist in several places. A thin lenticular occurrence of green, planar bedded quartzite of "Zion Hill" type is seen in the top of the Bomoseen at the base of the cliff. A few thin (mm) laminae of silty quartzite are present here in the Truthville Slate Fm.

At the first rapids with a large erratic boulder in midstream, the first black-green boundary is exposed, the contact between the Truthville Slate Fm. and the Browns Pond Fm. The slate grades rapidly from green to dark grey and loses its silty nature and mica-flakes. Upward (stratigraphically) there is a debris flow with limestone, laminated micrite and dark slate clasts in a slaty matrix. Above this, at the small promontory, several 30 cm to 4 m thick beds of Mudd Pond-type quartzite occur within dark slate and minor black calcareous wacke. (Black Patch grit lithology). Large load casts can be seen on the base of the quartzite beds and evidence is seen for injection of black slate and wacke into the quartzite. A small fault cuts across the quartzites parallel to the stream.

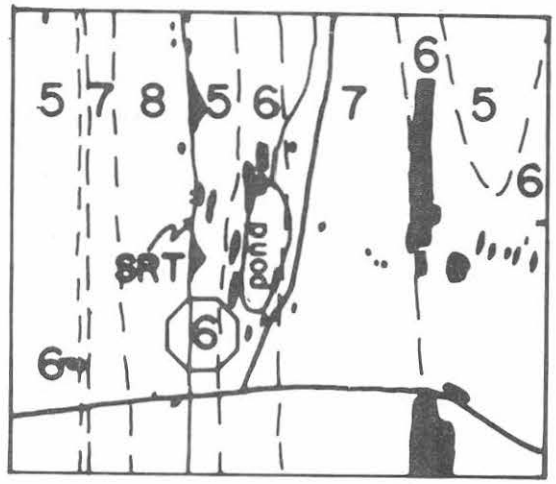
Small quantities of black quartz wacke are found in black slate for a short distance above the quartzites, as at Stop 3a. Here it is not clear if they are pieces in a debris flow or in lenticular beds. In either case their shapes have been much changed by flattening in the slaty cleavage. Very thin bedded calcareous black slate and slaty limestone occur to the west. Opposite a large erratic block on the south bank, there is 2 m. thickness of limestone breccia containing calcarenite to micrite and black slate clasts, in a slaty matrix. Bedded micrites of varying nodularity, 1-10 cm thick, are found in calcareous dark grey to black slate above this breccia. Some thicker micrite lenses in this interval are associated with soft-sediment disruption. At the east end of the stone foundation of an old mill, there is a rapid gradation from dark grey and black to green slates over a meter or two. Micrite, mostly in disconnected nodules, occurs on both sides of this contact in a similar manner to the same one seen at Stop 2, between Browns Pond Fm. and Metawee Slate Formation.

If the water is high, it will be necessary to go up the bank and around the outcrop of green slate under the mill foundation. Some thin calcisiltite and a few calcarenite beds occur in the green slate; no purple slate exists here, as is the case in many places, particularly on the western side of the area. The slate becomes greyish in its upper part and just to the west of a small cave in the outcrop, there is a contact with black slate of the overlying unit.

This might be mapped as West Castleton, since laminated calcarenites, calcisiltites and micrites are exposed within the base of this black slate. However, they form a very thin interval and are succeeded, close to another stone wall foundation, by orange-weathering dolomitic sandstone and quartzite beds typical of the Hatch Hill Formation. These can be found in fairly continuous outcrop, with decreasing dips to about 10°E by the parking lot. The thicker arenite beds here are at about the same stratigraphic level as those seen at the beginning of Stop 4 on Tanner Hill Road.

To the west along the river, there is reasonably good exposure along the south bank, exposing Poultney Formation from a short distance west of the parking lot. We will not visit this part of the section. Instead, walk (if on bus trip) or drive back to the road, turn left and cross the bridge. Park cars on the left just across the bridge, and find the footpath down to the river on the west side of the road.

STOP 5B: - Dark slabby cherts of the Mt. Merino Formation are exposed under the bridge. To the east of the bridge, pale green slates are assigned to the Indian River. The cherts are somewhat disturbed by minor faulting. To the west, across an unexposed interval, outcrops of well-bedded silty and sandy greywacke with interbedded grey slates belong to the Pawlet Formation. These are better exposed on the north bank, where inverted sedimentary structures can be found, but it is not feasible to take a large group there.

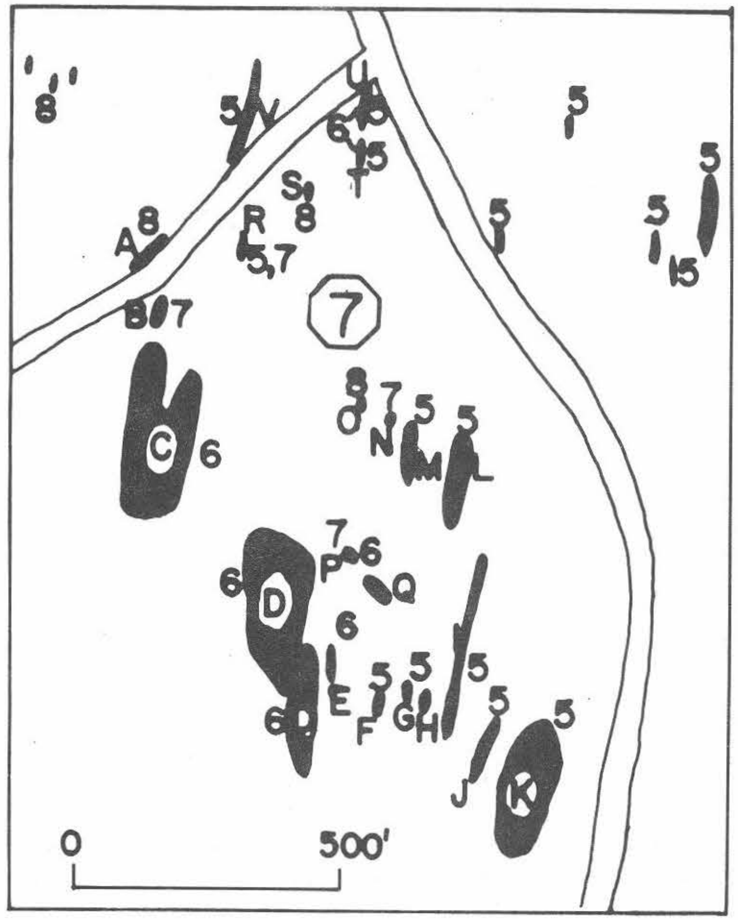


STOP 6: Stoddard Road Thrust

At this stop we will visit outcrops of Indian River, Poultney, and Pawlet Formations. Indian River and Poultney Fms. lie on the western (lower) limb of a large F_1 syncline which is cored by Mount Merino Fm. (not visited). The lower limb of this syncline is thrust westward over Pawlet greywackes which lie in the core of an F_1 syncline to the west. This stop is important because here a thurst relationship can be unequivocably demonstrated due to the well constrained stratigraphy and regional structural framework. Equally important is the presence of fault or at least fault-related rocks in outcrop. Mesoscopic and microscopic examination of these fault-related rocks constrain the timing and style of faulting in this area. The stop also demonstrates that caution is necessary in statements concerning the density of faults in regions where stratigraphy is less well constrained.

Indian River; hard, green, well cleaved, porcellanous slates, crop out alongside Stoddard Road and south and immediately adjacent to the pond. The small abandoned quarries to the north of the pond are in the Indian River. To the west of the Indian River are a series of low outcrops of gray-green, less fine grained argillites and slates with interlayered, thin silty quartzites, characteristic of the Poultney Formation. A short distance to the west-northwest is a steep, 1-1.5 m high ledge of medium to dary gray, fine silty, moderately to well cleaved, moderately fissile argillite with thin (0.1-3 cm), silty, often laminated, discontinuous and lensoid quartzites. At the base of the ledge are a series of small outcrops of poorly exposed, though very distinctive, gray weathering, medium to dark gray, medium grained, lithic greywackes of the Pawlet Formation. On the hill to the northwest the greywackes are well bedded and interlayered with dark gray slate.

The 1-1.5 m high ledge outcrop, containing Poultney lithologies, is interpreted to be fault-related. The mesoscopic character of these fault related rocks is more completely described in the structure section above. Important features to note here are: 1) the mesoscopic foliation in the argillite matrix, 2) sharp, tectonic truncations of laminations in the quartzites, 3) shape preferred orientation of the discontinuous quartzites, 4) presence of isolated fold hinges (none have been noted so far), and 5) lack of mineralization, brecciation or other evidence so commonly cited as evidence against the presence of thrust faults in other parts of the Taconics.



STOP 7: (Optional) Complex Stratigraphic and Structural Relations

This stop illustrates the problems that result in regions of complex stratigraphic and structural relationships. Specifically the problems here include: (1) difficulty of assigning lithologies to lithostratigraphic units in areas where stratigraphic succession is disrupted, even in areas with reasonably good exposure, (2) all contacts are unexposed or at best poorly exposed and thus the nature (sedimentary or tectonic) of the contacts is uncertain, (3) local relationships that are not in accord with regional relations, and (4) problems of distinguishing between pre-D_1, syn- to late D_1 or D_2 structures.

Very brief lithologic descriptions of each of the outcrops (lettered) is provided below. Possible lithostratigraphic unit assignments are given. Participants visiting the outcrops may thus experience for themselves the local complexities and problems. Structures observable in these outcrops include F_1, F_2, S_1, S_2 and local late veining.

(A) Dark gray partly silty argillites with thin silty greywackes. Pawlet.

(B) Black argillite, moderately cleaved. Mount Merino.

(C) Pale green to blue-green (sea green) moderately hard, well cleaved slate. Indian River.

(D) Pale green to pale gray, hard, moderately to well cleaved argillite with thin silty quartzites(?) (possibly tuff bands). To the south, red well cleaved slate. Indian River.

(E) Pale gray to pale green to gray argillite. Indian River.

(F) Medium gray argillite with moderate cleavage. Poultney-top of the Indian River.

(G) Gray weathering, medium to dark gray, fine silty argillite. Poultney.

(H) Same as G.

(I) Gray weathering, medium to dark gray, some almost black, slightly fine silty, moderately-cleaved argillite. Also 25 cm layer of brown weathering gray, fine grained, laminated, dolomitic arenite. Poultney (?).

(J) Gray weathering, dark gray, fine to partly silty moderately cleaved argillite. Poultney.

(K) Gray to dark gray, fine to silty argillite, moderately to poorly cleaved, locally highly veined. Poultney.

(L) Medium to dark gray, fine to partly silty argilite, moderately cleaved, with thin (1-15 mm) silty quartzites. Local bioturbated color laminated slate. A few 2-10 cm thick, brown weathering, fine-grained, dolomitic quartz arenites in medium gray argillite. Poultney.

(M) Pale gray-green, argillite with thin (less than 15 mm) silty quartzites. Poultney.

(N) Gray weathering, pyritiferous(?), dark gray to black siliceous argillite.

(O) Brown weathering, calcareous, medium to fine grained greywacke. Pawlet.

(P) Pale green-gray, moderately soft, well cleaved argillite. Indian River. Just to the north (approximately 3 m), sooty black graptoliferous (poorly preserved) argillite. Mount Merino.

(Q) Medium to dark gray moderately to well-cleaved argillite with some dark gray siliceous mudstones. Poultney(?), Mount Merino(?).

(R) Medium gray, moderately hard argillite. Poultney(?), Mount Merino(?).

(S) Brownish weathering greywacke with minor dark gray slate. Pawlet.

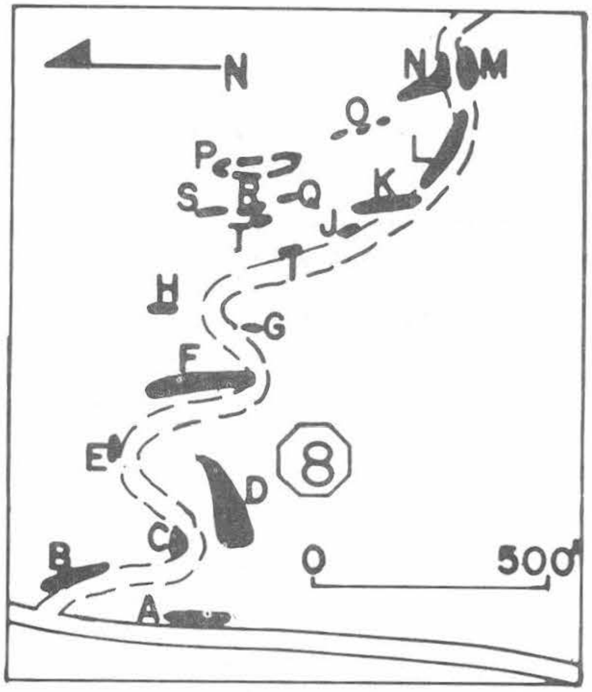
(T) Medium to dark gray partly silty argillite with thin, fine siltstone layers. Poultney.

(U) Medium to dark gray partly silty argillite with thin fine siltstone layers and a few silty quartzites. Poultney. On west side of outcrop small amount of pale green to blue green well cleaved argillite. Indian River (?).

(V) Medium gray partly silty argillite with moderately to well developed cleavage. Poultney(?) Mount Merino(?).

Regional Picture:

To the south along strike, a well defined east-facing sequence from Poultney to Pawlet lies on the upper (eastern) limb of a large F_1 anticline. This limb is truncated to the east by the New Boston Thrust, which juxtaposes Poultney over east-facing Pawlet greywackes. To the north and immediately to the west is a small klippe of Pawlet Formation. Thrusting of the klippe probably occurred as a pre- to early D_1 event. The overall distribution of lithologies outlined above suggest the presence of a north or west-facing sequence. This is not compatible with the relationships defined both to the north or the south. For this reason we suggest that the area is disected by a series of essentially phacoidal thrust faults which give rise to the apparent reversal in facing.



STOP 8:

The purpose of this stop is to examine a typical section of Pawlet Formation and the complex character of it's contact with stratigraphically underlying lithostratigraphic units. Most workers, including Zen (1961, 1964) Shumaker (1967) and Potter (1972) have argued that the Pawlet Formation unconformably overlies lower Taconic lithostratigraphic units. Shumaker (1967) interpreted the Pawlet contact at this locality to be sedimentary and unconformable, possibly angular. We interpret this contact to be tectonic. Support for this contention include the following observations: (1) complex interleaving of lithostratigraphic units. (2) East-facing Pawlet greywackes just below (topographically) the overturned contact. (3) Regionally, there is a marked apparent thinning from the lower (west) limb to the overturned upper (east) limb of the F_1 syncline defined by the Pawlet Formation, suggesting that part of the upper limb has been tectonically excised. The outcrops visited at this stop illustrate the extreme difficulty of demonstrating the precise nature of this contact on the outcrop scale.

The majority of the outcrops are of Pawlet greywackes and slates. Other lithologies include: (1) dark gray variably siliceous argillites and slates. (2) Medium gray fine silty argillites with thin, mostly silty quartzites. Poultney. (3) Medium to dark gray finely cleaved slates with a silky sheen on cleavage surfaces. Poultney (?). (4) Green, gray and gray - green fine well cleaved slates. Minor thin calcareous siltstone (silty limestones) and quartzites. Mettawee (sensu lato). Figure shows the distribution of lithologies. Numbers refer to the lithostratigraphic units, following the scheme of Figure 1b . Letters refer to the brief descriptions that follow.

Descriptions:

Start at small roadcut on the main road 10 m south of H. & H. Slate Co. quarry access road.

A - Greywackes and slates. Folded by F_1, moderately NE plunging fold with an axial surface slaty cleavage. Note cleavage refraction through greywackes. Moderately developed steep spaced crenulation cleavage. Veining and late disruption of the south end of cut.

B - Low outcrops on the east side of access road. Greywackes and slates. East-facing.

C - Bulldozed greywackes at the first turn.

D - Across small stream, south of C. West part of outcrop, east-facing bedded greywackes and slates. Central part of outcrop, deformed, tectonically sliced greywackes and slates. East side of outcrop, bedded, east-facing greywackes and slates in gently south plunging antiform.

E - Bedded greywackes, bounding steep zone of veined and disrupted greywackes.

F - Bedded greywackes and slates. Slates more abundant. Bed thickness varies from a few to 10's of cms. Fresh greywacke exposed at corner. Note medium grain size and lithic component.

G - Very small, mostly covered outcrop of greywackes and slates.

H - More greywackes to the north of access road.

I - Small outcrop of thinner (4-8 cm) greywackes and slates. Possibly west-facing.

J - Another outcrop on the east side of the access road, same as I.

K - Contact. Three lithologies present, from west to east these are: discontinuous, west facing(?), greywackes and slates. Dark gray, variably siliceous argillites and slates, some chert. Interlayered medium gray fine silty argillites and thin, fine grained to silty quartzites, typical Poultney. The thin siliceous lithology is often observed at this contact. Contact appears sedimentary at this outcrop.

L - Predominantly medium gray argillites and slates with thin quartzites. Poultney.

M and N - Bulldozed cut in medium to dark gray slates, thin calcareous siltstone layers, thin quartzites and minor Pawlet-like greywacke. Relationships of lithologies not clear, but probably tectonic. Second generation structures prominent.

O - Small outcrops along jeep track, taking off to the north of the access road. Lithologies include gray to dark gray slates, greywackes, gray, green and gray-green slates, some slates with thin quartzites, some dark gray siliceous slates.

P - Scattered outcrops of finely cleaved medium gray slate (Poultney?). Locally highly veined.

Q - Chalky weathering, medium to dark gray, variably siliceous argillites. Brecciated chert. Greywackes downslope.

R - Graywackes

S - Same as Q. Note greywackes and small amounts of gray slate with thin quartzites 1 m below ledge. Also, in bottom part of ledge of siliceous argillite a 'layer' of greywacke lithology truncates the siliceous lithologies across at least the cleavage. This greywacke 'layer' does not possess bedding characteristics and is not believed to be of primary sedimentary origin. Other possibilities include injection or tectonic slicing.

T - Downslope to the southwest of R, small outcrop of medium gray slates with thin quartzites, typical of the Poultney. Greywackes occur both above and below this exposure.

As you can see simple contacts cannot be drawn in this area.