TRIP E: TACONIAN ISLANDS AND THE SHORES OF APPALACHIA

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INTRODUCTION

Within the Precambrian Highlands of northern New Jersey and adjacent New York are several infolded and infaulted belts of Paleozoic sediments. The easternmost of these belts, the Green Pond - Schunemunk outlier, preserves Silurian and Devonian rocks as well as Cambrian and Ordovician. The mid-Paleozoic sediments lie some 25 miles farther southeast than the main outcrop belt of the miogeosyncline, and represent a sampling of material deposited approximately that much nearer the source. They provide a record of those tectonic events and geographic conditions in the source area whose influence did not spread far enough to become manifest farther west.

TACONIAN ISLANDS AND RELATED MATTERS

A glance at the map (Figures 1 and 2) will show that the Silurian is in contact with the Precambrian in some places and with the Cambro-Ordovician in others. Some contacts with the Precambrian lie along the traces of high-angle faults that cut across the strike of the beds. The remaining Silurian-Precambrian contacts are parallel to the strike of the Silurian. It is possible that they are also faults, for the actual contacts are nowhere observable in the field, although outcrops are continuously exposed within a few feet of them (STOP 3). In certain places, as at the north end of Bowling Green Mountain (see Figure 1) the contact wraps around the nose of a fold and is parallel to Silurian beds of rather gentle dip (less than 45^{o}). It is unlikely that a single thrust, much less a composite of separate faults, would be consistently parallel to a gneiss-conglomerate contact. It is more likely that this is an uncomformable sedimentary contact.

The area in which the Silurian rests on the Precambrian is quite circumscribed. Its precise outlines and limits cannot be completely determined because the outcrops of the Siluro-Precambrian contact are confined to a few narrow belts parallel to the axis of the present inlier. Direct evidence for the northern and southern limits are preserved near Newfoundland and Dover, New Jersey, respectively (Figure 2) but the eastern and western limits are somewhere outside the outlier. Nevertheless, we can establish the western limit as east of the Walkill Valley, for there the complete Cambro-Ordovician sequence rests on the Precambrian (STOP 4). East of the outlier, along the Triassic border fault, the Cambro-Ordovician is exposed intermittently: the complete unmetamorphosed sequence at Clinton, and a partial one at Peapack-Gladstone, New Jersey; Ordovician phyllite at Pompton, New Jersey, (STOP 2); phyllite and marble at Stony Point, New York (Trip H). Elsewhere, Cambro-Ordovician carbonate cobbles are abundant in the Triassic border conglomerates, as at Pompton Lakes, New Jersey (STOP 1) and in Rockland County, New York (Trip D) revealing that they were extensively exposed immediately west of the border fault as late as Triassic time. Thus we can establish that the local area of exposed Precambrian during the early Silurian was confined within this perimeter.

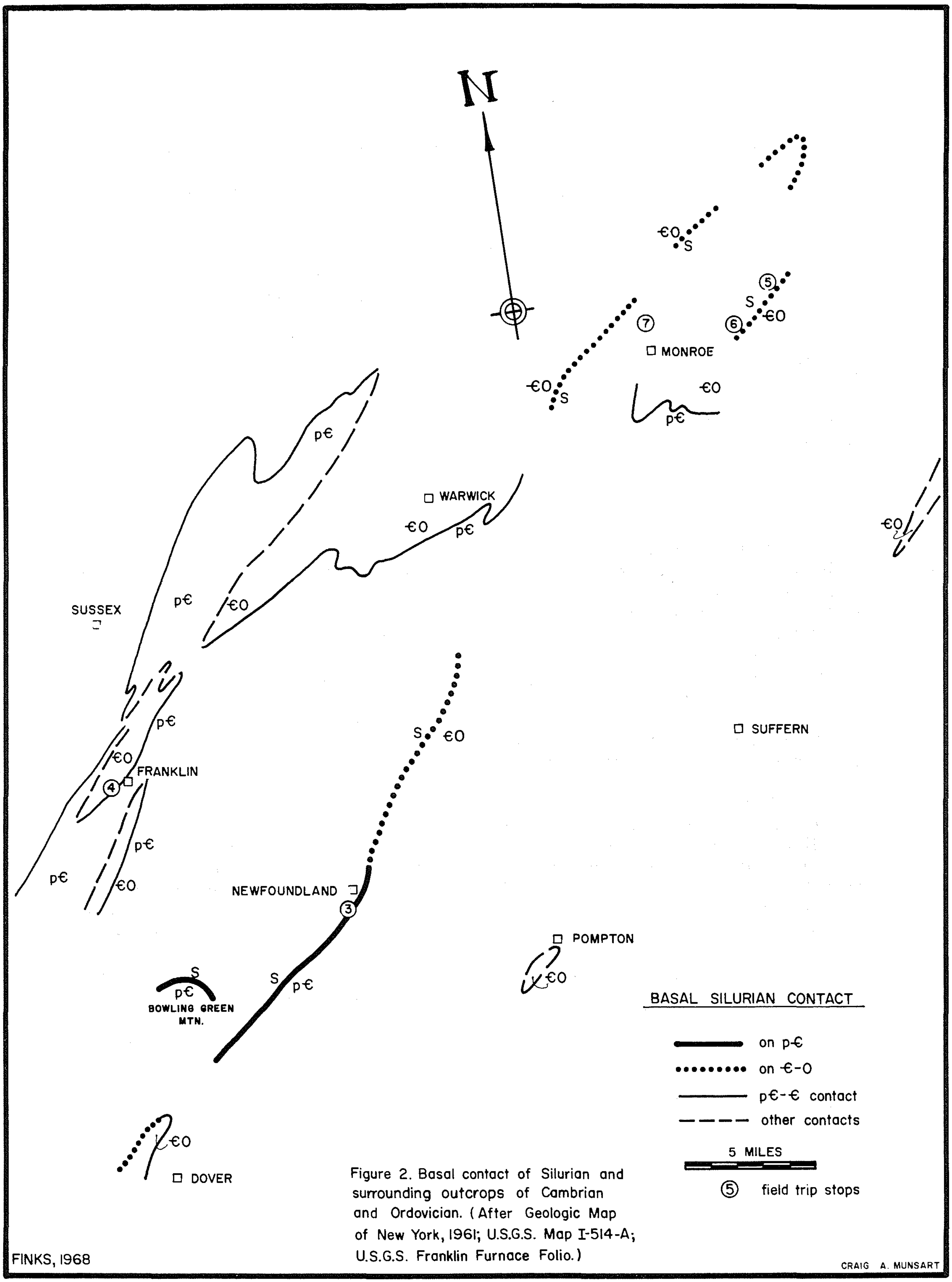

Figure 2. Basal contact of Silurian and surrounding outcrops of Cambrian and Ordovician. (After Geologic Map of New York, 1961; U.S.G.S. Map I-514-A; U.S.G.S. Franklin Furnace Folio.)

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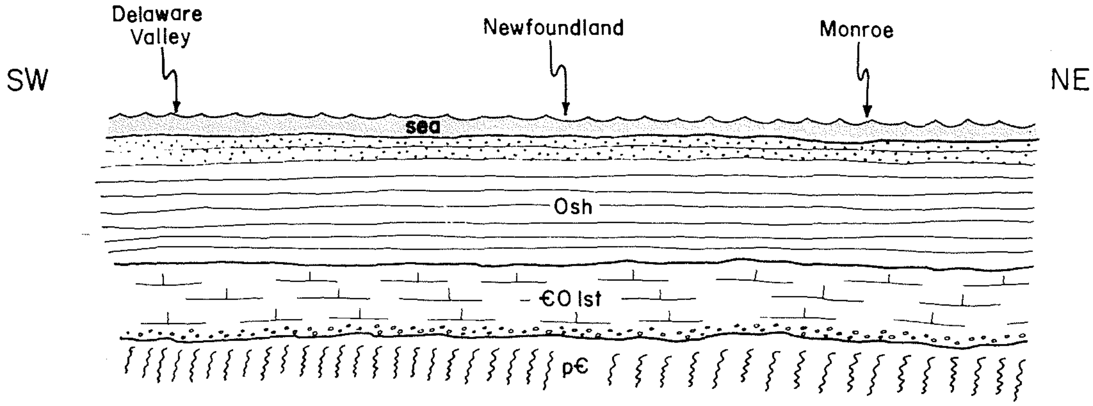
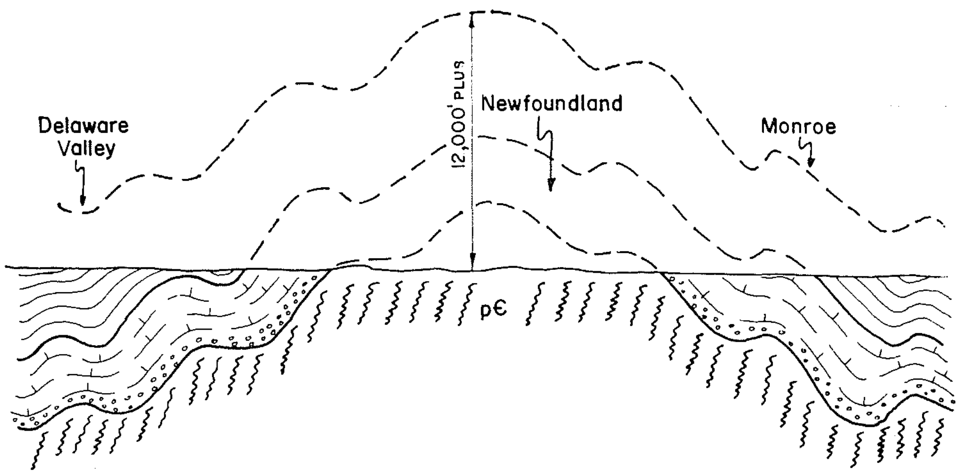
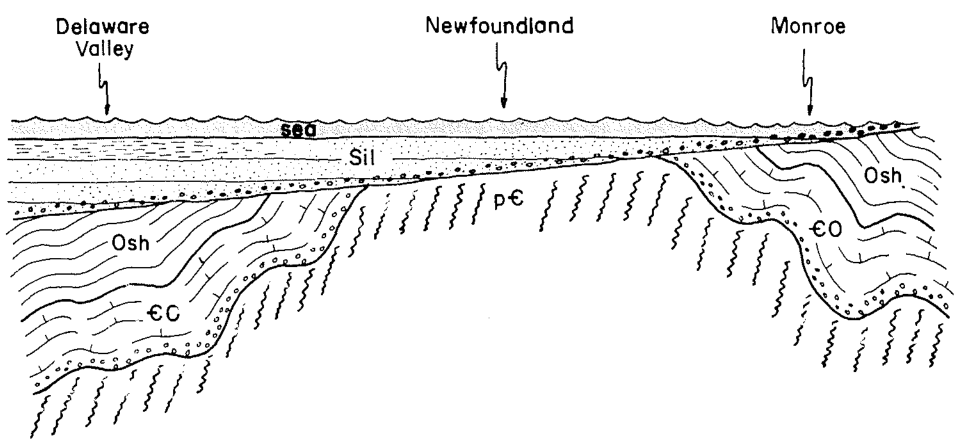


A- About 12,000 feet of sedimentary cover on pre-€ at end of Snake Hill (Trenton) time. Pre-Trentonian unconformity omitted.



B - Removal of more than 12,000 feet of cover before Shawangunk-Green Pond (Niagaran) time.



C- Condition during Later Silurian (Cayugan) time after Shawangunk-Green Pond deposition.

Vertical scale: 1"=10,000' Exaggeration approximately x6

Figure 3.

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The Silurian area of exposed Precambrian was almost certainly once covered with the full Lower Cambrian through Trentonian sequence. This sequence is essentially uniform in its stratigraphy on all sides of our area, and shows no signs of any uplift within the area in the form of a terrigenous clastic aureole. There is one rather widespread unconformity within the sequence, namely that at the base of the Trentonian (Balmville-Jacksonburg Limestones), but its very widespread nature indicates that it has no special significance for the local area. The strongest indication of this unconformity within our region can be seen to the northeast of Warwick, New York, where the Trentonian sequence oversteps rocks as low as the Upper Cambrian Pine Plains Formation (Offield, 1967). This amounts to the removal of about 1000 feet of section out of the entire 12,000 foot Cambro-Ordovician sequence (thickness from Offield, 1967). Consequently the remaining 11,000 feet or so was removed after the Trentonian and before the deposition of the Green Pond Formation by an uplift of this amount. As to the nature of the uplift, simple anticlinal folding might produce it, as shown in Figure 3, but thrust faulting would not be inconsistent with the style of Taconian deformation.

Because the entire Cambro-Ordovician sequence, completely surrounding the uplifted area, is wholly marine, the uplift may have risen as an island, or islands, out of the post-Trentonian sea. If so, its total area initially cannot have been much greater than the area of exposed Precambrian beneath the Silurian, a few tens of miles in greatest dimension. Ultimately it may have become joined to a larger Taconian landmass before being buried under Silurian sediment. Alternatively, it may have formed a mountain range in the Late Ordovician landscape, being uplifted only after the general emergence of the area from the sea. In either case, we must account for the widespread preservation of Trentonian and older rocks by assuming a protective cover of Late Ordovician sediment, subsequently removed, or else by assuming minimal uplift above sea level of the surrounding area.

THE SHORES OF APPALACHIA

Appalachia isn't dead, it's just gone to Africa. This paraphrase of Anna Russell's remark about vaudeville and England may serve to sum up more than a century of discussion concerning the source of eastward-coarsening terrigenous clastics in the Appalachian miogeosyncline. Whatever one considers Appalachia to have been, there is no doubt that it has manifested something of its geographic and tectonic nature in the sediments that it shed westward into the neighboring geosynclinal area. Major tectonic events have spread clastic debris even onto the craton, as for example the Catskill Delta. Lesser events have spread their influence more modestly. The Siluro-Devonian outlier of northern New Jersey and southeastern New York offers a unique opportunity to "take the pulse" of Appalachia, for it is nearer to this enigmatic body than the main Siluro-Devonian outcrop belt by about 25 miles.

Tectonism.

True to this prediction, the Silurian and Devonian of the outlier do record, in the form of pulses of highly feldspathic sediments, periods of increased erosion of crystalline rocks not recorded elsewhere. The first of these is represented by the Middle Arkose Member of the Green Pond Formation. It consists of coarse, hematitic arkose containing fresh cleavage fragments of feldspar up to 1/2 inch across. The unit can be identified at the northeast end (STOP 5) and southwest end (STOP 6-A and Figure 4) of Pine Hill on the east side of the outlier and has been recognized in outcrops on the west side of the outlier to the west of Schunemunk Mountain (Coates, 1948). The member does not seem to be present to the south, at Newfoundland (STOP 3). This tongue of feldspathic material is conspicuous by contrast with the underlying beds of conglomerate which consist of pebbles of chemically-stable material such as milky quartz, quartzite and chert. The lower conglomerates represent the initial erosion products of the deeply-weathered Taconian landmass, and the angularity of the lowermost cobbles imply a nearby source (STOP 3 and Plate 1, figure 2). The feldspathic tongue represents the beginning of rapid mechanical erosion of fresh crystalline rock, and requires an essentially contemporaneous, nearby uplift, in late Niagaran or early Cayugan time. The presence of hematite indicates that the source area was simultaneously undergoing chemical weathering, probably on the interfluves in the manner of Krynine's interpretation of the Newark Series (Krynine, 1950).

The second episode of uplift in the source area is represented by the Lower Arkose Member of the Longwood Formation, shown on Figure 4 and described in the measured section at the south end of Pine Hill, Table I (STOP 6-A). This unit can also be recognized at Newfoundland (STOP 3). It is a medium-grained, red sandstone, with abundant light-colored feldspar grains. Similar, but somewhat less feldspathic, red sandstone beds are intercalated in the immediately underlying upper beds of the Green Pond Formation (Table I). This feldspathic sequence is separated from the Middle Arkose Member of the Green Pond by the clean quartz sands of the Upper Quartzite Member. It undoubtedly represents a renewal of strong mechanical erosion of a crystalline source, though by now the source is either lower or farther away. Conceivably it might be explained by increased rainfall, but a second pulse of uplift is at least as likely. This pulse would have taken place in middle to late Cayugan time.

Feldspar disappears from the section following this unit, and indeed, terrigenous detritus of any kind almost entirely drops out in the uppermost Silurian (STOP 6-A and Figure 4) and lowermost Devonian. In the presumably upper Helderbergian Central Valley Sandstone feldspar reappears in limited quantity, and continues, after an interuption by the Oriskanian Connelly Conglomerate (STOP 6-B) throughout the Onesquethawan sequence of Highland Mills Sandstone to Woodbury Creek Sandstone (STOP 6-C). Thus there is a third pulse of uplift in late Lower Devonian time, more or less centering on the Esopus Formation and its equivalents. These beds, of subgreywacke type, are not very coarse, though partly near-shore, and the source may have been relatively distant.

The late Onesquethawan Kanouse Sandstone is again a clean, non-feldspathic sediment, and is followed by the black Cornwall or Pequannock Shale. Beginning with the Bellvale Sandstone, (STOP 7), we have an increasingly coarse and lithic-fragment-rich, flysch sequence of Hamilton age, that represents the prograding Catskill Delta and the classic Acadian Orogeny. The initial beds are marine greywackes carrying Hamilton fossils (Mucrospirifer and Spinocyrtia) and grade up through subgreywackes and shales with wood fragments to the hematitic coarse conglomerates of the Skunnemunk Formation. Because this outlier is closer to the source than any other preserved part of the Catskill Delta the definite Hamilton age of the initial greywacke beds provides a terminus post quem for the onset of the classic Acadian orogeny.

In summary, there are three minor pulses of uplift of the source area recorded in the outlier between the Taconian orogeny and the classic Acadian orogeny of the middle Devonian. The first, strongest at the northeast end of the outlier, is represented by the middle arkose tongue of the Green Pond. If the Green Pond is the transgressing sourceward feather edge of the Shawangunk, then Niagaran eurypterids in the Shawangunk due west of the outlier, at Otisville, date the pulse as slightly later, perhaps late Niagaran or even early Cayugan (Wenlock or early Ludlow). The second pulse is represented by the Lower Arkose Member of the Longwood, of probable Cayugan (Ludlow) age. The third, represented by the Central Valley through Esopus interval, was late Helderbergian through early Onesquethawan (Siegenian and Emsian). These three pulses might be considered faint echoes of the Caledonian orogeny, perhaps less physically distant then once thought. The major Acadian orogeny begins in the Hamilton (Givetian).

Shorelines.

It is not clear whether the initial beds of the Green Pond Formation represent a transgressing shoreline or piedmont alluvium. The lowermost beds at Newfoundland (STOP 3) have coarser and more angular clasts than higher in the section, and they contain a higher proportion of pebbles other than milky-quartz. Such pebbles include green and red chert, quartz-hematite phyllonite, quartzite, and shale. None of them have any obvious relation to the underlying Precambrian gneiss. They could represent a local weathering residue from Cambro-Ordovician sediments, reworked in the shore zone of an advancing sea. Their angularity favors such a local source, but the difficulty of matching them to anything from the immediately surrounding Cambro-Ordovician, except for the lighter cherts and the shale, argues against it. The eugeosynclinal Taconic sequence to the east might provide a suitable source, and swift, relatively short, streams might bring them in and deposit them without altering their angularity. The higher conglomerate beds of the Green Pond resemble the undoubtedly continental Skunnemunk Formation, and the Middle Arkose Member resembles typical continental red-beds. Thus it is quite possible that the entire lower part of the Green Pond is alluvial rather than marine. The prominent cross-bedding and "fining-upward" cycles (Plate 1, figure 3) is consistent with fluvial deposition. It may be therefore that the first marine shoreline does not appear in the Silurian section of the outlier until the Upper Quartzite Member of the Green Pond.

The Middle Arkose Member of the Green Pond in the Schunemunk area, however, need not have been continental. Because of the coarse, fresh feldspar clasts, it must have been derived from nearby exposed crystallines, but the situation could have been analogous to the Pennsylvanian and Permian marine arkoses that formed a narrow aureole around the "Ancestral Rockies" uplifts of Colorado. Unfortunately no fossils are known.

The same may be true of the Lower Arkose Member of the Longwood. The Upper Shale Member appears to be marine, for marine fossils have been reported from it (Hartnagel, 1907). Its uniform nature, and occasional mud-cracked surfaces, suggest a lagoonal or tidal mud-flat environment. The overlying "Binnewater" sandstone unit may be a beach or barrier bar, and the "Waterlime" unit, with its mud-cracks, intraformational conglomerates and stromatolitic structures, is almost certainly an intertidal flat, differing from the Longwood perhaps by a lesser influx of terrigenous sediment.

The Skyline Calcarenite Member of the Decker Ferry Formation (see Road Log, STOP 6-A, for formal description) consists of cross-bedded, coarse bioclastic debris of marine animals partly replaced by hematite. It has quartz-sandstone interbeds. It may represent a barrier-bar environment, similar to the "Binnewater" but under conditions of lower influx of terrigenous material. Alternatively, it may have been a more offshore shell-bank, but in any case in shallow water of high wave-energy. The intergradational nature of the "Binnewater", "Waterlime" and Skyline Calcarenite Units of the Decker Ferry (Figure 4 and STOP 6-A) indicate they are part of a single system of shifting environments. Indeed, the strong hematite content of the Skyline links it to the underlying Longwood and Green Pond Formations.

Limestones and calcareous shales with Lower Helderberg fossils ("Manlius," "Coeymans," and "New Scotland") are exposed at the north end of the outlier, at Cornwall (Hartnagel, 1907). These represent completely marine, and relatively off-shore conditions, for the first time in the sequence.

The Central Valley Sandstone may still be relatively offshore, though receiving much more terrigenous clastics. With the Connelly Conglomerate (STOP 6-B) there is a definite recession of the sea. This Oriskanian deposit, with its uniformly-sized, well-rounded quartz pebbles, and its abraded shells, (Boucot, 1959) was almost certainly a pebble beach. The distinctive nature of its typically Oriskany fauna (Costispirifer arenosus, Hipparionyx proximus and Rensellaeria ovata) make it possible to correlate it with more distant deposits. At Port Jervis, 25 miles due west, the same fauna occurs in an argillaceous limestone. At Kingston, 40 miles to the north, the type Connelly Conglomerate, occurs succeeded gradationally by the Glenerie Limestone carrying the same fauna. It is difficult to construct a paleogeography from three points, but the Schunemunk area would seem to have lain upon the Oriskanian shore.

The succeeding Esopus sequence (STOP 6-C) represents deeper water and presents a beautiful and classic example of the Cruziana-facies and the Zoophycos-facies of Seilacher (1964) alternating with one another. The Cruziana-facies represents a littoral to sublittoral environment above wave-base, the Zoophycos-facies a sublittoral to bathyal environment below wave-base. The shore of Appalachia at this time lay somewhere to the east, though in view of the good development of shallow-water features (see Road Log under STOP 6-C) probably not too far to the east.

The Kanouse Sandstone is another pebbly to sandy beach or near-shore environment, lithologically very similar to the Connelly. It is less pebbly, the fauna is much richer including many solitary rugose corals, and the shells are not abraded. It is likely to have been somewhat off-shore but probably close to it. It has been variously correlated with the Onondaga (Kindle & Eidman, 1955) or Schoharie (Rickard, 1964). In either case it is much richer in terrigenous detritus than its equivalent to the north and west.

The last shoreline recorded in our outlier differs from the rest in being the prograding shore of a delta. The Bellvale Sandstone (STOP 7 and Table II) begins with evenly-laminated greywacke and siltstone units representing a prodelta environment. They are succeeded by beds with "pillow-structures" (once referred to as "storm-rollers") and cut-and-fill structures, marking the beginning of the deltaic environment proper. The beds still contain marine fossils, but a possible wood fragment has also been found as well as zones of floating pebbles. These beds are succeeded by coarser, cross-bedded subgreywackes with shale chips and plant fragments. The higher sandstones become coarser, and more lithic-fragment-rich. A long succession of massively cross-bedded subgreywacke sandstones alternating with mudstones, and ending with coarse pebble-beds,

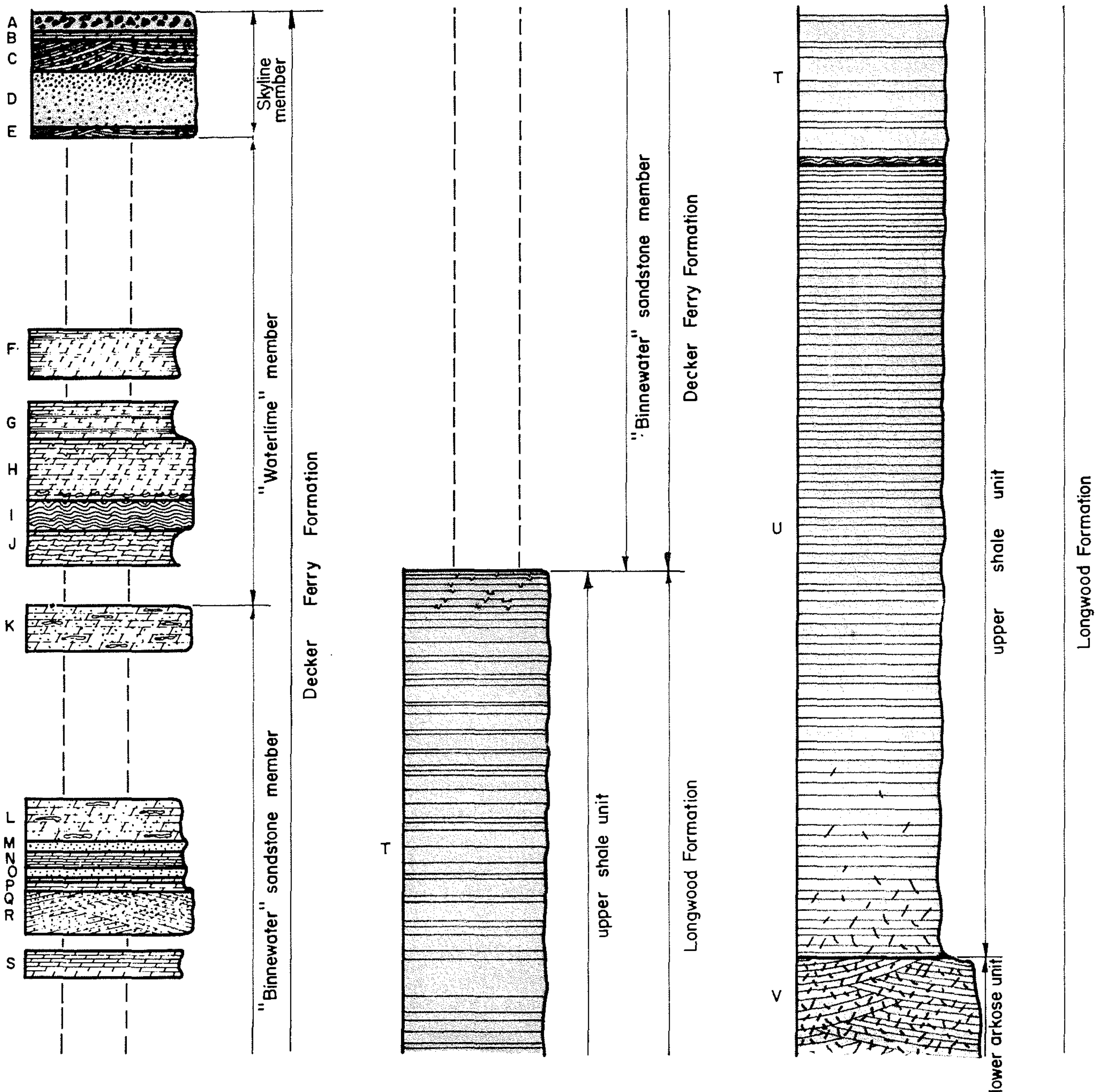
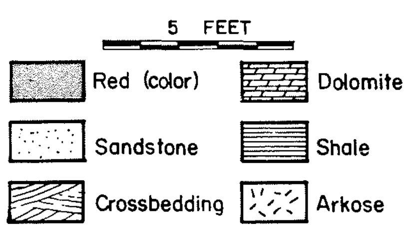


Figure 4. Silurian Section at the South End of Pine Hill. Page 1 of 3.



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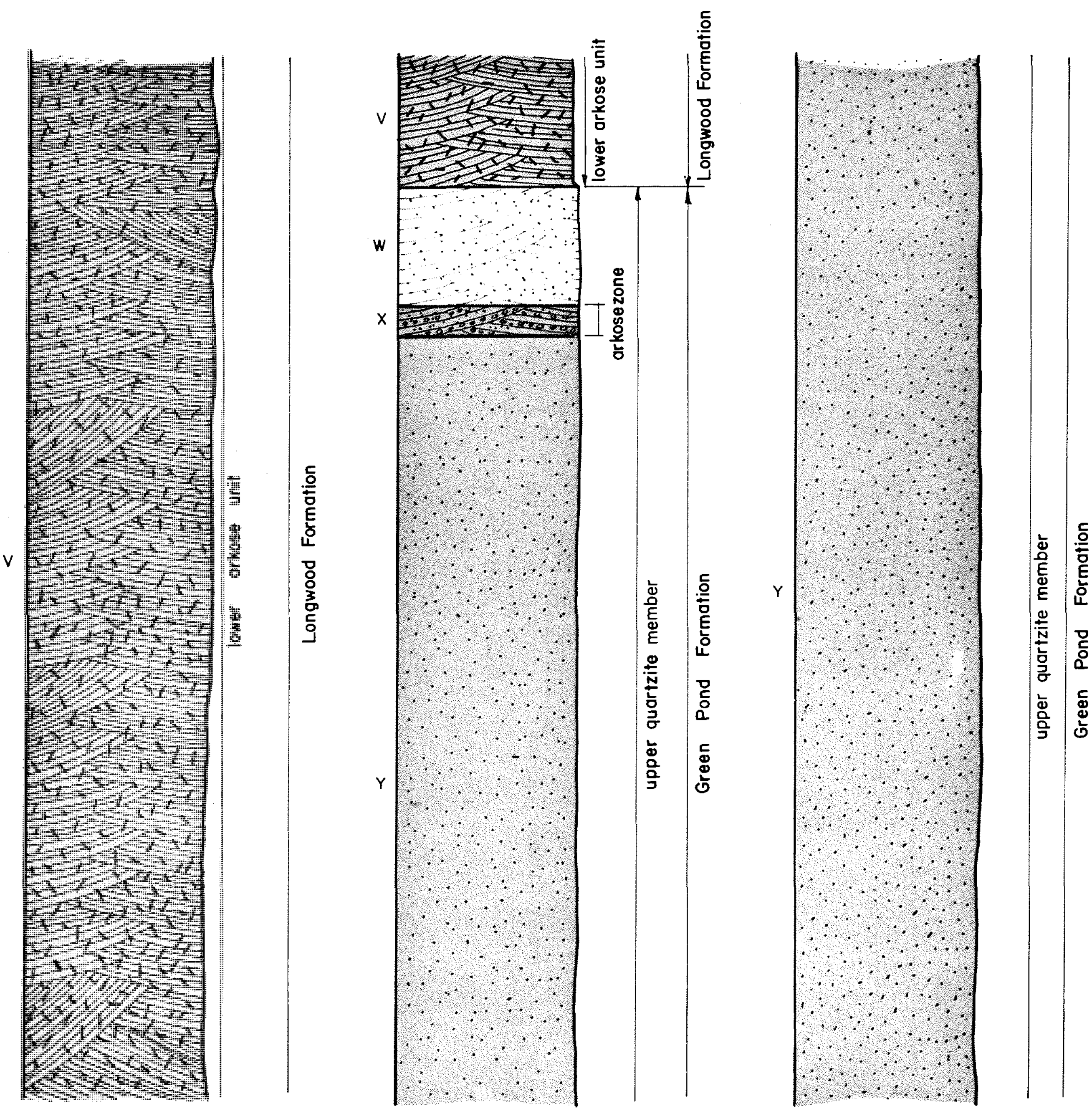

Figure 4. Silurian Section at the South End of Pine Hill. Page 2 of 3

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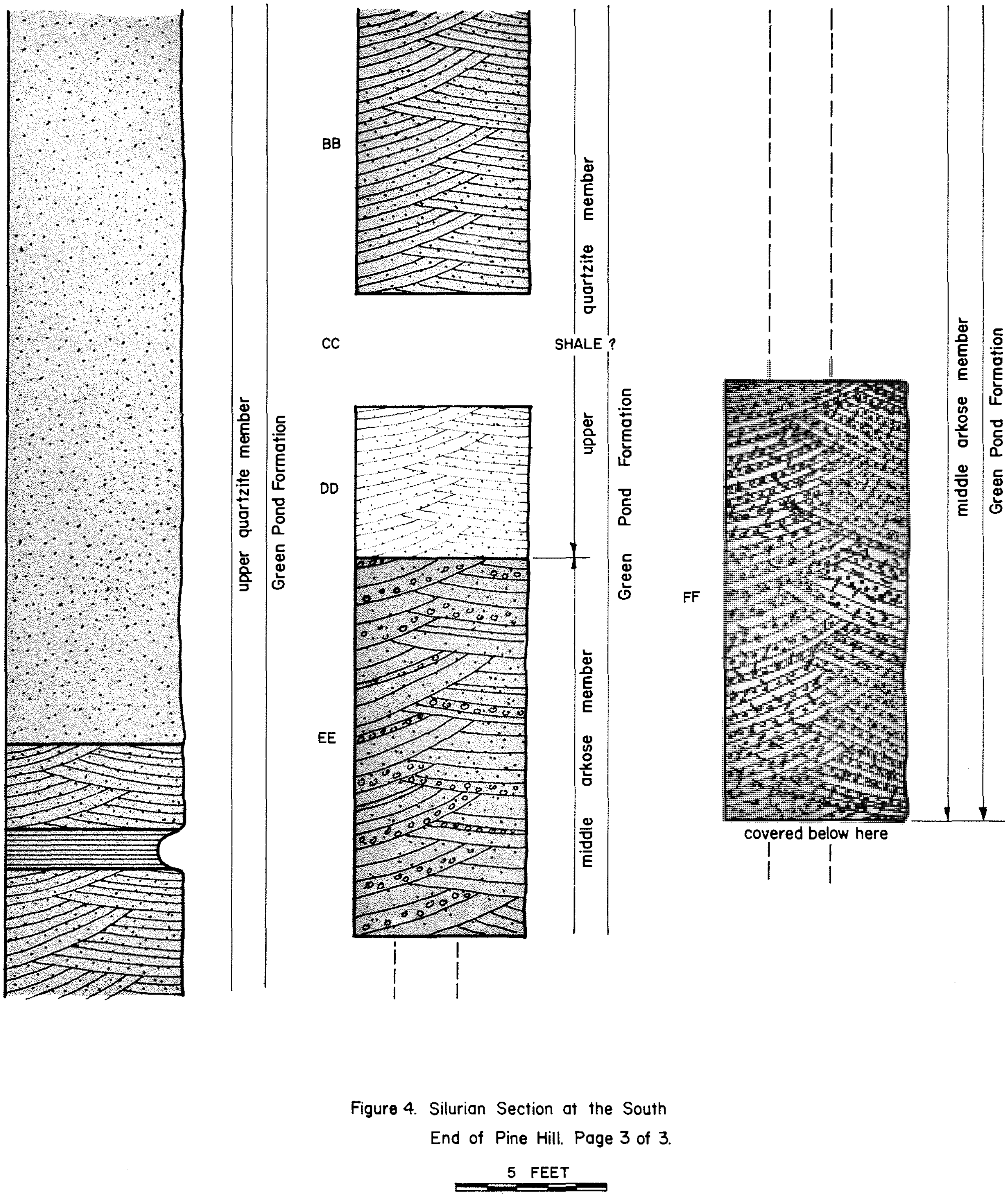

Figure 4. Silurian Section at the South End of Pine Hill. Page 3 of 3.

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Table 1. Section of Silurian measured at S.W. end of Pine Hill Highland Mills, Orange Co., N.Y., S. E. across strike from north end of shale quarry east of Skyline Road just north of intersection with Pine Hill Road. Measured by R. M. Finks and F. H. Wind (Figure 4).

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Unit	Thickness		Description
			Top of section.
			Decker Ferry Formation
			Skyline Member:
A	1'	1"	Calcarenite, gray-blue to red, weathers red, massive; crinoid clasts, 1 to 3 mm modal diameter, form matrix enclosing numerous large, frequently unbroken, fossils: 3 or more spp. of brachiopods, strap-like bryozoa (*Ptilodictya*), hemispherical massive bryozoan, fragmental 1 inch across (*Monotrypa*?), hemispherical *Favosites*, small horn coral; much hematite in pellets (?) 1-2 mm in diameter, and replacing crinoid debris.
B	0'	7"	Silty shaly dolomite, buff, weathers buff-gray, 1/8 to 1/4-inch beds, no fossils observed.
C	1'	10"	Calcarenite, gray-blue to red, weathers darker red, massive but with cross-bedded sheets 1 to 2 inches thick outlined by concentrations of hematite and/or red shale; clasts 1 to 3 mm modal diameter, fossils less obvious than in Unit A but similar.
D	3'	6"	Quartz-sandstone, speckled gray, yellow, buff, weathers buff; more massive at base, ranging from 3-inch beds at base to 1/4-inch beds at top; modal diameter of quartz sand about 1/2 mm, fine laminae 1/8 inch or so thick outlined by fine dark partings, vertical tension fractures 1/4 to 1/2 inch apart filled with similar dark partings.
E	0'	8"	Calcarenite as in C above.
			"Waterlime" Member:
	11'	10"	Covered interval.
F	3'	10"	Dolomitic siltstone or silty dolomite, argillaceous, gray, weathering buff, shaly-bedded in 1/4 to 1/2-inch beds, no fossils observed.
	1'	6"	Covered interval.
G	2'	4"	Same as Unit F.

H	3'	9"	Dolomite, aphanitic, medium-gray, weathering buff, massive with shallow, irregular, filled mudcracks. Obscure bedding planes from 2 inches to 1/4 inch, with finer laminae down to 1/32 inch. Bedding surfaces mud-cracked: polygons mostly 2 to 3 inches across, locally polygons in top bed as much as 5 inches across; larger cracks filled with quartz sand grains 1/2 mm across; conspicuous 1/2 inch diameter angular to rounded clasts (?) weather bright buff, forming depressions on weathered surface; Basal half-foot of this unit a coarse quartz sandstone (rounded grains, modal diameter about 1/2 mm) containing large angular clasts, up to 2 inches diameter, of unit below (Unit I).
I	1'	10"	Dolomite, aphanitic, algal (?), wavy-bedded; light dove-gray, weathering light buff, beds 1/2 to 1/4 inch thick with much finer laminae; length of waves 5 to 10 inches, amplitude 21 inches; many quartz-sandy partings, 1/8 to 1/4 inch thick, associated with breakage and reworking of algal laminae; upper surface of unit truncated by edgewise conglomerate (see above).
J	2'	0"	Dolomite, aphanitic, light greenish-gray, weathering buff in half-inch somewhat rubbly beds.
	2'	6"	Covered interval.
			"Binnewater" Member:
K	2'	8"	Quartz-sandy dolomite, slightly blue-green-gray, weathers buff, with rounded quartz grains up to 1 mm in diameter; unit mud-cracked, polygons 4 to 6 inches in diameter, extending through 6 inches vertically; laminar algal interbeds and intraformational conglomerate with lighter-weathering clasts 1/8 to 1/4 inch across; entire unit massive with obscure half-foot bedding.
	9'	2"	Covered interval.
L	2'	7"	Quartz-sandy dolomite with algal interbeds as above.
M	0'	7"	Quartz-sandstone, calcareous, gray, weathering buff, rounded quartz grains, modal diameter 1/2 mm.
N	1'	0"	Dolomite, greenish-grey, weathers buff, weathers shaly in 1/8 to 1/4-inch beds, irregular; sandy with rounded quartz grains 1/2 mm diameter.

O	0'	8"	Quartz-sandstone, lens-like, pinches to 4 inches surrounded by N lithology; pink-buff, quartz grains rounded, diameter approximately 1/2 mm.
P	0'	2"	Dolomite as in Unit N.
Q	0'	7"	Quartz-sandy dolomite, pink and gray.
R	2'	8"	Quartz-sandstone, gray with rusty banding, weathering red-buff, 2 to 6-inch beds, cross-laminated, quartz grains 1/2 to 1 mm in diameter and well-rounded.
	0'	10"	Covered interval.
S	1'	8"	Dolomite, laminated, as in Unit N.
	40' approx.		Covered interval.
			<u>Longwood Formation.</u>
			<u>Upper Shale Member:</u>
T	39'	2"	Shale, red, silty, hematitic slightly micaceous, breaking in 1-inch to 4-foot beds. Bedding surfaces mudcracked. Mud-cracks and (gas?) pits (1-6 inches in diameter) on bedding planes near top of exposed section, along with possible obscure fossils (fish plates?); 4-inch zone of contorted bedding at base. Base of unit is large bedding plane forming east wall of quarry to top of hill.
U	49'	0"	Red shale, east from brink of cliff above quarry; partly covered, transitional to unit below. (Unit U and underlying remainder of section measured east from brink of cliff across top of Pine Hill.)
			<u>Lower Arkose Member:</u>
V	80' (approx.)		Arkose, red, feldspathic, fine-grained in 1/2-inch beds, cross-bedded in 6-inch to one-foot units; chips of shale, 1/4 to 2 inches across, are abundant in some beds; intermittent exposure, mostly covered.
			<u>Green Pond Formation.</u>
			<u>Upper Quartzite Member:</u>
W	7'	4"	Quartz-sandstone, gray with pink spots, massive in 1 to 2-foot beds, cross-bedded in persistent 1/2-foot units, quartz rounded to subrounded, scattered hematitic staining and pebbles; local thin quartzites.

X	1'	10"	Quartz-sandstone, sub-arkosic, hematitic, cross-bedded in 1/2 to 1-foot units; subrounded medium quartz-sand with scattered pebble-layers and isolated pebbles of subrounded white quartz up to one inch in diameter; some beds with shale chips as in Unit U above.
Y	161'		Quartz-sandstone, quartzitic, prominent quartz-filled fractures, not cross-bedded, color ranges from dark red to cream-white in alternate bands; rather even 2 to 3-inch beds with finer laminations, medium-grained.
Z	5'	8"	Cross-bedded pink sandstone as in Unit W.
AA	2'	8"	Red shale.
BB	27'	2"	Red cross-bedded sandstone as in Unit W; mud-cracks (?) at base.
CC	7'	3"	Covered interval (shale?).
DD	10' approx.		Sandstone as in Unit W.
			Middle Arkose Member:
EE	25'		Conglomeratic quartz-sandstone, subarkosic, red, with scattered, white quartz, subrounded pebbles up to one-inch diameter; cross-bedded in units up to 2 feet thick.
	28'	6"	Covered interval.
FF	29'		Conglomerate, arkosic, red to light gray, quartz pebbles angular to subrounded, up to 1-inch diameter; feldspar pebbles are angular cleavage-fragments up to 1/2-inch diameter, pebbles of feldspar may show imbrication; strongly cross-bedded in 1/2-foot to 1/3-foot units.
			Base of exposed section.

Table 2. Section of Bellvale Sandstone measured along north side of Route 17, between Monroe-Washingtonville exit and a point 0.5 mile to the east, Orange Co., N. Y. Base of section is at the east end. Section measured by R. M. Finks and L. Mesticky.

Unit	Thickness	Description
		Top of section.
NN	20' 0"	Conglomerate and sand: sand festoon cross-bedded in 2-foot units, interbedded with conglomerate beds up to 2 feet thick, containing rounded pebbles of milky-quartz, quartzite, chert (minor), and shale or slate (minor); pebbles up to 3-inch diameter in sandy matrix, color dark-gray, weathering lighter gray.
covered	100' approx.	Covered interval is 200 feet along ground but beds at east end dip 55° NW and there is some indication that a similar dip is maintained through covered interval. Overlying Unit NN is nearly horizontal, dipping gently NE along plunge of syncline axis. Some faulting is possible at west end of covered interval.
MM	100'	Sand as below, massive, cross-bedded in 3 to 5-foot units.
LL	58'	Sand, as below, grades into mudstone at top; upper 13 feet of unit are mudstone; base of unit fills channel cut in underlying Unit KK.
KK	11'	Mudstone, cleaved.
JJ	61'	Sand, as below.
II	20'	Mudstone, cleaved.
HH	220'	Sand, with minor shale interbeds. At 140 feet above base of unit is a ten-foot thick probable channel fill; at 90 feet above base a zone of quartz-veins with slickensides, at 40 feet above base a small zone of quartz veins.
GG	25'	Mudstone, gray, weathers brown; cleaved.
FF	140'	Sand, massive, cross-bedded, contains shale chips.
EE	2'	Sheared sand with quartz veins.
DD	3'	Sand.
CC	31'	Mudstone, cleaved.

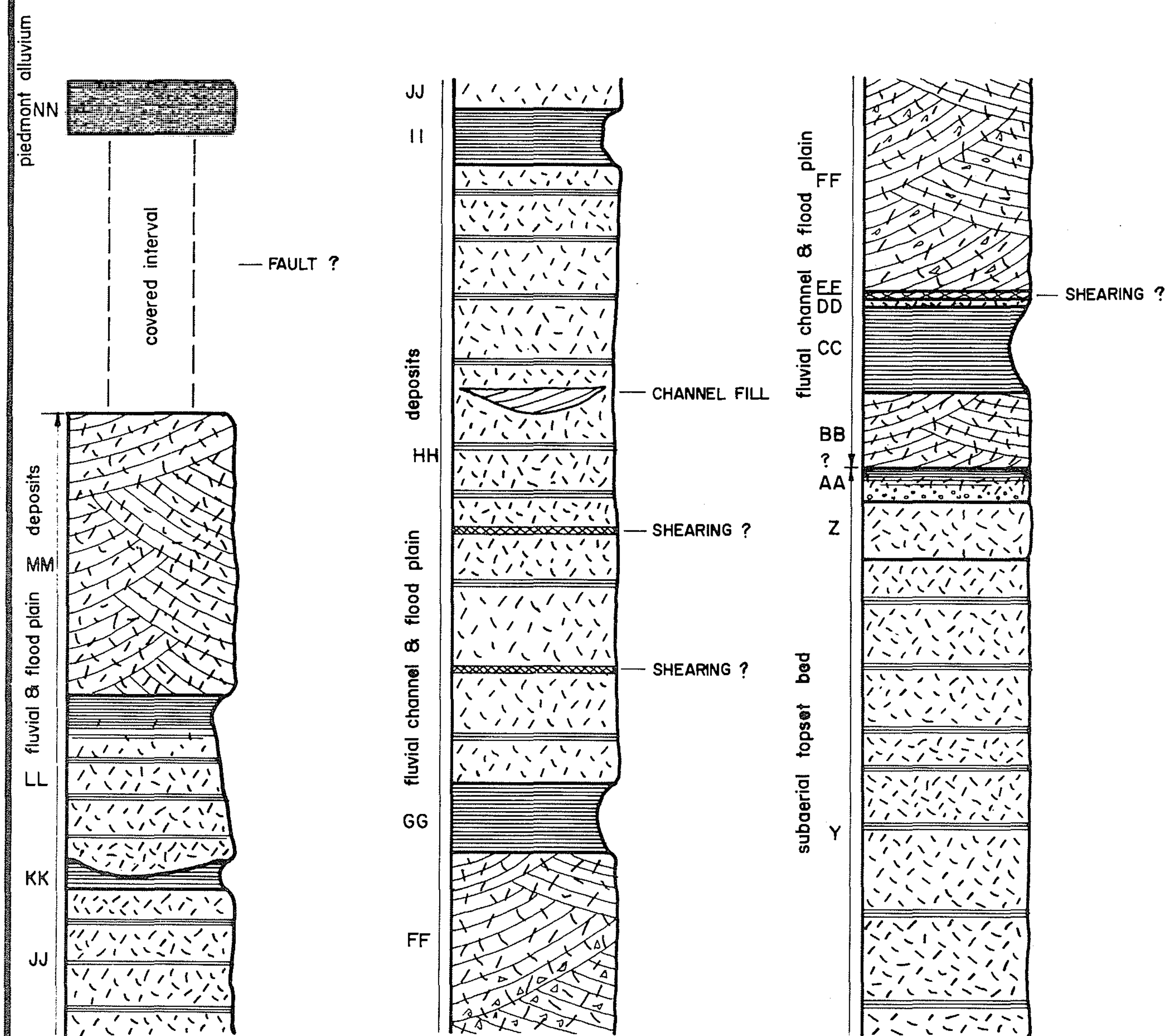


Figure 5. Section of Bellvale Sandstone on Route 17. Page 1 of 2.

50 FEET

LEGEND

Graywacke
Siltstone
Subgraywacke
Shale Mudstone
Crossbedding
Coarse sand

FINKS, 1968

CRAIG A. MUNSART

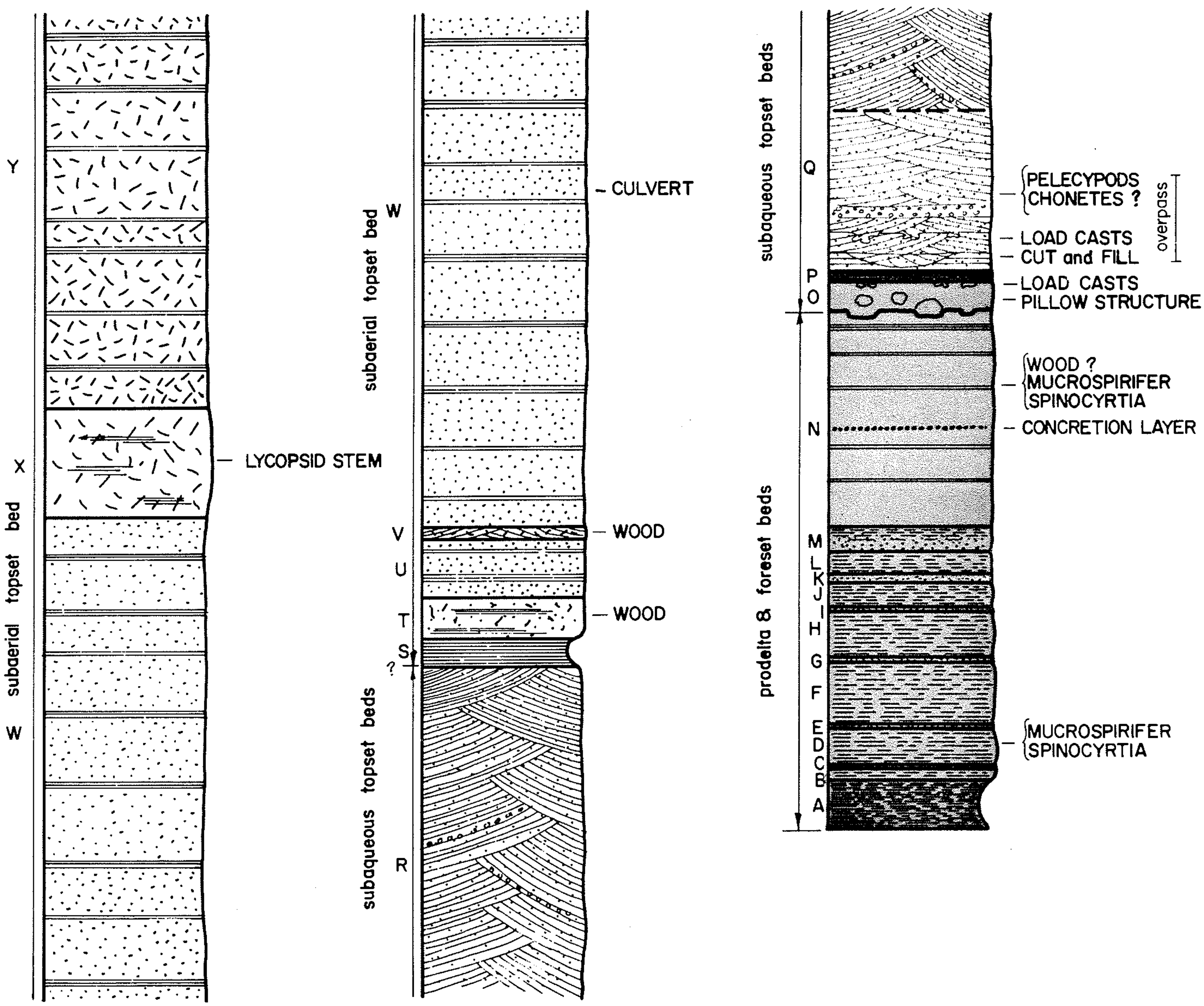


Figure 5. Section of Bellvale Sandstone on Route 17. Page 2 of 2

50 FEET

FINKS, 1968

CRAIG .A. MUNSART

BB	27'	6"	Sand , massive, cross-bedded, light greenish-gray.
AA	11'		Sand with shale pebbles, fining upward.
Z	20'		Sand
Y	310'		Intermittently exposed sand and shale.
X	40'		Coarse lithic-fragment-rich subgraywacke, light gray, weathers light brown; layers of black shale chips; contains lycopsid stems 1/4-inch in diameter. (Good glacial striae on outcrop surfaces.)
W	367'		Intermittently exposed subgraywacke with shale interbeds. (East side of culvert is at 125 feet above base of unit.)
V	4'		Sand , cross-bedded, coarse (grains up to 2 mm diameter) with shale chips. Possible lignite chip and wood impressions.
U	22'		Subgraywacke, with minor shale interbeds.
T	15'		Subgraywacke, highly lithoclastic and micaceous, coarse, with zones of dark-gray shale chips up to 2 inches in diameter; possible wood fragment.
S	10'		Shale, dark gray.
R	164'		Intermittent exposures of subgraywacke and shale as in Q (below), including at least one pebble bed.
Q	59'		Subgraywacke with minor shale interbeds, subgraywacke medium-gray, weathers light brown; coarser beds form cross-bedded lenses up to 2 feet thick; load-casts or ball and pillow structures present at intervals, especially in lower part of unit; at 36 feet from top of unit is a zone of well-rounded quartz and quartzite pebbles, up to 3/4-inch in diameter, floating in a matrix of subgraywacke; fossils in upper part of unit include pelecypods and, reportedly, brachiopods. Base of unit may be a channel fill cut into underlying Unit P. (Top of Unit Q is just west of overpass, remainder is mostly beneath overpass.)
P	3'	5"	Graywacke and shale interbedded in even 2 to 3-inch units. (This unit is just east of overpass.)
O	10'	3"	Massive graywacke with abundant ball and pillow structures (flow-rolls, "storm-rollers") 2 feet in diameter at base of unit, 2 inches in diameter at top of unit.
N	79'	5"	Graywacke and shale, dark-gray, weathering brown to orange, in graded units, each from 2 feet to 5 feet thick; at 35 feet from base of Unit N is a 1-inch concretionary layer.

M	8'	6"	Uncleaved sandy bed grading upwards through fine sandstone to 5 inches of shale with calcite laminae at top.
L	8'	0"	Fine sandstone as below.
K	2'	10"	Uncleaved medium graywacke somewhat gradational into overlying unit.
J	8'	8"	Fine sandstone as in Unit H.
I	1'	0"	Uncleaved sandy bed.
H	17'	7"	Fine sandstone as in Unit F below.
G	0'	5"	Uncleaved sandy bed.
F	23'	0"	Fine sandstone as in Unit B below but somewhat more massive.
E	0'	8"	Uncleaved sandy bed.
D	14'	0"	Fine sandstone as in Unit B below, frequently in 1-inch to 2-inch units showing concretionary structure; <u>Mucrospirifer</u>, <u>Spinocyrtia</u>, pelecypod (<u>Grammysia</u>?).
C	0'	2"	Uncleaved sandy bed.
B	4'	2"	Fine sandstone (graywacke) weathering with limonitic stain, bedding in 1-inch units; strongly cleaved; contains <u>Mucrospirifer</u> and <u>Chonetes</u>.
A	17'	8"	Siltstone, finely laminated, dark gray, weathering somewhat brownish; highly cleaved.
			Base of section.

Units A through N are probably prodelta and foreset beds, Units O through perhaps R are subaqueous topset beds, from Unit S or so, on up, probably subaerial topset beds grading up into river channel sands and flood-plain mudstones (such as Units BB through MM) to more piedmont type deposits as in Unit NN.

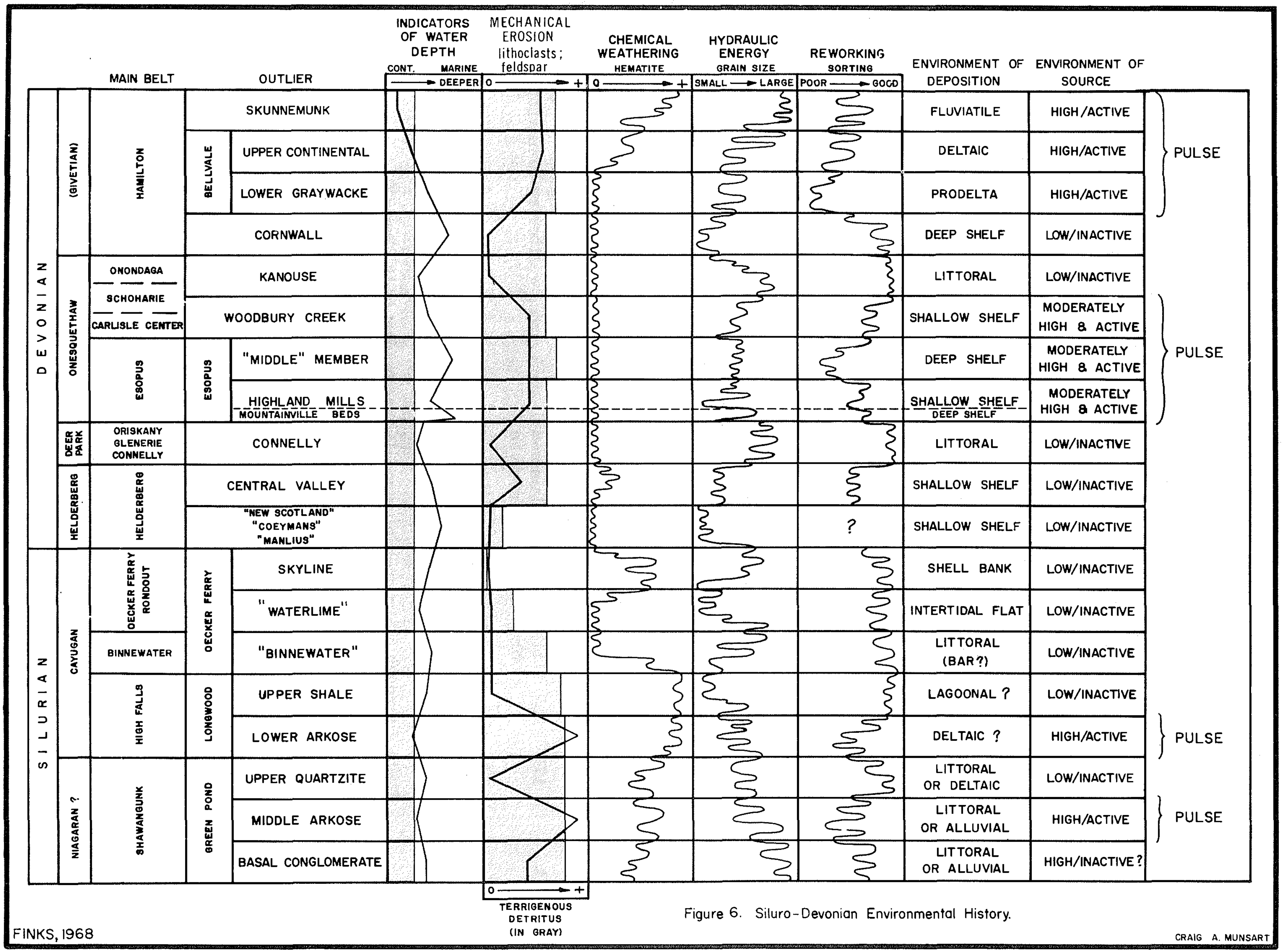


Figure 6. Siluro-Devonian Environmental History.

probably represents an alluvial environment. The pebbles are curiously similar to those of the Green Pond, including not only milky-quartz but also quartzite, chert, shale and phyllite. The Siluro-Devonian succession thus ends almost as it began.

In summary, the entire Siluro-Devonian sequence of the outlier contains three major types of shoreline. (1) The upper Silurian sequence, from at least the upper part of the Green Pond through the Decker Ferry, represents a transgressing shoreline in various stages of development, from the possible reworked regolith of the lower parts of the Green Pond, through the clean, possible shore sands of the upper Green Pond, to the intricate lagoon and barrier beach development of the Upper Longwood and Decker Ferry. (2) The Connelly and Kanouse Formations represent stable shorelines in which considerable reworking leaves a well-sorted, well-winnowed lag-concentrate of rounded quartz pebbles. (3) The Bellvale Formation represents the prograding shoreline of a delta, with a progression from prodelta and foreset beds through topset beds to alluvial plain and piedmont alluvium deposits.

Figure 6 presents a more complete summary of the Siluro-Devonian history of the outlier. Rough estimates of various environmental indicators are given. Water depth was based on evidence from fauna and primary structures. Sorting indicates degree of reworking and therefore tectonic stability. Grain size indicates hydraulic-energy conditions. Feldspar indicates rapidity of mechanical erosion, and therefore possibly relief of the source area. The proportion of terrigenous detritus to autochthonous sediment indicates general erosion rate and therefore also relief (or rainfall). Hematite suggests strength of chemical weathering in the source area, as well as oxidizing conditions in the sedimentary environment.

ACKNOWLEDGEMENTS

The late Professor Walter H. Bucher of Columbia University first introduced me to the section at Newfoundland, and Professor Cecil H. Kindle of City College and Professor Grace M. Carhart of Hunter College first told me of the outcrops at Highland Mills. Dean Herbert P. Woodward of Rutgers University introduced me to many other aspects of the local geology. It is impossible to thank individually all the many students I have taken to these localities during the past sixteen years, and whose eyes and wits have often been sharper than mine. Some contributions have been mentioned by name in the text and I hope the rest will accept this expression of my thanks. Mr. Frank H. Wind helped me measure the section at Pine Hill and Mr. Lubomir J. Mesticky that of the Bellvale at Monroe. Mr. Wind also identified some of the fossils of the Skyline Calcarenite, now being further studied by Miss Lillian Musich. Mr. Nicholas F. Avignone assisted in preparing the road log. The figures were drafted by Mr. Craig A. Munsart and the photographs prepared by Mr. Maurice W. Kalisky. I thank Mr. David P. Schwartz for petrographic consultation.

ROAD LOG

From the Hotel Sheraton-Tenneyfollow Astoria Boulevard to the Triboro Bridge, thence to the Major Deegan Expressway, to I-95 and across the George Washington Bridge.

Mileage.

0.0	0.0	George Washington Bridge Toll Plaza. Keep left and take I-80 express lane. Between 0.7 and 1.2 is a spectacular new cut in the Palisades Diabase. At the west end (1.2) overlying baked shales of the Newark Series may be seen, parallel to the top of the sill.
2.2	2.2	Meanders of the Hackensack River on its flood plain.
3.7	1.5	Cut in Newark sandstones.
11.3	7.6	Turn-off for Route 20.
12.2	0.9	On to Route 20 south. Road follows Passaic River flowing south.
13.6	1.4	On to Route 46 west.
16.8	3.2	Cut in First Watchung Basalt, an extrusive lava. Note curvicolumnar jointing.
17.2	0.4	Fanned columnar jointing followed on LEFT by pillow-lava.
18.3	1.1	Passaic River flowing north in subsequent valley between First and Second Watchung ridges. This is upstream from where we last saw it. It crosses First Watchung Ridge at Paterson Falls.
18.5	0.2	Second Watchung Basalt.
19.9	1.4	Turn north (right) on Route 23.
21.8	1.9	Third Watchung (Hook Mountain) Basalt.
23.2	1.4	Wisconsin terminal moraine.
23.9	0.7	North (right) on Route 202.
26.4	2.5	Turn left to follow Route 202.
27.1	0.7	Turn right to follow Route 202.
27.3	0.2	Third Watchung (Hook Mountain) Basalt again. This has been bent around as part of a syncline in the Newark Series.
27.6	0.3	Turn left into Moyias Road and park. Walk across road (CARE!) and north along grass (STAY OFF PAVEMENT!) to outcrop.

STOP 1. Pompton Lakes. Triassic Border conglomerate.
(Wanaque, N.J., 7 1/2 - minute Quadrangle.)

This outcrop provides a sampling of the exposed bedrock that lay immediately to the west of here during late Triassic time. Coarse conglomerates such as this are confined to the immediate vicinity of the Triassic border fault and were apparently deposited as alluvial fans at the base of the fault scarp by east-flowing streams. No Precambrian pebbles can be recognized in this outcrop and presumably the Precambrian, now exposed in the hills immediately to the west, still lay covered beneath Paleozoic sediments. Large rounded cobbles, some more than a foot across, of a conglomerate of white quartz pebbles in a red quartzite matrix, closely resemble existing outcrops of the Silurian Green Pond Formation or the Devonian Skunnemunk Formation, both exposed in the outlier some ten miles west of here. Of more interest for the reconstruction of the paleogeography of the pre-Silurian uplift, is the abundance of white-weathering dolomite cobbles that could only have come from the Cambro-Ordovician carbonate sequence. These cobbles are sometimes less well rounded than the quartzite cobbles and must have been transported for no very great distance. The base of the Silurian rests directly on the Precambrian ten miles to the west. The Cambro-Ordovician carbonates were probably exposed somewhere between there and here in Triassic times and therefore could not have been removed during the pre-Silurian uplift. We will see at STOP 2 that the Trentonian phyllites are still preserved in this vicinity. These data place the eastern border of the pre-Silurian uplifted and eroded area as somewhere between here and STOP 3, only ten miles to the northwest.

28.1 0.5 Turn right at first traffic light.

28.6 0.5 Bear left at Y-intersection.

29.1 0.5 Park in lot of Riverdale Diner.

STOP 2. Riverdale - Pompton. Annsville Phyllite.
(Pompton Plains, N.J., 7 1/2 - minute Quadrangle.)

After looking at the outcrop we will take a short REST STOP in the Riverdale Diner.

Walk east a little more than a block on the south side of the Hamburg Turnpike, crossing the bridge over the Wanaque River, and descend to the south side of the east abutment of the bridge. Here is exposed a small, but apparently genuine, outcrop of black phyllite; the outcrop is submerged at high water.

This outcrop was mapped as Hudson Schist in the USGS Passaic Folio (Darton, *et al.*, 1908) a name applied to the rocks now called Manhattan Schist, as well as to the metamorphosed pelites of the upper Hudson Valley now referred to the Normanskill - Snake Hill sequence (Ordovician, Trentonian). I see no reason to question these correlations. This outcrop is called Annsville here because it occurs in the same structural position as the type Annsville at Peekskill, 30 miles to the northeast along the Triassic border fault, and because it resembles the type Annsville lithologically. It also resembles lithologically (and structurally: refolded-foliation) the phyllitic phase of the Mount Merino Formation in Balk's classic area in Dutchess County, as at Noxon near Lagrangeville. Near Clinton, New Jersey, 40 miles to the southwest along the border fault, a sizeable patch of the Cambro-Ordovician sequence is exposed between the Triassic and the Precambrian. The Ordovician pelites in it were mapped as Martinsburg Shale (Bayley et al., 1914).

The present outcrop was interpreted in the Passaic Folio as a fault-sliver, or "horse," along the Triassic border fault. It is also possible that the pre-Triassic basement is generally much closer to the present surface along the border fault than usually reconstructed, and that much of the Triassic subsidence was taken up by faulting or warping farther east beneath the basin. The Cambro-Ordovician area near Clinton was mapped in the USGS Raritan Folio (Bayley et al., 1914) as lying uncomformably beneath the Triassic, and the present outcrop may have the same relationship.

Continue west on Hamburg Turnpike.

29.3	0.2	Turn left at traffic light following sign to Route 23.
30.0	0.7	Turn right onto Route 23 north.
30.2	0.2	Glacial lake delta on left. We have crossed Triassic border fault.
30.6	0.4	Outcrops of Precambrian gneiss.
31.4	0.8	Cut in Wisconsin till on left.
37.8	6.4	Cross Echo Lake Road.
38.1	0.3	Park in grassy area on right between highway and abandoned segment of old Route 23.

STOP 3. Newfoundland: South end of Kanouse Mountain. Green Pond Formation. (Newfoundland, N.J., 7 1/2 minute Quadrangle.)

Walk north across old highway to nearest outcrop on north side of road. These are the lower conglomerate beds of the Silurian Green Pond Formation dipping steeply northwest. The conglomerate occurs in rhythmically repeated, upwardly-fining, 2 or 3 foot, cross-bedded units. Most of the pebbles are rounded milky-quartz, but red chert, dark shale, and other rock types occur.

Walk uphill, northeastward into the woods, paralleling the base of the cliffs but keeping about 50 feet east of them. About 100 feet or so into the woods large talus blocks of the lowermost beds are passed. They are more coarsely conglomeratic, and contain many angular or sub-angular pebbles, a few inches across, of green chert, red chert, quartz-hematite phyllonite, quartzite, dark shale or slate, along with milky-quartz.

Another hundred feet or so further will bring you to the first outcrops of Precambrian Gneiss. An interval of 25 feet or so, covered with large talus blocks of Green Pond separates the nearest Precambrian outcrops from the exposures of Green Pond in the base of the cliffs. The contact is not exposed.

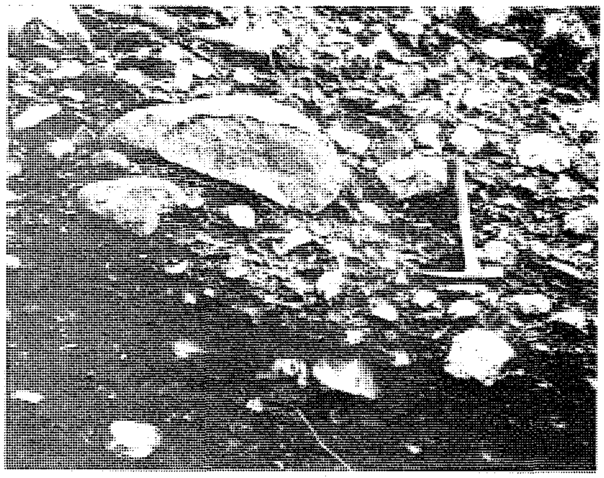
Return, following the base of the cliff as closely as talus and underbrush permit. At a point opposite the first ledges seen near the road, climb up to a broad rock surface on top of these ledges to observe spectacular Liesegang rings of hematite developed in the finer-grained layers of the rhythmic sequences. (WATCH YOUR STEP.)

Return to the road, cross the old highway and continue west across the grass plot to the main highway. Walk west along the shoulder (STAY OFF HIGHWAY! WATCH TRAFFIC!) to a cut in the Upper Quartzite Member of the Green Pond. The cut shows a small anticline and syncline parasitic upon the main synclinal structure (drag folds). A prominent thin pebble bed makes a convenient stratigraphic marker. Note well-developed quartz-filled gash-fractures along minor shear zones. At the westernmost end of the cut the lowermost red arkose beds of the Lower Arkose Member of the Longwood Formation are exposed in contact with the top of the Green Pond. These beds will be seen in the same stratigraphic position at Highland Mills (STOP 6-A).

Return along road to the bus.

(Note: A complete section between the basal beds and the Upper Quartzite Member is exposed in the woods along the south end of Kanouse Mountain, but we will not take the time to visit it. The Middle Arkose Member seen at the north end of the outlier (STOP 5) does not seem to be present here.)

41.9	3.8	Oak Ridge Reservoir. Crossing high-angle fault between outlier and precambrian forming west boundary of outlier. Fault-line scarp visible to left along west shore of reservoir.
42.5	0.6	Flood plain of Pequannock River.
48.8	6.3	Bear right, following Route 23. Entering small outlier of Cambro-Ordovician.
49.3	0.5	Turn left at Franklin Diner.
49.4	0.1	Outcrop on right of Cambro-Ordovician carbonate.
49.8	0.4	Bear left.
49.9	0.1	Dump of old Buckwheat zinc mine on right. Franklin minerals may be collected here (fee). Outcrops of Precambrian Franklin Marble.
50.3	0.4	Turn left on Wildcat Road.



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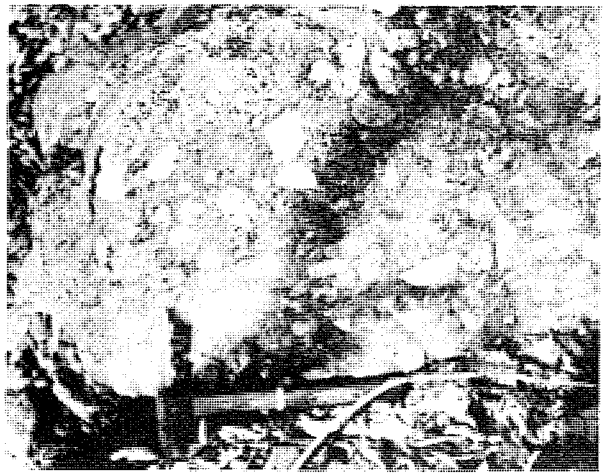

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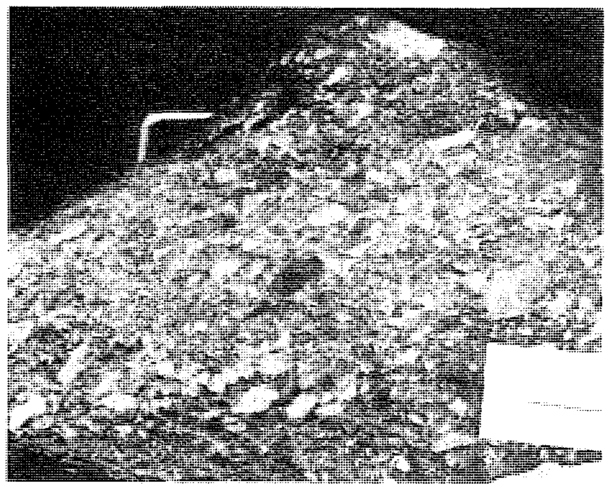

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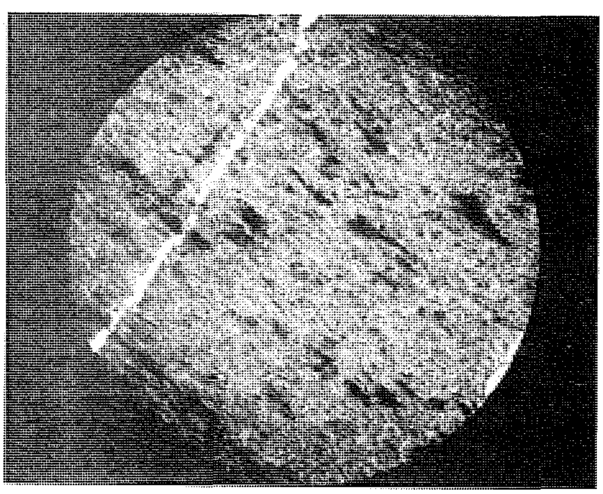

PLATE I

5

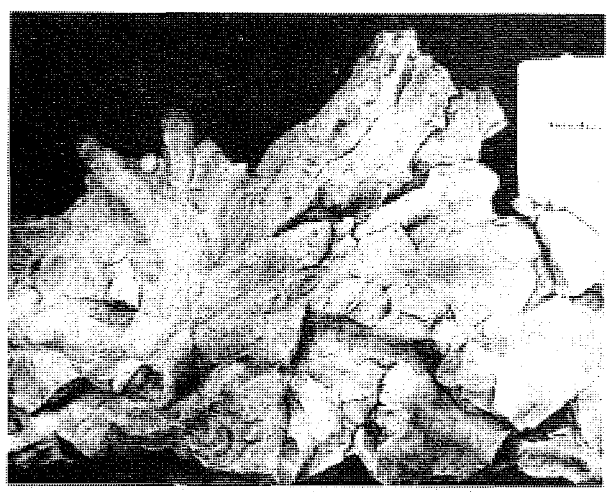

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Plate 1.

Figure 1, Triassic border conglomerate at STOP 1. Largest cobble is probably Green Pond conglomerate, or else Skunnemunk Comglomerate. The white cobbles are Cambro-Ordovician dolomites.

Figure 2, Basal Green Pond conglomerate at STOP 3, showing large angular pebbles of chert and metaquartzite.

Figure 3, Basal Conglomerate Member of the Green Pond Formation at STOP 3, showing repeated graded units.

Figure 4, Hand specimen of Middle Arkose Member of Green Pond (base of Unit FF) from measured section (Table 2 and Figure 4) at southwest end of Pine Hill near STOP 6-A. White angular clasts are fresh cleavage fragments of feldspar. They show somewhat imbricate texture (bedding approximately horizontal). Scale in millimeters.

Figure 5, Photomicrograph (x100) of quartz-hematite phyllonite pebble from basal Green Pond at STOP 3. Dark mineral is hematite. Crossed-nicols. Photograph by David P. Schwartz.

Figure 6, Phycodes sp., ichnofossil from shaly layer in upper part of Highland Mills Sandstone member of Esopus Formation at STOP 6-C. Top of bed shown. Shaly layer was immediately above large ripple-marked surface and below lens of shells in sandstone. Millimeter scale.

50.5	0.2	Cut in Cambro-Ordovician carbonates on left.
50.9	0.4	Park in Metaltech Laboratories lot. Walk back (north) on Wildcat Road 0.1 mile to STOP 4.

STOP 4. Franklin. Hardyston - Precambrian Unconformity and Stissing Dolomite. (Franklin, N.J., 7 1/2 - minute Quadrangle.)

Walk east from Wildcat Road toward golf course just south of point where wooded ridge intersects road obliquely. Walk northeast along east base of ridge facing golf course about 25 feet to first outcrops. Here Lower Cambrian Hardyston Formation rests on light colored Precambrian gneiss. The Hardyston dips 55° NW. The basal five feet or so of the Hardyston contains pebbles of quartz and fresh feldspar up to an inch in diameter. About 20% of the pebbles are feldspar. PLEASE DO NOT HAMMER ON THIS OUTCROP. Exposures of the Cambrian - Precambrian unconformity are rare and should be preserved as an exhibit for students.

The type locality for the Hardyston is 2 miles to the northeast at Hardystonville along this same continuous outcrop belt. The Hardyston here is in one-foot beds that are internally cross-bedded in smaller units. The five feet or so of conglomerate grades upward into dark-gray, flaggy, quartz-sandy dolomite that underlies most of the ridge and totals about 100 feet in thickness. The dark-gray dolomite may represent the Lower Cambrian Stissing Dolomite.

Climb over the ridge across strike to Wildcat Road and walk north along the road past a covered swale to the next outcrops. These may be the base of the Upper Cambrian Pine Plains Formation. The light-weathering dolomite is interbedded with thin, ripple-marked beds of quartz-sandstone. Oscillation and interference ripples are beautifully displayed both on bedding surfaces and in cross-section. An extensive section of higher carbonate beds is exposed along the road for several hundred feet.

The base of the Hardyston represents a shore, but not a shore of Appalachia. The Early Cambrian sea transgressed westward onto the craton. The importance of this outcrop is to show that the Precambrian which was exposed at the surface at Newfoundland, during the Silurian, is still covered by the Cambrian at Franklin, only 10 miles to the west.

Return north on Wildcat Road.

51.5	0.6	Turn right (east).
51.8	0.3	Town Park. LUNCH.
52.5	0.7	Turn right (south) on Route 23.
52.6	0.1	Bear left following Route 23.

NEW YORK STATE GEOLOGICAL ASSOCIATION GUIDEBOOK

MAY, 1968, MEETING AT QUEENS COLLEGE

ADDENDUM TO TRIP E: TACONIAN ISLANDS AND THE SHORES OF APPALACHIA.

Robert M. Finks, Queens College

After the description of this trip had gone to the printer, Dr. Stockton G. Barnett III, of the State University at Plattsburgh, informed me that he had recently completed a doctoral dissertation (Ohio State, 1966) on the Siluro-Devonian outlier, which is now in press. Dr. Barnett has completely remapped the New Jersey part of the outlier and has made a great many important new findings and interpretations, especially with regard to the stratigraphy of the late Silurian and Early Devonian. Dr. Barnett was unable to accept my invitation to be co-leader of this trip, but has kindly provided some of his new information. One of the most important results of his study is the discovery of an open-water marine facies of latest Silurian and Early Devonian age in the southern part of the outlier corresponding to the more lagoonal and intertidal facies both to the north and to the west! In collaboration with John Southard, he has also traced the Esopus Formation members, recognized by Boucot and Southard in the Highland Mills Area, into the southern part of the outlier.

In addition, Dr. Barnett kindly guided me to a classic locality that I had not visited before. This is of such interest that if time permits we will include this in our trip.

- -

ADDITION TO ROAD LOG

63.6	0.0	Intersection of Union Valley Road and Route 23. Continue east on Route 23.
65.0	1.4	Turn left onto Echo Lake Road.
67.2	2.2	Left turn.
67.6	0.4	Left Fork.
68.1	0.5	Turn left on Gould Road.
69.1	1.0	Park opposite dirt road on left just after right-angle turn to the right (north) in Gould Road.

STOP 4A. (If time permits.) Gould Quarry. Unconformity of Silurian on Cambrian. (Newfoundland, N.J., 7½-minute Quadrangle.)

Walk west into woods following old dirt road to abandoned and overgrown Gould limestone quarry. The first exposures are of Precambrian gneiss. A few feet of covered interval are succeeded by ledges of Hardyston Sandstone outcropping on the east side of a low ridge. The Hardyston dips steeply northwest and grades upward from a few feet of pebbly quartzite to a quartz-sandy dolomite, that forms the top of the ridge. Walcott (1893) found *Olenellus* in this dolomite a mile or so

to the north, and it is presumably the equivalent of the Lower Cambrian Stissing Dolomite of New York. Just over the crest of this ridge, on its western slope, and about 60 feet stratigraphically above the Hardyston Quartzite, the dolomite is succeeded abruptly by a coarse quartz-pebble conglomerate that rests on the irregular upper surface of the dolomite and includes clasts of dolomite just above the contact. This coarse conglomerate appears to be the base of the Green Pond Formation, for it is exposed intermittently from this point westward, across a narrow valley to the main mass of the formation in Kanouse Mountain. The upper surface of the dolomite, on which the Green Pond rests, is a karstic surface, for pockets of the same conglomerate appear in the basal part of the dolomite, on the east side of the ridge toward the south end of the old quarry, not far above the Hardyston Quartzite. Kümmel and Weller (1902, p.7) were apparently the first to interpret these pockets as solution cavities filled from above. The pockets are lined with a thin layer of shaly sediment between the dolomite and the conglomerate. These solution fissures extended some 30 feet below the pre-Silurian surface.

This locality is about three miles north of STOP 3 where the Green Pond rested directly on the Precambrian. The Cambrian first appears beneath the Silurian a half-mile south of here at the north end of Echo Lake. The obvious unconformity here, barely 70 feet above the base of the Cambrian, is the strongest evidence for the unconformable nature of the less well exposed Silurian-Precambrian contact to the south. We are here on the northerly flank of the pre-Silurian uplift.

Dr. Barnett has discovered Ordovician shales on the west side of the outlier northwest of Bowling Green Mountain. Inasmuch as the Silurian rests directly on the Precambrian at Bowling Green Mountain, the northern limit of the exposed Precambrian lay just north of there. A line connecting that point with the corresponding contact at the north end of Echo Lake should be parallel to the axis of the pre-Silurian uplift. It has an ENE-WSW trend that is at variance with the axis of the outlier, though one that corresponds with late folds in the New York City group in Westchester County (see Trips A and H as well as Fisher <u>et al</u>., 1961.) This may be a late Taconian fold direction. It is also parallel with the Cambrian-Pre-Cambrian contact on either side of the outlier south of Monroe (see Figures 1 and 2.) Unfortunately the Silurian is faulted out of the outlier at that point so that the trend cannot be demonstrated to be pre-Silurian there.

Continue west on Gould Road to Union Valley Road at Postville.

70.4 1.3 Turn right (north) on Union Valley Road. This is mileage 66.9 on original road log.

ADDITIONAL REFERENCES

Kümmel, H.B., and Weller, S., 1902. The rocks of the Green Pond Mountain region, in Annual Report of the State Geologist for 1901, New Jersey Geological Survey, pp. 3-51.

Walcott, C.D., 1893, On the occurrence of Olenellus in the Green Pond Mountain Series of northern New Jersey, with a note on the conglomerates, Amer. Jour. Sci., ser. 3, v.47, p. 309-311.

4/22/68

63.6	11.0	Right on jughandle turn marked "To Greenwood Lake." Cross and turn left on Route 23 west then right (north) onto Union Valley Road (Route 513).
65.6	2.0	Outcrop of Cornwall (Pequannock) Shale (Middle Devonian). The road follows the strike of the Upper Silurian-Lower Devonian. On the right is the ridge of Green Pond Conglomerate, on the left the ridge of Bellvale Sandstone.
70.6	5.0	Left turn in West Milford, staying on Union Valley Road.
72.6	2.0	Bear right.
73.6	1.0	Turn left onto Lakeside Road.
74.6	1.0	To the right is Greenwood Lake. Beyond it to the east are hills of Precambrian forming the east boundary of the outlier. The Green Pond has been faulted out. To the left are nearly continuous outcrops of the lower beds of the Bellvale Sandstone (or the upper part of the Cornwall shale). The ridge to the left (west) is Bellvale Mountain, the type locality of the Bellvale Sandstone.
75.6	1.0	Entering New York. Road becomes Route 210.
79.6	4.0	Turn left following Route 210.
80.1	0.5	Bear left onto Route 17A, then bear right.
87.1	7.0	Bear right.
89.1	2.0	Bear right and follow road through Monroe business district.
89.6	0.5	Just past railroad station turn left through underpass, then right at stop sign.
90.6	1.0	Join Route 208 east.
94.6	4.0	Turn left (north) on Route 32 through Highland Mills.
95.6	1.0	Woodbury Falls, where railroad trestle crosses road. Marine beds of Bellvale sandstone in bed of Woodbury Creek on right, non-marine beds on left (west) side of road.
96.4	0.8	Turn right onto Smith's Clove Road. Precambrian hill on left (north) and Siluro-Devonian hill on right.
97.3	0.9	Turn right (south) at junction with Mineral Spring Road.

97.6 0.3 STOP 5. North end of Pine Hill. Green Pond Formation. (Popolopen Lake, N.Y., 7 1/2 - minute Quadrangle.)

Outcrops near the road, at turn-off of private dirt road, are of Lower Conglomerate Member, dipping steeply northwest. The pebbles are almost entirely milky-quartz.

Walk into the woods across strike. About 100 feet NNW are outcrops of the Middle Arkose Member. Fresh, angular, cleavage fragments of feldspar, up to 1/2 inch across, are common along with quartz pebbles in a fine reddish matrix. This unit can be recognized 2 1/2 miles to the southwest along strike near Highland Mills (Figure 4 and Table 1).

Continue 200 feet or so further northwest to the base of ledges that expose the Upper Quartzite Member. (Some care should be exercised to avoid Copperheads in climbing over these ledges.)

Beyond this the Longwood is poorly exposed on the top of the ridge. We will see a better section at the next stop.

Return to the road.

Continue south on Smith's Clove Road. Precambrian hills on left (east), ridge of Green Pond (Pine Hill) on right (west).

99.6 2.0 Turn right (west) on Pine Hill Road.

100.2 0.6 Park on grass just beyond intersection with Skyline Road. Bus will continue to old Highland Mills Station and wait to pick up party.

STOP 6-A. South end of Pine Hill. Green Pond - Longwood - Decker Ferry. (Popolopen Lake, N.Y., 7 1/2 - minute Quadrangle.)

Walk north along Skyline Drive from intersection with Pine Hill Road. The first outcrops on the right (east) side of road are of the Upper Quartzite Member of the Green Pond, with characteristic Liesegang rings of hematite, and quartz-filled fractures.

Farther on the Lower Arkose Member of the Longwood is exposed in poor outcrops. If time permits, climb the hill to the well-exposed ledges on top of the ridge. The lower part of the measured section (Figure 4 and Table 1) was made here, from the Lower Arkose Member of the Longwood down to the Middle Arkose Member of the Green Pond; the section in the Green Pond was measured with several jogs northeastward along strike to preserve continuity of section. The intergrading contact of the Green Pond and Longwood is well exposed here. Do not go further up-section (northwest) than the lower beds of the Lower Arkose Member of the Longwood: the ground slopes downward to the unprotected edge of a sheer 100-foot cliff that drops vertically into the shale quarry to the northwest. STAY AWAY FROM THE EDGE OF THE CLIFF!

Continue north on Skyline Drive to the entrance to the shale quarry and turn right into the quarry. Steeply northwest-dipping bedding planes of the Upper Shale Member of the Longwood form the southeast wall of the quarry, higher beds being exposed stepwise toward the north. A zone of contorted bedding is exposed just above the first large bedding plane. Mud-cracks and curious spheroidal pits one to six inches in diameter, are common on some of the higher bedding planes.

The remainder of the section was measured at the northeast end of the quarry, where the Decker Ferry Formation is exposed, separated from the highest beds of the Longwood by a 40-foot interval covered with red shale debris. Some of the Decker Ferry is covered by a few inches of soil, but can be exposed by digging with the hammer. The beds seem to be in place and were measured inch-by-inch with a tape. Most of the formation consists of interbedded quartz-sandstone and dolomite. Quartz-sandstone predominates in the lower beds and this part is here called informally the "Binnewater" Member because it is homotaxial with the type Binnewater of the High Falls area, 40 miles to the north. A prominent outcrop (Unit R) of this lower part of the Decker Ferry is exposed half-way up the slope at the northeast end of the quarry, to the right of a grassy embankment.

Higher in the section thinly laminated (stromatolitic ?) mud-cracked, somewhat argillaceous dolomites predominate, with minor quartz-sandstone interbeds. Intraclasts are common. This part of the formation is designated informally as the "Waterlime" Member. It resembles lithologically the waterlimes of the Rondout Valley which lie above the Binnewater Sandstone at its type locality. Outcrops may be seen lower on the slope and towards the northwest.

The continuous alternation of the two rock types, sandstone and dolomite, with mud-cracks in the dolomite often being filled with quartz-sandstone, suggests that the two types of sediment were being deposited contemporaneously in adjacent, spatially shifting areas, perhaps sandy beach and tidal mud-flat. (Southard, 1960, mapped the "Binnewater" and "Waterlime" units together as his <u>sandy-claystone unit</u>, emphasizing their continuity.)

The highest beds of the Decker Ferry are lithologically quite distinct, though sandstone & dolomite interbeds indicate their relationship to the underlying units. This unit is separated as the <u>Skyline Calcarenite Member of the Decker Ferry Formation</u> (new name). It includes all the calcarenite beds exposed in the quarry, its type section (see measured section, Table I). Minor interbeds of sandstone and dolomite are present. The principal, lithology is a red to blue-gray coarse crinoidal clastic limestone, full of whole shells (see faunal list), cross-bedded, and heavily charged with hematite, which frequently partially replaces some of the fossils. The fauna has not been completely studied but the following have been tentatively recognized:

<u>Bryozoa:</u>

<u>Ptilodictya</u> sp. cf. <u>P. frondosa</u> Weller
massive trepostome, cf. <u>Monotrypa corrugata</u> Weller

Brachiopoda:
- Atrypa "reticularis"
- rhynchonellid, cf. Camarotoechia sp.

Coelenterata:
- Favosites sp.
- horn coral

Arthropoda:
- ostracode, cf. Dilbolbina sp.

Echinodermata:
- pelmatozoan (Probably crinoid) columnals

This fauna is hardly diagnostic of age, but is consistent with the Decker Ferry of New Jersey (Weller, 1903). Neither the fauna nor the lithology are anything like either the Wilbur Limestone or the Glasco Limestone, which fall into this part of the section in the Rondout Valley. Neither is it like any of the higher limestones of the Helderberg Group. The Becraft is the closest lithologically, and probably environmentally, but the fauna is certainly not the same. This appears to represent a shallow-water shell-bank environment. The name of the member is derived from the nearby Skyline Road.

Thicknesses of the members recorded in this section are as follows:

Decker Ferry Formation		
Skyline Member	7'	8"
"Waterlime" Member	28'	9"
"Binnewater" Member	22' plus.	
Longwood Formation		
Upper Shale Member	88'	2"
Lower Arkose Member	80'	
Green Pond Formation		
Upper Quartzite Member	222'	10"
Middle Arkose Member	82' plus.	

Walk back out of the quarry, south on Skyline Road and west on Pine Hill Road. At the bridge over the Thruway one can see the Lower Arkose Member of the Longwood exposed north of the east abutment. On the west side of the Thruway, the first visible outcrop is that of the Connelly Conglomerate. When the writer first visited this cut in 1954, just after it had been partly blasted through, a white-to-violet-mottled, friable, clayey, fine sandstone, with characteristic thin interlaminae of dark-gray shale crumpled to give the rock a "zebra-stripe" appearance, was exposed to, the south of the Connelly. It has since been grassed over. Boucot (1959) named this unit the Central Valley Sandstone, and this is its type locality. North of the Connelly, on both sides of the Thruway, is a nearly complete section of the Onesquethawan Series. Access to the Thruway cut is prohibited and the prohibition strictly enforced by State Police.

Continue west on Pine Hill Road to the first black-top road on the right and walk up this road to its dead end.

STOP 6-B. Connelly Conglomerate.

Low ledges on the east side of the road expose the rather well-sorted quartz-pebble conglomerate (2 to 6 mm clasts) of the Connelly. Oriskany fossils establish its age. It is equivalent to an argillaceous limestone 25 miles to the west and to a similar conglomerate followed by an argillaceous limestone 40 miles to the north. This represents a shoreline facies, a pebbly beach on the temporarily stable shore of Appalachia. Most of the fines have been winnowed out.

It may be possible to find Central Valley float on the ground to the south.

Walk back to Pine Hill Road and turn right. At the bend in the road is a stone fence made of Connelly boulders, resting on small outcrops of the Connelly. Where road bends sharply to the left, turn right on private road, then take short path down to railroad tracks opposite abandoned station. Turn right and walk to first outcrops on east side of tracks.

STOP 6-C. Highland Mills. Highland Mills Sandstone and "Middle Member" of the Esopus Formation. (Popolopen Lake 7 1/2 - minute Quadrangle.)

WATCH OUT AND LISTEN FOR TRAINS. DO NOT SIT ON TRACK OR PLACE OBJECTS ON TRACK. TRAINS COME THROUGH FAST AND WITHOUT WARNING. If a train comes stand well back; there is plenty of room on either side of the track.

This stop demonstrates near-shore and off-shore deposits under conditions of strong influx of terrigenous clastics. The series of beds at the south end of the cut are of the upper part of the Highland Mills Sandstone of Boucot (1959). These light-blue-gray, light-brown-weathering, subgraywackes are dominated by evidences of shallow-water deposition. A prominent set of bedding planes display oscillation ripples of various sizes. The ripples tend to be uniformly oriented, roughly NNW - SSE when rotated back to horizontal. (The beds here strike N 50° E and dip 60° NW.) Just north of the ripple-marked layers are lenses of closely packed, jumbled, disarticulated shells. The lenses pinch out within a few feet, from thicknesses of a foot or so. (Preservation on the weathered surfaces is in the form of molds; the most common fossil is *Leptocoelia flabellites*, but besides the many other brachiopods described by Boucot (1959) there occur gastropods, pelecypods, horn corals, trilobites and other fossils.) Associated with the shell-lenses are shaly beds packed with the ichnofossil *Phycodes.* All these features are characteristic of the *Cruziana*-facies of Seilacher (1964) representing shallow-water above wave-base, littoral or sub-littoral.

The "Middle Member" on the other hand, exposed farther north along the tracks, represents Seilacher's deeper-water, sublittoral to bathyal Zoophycos-facies. Bedding planes are covered with the ichnofossil Zoophycos (= Taonurus, = Spirophyton). The rock is massive-bedded and the bedding planes very even. (The rock weathers brown to orange, the fresh rock is almost black.) Although described in the literature as a mudstone, most beds are poorly-sorted graywacke sandstone with about 55% to 85% quartz-grains of fine-sand size, and the rest chiefly fine-grained matrix (data from Miss Janice Lumnitz and Mr. Maury Morgenstein). Fossils are sparsely scattered on the bedding surfaces, mainly the brachiopods Leptocoelia flabellites and Spirifer macra. On many bedding-planes concave-up valves outnumber concave-down valves (from Miss Janice Lumnitz) suggesting settling-out through water followed by rapid burial without further reworking. The unsorted nature of the sediment also points to rapid sedimentation and the sparseness of fossils suggests dilution by rapid influx of terrigenous material.

Feldspar may be less abundant here than in the underlying Highland Mills Member, but the whole Esopus sequence is strongly suggestive of a pulse of erosion of the source area (Appalachia).

The Esopus sequence starts with deep-water Zoophycos-bearing beds (the Mountainville Member of Southard, 1960). The upper part of the Highland Mills Member (restricted Highland Mills Member of Southard) is mostly shallow-water. The "Middle Member" is again mostly deeper-water. The Woodbury Creek Sandstone appears to be mostly shallower water again. It is more fossiliferous than the "Middle Member" (dominated by the pelecypod Cypricardinia and the brachiopod Schuchertella). The fossils are evenly spread on the bedding planes, rather than in lenses as in the Highland Mills Member, and ripple marks are not well-developed. Also Zoophycos has been observed on some beds. It would thus seem to be of a depth intermediate between that of the Highland Mills Member and that of the "Middle Member".

The succeeding Kanouse Sandstone, a clean, somewhat pebbly, orthoquartzite, again marks a stable shoreline deposit, with a falling off of terrigenous influx permitting better sorting of the material. It appears to be the shoreward equivalent of limy deposits to the north and west (Schoharie and/or Onondaga).

100.7	0.5	Board bus at Highland Mills Station. Continue on Pine Hill Road west to Route 32.
101.1	0.4	Turn left (south) on Route 32.
102.1	1.0	Central Valley Diner. REST STOP.
103.1	1.0	Turn right (west) on Route 17 (Quickway).
105.1	2.0	Pull over to side just before second overpass. Bus will continue to Monroe-Washingtonville exit (0.5 mile further) to wait for party.

STOP 7. Monroe. Bellvale Formation. (Monroe, N.Y., 7 1/2 - minute Quadrangle.)

Between here and the Monroe-Washingtonville exit are exposed about 2000 feet of the Bellvale Formation, essentially a complete section. Details of the section are given in the measured section, Table II and Figure 5.

The lowest beds at the east end of the outcrop are shaly siltstones that are close to the base of the Bellvale, if indeed they are not to be considered the highest beds of the underlying Cornwall Shale. The beds immediately above are graywackes that carry *Mucrospirifer* and *Spinocyrtia*, thereby demonstrating their Hamilton age and marine nature. A small *Chonetes* is also common. This entire lower part of the section here is identical, lithologically and faunally, to the section exposed in the bed of Woodbury Creek, at Woodbury Falls, north of Highland Mills, where the railroad trestle crosses Route 32.

As one goes up-section, intercalated beds of uncleaved sandstone increase in thickness and ultimately dominate the section by the time one reaches the abutment of the overpass. Up to here the beds are evenly laminated without any indication of large scale cross-bedding or channeling.

Just at the east side of the overpass is a zone of ball and pillow structures and load-casts. These structures are widely recognized in the Catskill Delta rocks as marking the transition-zone from marine to non-marine beds. The beds beneath the overpass are still marine, however, as brachiopods have been found in them. Nevertheless, the nature of the bedding changes from the preceding even lamination, to evidence of channeling, cut-and-fill structure, and cross-bedding. The rock becomes lighter and coarser, a subgraywacke. Load-casts are present intermittently, and at least one zone of pebbles scattered in subgraywacke is present. It would appear that we have passed from the evenly laminated prodelta and foreset beds to channeled and irregular topset beds.

West of the overpass the subgraywacke becomes still coarser and lighter. Thin interbeds of shale become more common and numerous shale chips appear in the sandstones. Many of the smaller grains appear to be shaleclasts or perhaps phyllite. Obscure plant remains and possible wood-fragments appear. No marine fossils have been found, and these deposits may have been made on the subaerial part of the delta.

Beyond the culvert the rock becomes even coarser and more lithic. Here unmistakable plant fragments are present including pieces of branches of scale-trees or related lycopsids a half-inch or so in diameter and clearly showing the leaf scars and internal woody fibers. (The first such were found by Mr. Harvey Zeiss; I have since found others.) Note the well-developed glacial striae and chatter-marks on some of the outcrop surfaces.

Beyond this point is a long succession of massively cross-bedded subgraywacke sandstones with shale interbeds. There are also four prominent units of highly cleaved mudstone, decreasing in thickness from 31 feet for the first such unit, to 11 feet for the last. These are probably flood-plain muds. The last of these units is clearly channeled and filled by the succeeding sand , probably a stream-channel deposit.

The Bellvale section ends with coarse pebble beds at the center of the syncline, just at the Monroe-Washingtonville exit. These beds have the character of the overlying Skunnemunk Formation, except that they lack the red color characteristic of that formation. The pebbles include besides milky-quartz, rocks such as chert, quartzite and shale or slate, not too unlike the pebbles included in the base of the Green Pond at STOP 3. We are probably dealing here with Piedmont alluvial deposits.

Continue on Monroe-Washingtonville exit ramp to Route 208. Turn left, cross over Route 17, then left into entrance for Route 17 eastbound. Return to the hotel via Route 17, New York State Thruway, Major Deegan Expressway, Triboro Bridge, Astoria Boulevard.

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4/22/68

APPENDIX TO TRIP E by S. G. Barnett
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Field Mapping and study of stratigraphic sections in the Green Pond-Schunemunk Mountain Outlier and along the main Silurian-Devonian outcrop belt 25 miles to the northwest have resulted in alteration and refinement of regional stratigraphic relations of Late Cayugan and Helderbergian strata in southeastern New York and northern New Jersey (Fig. 1). Many well-established stratigraphic units of New York and eastern Pennsylvania can be recognized in the Outlier. Two new units in the Outlier will be proposed - (Barnett, in preparation). A detailed statistical study of the evolutionary development of seven measurable characters of the conodont species Spathognathodus remscheidensis Ziegler has made precise intrabasinal time correlation possible. This technique relies upon the relationship between morphological evolution, environmental distribution, and environmental succession. A tentative paleoenvironmental analysis has resulted in the recognition of eight environmental facies: deltaic redbed, supratidal, intertidal lagoonal, subtidal lagoonal, biostromal reef, shallow neritic (crindial bank and sandstone), intermediate neritic, and deep neritic arranged in basinward order. Their approximate geographic distributions at twelve successive time horizons during the Late Cayugan and Helderbergian are shown on a series of lithofacies-paleoenvironmental maps (Barnett, in preparation). It can be inferred from these maps that the report area was situated on the eastern side of a generally deepening northern Appalachian basin. The north - south trending shoreline was predominantly located within the report area but at times receded to the west or advanced to the east. A sediment source was continually active in eastern Pennsylvania south of the main outcrop belt, whereas a source east of the northern portion of the Outlier was active only during the late Helderbergian. Deposition in the southern part of the Outlier appears to have alternated between acting as a marine embayment connected to a marine sea located to the southeast and acting as a passageway which connected the northern Appalachian basin to this marine sea. The southern part of the Outlier was subjected to rather extensive pre-Oriskany (Deerparkian) erosion, whereas pre-Oriskany erosion in the northern Outlier was considerably less. On the other hand, deposition continued uninterrupted along the main outcrop belt throughout Late Cayugan, Helderbergian and Deerparkian time.

The stratigraphic relations in the Outlier of the Connelly, Esopus, and Kanouse Formations in ascending order are shown in figure 2.

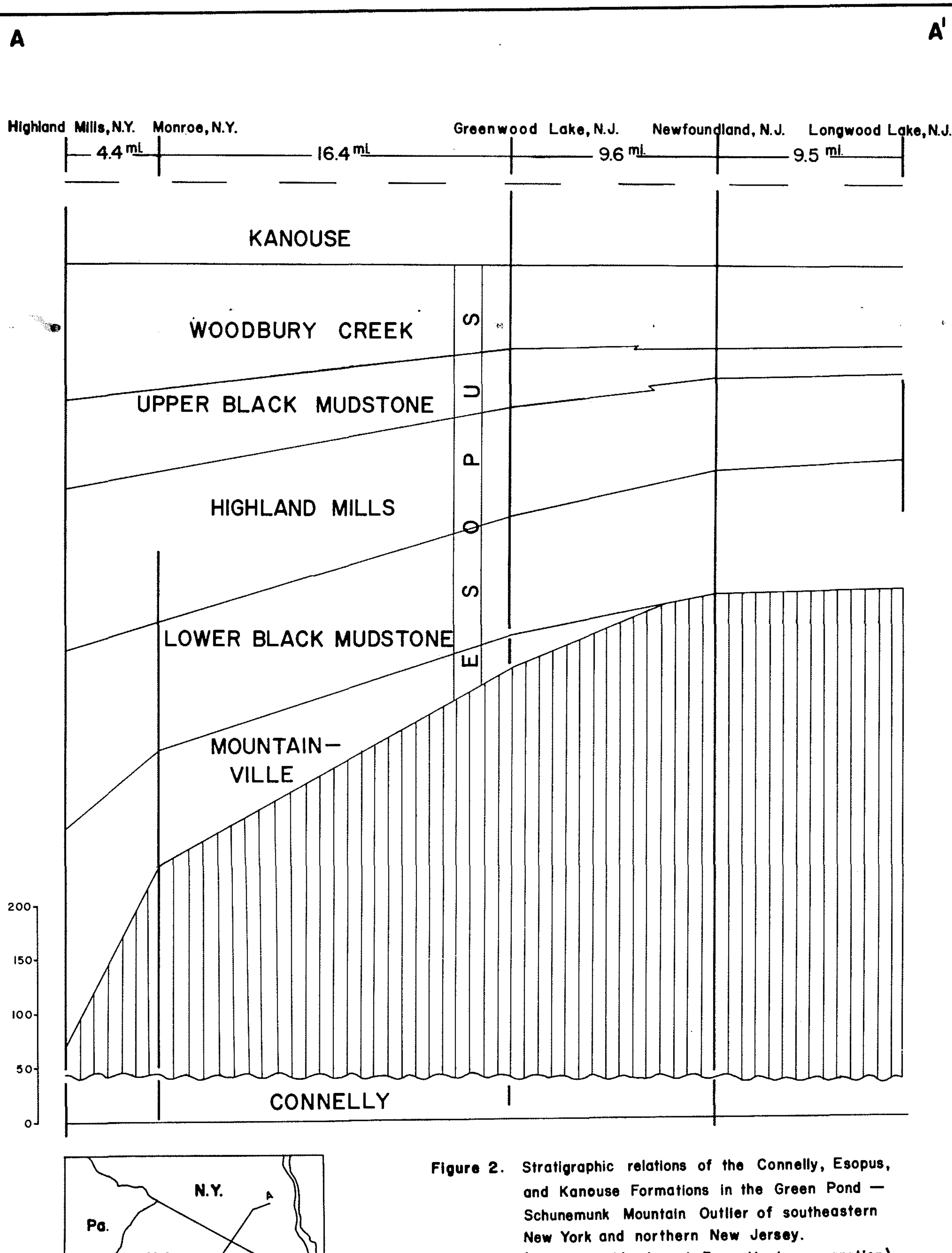

Figure 2. Stratigraphic relations of the Connelly, Esopus, and Kanouse Formations in the Green Pond — Schunemunk Mountain Outlier of southeastern New York and northern New Jersey. (after Southland and Barnett, in preparation) Terminology is that of Southard (1960)

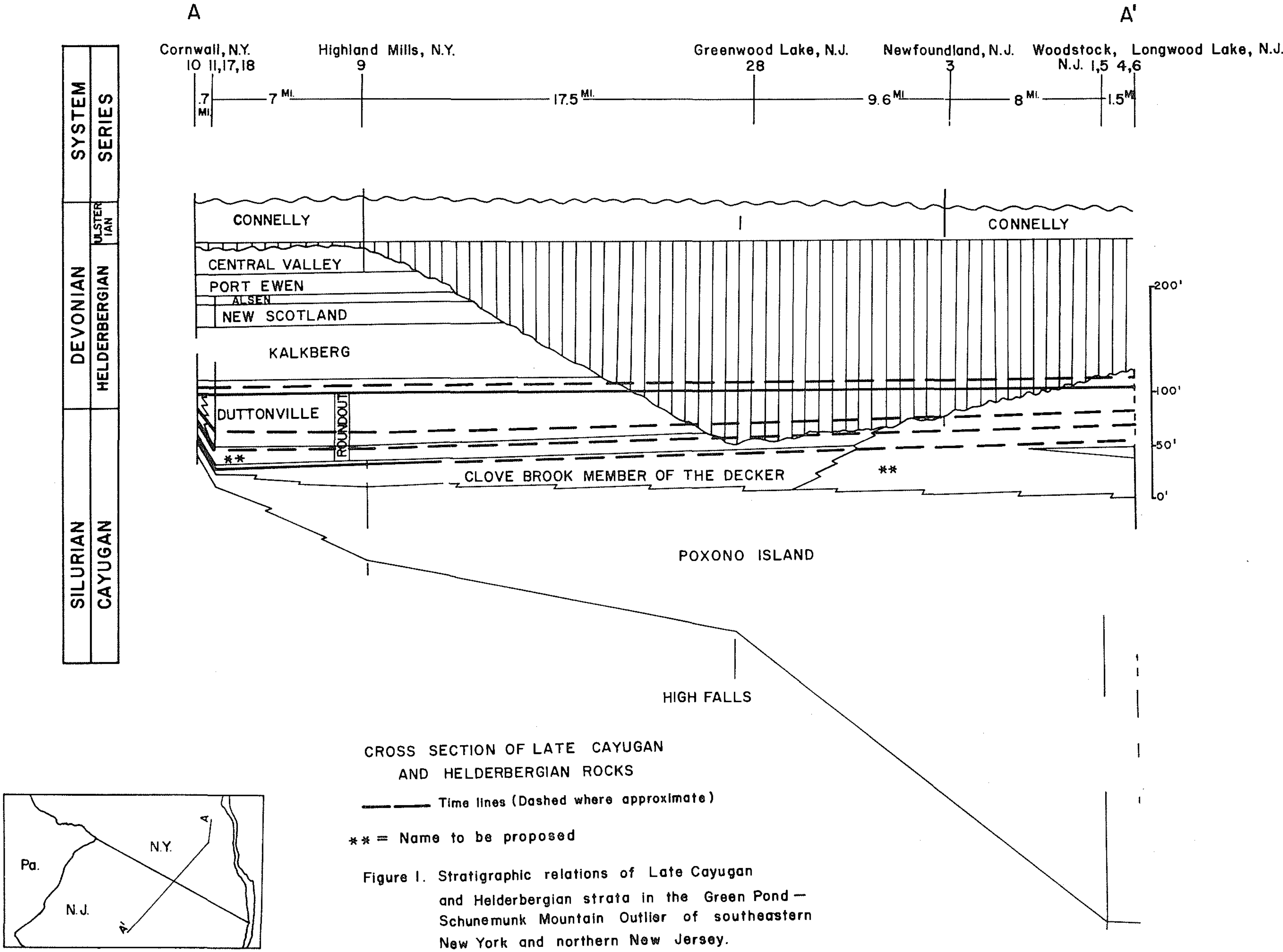

Figure I. Stratigraphic relations of Late Cayugan and Helderbergian strata in the Green Pond — Schunemunk Mountain Outlier of southeastern New York and northern New Jersey. (after Barnett, in preparation)