TRIP B-4

STRATIGRAPHY AND STRUCTURE OF SILURIAN AND DEVONIAN ROCKS IN THE VICINITY OF KINGSTON, N.Y.

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I. INTRODUCTION

On this trip the lower contact of the Rondout formation will be observed at two locations (Fig. 1). In the southernmost exposure at Tillson Hill the Rondout lower contact is sharp to gradational with the Binnewater sandstone. The significance of this contact is that it is in paraconformity or conformable with the earlier Silurian rocks.

At stops two and three to the north of Kingston (Fig. 1) the lower contact of the Rondout formation lies in angular unconformity to the Ordovician Normanskill formation. At these two northern stops the Shawangunk conglomerate, High Falls shale and Binnewater sandstone are all missing. There are three possible hypotheses which may explain this:

a. The northern area was being eroded while the southern area was submerged for deposition (a Silurian shoreline).
b. The northern area was undergoing deposition and later erosion. Thus, eroding the unconsolidated earlier Silurian sediments (a regressive sea).
c. In the later Devonian time, the entire area was thrust faulted and the angular unconformity is a thrust fault plane.

The authors favor explanation "a" since the missing formations are all thinning in a northeasterly direction although there is some evidence in support of each hypothesis

In the later Silurian the upper part of the Rondout formation was gradationally deposited with the Thacher limestone of Early Devonian. The Silurian-Devonian time division has therefore been placed within the upper Rondout formation (Rickard, 75). The Early Devonian was characterized by rather low energy environments in which a general carbonate and calcareous mud sequence was deposited.

The lower Devonian carbonates are exclusively marine, although the energy levels vary indicating fluctuations in sea level throughout the area. The lowermost Thacher limestone is variable from low to high energy levels perhaps tidal to subtidal while the Thacher is biostromal near the top.

From the overlying Ravena limestone through the Kalkberg limestone and New Scotland formation the energy levels fell off and the sea level was rising until the depth exceeded 200 feet at local wave base level. This sequence was followed by a recession of the sea during the deposition of the Becraft limestones. The environments deepened again during the deposition of Alsen limestone and the Port Ewen formation.

Fluctuations occurred perhaps during the deposition of the Glenerie formation and stabilized in a deep water environment during Esopus and Schoharie times (Waines, 67).

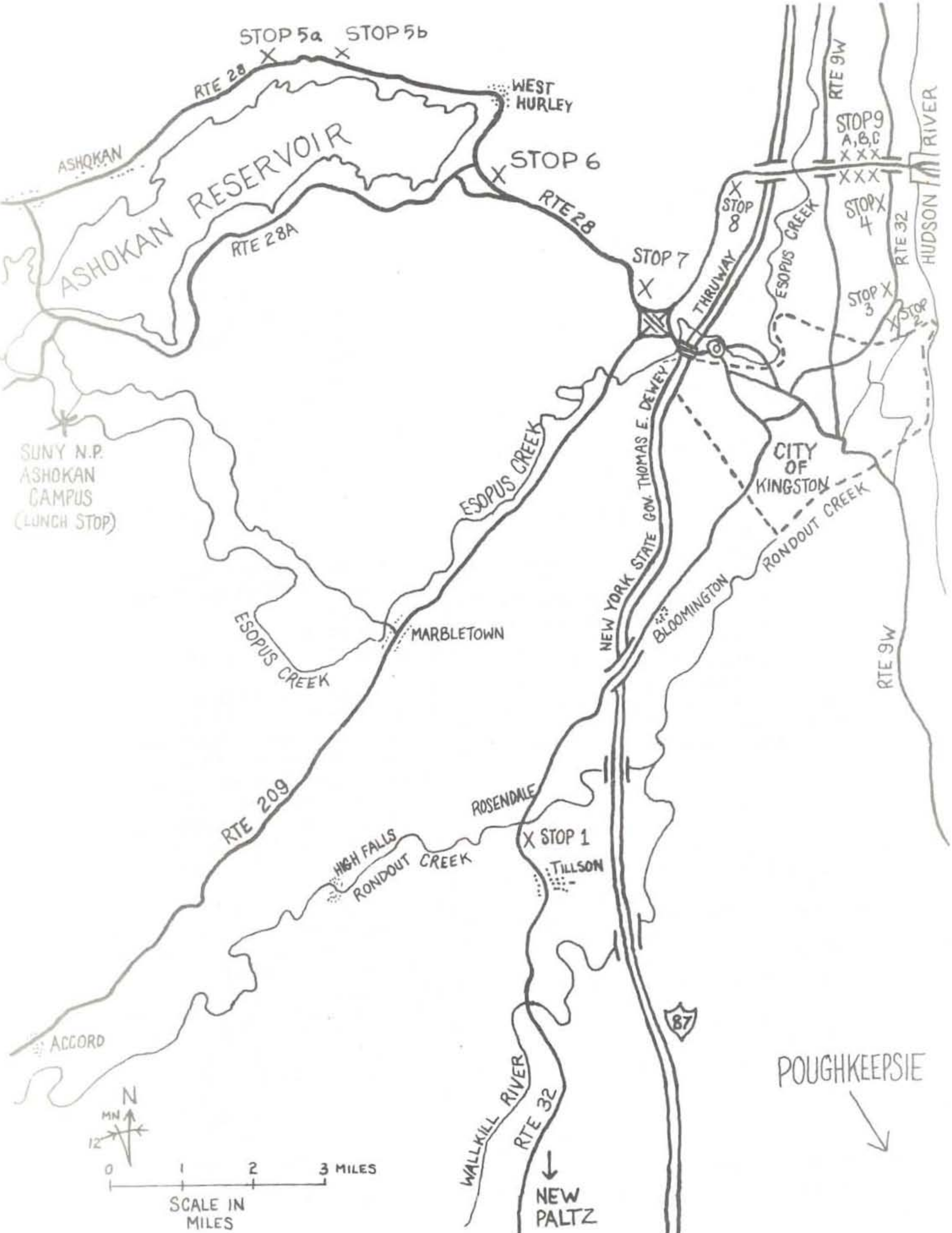

FIGURE 1. ROAD MAP.

The Middle Devonian Period is initiated with the deposition of the cherty Onondaga Limestone which has been subdivided into various units (Oliver, 1956, 1962). Only the Edgecliff and Moorehouse members occur in this region. This culminates the lower Paleozoic periods of carbonate deposition; the remainder of the Paleozoic is now characterized by the various clastics derived from the uplifted New England provinces deformed during the Acadian orogeny.

The first major pulse of sediments (Hamilton Group) form a vertical and lateral progradation of marine, coastal, and alluvial deltaic environments that continue to fill the various embayments near the edge of the basin and spread westward across the state - the initial development of the classic Catskill delta or deltaic complex (Barrell, 1913, Chadwick, 1933, Wolff, 1965, Friedman and Johnson, 1966).

This trip will examine some of these sediment phases or "facies" as represented by the Marcellus Formation (Table 1). Each of these units can be traced northward by physical correlation because of the similarity between regional structure (the Hoogeberg escarpment) and depositional strike, and then westward by thickening rates (Rickard, 1964) and paleontological control (Cooper, 1933). The vertical section of rock units and inferred depositional environments seen here are quite similar to those seen southward toward Pennsylvania (Mazzullo, 1973) and northward toward Albany (Wolff, 1969).

The Onondaga Limestone is conformably overlain by the fissile, black, Bakoven Shale which transitionally grades into the Stony Hollow Siltstone. Both of these units are slightly calcareous. They are overlain by a thick sequence of interbedded dark gray shales, siltstones, and massive fine-grained sandstones (Mt. Marion Fm.), and these transitionally grade into the cross-bedded, relatively unfossiliferous, sandstones of the Ashokan Formation. This unit, of variable thickness, is also transitionally overlain by the sandstones and shales of the Plattekill Formation. The presence of red shales and mudstones in place of only olive-green knobby mudstones adjacent to and in conjunction with the cross-bedded sandstones, is used as the facies boundary between these units.

The entire vertical section represents the single initial deltaic progradational sequence followed by a series of at least four other major deltaic sequences (Wolff, 1965, 1969) within the Devonian "Catskill deltaic complex." Road stops (5A-8) will begin at the top of the section (Table 1) in the Plattekill Formation and end at the Bakoven Shale. Previous trips examining the stratigraphy of this area include: Dunn and Rickard (1961), and Wolff (1969).

II, STRUCTURES

The New York sector of the Appalachians is unusual because it includes much of a major recess in the Appalachian mountain chain. The recess is that part of an orogenic belt where the axial traces of the folds are concave toward the outer part of the belt and is notable for the angular intersection of structural trends. The angularity may have been produced by the overlapping and crossing of orogenic trends

TABLE 1

GENERALIZED GEOLOGIC SECTION FOR THE TRIP

FORMATIONS	THICKNESS IN FEET	GENERAL LITHOLOGY
DEVONIAN PERIOD		
Middle Devonian		
Plattekill Fm.	800	Reddish-purple mudstones and siltstones, dark-gray shales and impure sandstone
Ashokan Fm.	300	Bluish-gray sandstone (flagstone), olive-gray shale
Mt. Marion Fm.	800	Gray sandstone and shale
Bakoven Fm.	200	Black shale
Onondaga Fm.	170-180	Gray limestone with dark-gray chert, gray coralline limestone with light-gray chert
Lower Devonian		
Schoharie Fm.	74-222	Medium-gray argillaceous limestone and calcareous mudstone, calcareous mudstone and siltstone with some gray argillaceous limestone; occ. chert
Esopus Fm.	150-200	Dark-gray shale and siltstone
Glenerie Fm.	20-55	Dark-gray siliceous limestone with chert
Port Ewen Fm.	10-100+	Gray argillaceous limestone with interbedded shale
Alsen Fm.	20-25	Dark-gray limestone with some chert
Becraft Fm.	35-50	Gray to pinkish-gray crinoidal limestone
New Scotland Fm.	95-150	Dark-gray calcareous mudstone and argillaceous limestone
Kalkberg Fm.	75	Gray argillaceous limestone and limestone with some dark-gray calcareous shale, dark-gray to gray limestone, gray shale partings, chert at base
Coeymans Fm.		
Ravena Member	20-28	Medium-gray to gray limestone
Manlius Fm.		
Thacher Member	48-50	Dark-gray to medium-gray limestone, occ. laminated; magnesium at base

FORMATIONS	THICKNESS IN FEET	GENERAL LITHOLOGY
SILURIAN PERIOD		
Upper Silurian		
*Rondout Fm.	30-55	
Whiteport Member	4-16	Gray argillaceous magnesian limestone
Glasco Member	10-13	Gray coralline limestone
Rosendale Member	6-27	Gray argillaceous magnesian limestone
Wilbur Member	4-12	Medium-to light-gray limestone
Binnewater Fm.	0-35	Blue-gray to greenish-gray cross-bedded, occ. ripple-marked quartz sandstone
High Falls Fm.	0-85	Red and green shale
Middle Silurian		
Shawangunk Fm.	0-6004	Milky white to gray quartzite and quartz pebble conglomerate
ORDOVICIAN PERIOD		
Middle Ordovician		
Normanskill Fm. (Martinsburg Fm)	2000	Graywackes, black and gray shale and siltstones

*The Silurian-Devonian time division has recently been placed within the upper Rondout Formation (Rickard, 75).

Adapted from J. H. Johnsen 4/67

produced at several different times in the Paleozoic. Probably the first geologist to emphasize the angularity was Arthur Holmes, who used it as an argument for Continental Drift, for he saw the westward convergence of Caledonian and Hercynian trends in the British Isles finally completed by the crossing in the New York recess, where, as noted above, the polarity of the orogenic migration during the Paleozoic reverses (Rodgers, 1967). In the Kingston area the angular intersection of structual trends can be observed.

The Silurian and Devonian formations lie unconformably on Ordovician graywackes, siltstones and shales which have undergone deformation. The Taconic orogeny is represented by the Normanskill-Rondout angular unconformity. The structures produced by tectonic processes in the Silurian and Devonian strata consist of symmetrical and asymmetrical folds and thrust faults which dominate the area, however, a normal fault was observed at the southeastern end of Stop 9 b.

A principal stress determination of the folds at stop 9 a, b, c and the thrust fault at stop 4 clearly indicates that the compressional regimes in this area did change in direction over time. The symmetrical anticline and syncline have their axial planes trending north-south, whereas the thrust planes dip 20° - 30° to the south. The thrust fault at stop 4 has developed a drag wedge which consists of several feet of crumpled, tilted and deformed beds produced when faulting occurred. Secondary calcite veins have filled feather joints which are the tension fractures genetically related to the thrust faulting. These feather (tension) joints are not confined to one side of the fault due to the equivalency of the tensile strength of the rocks on either side.

At stop 3 the Normanskill sandstones, siltstones and shales have reacted differently to the tectonic forces which have effected these rocks. The high angle thrust faults in these beds are evidence of the compressional stresses which acted on these rocks. During the faulting the sandstone and siltstones were the most compenent beds and failed by brittle fracture, the shales (which became phyllitic) behaved incompetently and adjusted themselves by flowage. The resulting structure exhibits rectangular blocks of sandstone and siltstone which have been forcibly plugged into the shales (phyllite) which in turn have flowed into any shape dictated by the moving blocks. This thrust plugging phenomena can be observed in the Normanskill in other outcrops in this area.

At stop 5B in the massive red-green mudstone of the Plattekill formation deep convolutions consisting of rounded synclines with intervening cuspate anticlines can be observed in the lower section of the outcrop (Fig. 6). This structure may have developed during deposition of the bed over initial synclinal troughs or by sliding or slumping after deposition had taken place.

An interesting soft-rock structure can be observed at stop 8 in the sandstones and shales of the Marcellus formation (Fig. 9). The soft rock structures are termed "pull-apart." The pull-aparts formed at the soft-rock stage where hydroplasticity is involved. There was limited hydro-plastic flow after deposition of the full sequence of beds. The sandstone layer which was embedded in the shale reacted differently to the overload compressional stresses at work. This normal stress disrupted the sandstone by lateral extension to produce a 'necking,' with final complete separation of this bed into segments. The more plastically behaving shale flowed around the sandstone segments. Finally, the flowage of the shale layers caused transposition of the sandstone segments so that now they overlap.

III. REGIONAL STRATIGRAPHY AND PALEOENVIRONMENTS OF MARCELLUS FORMATION (MIDDLE DEVONIAN)

A. Previous Work - Correlations

The initial clastic sequences above the Lower and Middle Devonian limestones in this area were described as the Hamilton Group in the first reports of the N.Y. State Geological Survey by Mather (1840) and Vanuxem (1842). The Marcellus Formation was not included as a subdivision until the work of Darton (1894) and this was further subdivided through the efforts of Grabau (1919), Cooper (1933), and Goldring (1935, 1943). Most of the members could not be adequately extended east of Schoharie Valley because of the lack of guide fossils and facies changes, though some suggestions were included (Cooper (in Goldring) 1935, 1943).

An attempt to extend these correlations between central and eastern New York and define the contact between the Marcellus and Skaneateles Formations was based on the last appearance of *Paraspirifer acuminatus* and the first appearance of *"Spirifer" sculptilis* (Wolff, 1967), but these are no longer recognized as guide fossils (Rickard, personal communication, 1969). However, based on the suggested fossil correlations of Cooper (op. cit.) and the application of sedimentologic criteria developed for the recognition of constructional and destructional deltaic phases (Scruton, 1950, Allen, 1965, McCave, 1968) the extension of the members of the Marcellus Formation in east-central N.Y. into the Mt. Marion-Ashokan Formations in this region are still believed to be valid (Wolff, 1969).

B. Regional Lithofacies and Depositional Environments

A recent description and correlation of the Devonian facies for the entire Catskill delta complex was proposed by Fisher and Rickard (1975) - a modification and extension of a previous model (Rickard, 1964). The suggested relation to the lithofacies and environments of the Marcellus Formation is indicated in Figure 2.

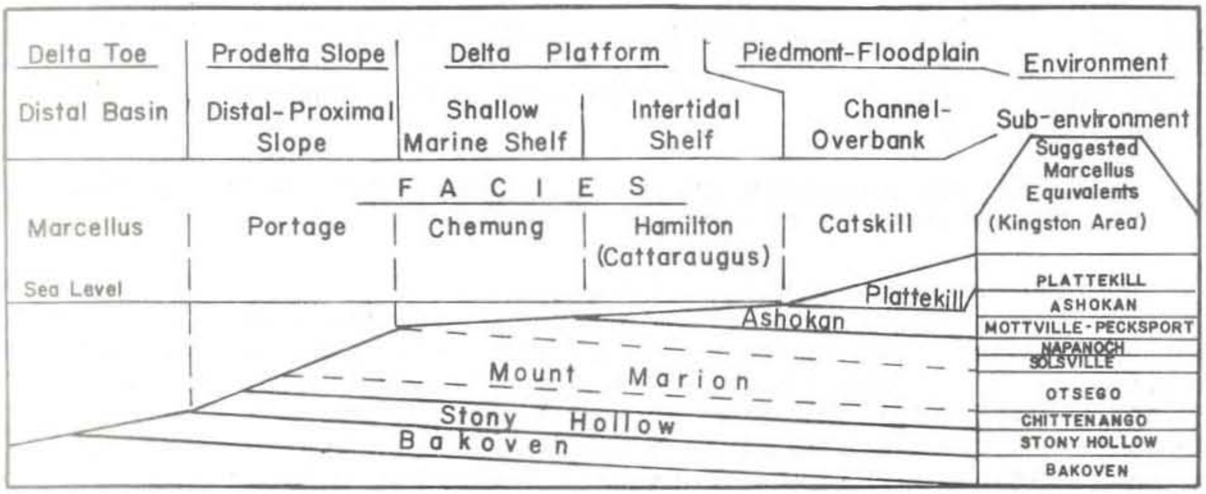

Figure 2. Deltaic environments, facies, and regional-and-local correlations for Middle Devonian Marcellus Formation in the Kingston area.

The following units and their facies and inferred depositional environments can be recognized (top to bottom).

1. Plattskill Formation - Catskill Facies: defined by Fletcher (1963) it consists of medium-coarse grained, large and small scale planar and trough cross-bedded subgraywacke sandstones over an erosional base arranged in upward-fining rhythmic sequences. The upper part of the sequence contains layers of siltstone, mudstone or shale, usually maroon-red or green, and lenses of pebbly conglomerates, mud clasts, and plant fragments. The knobby red mudstones may contain zones or horizons of calcareous nodules, plant root traces, or mud cracks. These have been interpreted by many (Burtner, 1963, Allen, 1968, McCave, 1968) as active and abandoned stream channel and floodplain deposits - the alluvial braided or meandering rivers draining the Devonian piedmont.

2A. Ashokan Formation - Chemung - Hamilton Facies: defined by Grabau (1919) and analyzed by Mencher (1938), it consists of interbedded medium-grained sandstones, (bluestones or "flagstone") massive siltstones, dark gray shales, and olive mudstones. Many of the cross bedded sandstones are laminated; the siltstones cross-laminated (wavy or lenticular bedding). Vertical and lateral contacts are sharp (erosional unconformities and pinchouts) or gradational. Current or wave ripples, load casts, zones of pebbles, mud clasts or plant fragments, iridescent organic films, and burrow mottles or vertical bioturbated structures (Taonurus velum) also occur.

A few brachiopods and pelecypods have been noted (Cooper (in Goldring) 1943, Cooper, 1957).

The thick sets of cross-bedded sandstones are interpreted as marginal alluvial channels and river mouth bars of deltaic distributaries, the thinner, more shallow-dipping and more variably-oriented cross-beds with frequent laminations represent minor distributaries and tidal channels (Wolff, 1969). The associated burrow-mottled gray siltstones and olive mud-stones, and the abundance of plant detritus may indicate the presence of adjacent levees and interdistributary swamps. The predominance of the gray-green colors reflects the solution of ferric iron minerals by groundwater. The presence of a high water table and the few brackish-marine fossils support a nearshore coastal position.

A series of lenticular bar-like sandstones interbedded with dark shales and siltstones and low angle cross-bedded sandstones in upward coarsening sequences also can be noted. These may be laterally continuous but are frequently partially eroded by tidal or alluvial channels. They are characteristic of transgressive sequences associated with tidal flats, lagoons, barrier bars and beaches (Reineck, 1972) and have been so interpreted for the Devonian in this region (McCave, 1968, 1973, Johnson and Friedman, 1969, Wolff, 1969).

While now classified as the "Chemung-Hamilton" facies by Rickard (1975) the features and inferred depositional environ-ments are more like his "Cattaraugus" facies except for the absence of redbeds and a brachiopod-crinoid fauna. They are intertidal rather than subtidal features - more like the original "Smethport" phase as originally defined by Rickard (1964). Perhaps a designation as "Hamilton" (restricted) would be more appropriate.

2B. Upper Mt. Marion Formation - Chemung-Hamilton Facies: originally defined by Grabau (1919) this unit now includes all the non-calcareous marine strata between the Stony Hollow and Ashokan Formations (Rickard, 1975). The upper part contains fine-medium grained, thick and thin bedded sandstones with interbedded siltstones and dark gray shales. There are some horizons of coquinites, low-angle, planar cross-bedding, ball and pillow structures, quartz or siltstone pebble conglomerates and megaripples.

This is the classic "Chemung" facies that is characteristic of the subtidal shelf and marine delta platform (Woodrow and Nugent, 1963, Sutton, Bowen, and McAlester, 1970, Fisher and Rickard, 1975), and initially appears within the Marcellus Formation. Based on the lateral persistence of some of these horizons, suggested faunal associations (Cooper (in Goldring), 1935, 1943, Chadwick, 1944), and the lateral relations of prograding deltaic sequences, these sections have been tentatively correlated with those in central New York (Wolff, 1967, 1969) based on suggestions of previous investigators. This would place the Ashokan sandstones into the Skaneateles Formation and subdivides the upper Mt. Marion Formation into the Solsville and Pecksport members of the Marcellus Formation (Fig. 2).

3. Middle and Lower Mt. Marion Formation - Portage Facies: as described in some detail by Chadwick (1944) it consists of thin-bedded gray sandstones, siltstones and dark arenaceous or fissile shales. Though shales dominate, interbedded siltstones are common and these become thicker, coarser, and more prevalent as one rises through the section. Current ripples, cross laminations and bioturbated layers also occur; flute and groove casts usually associated with these "turbidite" sequences, are relatively rare.

This facies forms the thickest part of the Marcellus (Mt. Marion) Formation and contains characteristics similar to the prodelta slope of most recent deltaic environments (Scruton, 1960, Allen, 1965, Kanes, 1970) though the influence of tectonics and subsidence must also be considered (Sutton, 1963, Sutton, Bowen, and McAlester, 1970). Based on the lateral variations associated with proximal and distal prodelta slope environments, the initial development of upward coarsening sequences (Rickard and Zenger, 1964), thickening rates (Rickard, 1964), and the suggested correlation of several fossil horizons (Cooper (in Goldring), 1935, 1943) the lower Mt. Marion has also been tentatively subdivided into equivalent strata (i.e. Otsego and Chittenango members) from east-central New York (Wolff, 1969). The distal position of the prodelta slope would also include the Stony Hollow member (Fig. 2).

4. Bakoven Shale - Portage - Marcellus Facies: originally defined by Chadwick (1933) this is a soft, black, calcareous shale with some large black calcareous or pyritiferous concretions. The lack of bioturbation, the high organic water content, and sparce pelagic fauna (Chadwick, 1944) all suggest a strongly reducing anerobic environment in the distal basin. A local disconformity (solution pits on the surface of the Onondaga Limestone filled with black shale) has been reported in the Kingston area (Chadwick, 1927, Cooper, 1930, Wolff, 1963). This indicates a marginal, nearshore (rather than distal basin) deposited environment for this unit.

ROAD LOG FIELD TRIP B-4

Leaders: Kenneth Pedersen, Michael Sichko, Jr., Manfred P. Wolff

TOTAL MILES	MILES BETWEEN POINTS	REMARKS
0.0	0.0	Vassar College parking. Exit parking lot, left turn for 0.075 miles to Raymond Avenue.
0.15	0.075	Right turn to Hooker Avenue.
2.10	1.95	Left turn to Montgomery Street.
2.60	0.50	Right turn to Lincoln Avenue.
2.80	0.20	Left turn to Mid-Hudson Bridge.
4.00	1.20	On the right ripple marks in the Martinsburg formation.
4.75	0.75	Right turn to 9W north.
7.25	2.50	Left turn to route 299.
13.70	6.45	Right turn onto route 32 (North Front Street).
13.85	0.15	Right turn onto route 32.
20.50	6.65	STOP 1: Silurian System - Tillson Hill, N.Y.: This stop shows an exposure of the formations of Silurian age which are exposed in the Hudson Valley. The Shawangunk conglomerate, the High Falls shale and the Binnewater sandstone are all found below the Rondout formation. The contact between the Binnewater sandstone and the Rondout formation is conformable at this locality. Farther North, however, the Rondout is found in angular unconformity to the underlying Normanskill formation of Ordovician Age. Proceed north on route 32 toward Kingston, N.Y.

TOTAL MILES	MILES BETWEEN POINTS	REMARKS
27.60	7.10	Right turn at the stop sign onto Greenkill Avenue.
27.80	0.20	Left turn onto Clinton Avenue.
27.85	0.05	Right turn onto Cedar Street.
28.20	0.35	At traffic light proceed straight across Broadway to Cornell Street.
28.70	0.50	At the stop sign left turn onto Foxhall Avenue.
29.00	0.30	Right turn onto Flatbush Avenue (route 32).
31.45	2.45	Right turn onto East-Kingston turn-off (a hairpin turn).
31.80	0.35	STOP 2: Subterranean exposure of the Ordovician-Silurian angular unconformity. The steeply tilted Normanskill formation is exposed in angular unconformity with the Rondout formation. At this location the only remnants of the Rosendale and Whiteport members are the columns which support the roof in the mines (Fig. 3). Make a U-turn and proceed back to route 32. Right turn onto route 32.

Figure 3. Subterranean exposure of the Rondout Formation.

TOTAL MILES	MILES BETWEEN POINTS	REMARKS
32.35	0.55	STOP 3: Subaerial exposure of the angular unconformity: Again the Normanskill-Rondout angular unconformity. At this locality, major structural deformation due to the Taconic Orogeny are easily observed. Proceed north on route 32.

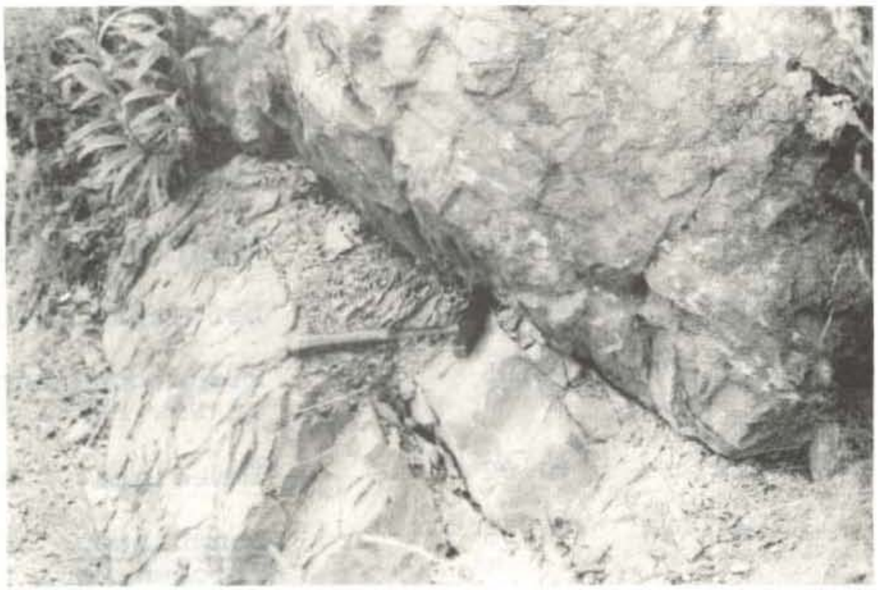

Figure 4. Subaerial exposure of the angular unconformity.

32.75	0.40	STOP 4: Thrust faulting within the Thacher member of the Manlius limestone: The Thacher limestone shows major structural deformation from the Acadian Orogeny in the form of thrust faulting. The carbonaceous interbedded shales have been metamorphosed into phyllites and phyllites shists. Proceed north on route 32.

TOTAL MILES	MILES BETWEEN POINTS	REMARKS
33.30	0.55	Right turn on entrance ramp to route 199 west.
34.40	1.10	Route 199 ends, proceed straight onto route 209 south.
37.95	3.55	Right turn onto route 28 west.
49.65	11.70	Left turn onto Ashokan Reservoir road.
51.40	1.75	Make a left turn.
51.50	0.10	Bear right (downhill).
51.90	0.40	Intersection of route 28A.
51.95	0.05	Aeration plant on the right.
52.05	0.10	Left turn onto Beaverkill Road.
53.10	1.05	Right turn onto State University of New Paltz Ashokan campus.
53.12	0.02	Immediately bear right.
53.45	0.33	Lunch Stop: Enjoy the scenery. Proceed back to Route 28.
53.75	0.30	Bear left.
53.80	0.05	Left turn onto Beaverkill Road.
54.80	1.00	Right turn onto 28A
55.00	0.20	Bear left.
55.45	0.45	Right turn onto Reservoir road.
57.20	1.75	Intersection of Reservoir road with Route 28 at Winchell's corner. Turn right onto route 28.
57.50	4.30	STOP 5A: Plattekill Formation (Catskill Facies) stream channel environment: Exposure consists of 14 feet (4.3 m.) of flat bedded and planar cross-bedded sandstones. These occur in a series of overlapping and truncated wedges

TOTAL MILES	MILES BETWEEN POINTS	REMARKS
		averaging 1-3 feet (0.3-1 m.) in thickness (Figure 5). The individual dark subgraywackes are 1/2 to 2 inches (1-3 cm.) thick and form accretionary slopes of 2-5°. While the regional direction of flow is S80°W, the individual sets of crossbeds trend northeast-southwest. Rather than a major upward-fining alluvial channel, this section is interpreted as an area of shallow distributary or braided stream channels laterally filled through point bar accretion and vertically filled by channel agradation. Continue east on route 28.

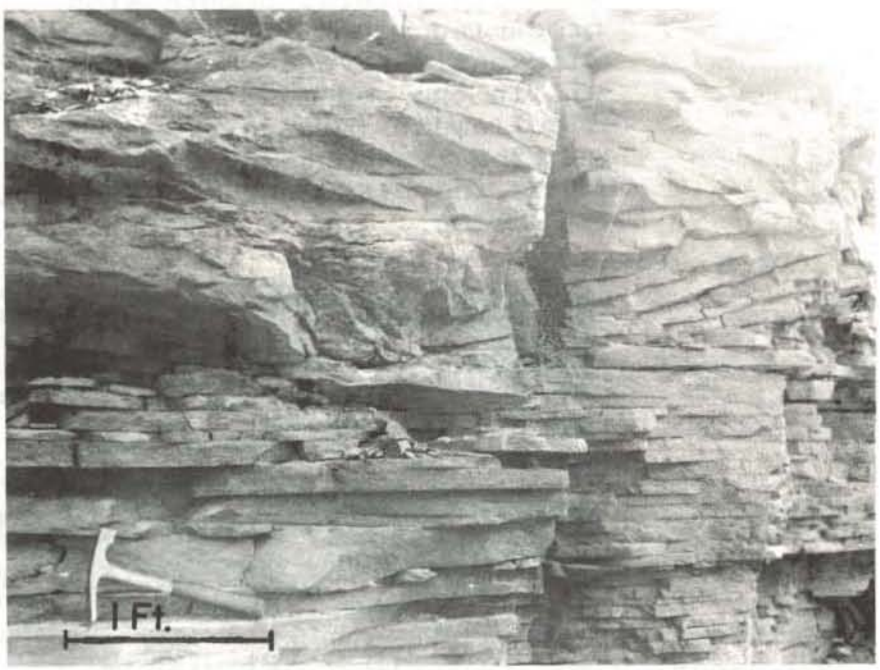

Figure 5. Horizontal-bedded and planar crossbedded subgraywacks sandstones of the Plattekill Formation (Catskill facies - channel environment).

TOTAL MILES	MILES BETWEEN POINTS	REMARKS
58.40	0.90	STOP 5B: Plattekill Formation (Catskill Facies) floodplain environment: Base of outcrop consists of 17 feet (5.2 m.) of knobby red-green mottled mudstone grading upward into 4-6 feet (1.3-3m) of olive green mudstone. Section is disconformably overlain by a sequence of medium-gray, shallow-dipping planar cross-bedded sandstones. The regional paleo-slope across the megarippled erosional surface trends S70°S. The zone of recent differential erosion about 8 feet (2.5m) above the base represents a section of westward lateral compression producing minor folding, slickensides, and thrusting within the red mudstones-a minor decollement (Figure 6.) This section is about 200 feet (61.5 m.) above the base of the Plattekill Formation.

Figure 6. Massive red-green mudstone disconformably overlain by gray crossbedded sand-stones of the Plattekill Formation (Catskill facies-floodplain environment). Note zone of compression in lower third of section.

TOTAL MILES	MILES BETWEEN POINTS	REMARKS
59.10	0.70	Junction with route 375, continue straight on route 28.
60.90	1.80	STOP 6: Skanneateles-Marcellus Formations (includes the local Ashokan and upper Mt. Marion Formations):

Contains features characteristic of the Chemung-Hamilton facies (intertidal environment). Use parking lot of Micrometrics, Inc. on the south side of the road.

A. South side of Rt. 28 roadcut - Mottville and Ashokan Sandstones. Major feature is the 8 foot (2.6m) laminated and cross-laminated, moderately sorted, planar cross-bedded sandstones. These occur on a series of enechelon "sand bars" here, over 130 feet (40 m.) wide and interbedded with dark shales and massive, fine-grained, bioturbated sandstones. These bars strike N70°W and have steep "foreshore" slopes (20°) trending northeast with more gentle (10-15°) "backshore" dips. Overlying the sandstones is a 5 foot (1.8 m.) succession of dark shales and fine-grained laminated sandstones with abundant plant fragments. This part of the section has been traced to Schoharie Valley (Mottville Sandstone) and is interpreted as a series of river mouth bars, intertidal or shallow subtidal sandbars, and sandflats (Wolff, 1969). These marginal sandstones are steeply truncated by a 40 foot (12.6 m.) section of thick, large-scale trough and planar cross-bedded sandstones with irregular lenses of olive mudstone (Figure 7). Individual beds are 2-4 inches (4-7 cm.) thick and dip at angles of 2-10° to the northwest. Worm burrows, shale chips, and plant fragments are common. This section represents the first major intertidal channel cutting across the sequence (Ashokan

TOTAL MILES	MILES BETWEEN POINTS	REMARKS
		sandstone). The paucity of marine fossils may reflect the alien ecologic conditions that would be associated with the rapid lateral and vertical erosion and sedimentation in this environment. However, small crustaceans Estheria (a brachiopod) and Beryrichis (an ostracod) have been collected in several areas at this interval (Goldring, 1943, p. 268) supporting a brackish-water interpretation.

Figure 7. Contact of bar like bipolar crossbedded sandstone and interbedded sandstone-shale sequence of the suggested Mottville Formation (Hamilton facies-intertidal environment) and the planar-crossbedded sandstones with interbedded shales and mudstones of the Ashokan Formation (Hamilton facies-intertidal environment).

TOTAL MILES	MILES BETWEEN POINTS	REMARKS
		B. North side of Rt. 28 - upper Mt. Marion Formation. Suggested to be equivalent to Pecksport member of Marcellus Formation (Copper (in Goldring) 1943, p. 260, and Wolff, 1967, 1969). Outcrop consists of 9 feet (2.8 m.) of brown-black interbedded shales and siltstones capped by a 3 foot (1 m.) bed of dark, small scale, planar cross-bedded sandstone (equivalent to base of section on south side of road). Many of the shales exhibit an "oily" irides-cent purple sheen. Structures include wave ripples, laminations, cross-laminations, lenticular bedding, flaser bedding, worm burrows, and tidal bedding - all features that can be associated with lagoons and tidal flats (Reineck, 1963, Klein, 1970). Fossils include Schizophoria, Pterinopecten, Paraspirifer, and Tropidoleptus, and are representative though not diagnostic for the uppermost Marcellus (Pecksport member). This area is interpreted as a region of wide sand flats containing barrier base and beaches, lagoons or tidal channels, and marshes or swamps that formed between deltaic laber during a period of general submergence. (Figure 8). After submergence (Pecksport interval - A) there is an interval of transgression, reworking, and nearshore deposition (Mottville interval - B), before the next major pulse of deltaic sedimentation (Ashokan interval - C).

TOTAL MILES	MILES BETWEEN POINTS	REMARKS

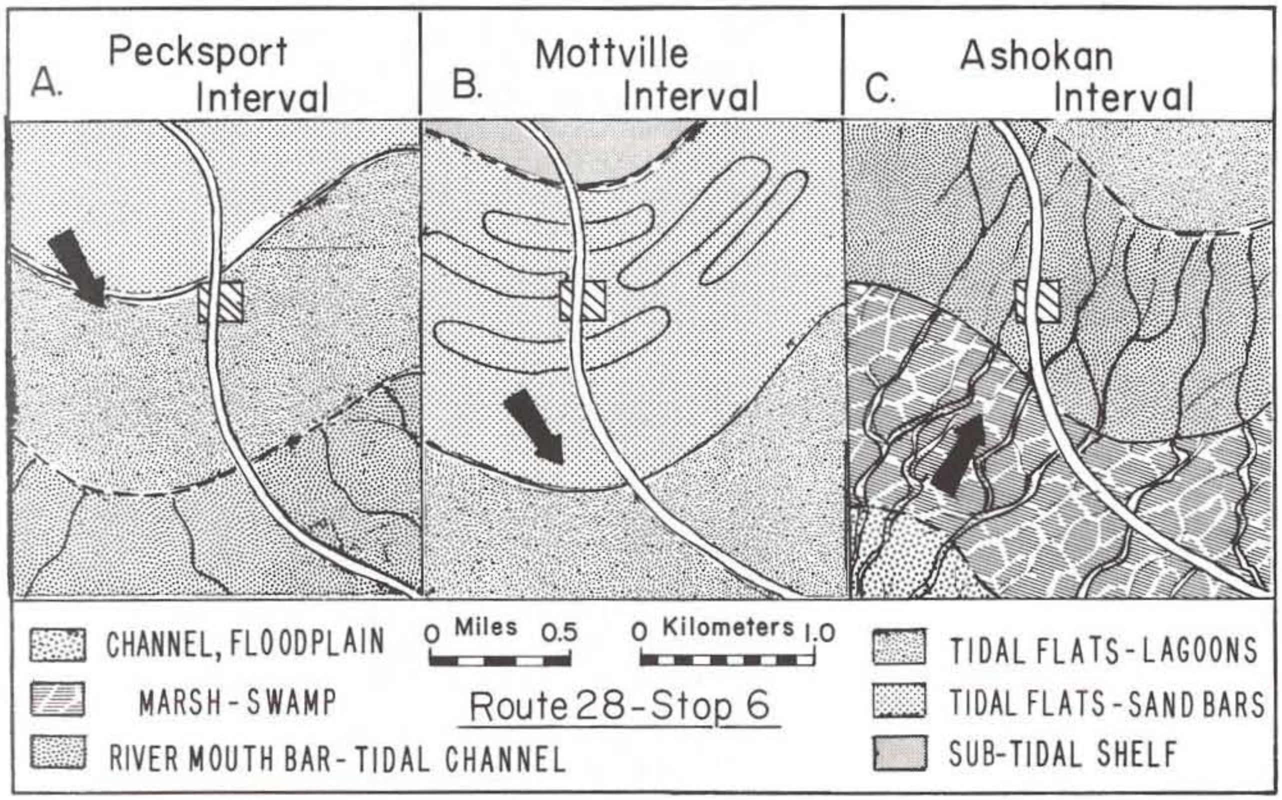

Figure 8. Interpretation of progressive changes during the deposition of Pecksport, Mottville, Ashokan members within the intertidal environment (Hamilton facies) At Stop 6 (see text).

62.00	11	Continue east on Route 28 passing by ball and pillow structure of upper Mt. Marion Formation.
62.60	0.6	Passing dark gray siltstones and shales of middle Mt. Marion (Otsego member) through "Hoogeberge escarpment."

TOTAL MILES	MILES BETWEEN POINTS	REMARKS
64.10	1.5	Passing buff-weathered siltstones of Stony Hollow member.
64.40	0.3	Turn left off route 28 onto Forest Hill Drive near Skytop Motel.
		STOP 7: Marcellus Formation (Portage Marcellus Facies) - Stony Hollow and Bakoven members (distal slope and basin environment): Base of section consists of 22 feet (6.6 m.) of thinly laminated black calcareous shales, commonly drag folded and faulted (underthrusts). The next 8 feet (2.3 m.) also contain black calcareous concretions (frequently slickensided), and compression fractures with quartz veins. The Bakoven is about 100 feet (30 m.) thick, but only the upper portion is exposed here. This unit grades into 8 feet (2.3 m.) of dark gray massive calcareous siltstones. The near vertical joints, trending N60°E are quite characteristic. Upon weathering the buff-colored surfaces exhibit the laminations or cross-laminations commonly associated with this unit. These may represent deposition by waning turbidity, or other marine currents. The siltstones contain some detrital carbonate and a few fossils, and become more massive through this 35 foot (11 m.) section. It is equivalent to the Cherry Valley (Agoniatite) Limestone in central New York and was first described by Cooper (in Goldring), 1943. Return to route 28 and continue south toward Kingston.
64.80	0.4	Junction with route 209 north, bear right onto 209. Pull off just before exit to Sawkill Road.

TOTAL MILES	MILES BETWEEN POINTS	REMARKS
67.10	2.3	STOP 8: Marcellus Formation - Portage Facies (locally the lower Mt. Marion Formation or the sandy equivalent of the Chittenango member of east-central New York: Road cut consists of 120 feet (37 m.) of dark gray arenaceous shale with some anomalous inter-bedded fine-grained sandstones through the lower 20 feet (6.2 m.) of the section. The overlying shales contain light gray conc-retions and include 5 "coquinite" fossil horizons. Of significance is the Meristella - coral zone in the central zone (now covered by the weathered shale) and horizons of brachiopods and pelecypods. Cooper (in Goldring) 1943, traced this horizon from the Berne Quadrangle (S.W. of Albany) into this area. The interval between the Stony Hollow member and the Otsego Shale was designated as the "Berne member" (Cooper, op. cit., p. 249) but it was restricted because of the few known locations. The extension of this member to the Kingston area enables it to be also correlated as the sandy equivalent of the Chittenango Shale (Cooper, op. cit.), and establishes the contact between this shale and the Otsego Shale in this region (Wolff, 1967, 1969). The pull apart and transposition structures at the base of this section (Figure 9) are described in the structure section of this article. Continue on route 209 toward the Kingston-Rhinecliff Bridge.

TOTAL MILES	MILES BETWEEN POINTS	REMARKS

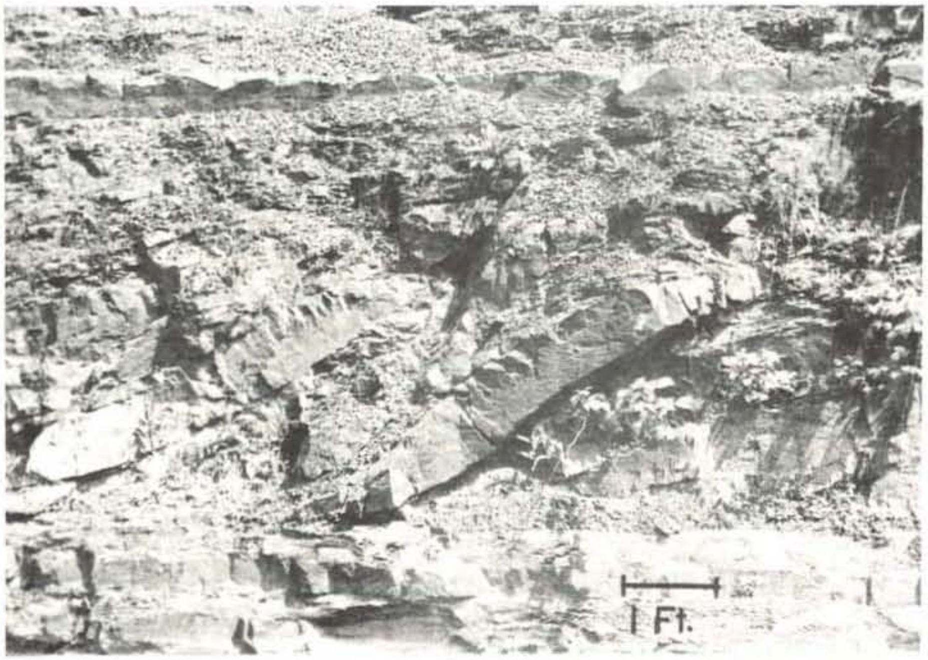

Figure 9. Pull apart and transposition structure (Note: "necked" ends).

68.30	1.2	STOP 9 a, b, c: Gentle folding in the lower Devonian Rocks: Here the gentle anticlines and synclines expose the lower Devonian section almost in its entirety. We are proceeding downward in the column so the rocks encountered are in the following sequence: Schoharie, Esopus, Glenerie, Port Ewen, Alsen, Becraft, New Scotland, Kalkberg, Ravena and Thacher (Waines, 1967). Proceed back to Vassar College.

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