1-1-1975

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Bird, J. M.

J. F. Dewey

Recommended Citation

Bird, J. M. and J. F. Dewey, "Selected localities in the Taconics and their implications for the plate tectonic origin of the Taconic region" (1975). *NEIGC Trips*. 224.
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Trip B1, C1

SELECTED LOCALITIES IN THE TACONICS AND THEIR IMPLICATIONS FOR THE PLATE TECTONIC ORIGIN OF THE TACONIC REGION

John M. Bird and John F. Dewey

(Cornell University, Ithaca, New York and
State University of New York at Albany, Albany, New York)

Introduction

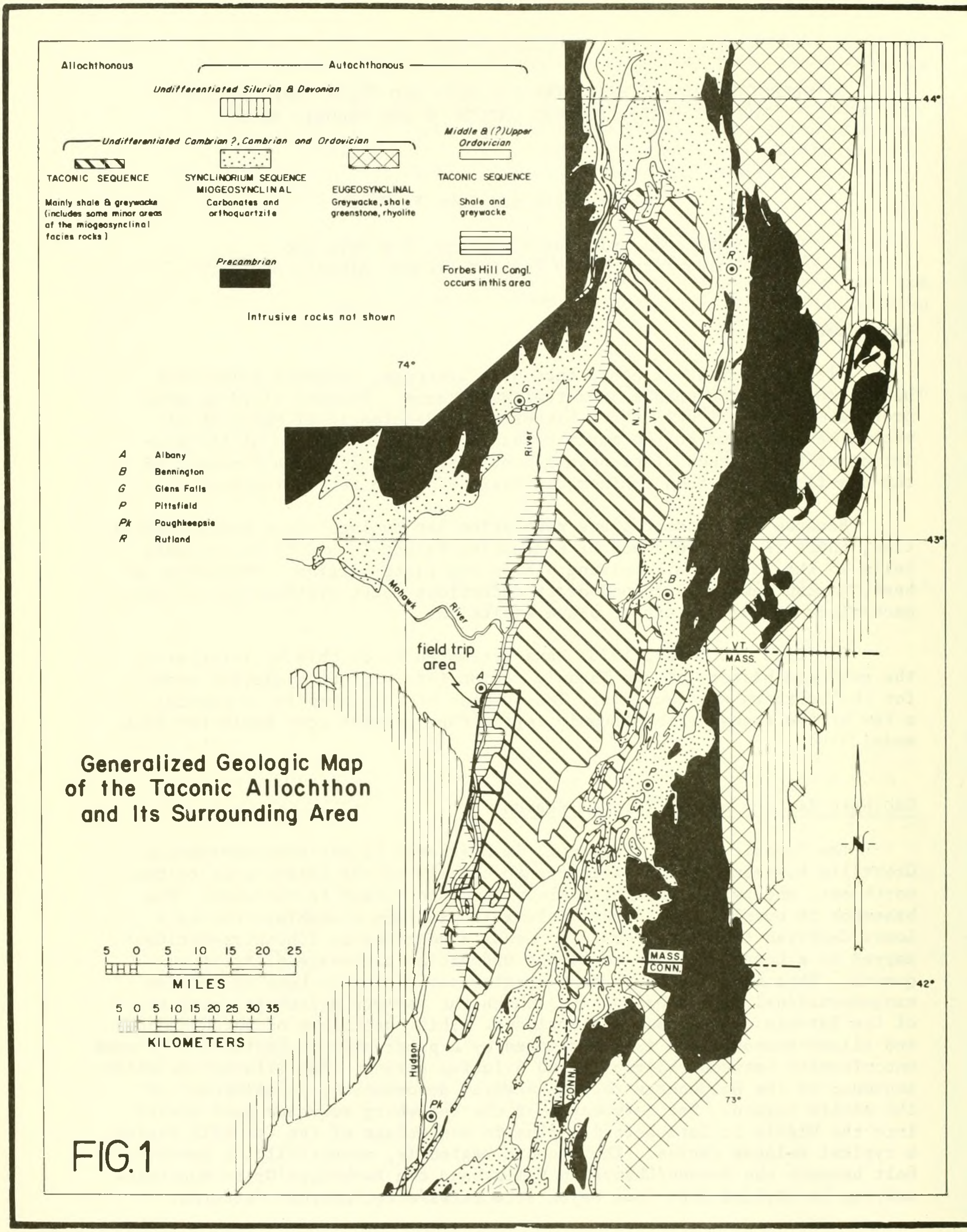
With the advent of plate tectonics concepts, orogenic belts have become more understandable in actualistic terms. Present plate margins provide examples of styles and histories of deformational belts which extend back in time to the early Mesozoic, as a consequence of the evolution of the present plate population. The magnetic anomaly record of the sea-floors provides a kinematic basis of plate reconstructions.

Because the present plate population has evolved since early Mesozoic time, there is no direct way of evaluating Paleozoic and older orogenic belts in the context of evolving plates and plate margins. Therefore, at best, we can make only second-order deductions about pre-Mesozoic orogenic mechanisms in the context of plate evolution.

We (Bird and Dewey, 1970) have attempted to do this by integrating the geologic history of the Taconic region into a plate evolution model for the northern Appalachians. The purpose of this trip is to examine a few of the rocks of the Taconic region that provide some basis for that model.

Geologic History of the Taconic Region

The Taconic region (Figure 1) is bracketed by the Precambrian-age Grenville basement igneous-metamorphic complex of the Adirondacks to the northwest, and by the Berkshire/Green Mountain massif to the east. The basement is overlain by a Lower Paleozoic platform assemblage having a Lower Cambrian to Lower Ordovician basal transgression (Cheshire-Potsdam) capped by a Lower Cambrian to Middle Ordovician carbonate platform sequence. This is followed by an autochthonous Middle to Late Ordovician exogeosynclinal flysch basin, into which the various structural members of the Taconic allochthon were emplaced. This assemblage of autochthonous and allochthonous rocks is overstepped by a progressively eastward-developed unconformity between Ordovician and Silurian strata. The Silurian/Devonian sequence of the Heldebergs records Acadian deformation, superimposed on the entire region. The carbonates of the Heldeberg sequence pass upward into the Middle to Late Devonian clastic assemblage of the Catskill region, a typical molasse facies. The Taconic region is, essentially, a synclinal belt between the Hudson/Champlain Valley and the Berkshire/Green Mountains and can be divided into four major structural/stratigraphic features:



Generalized Geologic Map of the Taconic Allochthon and Its Surrounding Area

FIG.1

1) The miogeoclinal basal transgression - carbonate platform wedge, 2) The Trenton-age Balmville Limestone (unconformable on the platform via the sub-Trenton/Black River unconformity) and Normanskill shale/Austin Glen flysch facies which changes into the Trenton limestone facies in the Mohawk Valley region, 3) The Taconic allochthon, and 4) the mantling Silurian/Devonian carbonates exemplified by the relations at Mt. Ida (see trip A3) and Becraft Mountain. The boundaries and regional distribution of all these stratigraphic/structural assemblages were discussed in detail by Zen (1967) and Bird (1969).

Of these four assemblages, the Taconic allochthon is the most complex, and most instructive; it includes rocks transported from original sites to the east which have been obliterated by intense deformation and metamorphism.

The Taconic allochthon was emplaced in several stages, the first being the gravity sliding emplacement of the Giddings Brook-Sunset Lake slices (Zen, 1961, 1967; Bird, 1969) in post-Balmville, Zone 13 (Berry, 1960) time. (The Sunset Lake slice is very small; for the purpose of this article we include it with the term Giddings Brook slice). This event produced an exotic, wildflysch-like facies, by the overriding of the frontal erosional products of the advancing submarine slide. We will examine several exposures of this syntectonic facies, along the western "front" of the Giddings Brook slice; it provides the evidence for the time/space framework, and mechanical aspects of the gravity sliding. Zen (1967) provided a detailed, regional synthesis of the relations of this and the higher slices of the Taconic allochthon. The timing and structural "style" of emplacement of the higher slices remains as one of the key problems of Taconic geology (see trips B2, B4, B6 in this guidebook). The intensity and grade of Taconic metamorphism increases eastward, and strong Acadian deformation and biotite-grade metamorphism of the eastern Taconic region in southern Vermont increases to garnet and sillimanite-grade east of the Hudson Highlands in the southern Taconic region. The western limit of the Acadian deformation is along the eastern border of the Catskills. Because of the extent of this deformation and metamorphism, the most useful strata for reconstructing Taconic time/space relations are preserved in the northern regions of the autochthon and for the most part, in the Giddings Brook slice, because of their contained faunal assemblages and original depositional features. Therefore, for the purposes of this trip, and because of logistical constraints, we will concentrate on the western region of the Giddings Brook slice.

The Giddings Brook Slice

Following the recognition of gravity sliding of the initial Taconic allochthon (Zen, 1961), Rodgers (1968) showed that the eastward termination of the carbonate miogeocline, in the Milton region of Vermont, was a facies change into breccias, and then to shale (the Rugg Brook Conglomerate - St. Albans Slate). He pointed out that this facies change and the regional stratigraphy show that the eastern termination of the carbonates was a carbonate platform edge, with the deeper-water shale to the east being of an off-shelf rise environment.

Also it has been learned, principally through the detailed mapping of Zen (1961) and Theokritoff (1964), that the Giddings Brook stratigraphy extends from Eocambrian through to Middle Ordovician (Zone 12 of Berry) and that the time span of the fossiliferous portion matches that of the carbonate miogeocline (Zen, 1961; Bird and Rasetti, 1968; Bird, 1969). In the eastern region of the autochthon, the Lower Cambrian Cheshire Quartzite overlies the Dalton and Nickwaket; the Mudd Pond Quartzite of the Giddings Brook slice is the equivalent of the Cheshire (Bird and Rasetti, 1968). The Cheshire and Mudd Pond both contain the stratigraphically lowest Olenellus biozone fossils of the region, and mark the base of the fossiliferous strata of the autochthon and allochthon, respectively. The Dalton-Nickwaket facies and the Cavendish facies further east, resemble sub-Olenellus biozone facies of the Nassau (or Bull) Formation. The facies of the West Castleton - Hatch Hill and Poultney Formations of the Giddings Brook slice can be readily attributed to the starved rise region that must have existed off the carbonate bank. (We will examine several exposures of these facies). Essentially then, through the work of Zen, Rodgers, Bird, and Bird and Rasetti, the fossils, facies and regional stratigraphic and structural relations of the autochthon and gravity slide portion of the allochthon have been fitted back to pre-orogeny configurations of shelf and off-shelf assemblages which were to be telescoped in the early phases of the Taconic orogeny. These original configurations are illustrated in Figure 2.

The boundaries of the autochthon, the basal transgression on the basement, from Lower Cambrian on the east to the Upper Cambrian on the west at the Adirondacks, and the mantling Normanskill shale and graywacke, are well established (Figure 1). The rocks of the Giddings Brook slice, however, are completely detached from their original setting. Mapping in the Nassau Quadrangle shows that the Nassau Formation includes hundreds and perhaps thousands of feet of shale and siltstone beneath the lowest fossil-bearing strata (Mudd Pond Quartzite horizon). Lower down in the Nassau are graywacke and shale directly equivalent with the Rensselaer graywacke, and apparently, this was of a graben-horst non-marine environment (Bird and Dewey, 1970; Bird, 1975). We do not know what may have constituted the "base" of the Giddings Brook strata; the higher slices of the Taconic allochthon contain older sequences of strata that resemble or are equivalent to the lower parts of the Nassau (or Bull) Formation (see Zen, 1967, p. 15, Fig. 4). With the bulk of the Taconic allochthon in the higher slices, it is important to note that most of the allochthonous rocks are in fact pre-Olenellus in age and therefore properly assigned to the Precambrian. The fossiliferous strata, from near the top of the Nassau or Bull Formation up-section to the Indian River - Mt. Merino sequence, in the Giddings Brook, Bird Mountain (Zen, 1967) and perhaps in the Chatham slice (see Ratcliffe, trip A3, this guidebook), are probably no more than 1000 to 1500 feet thick (Fig. 2).

The "top" of the allochthonous sequence, the Indian River - Mt. Merino facies of the Poultney Formation (Bird, 1969), best seen in the Giddings Brook slice, is correlative with the sub-Trenton/Black River unconformity of the autochthon, and includes the last sediments deposited in the off-shelf region before gravity sliding. The Indian River and Mt. Merino are entirely allochthonous. The upper boundary of the Giddings Brook slice is a syn-gravity sliding facies - the Pawlet in the northern

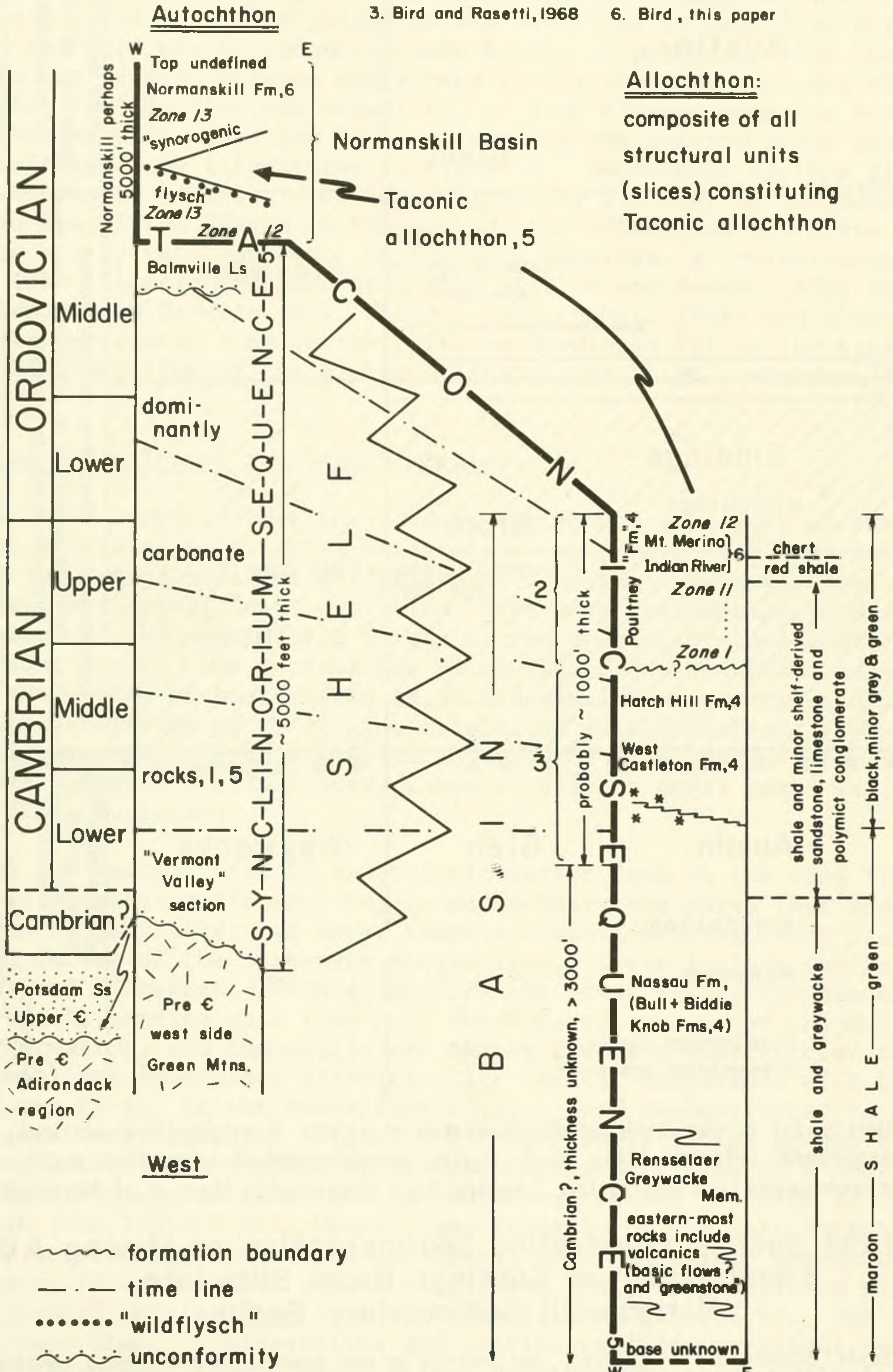
FIG. 2

Eastern New York State

Schematic reconstruction of pre-"Taconian orogeny" stratigraphic relations

Thicknesses and distances variable or unkown

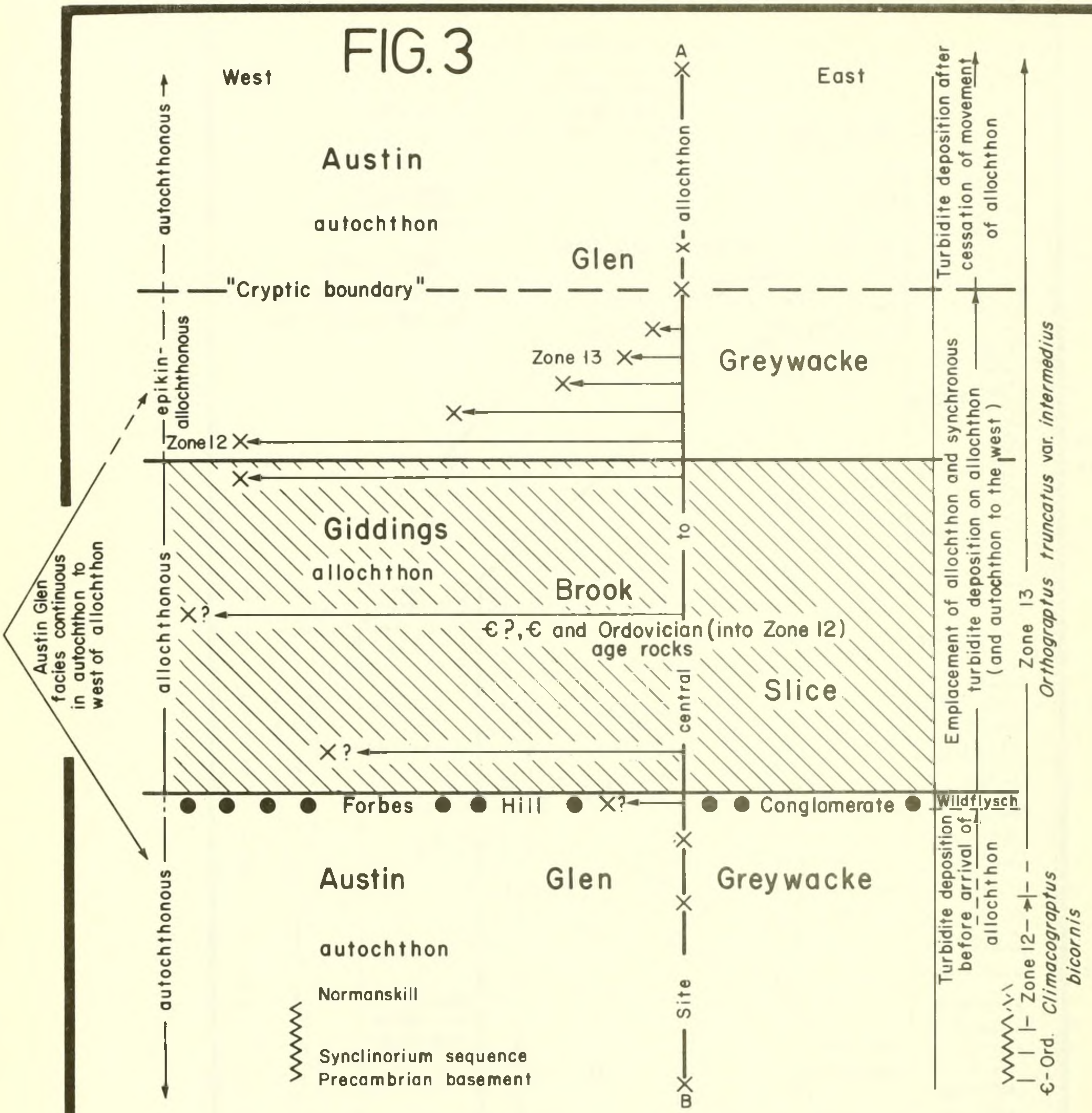
Stratigraphic data:
1. Fisher, 1962 a, b
2. Berry, 1962
3. Bird and Rasetti, 1968
4. Zen, 1964b
5. Zen, 1967
6. Bird, this paper



Zone 13: *Orthograptus truncatus* var. *intermedius*
Zone 12: *Climacograptus bicornis*
Zone 11: *Nemagraptus gracilis*
} 2

**Olenellus* faunizone (*Elliptocephala asaphoides*), 3

FIG. 3



Horizontal arrows indicate displacement of points X originally at vertical geographic reference line A-B, during emplacement of allochthon and synchronous sedimentation (Austin Glen Greywacke, Mem. 4 of Normanskill)

Hypothetical Section Illustrating Sedimentation on Moving Allochthon Emplacement of Giddings Brook Slice into Normanskill Sedimentary Basin

Scale: Schematic - thicknesses, and relative lateral positions and distances variable; horizontal boundaries assumed; Zig-Zag represents abbreviated section.

Taconics and the Austin Glen in the central and southern regions, which is either gradational with the upper Poultney, the Mt. Merino shale and chert, or has a deep-bite unconformity with rocks of the Giddings Brook slice as low as the Mettawee of the Nassau or Bull Formation (Zen, 1961; Theokritoff, 1964). These relations are described in detail by Bird (1969), and need not be recounted here except to point out that they indicate the gravity sliding was submarine for the most part and that the Pawlet /Austin Glen was deposited, in some places, upon the moving allochthon as well as in the basin into which the gravity slide was moving. These relations are illustrated in Figure 3. Deposition of this flysch facies continued on after cessation of gravity sliding, as indicated by distribution of the flysch to the west of the allochthon and above the wildflysch. To the southwest, at Illinois Mountain, a coarse molasse facies (the Illinois Mountain quartzite of Bird and Dewey, 1970) bears upper Ordovician fossils (D.W. Fisher, pers. comm., 1969) and almost certainly represents a syntectonic facies developed during the later Ordovician thrusting of the higher slices of the "high" Taconics (Fig. 4C).

Model for Evolution of the Taconic Region

We have proposed that the Taconic region was a segment of the continental margin of an evolving Paleozoic ocean system (Bird and Dewey, 1970). The pre-deformation stratigraphic framework represents the structural and depositional evolution, from late Precambrian to Middle Ordovician, of the continental margin of the opening proto-Atlantic, or Appalachian ocean. The emplacement of the Taconic allochthon was an effect of the conversion of that margin to an Andean-like orogenic system. The structural evolution of the region culminated in the Acadian, with suturing by continent to continent collision, during the final stages of closing of the ocean. Figure 4 illustrates, schematically, a model based on lithosphere plate evolution.

On the eastern side of the Taconic region, and on the east limb of the Green Mountain anticlinorium are sedimentary sequences that underlie the Cheshire quartzite, the Lower Cambrian fossil-bearing basal transgression facies of the carbonate miogeocline. These include the Dalton (Mendon) and Nickwaket. Within the Giddings Brook slice, far beneath the lowest fossil-bearing unit (the Mudd Pond Quartzite zone of the Bull or Nassau Formation, and the equivalent of the Cheshire Quartzite of the autochthon) are Rensselaer graywacke-like strata, comparable with the bulk of the facies in the Rensselaer slice. When reconstructed to a pre-orogenic configuration (Figure 4A), these early facies occupy a position consistent with a model of Late Precambrian rifting of a continental mass. Basic volcanics occur in the Rensselaer facies and also in the Cavendish (the Tibbett Hill Member) and Pinnacle of the East Vermont sequence and we suggested (Bird and Dewey, 1970) that this assemblage accumulated in extensional graben structures during the earliest phases of continental rifting (see stop 8, trip A3, this guidebook). The Appalachian ocean shelf or miogeocline and continental rise (original position of Bull - West Castleton - Hatch Hill - Poultney sequence) evolved synchronously with the late Precambrian - Early Paleozoic opening of the Appalachian Atlantic (or proto-Atlantic) Ocean. Grenville basement rocks must have occurred under this segment of rise sediments, as indicated by the existence of this basement to the east, in the Chester Dome. However, in the context of continental lithosphere rifting it is likely that a full thickness of continental basement did not exist oceanward, beyond the shelf edge. This boundary, persistent through the time of evolution of the carbonate platform and rise, later became a significant tectonic and stratigraphic break that influenced the development of the major, regional structural features of the Taconic allochthon.

In addition to their synchroneity with the carbonate platform sediments, the West Castleton through Poultney sediments contain varieties of facies and sedimentary structures that are evidence of a starved rise region of deposition (Bird and Rasetti, 1968). We will examine some of these facies and structures at Schodack Landing and Judson Point. Also, the absence of significant amounts of coarse terriginous sediments in this sequence indicates not only the extent of the carbonate platform and effective terriginous sediment-blocking, but also that no significant relief developed in the interior craton during the time of deposition. It is very important to recognize that the coarse clastics of the pre-Olenellus Taconic sequence must have been underneath and perhaps further oceanward from the rise assemblage, as indicated in Figure 4A. On the other hand, very coarse and angular limestone breccias and conglomerates occur in the Upper Nassau and West Castleton. These chaotic layers, usually having a rounded-sand and carbonate-cement matrix, are interbedded with black and green shale, and clearly, are exotic slump deposits from a shallow carbonate-bank edge environment. Also, further up-section, in the Hatch Hill, ferruginous quartzite beds in shale, up to several meters thick, are best attributed to sand-flow and turbidite mechanisms, again from a shallow shelf environment. There is also a wealth of turbiditic, sandy, silty and carbonate beds and minor conglomerates in the Poultney, particularly in the Deepkill and Schaghticoke facies, that are evidence of continued starved, off-shelf depositional environments, contemporaneous with the Early and Middle Ordovician platform sediments.

During early Middle Ordovician time, the miogeocline-rise couple was affected by uplift and block faulting. An extensive erosional surface developed which was to become the sub-Trenton/Black River unconformity (see Zen, 1967, for a detailed account of this phase of Taconic evolution). This event was coeval with development of the Indian River facies of the Poultney; the red shales of the Indian River are thought to be derived from a terra rosa soil horizon on the erosional surface (Bird and Dewey, 1970). The Indian River red shales pass upward into the green and black shales and cherts of the Mt. Merino. Detailed petrographic study (Bird and Lang, unpublished) indicates clearly a volcanogenic origin for much of the Indian River - Mt. Merino chert. These chert facies are correlative with the Ammonoosuc volcanics, of Vermont and Massachusetts, and pass upward, locally, into shale and graywacke beds of the Pawlet.

As shown in Figures 2, 3, and 4B, the emplacement of the Giddings Brook slice was contemporaneous with the westward encroachment of flysch into the Mt. Merino environment, the sagging of the miogeocline and attendant westward migration of the Balmville carbonate facies to become the Trenton limestone of the Mohawk Valley, and deposition of Normanskill shale. The Pawlet - Austin Glen Graywacke facies overwhelmed the subsiding continental margin, contemporaneously with a major relief inversion. The

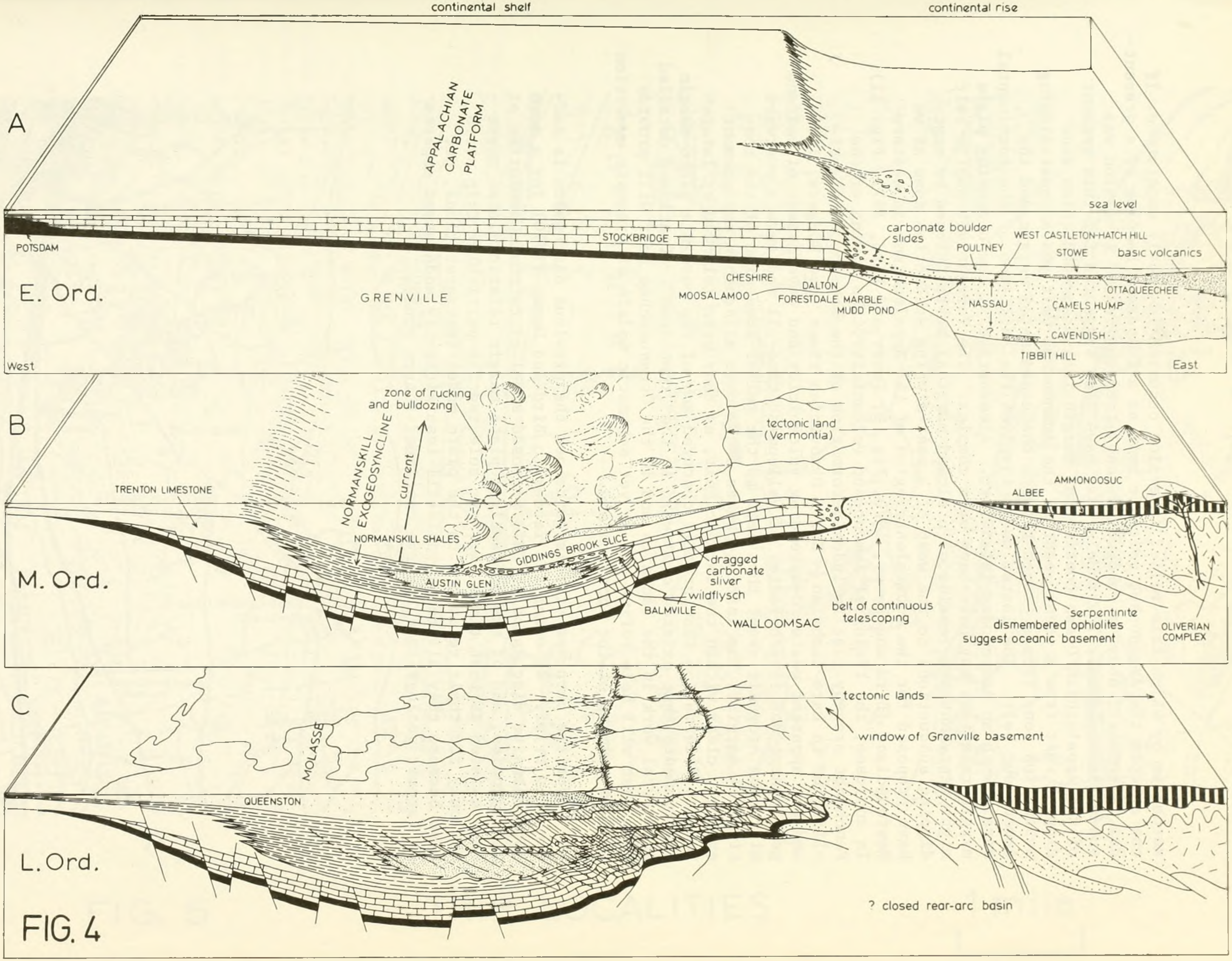

continental shelf
continental rise
A
APPALACHIAN CARBONATE PLATFORM
sea level
carbonate boulder slides
STOCKBRIDGE
POTSDAM
WEST CASTLETON-HATCH HILL
POULTNEY
STOWE
basic volcanics
CHESHIRE
DALTON
OTTAQUEECHEE
E. Ord.
GRENVILLE
MOOSALAMOO
FORESTDALE MARBLE
MUDD POND
NASSAU
CAMELS HUMP
?
CAVENDISH
TIBBIT HILL
West
East
B
zone of rucking and bulldozing
NORMANSKILL EXOGEOSYNCLINE
current
tectonic land (Vermontia)
TRENTON LIMESTONE
AMMONOOSUC
ALBEE
NORMANSKILL SHALES
GIDDINGS BROOK SLICE
dragged carbonate sliver
M. Ord.
AUSTIN GLEN
wildflysch
BALMVILLE
WALLOOMSAC
belt of continuous telescoping
serpentinite
dismembered ophiolites suggest oceanic basement
OLIVERIAN COMPLEX
C
tectonic lands
window of Grenville basement
MOLASSE
QUEENSTON
L. Ord.
? closed rear-arc basin

FIG. 4

mechanism by which this relief inversion occurred is poorly understood. If one accepts the Ammonoosuc volcanic belt as a Paleozoic homolog of a present-day island arc, above a subduction zone, then the relief inversion was subduction-related. The models that have been suggested for this segment of the Appalachian Ocean continental margin include a subduction zone dipping west from a trench east of the Ammonoosuc belt and an east-dipping subduction zone from a trench between the continental margin and the Ammonoosuc belt. The latter model involves the collision of the continental margin with an Ammonoosuc island arc. Alternatively, the consuming plate margin relations may have been more complex. The Vermont ultramafic belt might represent the remains of a closed marginal basin (closed by east-dipping subduction) to the west of a west-dipping subduction zone as we have proposed for the equivalent region of the Appalachians in western Newfoundland (Bird and Dewey, 1970, Fig. 8; Dewey and Bird, 1971, Fig. 11). In any case, the timing of Ammonoosuc volcanicity, the timing of the Penobscot orogeny that includes deformation of the Bronson Hill anticlinorium in Late Cambrian - Early Ordovician times (see Rodgers, 1970), and the apparent westward-spreading vulcanicity and development of volcanogenic chert and flysch facies of Walloomsac time all indicate a westward migrating orogenic event that lead to the relief inversion of the continental margin. The initial phases of Taconic allochthon emplacement are only clear within the Taconic belt, as they were followed by later, intense deformation that greatly obscured any of the possible plate margin environments that existed oceanward in the "root zone". Continued detailed structural work in the Taconics and in the Ottaqueechee belt will provide data that will help refine our as yet schematic models of orogenic evolution of this segment of the Appalachians.

For the purposes of this guidebook the previous discussion is necessarily brief. We refer the reader to Bird and Dewey (1970) for a more comprehensive discussion of this proposed model of tectonic evolution of the Taconics, and of the theoretical plate margin relations that might have existed at that time. We have selected the particular trip stops, not only for their relevance to the plate model interpretations, but also because they all remain as still insufficiently understood aspects of Taconic geology that deserve continued future study.

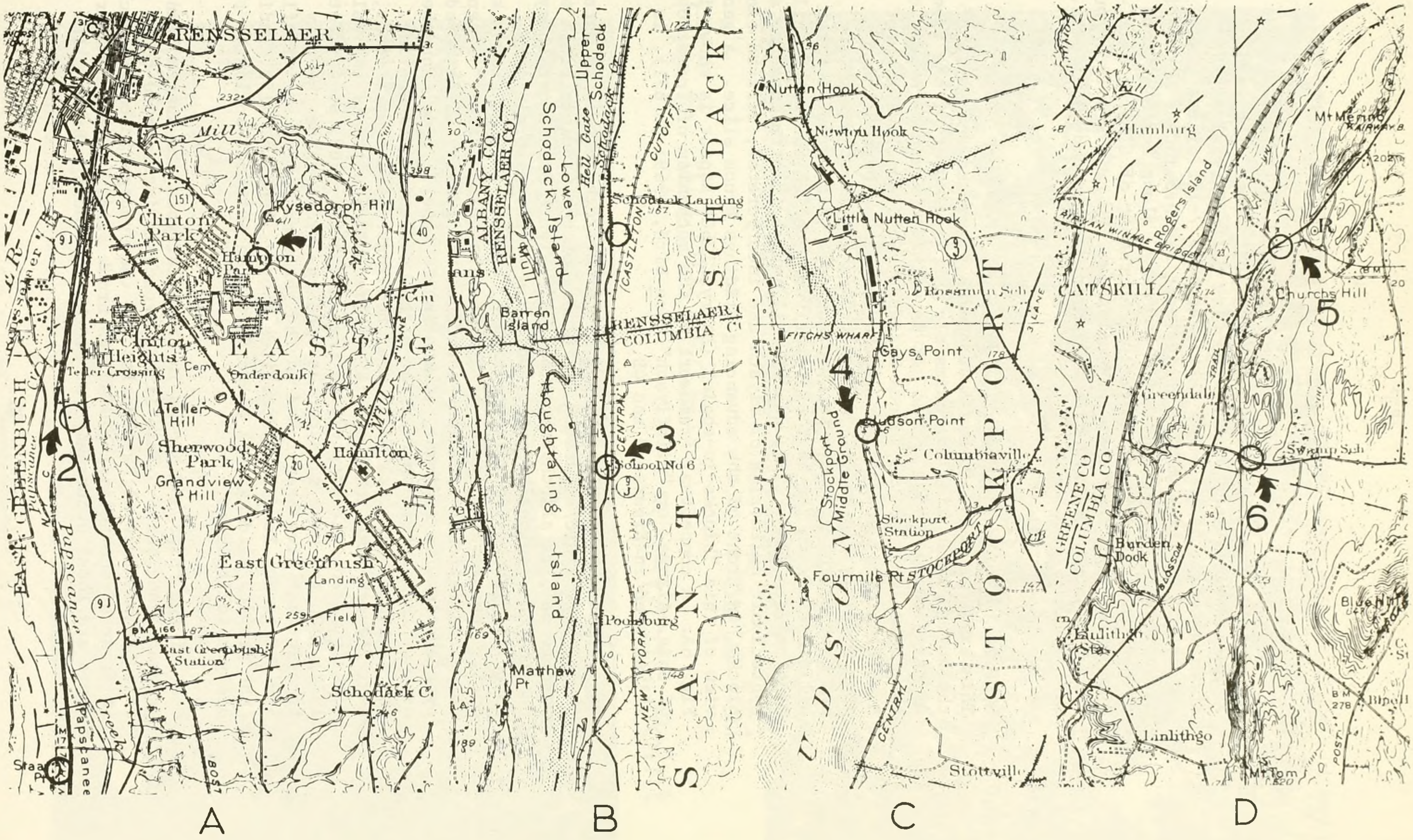


FIG. 5 TRIP LOCALITIES

1 mile

ROAD LOG

Start trip at road-cut on Route 151, just south of Rysedorph Hill, 1.7 miles southeast of the City Hall, Rensselaer, New York; see Fig. 5A. On the East Greenbush 7-1/2 minute Quadrangle the position is 4.0 inches east and 0.5 inches south of the northwest corner, and north boundary, along Red Mill Road between Couse and Rensselaer, just northeast of Clinton Park. Appropriate 7-1/2 minute quadrangles for the trip are Troy South, East Greenbush, Delmar, Ravena, Hudson North and Hudson South.

mileage

00.0 STOP 1 Wildflysch, Route 151 road-cut.
This exposure, of deformed Austin Glen graywacke and shale of the Normanskill, lies approximately 1.2 miles west of the front of the Giddings Brook slice. It is within the southern-most of three small hills; the famous Rysedorph Hill conglomerate (of Rysedorph Hill) occurs just to the north, and beyond that, approximately 0.4 miles, is Olcott Hill (see East Greenbush and Troy South 7-1/2 minute Quadrangles). All three of these hills are within the belt of wildflysch, called the Forbes Hill Conglomerate (Zen, 1961; see Fig. 1), which is attributed to a syntectonic bulldozing of flysch and incorporated, derived exotic blocks, in front of the advancing Giddings Brook slice. A general view of this "blocks-in-shale" (Berry, 1960) aspect is shown in Fig. 6A. A conceptual framework of the mechanism of formation of this mélange, or "wildflysch" (see Bird, 1969; p. 671), is illustrated in Figures 3 and 4B.

To evaluate the significance of the wildflysch we need to establish the stratigraphic/structural relations of the Giddings Brook slice that reveal its allochthonous nature. Figure 3 is meant to synthesize the regional stratigraphic and structural relations, especially those of syn-deposition of the Austin Glen Graywacke during the gravity sliding of the Giddings Brook slice. Essentially, the regional relations show that the gravity slide moved over Austin Glen sediment, commencing in Zone 12 time, somewhere east of the eastern-most extent of the carbonate miogeocline. To the east, at Whipstock Hill, near Bennington, Vermont (Potter, 1972), a wildflysch-like conglomerate overlies black slate of the Walloomsac containing Zone 12 graptolites (Zen and Bird, 1963, p. 45; Potter, 1972). On the west side of the Giddings Brook slice the only fossils that have been found in the shale matrix of the wildflysch are indigenous Zone 13 graptolites (Berry, 1962, p. 715), indicating that gravity sliding took place during an interval no longer than one graptolite zone.

Most of the chips and blocks in the wildflysch are Austin Glen graywacke and shale. This lithic aspect is interpreted to be due to a predominance of "bulldozing" of the syndepositional flysch in front of the advancing Giddings Brook slice. Also, however, there are local occurrences of blocks of Giddings Brook slice

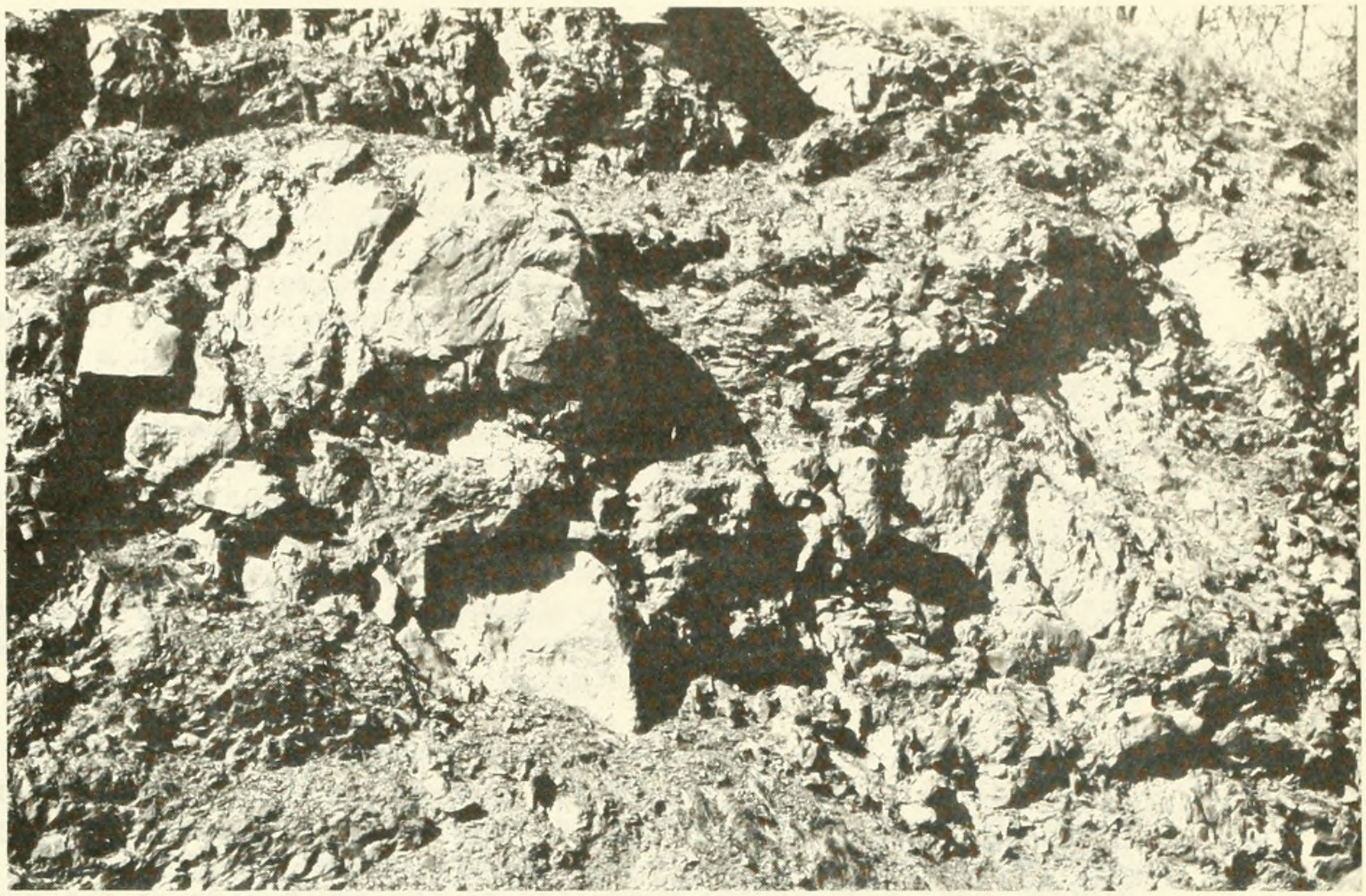


FIG. 6 WILDFLYSCH

A. Route 151

B. Staats Point

strata, and carbonates that can be readily attributed to the carbonate sequence of the autochthon (we will examine some of those at Stop 2). The oldest-dated blocks are Elliptocephala (Lower Cambrian) fauna-bearing limestone, within the wildflysch exposed in the lower falls of the Moordener Kill. The Moordener locality is approximately 10 kilometers south of here, just east of the Brown Company paper mill which is indicated as a large group of buildings just north of Castleton-on-Hudson on the East Greenbush 7-1/2 minute Quadrangle. The locality is not a suitable stop for a large field-trip group; it is recommended, however, as a place to see the variety of lithic clasts that can be readily matched with Giddings Brook slice strata. The blocks include Zion Hill quartzite, West Castleton-Hatch Hill shale and limestone, Poultney shale, Mt. Merino chert, and the Rysedorph Hill Limestone Conglomerate. The "exotic blocks", i.e. not of the Normanskill shale/Austin Glen graywacke stratigraphic sequence, are thought to have been shed from the advancing Giddings Brook slice, into the frontal mélange, as illustrated in Fig. 4B.

This exposure is composed entirely of Normanskill/Austin Glen lithologies. The large blocks of graywacke "floating" in deformed shale are practically undeformed internally and were apparently completely lithified before deformation. Some of the smaller blocks, best seen in the rock-face on the south side of the road, have internal deformation that indicates they were semi-indurated at the time of formation of the block. In general, the spectrum of internal deformation features of the graywacke blocks of the wildflysch indicates there was a range of sediment consolidation, from soft to hard, within the autochthonous Austin Glen graywacke strata at the time of overriding and bulldozing by the advancing gravity slide. Although no precise measurements can yet be made to evaluate the deformational aspects of the zone of bulldozing, regional mapping shows a progressive decrease in intensity of deformation and size of blocks, to the west, away from the "front" of the Giddings Brook slice. For example, on the west side of the Hudson River, particularly around the Normanskill Creek locality just south of Albany (Albany 7-1/2 minute Quadrangle) one can see a gradual eastwardly increasing disruption of Austin Glen strata, from essentially flat-lying to the west, to bulldozed, in the creek-bed to the east, and also in exposures along the west bank of the Hudson River (Bird, 1969). The only exotic blocks known in the wildflysch west of the Hudson River are a few hills and knolls of Mt. Merino chert and shale such as Flint Mine Hill approximately 3 km southwest of Coxsackie, and Mettawee and Poultney(?) shale such as at the Barren Island, on the west shore approximately 1.6 km south of Coeymans. Exotic blocks older than the Mt. Merino of the Giddings Brook slice, and Trenton-age and older carbonates of the autochthon occur along the east bank of the Hudson (in the region of this field trip) and increase in frequency of occurrence eastward to the "front" of the Giddings Brook slice. This destribution of blocks suggests that at the time of gravity sliding the allochthon extended further west than its present limit, perhaps approximately as far west as the western-most predominance of exotic (non-Austin Glen) blocks in the wildflysch.

The Rysedorph Hill Limestone Conglomerate occurs on the south side of Rysedorph Hill, about 375 meters north of the road-cut. (The exposures are small and difficult to show to a large group; we will not visit them). This famous lithology was studied in detail by Ruedemann because of its apparently unique fauna, ranging from Lower Cambrian to Trenton (see Zen, 1964a, p. 70, for summary of references and interpretations). Zen (1967) discussed the Rysedorph conglomerate in detail and showed that its occurrence, contained faunas, and its carbonate conglomerate character all indicate a syn-gravity sliding origin. We suggest that the Rysedorph and similar lithologies (Stop 6) may have originated in a fringing, carbonate-deposition environment on the leading edge of the Giddings Brook slice, where it was near sea-level (Bird and Zen, in preparation), and also perhaps on slide-block islands that slid off the front of the advancing allochthon into the wildflysch mélange environment. Perhaps Rysedorph Hill was such an island. In any case, the age-span of clasts of the Rysedorph conglomerate, from Lower Cambrian to Trenton, indicates a rock source for the clasts; the black shale (local) and Trenton-age fossil debris in the matrix of the conglomerate and its occurrence within the wildflysch matrix indicate a time of formation synchronous with gravity sliding.

The principal features to observe in the road-cut are the deformational aspects of the blocks and shale, and the size, shape, composition and distribution of the blocks. Note the "injection" of the black shale (mud) into some of the blocks, and the pervasive slatey cleavage of the matrix, and possible slatey cleavage within some of the blocks. (This cleavage is not the upright cleavage of Acadian-age seen throughout the region. It is thought to be either Middle or Late Ordovician age, formed during emplacement of the Giddings Brook slice, or the higher and later slices to the east). Elaterite (anthraxalite), a hardened hydrocarbon thought to be derived from petroleum, occurs in some of the graywacke blocks. Note the ferroan dolomitic (ankerite?) blocks, especially toward the west, on the south side of the road. These might be of a very local syn-gravity sliding facies (see Stop 6 discussion). Going from east to west, the stratigraphically upper portion of the outcrop, which has the usual black shale matrix, passes down-section to the west into green and grey shale having phacoidal slip-surfaces. These surfaces produce the structure known as argille scagliose, or scaley clay that is common in mélanges, both of subduction zones and wildflysch zones of exogeosynclines such as here. Note also the pronounced, laminated and annealed mylonite zones which cross-cut all lithologies of the mélange. These mylonites, which clearly post-date formation of the wildflysch, can be attributed to either the Late Ordovician emplacement of the high Taconic slices to the east which then also affected these rocks, or to the compressive events of the Acadian which superimposed deformation on the Taconic structures in Middle Devonian time.

0.3 Proceed 0.3 miles west along Route 151 and turn left on Sherwood Rd. (Rensselaer County #59).

1.0 Go 0.7 miles southwest to the T intersection of Sherwook Rd. and Routes 9 and 20, at Clinton Heights.

1.9 Turn right onto Routes 9 and 20 and proceed 0.9 miles northwest. Just past the bridge over the railroad, turn right at the sign indicating Castleton and Route 9J. Continue to bear right, going several hundred yards under the bridge and connecting with Route 9J where you bear left (south).

3.1 Follow Route 9J south. At 1.2 miles, outcrop of wildflysch on left (east) at base of hill with large tanks on top.

3.4 Continue 0.3 miles, past a gully, to the next outcrop on left, just opposite an old barn on the right, which is Stop 2 (Fig. 5A).

STOP 2 Wildflysch, Route 9J outcrop, 1.7 miles north of East Greenbush Station.

This road outcrop, recently exposed by the re-routing of Route 9J, is part of a belt that includes several excellent exposures along approximately 2 km of the New York Central Railroad tracks extending north from East Greenbush Station, about 0.3 km east of Route 9J (see East Greenbush 7-1/2 minute Quadrangle). Another similar exposure, having spectacular lithic aspects, occurs on the west side of Papscanee Island at Staats Point along the east shore of the Hudson River, approximately 2.4 km directly south southwest (on the border of the Delmar and East Greenbush 7-1/2 minute Quadrangles) of this stop. Further to the south is the previously mentioned Moordener Kill outcrop. Logistical constraints prevent us from visiting those exposures, although they bear on the discussion of this outcrop.

Most of the aspects of Stop 1 also apply to this stop. Here, however, the wildflysch is typical of that containing exotic clasts. Included are clasts of carbonates that can be referred to the carbonate miogeocline of the autochthon, and Mt. Merino chert, and Poultney(?) shale and limestone of the Giddings Brook slice. Some of the carbonate clasts contain fossils characteristic of Trenton faunules, and are either from the autochthon or the fringing reef environment invoked for the Rysedorph lithologies. A carbonate boulder, about 1.5 meters across, occurs near the central part of the outcrop. Note that the block is deformed internally; some of the carbonate is apparently reefal. Approximately 4 meters to the right (south) is a 10 cm cobble of white quartzite, with carbonate cement. This cobble is reminiscent of West Castleton-Hatch Hill sandstones. Another possible interpretation is that the cobble is of a local sand-carbonate, syn-gravity sliding facies that was disrupted and shed into the wildflysch. (A similar lithology fitting this interpretation occurs at Stop 6).

In addition to the variety of clasts and their shape and distribution, note the severe deformation of the shale matrix and the injection features which indicate soft, water-saturated-sediment conditions during deformation.

Figure 6B is of a portion of the Staats Point exposure (circle, lower left, Fig. 5A), and is included here to show better the aspects of the clasts in this facies of the wildflysch. At Staats Point there are also Trenton fossil-bearing carbonate clasts and one clast containing a Chazy-age faunule (D.W. Fisher, <u>pers</u>. <u>comm</u>., 1970) which lithically match the equivalent limestones in the autochthonous carbonate sequence. This is a significant occurrence because the clasts almost certainly came from the region of eastern carbonate belt (Stockbridge) and yet the Chazy-age fossils have not been reported from there. Ferroan-dolomitic carbonate blocks about 2 to 3 meters long, severely soft-rock-deformed Mt. Merino chert blocks, and chips and blocks of Poultney and Mettawee-like shale also are exposed at Staats Point. Along the contacts of the large carbonate blocks with the wildflysch shale matrix are quartz crystals up to 5 cm long that contain bubbles, now hardened, of what was a black fluid, probably the same as the elaterite seen at Stop 1. It is thought that the elaterite and the quartz crystals there and in many of the wildflysch outcrops, grew during development of the wildflysch under thermal conditions of about 100°-200°C, as the sediment was deformed and dewatered during overriding by the allochthon. No significant regional thermal event has been determined for these rocks or for the Lower Devonian rocks of the Heldebergs. Quartz and calcite mineralization also occurs in the Devonian rocks locally along fault surfaces.

Continue south on Route 9J.

5.1	Hays (Hayes) Rd. (Rensselaer County #58)
6.1	Staats Island Rd. (Staats Point)
8.1	Bridge over Moordener Kill
8.3	Road to Brown Co. paper mill (Moordener Kill wildflysch outcrop)
9.1	Junction with Route 150, in Castleton-on-Hudson
11.0	Berkshire Spur of N.Y.S. Thruway and N.Y. Central Railroad bridge
12.9	Intersection of Rensselaer County Rd. #2 and Route 9J, in Schodack Landing village
13.2	Park Inn Restaurant Bar, excellent wildflysch exposure in back yard; Berry's (1960) original "blocks-in-shale" outcrop (unnumbered circle, Fig. 5B).
14.0	Rensselaer County-Columbia County Line

14.9 Nearly one mile further is an upgrade and bend to the left, with a thin-bedded limestones-in-shale outcrop on the left (east) side of the road, just before the crest of the hill. There is an abandoned schoolhouse on the right side of the road. Just beyond the road-cut, on the left, is a dirt road with a cable barrier. Park at this turn-off, walk east about 75 meters, and then walk left (north) along the railroad tracks. The exposures are Stop 3 (Fig. 5B).

STOP 3 *Nassau and West Castleton Formation rocks*, exposures along the "Castleton cut-off" of the New York Central Railroad.

This stop (Ravena 7-1/2 minute Quadrangle), is the famous "Schodack Locality" of the Giddings Brook slice of the Taconic allochthon. The rocks exposed constitute some of the most significant of the Taconics in terms of the development of Taconic geology. The reader is referred to Theokritoff (1963) and Zen (1964a) for succinct accounts of previous work, regional correlations and the occurrences of the Lower Cambrian *Elliptocephala asaphoides* fauna. See Figure 2 for stratigraphic relations.

Exposures are poor in this region with the exception of those along the ridge overlooking the Hudson River, from here to Poolsburg, about one mile south. Mapping shows that this locality is along the front of the Giddings Brook slice; wildflysch crops out just below the cliff, about 150 meters west of the cut-off tracks. The wildflysch is severely deformed, with inclusions of Mt. Merino chert that apparently were soft when deformed. The overlying allochthonous rocks, as seen in the railroad cut, are only slightly deformed. The bedding dips generally eastward about 30 degrees, not quite parallel to that of the cliff exposures on the west side of Route 9J. The highest beds, at the southeast corner of the railroad-cut are not exposed elsewhere in the area. The following is a description of the section, downward from these uppermost beds which are referred to the West Castleton Formation. The transition to dominantly green-olive shale between units 7 and 6, is the transition zone into the uppermost part of the Nassau (Bull) Formation (Fig. 2). The section is measured downward through older rock in a direction almost due west (with dip correction) to the base of the cliff west of Route 9J.

		Thickness in feet
11.	Shale: black, finely fissile, with some thin siltstone and limestone beds; top not exposed	15+
10.	Massive, coarse sandstone	5
9.	Sandstone, shale, and sandy limestone	5
8.	Sandstone: one bed, in part conglomeratic with small limestone pebbles	3

7.	Shale alternating with sandstone and sandy limestone beds. One bed 13 feet below the top yielded inarticulate brachiopods, possibly including *Botsfordia caelata* (Units 11 through 7 constitute beds referred to by Zen [1964a, p. 75-76] in his discussion of the stratigraphic nomenclature of these rocks)	20
6.	Shale: dark-grey in upper part, grading to green shale near base	30
5.	Limestone pebble conglomerate in sandstone matrix; tapers northeastward and disappears. Better developed (4 feet) on west side of railroad cut. Some of the limestone pebbles aphanitic, blue-grey, weathering light-grey, identical with limestone of underlying unit; other pebbles crystalline, medium-grey, filled with *Elliptocephala* fragments	0-1.5
4.	Green shale, in lower part with nodules of aphanitic, tan-weathering limestone, forming transition to underlying unit	18
3.	Limestone: thin-bedded (1-3 inches), aphanitic, blue-grey, weathering light-grey, of very uniform lithology. Basal beds regularly bedded with thick shale partings, becoming nodular upward, in part brecciated near top. Forms extensive exposures in the cliff below the road for over 0.5 mile	14
2.	Green, silty argillite, weathering to tan slabs. In bottom 10 feet beds and lenses up to 6 inches thick of finely crystalline, light-grey limestone, yielding numerous specimens of inarticulate brachiopods and *Coleoloides*, and more rarely *Hyolithellus*. One large lens of limestone conglomerate occurs in this interval in the southernmost part of the exposures in the cliff between the road and the river shore. The matrix of the conglomerate is a grey limestone filled with quartz granules and pebbles up to a few millimeters in diameter, in places also containing numerous fragments of *Elliptocephala asaphoides* and opercula of *Hyolithellus*	45
1.	Green, finely fissile shale, forming sharp contact with overlying unit. Base nowhere exposed. At the base of the cliff at this locality, this unit rests on the wildflysch containing blocks of the Middle Ordovician Mt. Merino Chert.	60+
	Total thickness of beds exposed in the section	217+

Ford (1884) and Goldring (1943) reported fossils of the Elliptocephala asaphoides fauna from bedded limestone undoubtedly corresponding to unit 5 of the above section. Near its base and top, the conglomerate includes large slabs of crystalline limestone lying parallel to the bedding, and in limited exposures these may simulate beds in place. Careful examination showed that, in fact, all the limestone in this interval occurs in the form of pebbles and blocks. The characteristic, light- to dark-grey, crystalline limestone that contains innumerable fragments of Elliptocephala and other smaller, often better preserved, associated trilobites, seems to be rare as regularly bedded strata, even though it is common in similar conglomerates in Washington, Rensselaer, and northern Columbia counties. Lithically, the matrix of the conglomerate of unit 2 above is similar to some of these conglomerate boulders, even though the matrix contains more quartz pebbles than are usually found in these conglomerates. Ford (1884) reported Serrodiscus speciosus from limestone undoubtedly belonging to unit 3 of the above section on the basis of his descriptions, but the only fossil we (Bird and Rasetti) found in this interval is Hyolithellus.

Thus, the Elliptocephala fauna occurs in place in the lower portion of the Schodack Landing section and ranges through at least 50 feet of strata. Unfortunately, no diagnostic fossils were recovered from the higher units in the section; hence we do not know whether all the beds exposed here belong to the time span of the Elliptocephala fauna, or whether some portion of the beds is the time equivalent of strata carrying younger faunules elsewhere. Lithically, however, the uppermost beds correspond to the West Castleton Formation, that elsewhere (see next stop) also carries the Elliptocephala faunule.

There are several important aspects of this locality for the purposes of our trip. First, because of the faunules found in this section and the fact that the black-green boundary between the West Castleton and Nassau beds is homotaxial throughout the Giddings Brook slice (Theokritoff, 1963) we can take this section as being representative of the fossiliferous base of the Cambrian, and representative of the mapping boundary between the West Castleton and Nassau Formation. The section corresponds in age to the Olenellus-bearing Cheshire Quartzite of the miogeocline (see Fig. 2). Elsewhere, the Mudd Pond Quartzite (see Zen, 1964a) occurs within equivalents of this section. It is a rounded-sand quartzite that is sporadically developed and although not present here, is comparable to unit 10 of the measured section. The Mudd Pond may contain the lowest occurrence of the Olenellid fauna, at Diamond Rock, Troy, New York (see Bird and Rasetti, 1968), because there the quartzite is within Nassau beds that appear, by mapping, to be lower in the section than the lowest fossils found here (unit 2); no Elliptocephala faunas have been found stratigraphically lower.

Second, these exposures are in an overthrust relation with the Normanskill strata of the Hudson Valley. At the base of the cliff is wildflysch which is of the regional belt (see Fig. 1) that everywhere has Zone 13 (Berry, 1960) graptolites. Going away from this contact to anywhere in the Taconic region, the facies of this locality is always found to be overthrust or allochthonous, and can only be tied to the Normanskill Cheshire sequence of the sutochthon via the age-correlation of the Olenellid faunas and not through a conformity of strata. The relations lead to a third aspect, that of the depositional environments that can be determined from the structures and petrology of the strata.

It has been suggested (Bird and Rasetti, 1968; Bird and Dewey, 1970) that these strata accumulated in a rise environment, offshelf from the early-developing miogeocline. The Mudd Pond Quartzite may represent a sand-flush from the shelf of Cheshire sediment. The bedded limestone, such as in units 3 and 4, are apparently carbonate mud turbidites; the conglomerates such as unit 5, may be slump-derived from a bank edge. Commonly, these limestone pebble conglomerates have at least three varieties of limestone clasts, and a rounded-sand matrix, all entirely devoid of a shale component comparable to the surrounding shale beds. Conversely the thin-bedded limestone section (unit 3) appears to have broken up into conglomerate and is an indication of syndepositional slope-instability. Figure 7A, of this unit, shows a limestone slab penetrating another, which is clearly criteria of both soft sediment and different states of induration conditions at the time of formation of the individual slabs. Also, there are a variety of current marks on bedding surfaces and load casts, cross-lamination, and graded bedding, both within regularly bedded strata and in the clasts of the polymict conglomerates, as well as in the thin, boudinaged to chaotically broken calcareous layers. The argillaceous rocks are bioturbated in many places. Various forms of deformed laminae occur within the regularly bedded strata. All these features indicate bottom current activity, deposition from turbidity currents and sediment slumping and slope instability in the environment of deposition of the strata. The carbonate and sand fractions were apparently derived from the correlative sand and carbonate terrains of the miogeocline. Therefore, this facies is taken to be of the early continental rise of the opening (post-graben) stages of the Northern Appalachian-Atlantic Ocean.

Continue south on Route 9J.

17.9 New York Central Railroad overpass

19.6 Village of Stuyvesant and intersection with Route 398

22.2 Intersection with Stuyvesant Falls Rd.-Ferry Rd., in Nutten Hook (Newton Hook)

24.7 At the end of Route 9J, intersection with Route 9, turn right (west) onto deadend, paved road to Judson Point

A. Castleton cutoff

FIG. 7 CAMBRIAN CONGLOMERATES

B. Judson Point

25.7 Descend hill and winding road and bear right at Southers Rd., about half way down the hill

25.9 Road ends at New York Central Railroad main line tracks. Exposures from old building foundation on south of road, over the hill to the railroad are Stop 4 (Fig. 5C).

STOP 4 Nassau and West Castleton-Hatch Hill Formation rocks, Judson Point (Fig. 5C).

This stop is included because strata here extend up-section from those at the Castleton cut-off, and the exposure is perhaps the best of the entire Taconic region in which to study in detail sedimentologic aspects of portions of the proposed continental rise facies. Mapping indicates that this hill is a detached block of the Giddings Brook slice, "floating" in the Forbes Hill Conglomerate or wildflysch zone, in front of the Giddings Brook slice (Fig. 1). The sequence consists of strata ranging from the upper part of the Nassau Formation into undifferentiated West Castleton-Hatch Hill Formation. Dark-grey shale outcrops in the cliff just south and east of the old building foundation pass westward into alternating sandstone, shale, limestone and conglomerate beds for several hundred feet in the cliff-face of the railroad cut. Detailed examination of the sequence shows that there are no significant tectonic breaks or unconformities present. The rocks are remarkably undeformed compared to the wildflysch. The bedding dips uniformly east at 40 degrees; sedimentary structures and unquestionable fauna evidence show the entire sequence to be inverted. The following is a description of the strata in descending order from unit 27 (along the railroad tracks) which is the youngest but geometrically lowest part of the sequence.

		Thickness	
		Feet	Inches
27.	Shale: dark-grey, with some thin-bedded limestone. (Younger beds concealed under railroad tracks)	6+	
26.	Sandstone: one bed	2	
25.	Shale and Sandstone	14	
24.	Shale	2	
23.	Shale and sandstone: the latter partly thick-bedded	11	
22.	Sandstone: massive, tan-weathering, two beds	6	
21.	Shale and sandstone	3	

20.	Shale and sandstone: at top lens of rusty-weathering polymict conglomerate 0 to 1 foot thick	9	
19.	Shale: dark-grey, fissile		7
18.	Shale and interbedded lenses of grey, light-weathering limestone		9
17.	Limestone: one bed, light-grey, sandy, in part rusty weathering, contains: *Pegmatreta* cf. *ophirensis* (Walcott) *Baltagnostus* sp. *Bathyuriscus* sp. *Centropleura* sp. *Hypagnostus parvifrons* (Linnarsson) This fauna is of the Late Middle Cambrian BOLASPIDELLA (North American) faunizone.		3-5
16.	Shale alternating with rusty-weathering siltstone	1	1
15.	Polymict conglomerate, including flat limestone pebbles of different lithic types and some siltstone pebbles, in a coarse, sandy, and calcareous, rusty-weathering matrix. Tapers and disappears southward (Fig. 7B)	0-2	
14.	Shale, siltstone, and limestone: most of the beds rusty-weathering	2	4
13.	Limestone: fine-grained, dark-grey, weathering light-grey, in thin, nodular beds alternating with black shale	1	6
12.	Limestone: silty, on bed		4
11.	Shale and sandstone	2	
10.	Conglomerate of calcareous pebbles in sandy, rusty-weathering matrix. Tapers and disappears northward	0-2	
9.	Sandstone: rusty-weathering, one bed	2	6
8.	Shale and thin-bedded sandstone		3
7.	Sandstone: coarse, thick-bedded, rusty-weathering	8	
6.	Shale and sandstone	3	

5.	Sandstone: coarse, rusty-weathering, with some shale. Unit forms the crest of the railroad cut at the north end	9	6
4.	Sandstone: coarse, thick-bedded, rusty-weathering	3	
3.	Shale and thin-bedded, rusty-weathering sandstone	11	6
2.	Siltstone, weathering to irregular fragments	6	
1.	Shale: dark-grey, in upper part finely fissile, splitting perfectly along bedding planes, grading downward, stratigraphically, to more silty or calcareous shale that breaks with conchoidal fracture approximately parallel to bedding. Continuously exposed for 80 feet, the exposures of lower beds somewhat discontinuous but certainly still representing a sedimentary sequence; about 100 feet below stratigraphic top of unit grades to coarser shale and siltstone, and becomes progressively more olive-green-colored	130+	

Fossils collected in this unit at 30 feet and 38 feet below stratigraphic top in lenses of more calcareous shale, and 80 feet below top in an interval of green shale. Same fauna in all collections:

<u>Hyolithellus</u> sp.
<u>Hyolithes</u> sp.
<u>Obolella</u> sp.
<u>Atops trilineatus</u> (Emmons)
<u>Elliptocephala asaphoides</u> Emmons
<u>Serrodiscus speciosus</u> (Ford)
<u>Rimouskia typica</u> Resser

This fauna is of the Lower Cambrian BONNIA-OLENELLUS (North American) faunizone.

The faunal evidence shows that the rocks of this section range from the upper Lower Cambrian to the upper Middle Cambrian; this is the only exposure of the Taconic sequence known to show the transition from Lower to Middle Cambrian fossiliferous strata. The thickness, representing what must be a long time interval, is surprisingly small, considering that the youngest Middle Cambrian faunule in the area, the <u>Centropleura</u> faunule of unit 17, occurs only 85 feet above the <u>Elliptocephala asaphoides</u> faunules of unit 1 which represents the oldest known Early Cambrian fauna of the Taconic sequence.

Approximately 370 meters to the north-northeast, there is an exposure of fine-grained, thin-bedded, grey limestone in grey shale at the shoreline and in the cliff, on the east side of the pond which is separated from the Hudson River by the New York Central Railroad tracks. Very small, rare, immature trilobites were found in a slightly granular portion of a 5 cm thick limestone bed in the shoreline exposure. The fossils include Richardsonella sp. and Theodenisia sp. which indicate a Late Cambrian, probably Trempealeauian age. The rocks are severely deformed and are, apparently, of another block in the wildflysch. The lithology resembles lower Poultney units, and are similar to exposures on the west shore of the north hill at Nutten Hook, and under the Columbiaville bridge.

Figure 7B is of the conglomerate in unit 15 of the described section. Note the variety of lithologies constituting the clasts in this bed. Some of the clasts are clearly of shallow-water, carbonate-mud environments; some of the sand grains are practically spherical and almost certainly of a beach or aeolian origin. Note that this conglomerate and similar ones further south in the outcrop lack any significant shaley fraction or shale clasts, which suggests loaded or perhaps fluxoturbiditic transport conditions. Many of the beds are composed of cross-laminated sand in a carbonate matrix, and are graded, as typical turbidites.

Bedding-surface strucutres, including "worm tracks", characteristic of turbidites are common on these and other thin calcareous and sandy beds throughout the upper half of the section. Note also that some of the thin-bedded, turbiditic carbonates appear to have reacted with shale, perhaps going from an initial calcitic composition upon deposition, to ferroan dolomitic composition by diagenetic reaction with the more iron-rich shale (mud) of the deeper-water, rise environment. The massive sandstones, containing carbonate clasts, might have been sand-flows from the shelf region.

In addition to the variety of sedimentologic features at this locality, the faunas also indicate these sediments accumulated in an off-shelf, starved-rise environment. As previously mentioned, the section from the Lower Cambrian faunules to the Upper Middle Cambrian is only about 100 feet (30 meters) thick. This is a surprisingly thin amount of sediment accumulation for such a long period of time. It corresponds to several thousand feet of the correlative Cheshire-Monkton-Winooski strata of the autochthonous shelf sequence. Also, the Centropleura-bearing bed (unit 17) is particularly interesting sedimentologically. These Middle Cambrian fossils were found by carefully searching with a hand-lens the weathered surfaces of the beds. The fossils, mostly complete immature forms, are within the grading sequence of the grains of the bed! Apparently the fossils were sorted along with the rest of the sediment during density-current transport from the carbonate environment source, to deposition as a turbidite in this shale environment.

Bird and Theokritoff (1967) originally suggested that most of the faunas of the Cambrian of the Taconic sequence were indigenous to the carbonate deposition environments of the shelf, or miogeocline, and its edge, and that all of the shelly faunas, such as here and at Stop 3, were transported from the shelf via density currents or slides and slumps of sediment (e.g. *Elliptocephala*-fauna bearing clasts in conglomerate), into the deeper-water mud environments. However, here at Judson Point complete specimens of *Serrodiscus speciosus* found in unit 1 of the measured section show no evidence of having been transported. This trilobite and *Atops trilineatus* (Rasetti, 1967), both of the *Elliptocephala asaphoides* fauna, may have adapted to the rise environment and therefore may actually be indigenous (*see* Theokritoff, 1968 for detailed discussion).

Please don't needlessly hammer this outcrop. Practically all the features can be best seen in the weathered surfaces, and as is true in most of the Taconics, good outcrops are hard to come by!

27.1	Turn around and go back to the intersection of Routes 9J and 9. Turn right on Route 9, going south toward Hudson, N.Y.
28.2	Columbiaville Bridge, over Kinderhook Creek
30.3	Stottville intersection, continue south on Route 9
33.1	City of Hudson line
33.3	Turn right on Routes 9 and 23B west
33.8	Junction of Routes 9, 9G, 23B west
33.9	Bear right (west) on Columbia St. and follow signs for Rip Van Winkle Bridge, along Routes 9G and 23B.
34.5	Turn left (south) on South 3rd Street, Routes 9G and 23B
35.2	Railroad tracks. Hill ahead and to right (southwest) is Mt. Merino.
37.4	End of Route 23B, junction of Routes 9G and 23. Outcrop on south side of Route 23 is Stop 5

STOP 5 *Mt. Merino Chert and Shale*, Mt. Merino (Fig. 5D)

The formal name Mount Merino Chert and Shale was proposed by Ruedemann (1942, p. 90) for these rocks. Beds exposed at the north end of Mt. Merino are apparently the type-locality. The Mt. Merino is composed of interbedded shale, siliceous shale and argillite, and green and black chert. It overlies the Indian River Slate of the northern Taconic region (equivalent to Hudson Red and Green Slate of Dale, 1899). Ruedemann and Wilson (1936) studied the "Normanskill cherts", and the older "Deepkill cherts", and concluded that the chert beds were originally accumulations of colloidal silica derived from submarine or continental volcanic activity. They describe radiolarian forms that occur in the chert. Ruedemann (1942), and Ruedemann and Wilson (1936) found that most of the Mt. Merino rocks occur in a NNE-trending belt of the western Taconics (Giddings Brook slice), east of a belt of graywacke and shale (Austin Glen facies). Ruedemann (1942) pointed out that both belts contain graptolite faunas characteristic of the "Lower Dicellograptus Zone", but the two rock assemblages are not interbedded. Ruedemann's only evidence to suggest they might be interbedded are a few exposures of black siliceous shale containing sparse, thin, sandy layers similar to Austin Glen graywacke (Ruedemann, 1942, p. 88). These outcrops, and the faunal evidence are probably what led Ruedemann (1942, p. 88) to construct his Normanskill Formation, being somprised of chert and black shale of the Mt. Merino exposures and the Austin Glen strata. Following this, Berry (1962) studied in detail the faunal assemblages of the various "Normanskill" strata including the Austin Glen and Mount Merino and found graptolite assemblages corresponding with his graptolite zones of the Mariavillas Chert and Shale of the Marathon, Texas, region (Berry, 1960). Berry (1962) also found that many of Ruedemann's "Deepkill cherts" are not Mt. Merino age but are correlative with upper portions of the Poultney Formation of the northern Taconic region, which ranges from Early to Middle Ordovician. The youngest Poultney is Zone 12 in age (unit 4 of Zen's Mt. Hamilton Group, see Zen, 1964a), correlative with the Mt. Merino. Berry then divided the "Normanskill" into four members, equivalent to the Indian River red slate and chert, the Normanskill shale, the Mt. Merino shale and chert, and the Austin Glen graywacke and shale. Bird (1969) discussed these relations in detail and showed that most likely the Indian River-Mt. Merino rocks are the uppermost facies of the Poultney Formation, are entirely allochthonous, and are not a stratigraphic part of the Normanskill rocks (see Fig. 2) of the exogeosyncline into which the Giddings Brook slice was emplaced. More recent mapping, particularly in this region, supports this and shows that the Indian River-Mt. Merino shale and chert facies is in stratigraphic continuity with underlying Poultney (Stuyvesant) strata. Conversely, in the northern Taconic region Zone 12 graptolites have been found in Pawlet Formation graywacke which is locally conformable above the Mt. Merino. Zen (1961) also showed that the Pawlet is unconformable on older rocks of the Giddings Brook slice and pointed out that the Pawlet is equivalent with the Austin Glen facies (Zen, 1964a). Therefore, the graywacke facies spans Zone 12 and 13 time, and its regional distribution and stratigraphic relations show that the facies was syn-tectonic with the emplacement of the Giddings Brook slice (Fig. 3); the Indian River-Mt. Merino chert facies apparently predates the conversion of the shelf-rise couple into the Giddings Brook allochthon/Normanskill exogeosyncline complex.

Essentially, then, whereas Berry's (1962) Members 1, 2 and 3 of his defined Normanskill belong to the Climacograptus bicornis Zone (Zone 12 of the Marathon sequence), only his defined Zone 13 (Orthograptus truncatus var. intermedius Zone) graptolite assemblage has been found in the wildflysch matrix west of the Giddings Brook slice, and in the autochthonous Austin Glen facies. Mapping shows that Members 1, 2 and 3 are either within the Giddings Brook slice or as blocks in the wildflysch. Furthermore, mapping in this region shows Mount Merino and Mount Tom (Mt. Thomas) to the south, to be large blocks within the wildflysch, either as erosional remanents or detached pieces of the Giddings Brook slice (Bird, 1969). It seems clear from these relations that, although they are intimately associated, both with the Giddings Brook slice and in the wildflysch, the Mt. Merino and Austin Glen facies were stratigraphically associated only during initial development of the Giddings Brook slice, in the region off the continental rise.

On the basis of graptolite chronology (Berry, 1963; Harwood and Berry, 1967) the Indian River-Mt. Merino rocks, and the early flysch facies (Pawlet, and some Walloomac) are synchronous with the Ammonoosuc "spilite" facies, east of the Berkshire-Green Mountain anticlinorium. This relation led Bird (1969) and Bird and Dewey (1970) to propose that the sub-Trenton/Black River unconformity of the shelf sequence developed as a respense to initiation of Ammonoosuc volcanism, and that in the off-shelf region the Indian River-Mt. Merino chert facies accumulated from colloidal silica derived from the vulcanism. Ruedemann (1942) concluded that Mt. Merino radiolaria indicate that the cherts accumulated in an abyssal environment, perhaps about 4000 meters deep. Zen (1967, p. 47) proposed such marine conditions for the Poultney and suggested the Timor Trough, adjacent to the Sahoel shelf of Northwestern Australia as a modern analog. Bird and Dewey (1970) proposed that the Ammonoosuc volcanics were of an island arc behind a subduction zone and that the Pawlet-Austin Glen flysch migration which "overwhelmed" the chert environments, was a result of westward-spreading vulcanicity, preceeding and synchronous with the evolution of the Giddings Brook slice (Fig. 4B).

Petrographically, the cherts of the Mt. Merino are found to be complex assemblages of thin laminae enclosing lenses of distinct clastic fragments, rare authigenic minerals, carbonate euhedra, carbonaceous shreds and radiolaria and radiolaria-like forms. Usually the lenses are deformed into planar, streaked-out shapes that indicate pre-lithification, diagenetic alteration of original bedding geometry. The varieties of the laminae include aggregates of non-clastic quartz micro-crystals, less than 0.02 mm and interspersed in brown isotopic material (1.55 RI); fine mosaic quartz less than 0.02 mm; coarse mosaic quartz greater than 0.03 mm; sparse, irregularly bounded, interlocking quartz crystals less than 0.02 mm, all elongate parallel to bedding, forming a "shredded quartz" network; numerous, irregularly bounded, interlocking crystals, less than 0.02 mm, all elongate parallel to bedding, forming a "spongy quartz" network; and felted masses of quartz which form a "semi-continuous quartz" network. Subangular grains of quartz and feldspar less than 0.02 mm in diameter are common; twinned sodic plagioclase is common while microcline and zoned plagioclase are rare. The boundaries of most of the grains are corroded. These grains are definitely clastic; they constitute less than 5 percent of most siliceous laminae. Other clastic grains found include chlorite, augite, hypersthene, garnet, biotite, schlorite, microcline, apatite, rutile, barite, all usually dispersed throughout the laminae. Some laminae contain euhedral to anhedral carbonate grains, 0.02 mm or less, dispersed in the chert. These include calcitic, dolomitic, and ankeritic compositions; the grains are perhaps both authigenic and clastic. Definite clastic and authigenic laminae of carbonate occur. Very fine-grained carbonate occurs in many laminae that are characterized by abundant spherules and rods of chamosite; the groundmass of these laminae is mosaic quartz. Siderite is rare, and occurs as spherulitic nodules surrounded by aggregates of euhedral pyrite and corbonate in a quartz matrix. Pyrite occurs in most laminae; granular aggregates are common in some laminae. The pyrite has selectively replaced larger carbonate euhedra; and some spherulitic forms.

The thin laminae that are outlined by various amounts of the fine-grained clastics (clay, quartz, feldspar), carbonates and sulphides within the textural distinct groundmass of quartz aggregates, both mosaic and felted, are almost certainly primary in origin. The mosaic quartz laminae probably formed from precipitated colloidal silica, while the felted network probably formed beneath or between mosaic quartz laminae, as a result of retarded silica diffusion during early diagenesis (possibly the silica had been adsorbed by clay minerals within the laminae during initial deposition). The authigenic minerals may represent stable mineral assemblages formed as a result of mineral equilibration during deposition, or almost certainly, during diagenesis.

Radiolaria are relatively scarce in the Mt. Merino chert. This, and the petrographic aspects mentioned, indicate that the beds did not accumulate as "radiolarian ooze". Rather it is thought, from both stratigraphic and petrographic aspects, that the beds accumulated relatively rapidly compared with computed rates of deposition of radiolarian ooze (0.5 to 1.0 cm/1000 years, equal to 0.17 to 0.33 cm of dry sediment, Strakhov, 1962). Radiolaria usually occur as lenses of radiolarian tests, within radiolaria-free beds, suggesting that radiolaria may have been abundant only near the ocean surface or at moderate depths. (Some of the lenses are xenolithic in the chert and may have agglomerated at or near the sea-surface and then fallen as clasts into the colloidal silica on the sea-floor).

This outcrop is fairly typical of the Mt. Merino Chert and Shale in this region. The chert beds are usually less than 0.6 meter thick, and most commonly, are less than 10 cm. The shaley partings are usually less than 5 cm. The thickest known sequence, about 38 meters, is at Fly Summit, Washington County. Berry (1962) estimated the total thickness of the Mt. Merino units to be 150 to 230 meters thick. More recent mapping shows the thickness to be less than 75 meters in the Giddings Brook slice. The color here i also typical.

Zone 12 graptolites have been found in this outcrop (identification by Berry, pers. comm. to Bird, 1969).

Note the fault contact of the chert beds with the Austin Glen graywacke and shale strata, about 2/3rds west from the eastern end of the outcrop. The graywacke and shale may also be a block in the wildflysch, which outcrops further west along the highway, near the junction of Routes 23 and 9J, before the Rip Van Winkle Bridge. Also, see the exposure just to the north on 9J; Stop 2 of trip A1, this guidebook.

37.8 Continue southwest on Routes 23 and 9G and turn left (south) at 9G and 23 intersection. Churchs Hill on left (south).

39.2 Follow Route 9G to intersection with Columbia County Road #13

39.4 Turn left onto #13 and proceed east to road-cut, which is Stop 6 (Fig. 5D)

STOP 6 Burden iron ore, south end of Cedar Hill

This outcrop is within the southern-most of the several ridges extending south from Churchs Hill, just south of Stop 5 (see Hudson South 7-1/2 minute Quadrangle). On the basis of detailed mapping it is thought that the several hills of the area are either on-strike separate blocks, or of the same block that constitutes Mt. Merino, within the wildflysch. The outcrop is comprised of ferruginous quartzite, and carbonate beds and argillite, part of the sequence of sideritic and limonitic Burden iron-ore strata that were mined in these hills, and especially at Mt. Tom to the south, in the late 1800's.

Ruedemann (1931, 1942) discussed in detail the origin of the Burden iron ore. He indicated (1931) that the ore was indigenous to Austin Glen strata ("Normanskill grit"), resulting from the contemporaneous alteration of magnetite sand with the calcareous matrix of the "grit", to form siderite; the siderite was then altered to limonite. Magnetite (and pyrite) have not been found in Burden iron ore-bearing strata. Later, he (1942) indicated the Burden iron occurs between the "Nassau" and "Schodack Formations" (this would correspond to the lower and middle beds of the section at Stop 4, Judson Point). He suggested that the rocks might have been structurally dislocated from the Copake region 22 km to the east, where similar ores occur. Ruedemann (1942) cites field and petrographic evidence that shows that the Burden ores were deposited as sediments, contemporaneously with the bounding strata. The ores are restricted to the crests of the various local hills.

We have selected this stop because the Burden iron ore remains as one of the more interesting unsolved geologic problems of the Taconics. Our preliminary results of the study of these rocks suggests an alternative explanation of origin for the iron ores. It is possible that the ferruginous quartzite and carbonate beds, and local carbonate and sand conglomerate, originated in a fringing reef and shore environment where the upper portions of the supposed slide-blocks in the wildflysch were exposed as islands in the Normanskill sea. Such an environment would produce quartz and carbonate sand, and conglomerates, along the slopes of the blocks. Possibly, the ferruginous carbonates formed by reaction of carbonate precipitates with the iron-rich, deep-water facies sediments of the allochthonous blocks. It is interesting to note that the ferruginous carbonate blocks seen in the wildflysch at Stop 1 are very similar to carbonate beds exposed here. Also, the Austin Glen facies is quite carbonate-rich in the region west of these hills. Perhaps some of the enigmatic carbonate conglomerates of the wildflysch, such as the Rysedorph, also had their origins in carbonate-reef and shore environments of moving islands of separated blocks in front of, and on tectonic salients along the leading edge of the advancing Giddings Brook slice.

End of road log.

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