FLYSCH AND MOLASSE OF THE CLASSICAL TACONIC AND ACADIAN OROGENIES: MODELS FOR SUBSURFACE RESERVOIR SETTINGS

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ABSTRACT

This field trip will examine classical sections of the Appalachians including Cambro-Ordovician basin-margin and basin-slope facies (flysch) of the Taconics and braided and meandering stream deposits (molasse) of the Catskills. The deep-water settings are part of the Taconic sequence. These rocks include massive sandstones of excellent reservoir quality that serve as models for oil and gas exploration. With their feet, participants may straddle the classical Logan's (or Emmon's) line thrust plane. The stream deposits are Middle to Upper Devonian rocks of the Catskill Mountains which resulted from the Acadian Orogeny, where the world's oldest and largest freshwater clams can be found in the world's oldest back-swamp fluvial facies. These fluvial deposits make excellent models for comparable subsurface reservoir settings.

INTRODUCTION

This trip will be in two parts: (1) a field study of deep-water facies (flysch) of the Taconics, and (2) a field study of braided- and meandering-stream deposits (molasse) of the Catskills. The rocks of the Taconics have been debated for more than 150 years and need to be explained in detail before the field stops make sense to the uninitiated. Therefore several pages of background on these deposits precede the itinerary. The Catskills, however, do not need this kind of orientation, hence after the Taconics (flysch) itinerary, the field stops for the Catskills follow immediately without an insertion of background information.

FLYSCH OF THE TACONICS

The first part of this field trip will examine classical sections of the Appalachians, specifically Cambro-Ordovician basin margin and basin slope facies of the Taconic sequences of rocks generally known as flysch. The term flysch is a corruption of the German verb *fliessen*, which means to *flow*. This term was applied because the outcropping parts of the shaley flysch in Austria were especially prone to slope failures. The strata named flysch are *a thick succession of marine sedimentary strata consisting of repetitively interbedded alternating and laterally persistent sands (and/or coarser sediments) and shales found in the interior of a fold-mountain chain.* These deep-water deposits are part of the Taconic Sequence (Fig.1). The term Taconic Sequence refers to basin strata correlative with various formations of the shelf (pericontinental) strata assigned to the Sauk Sequence and lower part of the Tippecanoe Sequence which spread across New York (Sloss, 1963; Guo, Sanders and Friedman, 1990) (Fig. 1).

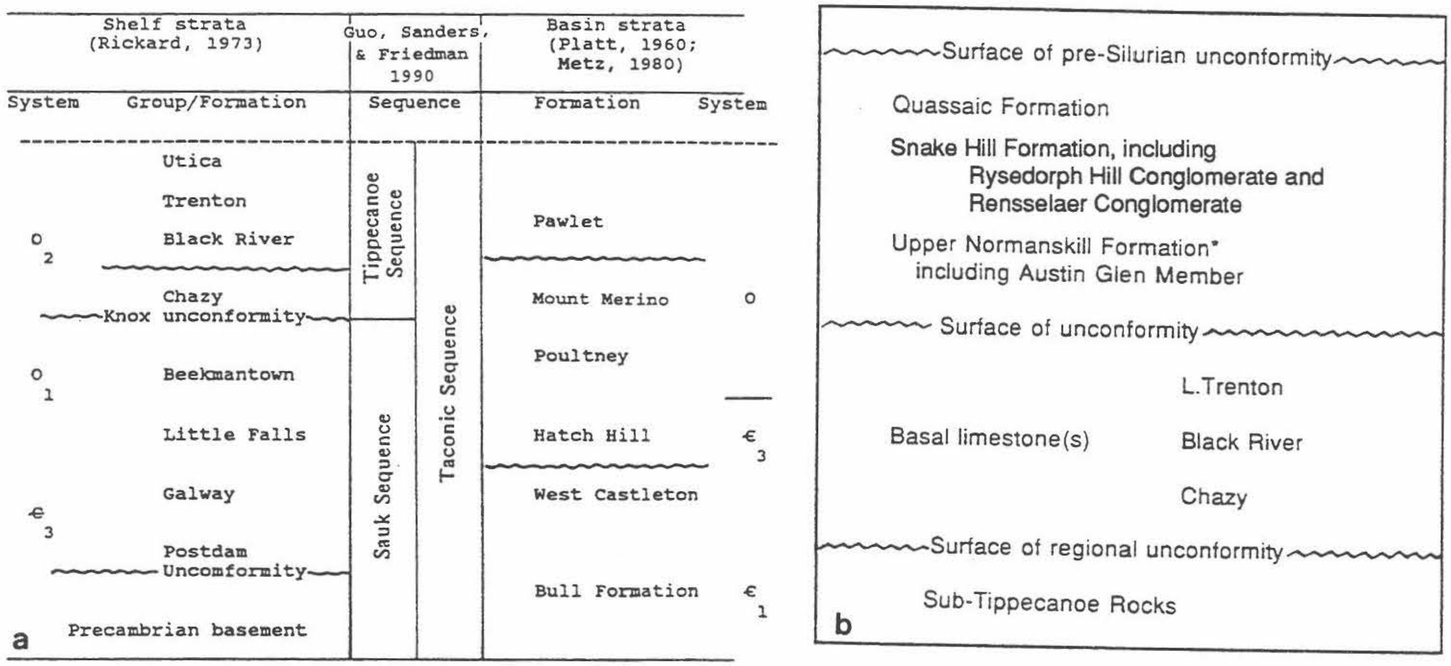
The Appalachian Basin is a multi-stage foreland basin. A foreland basin is defined as a *sedimentary basin located between the front of a mountain range and the adjacent craton, and related to overthrusting at the convergent plate margin (Friedman, Sanders, and Kopaska-Merkel, 1992).* Thrusting is the active basin-forming mechanism.

The rocks of the Taconic Sequence are part of the Taconic allochthon, a remnant of an accretionary prism that includes latest Precambrian (?) -Early Cambrian rift facies and overlying Cambrian through early Middle Ordovician passive margin, deep-water sedimentary rocks. This sequence was pushed westward at least 30 km onto the foundered autochthonous platform during the Middle Ordovician Taconic orogeny (Jacobi, 1981; Rowley and Kidd, 1981).

While deposition of shallow-water carbonate sediments was going on in a shelf or pericontinental sea throughout New York State, in a direction that during the Early Paleozoic was south, but is now east, deposition of both terrigenous and carbonate, but for the most part terrigenous sediment, was taking place in a slope-rise environment (Friedman, 1972;1979;

In Garver, J.I., and Smith, J.A. (editors), Field Trips for the 67th annual meeting of the New York State Geological Association, Union College, Schenectady NY, 1995, p. 109-143.

Friedman, Sanders, and Martini, 1982). The shelf-edge setting was that of a passive margin which the Taconic tectonic event terminated. This event began in early Middle Ordovician times and lasted through the early Silurian. It involved collision of the North American continental margin with a belt of oceanic island arcs above an east-southeast dipping subduction zone (Rowley and Kidd, 1981; Hiscott et al., 1986)(Figs. 2, 3).



Shelf strata (Rickard, 1973)		Guo, Sanders, & Friedman 1990		Basin strata (Platt, 1960; Metz, 1980)	
System	Group/Formation	Sequence		Formation	System
	Utica	Tippecanoe Sequence			
	Trenton			Pawlet	
O_2	Black River				
	Chazy		Taconic Sequence	Mount Merino	O
	Knox unconformity				
O_1	Beekmantown	Sauk Sequence		Poultney	
	Little Falls			Hatch Hill	$€_3$
	Galway			West Castleton	
$€_3$	Postdam				
	Uncomformity			Bull Formation	$€_1$
	Precambrian basement				

Surface of pre-Silurian unconformity

Quassaic Formation

Snake Hill Formation, including
Rysedorph Hill Conglomerate and
Rensselaer Conglomerate

Upper Normanskill Formation*
including Austin Glen Member

Surface of unconformity

	L.Trenton
Basal limestone(s)	Black River
	Chazy

Surface of regional unconformity

Sub-Tippecanoe Rocks

Figure 1. (a) Stratigraphy of Cambro-Ordovician in northern New York State (after Guo, Sanders, and Friedman, 1990). (b) Names of formations in Tippecanoe Sequence, eastern New York State (modified from Sanders, 1995).

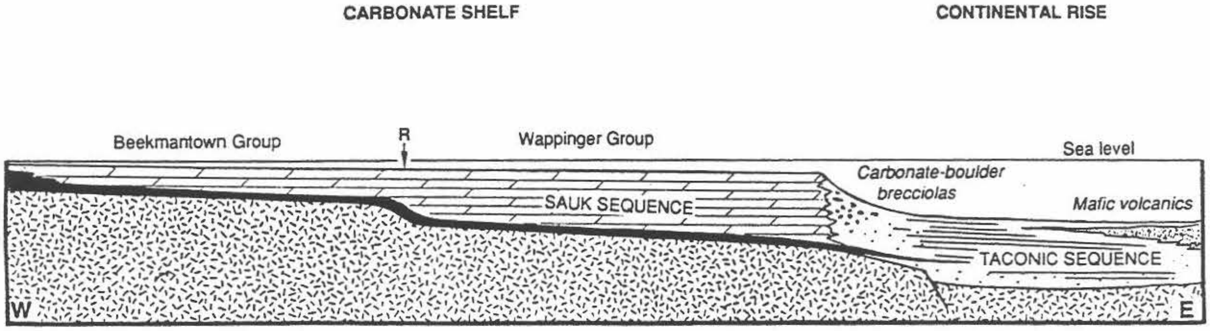


Figure 2. Reconstructed paleogeomorphologic profile-section across the Early Paleozoic passive margin in North America. Short line segments in random pattern, Precambrian basement; black basal quartzose sandstone (Upper Cambrian Potsdam on the W and Lower Cambrian Poughquag on the E). Dolostone pattern for Sauk Sequence includes limestones (now calcite marbles) on the seaward part of the former carbonate shelf (modern E; Early Paleozoic S) (Friedman, Sanders, and Guo, 1993).

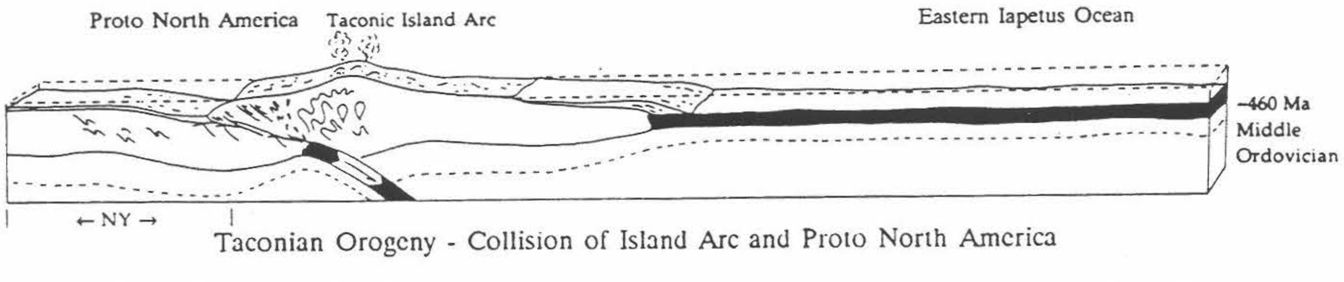


Figure 3. Block diagram showing the collision between the North American platform and island arc. This collision is the Taconic Orogeny (Ysachsen et al., 1991).

The stratigraphy of the northern Taconic sequence is shown in Figure 1. Previous workers considered the Cambrian interval which we shall study in the field as West Castleton Formation (Fig. 1)(Bird and Rasetti, 1968; Keith and Friedman, 1977; Friedman, Sanders, and Martini, 1982), but this formation is now mapped as part of the Hatch Hill Formation (Fisher, 1984; Landing, 1993). The rocks are part of the structurally lowest, youngest, less deformed and least metamorphosed Giddings Brook slice of the Taconic allochthon.

Between Early Cambrian and Early Ordovician times the shelf to basin transition was east of Rutland, Vermont. Tectonic movements shoved Cambrian and Ordovician rocks of slope, rise and basin facies across the shelf facies so that today the exposures at and near Troy, New York, are basin or basin margin (rise facies with shelf facies of Cambrian and Ordovician age occurring to the west) (Friedman, 1972) (Figs. 4 , 5).

During Cambrian-Ordovician time, most of the North American continent was a shallow epeiric or epicontinental sea, like the present-day Bahama Bank, now often referred to as the Great American Bank. At the eastern edge of this shallow sea, that is at the eastern edge of this continent, a relatively steep slope existed down which terrigenous and carbonate sediment moved by slides, slumps, turbidity currents, mud flows, and sandfalls to oceanic depths to come to rest at the deep-water basin margin (rise), where a shale facies was deposited (Sanders and Friedman, 1967; Friedman, 1972, 1979; Keith and Friedman, 1977, 1978; Friedman and Sanders, 1978; Friedman, Sanders, and Martini, 1982). Shale also formed much of the basinal facies in the deep water beyond. Because allochthonous transport has been inferred for large blocks of rocks presently exposed in and near Troy, where our field study begins, the evidence on the ground shows that the area is the site of Cambrian and Early Ordovician rocks of basin margin (rise) and deep basin facies [shales deposited in the Middle Ordovician (Schenectady) west of Troy are autochthonous basin facies]. Thus deep-water basin margin (rise) and basinal facies can be visited in and near Troy, whereas to the west carbonate shelf facies are exposed that are analogous to those of the west shore of Andros Island on the Great Bahama Bank (Fig. 5). The paleoslope was probably an active hinge line between the continent to the west and the deep ocean to the east, similar to the Jurassic hinge line of the eastern Mediterranean between carbonate shelf facies and deep-water shales (Friedman, Barzel, and Derin, 1971). Such hinge lines in the early geosynclinal history of mountain belts are fixed by contemporaneous down-to-basin normal faulting (Rodgers, 1968, quoting Truempy, 1960), as probably occurred with the rocks in the Troy area. Later thrusting to lift the deep-water facies across the shelf facies along hinge-line faults resulted in the contiguity of the two facies. This later displacement was so great that the Cambrian and Early Ordovician deep-water sediments were shifted far west of their basin margin. The original basin margin (rise) was located near the present site of the Green Mountain axis.

Preceding plate collision, as the continental margin approached the subduction zone, the seaward part of the carbonate shelf floundered, probably due to "normal faulting caused by plate flexure with down bending" (Hiscott et al., 1986). As

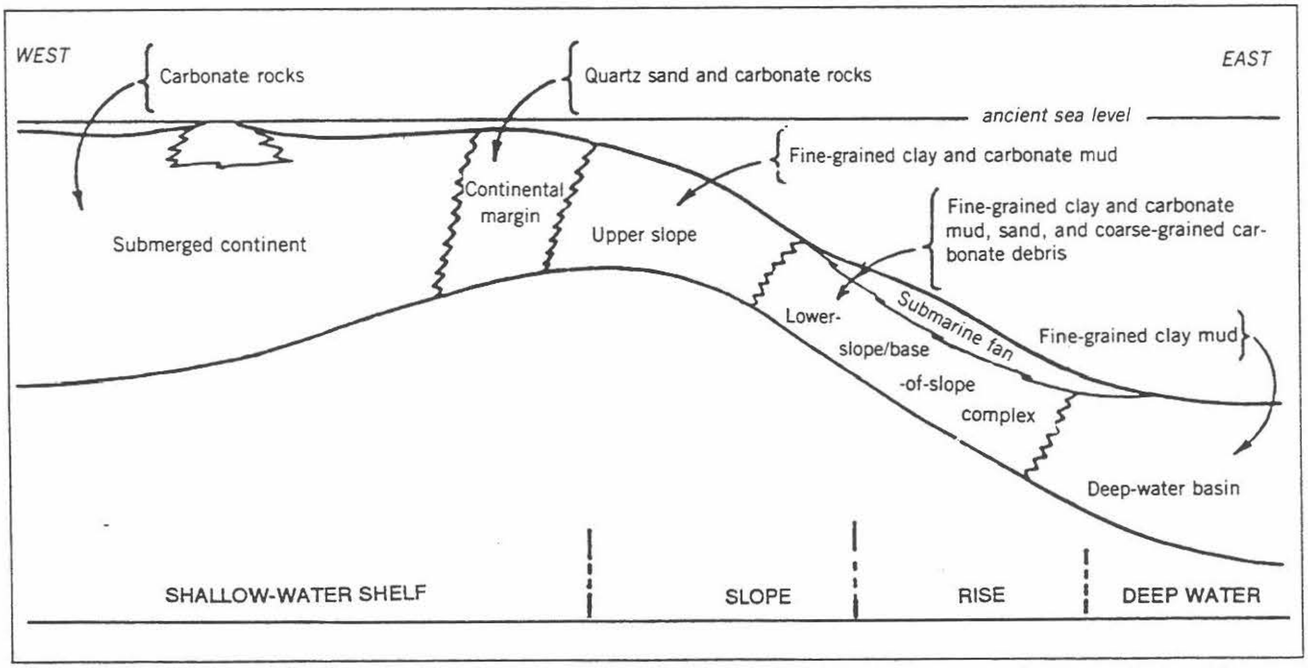


Figure 4. Schematic profile from basin margin to shelf showing depositional environments and characteristic sediments for Proto-Atlantic (Iapetus) Ocean during the Early Paleozoic (after Keith and Friedman, 1977; Friedman,1979; Friedman, Sanders, and Kopaska-Merkel, 1992).

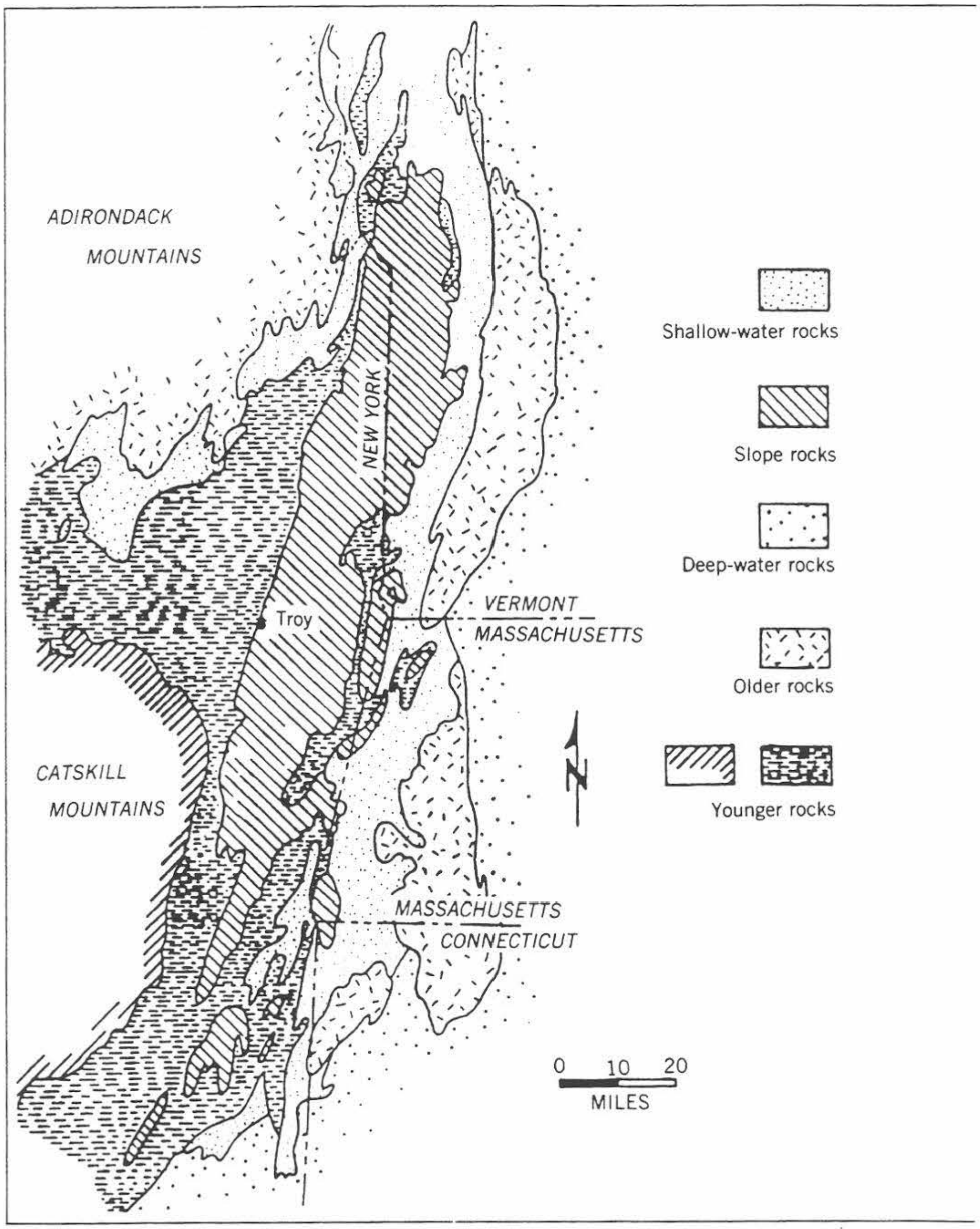


Figure 5. Generalized geologic map of Taconic area showing general rock types of Sauk and Taconic Sequence (Fig. 1). The fine stipple shows shallow-water rocks from the submerged continent, coarse stipple shows deep-water rocks from the ocean basin, and diagonal lines show rocks from slope and rise. The older rocks shown on map are Precambrian and the younger rocks are part of the Silurian-Devonian Catskill Complex (after Keith and Friedman, 1977; Friedman, 1988b).

convergence continued, stacked thrust-sheets overrode the outer parts of the continental terrace and resulted in rapid flexural downwarping of the ancestral continental slope and rise (Price and Hatcher, 1983; Quinlan and Beaumont, 1984; Tankard, 1986). The downwarped continental margin bounded on the oceanic side by the rising Taconic orogenic belt created the elongate Appalachian foreland basin (Fig. 3).

As already explained, the strata of deep-water setting are part of the Taconic Sequence (Fig.1). These rocks have received the attention of geologists for more than 150 years, and because of their exceedingly complex structural and stratigraphic relations have been the object of considerable debate. In fact, approximately 150 years ago Ebenezer Emmons' (1799-1863) advocacy of the Taconic System (1842, 1844, 1848, 1855) and the division of thought on this problem resulted in the famous duel between James Hall (1811-1898) and Emmons which ultimately forced Emmons to leave New York State. A court decision involving several of the most well-known geologists of the last century assured Hall's victory byforcing Emmons out of New York; he settled in North Carolina, where he became state geologist, away from his Taconic rocks. A field view of

Emmons' classical book on his beloved Taconic Mountains is shown in Figure 6. Ironically, in death Hall and Emmons were reunited. They are buried almost next to each other in the Albany Rural Cemetery.

Strata of the Taconic Sequence extend from north to south approximately 150 miles (Fig. 5), and for the most part within New York State are composed of shales and sandstones. Carbonate rocks are minor by comparison, but are important as they reflect depositional conditions. Although the stratigraphy and tectonics of the area have been the subject of considerable controversy (a debate that has become known as the "Taconic Problem"), stratigraphic succession and structure have more recently been clarified (Zen, 1967; Bird and Rasetti, 1968; Rowley and Kidd, 1981; Friedman, Sanders, and Martini, 1982; Isachsen et al., 1991).

Environmental reconstruction for the Cambrian part of the Taconic Sequence in eastern New York State indicates a depositional environment analogous with a modern continental rise or more specifically with a slope-fan-basin-plain model (Fig. 4) (Keith and Friedman, 1977, 1978). Terrigeous and carbonate sediment was removed from the Cambrian shelf and deposited with muds of the slope, now slates and siltstones, by a variety of processes at work on the slope and within submarine canyons. In addition, carbonates accumulated on the slopes. These sediments can be divided into seven main lithofacies, each bearing the imprint of the principal process or processes involved in its deposition. These include: (1) microcrystalline or cryptocrystalline limestone (micrite, a lithified marine carbonate deposit); (2) carbonate-sandstone clast conglomerates (inferred products of debris flow), (3) blocks of bedrock (olistoliths); (4) massive, coarse sandstones (apparent deposits of liquefied cohesionless particle flow), (5) graded sandstones (presumed turbidites), (6) parallel-laminated sandstones (probable turbidites), and (7) current-ripple-laminated sandstones (thought to be the products of reworking by contour-following bottom currents or submarine overbank levee deposits). All of these processes were working together or in opposition. Analysis indicates that only the lower slope and base-of-slope portion of the early Paleozoic continental margin has been preserved in the Taconic Sequence (Keith and Friedman, 1977, 1978). We shall discuss these lithofacies.

Microcrystalline or Cryptocrystalline Limestone (Micrite)

This lithofacies is composed of beds of dense, texturally simple, peloidal, intraclastic microcrystalline or cryptocrystalline limestone resembling micrite that in thin section locally shows neomorphism, where the original cement has become recrystallized. Beds of this lithofacies are found at several of the sections to be seen on this field trip and comprise a significant amount (approximately 20%) of all the lithofacies south of Schodack Landing. Single and multiple beds are found interbedded with beds of shale (Fig. 7). These beds show some pull-apart or boudinage structure and, locally, slump folds.

This peloidal and intraclastic microcrystalline or cryptocrystalline limestone resembling micrite is widely considered to be the most common kind of carbonate deposit in both modern and ancient submarine environments and originates as magnesian calcite (Friedman, 1964; Ginsburg et al., 1971; Alexandersson, 1972; Schroeder, 1973; Friedman et al., 1974; MacInyre, 1977, 1985; Longman, 1980; Stentoft, 1994; Friedman, 1985, 1995; Reitner et al., 1995). Peloids are ubiquitous throughout. This fabric was precipitated as a submarine cement and not deposited mechanically as a lime mud (Friedman,

Figure 6. View of Taconic Mountains in Ebenezer Emmons' classical book on the Taconics (1843; p.75). It is labeled "part of the Taconic Range from Stone Hill". (By Nancy A. Payzant, adapted from lithograph by Ebenezer Emmons *in* Friedman, 1988b).

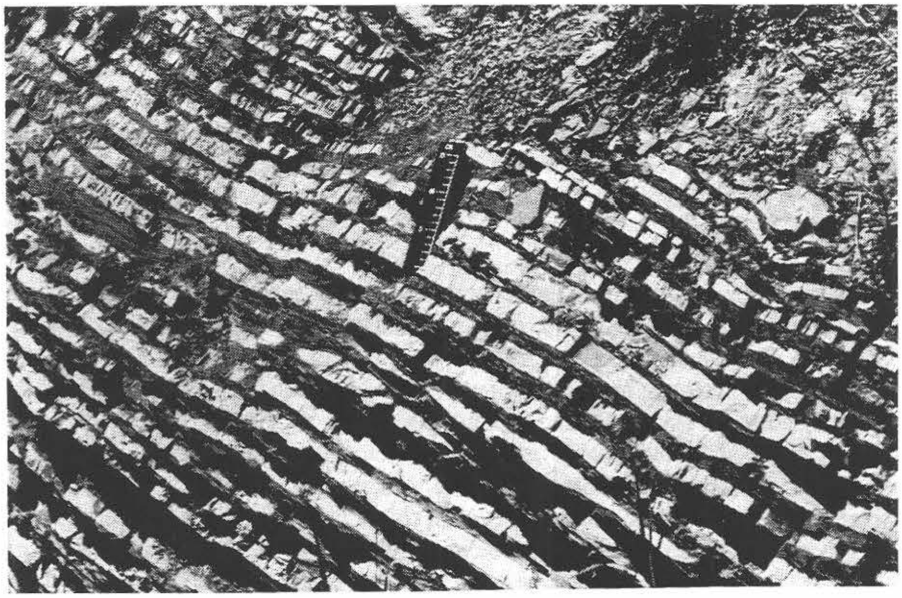


Figure 7. Field photograph of cycles of alternating microcrystalline or cryptocrystalline limestone (micrite) and calcareous shale of the Hatch Hill Formation of the northern Taconics of eastern New York, south of Hudson, N.Y. (Stop 9).

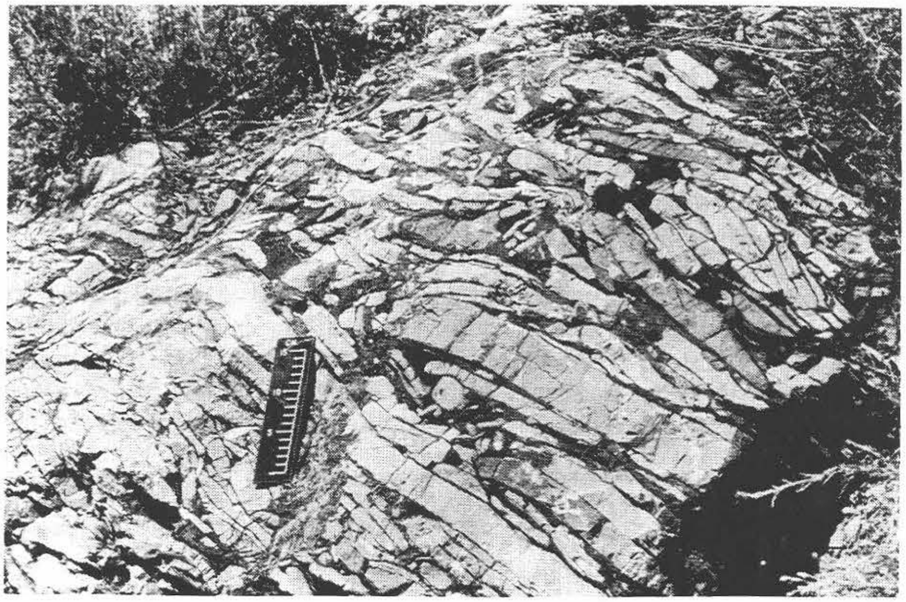


Figure 8. Carbonate-clast conglomerate of shallow-water origin displaced by debris flow from shelf margin into deep water. Hatch Hill Formation (Cambrian) south of Hudson, N.Y. (Stop 9).

1985). In places a bed will contain fossil fragments. Modern analogues for such carbonate deposits are lithified carbonate sediments of Atlantis Seamount, Mid-Atlantic Ridge (Friedman, 1964) and steep slope limestones of the Tongue of the Ocean, Bahamas (Grammar et al., 1993). These deposits are analogous to those of steeply dipping slope deposits documented from the fossil record. Carbonate slopes from the Permian of west Texas and New Mexico (Yurewicz, 1977; Ward et al., 1986; Garber et al., 1989), the Lower Ordovician of Utah (Wilson et al., 1992), the Devonian of Western Australia (Playford, 1980; Playford et al., 1989), the Triassic Dolomites of northern Italy (Bosellini, 1984; Harris, 1988), the Cretaceous of east-central Mexico (Enos, 1986), and the Miocene of the Gulf of Suez (Haddad et al., 1984) all exhibit primary depositional slopes of 30-40°. In addition to slope declivity, the geometry and thickness of beds as well as the dominant texture of the slope deposits in the Tongue of the Ocean, Bahamas, are also similar to these ancient examples (Grammar et al., 1993). Steep-slope profiles similar to those observed in outcrop are also frequently observed in seismic profiles from ancient carbonate platforms in the subsurface (e. g. Sarg, 1988).

By analogy with both modern and ancient submarine carbonate facies cited above, these limestones are interpreted as deposits that cemented in place on a steep slope. The correlative sediments on the shelf were sands and muds, not carbonate sediments, because where beds of these cemented carbonate slope deposits broke up clay or sand, now sandstone and shale, are wedged between the breaking-up slabs.

Carbonate-Sandstone Clast Conglomerate (Figs. 8-11)

Monomictic carbonate to polymictic carbonate-sandstone conglomerates occur throughout the Taconic Sequence; a significant percentage of sand particles or clay may be present in some beds (Figs. 8, 9). The carbonate clasts are the most common; they have a general preferred orientation parallel to the bed boundaries, where they are exposed, but some clasts in a bed are oriented up to 90° to the general trend.

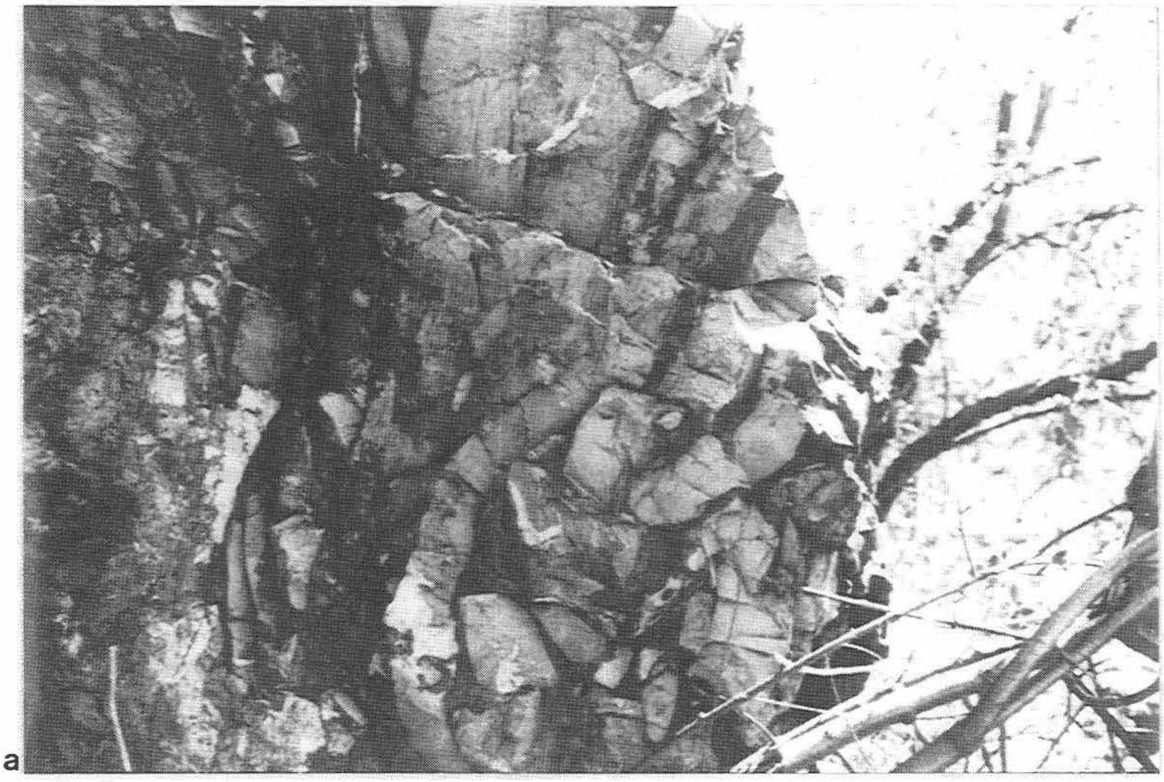
The shape of the clasts ranges from irregular to tabular and from angular to rounded. Some elongated clasts are bent (Fig. 10). The fragments show considerable variation in size, up to 60 cm thick and 240 cm long. *Deposits composed of rubble of carbonate rocks, usually angular, interstratified with dark-colored shale* are known as **brecciolas.** The brecciolas have been interpreted as products of turbidity currents, gravity slides, and debris flows. Such brecciolas formed along hundreds of kilometers of the original eastern edge of the carbonate shelf. They mark the former margin of the basin during the Cambrian and Lower Ordovician periods. Slides, slumps, turbidity currents, mudflows, and sand falls moved down the steep unstable slope beyond the shelf edge. Brecciolas and other gravity-displaced deposits can originate at the shelf margin or in deeper water on the slope.

Large clasts occur as slabs and consist of laminated to bedded finely textured limestone. The alignment of long axes of clasts with bedding planes (Fig. 8) suggests laminar flow conditions typical of plastic debris flows. In places coarse heavy blocks or slabs accumulated near the base of a debris flow and smaller lighter fragments at its top (Fig. 11). Such a slump deposit, showing graded bedding which may be 2 to 3 m thick, may have accumulated in a few hours. Figure 11 shows such a brecciola deposit which is about 1.2 to 1.5 m thick that accumulated probably in a matter of hours, whereas the overlying sediment of comparable thickness took thousands of years or even longer to accumulate. The contrast in timing between the two kinds of flow is extraordinary.

Some of the conglomerates are parts of turbidite beds 3 m thick in which the matrix at the base is coarse sand and the top of the bed is fine-textured shaly matrix.

In contrast to the relative calm of the deep water to the east and the high-energy shallow water to the west, the steep slopes of the continental margin were subjected to periodic violent activity. Sediments building on the edge of the continent or on the slope sometimes broke loose; the resulting slumps sent debris cascading down the steep slopes to form fans of coarse rock fragments. The debris moved with tremendous force; we know from modern ocean studies that catastrophic subsea avalanches can pack a tremendous wallop, flowing with extraordinary speed down the slopes and through submarine canyons.

Figure 9. Rubble of incoherent slump or debris flow composed of boulders of limestone, sandstone, and chert. This rubble, known as brecciola, originated in shallow water behind shelf edge and was displaced into deep-water, dark-colored shales. Note calcite-healed fractures in view. Boulder in center is approx. 30 cm across. Hatch Hill Formation (Cambrian), Campus of Rensselaer Polytechnic Institute (Stop 1).



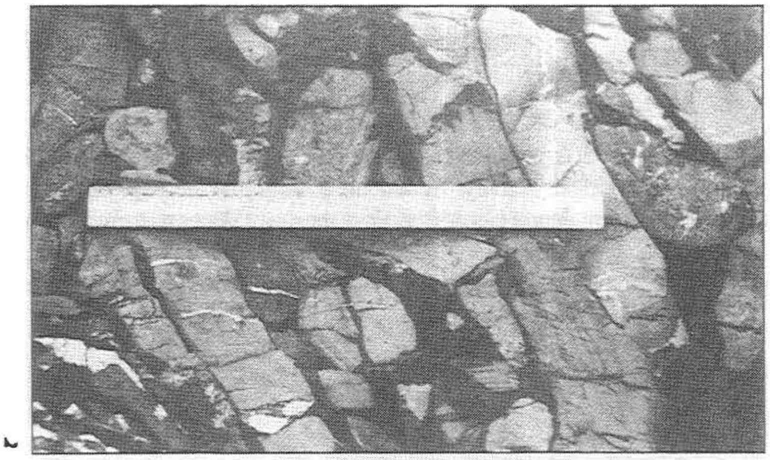


Figure 10 a,b. Slump rubble of skeletal and pelletal limestone (micrite) resembling breccia displaced into deep-water, dark-colored shale. This limestone rubble is known as brecciola. Note that tabular slabs have been bent and twisted. Slab in upper middle view of photograph Fig. 10a is 30 cm thick. Bent slab in lower middle of same photograph is 1 m long and 5 cm thick. Hatch Hill Formation (Cambrian), Troy, N.Y. (Stop 2).

The recognition of a debris-flow model for many of these conglomerates having a lack of organized internal structure has become well established (Fraser, 1989; Friedman et al., 1992; Savage, 1984). A **debris flow** is defined as a *flowing muddy mixture of water and fine particles that supports and transports abundant coarser particles* (Friedman, et al., 1992, p. 236).

Such a model does fit well with the large clasts in a clay matrix. The range of composition of the clasts can be easily accounted for, as being derived from the shelf buildup, or the basin-margin or slope beds. Some conglomerates appear to be quite local in origin, and interbedded with beds similar to the source beds for the clasts, which also seems compatible with a debris-flow model. The upward decrease in clast size in some beds (Fig. 11), with the pervasive preferred orientation and local imbrication, indicate movement and settling of the individual clasts within the flow. The matrix of some beds is typically graded: the base of the flow in which large clasts and slabs were transported consists of coarse quartz sand, whereas that of the top of the flow is clay. Hence these beds are turbidite rather than debris-flow deposits.

It is not clear whether the conglomerates of the Taconic Sequence were deposited as sheets or were confined to channels. Some of the conglomerates are associated with turbidites, which are generally considered to be confined to submarine canyons or to channels on a submarine fan. Thus, these conglomerates might have been similarly confined.

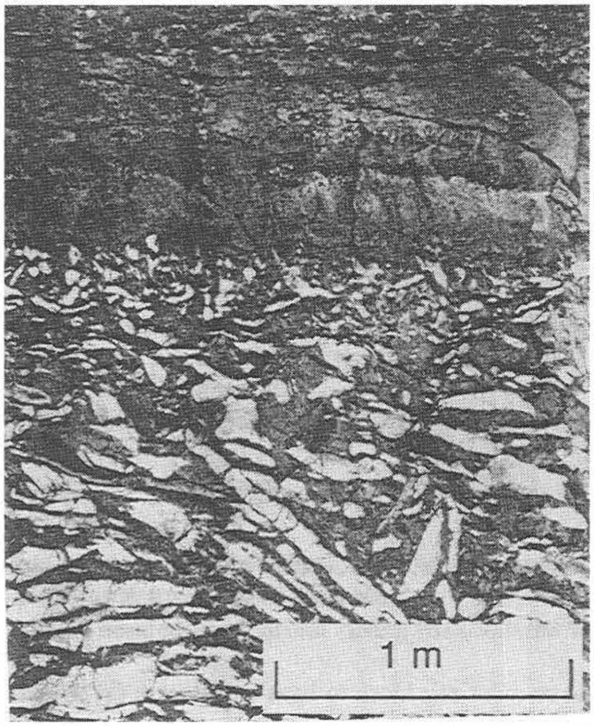


Figure 11. Graded layer of brecciola. The overlying strata took far longer to form than did the slump which may have accumulated in a few hours. Hatch Hill Formation (Cambrian) about 16 km south of Troy, New York, (Stop 7).

In places hummocky strata of brecciolas overlie regularly bedded microcrystalline or cryptocrystalline limestones (micrite)(Friedman and Sanders, 1995).

To break up beds of cemented slope deposits into slabs, some of which are a least 60 cm wide and up to several meters long, but most of which are only 20 to 40 cm long, takes a lot of force. These brecciolas are event deposits that record episodic erosion and deposition of coarse clasts by intense flows that must have involved substantial removal of cemented slope deposits. One mechanism may have been earthquake shocks which triggered tsunamis. The hummocky strata of brecciolas suggest a possible tsunami origin. Storm deposits, likely to be tsunamis, are widespread in Sauk deposits across the entire margin of the Sauk carbonate bank including China (Chuanmao et al., 1993) and Australia (Mount and Kidder, 1993), the Mid-Continent(Carozzi, 1989; Marsaglia and Klein, 1983), western Canada sedimentary basin (BrianTuffs, personal communication), as well as more locally in Vermont, New York, and elsewhere in the Appalachians (Sepkoski, 1982; Whisonant, 1987; Pollock, 1989; Friedman, 1994), and along the western margin of the Sauk North American platform in Nevada (Cook and Taylor, 1977). Such a worldwide episodic event at the end of the Cambrian may even mark a meteorite impact. To break down such a tough, cemented rock at a water depth of up to several kilometers may require an energy level of a meteorite impact. Under the petrographic microscope I looked for microscopic lamellar deformation features in quartz that identify shock-generated events, such as meteorite impact (Alexopoulos et al., 1988). Almost all quartz particles were clear and devoid of such features, however two particles displayed well-defined and continuous planar features suggestive of shock metamorphism. However, such features may have been inherited from a previous geologic cycle, hence whether meteorite impact or earthquakes were responsible for the break-up of the bedded deposits into blocks, slabs, and other rubble is at this stage equivocal.

Olistoliths

Olistoliths are defined *as large blocks of rock in a debris-flow deposit* (Fig.12). One large block of orthoquartzite approximately 30 feet by 15 feet, settled in a deep-water shale and was exposed until recently on the grounds of the Troy YMCA (Friedman et al., 1982), formerly listed as Troy Jewish Community Center (Friedman, 1972). This block is now concealed beneath soil and vegetation. The exposed shale surrounding this erratic block showed that this block occurred singly. This block occurred along strike of the brecciolas and many more exposures of the brecciolas are present north of it in Frear Park. In a pit about 100 feet or so north of this block we exhumed from the shale a block of dark gray, fractured, and veined micritic dolomitic limestone.

The size and shape of the block of orthoquartzite suggests more than a steep slope. To detach a block of this dimension required considerable instability, such as severe shakes as occur during earthquake or meteorite impact. This block

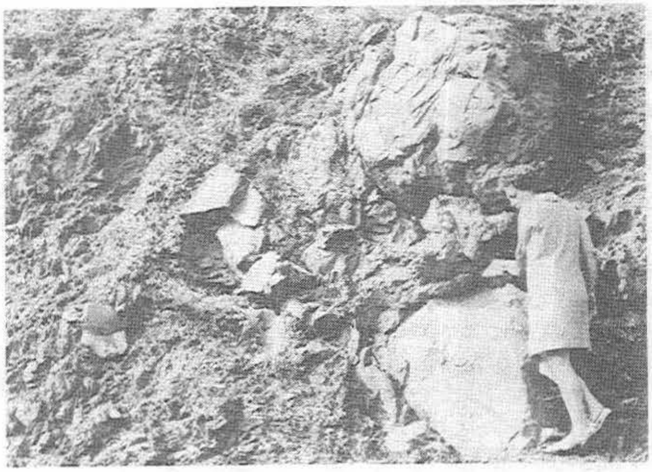


Figure 12. Two large blocks and various smaller blocks of limestone and sandstone set in a fine-grained dark-colored, deep-water shale. The blocks known as olistoliths are interpreted as having moved down a steep slope from near a shelf edge to a basin or basin margin. Note how well rounded the upper block is. Rensselaer Conglomerate, Hatch Hill Formation, (Middle Ordovician), Rysedorph Hill, Rensselaer, New York (Stop 4) (Friedman, Sanders, and Kopaska-Merkel, 1992, figure 17-1, p. 635)

of rock differs in lithology from the brecciolas. In contrast to the flat limestone boulders this huge block with its irregular outline suggests that it was forcibly detached from the shelf edge or basin slope. Could it be that this block was part of the wall of a submarine canyon which became detached and was moved by gravity into the basin or basin margin?

The alternative interpretation would be to consider this block to have been caught up in fault movement. Indeed slicken-sides are present on this block. However, the lower exposed contact with the shale is depositional and not faulted. Because the orthoquartzite block occurs along strike with brecciolas, and a limestone block has been found about 100 feet away, the evidence suggests that emplacement was by gravity rather than by faulting. This displaced orthoquartzite block may be as old as Precambrian. Large blocks of limestone likewise occur as olistoliths .

Massive Coarse Sandstone

These beds of massive sandstone show no bedding, lamination, or grading. The beds seem to fall into two groups, which are: (1) coarse-grained sandstone, and (2) thicker, coarse- to very coarse-grained sandstone. The beds are generally very coarse grained, with no internal features other than a few micrite pebbles. In places the beds contain either micritepebbles, or wisps that stand out on the weathered surface (Keith and Friedman, 1977, 1978).

These sandstones are well sorted and porous and analogous to those forming deep-water reservoirs in California and elsewhere. In fact, they are as well sorted as beach sands and those not knowing the regional geology may mistake them for high-energy shallow water deposits. Yet these massive beds correspond to beds described extensively from turbidite sequences in the literature (Friedman et al., 1992).

A depositional mechanism that appears to fit these coarse-grained generally structureless sandstone beds is fluidized sediment flow. This mechanism works when a loosely packed sand is subjected to an initial shock, destroying its fabric, so that water is incorporated and the sand liquefies, that is, the grains are supported by excess pore pressure. Since the sand is not sealed, pore-fluid loss is rapid, and the flow short-lived. As the pore fluid escapes, the viscous properties of the mass disappear and the sediment comes to rest. Because the concentration of sediment relative to fluid is high, features associated with traction deposits, such as different types of lamination, cannot form (Keith and Friedman, 1977, 1978).

Generally, the beds of this lithofacies appear to fit a nebulous category of thick, coarse-grained massive sandstones "proximal" in nature (or possibly channel deposits). They were deposited by one or more processes, involving fluidization of the sediment (Keith and Friedman, 1977, 1978).

Graded Sandstones

The graded beds are found associated with beds of other lithofacies. These beds are prominent except south of Hudson, where they are only a minor constituent of the exposed section. Shales are interbedded with this lithofacies at all exposures, except for Judson Point, where sandstone beds are commonly in depositional contact with each other, or with only a very thin shale parting between them (Keith and Friedman, 1977, 1978).

The graded beds range in composition from pure sandstone to limestone, with little or no sand. There are some beds that are half sand and half carbonate. Generally, within one exposure the lithology will be fairly constant. At Judson Point, the beds of this lithofacies are essentially pure sandstone. South of Hudson the beds all contain nearly equal amounts of carbonate and sand. Carbonate is present as rounded intraclasts, individual grains, and as a matrix in the sandy beds. The rounded intraclasts are commonly found near the base of the bed. The intraclasts are composed of pelmicrite, pelsparite or micrite. One intraclast of oomicrite was seen. Sparite and pelmicrite occur as matrix for sandy carbonates (Keith and Friedman, 1977, 1978).

Beds of this lithofacies display many kinds of sedimentary structures. Graded beds, parallel lamination, and cross-lamination (commonly ripple lamination) are all common. Grading takes on several forms in the beds studied. Many beds at Judson Point show delayed grading (Dzulynski and Walton, 1965), where most of the bed is coarse- or medium-grained sand, uniformly distributed, up to the very top, where the bed quickly becomes argillaceous with essentially no intermediate grain sizes. The grading then takes place in a narrow zone at the top, rather than throughout the bed. Beds at the locality south of Hudson commonly show coarse bimodal sand at the base in a carbonate matrix, with the sand decreasing in amount upward, leaving only the carbonate at the top. This would be a type of discontinuous grading with no medium-grained portion (Keith and Friedman, 1977, 1978).

Parallel lamination is quite common. It appears to be especially well developed in the medium-grained sandstones. The laminae are generally less than 1 mm in scale. The coarse- grained sandstones, as seen at Judson Point, show only faint lamination, if any at all. Ripple lamination is quite well developed in some beds, but is not common. Not seen elsewhere was larger scale cross-lamination that could be considered cross-bedding in a bed south of Schodack Landing. Many examples of the various internal structures, alone or in combination with others, can be seen (Keith and Friedman, 1977, 1978).

Beds of sand-sized material, displaying grading and lamination in a systematic order (Bouma Sequence) and which are interbedded with basinal shales are turbidites. In general, these graded beds bear more resemblance to distal, rather than proximal, tubidites, but may be transitional (Keith and Friedman, 1977, 1978; Friedman et al., 1992)

Parallel-Laminated Sandstones

Beds identified as belonging to this lithofacies comprise a significant amount of the lithofacies at all of the major sections to be seen on this field trip. The beds of this lithofacies range from medium-grained, parallel-laminated sandstones, to medium-grained sandstones with parallel lamination and some cross-lamination, to coarse-grained sandstones. Most of the sandstone beds are composed of medium-grained quartz sand with a variable amount of carbonate matrix forming the laminae. Some of the sandstone beds will contain fossil fragments, and, in fact, nearly all the identifiable trilobite fauna recovered by Bird and Rasetti (1968) from Judson Point, and Nutten Hook, and used by them for dating, came from beds identified in the Keith and Friedman (1977) study as belonging to this lithofacies. All but one of the sandstone beds of this lithofacies show lamination of some sort. Commonly, only parallel lamination is present in the sandstones, but some sandstone beds show some cross-lamination.

The beds here probably represent channel-edge equivalents of the coarser, probable channel deposits represented by the conglomerates, massive sandstones and turbidites.

Beds of this lithofacies are intimately associated with turbidites and may even be types of turbidites themselves (Keith and Friedman, 1977,1978; Friedman, 1979; Friedman et al.,1982).

FOR COMPARISON: GEOLOGIC SETTING OF DEPOSITS OF MIDDLE TO LATE ORDOVICIAN NORMANSKILL FORMATION.

On this field trip we shall compare flysch deposits of the Taconic Sequence with those of the post-Taconic Sequence, specifically with the Austin Glen Member of the Upper Normanskill Formation, which is Middle to Late Ordovician in age. Deposition of the Austin Glen Member followed the collision between the North American platform and the Taconic island arc (Fig. 3). In contrast to the rocks of the Taconic Sequence these Normanskill deep-water rocks were derived from a direction that is now west, but during the Early Paleozoic was north.

We shall see the deep-water facies of the Austin Glen Member at two stops and then look for Austin Glen lithology at a third stop.

OUTCROP GUIDE AND ITINERARY: FLYSCH OF THE TACONICS

Figure 13 is the road log.

Depart from Union College and drive to Troy via U.S. 7. From U.S. 7 on arrival in Troy head west to River Street, head south on River Street, past Castaway Restaurant, Super 8 Motel, and City Garage, cross Fulton Street, and between Fulton Street and Broadway on Third Street park across from the Rensselaer Center of Applied Geology on 15 Third Street. We shall stop at the Rensselaer Center of Applied Geology, headquarters of the Northeastern Science Foundation affiliated with Brooklyn College of the City University of New York, for a brief review of the geology.

Mileage Between Points	Cumulative	
0.9	0.9	From Rensselaer Center of Applied Geology on Third Street proceed to corner of Broadway, one block (right) on Broadway to Second Street (Monument Square), turn right on River Street which becomes Fulton Street. Head east (uphill) on Fulton Street to Sixth Street. Make a left turn onto Sixth Street for one block to traffic light, turn right onto Federal Street (no street sign at corner) which becomes Sage Ave., hang right and drive to RPI '87 gymnasium.

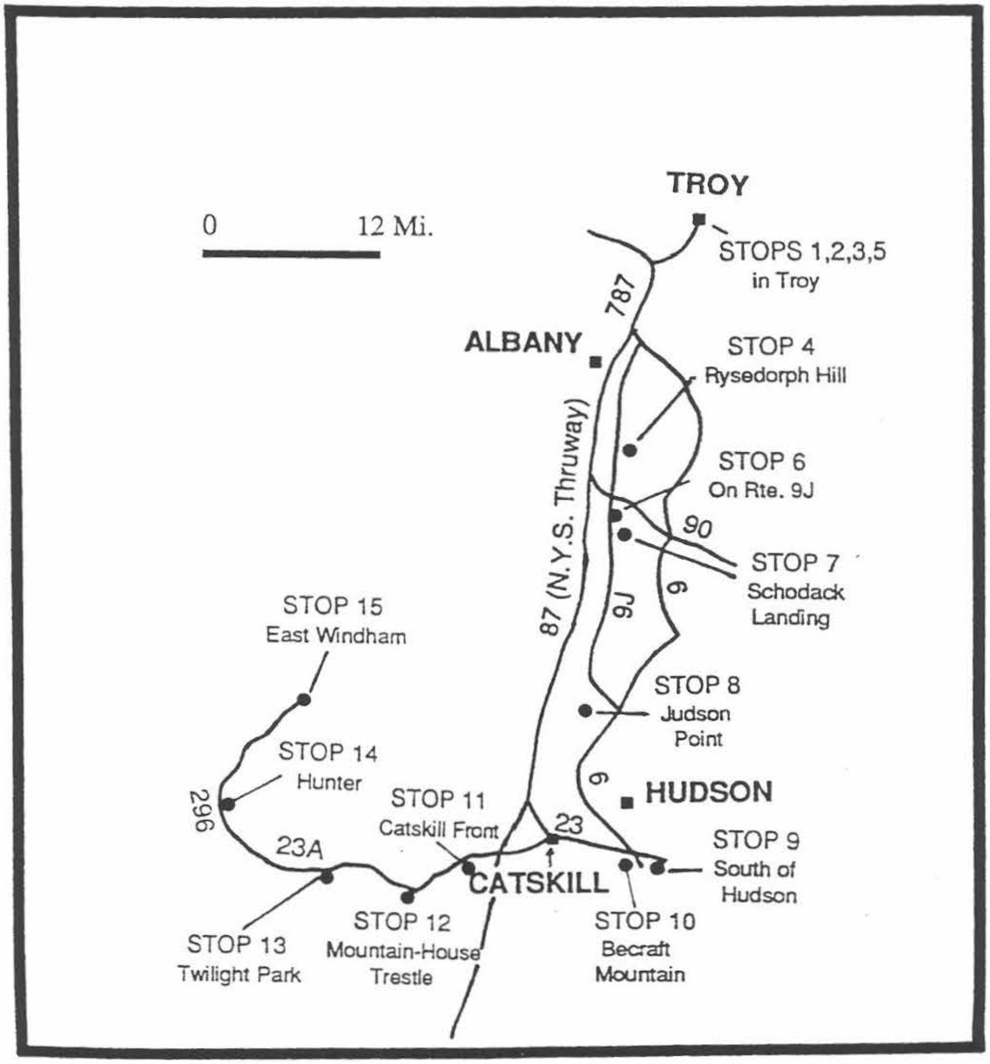


Figure 13. Road log with stops.

STOP 1 . RENSSELAER POLYTECHNIC INSTITUTE, '87 Gym

Exposure behind fence adjacent to gym.

Ruedemann (1930, p. 114; also Fig. 64) described and photographed this exposure as a good example of a "cliff of mylonite," one of the "excellent exposures of a fault breccia" on the campus of Rensselaer Polytechnic Institute. According to Ruedemann and reconfirmed by Elam (1960) a thrust fault follows part of this street (Sage Ave.) and Ruedemann mistook this conglomerate for a fault breccia. Perhaps the presence of criss-crossing veins in this exposure led to his interpretation of a "cliff of mylonite." Jack G. Elam (1960; unpublished Ph.D. thesis at Rensselaer Polytechnic Institute) assigned the rocks at this exposure to the Schodack lithofacies of Early Cambrian age. Cushing and Ruedemann (1914) had introduced the "Schodack Formation". Zen (1964) has renamed this formation the West Castleton Formation. As already explained, this formation is now assigned to the Hatch Hill Formation (Fig. 1).

Lowman (1961) recognized that the boulders are a conglomerate and not a breccia, and following Kuenen and Migliorini (1950), he introduced the term brecciolas for these rocks.

The limestone, sandstone, and chert boulders which are embedded in shales at this exposure range from angular to rounded and show considerable variation in size (Fig. 9). Some boulders are coarse-grained fossiliferous limestone fragments with a micritic dolomite matrix. The rocks above the brecciolas are greenish-gray shale.

0.4 1.3 Continue on Sage Ave. due east past 15th Street, hang right and continue to Burdett Ave. and park in parking lot of Doyle Middle School across the street.

STOP 2. TROY HIGH SCHOOL QUARRY

Walk to the running track and on track proceed left (north) to exposure below RPI housing units.

The spectacular brecciolas at this exposure consist of three members with eleven sub-members (Lowman, 1961); some of the deposits that Lowman studied have since been destroyed. For details of the rocks, refer to Lowman's descriptions (1961). The brecciolas are lithofacies of the Hatch Hill Formation, as at Stop 1.

A thin-section study shows the limestone clasts to consist of biomicrites, biointramicrites, and micrites with varying terrigenous quartz and clay-minerals. The intraclasts are of pelmicrite. Shell fragments have been selectively dolomitized. The carbonate sediments must have lithified before their displacement downslope.

The brecciola bed is steeply dipping (80°) and is approximately 3 m thick. It is interbedded within a fissile shale. The basal contact of the bed is at the top of the exposure, and the top of the bed is at the base of the exposure. The matrix between the clasts ranges from sand at the base of the bed (top of the exposure) to clay at top of the bed (base of the exposure). This change in the texture of the matrix is typical graded bedding.

Although some clasts are rounded, most of them are angular and slab-shaped (Fig. 10). Some slabs experienced multiple bending reflecting high-energy impact (Fig. 10). Sporadic slabs ½ m to 1 m long appear to have been in the process of breaking up, with clay wedged into the fractures of the separating clasts. The clasts are sub-parallel to the boundaries of the bed.

Mileage Between Points	Cumulative	
1.5	2.8	From parking lot turn left onto Burdett Ave., continue to Tibbits Ave. (traffic light), turn right onto Tibbits Ave. for one block to Brunswick Ave., turn left onto Brunswick Ave. and drive downhill to Congress Street (traffic light). Turn left onto Congress Street and hang right at fork, follow NY 66 across Poestenkill Bridge to Linden Ave. Turn right on Linden Ave. and drive downhill (past Poestenkill Falls Park) to Spring Ave. Turn right onto Spring Ave. for one block to Canal Street. Turn left on Canal Street to South Troy Recreation Center at corner of 5th Ave. Turn left on 5th Ave. for one block and park at corner of 5th Ave. and Madison Street. Walk old wagon road uphill to ruins of former buildings (now only the floor of the buildings is preserved), site of former abandoned quarry. Look at exposure in old quarry (Rushor's Quarry)

STOP 3. RUSHOR'S QUARRY, TROY

The rocks at this exposure are part of the Austin Glen Member of the Normanskill Formation of Middle Ordovician age. In contrast to the Cambrian (Hatch Hill Formation) deep-water rocks which were tectonically emplaced in the Troy area, the Normanskill deep-water suite formed *in situ* after deep submergence of the Cambrian-Early Ordovician carbonate shelf. The sediment composing the rocks at this site were derived from what is now east (Fig. 3), but was north during the Paleozoic. At this stop we see basin-margin sediments devoid of brecciolas. The clue to the presence of a paleoslope are sole marks on the undersides of sandstone beds (Fig. 14). These marks are infillings (molds) of depressions that formed in the soft bottom clays

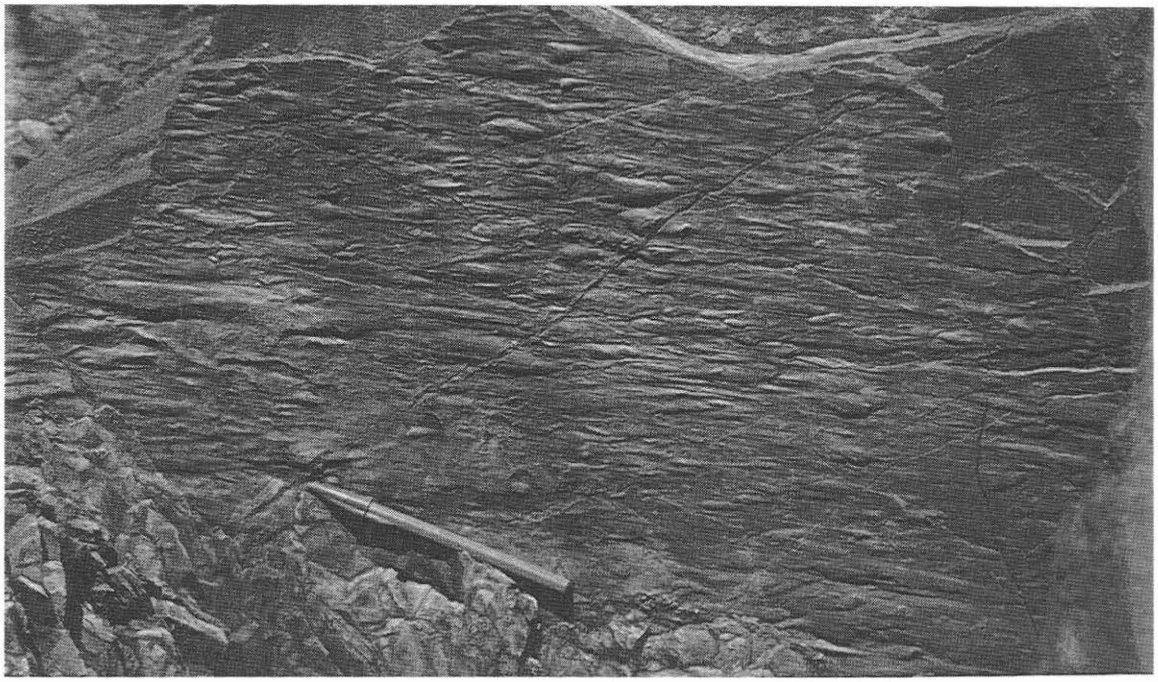


Figure 14. Sole marks made on cohesive mud substrate by erosive/reworking current and preserved as counterparts on the base of the overlying sandstone. These scour marks are known as flutes. Austin Glen Member of the Normanskill Formation. Rushor's Quarry, Troy, N.Y. (Stop 3).

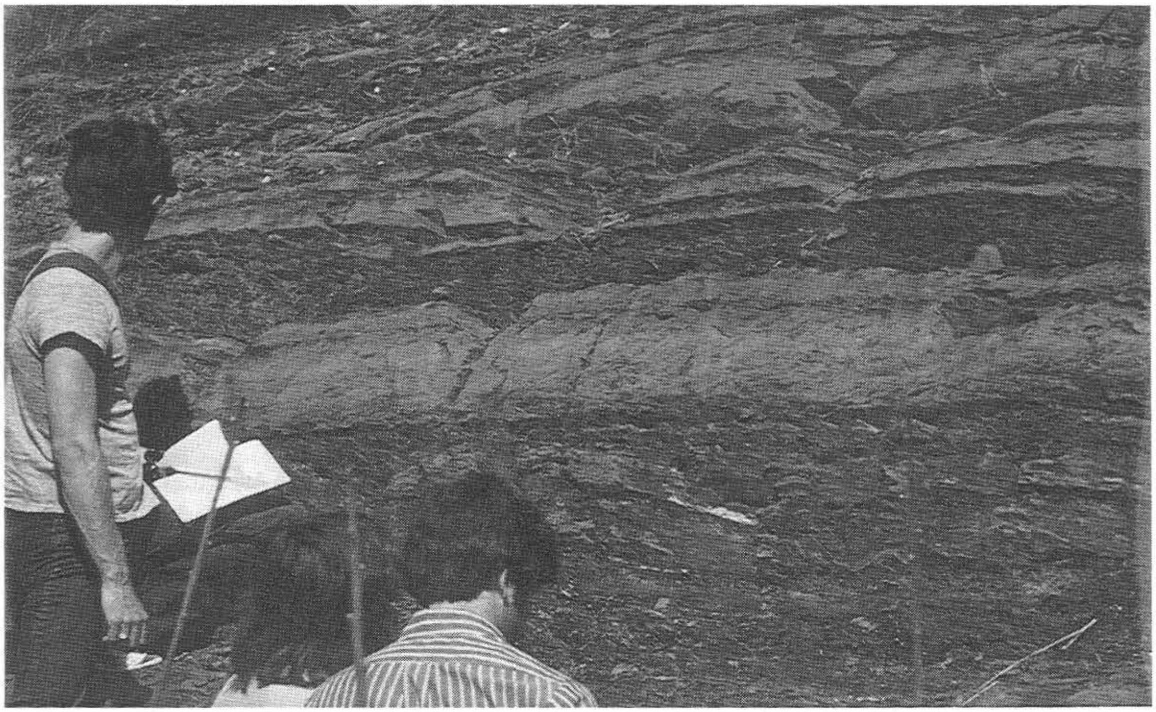


Figure 15. Alternating sandstones and shale of typical flysch facies, Austin Glen Member of the Normanskill Formation. Rushor's Quarry, Troy, N.Y. (Stop 3).

(now shales) as particles in turbidity current flows or sandfalls scoured or gouged the bottom. They are also known as impact marks or tool marks. The following sole marks can be seen (definitions modified from Pettijohn and Potter, 1964): flute molds - a raised sub-conical structure, the upcurrent end of which is rounded or bulbous, the other end flaring out and merging with the bedding plane; groove molds - rounded or sharp-crested rectilinear ridges produced by filling of grooves; brush marks - essentially a bounce cast with a crescentic depression on the down-current end; prod molds - a short ridge, parallel to the current, which unlike flute molds, rises down-current, and ends abruptly; frondescent marks - a type of load-flow structure that covers some soles with crowded lobate molds overlapping in the down-current direction.

The rocks in this quarry consist of interbedded sandstone and shale (Fig.15) which show the characteristics of distal turbidites (Walker, 1967): cross laminae, convoluted laminae, sole marks, graded beds, parallel sides and regular beds, thin beds, fine grain size; individual sandstone beds rarely amalgamate.

The exposure in this quarry is that of a typical flysch composed of alternating sandstones and shales (Fig. 15). Most sandstone beds are composed of two units: an underlying finely laminated sandstone and an overlying ripple cross-laminated sandstone (Figs. 16, 17). The ripple cross-laminated sandstone may scour into the underlying finely laminated sandstone. These two sandstone units correspond to the B and C units of a Bouma sequence; the shale would be a Bouma E unit. Please look carefully at the two sandstone units, keep a mental image of their appearance, and carry this image to the next stop where you will need it for interpreting the geological history.

10.1 12.9 Turn right on Madison Ave. to Third Street. Turn left onto Third Street which runs into Fourth Street and continue (south) on to Burden Ave. , keep hanging right on Burden Ave. to bridge over Hudson River. Bear left on bridge to Interstate 787 south (towards Albany). Exit at Rensselaer sign and cross Hudson River Bridge and take East Greenbush ramp to City of Rensselaer and make a left turn onto Washington Street. Drive down Washington Street to Third Street and make right turn (US 43 east) to US 151. Turn right on US 151; outcrops are located just north of corner with Eastern Ave.

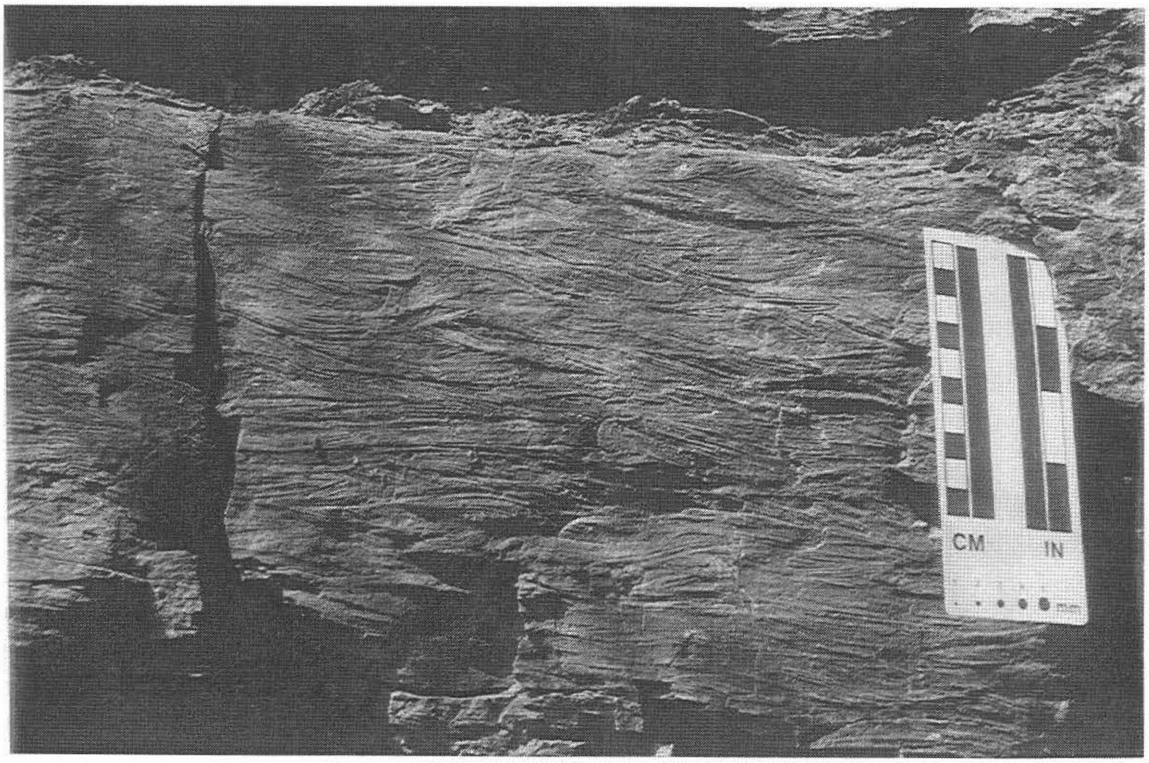


Figure 16. Ripple-crosslaminated sandstone unit (C unit of Bouma) which overlies finely laminated sandstone unit (B unit of Bouma). Austin Glen Member of the Normanskill Formation, Rushor's Quarry, Troy, N.Y. (Stop 3).

Figure 17. Flysch sandstone composed of two units: an underlying finely laminated sandstone and an overlying ripple crosslaminated sandstone. Geologist points at contact between these two units. Austin Glen Member of the Normanskill Formation, Rushor's Quarry, Troy, N.Y. (Stop 3).

Figure 19. Block of Ordovician Austin Glen / Normanskill Sandstone in shale matrix. Top of block is on left. Note fine laminae of Bouma B unit in sandstone and on their left ripple-cross laminae of C unit. To the left of the block is slickensided calcite-healed fracture. Rensselaer Conglomerate, Hatch Hill Formation, Rysedorph Hill, N.Y. (Stop 4).

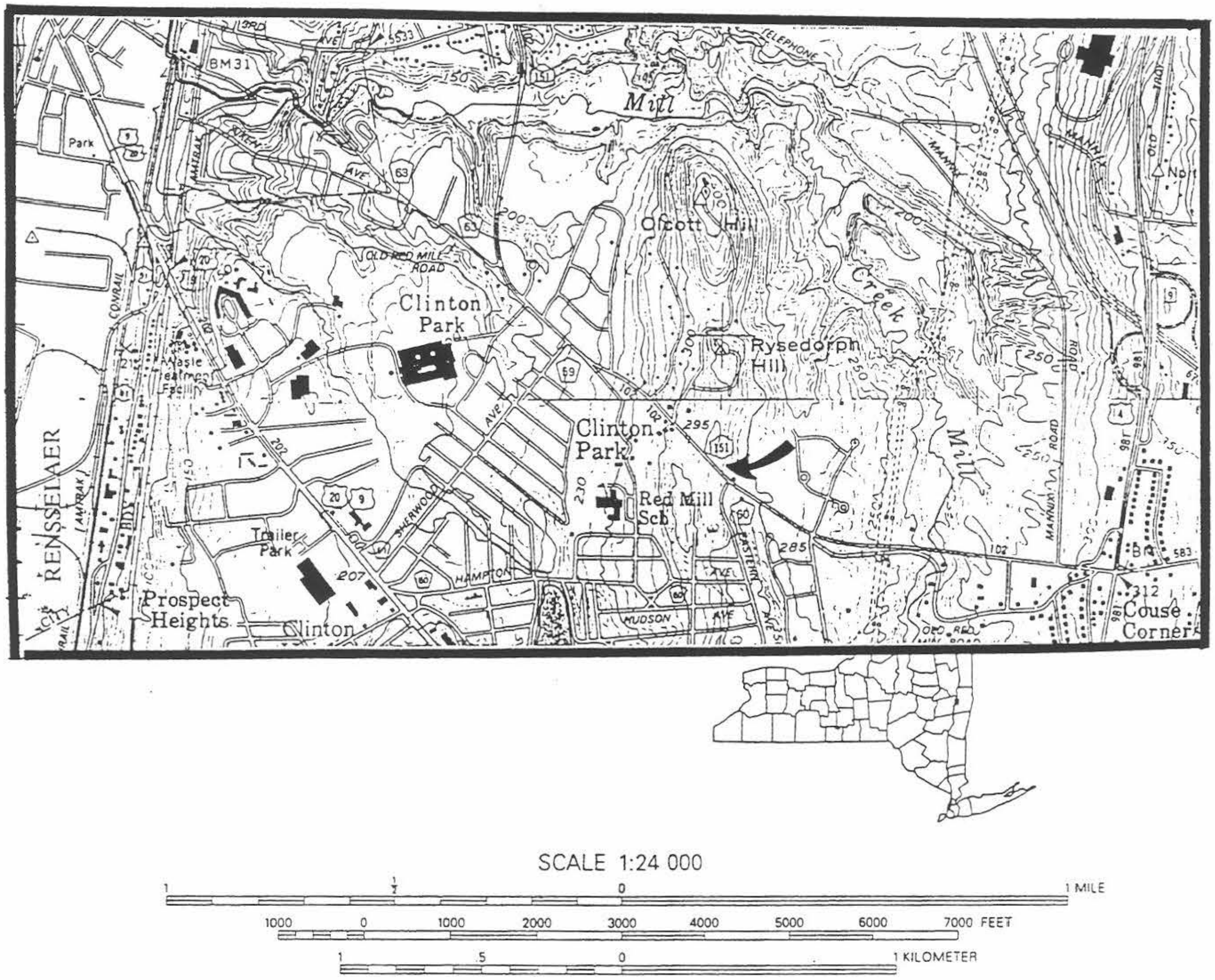


Figure 18. Location of map of Rysedorph Hill.

STOP 4. RYSEDORPH HILL

This roadcut is on the southern flanks of an unnamed peak of Rysedorph Hill which is topographically part of a ridge composed of two hills (Rysedorph Hill and Olcott Hill)(Fig. 18) . At and near the peak of Rysedorph Hill Ruedemann (1930) discovered spectacular conglomerates and faunas which are now obscured by vegetation; only small sporadic blocks or pebbles of limestone are now found dispersed in shale. This spectacular deposit is known as Rysedorph Hill Conglomerate and, as Ruedemann described, consisted for the most part of limestone conglomerate (see Sanders, 1995).

The rocks at this roadcut are quite different from those which Ruedemann described. Large and small blocks of sandstone and carbonate rock are set in a dark-colored deep-water shale. One of the blocks on the east side of the road is of particular interest. This block consists of Austin Glen/Normanskill sandstone lithology. In fact, it reveals the typical two kinds of sandstone units that we have seen at STOP 3 (Rushor's Quarry in Troy): an underlying finely laminated sandstone and overlying ripple cross-laminated sandstone which correspond to the B and C units of a Bouma sequence (Fig.19). One wonders how this one block traveled from Rushor's Quarry in Troy to this site!

The kind of lithology exposed at this stop has been designated **wildflysch,** a term applied to a *spectacular deposit consisting of small- to enormous blocks of sedimentary-, igneous, and metamorphic rocks set in a matrix of fine-grained, typically dark-colored marine shale, siltstone, or mudstone* (Fig.12). In modern terms, we would designate the wildflysch as one kind of diamictite (Friedman et al., 1992).

Study of sandstone blocks show them to be fine- to medium-grained and for the most part composed of quartz. Authigenic quartz overgrowth is in places so intense that the original texture is obscured. Plagioclase feldspar and microcline are common. They are commonly sericitized and calcitized. Fragments of sedimentary, igneous, and metamorphic rock are abundant, especially those of sedimentary rocks. Particles of carbonate rock include micrite, oolitic and pseudo-oolitic limestone, peloidal limestone, dolomitic limestone, and crinoidal limestone. These fragments of carbonate rock contain authigenic feldspars which are diagnostic of pre-Knox unconformity (Beekmantown or Sauk) deposits (Buyce and Friedman, 1975). Other kinds of rock fragments are composed of siltstones and shales, especially bituminous shales. Metamorphic rock fragments are those of sericite-chlorite schists and quartzites. Igneous rock fragments have porphyritic-ophitic texture. Finely-crystallized rock-fragment particles are those of recrystallized volcanic glasses or volcanic rocks, and contain chalcedony and chlorite.

Table 1 shows the petrographic composition of the sandstone blocks. They do not qualify to be called graywacke, despite such usage for these rocks in the literature (Potter, 1979). According to the classification of Friedman et al. (1992) the sandstones are classified as quartz-feldspar-rock fragment sandstones.

Carbonate blocks are for the most part composed of dolostone. The provenance of these blocks includes Cambro-Lower Ordovician platform carbonates (oolitic and peloidal carbonates and authigenic feldspar) and deep-water Austin Glen/ Normanskill sandstone. Hence these conglomerates are younger than Normanskill which would make them Upper Ordovician Snake Hill Formation which is the only Ordovician unit younger than Normanskill present in New York (Fig. 1b)(Fisher, 1977). Because of age uncertainties I prefer to label these rocks Tippecanoe-correlative conglomerates and call them Rensselaer Conglomerate since they occur in the town and county of Rensselaer.

To recycle deep-water Austin Glen/Normanskill deposits an initial uplift is necessary. As Sanders (1995) points out "because eastern New York is part of the Appalachian orogenic belt....'uplift' means thrust faults". This mechanism displaced deep-water Normanskill deposits into a setting of shallow water or emergence from which erosion detached the blocks and recycled them downslope, once again into deep water. This view is at variance with that of those who feel that these conglomerates resulted from tectonic emplacement (Potter, 1979). However, these deposits are incoherent subaqueous slumps (debris flow) of deep-water setting which were part of a slumped mass that moved by gravity downslope (Friedman et al., 1992, p.). Some of the boulders form a nearly perfect sphere (Fig.12) implying erosional rather than tectonic forces. The blocks are related to erosion on the front of the thrusts which contained rocks from each of the three sequences: Taconic, Sauk, and Tippecanoe (Normanskill) (see Fig. 1a) . The presence of Sauk material indicates that some thrusts broke loose inboard of the former shelf edge and transported the carbonate-sequence material over the foreland-basin shales of the Tippecanoe Sequence (see also Sanders, 1995; DeAngelis, 1995).

TABLE 1. QUANTITATIVE PETROGRAPHIC ANALYSES OF SANDSTONE BLOCKS FROM RYSEDORPH HILL

Minerals and Rocks	Sample Numbers											
%	3	4	5	6	7	8	9	12	16	5a	6a	9a
Quartz & Acces.Minerals	47.5	71.8	51.8	68.6	67.2	71.5	57.9	58.4	48.5	55.2	62.6	46.0
Feldspars	19.0	8.4	15.9	10.4	9.1	10.2	13.7	12.7	12.6	12.0	16.0	14.7
Sedimentary Rocks	4.5	3.1	3.5	5.2	1.0	3.7	2.5	4.7	2.2	3.6	5.3	5.3
Metamorphic Rocks	-	-	0.3	-	-	-	1.1	0.2	-	0.01	-	0.01
Igneous Rocks	0.01	0.01	0.01	-	-	-	0.01	-	-	0.01	-	0.01
Matrix & Cement	29.0	16.8	28.6	15.9	22.6	14.7	24.9	24.1	36.8	29.2	16.0	34.0
Total	100.01	100.11	100.11	100.1	99.9	100.1	100.11	100.1	100.1	100.02	99.9	100.02
Total No.of Points Counted	7.186	6.010	6.506	7.052	7.142	3.108	7.776	5.770	4.964	4.626	5.026	7.486

Analyst: Vincent Durovic

Mileage Between Points	Cumulative	
15.8	28.7	Turn around and return on US 151 to Washington Ave., now US 43 East, and turn right and drive to junction with US 4 North (but still US 43 East). Turn left at junction (traffic light) and continue to intersection, where US 43 East turns right. Turn right onto 43 and follow Sand Lake Road. Note Town of Sand Lake and junction with US 150. Turn left onto US 150 and follow to junction with US 66. Turn left onto US 66 (north) which becomes Pawling Ave. in Troy. Follow US 66 to Linden Ave. on left side of street. Turn left and drive downhill to parking lot on right.

STOP 5. POESTENKILL FALLS AND GORGE (SOUTH TROY QUADRANGLE, N.Y.)

We are back in Troy from where we initially set out; in fact we passed this site on our way between stops 2 and 3. You may ask why has a visit to this remarkable site been postponed till now, and why did we have to backtrack this circuitous route between Rysedorph Hill and Poestenkill Falls? The answer is that the experience of Rushor's Quarry (Stop 3) and Rysedorph Hill (Stop 4) is essential to an understanding of the geology of Poestenkill Falls and Gorge.

At this classical site Ruedemann (1930) shows "Logan's Line" (now known as Emmons' Line; Rodgers, 1970), the thrust plane which places Cambrian over Ordovician rocks surfacing at this site. Elam (1960) concurs and places Lower Cambrian rocks (his Poesten lithofacies, later West Castleton Formation; Zen, 1961) in contact with Middle Ordovician rocks (the Austin Glen Member of the Normanskill Formation). As already explained, the Cambrian strata , a typical flysch, have now been assigned to the Hatch Hill Formation (Fig. 1a). The Ordovician rocks are wildflysch, as at Rysedorph Hill, and hence I prefer to label them Tippecanoe-correlative strata and call them Rensselaer conglomerate (Hatch Hill Formation) as at Rysedorph Hill. As at Rysedorph Hill, the boulders and blocks consist of sandstones, shales, and limestones (Fig 20). Among the sandstones, blocks of Normanskill rocks can be identified. At this site Cambrian flysch has been thrust over Ordovician wildflysch. In places interbedded with the Ordovician wildflysch are strata of bedded flysch of Normanskill lithology which remind us of Rushor's quarry. Hence although consisting for the most part of debris-flow deposits the Ordovician strata are in part of turbidite origin.

This overthrust (Fig. 21) is interpreted as a segment that extends from Canada through Vermont, New York, and farther south. The fault line is well exposed in the south wall of Poestenkill Gorge. Cambrian shales occur above (east of) the fault, and Ordovician strata below (west of) the fault. The Ordovician strata have been described as a fault breccia or mylonite in which blocks of large size have been incorporated in shaly matrix. The matrix shows an anastomosing cleavage pattern that does not penetrate the boulders and blocks. Although described as a fault breccia or mylonite (Ruedemann, 1930;Elam, 1960)

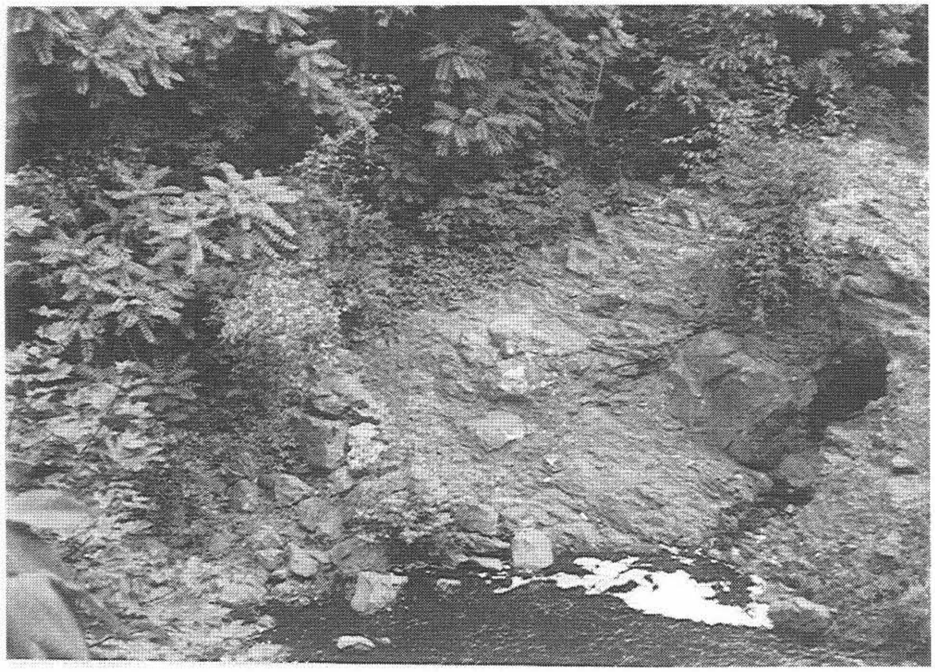


Figure 20. Boulders and blocks of sandstone and other lithologies in shale matrix, a debris-flow deposit. Ordovician Rensselaer Conglomerate (Hatch Hill Formation), Poestenkill Falls and Gorge, Troy, N.Y. (Stop 5).

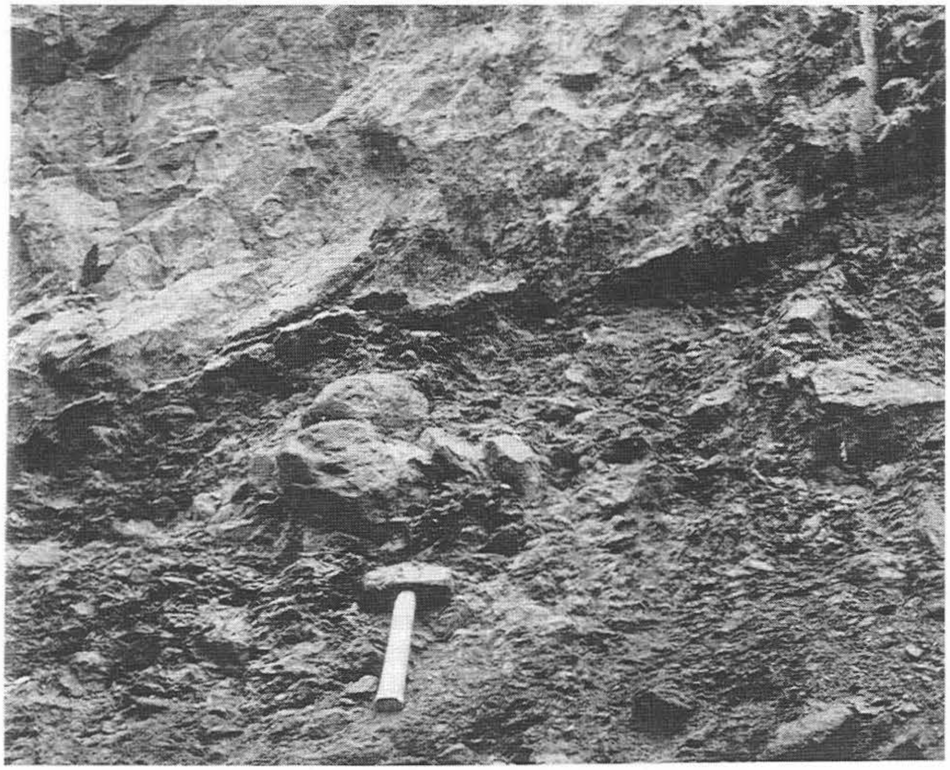


Figure 21. Thrust plane, known as part of "Logan's Line" or Emmon's Line, showing overlying Cambrian and underlying Ordovician deposits. Poestenkill Falls and Gorge, Troy, N.Y. (Stop 5).

this rock is a wildflysch. The blocks are interpreted as having moved down a steep slope from near a shelf edge to a basin or basin margin.

The Ordovician rocks are highly tectonized, especially towards the thrust. Antithetic post-thrust faulting is noted on the north side of the thrust sheet with an approximately 2 m displacement seen on the steep slope above the thrust. At and below the thrust sheet in the south wall of Poestenkill Gorge a dense black material may be **pseudotachylite**, a rock produced in the compression and shear related to intense fault movement, involving extreme mylonitization. My own professor Dr. S. James Shand introduced this term (Shand, 1916) for mylonites he encountered in the Orange Free State of South Africa. As Shand (1947) points out, this kind of "mylonites... proved most puzzling to field geologists meeting them for the first time".

The Cambrian rocks contain abundant black particles which may be phosphatic.

During the Industrial Revolution numerous factories, clustered on the north slope of Poestenkill Gorge, were making cotton cloth, and curry combs, barbed wire, and buckwheat flour machines, and much more. The first mills were developed in the lower section of the gorge as early as 1791. Their full potential was realized when Benjamin Marshall constructed a brick cotton mill on the north side. Water power began its decline with the popularity of steam power at the turn of the century. Today obscure, moldering industrial ruins testify to this former busy activity. The last of the abandoned mill buildings tumbled into the stream in the fierce flood of 1938.

Mileage Between Points	Cumulative	
12.0	40.7	From parking lot take right turn onto Linden Ave. to Spring Ave. and make a right turn onto Spring Ave. Continue on Spring Ave. which becomes Hill Street and hang left to where Hill Street merges into Fourth Street. Continue on Fourth Street to Congress Street and make a left turn onto Congress Street. Cross Hudson River over Congress-Street Bridge and follow sign to 787 (right turn after crossing bridge on to Second Street). Make right turn at Twenty-Third Street and enter ramp to Interstate 787 south. Exit at sign for Rensselaer, cross Hudson River and exit on East Greenbush ramp. Continue on US 9 and 20 to junction with Route 9J. Head south on Route 9J past Port of Rensselaer through Town of East Greenbush. Stop at site of olistoliths on slope of left (east) side of highway, located 0.7 mi south of Rensselaer Town line. Note especially a large white block of limestone.

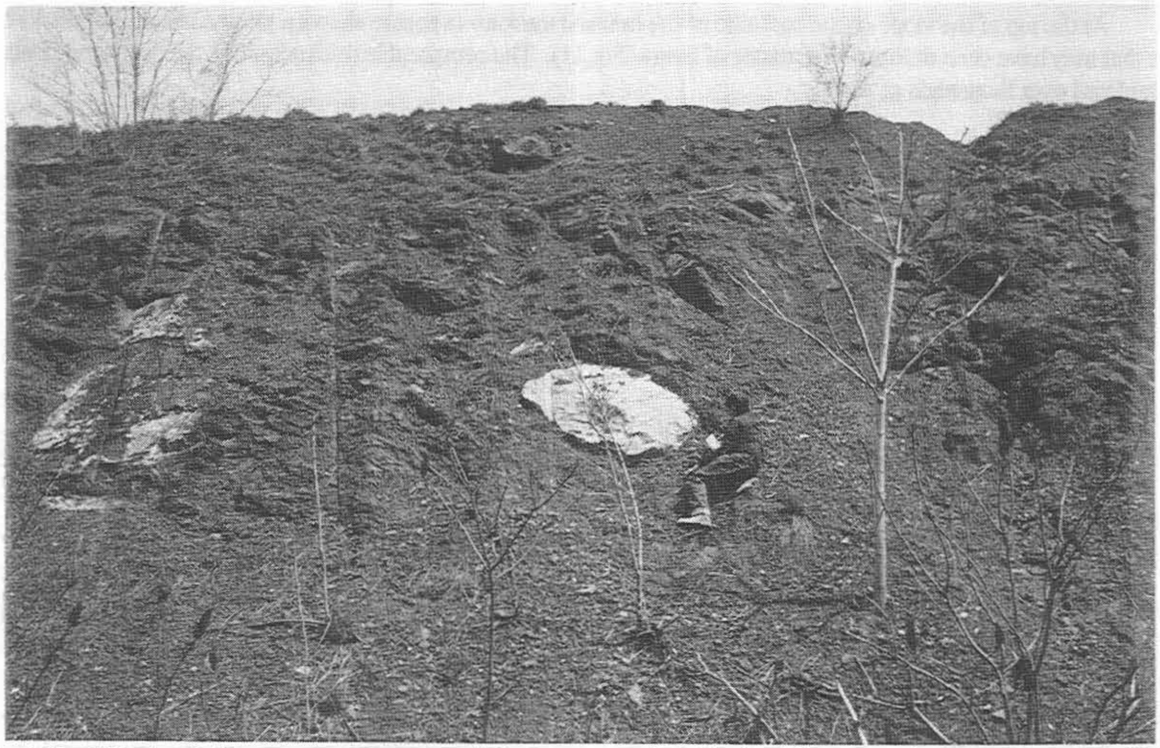


Figure 22. Olistoliths in shaley matrix. Note especially large, rounded block of limestone in approx. center of view. Snake Hill Formation, Ordovician, cut on east side of Route 9J, 0.7 mile south of Rensselaer Town Line Rensselaer County, N. Y. (Stop 6).

STOP 6 . OLISTOLITHIS

At this site "exotic" boulders of various kinds are scattered through shale. Of these one large well-rounded boulder of white limestone demands particular attention (Fig. 22). Smaller angular blocks include those of sandstone and limestone. These olistoliths recall those of Rysedorph Hill and Poestenkill Falls and Gorge and are considered Tippecanoe correlative Snake Hill Formation which at the other two sites have been designated Rensselaer Conglomerate and deserve the same label here. Fisher (1977) applied the term Poughkeepsie Mélange to this deposit. However, for a deposit to be called a mélange it should be incorporated within a unit "that was moving as an overthrust or as a gravity-gliding mass"(Friedman et al., 1992). The deposit at this site is composed of olistoliths and is not a mélange, as Rowley and Kidd (1982) likewise observed.

11.4	52.1	Continue south on Route 9J through Town of Schodack, Village of Castleton on Hudson and Schodack Landing, past signs of Columbia County and Town of Stuyvesant, and pull into unpaved driveway on left at AT&T Stuyvesant facility (which is somewhat hidden behind vegetation).

STOP 7. EXPOSURES SOUTH OF SCHODACK LANDING

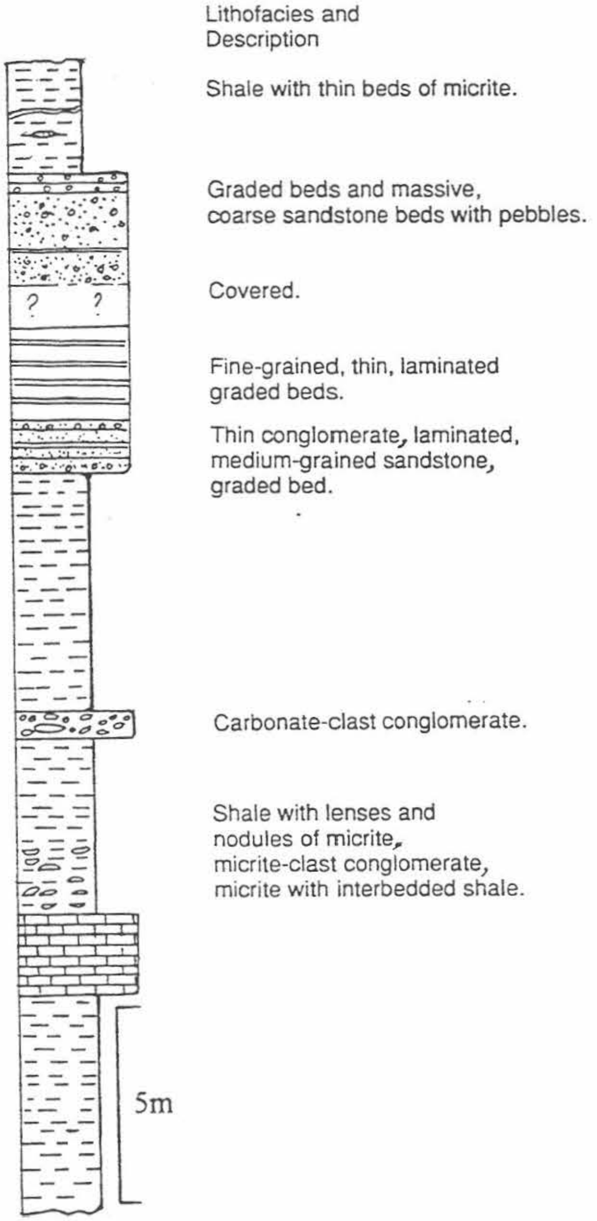
We shall first examine the road cut on the east side of the highway and then walk on dirt road across the railroad tracks to view more fine exposures.

Figure 23 describes and illustrates the section seen. Note exposures of bedded micrite. Micrite is overlain by distinctive lenticular brecciolas. Many of the clasts in these conglomerates/brecciolas evidently were derived from the digging up and local transport of nodular bodies of carbonate that may have become segregated as isolated "nodules" during early marine diagenesis of these deep-water carbonates. The conglomerates form convex-up lenses up to 2 m thick and at least 10 m across . Their bases are flat surfaces or fillings of local channels cut a decimeter or so into the underlying nodular zone. Siltstone strata lacking carbonates drape over the convex-up lenses (Friedman and Sanders, 1995, in press).

These lenses are analogous to hummocky strata, which have been ascribed to combined effects on shelf sediments of waves and currents. The waves involved in the origin of these deep-water, off-shelf brecciolas probably were tsunami (see previous discussion).

At the top of the slope on the east side of the railroad track an exposure shows a graded layer (2 m thick) of shingled clasts that may have been dumped in a matter of hours (Fig.11). The comparable thicknesses of the overlying strata may have accumulated over thousands of years.

Mileage Between Points	Cumulative	
10.8	62.9	Continue south on Route 9J through Stuyvesant towards junction with US 9 North and South. After double signs for US 9 (North and South) and just before junction with Rate 9 (100 ft.) take a right turn onto road designated Dead End. Bear right at fork. Park at railroad track.



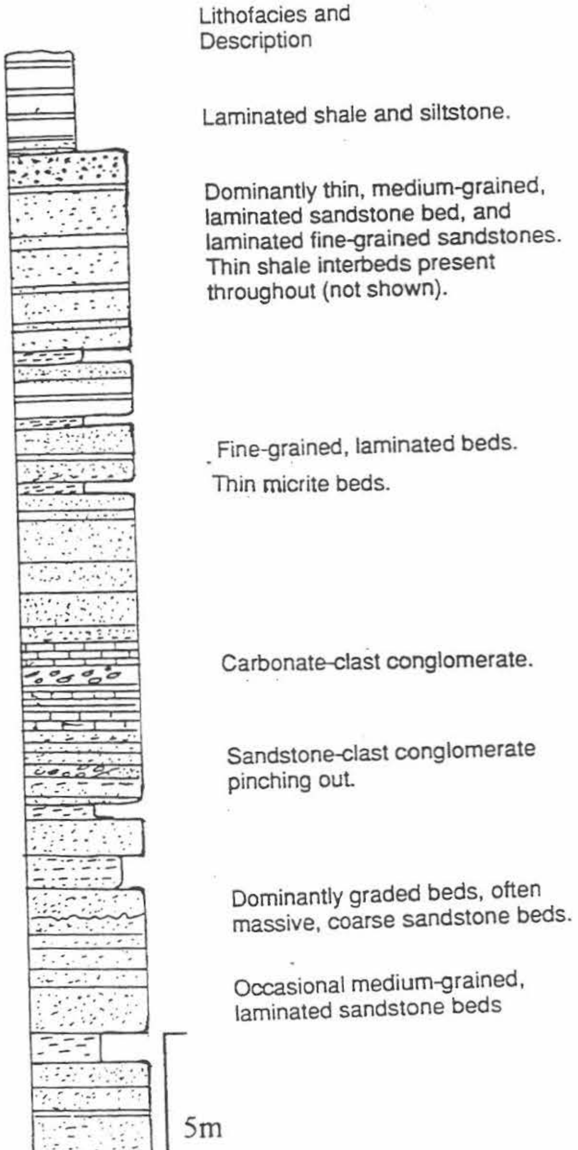


Figure 23. Section of Schodack Landing, N.Y. (Stop 7), (modified from Keith and Friedman, 1977, Fig. 20, p.1234).

Figure 24. Section at Judson Point, N.Y. (Stop 8), (modified from Keith and Friedman, 1977, Fig. 21, p. 1235).

STOP 8. JUDSON POINT

Figure 24 illustrates the section seen at this stop and describes lithofacies. The section is dominated by massive coarse sandstone beds of excellent reservoir quality which display high porosity and excellent sorting. They are analogous to sandstones forming deep-water reservoirs in California and elsewhere. Those not knowing the regional geology may mistake them for high-energy shallow-water deposits. In places the beds contain micrite pebbles.

11.7	74.6	Turn around and at Route 9 turn right and head south on Route 9 through Town of Hudson and Town of Greenport to junction with US 23. Turn left onto US 23 east which coincides with Route 9 south and continue to white house on right side (0.9 mile from junction of Route 9 and US 23).

STOP 9. EXPOSURE ON EAST SIDE OF ROUTE 9 (across from a white house)(SECTION SOUTH OF HUDSON)

Figure 25 shows and describes the lithofacies exposed at this stop and located across from white house. Note especially the interesting interbeds of fine-grained limestone (micrite) and dark shale (Fig. 7) and the carbonate-clast conglomerate (Fig. 8). The cycles consist of alternating thin-bedded micrite and calcareous shale (Fig. 7). The thickness of the micrite beds is about 1 to 5 cm and that of the calcareous shale varies between 3 and 20 cm. Table 2 and figure 26 provide data on the mineralogic and isotopic compositions of the alternating beds of micrite and calcareous shale. The micrite is pure calcite and encloses particles of quartz. The calcareous shale is composed of clay minerals and feldspar particles; its carbonate concentration is about 10% (calcite, dolomite, siderite) (Table 2). The stable carbon isotopic composition of the carbonate of the two interbedded lithologies is almost identical; the oxygen isotopic composition reflects deep-burial diagenesis (Table 2). The carbon isotopic composition of the brecciola overlying the micrite-calcareous shale cycles is enriched in ^{13}C. Although the range of carbon isotopic composition of total dissolved carbon in seawater is relatively narrow, a consistent decrease in ä^{13}C occurs with depth of water (around 2.6 per mil) (Berger and Vincent, 1986). Thin-section study of the brecciola confirms its shallow-water origin: radial ooids, echinoderm fragments, and intraclasts of oolitic facies. An approximately 2.6 per mil increase in ä^{13}C is shown by comparing the shallow-water brecciola facies with the deep-water micrite. The brecciola facies at this stop represents a shelf-edge facies that a tsunami broke loose and transported to great depth.

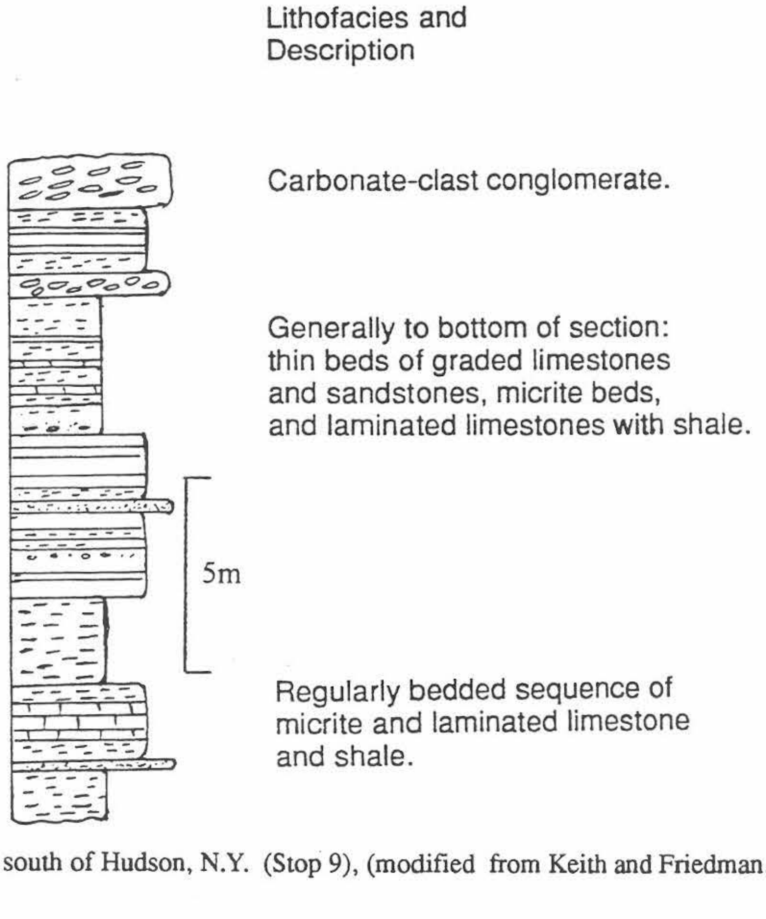


Figure 25. Section south of Hudson, N.Y. (Stop 9), (modified from Keith and Friedman, 1977, Fig. 23, p. 1237).

TABLE 2 TACONIC CARBONATE-SHALE CYCLES (SOUTH OF HUDSON, N.Y. STOP 9)

Sample No.	Lithology	Thickness above base of section (Meters)	$\delta^{13}C_{PDB}$	$\delta^{18}O_{PDB}$	$^{87}Sr/^{86}Sr^{*}$	Carbonate %**	% Clay Minerals ***	Quartz %	Feldspar %
1-1	Micrite	0.00	-1.0			92	0	5	3
1-2	Micrite	0.03	-0.5	-11.4		96	0	3	1
1-3	Micrite	0.08	-0.3	-11.4		97	0	3	0
1-4b	Calc.shale	0.22	-1.1	-11.5		20	27	35	18
1-4a	Micrite	0.35	-0.4	-11.6		97	0	3	0
1-5b	Calc.shale	0.48	-1.2	-11.5	0.715163(10)	10	36	36	18
1-5a	Micrite	0.63	-1.0	-11.3	0.711110(10)	96	0	4	0
1-6	Micrite	0.40	-1.2	-11.5		96	0	4	0
1-7b	Calc.shale	1.00	+0.3	-11.8		5	36	38	17
1-7a	Micrite	1.15	-0.9	-11.5		93	0	6	1
2-1	Micrite	2.0	-1.0; -1.1	-11.5	0.711353(10)	92	0	5	3
2-2	Calc.shale	2.2	-1.4	-11.5		11	33	44	10
2-3	Micrite	3.1	-2.0	-10.6		38	5	48	7
2-4	Micrite	3.4	-1.1	-11.3		60	0	39	0
3-0	Micrite	4.7	-1.3	-11.2		97	0	3	0
3-1	Micrite	4.8	-0.5	-11.0	0.710167(10)	91	0	8	0
3-2	Micrite	5.3	-0.6	-11.0		94	0	4	2
3-3	Micrite	5.6	-1.2	- 9.2		78	1	19	2
3-4	Micrite	5.7	-1.1	-10.6		70	3	22	4
3-5	Micrite	5.8	-1.4	-10.7		48	2	42	4
3-6	Micrite	5.9	-1.6	-11.0		73	0	24	3
3-7	Calc.shale	6.0	-2.2	-11.3		1	52	37	10
4-1	Carbonate-clast congl.	6.5	+0.6	-10.7	0.710177(10)	94	0	5	1

*The Sr analyses are normalized to $^{86}Sr/^{88}Sr = 0.11940$.

Analyses of NBS 987 averaged 0.710241 (09) (n = 39) during the period of these analyses.

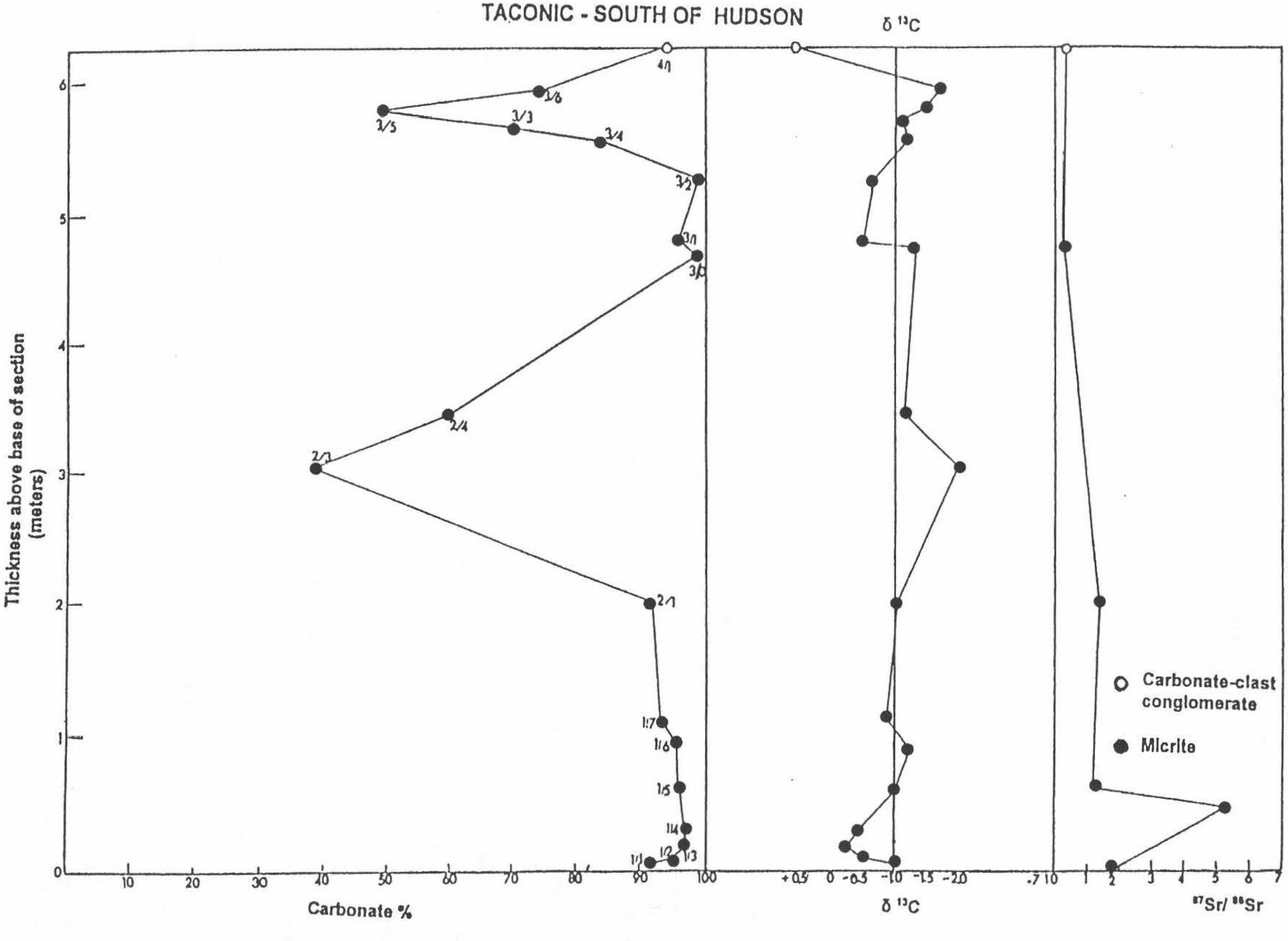
Errors on $^{87}Sr/^{86}Sr$ are given as 2 sigma (95%) in the last two digits.

**The carbonate minerals calcite, dolomite and siderite occur in calcareous shale.

***The clay minerals are illite and chlorite.

The strontium isotopic composition requires discussion (Table 2). The principal sources of marine Sr withdistinctive $^{87}Sr/^{86}Sr$ ratios are (1) old granitic basement rocks of the continental crust (high Rb/Sr, high $^{87}Sr/^{86}Sr$); (2) young volcanic rocks (low Rb/Sr; low $^{87}Sr/^{86}Sr$); and (3) marine carbonate rocks on the continents (low Rb/Sr, intermediate $^{87}Sr/^{86}Sr$)(Faure, 1991, p.359). Because young volcanic rocks are not relevant in a discussion of the Lower Paleozoic, only granitic basement rocks and marine platform carbonates determine strontium isotopic composition. The $^{87}Sr/^{86}Sr$ compositions of the carbonate in micrite and calcareous shale (0.711110 and 0.715163) are higher than in Lower Paleozoic seawater (0.7090-0.7095)(Burke et al., 1982) (Fig. 27) and consistent with precipitation from waters containing significant proportions of continent-derived fluids enriched in ^{87}Sr as a result of basement weathering or percolation through soils or sediment on the continental platform.

Figure 26. Isotopic composition of carbonate in micrite and carbonate-clast conglomerate in cycles of section south of Hudson, N.Y. Stop 9.



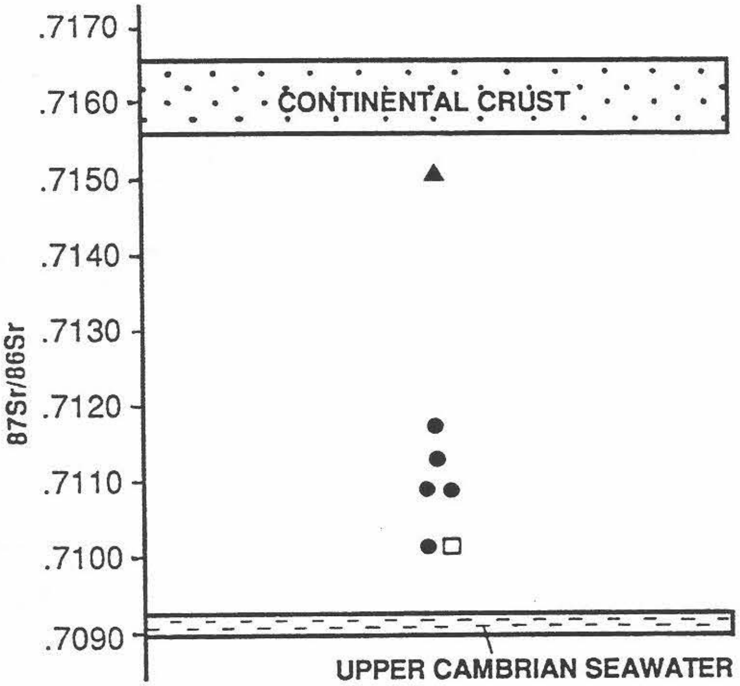


Figure 27. Strontium isotopic composition of carbonate (micrite, calcareous shale, carbonate-clast conglomerate) for cycles in section south of Hudson.

Weathering of Precambrian terrain causes enrichment of radiogenic ^{87}Sr (^{87}Sr/^{86}Sr 0.716±0.004) within river and lake waters (Faure et al., 1963). Waters originating from a granitic continental source have a high ^{87}Sr/^{86}Sr ratio relative to those derived from a platform of marine carbonates (Fig. 27). Even though the ^{87}Sr/^{86}Sr composition of the carbonate in both the micrite and calcareous shale is higher than in Paleozoic sea water, the difference between the two compositions is remarkable. The strontium isotopic composition of the carbonate in the calcareous shale almost overlaps that of the granitic basement crust, whereas that of the micrite is much lower and closer to that of Paleozoic sea water (Fig. 27). What determines these drastic changes in isotopic composition of such closely interbedded units? The highly radiogenic isotopic ratios of the carbonate of the calcareous shale reflect supply of radiogenic strontium from the decomposition of the detrital particles, such as feldspar and clay minerals which are present in this rock. By contrast, because the calcite of the micrite is essentially devoid of such detrital particles, its strontium isotopic composition is closer to that of Lower Paleozoic seawater.

Because strontium isotopes are not subject to significant mass fractionation during precipitation (Faure, 1986), the waters responsible for precipitating the carbonate of the calcareous shale must have derived from a granitic continental source. The only such source would be the Precambrian shield which must have been exposed during Early Cambrian times. The ^{87}Sr/^{86}Sr ratio of the micrite, though much lower, still indicates enrichment of radiogenic strontium from the granitic continental terrain, but its signature is considerably closer to that of marine platform carbonates.

The strontium isotopic evidence indicates that the calcareous shales were derived from exposed granitic basement. Sea level must have been low so that weathering and erosion of the granitic continental terrain generated the fine-textured particles. Rivers then distributed the debris across the emergent continental platform and down the slope, probably through submarine canyons. As pointed out earlier, a large block of quartzite in this formation has been tentatively identified as derived from part of the wall of a submarine canyon (Friedman, 1972; Friedman Sanders and Martini, 1982). By contrast, the strontium isotopic evidence for the micrite suggests mixing of waters originating from granitic continental terrain with waters from the epeiric marine carbonate platform under conditions of high stand of sea level. Thus the calcareous shale beds represent low-stand sea-level facies tracts, whereas the micrites are high-stand sea-level facies tracts.

The alternating thin-bedded micrite and calcareous shale beds reflect rapid changes in sea level. To produce such closely interbedded lithologies, the sea level must have moved up and down like a piston. Such cycles have been explained as astronomical rhythms (de Boer, 1991). For low latitudes, the precession of the Earth's axis has been assumed the cause of such rhythmicities. Precession cycles last about 19,000 and 23,000 years. At this time no dates are available to determine the rate of sea-level changes, but 19,000 to 23,000 years are possible time frames for micrite-calcareous shale couplets to accumulate.

Mileage Between Points	Cumulative	
0.8	75.4	Turn around and return on Route 9 and US 23 to intersection of Route 9 north and US 23 west. Note exposure on southwest corner of Becraft Mountain.

STOP 10. SOUTHWEST CORNER OF BECRAFT MOUNTAIN (Fig. 28)

At the base of this exposure rocks of the Mount Merino Formation of the Taconic Sequence (Fig. 1) consist of highly

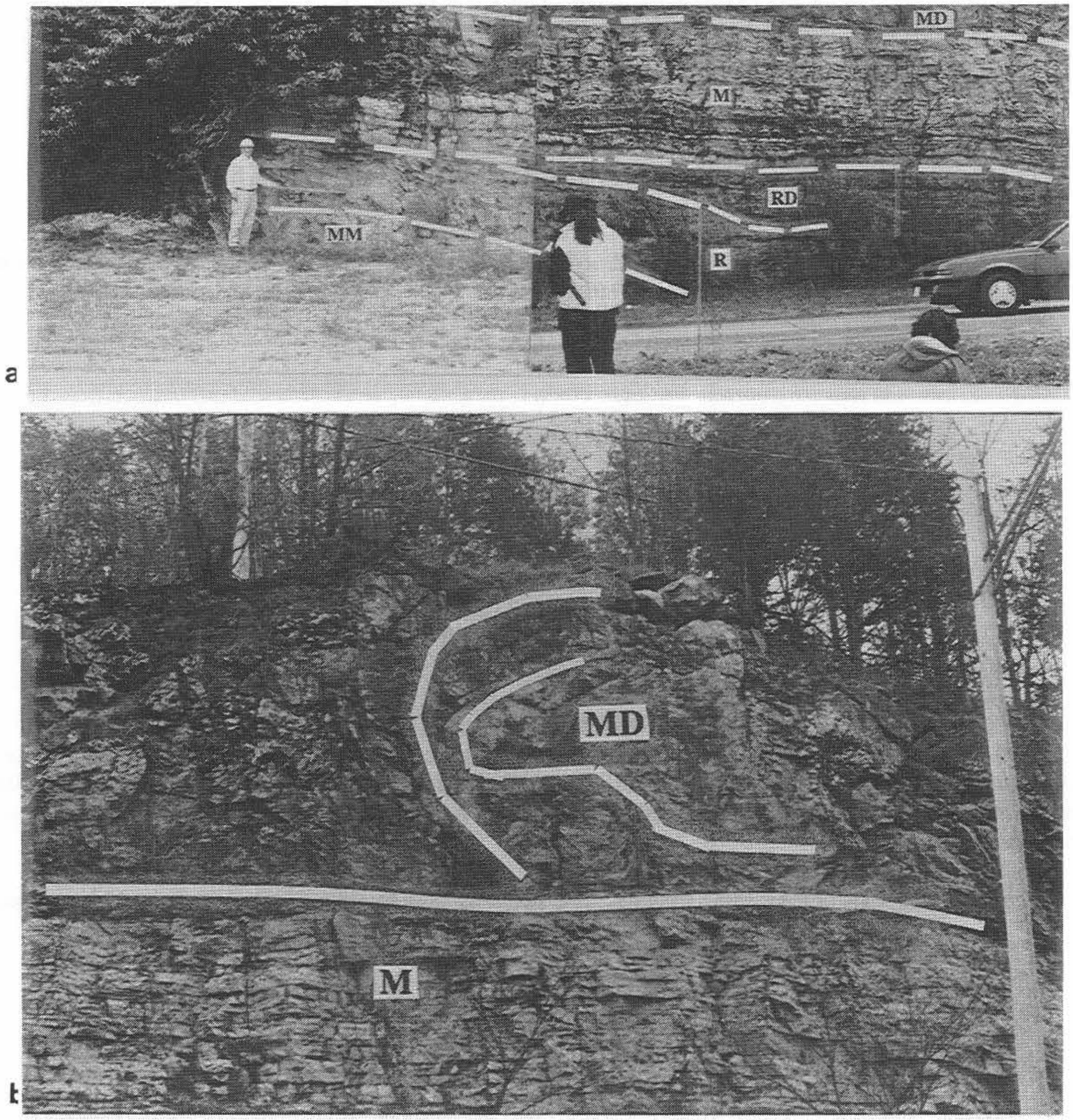


Figure 28. View of exposure at southwest corner of Becraft Mountain. (Stop 10).
(a) MM: Mount Merino Formation of Taconic Sequence.
R: Rondout Formation (Silurian) unconformably overlying Mount Merino Formation.
RD: Deformed Rondout Formation: note thrust between undeformed and deformed Rondout Formation.
M: Manlius Formation.
MD: Deformed Manlius Formation.
Geologist at left points stick just above unconformity with underlying Ordovician Mount Merino Formation.
(b) Note intense folding in deformed Manlius Formation as a result of thrusting.
M: Manlius Formation. **MD**: Deformed Manlius Formation.

deformed cherty dolomite. A low-angle, irregular unconformity separates this Ordovician formation from the overlying Silurian Rondout Formation, a silty dolomite. The lower part of the Rondout Formation is undeformed, however, a bedding thrust through this formation has deformed the Rondout Formation above this thrust (Fig. 28). Undeformed, laminated, whitish limestones of the Manlius Formation overlie the Rondout Formation. Within the Manlius Formation a bedding thrust folded the upper part of this formation (Fig. 28).

X-ray study of the rock of the bedding thrust within the Manlius Formation shows it to consist of calcite (96%) and quartz (4%). Its isotopic signatures are ä^{13}C$_{PDB}$ +2.4, ä^{18}O$_{PDB}$ -9.9, and ^{87}Sr/^{86}Sr 0.715096 (10) (± 2 S.D.) (The Sr analyses are normalized to ^{86}Sr / ^{88}Sr = 0.11940. Analyses of NBS 987 averaged 0.710241 (09) (n = 39) during the period of these analyses. Errors on ^{87}Sr/^{86}Sr are given as 2 sigma (95 %) in the last two digits). The carbon and oxygen isotopes tag a hot heavy-carbon enriched fluid and the strontium isotopes a radiogenic strontium of composition close to that of the continental crust.

The thrusts at this exposure are post-Taconic and resulted from Acadian or Alleghanian orogenesis.

OUTCROP GUIDE AND ITINERARY: MOLASSE OF CATSKILLS

The term **molasse** designates a *tectono-stratigraphic unit consisting of a wedge-shaped body of extrabasinal sediments typified by patterned successions of shallow-marine- and nonmarine strata, whose particles were derived from erosion of the older rocks, including flysch, that composed the rising mountain chain* (Friedman, Sanders, and Kopaska-Merkel (1992). The Devonian Acadian orogeny generated the Catskill deposits. The Devonian succession in the Catskill region has been, named a *tectonic fan-delta complex* (Friedman, 1988a).

14.9 90.3 Drive on US 23 west to Rip Van Winkle Bridge, note Catskill front from distance as you approach bridge. Cross bridge over Hudson River, get off US 23 at sign Jefferson Heights and Leeds, and make left turn towards Jefferson Heights on to Green County 23B through Catskill. Take right turn at junction with US 23A towards Hunter.

Stop 0.1 mile east of junction of US 23A with US 32.

VIEW OF CATSKILL FRONT

STOP 11 . BRAIDED AND MEANDERING STREAM FACIES SEEN FROM A DISTANCE

From the vantage point of this stop we see to the west the classical fluvial sequence of the Middle and Upper Devonian rocks of the Catskill front. Note continuous ledges near the top of the front which reflect the presence of laterally continuous, coarse-grained sandstones and conglomerates deposited in braided streams (Buttner, 1968). Below the continuous ledges are discontinuous cliffs which reflect laterally interfingering channel sandstones and overbank shales deposited in meandering streams.

Infrared photography of the Catskill front from this stop brings out amazing details (Mutch, Head, and Saunders, 1968).

2.3 Continue west on NY 23A to Palenville. Turn right (north) on Boggart Road.
1.1 93.7 Turn left at fork on to dirt road and drive <O.1 mile to tresle to Mountain House.

STOP 12. TRESTLE TO MOUNTAIN HOUSE

Walk approximately 300 feet uphill to first sandstone body.

Meandering-Stream Facies

This grayish green, medium-grained graywacke of the Hamilton Group of Middle Devonian age displays abundant truncations resulting from lateral cutting; the sandstones within the channels are crossbedded and display abundant reactivation surfaces. This channel complex is about 15 feet thick and is sandwiched between overbank shale which is well exposed in the hangover at the lower sandstone contact. Note sporadic pebbles, wood fragments, and wood casts as wellas onlap and toplap. Looking uphill along the clearing of the old trestle to Mountain House between cliffs of similar sandstone bodies the slopes mark the sites of interbedded shale. The interbedded sandstones and shales represent interfingering channel and overbank deposits of meandering- stream facies. The lateral relationship between channel and overbank will be apparent at stop 15. The green color of the graywacke reflects the abundance of chlorite in the rocks. This chlorite was derived from the source terrain to the east which consisted of metamorphic rocks of the greenschist facies.

A similar sandstone body occurs about 300 feet below which is underlain by gray, red, and green shales.

1.1	94.8	Return to NY 23A. Turn right (west) on NY 23A; cross Kaaterskill Clove three times ascending Catskill Front. Note red beds in gorge: interbedded channel sandstones and overbank shales. At sign on right designated STATE LANDS 1885-1935 pull over to view interbedded red sandstones and shales.
3.8	98.6	Turn left at Twilight Park entrance and park at bridge of Kaaterskill Clove. A "clove" is a deep ravine.

STOP 13. TWILIGHT PARK

Twilight Park is a private residential section and permission is needed to park here which may be obtained from the Superintendent Hillard Hommel or Justine L. Hommel, Box 129. Haines Falls, NY 12436 (phone 518-589-6191).

The site at this bridge was one of the preferred views of the Hudson River School of Landscape Paintings. Asher Durand (1786-1886) in his painting *Kindred Spirits* illustrated this site , including the crossbedding developed within the pointbars of the meandering stream facies visible below this bridge (Jordan, 1995).

0.1	98.7	Return to NY 23A and turn left (west). Drive through Haines Falls, Tannersville and Hunter on NY 23A. At junction of NY 23A and NY 296 is the next stop.

STOP 14. BRAIDED-STREAM FACIES, HUNTER

At this site polymictic conglomerate of braided-stream facies overlies sandstone of meandering-stream facies (Friedman, Sanders, and Kopaska-Merkel, Fig. 4-17). Small channels of conglomerate also cut through sandstone. The pebbles in this conglomerate range in diameter between 3 and 10 cm. The pebbles and sand particles are composed of quartz, including vein quartz, and various sedimentary and metamorphic rock fragments.

Streams of high energy must have been at work to transport these large pebbles. As we have seen from stop 11 these streams were laterally continuous channel complexes devoid of intervening overbank deposits. The coarse particle size of the conglomerates and the absence of overbank shales or siltstones suggest a braided-stream deposit. This complex stream system developed on a slope of steep gradient, most probably in association with a series of coalescing alluvial fans that spread westward from the high, tectonically active source terrain to the east.

6.9	105.6	Continue north on NY 296. Drive through Hensonville.
7.0	112.6	Turn right (east) on NY 23; drive beyond Point Lookout.
5.8	118.4	STOP 14. EAST WINDHAM. Stop before curve at yellow roadsign showing bent arrow (< O.1 mile before parking lot on left).

STOP 15: MEANDERING-STREAM POINT-BAR FACIES: CHANNELS, OVERBANK, AND SWAMP

This exposure shows a point-bar sequence in Tully-clastic correlative strata of the Gilboa Formation (Upper Givetian, Uppermost Middle Devonian). Two channels are exposed in this road cut, a lower channel and an upper channel (Fig. 29). The lower channel truncates overbank siltstone, whereas the upper channel truncates the lower channel and laterally adjacent overbank siltstone. A shale-pebble conglomerate, as a lag concentrate, overlies the truncation surface of the lower channel; in part this conglomerate is now hidden by fallen debris. This point-bar sequence at this site represents an abandoned meander which became an oxbow lake.

In rocks of the overbank facies, dark gray to black interbeds and, lenses containing abundant coarse plant remains,

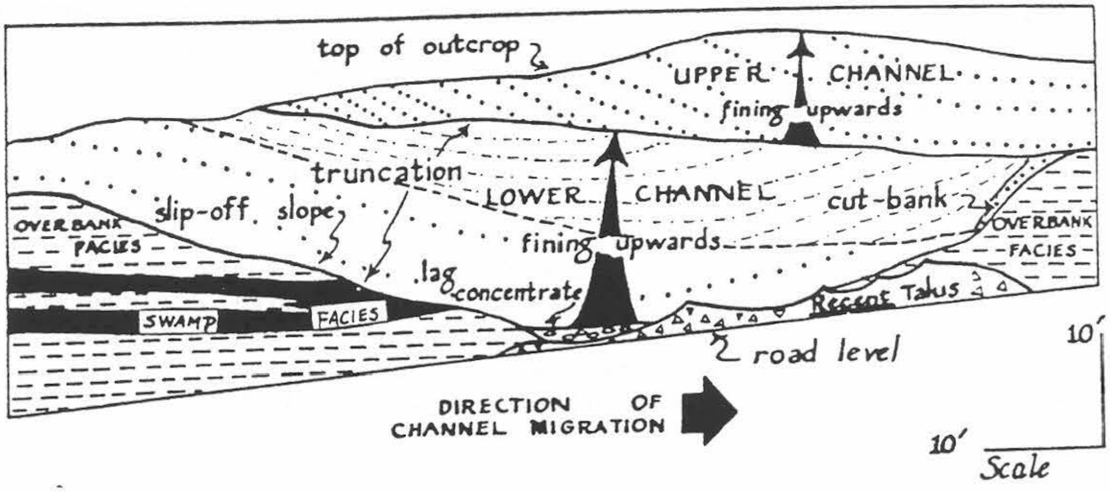


Figure 29. Compound channel in meandering stream point-bar facies. East Windham, N.Y. (modified from Johnson and Friedman, 1969) (Stop 15).

consisting of what appear to be stems and branches primarily, and locally developed coaly material, represent a back-swamp environment located on the slip- off slope side of the lower channel. The back-swamp facies appears to overlie crevasse- splay deposits. These beds, which occur in red overbank siltstone and contain very abundant plant material, some of which has been altered to a coaly substance, are some 5 feet thick and measure well over 60 feet in lateral extent.

The woody cells of the plant debris were in part converted to anthracite and in part replaced by pyrite. Replacement occurred at an early stage as evidenced by the lack of deformation of the replaced woody cells. Most of the pyrite has now been oxidized to hematite and limonite, probably by surface weathering. Even the anthracite, which usually resists oxidation, shows evidence of undergoing oxidation in this material. Surface oxidation was probably intensified by sulfate-bearing water derived from pyrite. The vitrinite reflectance of samples of this plant debris is 2.2% to 2.3%. The mean reflectivity of the vitrinites in oil using light with wavelength of 546 ìm is 2.5%. This indicates that the vitrinite contains 93% to 94% fixed carbon, about 3.5% hydrogen, and other volatile matter. Locally the coalified plant chambers contain anhedral pyrite and galena: the paragenetic sequence is pyrite and then galena. The vitrinite (coalified woody tissue) contains micron-sized pyrite cubes. Outside the plant tissues, small amounts of chalcopyrite and possibly sphalerite are present (Friedman, 1987a,b; Friedman and Sanders, 1982). The deposits observed at this site were buried to a depth of 6.5 km for a duration of about 200 million years (Friedman and Sanders, 1982).

The steep cut-bank on the right of the lower channel may initially have extended upward for many more tens of feet and tapped sand from an earlier upper channel. Sand, now sandstone, moved down the cut-bank as a liquefied cohesionless particle flow or grain flow and is now preserved as an inclined sand body paralleling the cut bank.

Bivalves of the Species *Archanodon (= Amnigenia*, Hall 1874) *catskillensis* (Heteroconchia, Archanodontacea) inhabited the back-swamp facies on the slip-off slope margin of the lower channel. These bivalves (up to 22 cm x 6 cm) are among the largest known fossil fresh-water pelecypods in geologic history. Unfettered, opportunistic growth in this swamp environment marked by rich organic matter and devoid of competition with other pelecypods, and possibly other benthic fauna of any kind, resulted in the unusually large sizes of these clams (Friedman and Chamberlain, 1995).

To the left of the point-bar sequence note onlap of stream facies on to an interpreted soil horizon.

Johnson and Friedman (1969, p. 463-468, including Figs. 7-17) provide a detailed description of this stop (their section 53); Figure 29 is a modified version of Figure 7 of Johnson and Friedman.

Return to Union College via New York Thruway (Interstate 787).

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ERRATA

in 1995 Field Trips for the 67th annual meeting of the New York State Geological Association, J.I. Garver, and J.A. Smith, Editors.

FLYSCH AND MOLASSE OF THE CLASSICAL TACONIC AND ACADIAN OROGENIES: MODELS FOR SUBSURFACE RESERVOIR SETTINGS

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In Figure 1b, page 110, note the position of the Rensselaer Conglomerate and the Rysedorph Hill Conglomerate within the Snake Hill Formation, here reprinted:

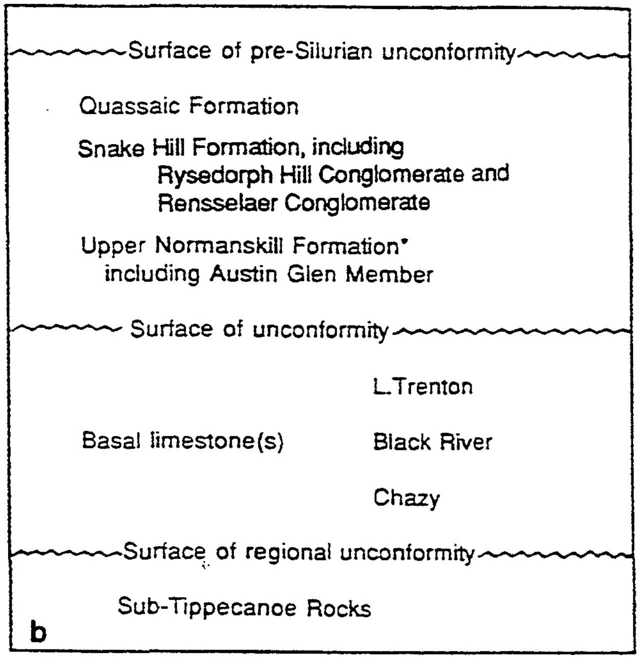

Figure 1b. Names of formations in Tippecanoe Sequence, eastern New York (modified from Sanders, 1995).

On page 127 in the second paragraph for STOP 5 and in the caption to Figure 20 the Rensselaer Conglomerate has been mistakenly noted as part of the Hatch Hill Formation which should be corrected to read Snake Hill Formation, as in the above figure. On page 118 the Rysedorph Hill Conglomerate was labeled Rensselaer Conglomerate and once again its formation was given as Hatch Hill Formation instead of Snake Hill Formation.

Participants on the trip made these corrections in the field.

Note also Figure 1a (p. 110) : this table from Guo, Sanders, and Friedman (1990) is not intended to be a strict correlation chart between the shelf and basin strata.

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