Stratigraphic Incompleteness: Milankovitch in the Manlius at the Margin

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Introduction

As a result of lower subsidence rates, stratigraphic sections at basin margins are less complete than those in shelfal and basinal positions. Determining degree of incompleteness and its specific stratigraphic location or locations have been difficult tasks dependent on the accuracy of detailed chronologic correlations from complete basinal sections to less complete marginal sections. In the Helderberg Group (Fig. 1), large-scale models of gradual stratigraphic accumulation (e.g. Rickard, 1962: Laporte, 1969) were able to recognize major group-bounding unconformities, but did not identify internal smaller-scale unconformities. Using a model of small-scale episodic accumulation of time-stratigraphic allocycles, Goodwin and Anderson (1986, 1988) recognized cryptic unconformities internal to the Helderberg Group, surfaces at which detailed correlation of cycles revealed missing cycles (Figs. 2 and 3).

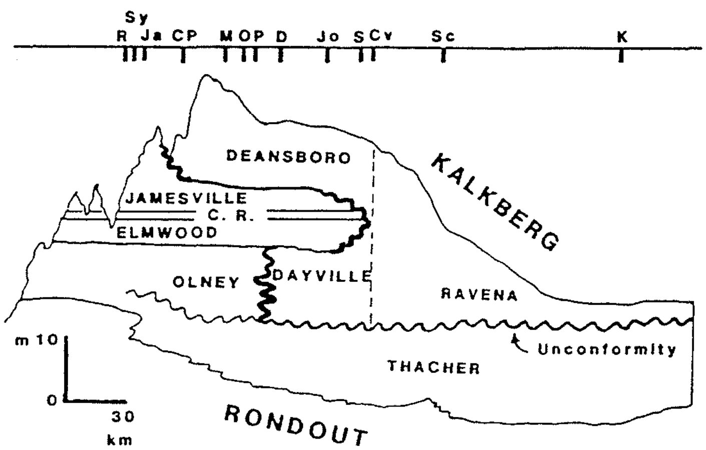


Figure 1. Schematic cross-section, Helderberg Group (from Goodwin and Anderson, 1988).

One such unconformity, traced from the Hudson Valley westward to the Syracuse area (Figs. 2 and 4), was interpreted as a sequence-bounding unconformity separating tectonically distinct portions of the Helderberg Group (Goodwin and Anderson, 1988). That third-order unconformity is the Manlius-Coeymans contact in the Hudson Valley and the Thacher-Olney contact in western sections (Fig. 1). Lesser unconformities, with fewer missing cycles, were recognized in the Manlius, but not fully explained (Fig. 2). It is the purpose of this trip to examine stratigraphic discontinuities of all scales within the Manlius Formation at four localities on the western margin of the Helderberg Basin, and to explain these unconformities in the context of the hierarchic model of orbital forcing.

The Milankovitch Hierarchy

Recent allostratigraphic studies (e.g. deBoer and Smith, 1994) have documented an orbital forcing mechanism for the origin of a stratigraphic record increasingly recognized as both hierarchic and allostratigraphic. The most frequently recognized orbital-forcing mechanisms are precession (approx. 20 ky period) and eccentrcity (periods of 100 ky and 400 ky). Obliquity is rarely recognized as a cycle-producing mechanism; studies supposedly documenting obliquity may well be describing highly incomplete sections of precessional cycles or sections

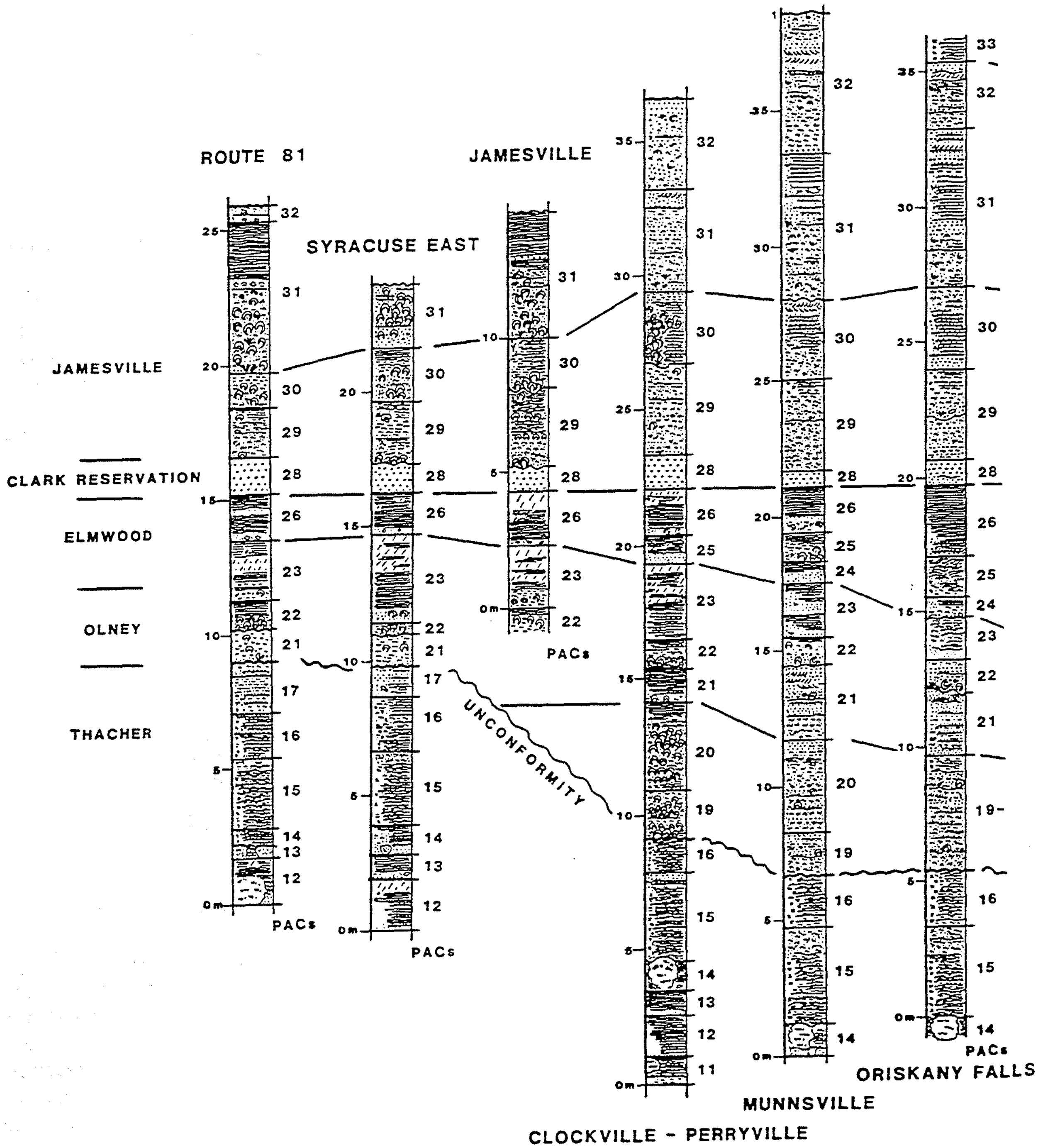
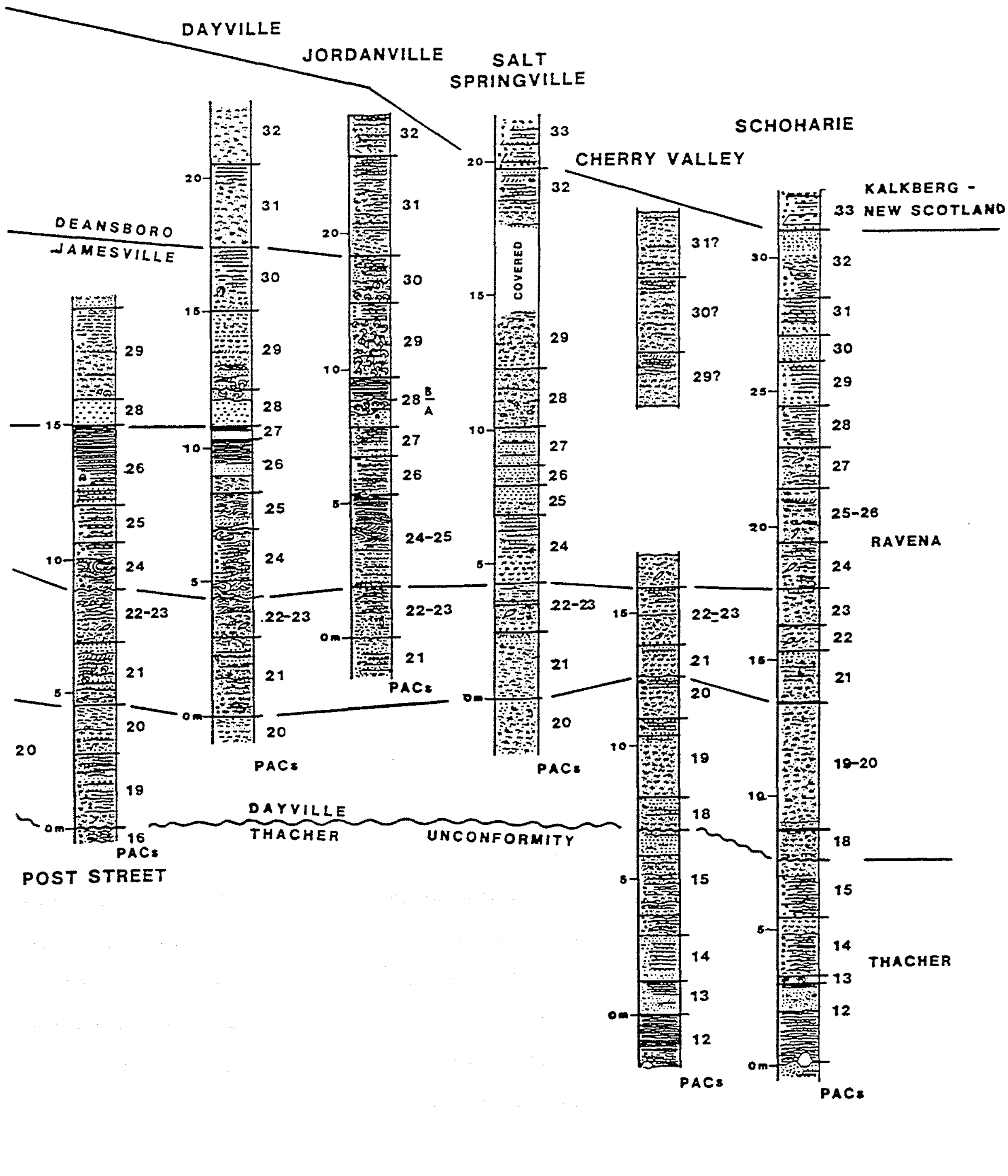


Figure 2. Correlated columnar sections, Helderberg Group, central New York (from Goodwin and Anderson, 1988).


DAYVILLE
JORDANVILLE
SALT SPRINGVILLE
SCHOHARIE
CHERRY VALLEY
KALKBERG - NEW SCOTLAND
DEANSBORO
JAMESVILLE
COVERED
RAVENA
DAYVILLE
THACHER
UNCONFORMITY
THACHER
POST STREET
PACs
33
32
31
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24-25
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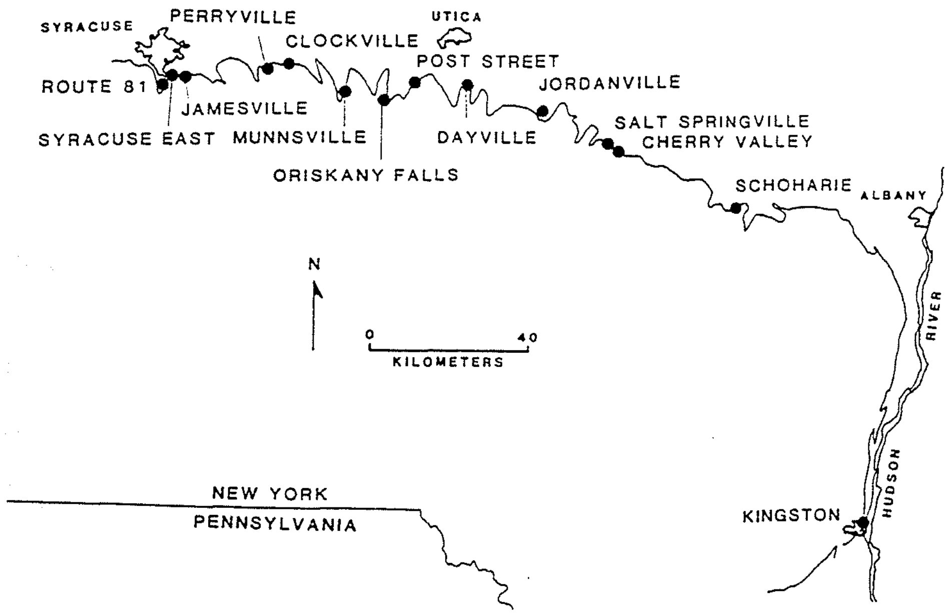

Figure 3. Helderberg outcrop belt, New York State. Localities for this trip are Munnsville, Clockville, Perryville, Jamesville and Route 81.

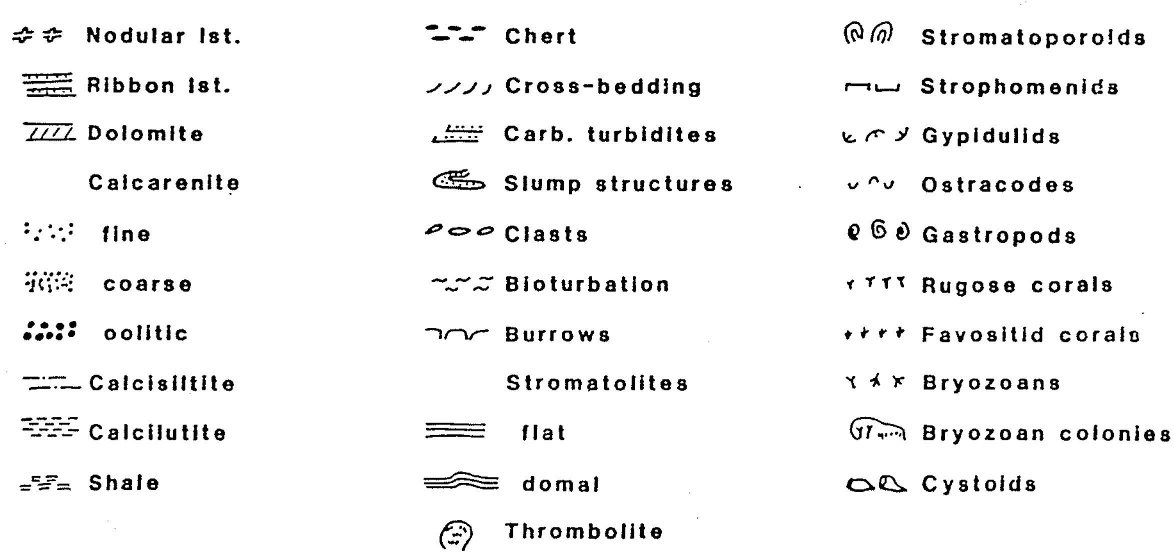

Figure 4. Symbols used in all columns.

consisting of poorly discriminated precessional and eccentricity-modulated cycles. Therefore, the hierarchic model used in this study is one which does not include obliquity (Table 1).

Rank	Period	Mechanism
2nd Order (Supersequence)	10 million years	Tectono-Eustasy
3rd Order (Sequence)	2 million years	Eccentricity ?
4th Order	400,000 years	Long Eccentricity
5th Order	100,000 years	Short Eccentricity
6th Order (PAC)	20,000 years	Precession

Table 1. Genetic Hierarchy of Allocycles

In this model (Table 1), the fundamental cycle-producing mechanism is precession (Fig. 5); eccentricity functions as a modulator of the precessional signal by enhancing or dampening its effect (Fig. 6). Precession produces a sharply bounded, shallowing-upward cycle (PAC) defined by disjunct facies relationships at its boundaries (Fig. 5). The sharp bounding surfaces are formed during times of non-deposition when sea level is rising at its maximum rate (i.e. the inflection point on the sea-level-rise curve). Modulation of the precessional signal by eccentricity produces fifth-order bundles of sixth-order precessional cycles (Fig. 6); these bundles are defined by major facies change (enhanced sea-level rises) at their boundaries. Internally, fifth-order sequences generally contain their deepest facies in the second PAC and exhibit a shallowing trend in successive PACs (Fig. 7).

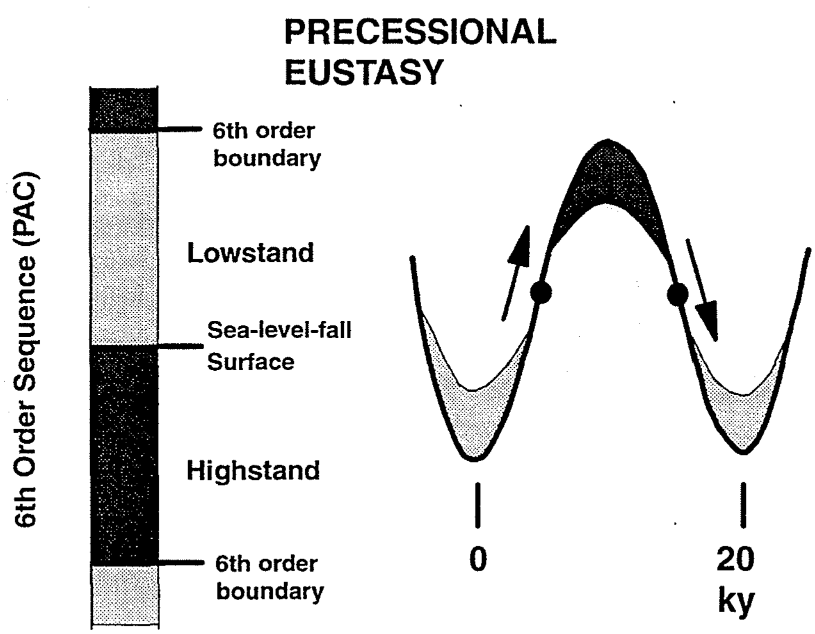

Figure 5. Relationship between precessional eustasy and sixth-order sequences. Sixth-order boundaries are produced at times of non-deposition associated with the maximum rate of sea-level rise (near the inflection point of the rising curve). Sea-level-fall surfaces, when present, are produced in a similar manner at times of rapid sea-level fall.

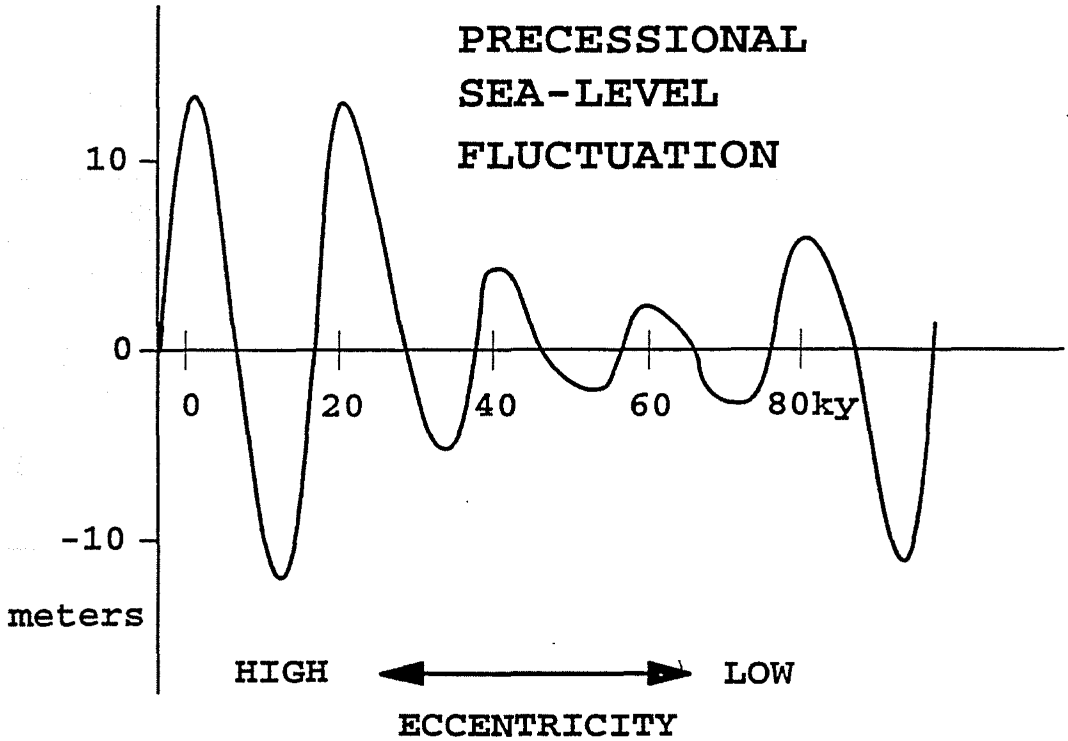

Figure 6. Eccentricity modulation of the precessional sea-level curve. At times of high eccentricity, precessional rises and falls are enhanced; at times of low eccentricity precessional rises and falls are dampened. Modulation by eccentricity produces asymmetric bundles of sixth-order sequences (Fig. 7).

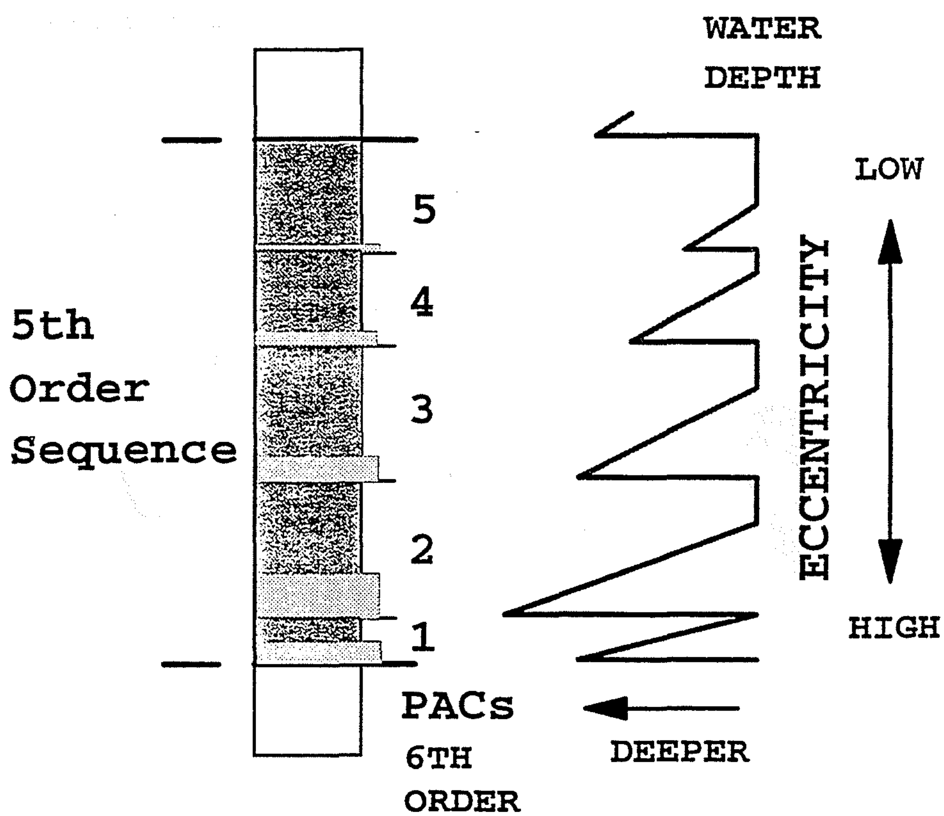

Figure 7. Asymmetric fifth-order bundle of sixth-order sequences. Enhanced precessional rises produce major facies changes at bundle boundaries; dampened rises produce a generally shallowing-upward upper portion of the fifth-order sequence. Deepest facies commonly occur at the base of the second PAC.

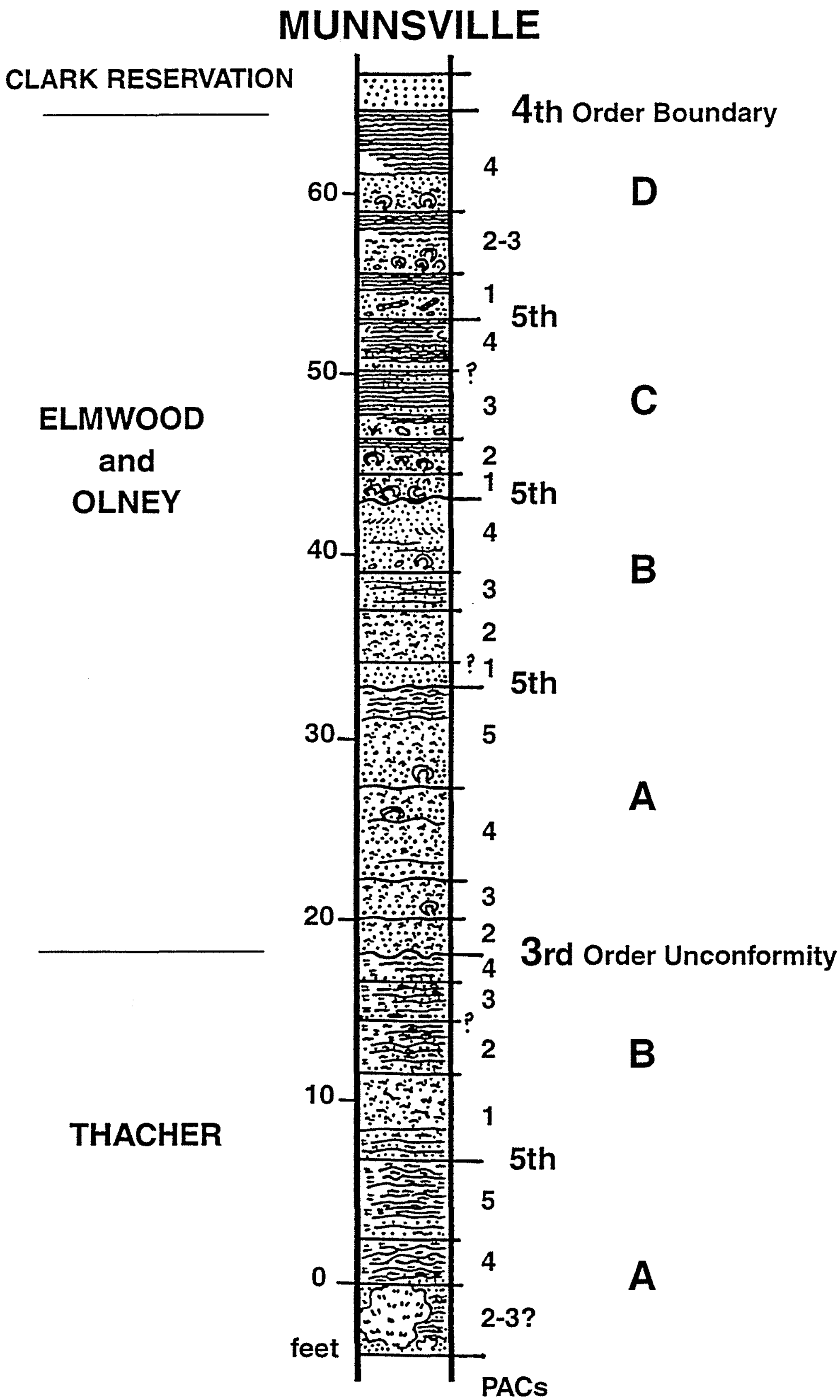

Figure 8. Columnar section, Munnsville Quarry, Munnsville, New York

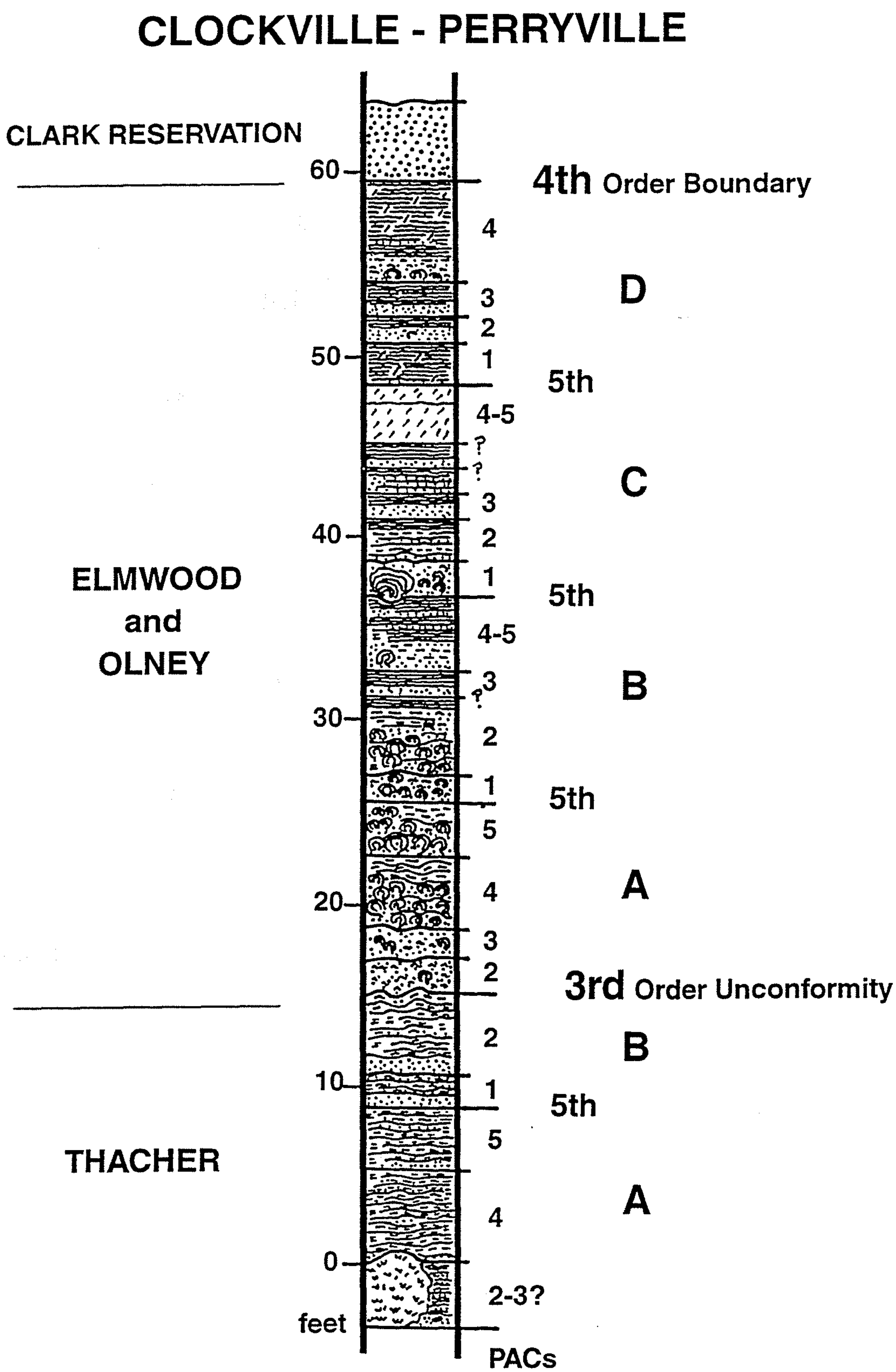

Figure 9. Columnar section, Clockville - Perryville, New York

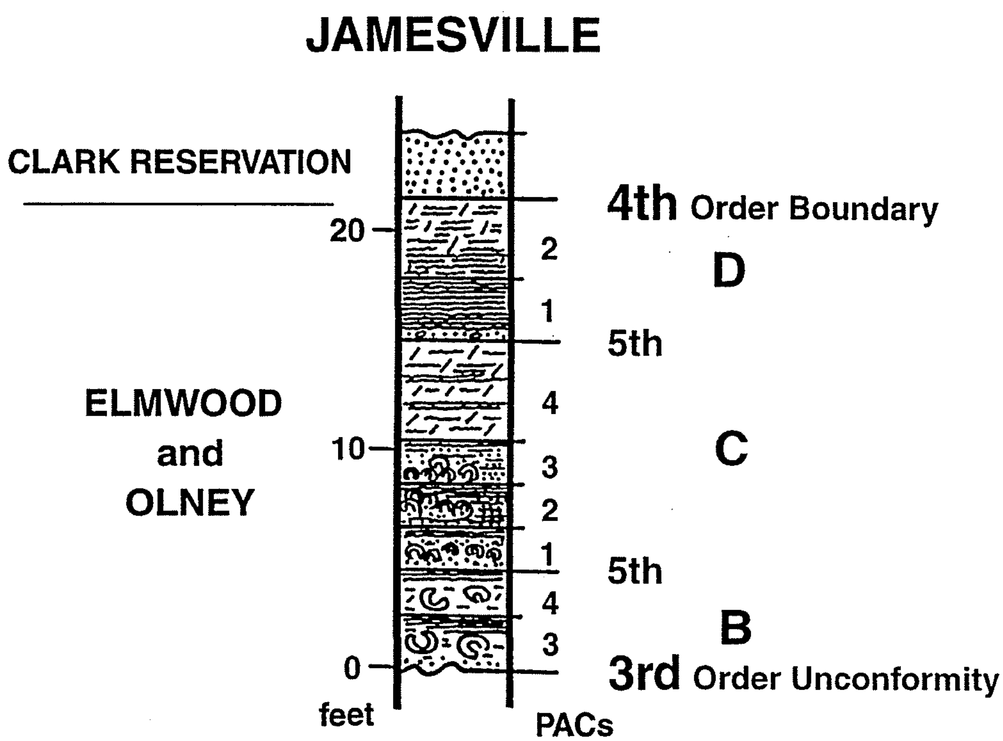

Figure 10. Columnar section, Onondaga County Quarry, Jamesville, New York

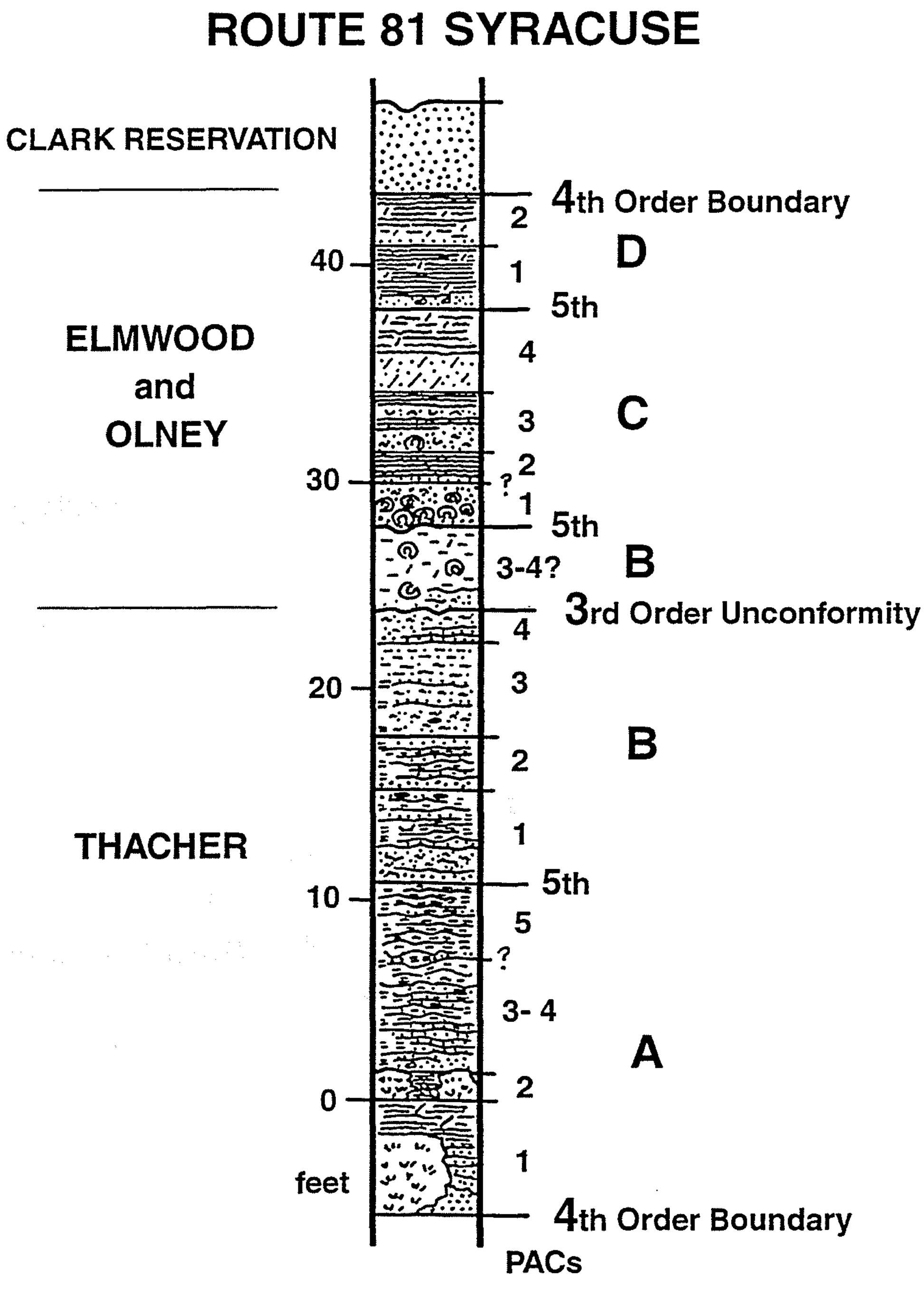

Figure 11. Columnar section, Interstate 81 northbound lanes south of Syracuse, New York

Stratigraphic Incompleteness in the Manlius Formation

In the Mohawk Valley, Olney-Elmwood sections to the East are more complete (thicker and containing more cycles) than those to the West. In contrast, Upper Thacher sections reveal the opposite trend, thickening by the westward addition of more cycles beneath the Thacher-Olney unconformity. At four localities from Munnsville to Syracuse (Fig. 4), this trip will document these trends, focussing on the Manlius interval between the third-order unconformity at the Thacher-Olney contact and the major facies change at the fourth-order boundary between the Elmwood and Clark Reservation Members. Application of the hierarchic orbital forcing model reveals that stratigraphic incompleteness (missing cycles) is a function of vacuity (erosion) and hiatus (non-deposition) at third-, fourth- and fifth-order boundaries, not simply at major unconformities. Incompleteness at fourth- and fifth-order boundaries is largely a function of eccentricity-modulated eustasy, whereas third-order incompleteness has a significant tectonic component.

The interval covered on this trip includes three fourth-order boundaries, one of which is also a third-order unconformity (Figs. 8-11). Principal focus is on the fourth-order sequence between the third-order Thacher-Olney unconformity and the fourth-order boundary at the Elmwood-Clark Reservation contact. This fourth-order sequence is nearly complete at Munnsville (Fig. 8), where it consists of the requisite four fifth-order sequences, each containing four or five sixth-order sequences (PACs). Westward, this fourth-order sequence is less complete, consisting of just three fifth-order sequences at Jamesville (Fig. 10) and at Route 81 (Fig. 11). Furthermore, at these western localities the basal fifith-order sequence consists of only two or three sixth-order PACs, suggesting significant hiatus at the third-order unconformity. Similarly, the uppermost fifth-order sequence consists of fewer PACs to the West, probably as a function of erosion or non-deposition at the fourth-order boundary and/or hiatus at the lower fifth-order boundary. Thus, westward thinning of this fourth-order sequence is a function of:

1. longer hiatus at the third-order unconformity;
2. fourth-order erosion or hiatus at the Elmwood-Clark Reservation contact; and
3. fifth-order hiatus and/or erosion within the fourth-order sequence.

In contrast, the highly incomplete fourth-order sequence beneath the third-order unconformity (Thacher-Olney contact) exhibits a different East-West trend (Figs. 8-11). Westward from the Hudson Valley (Goodwin et al., 1986), this interval thickens because additional cycles are preserved beneath the unconformity, indicating that uplift to the East caused deeper erosion (vacuity) at the eastern localities. Thus, the origin of the third-order unconformity has a tectonic component: first greater uplift to the East and then greater subsidence at those same localities. In other words, vacuity is greater at eastern localities and hiatus is greater at western localities.

In summary, stratigraphic incompleteness of the Manlius Formation is a function of a hierarchy of eustatic sea-level fluctuations superimposed on a tectonic component. Differential uplift and subsidence produced a third-order sequence-bounding unconformity, at which fifth- and sixth-order cycles are missing by vacuity and hiatus. At smaller scales, sixth-order cycles are missing in some fifth-order sequences to the West as a result of erosion and/or non-deposition at fifth-order boundaries at the low-subsidence basin margin. Assuming that the detailed correlations of this hierarchic allostratigraphic fabric are accurate, this approach facilitates the determination of the exact location of missing section as well as the amount of time (number of 20,000 year cycles) encompassed by those missing cycles.

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Road Log

Cumulative Mileage	Miles From Last Point	Route Description
0.0	0.0	Road log starts at Hamilton College entrance on Route 412
4.8	4.8	From Hamilton College, go west on Route 412 to Vernon Center
9.3	4.5	Turn south (left) on Route 26 to Knoxboro Rd
13.3	4.0	Turn west (right) on Knoxboro Rd, through Knoxboro to Cook Rd.
14.7	1.4	South on Cook Rd. to Munnsville and intersection with Route 46
15.7	1.0	South on Route 46 to Quarry Rd.
16.2	0.5	Left on Quarry Rd. to Munnsville Quarry entrance (STOP 1)

STOP 1. Manlius Formation at Munnsville Quarry (Rickard Loc. 137)

The Munnsville Quarry Manlius section begins in the Thacher Member at the quarry entrance and continues into the Olney Mbr. on the north wall of the quarry. The upper Olney, Elmwood , Clark Reservation and Jamesville members are exposed in the west wall of the quarry.

At this locality, a third-order unconformity forms the Thacher-Olney contact (Fig. 8); extended eastward this unconformity becomes the Thacher-Ravena contact at Schoharie and in the Hudson Valley (Figs. 1 and 2). Between this unconformity and the fourth-order boundary at the base of the Clark Reservation Mbr. the Olney-Elmwood interval (46.5 ft thick) consists of four relatively complete fifth-order sequences (A, B, C and D). Each of these fifth-order sequences consists of four or five sixth-order sequences (PACs). The fourth-order sequence below the unconformity consists of portions of two fifth-order sequences (A and B), the upper two missing by vacuity (erosion) at the unconformity.

16.7	0.5	Return to Route 46 on Quarry Rd.
17.7	1.0	North on Rte. 46 into Munnsville to intersection with Williams Rd.
22.1	4.4	West (left) on Williams Rd. to intersection with Peterboro Rd.
23.2	1.1	West (left) on Peterboro Rd., through Peterboro to Old Country Rd.
23.3	0.2	North (right) on Old Country Rd. to Oxbow Rd.
28.8	5.5	Left on Oxbow Rd. to picnic/parking area across from Stop 2.

STOP 2. Clockville Roadcut (Thacher-Olney Interval, Manlius Fm., Rickard Loc 142)

At this locality, the Thacher Mbr. and the lower Olney Mbr. are exposed. The described section (Fig. 9) begins near the top of the thick-bedded Thacher of Rickard (1962). The third-order unconformity (Thacher-Olney contact) is exposed near the top of the outcrop. The Olney-Elmwood portion of the columnar section was described at Perryville, 3.5 miles to the West.

As at Munnsville (Fig. 8), the fourth-order sequence below the unconformity consists of two incomplete fifth-order sequences (A and B). The smaller number of sixth-order cycles in fifth-order sequence B at Clockville relative to Munnsville suggests slightly deeper erosion at the third-order unconformity at this locality.

29.3	0.5	South on Oxbow Rd. to Ingalls Corners Rd.
32.5	3.2	West (right) on Ingalls Corners Rd. to Quarry Rd.
33.3	0.8	North (right) on Quarry Rd. to entrance to Madison Products Quarry (Stop 3)

STOP 3. Madison Highway Products Quarry, Perryville (Rickard Loc. 144)

At this locality, the upper Thacher, Olney, Elmwood and Clark Reservation Members are exposed in the north wall of the old pit behind the maintenance shed and scale house. The base of the section begins six feet below the Thacher-Olney third-order unconformity (Fig. 9). The Thacher portion of the column was described at Stop 3.

As at Munnsville, the Olney-Elmwood fourth-order sequence consists of four nearly complete fifth-order sequences (A, B, C and D). The slight difference in thickness (less at Perryville) and the generally more restricted facies at Perryville suggest that this locality is onshore of Munnsville. However, the similar stratigraphic structure of the two sections indicates very little topographic relief between the two localities.

36.1	2.8	From quarry entrance north (left) on Quarry Rd. to Route 5
39.3	3.2	West (left) on Rte. 5 to intersection with Rte. 173 in Chittenango
50.7	11.4	West on Rte. 173, through Manlius to intersection with Rte 91
51.2	0.5	South (left) on Rte. 91 to the County Quarry on left (Stop 4)

STOP 4. Onondaga County Quarry, Jamesville (Rickard Loc. 151)

At the Jamesville locality, the section (Fig. 10) begins in the Elmwood Mbr. on the road north of the quarry entrance. The upper Elmwood, Clark Reservation and Jamesville Mbrs. are exposed in the east wall of the quarry.

At Jamesville (Fig. 10), the Olney-Elmwood fourth-order sequence is less complete than at Perryville (Fig.9), consisting of portions of three fifth-order sequences (B, C and D). Sequence A was not deposited because this area remained positive until flooding during the deposition of sequence B. As yet, we have not determined which two sixth-order flooding events in sequence B are recorded at this locality. Similarly, fifth-order sequence D is less complete at Jamesville than at localities to the East. Whether this difference is the result of hiatus at the base of the sequence or erosion at its top has not been determined.

51.7	0.5	North on Rte. 91 to Rte. 173
55.6	3.9	West (left) on Rte. 173, under I 81 to Rte. 11
58.6	3.0	South (left) on Rte. 11 to intersection with I 81
61.5	2.9	North on I 81 to Manlius roadcut on right, beyond guardrail (Stop 5)

STOP 5. Interstate 81 Roadcut (Olney, Elmwood, Clark Reservation, Jamesville Mbrs.)

This roadcut south of Syracuse exposes the upper Thacher, Olney, Elmwood, Clark Reservation and lower Jamesville Mbrs. of the Manlius Fm. The Thacher Member is completely exposed in the roadcut of the southbound lanes of Interstate 81, a locality not visited on this trip.

At this locality (Fig. 11), the Olney-Elmwood fourth-order sequence is even less complete than at Jamesville, approximately 4 miles to the East. As at Jamesville (Fig. 10), the sequence cosists of three fifth-order sequences (B, C and D), but sequence B consists of just one sixth-order cycle (PAC). Beneath the third-order unconformity (Thacher-Olney contact), the Thacher fourth-order sequence contains more sixth-order cycles than at locaities to the East, indicating that erosion did not cut as deeply (vacuity is less). Still, this fourth-order sequence is far from complete, consisting of just two fifth-order sequences.