CORRELATION OF PUNCTUATED AGGRADATIONAL CYCLES, HELDERBERG GROUP, BETWEEN SCHOHARIE AND THACHER PARK

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INTRODUCTION

The purpose of this trip is to instruct participants in the field application of the PAC Hypothesis. Specific objectives include:

1. demonstration of criteria for recognition of PACs in shallow - water carbonate facies of the Manlius Formation;
2. construction of a PAC column by participants at Schoharie N.Y. in the Manlius Formation;
3. observation and evaluation of the stratigraphic section of the Manlius Formation at Thacher Park from an episodic perspective and comparison of those observations to a PAC column constructed by the trip leaders and
4. discussion of the methods, problems and implications of correlation of Manlius PACs between the Thacher Park and Schoharie sections.

THE HYPOTHESIS OF PUNCTUATED AGGRADATIONAL CYCLES

The Hypothesis of Punctuated Aggradational Cycles (PACs) is a comprehensive stratigraphic model which states that most stratigraphic accumulation occurs episodically as thin (1-5 meters thick) shallowing-upward cycles separated by sharply defined non-depositional surfaces (fig. 1). These non-depositional surfaces are created by geologically instantaneous basin-wide relative base-level rises; deposition occurs during the intervening periods of base-level stability. Thus all deposition occurs in aggradational episodes interrupted by very short periods of non-deposition (punctuation events).

A basic tenet of the PAC Hypothesis is that the shallowing-upward motif on the scale of a few meters of thickness is pervasive throughout the stratigraphic record. We have observed the PAC motif in numerous clastic and carbonate sequences from several geologic periods. In addition numerous published accounts specifically describe depositional patterns comparable to PACs in both scale and motif. The abundance of such examples coupled with a lack of documented small-scale deepening-upward cycles suggests that the PAC Hypothesis is applicable to essentially the entire stratigraphic record which potentially is totally divisible into PACs.

The hypothesis predicts that punctuated aggradational cycles (PACs) exist in rocks representing all environments in which a

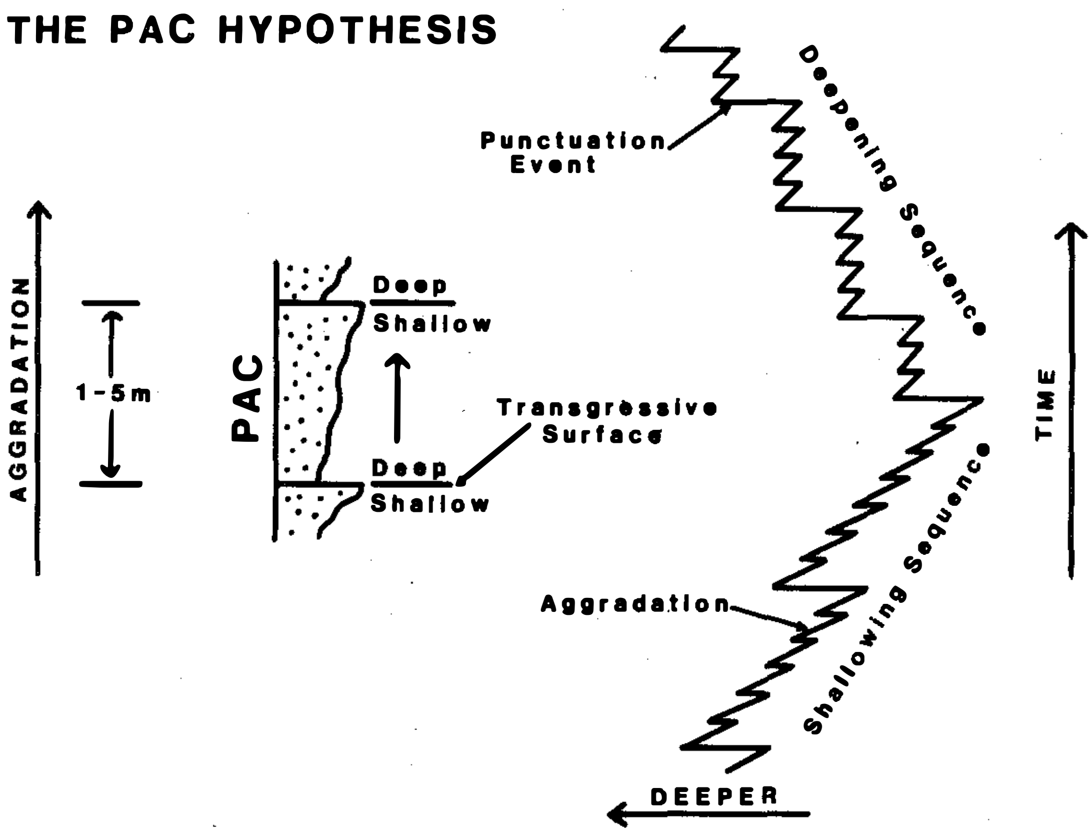


Fig. 1.-General model of the Hypothesis of Punctuated Aggradational Cycles. Each PAC is bounded by surfaces of abrupt change to deeper facies. Facies changes within a PAC are gradational. At a larger scale shallowing and deepening sequences consist entirely of PAC's produced during periods of aggradation punctuated by deepening events.

rapid base-level rise can directly or indirectly influence depositional processes. Thus fluvial, deltaic, tidal, shelf, slope, turbiditic fan, and basinal clastic environments as well as the full spectrum of marine carbonate environments should produce deposits which display the PAC motif. Not only are PACs expected in all sedimentary environments, but also PACs are basin-wide rock units which may be traced laterally through the deposits of a variety of co-existing environments. Theoretically PACs terminate at the lateral limit of all contiguous depositional sites affected by a specific position of sea level. Therefore a particular PAC will be defined by different sedimentologic evidence at different places in the basin. A new and different environmental spectrum is created by each deepening event and modified by aggradation during periods of base-level stability.

PACs are thin rock units averaging 1-5 meters in thickness. This thickness is a function of the magnitude of punctuation events, the amount of gradual sea-level rise occurring between punctuation events, initial topography, and rate of sedimentation. Analysis of PACs (see the Helderberg example) suggests that punctuation events contribute a significant portion of the stratigraphic room available for accumulation. Between punctuations sedimentary aggradation tends to establish equilibrium with distributional sedimentary processes, often depositing sediment to the limits of room available. Gradual sea-level rise permits additional sedimentary accumulation which can be a significant portion of total PAC thickness if sedimentation rates are high and the time between punctuation events is long. Finally PACs will be thinner over topographic highs and in environments where rates of sedimentation are low.

We hypothesize that the punctuation events which produce PACs are geologically instantaneous and at least basin-wide in their influence. Very rapid deepening events are indicated by sharp surfaces of non-deposition at PAC boundaries and by the absence of gradationally deepening-upward cycles. The basin-wide influence of punctuation events is indicated by the lateral persistence of PACs for tens of kilometers across the Helderberg basin and by the traceability of PAC sequences throughout the basin.

Because punctuation events are both frequent and rapid the resulting PACs (punctuated aggradational cycles) are very thin time-stratigraphic units bounded by isochronous surfaces. As thin mappable rock units which are also time-stratigraphic, PACs offer a potential for very detailed chronologic correlations at least on a basin-wide scale. In contrast, correlations based on major facies and formations are less accurate because these units are much thicker and are generally diachronous. Biostratigraphic control, as a consequence of evolutionary rates, is also less precise by perhaps an order of magnitude.

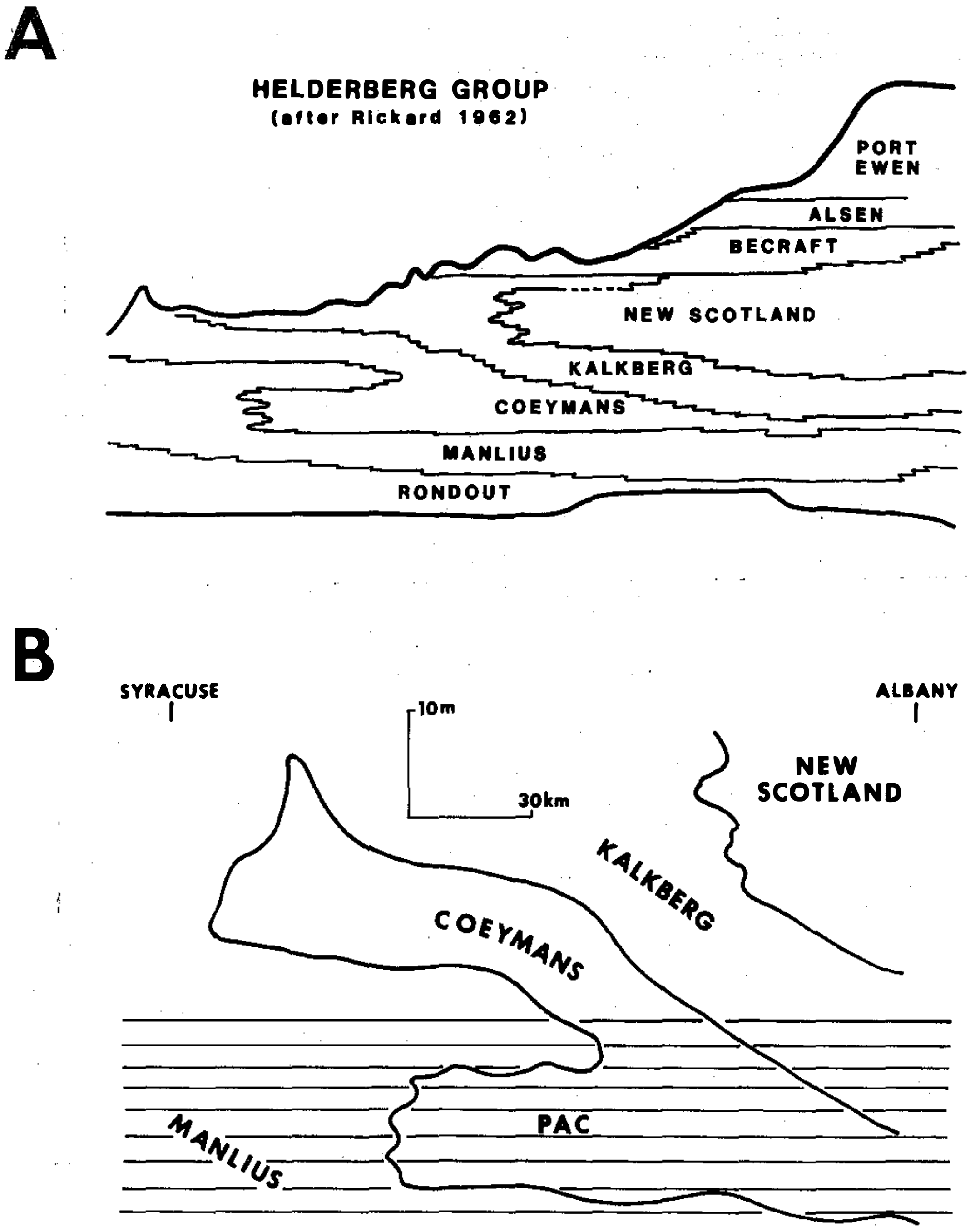


Fig. 2.-A) East-West cross-section of formations in the Helderberg Group. B) Conceptual relationship between PACs and Helderberg stratigraphy. PAC's are thin time-stratigraphic units which cut across major facies (generally diachronous formations). For simplicity, PAC's are illustrated schematically only in the lower portion of the cross-section.

In traditional surface stratigraphy only occasional key beds and bentonites provide the degree of temporal control suggested by the PAC Hypothesis. Even in the subsurface, where seismic stratigraphy has traced some isochronous reflection surfaces basin-wide, correlations at the scale of individual PACs have not been achieved except locally when seismic information is combined with logs from closely spaced wells.

In summary, the essential elements of the PAC Hypothesis are:

1. The basic stratigraphic motif is the small-scale shallowing-upward cycle (PAC) separated by sharply defined non-depositional surfaces.
2. PACs are produced by frequent (every 5-100 thousand years) geologically instantaneous base-level rises (punctuation events) which are at least basin-wide.
3. PACs are theoretically traceable throughout a basin of deposition as time-stratigraphic units bounded by isochronous surfaces.
4. PACs are the fundamental rock units for paleoenvironmental and paleoecologic analysis.
5. As mappable rock units which are also time-stratigraphic, PACs offer unequalled opportunity for establishing basin-wide chronologic correlations and paleogeographic reconstructions.

PACs AND HELDERBERG STRATIGRAPHY

General Relationships

The Helderberg Group of New York State has been interpreted as a transgressive carbonate sequence (Laporte 1969) representing a sprectrum of paleoenvironments including tidal flat (Manlius Formation) shallow shelf (Coeymans Formation) and deep shelf (Kalkberg and New Scotland Formations) facies. Detailed stratigraphic relationships were established by Rickard (1962) from a series of approximately 160 closely spaced localities along the outcrop belts in the Hudson Valley and in the Mohawk Valley (fig. 2). Using this stratigraphic framework Laporte (1967) and Anderson (1972) developed paleoenvironmental interpretations of Manlius and Coeymans facies, thereby establishing the basic paleogeographic setting of the Helderberg Basin.

More recently Goodwin and Anderson (in press) have developed the PAC Hypothesis and applied it to the Helderberg Group especially in the nearshore facies of the Manlius Formation in central New York State (Anderson and Goodwin, 1980). This approach has aided in refining facies interpretations and in understanding the dynamics of facies succession. Viewed as sequences of PACs, large-scale carbonate facies developed episodically in response to basinwide punctuation events (relative base-level rises). However within individual PACs facies developed gradually in response to aggradation during periods of base-level stability.

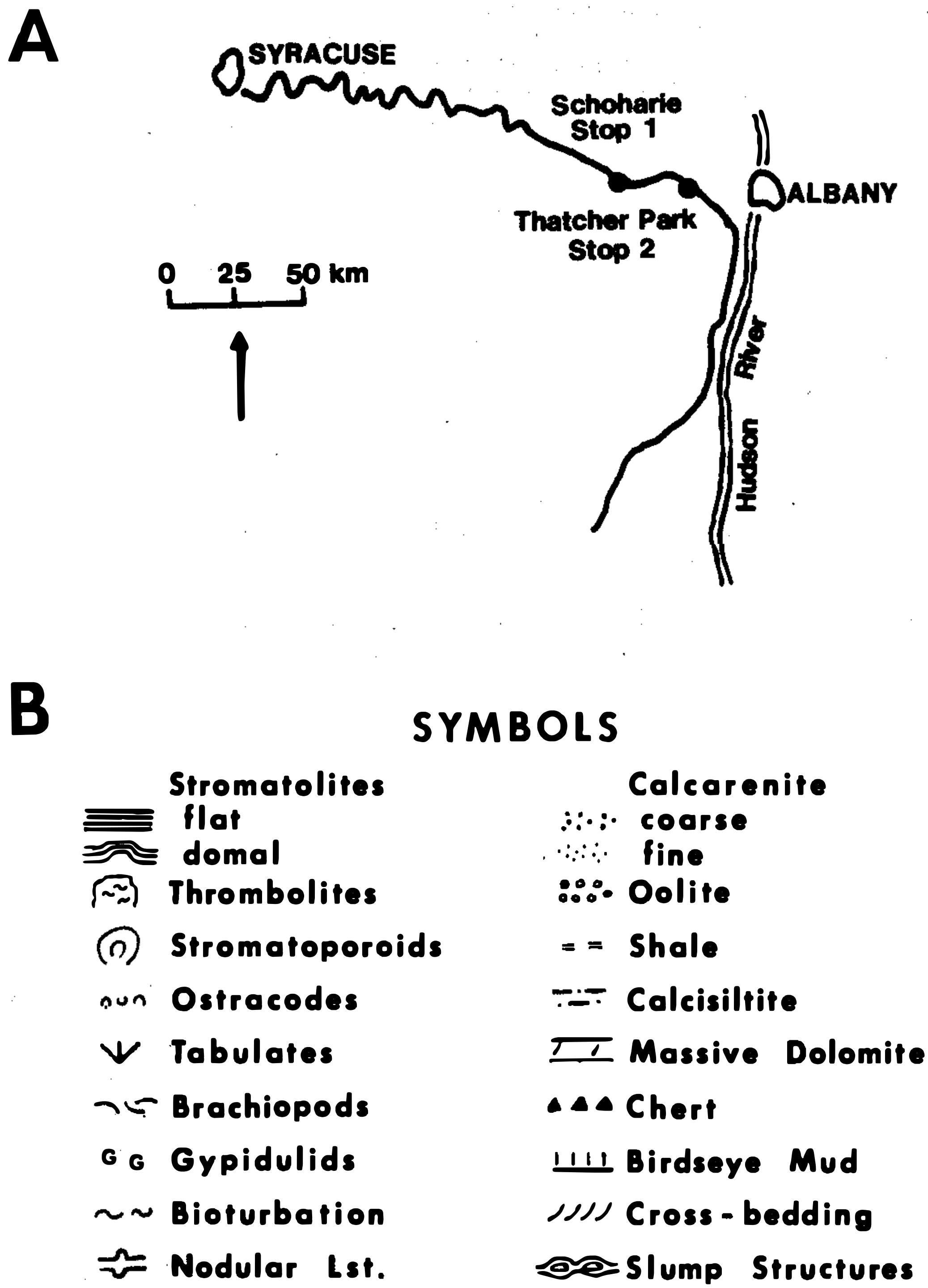


Fig. 3.-A) Outcrop and locality map of the Helderberg Group. B) Legend for stratigraphic columns.

Analyzing the Helderberg Group from an episodic perspective leads to correlation of thin stratigraphic units throughout, reinterpretation of the stratigraphic dynamics that produce formational boundaries and a different concept of the relationship between Helderbergian stratigraphic units and their depositional environments. The PAC Hypothesis predicts that the Helderberg Group is totally divisible into small-scale, time-stratigraphic, shallowing-upward cycles that cut across major facies generally mapped as diachronous formations (fig. 2). Each PAC is bounded by sharp surfaces separating facies representing non-contiguous environments. Therefore each PAC boundary is a significant paleoenvironmental discontinuity which can be traced laterally from one diachronous formation (e.g. Coeymans) into contemporaneous facies mapped as other formations (e.g. Manlius to the west and Kalkberg to the east). At single localities formation boundaries generally coincide with PAC boundaries (Anderson, Goodwin and Sobieski, 1984). Therefore these formation boundaries are discontinuities separating environmentally disjunct facies which were superimposed episodically, not gradually (figs. 3, 4 and 5).

Field Trip Stops

Stop 1. Interstate 88, Schoharie, N.Y. The Cobleskill-Rondout-Manlius interval (85 feet thick) completely divisible into 13 PACs (fig. 4). The 5 Cobleskill-Rondout PACs comprise a sequence of peritidal cycles initiated and ended by large punctuation events (see water-depth curve). The first of these events followed a sea-level fall which produced the unconformity with the Brayman Shale. After the deposition of 5 PACs, a second large event terminated tidal-flat deposition and initiated a sequence of basically subtidal PACs in the lower Thacher Member of the Manlius Formation. Thus each of these major punctuation events is marked by the introduction of significantly different facies.

Within the sequence of 8 Manlius PACs the boundary between PAC 5 and PAC 6 is unique. At this boundary the upper part of PAC 5 is marked by a laminated cryptalgal crust on a scalloped surface, features which suggest subaerial exposure and erosion resulting from a minor sea-level fall. This surface is a widespread marker horizon traceable throughout the Hudson Valley. The subsequent sea-level rise created water depths sufficient to produce the subtidal bioturbated stromatoporoid-bearing limestones of PAC 6. Another significant punctuation event resulted in even greater water depth and the diversely fossiliferous subtidal facies of PAC 7. PAC 8 is like 7 but is truncated by an unconformity.

The Manlius-Coeymans boundary is a surface with a complex history. At Schoharie, at the top of Manlius PAC 8 (fig. 4),

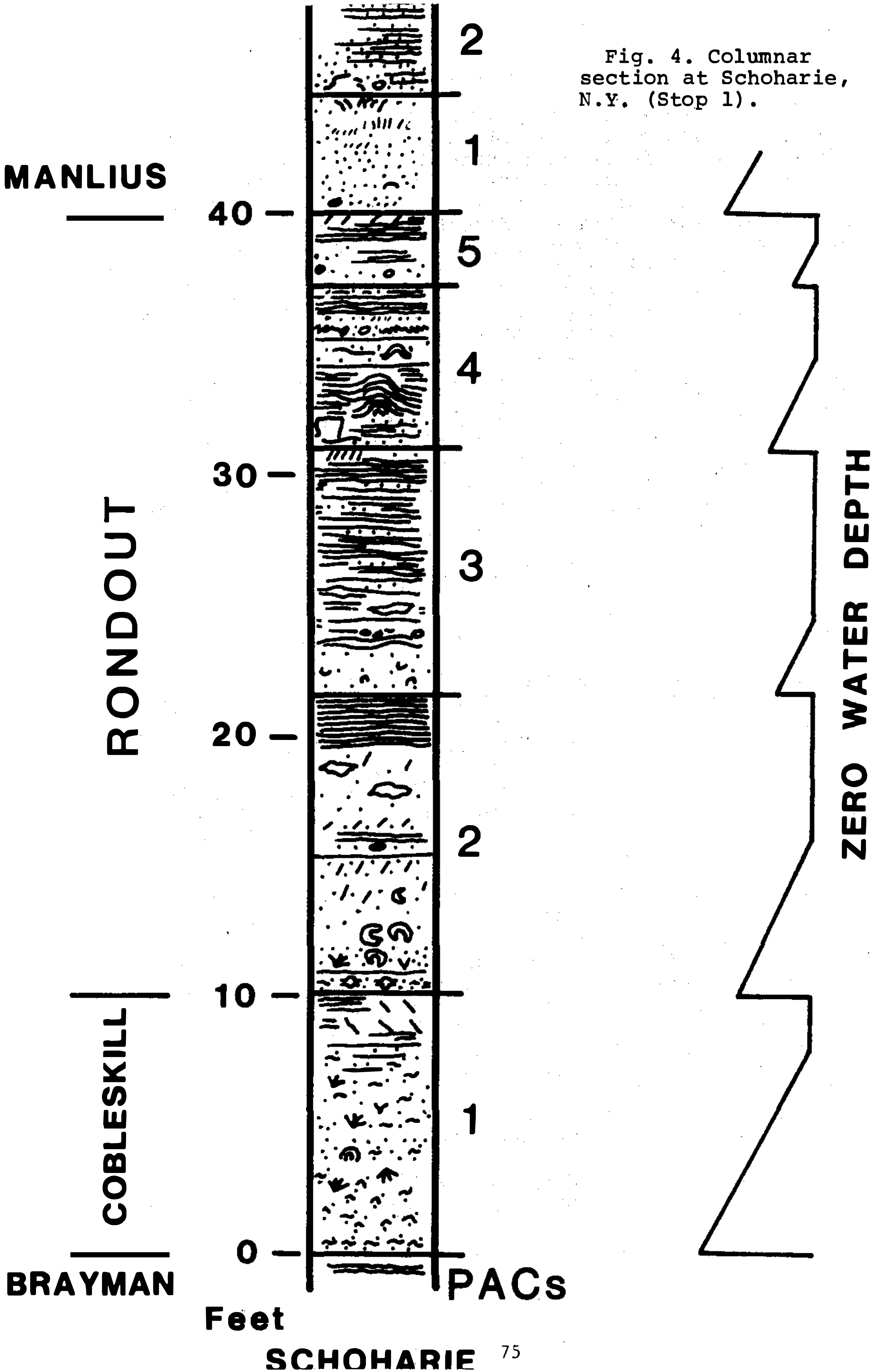
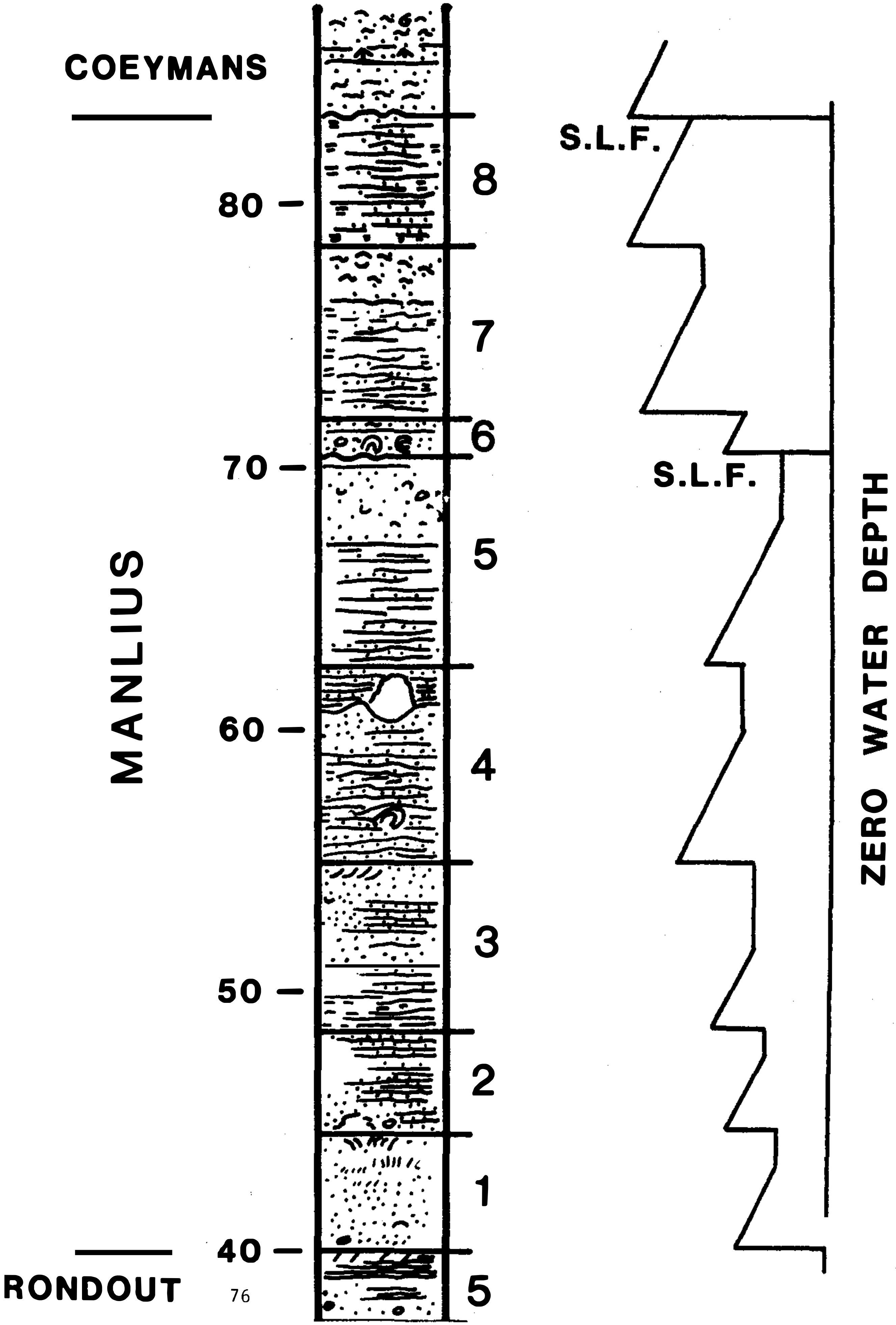


Fig. 4. Columnar section at Schoharie, N.Y. (Stop 1).


COEYMANS
8
80
7
6
70
S.L.F.
S.L.F.
5
MANLIUS
60
4
3
50
2
1
40
RONDOUT
5
ZERO WATER DEPTH

it appears to be a normal PAC boundary marking a major punctuation event which introduced facies very different from Manlius facies below. However, correlation of PACs to the east and south indicate progressive erosion and elimination of PAC 8,7 and 6 in the Hudson Valley as a result of differential uplift. This erosional surface was then inundated by a sea-level rise which initiated Coeymans deposition throughout the area.

Thus the Cobleskill-Rondout-Manlius interval at Schoharie represents episodic stratigraphic accumulation in response to a complex history of small-scale sea-level fluctuations including 3 sea-level falls and 14 sea-level rises. That each of these events is truly allogenic and probably eustatic is suggested by correlating each PAC and PAC boundary between Schoharie and Thacher Park (fig. 5).

Stop 2. Indian Ladder Staircase, John B. Thacher State Park. At this locality the Rondout-Manlius interval consists of 9 PACs, 2 in the Rondout and 7 in the Manlius (fig. 5). The smaller number of Roundout PACs relative to Stop 1 reflects the episodic overstepping of the land mass which was topographically higher at Thacher Park than at Schoharie. Manlius PAC 8 at Thacher Park is absent as a result of pre-Coeymans erosion. Correlation of PACs between the two localities was accomplished by matching unique facies and major facies changes produced by punctuation events. When the columns are correlated by these methods, the number of PACs between major punctuation events is the same at each locality.

Within the Manlius Formation PACs generally consist of facies representing more restricted paleoenvironments than those at Schoharie. For example, PACs 3 and 5 at Thacher Park are capped by a significant thickness of cryptalgal laminites representing aggradation to sea-level. At Schoharie PACs 3 and 5 are capped by shallow subtidal facies reflecting the presence of persistently deeper and less restricted environments at this locality.

Patterns of punctuation events are similar at both localities as interpreted by comparision of facies changes at PAC boundaries. For example a major punctuation event introduced Manlius facies (PAC 1) at both localities; major events also produced marked facies changes at the PAC 3-PAC 4 boundary and at the PAC 6-PAC 7 boundary (fig. 5).

Interpretation of the Manlius-Coeymans Formation boundary as an unconformity at Thacher Park is based on the absence of PAC 8 and on the sharp contact separating markedly disjunct facies. Farther to the south along the Hudson Valley progressively more PACs were eroded as a result of differential uplift of the eastern side of the basin.

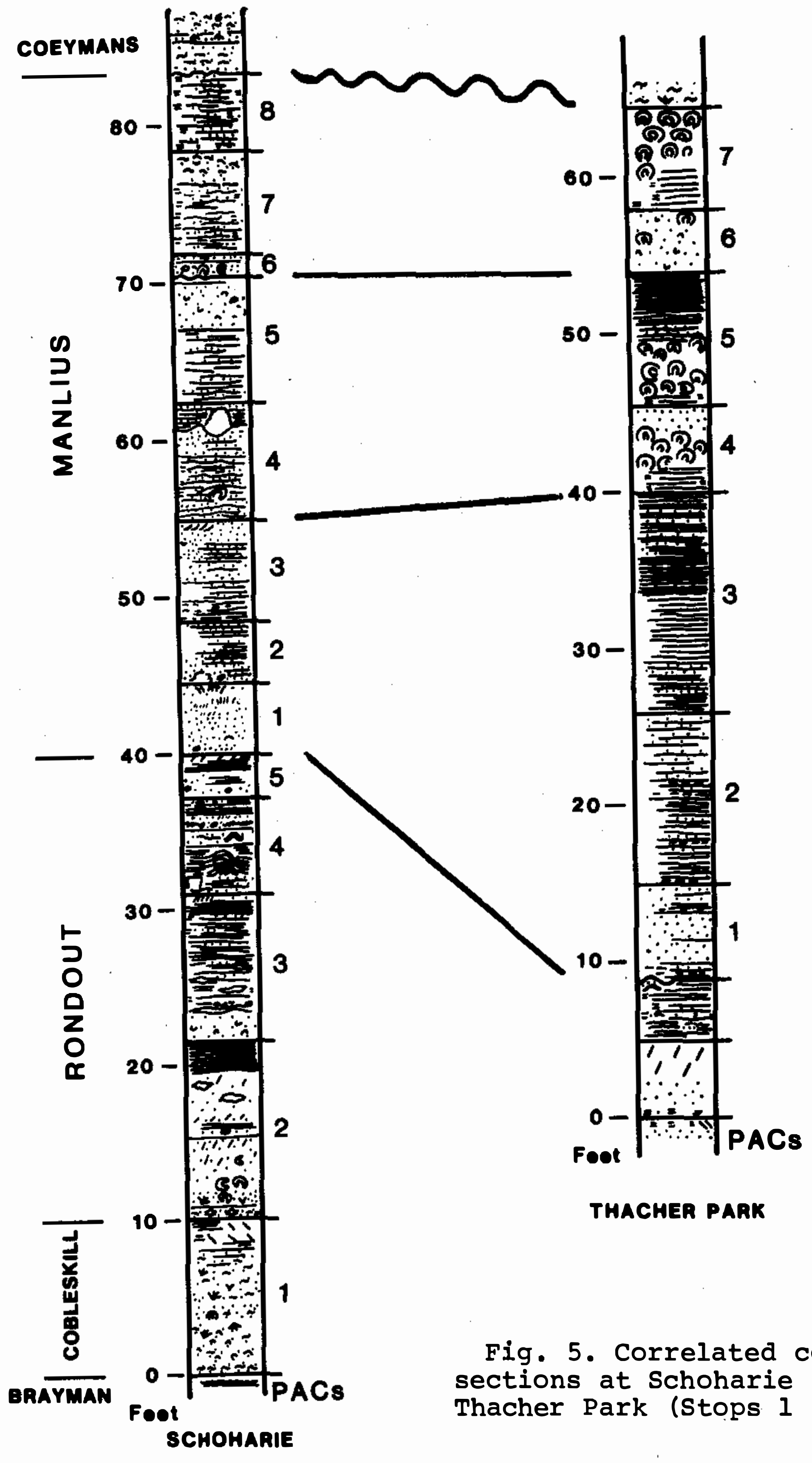


Fig. 5. Correlated columnar sections at Schoharie and Thacher Park (Stops 1 and 2).

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ROAD LOG

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0	0.0	Start at intersection of Interstate 88 and N.Y. State Thruway (Exit 25B), southwest on I-88.
16.7	16.7	Schoharie Exit of I-88. Continue on I-88.
18.4	1.7	Large road cut in lower Helderberg Group (STOP 1) on south side of I-88.
20.4	2.0	Small road cut in Kalkberg Formation on north side of I-88; large road cut on south side in New Scotland and Becraft Formations.
22.0	1.6	Small road cut on south side of I-88 in upper Becraft Oriskany and Esopus Formations.
22.6	.6	Cobleskill exit. Turn around and head back east on I-88.
26.8	4.2	STOP 1. Large road cut on south side of I-88, section includes Brayman, Rondout Manlius and Coeymans Formations.
28.5	1.7	Continue east on I-88 to Schoharie Exit. Turn south on Route 30A.
29.4	.9	End Route 30A. Continue south on Route 30.
30.7	1.3	Intersection with Route 443. Turn east on Route 443.
34.7	4.0	The village of Gallupville. Continue east on Route 443.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
35.9	1.2	Quarry in the Manlius-Coeymans interval on the south side of road (Rickard Locality 67).
38.3	2.4	The village of West Berne.
41.1	2.8	The village of Berne. Continue east on Route 443.
44.6	3.5	The village of East Berne. Turn left to Route 157A.
45.0	.4	Warner Lake. Turn east (right) on Route 157A toward Thacher Park.
47.3	2.3	Intersection Route 157, Thompson Lake. Continue straight northeast on what is now Route 157.
48.8	1.5	Thacher State Park, pool and recreation area on left.
49.4	.6	Turn left into parking lot for mine Lot Falls. STOP 2.
52.8	3.4	Turn left out of parking lot and continue east on Route 157 to the intersection of Route 85. Turn left on Route 85.
53.7	.9	Village of New Salem. Turn north (left) on Route 85A to Voorheesville.
57.2	3.5	Village of Voorheesville. Continue straight east on 85A.
57.7	.5	Turn left on State Farm Road, Route 155 (formerly Route 310) and go north to Route 20.
61.7	4.0	Turn east on Route 20 to I-87.

END OF ROAD LOG