Punctuated Aggradational Cycles (PACS) in Middle Ordovician and Lower Devonian Sequences

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Hypothesis

Observations of numerous clastic and carbonate sequences as well as recent papers on asymmetric cycles (Ryer, 1977; Beukes, 1977; Talbot, 1974) have led us to the hypothesis that all geosynclinal and cratonic sedimentation occurs as upward-shallowing (aggradational) cycles following rapid non-depositional transgressions (Fig.1). The general hypothesis can be viewed as a series of increasingly interpretive statements:

1) Sedimentary sequences consist of upward-shallowing packages separated by sharply defined surfaces (punctuated aggradational cycles).

2) These sharp surfaces represent intervals of rapid transgression during which no net deposition occurs. All deposition is aggradational during relatively long stable periods following transgressive events.

3) Therefore large-scale transgression is not a continuous process but rather an episodic one. Large-scale transgressive sequences consist of numerous punctuated aggradational cycles (Fig.1): basin-wide transgression is accomplished through a series of deepenings and shoalings, not by a continual deepening.

4) Rapid transgressive episodes are caused by basin subsidence.

5) Rapid basin subsidence occurs in response to abrupt movements of the elastic lithosphere.

The primary purpose of these two field trips is to demonstrate that two chronologically distinct sedimentary sequences, representing a broad range of environments, consist entirely of punctuated aggradational cycles (PACS). These two generally transgressive carbonate sequences (Black River and Helderberg), traditionally described as successions of numerous formations and members, can be viewed in a more genetic and integrative sense as sequences of a single depositional motif: punctuated aggradational cycles. The spectrum of environments is sufficiently broad to suggest that this motif is pervasive and applicable to all paleoenvironmental situations.

A second purpose of the trips is to introduce some of the stratigraphic implications of the PAC Hypothesis. Application of the PAC idea raises questions such as:

1) What is the relationship between aggradational cycles and traditional stratigraphic units (formations and members)?

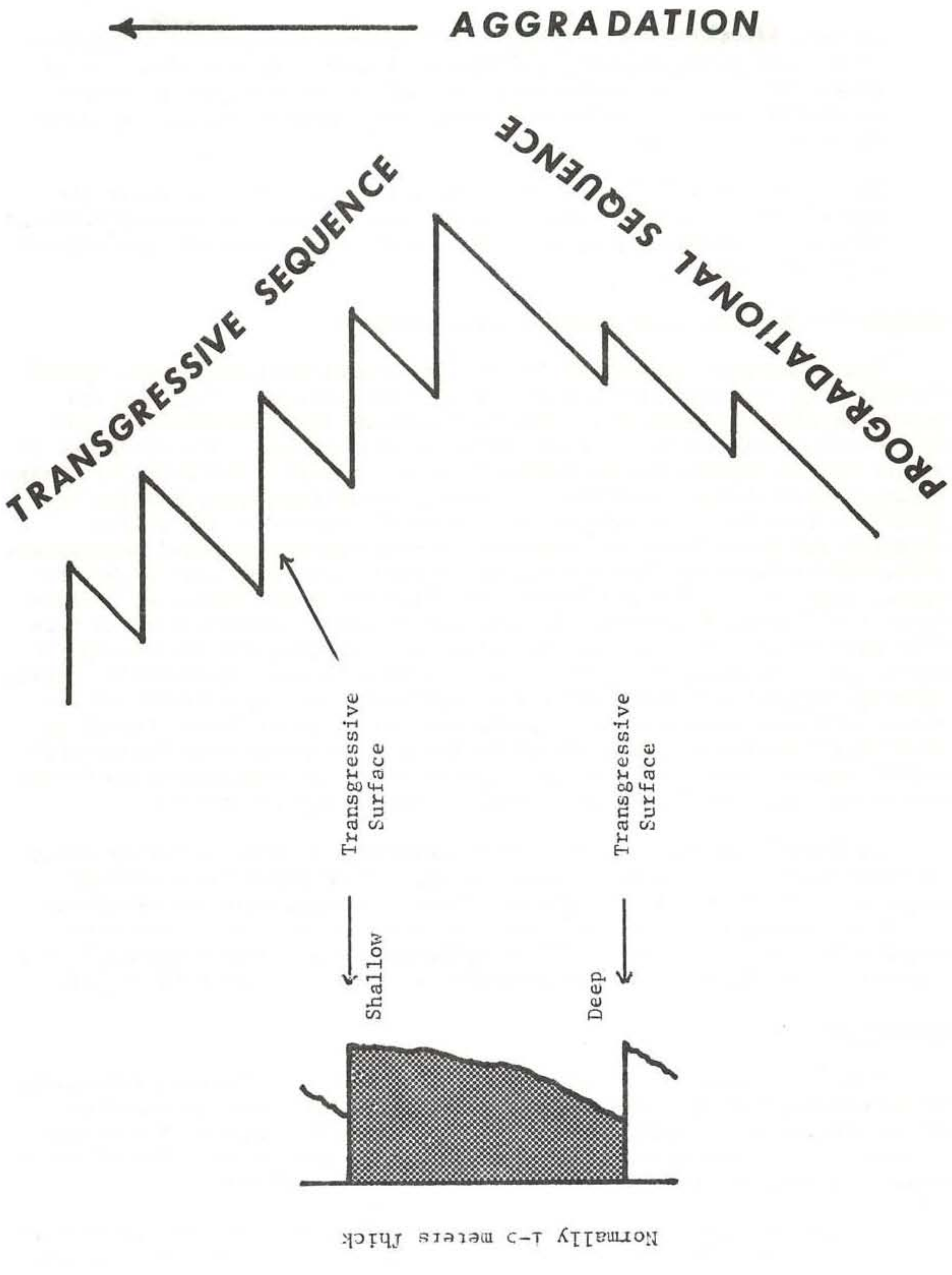

Figure 1. Components of typical PAC and relationship of cycles to transgressive and progradational sequences.

2) What are the paleogeographic implications of episodic transgression? Was paleogeography modified with each transgression? Is it still valid to view large-scale transgression as a gradual shoreward migration of a relatively fixed geographic pattern, i.e. does Walther's Law apply?

3) Can cycles and transgressive surfaces be traced throughout the basin? Are subsidence events basin-wide and essentially synchronous? If so, are transgressive surfaces the ultimate means of intrabasinal correlations?

Recognition of Punctuated Aggradational Cycles

The essential ingredients of PACS are gradational shallowing upward deposits and sharply defined bounding surfaces (Fig.1). Surfaces are generally slightly undulatory, may be erosional (e.g. ravinements) and are always evidenced by an abrupt environmental change. The thickness of cycles varies greatly but is generally 1 to 5 meters. Criteria for recognizing upward shallowing differ for each paleoenvironmental setting but generally fall in three categories: textural parameters reflecting strength and persistence of currents and wave motion; physical sedimentary structures related to flow regime; and biogenic features such as burrow types, algal structures and faunal diversity which are sensitive indicators of ecologic conditions. In conjunction these criteria yield a relative measure of depth, lateral environmental position and circulation in the basin. For example lagoonal cycles generally are calcarenitic, argillaceous, bioturbated and diversely fossiliferous at their bases and micritic non-argillaceous, less bioturbated and sparsely fossiliferous in their upper portions. This set of criteria suggests an open lagoon with normal salinity and good circulation which fills by aggradation to become restricted, thereby decreasing diversity and energy conditions.

On these trips we will attempt to demonstrate criteria for defining aggradational cycles in environments ranging from tidal flats through lagoons and barriers, to the shallow shelf. Ideally each paleoenvironmental situation should be defineable by a basic PAC and its variants. Major shifts of environment will be reflected in a distinct change in the characteristic PAC but all environments will have the basic PAC motif.

Mechanisms

Possible mechanisms to explain the empirically formulated hypothesis of punctuated aggradational cycles include: 1) tectonically produced basin subsidence; 2) eustatic rises of sea level, resulting from changes in sea floor spreading rates or glacial melting and 3) migration of environmental mosaics superimposed on gradual basin subsidence.

Changes in sea floor spreading rates operate at the wrong periodicity to produce cycles (they are too slow). Several environments such as the open shelf and lagoons do not contain a mechanism for causing lateral migration of environmental mosaics and producing sharp cycle bases. Eustatic sea level rises produced by melting of polar ice are difficult to apply to equable climatic geologic periods such as the Cretaceous and cannot produce differential subsidence across a depositional basin. Tectonic mechanisms would appear to work well at continental margins (geocynclinal areas) but are more difficult to apply to cycles in the stable craton. However a tectonic mechanism of some kind seems the best possibility for producing differential subsidence and thus developing a sedimentary basin containing thick stratigraphic sequences.

BLACK RIVER AND TRENTON GROUPS

Introduction

Since the early 19th century geologists have been studying the Medial Ordovician Black River and Trenton groups of the Mohawk Valley (Figs.2,3). Thus, these rocks have become well-known as part of the disputed Medial Ordovician standard reference section of North America - the type Ordovician being in Europe. Although many of the rock units are believed to be time-stratigraphic regionally, some are locally diachronous and locally change facies into each other. Environmentally, the Black River and lower Trenton carbonates change facies eastward into the deeper water Utica black shales. The cyclic aspect of their sedimentation, namely the presence of punctuated aggradational cycles, was not recognized until recently.

Black River Group

The Black River Group in New York is composed of four formations (Cameron and Mangion, 1977): Pamelia, Lowville, Watertown, and Selby, in ascending order. The Pamelia Formation, which disappears south of Boonville, Lewis County, is a supratidal dolostone that overlies Precambrian and Cambrian rocks north of the field trip area. In the field trip area the lower Lowville contains facies similar to those of the Pamelia farther north. The Lowville, once known as the "Birdseye Limestone", comprises most of the relatively thin (26-37 feet) Black River Group in the central Mohawk Valley. It has been divided into two informal members (Cameron and Kamal, 1977): a lower buff-colored, sandy and dolomitic limestone and an upper dove-gray, pure limestone. The overlying Watertown Limestone is the youngest unit of the group in the area and ranges from zero to seven feet thick, increasing in thickness northward. The Selby Limestone is absent this far south.

Trenton Group

In northwestern New York lower Trentonian formations are believed to be essentially time-stratigraphic in nature while they have been shown to be time-transgressive in the field trip area where the paleoshoreline is eastward along the north-south trending Adirondack Arch near Canajoharie. The northern basal Napanee Limestone pinches out southward before reaching the field trip area where the lower Trenton formation is the Kings Falls Limestone. The age of the base of the Kings Falls becomes progressively younger to the southeast because its basal Rocklandian-aged beds disappear indicating that the lower Kings Falls in central New York is Kirkfieldian in age. Conglomeratic beds also sporadically occur at its base, such as

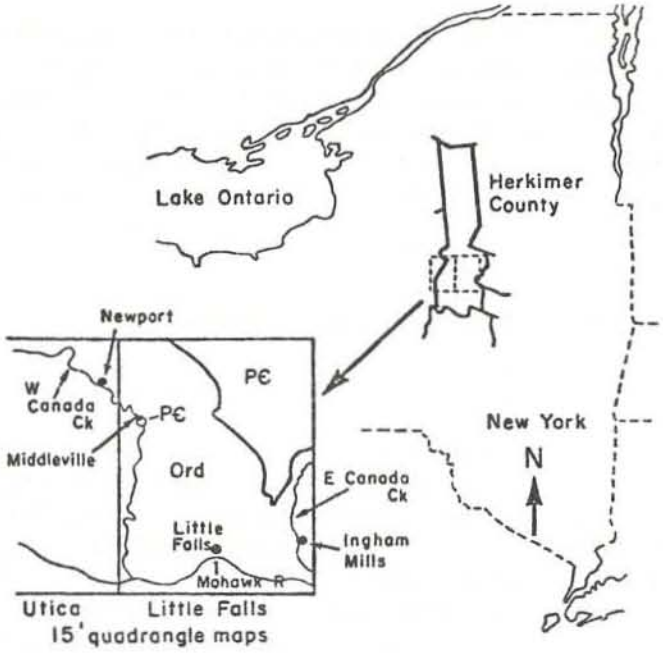

Figure 2. Partial map of New York State with index maps showing location of quadrangles and field trip stops.

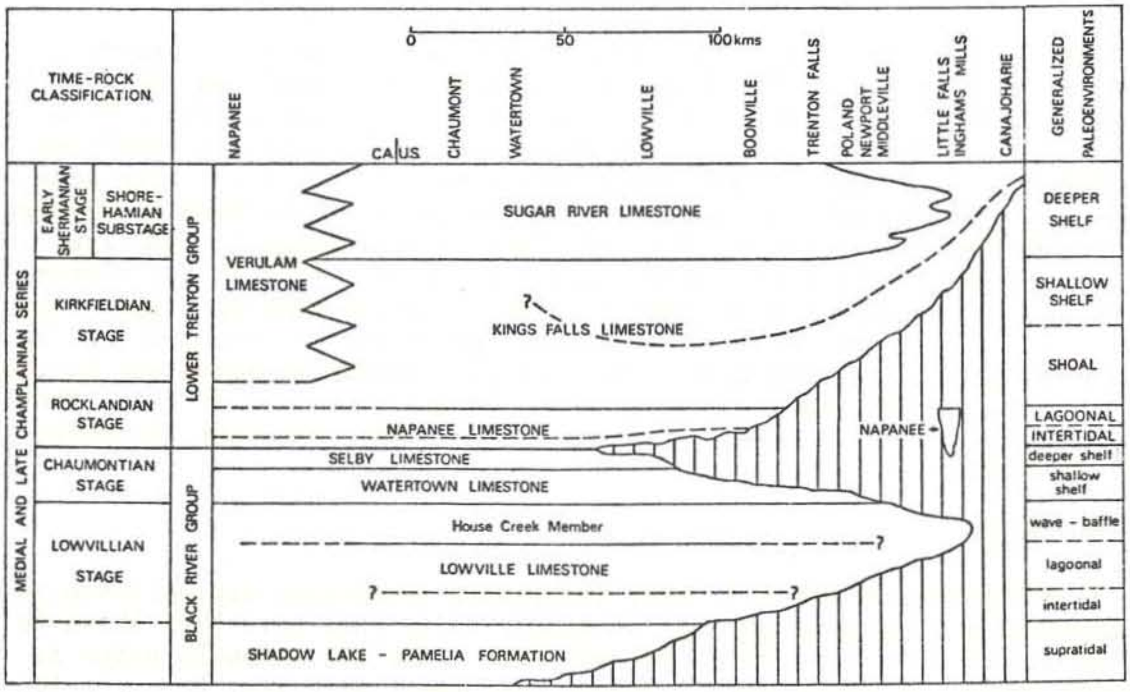

Figure 3. Generalized correlation chart of Black River and lower Trenton groups from central Mohawk River Valley in New York to southeastern Ontario. Width of each unit approximates relative thickness which is estimate of time. Generalized paleoenvironmental framework in shown in right-hand column. Note ambiguous and problematic portrayal of Black River Group in southeast, i.e., central Mohawk River Valley (from Cameron and Mangion, 1977, p. 489).

at Inghams Mills (Stop #2). In addition, the Kings Falls decreases in thickness eastward, becomes Shorehamian in age, and disappears east of Canajoharie.

STOP DESCRIPTIONS

Stop #1, Newport Quarry (Figs.4,5)

Three formations are exposed in the large northwest Newport Quarry: the Late Cambrian Little Falls Dolostone and the Medial Ordovician (Black River Group) Lowville and Watertown Limestones (Cameron & Kamal, 1977). The top of the sandy upper Little Falls presumably forms the quarry floor. The Lowville can be divided into a lower sandy dolomitic member (13½') and an upper purer limestone member (21½'). A metabentonite and a 2-foot thick argillaceous marker horizon, both useful for local correlation (Cameron & Kamal, 1977), are at about 9 and 30 feet, respectively. The Watertown Limestone at the top of the quarry is massively bedded, burrow-reworked, black chert-bearing and fossiliferous calcisiltite and calcarenite. The fauna is more diverse and fossils are more commonthan in the Lowville below, but they are hard to collect. Large tabulate corals, brachiopods, mollusks, and bryozoa are evident.

Ten cycles that average 4 feet in thickness have been identified: three in the lower Lowville Limestone (Cycles 1-3), six in the upper Lowville (Cycles 4-9), and at least one in the Watertown (Cycle 10). Another cycle in the Watertown is postulated by correlation with nearby exposures. The three lower dolomite Lowville cycles are interpreted as representing restricted tidal conditions. At their bases they are argillaceous and contain horizontal burrows. Horizontal algal stromatolitic laminations, fenestral fabrics, and vertical burrows occur mostly in the middle. The quartzose tops of cycles 2 and 3 may be lag deposits from tidal channels. They both contain quartz arenites at the base of the sandy beds and the upper one is quite fossiliferous. The upper Lowville contains six less-restricted tidal cycles. Their bases are typically abrupt, burrow-reworked, and fossiliferous. The lower and middle parts are typically argillaceous. Towards their tops they become more micritic. Vertical burrows, intraclasts, fenestral fabrics, and stromatolitic laminations are common.

The Watertown Limestone is subtidal, possibly shallow shelf or lagoonal in nature, and less restricted than the Lowville, as evidenced by the thorough burrow-reworking and by the diverse invertebrate and calcareous algal fossil assemblages here and elsewhere. Most of the shelly fossils are concentrated at the bases of small subcycles 6 to 12 inches thick that mimic larger cycles.

Stop #2, Inghams Mills (Fig.6)

Three limestone formations of Medial Ordovician age are excellently exposed along with the top of the Late Cambrian Little Falls Dolostone below the dam on East Canada Creek. The Lowville here comprises the whole

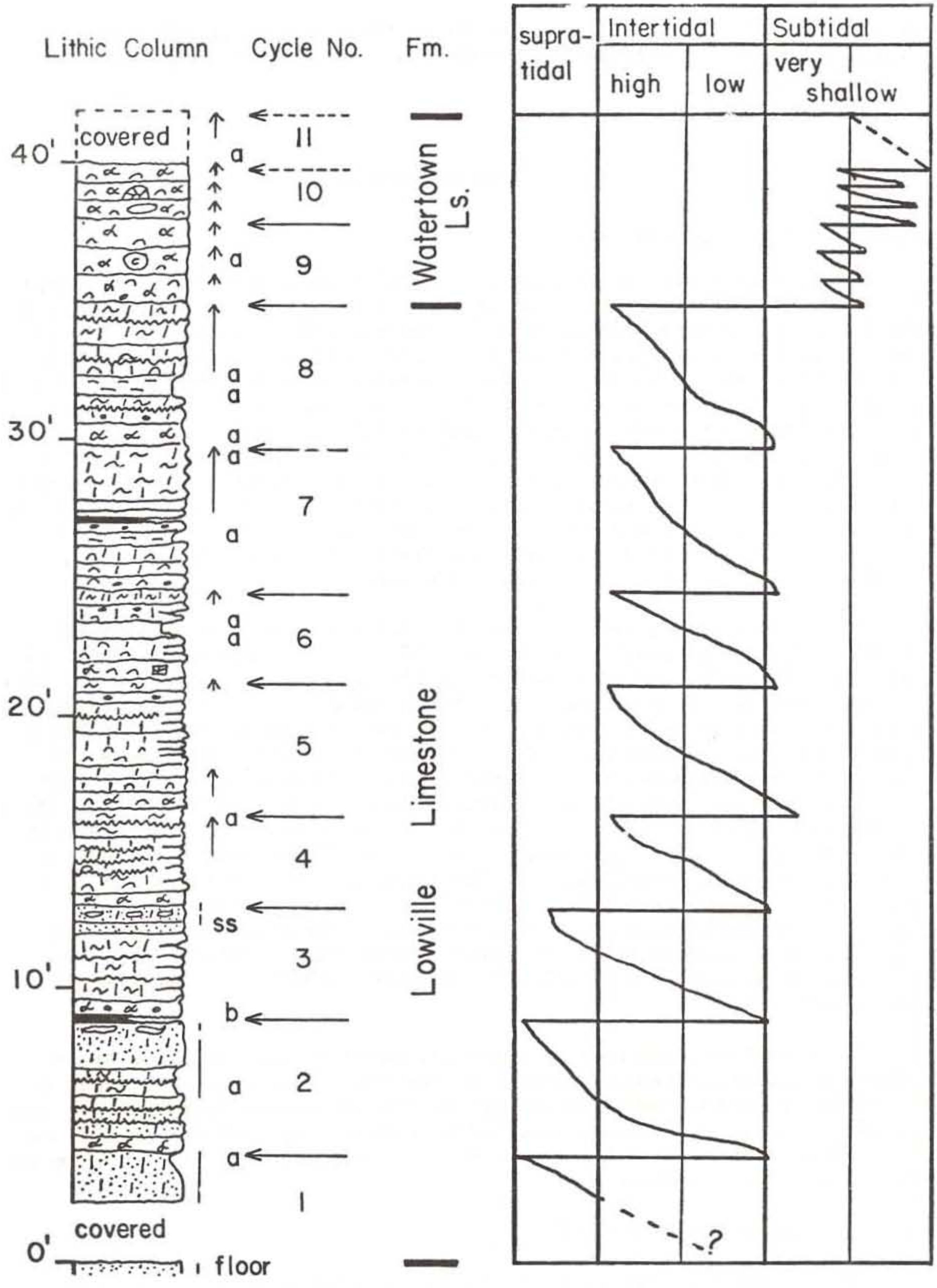

Figure 4. Newport Quarry.

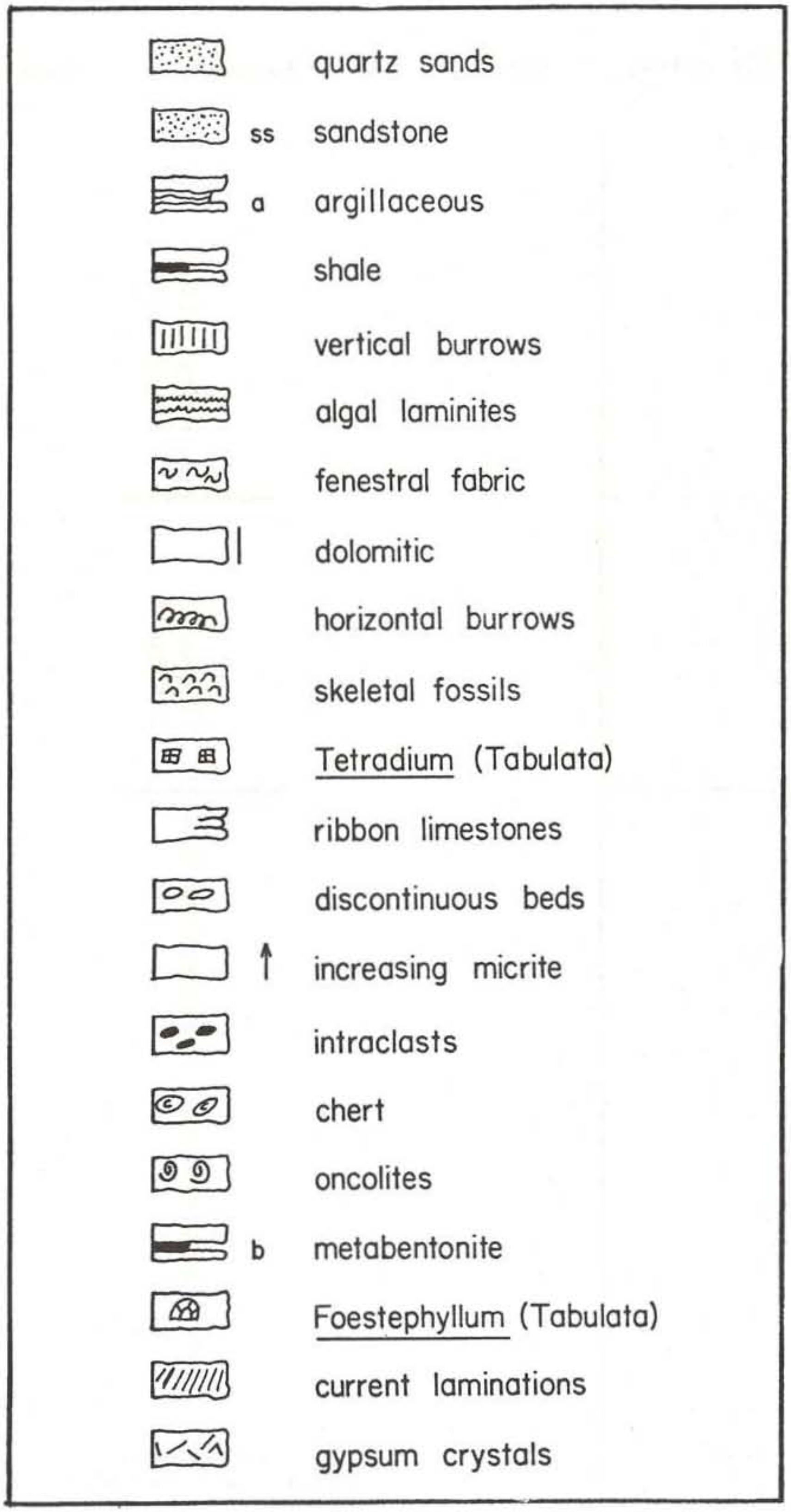

Figure 5. Key to lithologic symbols

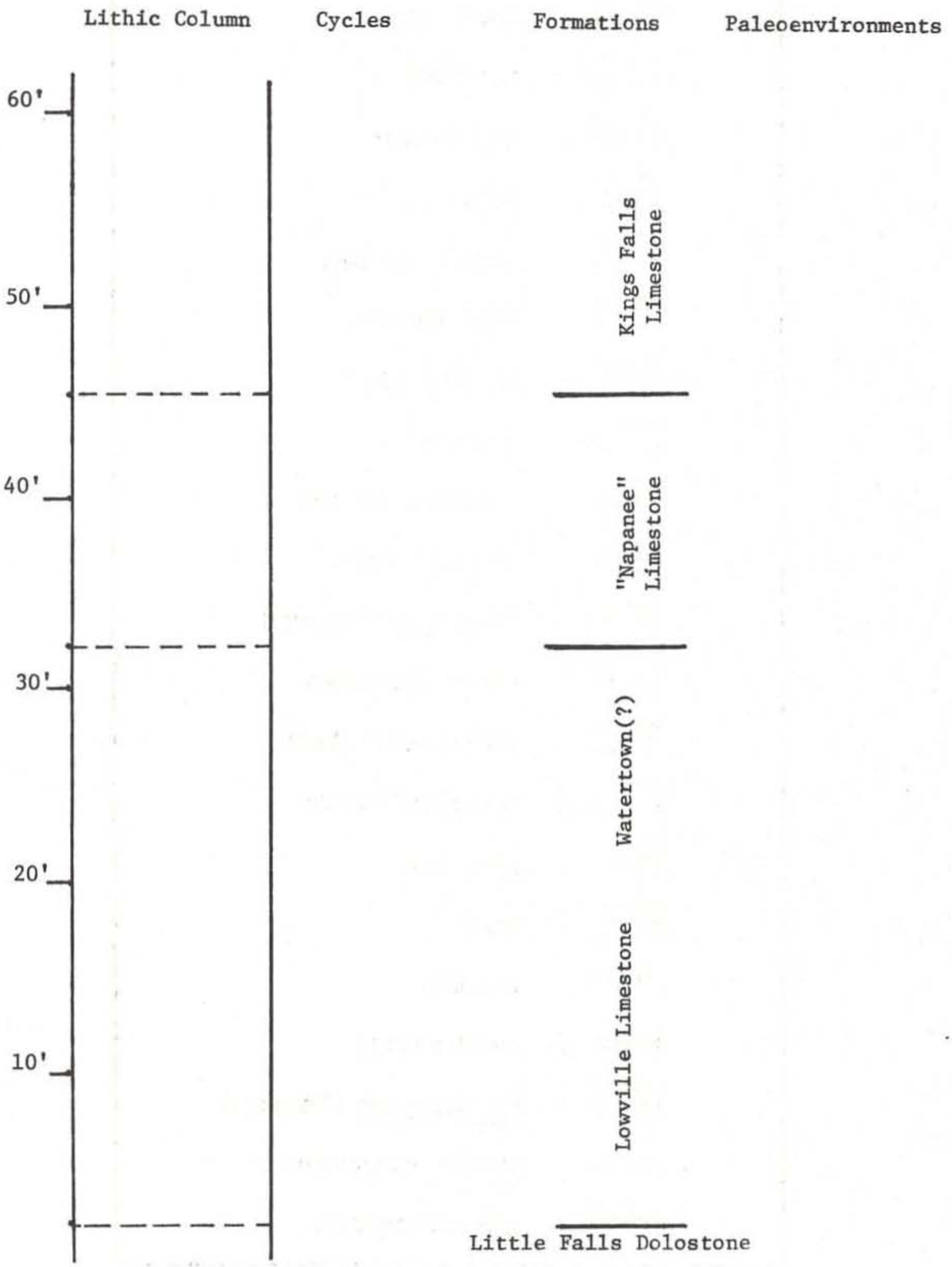

Figure 6. Inghams Mills Section.

of the Black River Group although a Watertown-like 4-foot thick horizon occurs near the top. The Trenton Group above is represented by an unusual facies of the Napanee Limestone and the Kings Falls Limestone, including what was once attributed to the Sugar River Limestone (Kay, 1968; Cameron, 1969). At this well-exposed outcrop, the field trip participants will be encouraged to use the many paleoenvironmental criteria observable here in an attempt to recognize the punctuated aggradational cycles themselves. After an outcrop discussion, we will leave to look at Devonian cycles.

Little Falls Dolostone.- Two feet of the Late Cambrian Little Falls Dolostone are exposed at this locality. The top of this unit has two feet of relief and is relatively thick-bedded, light to medium brown weather ing, quartz arenitic, pyrite-bearing dolostone with thin inter-bedded shale layers.

Lowville Limestone. - Approximately 30 feet of Lowville are exposed, beginning with several feet of fossiliferous gray shaly limestone at the base. Middle Lowville contains horizontally laminated (algal?) calcilutites with abundant vertical burrows, a few ostracodes, and mudcracks confirming an intertidal origin. Tide channels (Cameron, 1969; Cameron and Kamal, 1977) are well-exposed on the southern and western sides of the lower outcrop. The upper half of the formation contains subtidal fossiliferous burrow-reworked calcisiltites overlain by intertidal vertically-burrowed lithologies. The subtidal lithologies resemble the Watertown Limestone to the Northwest.

"Napanee Limestone". - The lowest 13 feet of Trenton(?) limestone consists of a lower 7.5 foot unit of chocolate brown argillaceous calcisiltites and calcareous shales overlain by a 5.5 foot unit of gray less argillaceous calcisiltites interbedded with thinner shales.

Kings Falls Limestone. - Twenty-three feet of brachiopod-rich shelly, lower Kings Falls Limestone overlies the "Napanee". The upper Kings Falls (14 feet) consists of encrinitic bryozoan-rich calcarenites.

Using these general lithologies and thicknesses for stratigraphic location, field trip participants will attempt to recognize punctuated aggradational cycles from criteria demonstrated at Newport Quarry. A blank columnar section (Fig.6) is provided for recording PACS with lithologic documentation. Formational boundaries are indicated along with vertical measurements for purposes of location. After outcrop analysis by small groups of participants there will be a full-group discussion of the outcrop.

LOWER DEVONIAN HELDERBERG GROUP

Helderberg PACS:

The Lower Devonian Helderberg Group (Fig.7) illustrates punctuated aggradational cycles developed in a diversity of environmental settings. Each formation and member of the Helderberg Group is divisible into

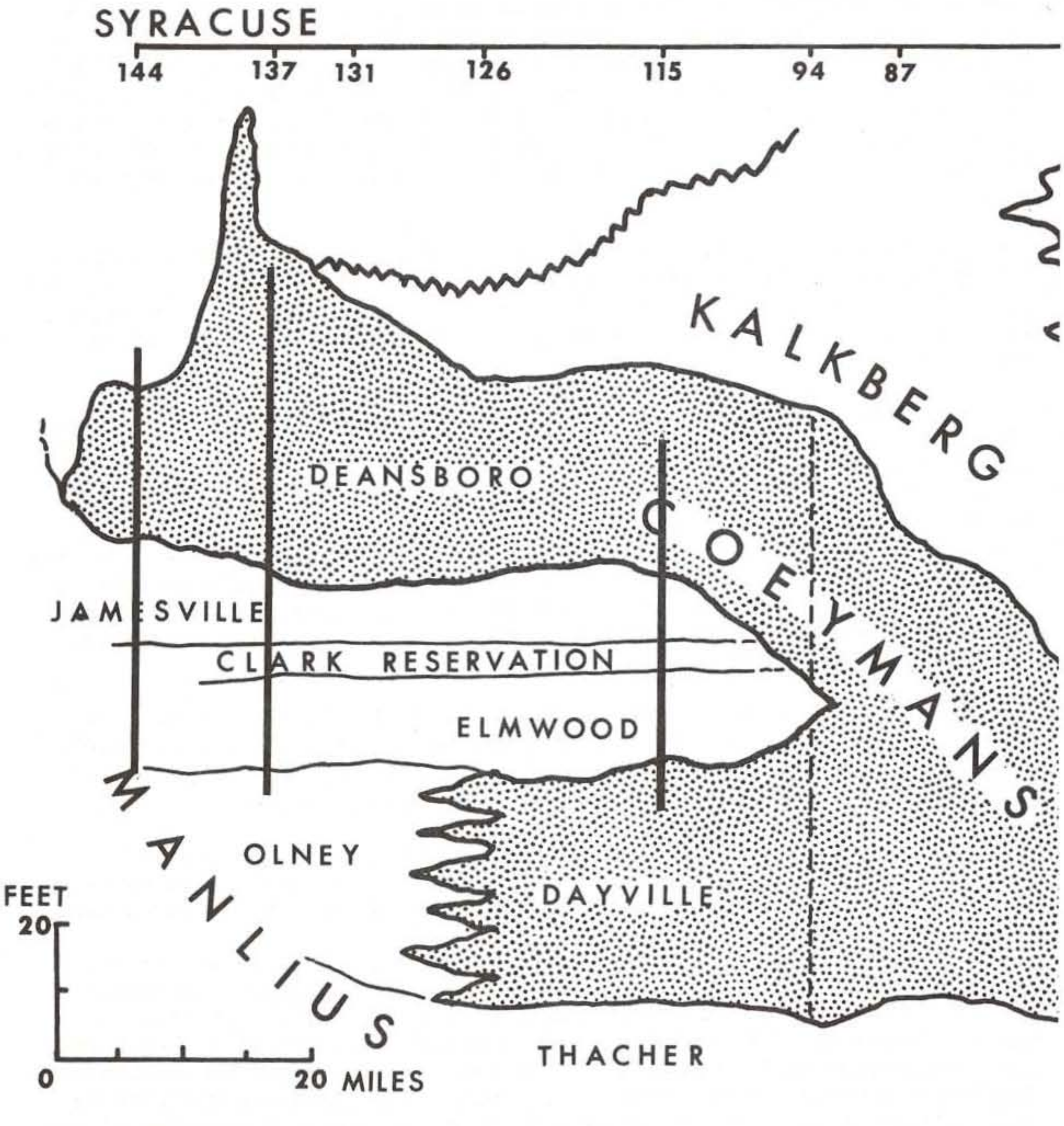

Figure 7. Helderberg stratigraphy in central New York, locality numbers from Rickard, 1962; Jordanville-115, Munnsville-137, and Perryville-144. Interval to be studied is shown by heavy vertical lines.

shallowing-upward cycles, separated by sharp (non-depositional or erosional) surfaces of transgression. Three stratigraphic sections will be studied on this trip: the Jordanville Quarry; the Munnsville Quarry; and the Perryville (Warlock) Quarry. At each of these large active quarries approximately the same stratigraphic interval (Fig.7) is represented and the section is continuously exposed and accessible. Environmental analysis based on PACS requires well exposed, continuous stratigraphic sections.

Jordanville Quarry: Eight cycles are exposed in the quarry, two in the upper Dayville and Elmwood, four in the Jamesville and two in the Deansboro (Fig.8). The Clark Reservation is probably not present (it appears to terminate further west). The two lower cycles (I and II) are thick and grade from coarse more argillaceous and fossiliferous beds up into fine very well sorted dune cross-stratified calcarenite. Note that these beds, which include the Elmwood Member of the Manlius, are not dolomitic algal laminites as they are further west at Munnsville and Perryville. The next three cycles in the Jamesville (III to V) are stromatoporoid-algal laminite cycles; laminites are well-developed only in Cycle III. These laminites, which are well developed in Cycle III in the north wall of the quarry, are not present less than a quarter of a mile away in the south wall. Cycle VI (Fig.8), a three foot cross-stratified calcarenite, has erosional upper and lower surfaces. This can be interpreted as a barrier island deposit bounded on the bottom by a migrating tidal inlet erosion surface and on the top by a ravinement. Cycles VII and VIII (the Deansboro) are shallow open shelf cycles consisting of bioturbated crinoid-brachiopod calcarenite which grades upward into current stratified deposits.

Munnsville Quarry: Nine Helderberg cycles (PACS) are exposed in the Munnsville Quarry (Fig.9), four in the Olney-Elmwood, one equivalent to the Clark Reservation, four in the Jamesville and two (plus a partial cycle) in the Deansboro. The first four PACS contain restricted subtidal micrites grading upward into supratidal laminites. The four cycles in the Jamesville are defined by gradation from argillaceous limestones up into purer bioturbated limestones deposited in restricted subtidal conditions. The two complete Deansboro cycles, like those at Jordanville, grade from bioturbated shelf deposits.

Perryville Quarry: The lower Helderberg Group (Thacher - Jamesville) is well exposed at the north end of the quarry and the upper part (Jamesville - Deansboro) at the south end. Figure 10 is an outline of the stratigraphy of the lower Helderberg (north quarry face) with cycle analysis present up through the Clark Reservation. The section in the south quarry overlaps the top of the north section and within the complete Jamesville and Deansboro at least five cycles are present (Fig.11). Cycles IX and XI, the first and third Jamesville cycles, begin in bioturbated argillaceous calcarenite which grades up into cleaner more current-stratified calcarenites. Cycle X, is a stromatoporoid-laminite cycle like those seen early at Jordanville and Munnsville. Cycle XII, a thin current-stratified deposit bounded by two erosion surfaces, is genetically distinct. This cycle may represent the remains of a barrier, the lower erosion surface having been cut by a migrating tidal inlet, the upper by a ravinement.

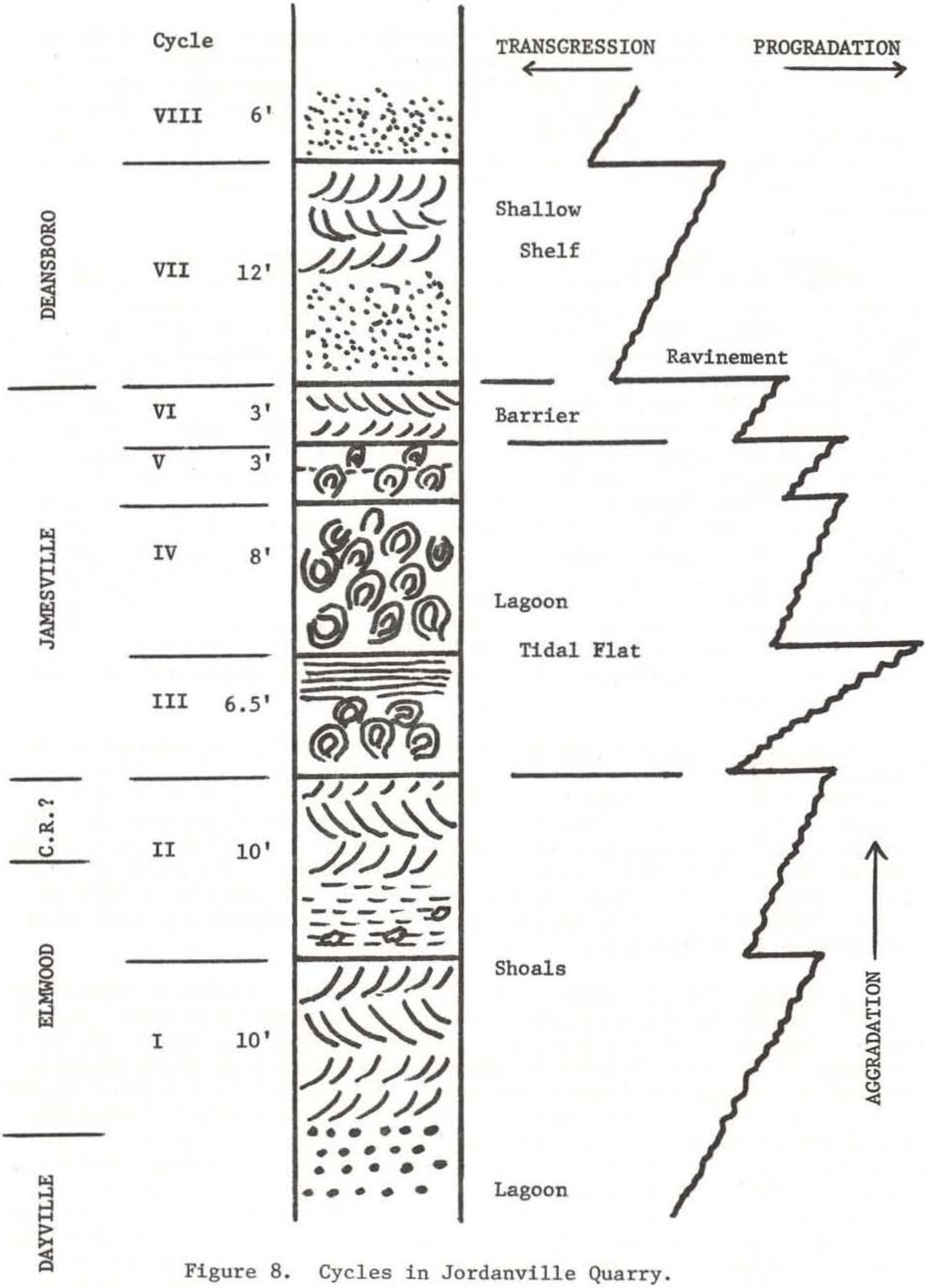

Figure 8. Cycles in Jordanville Quarry.

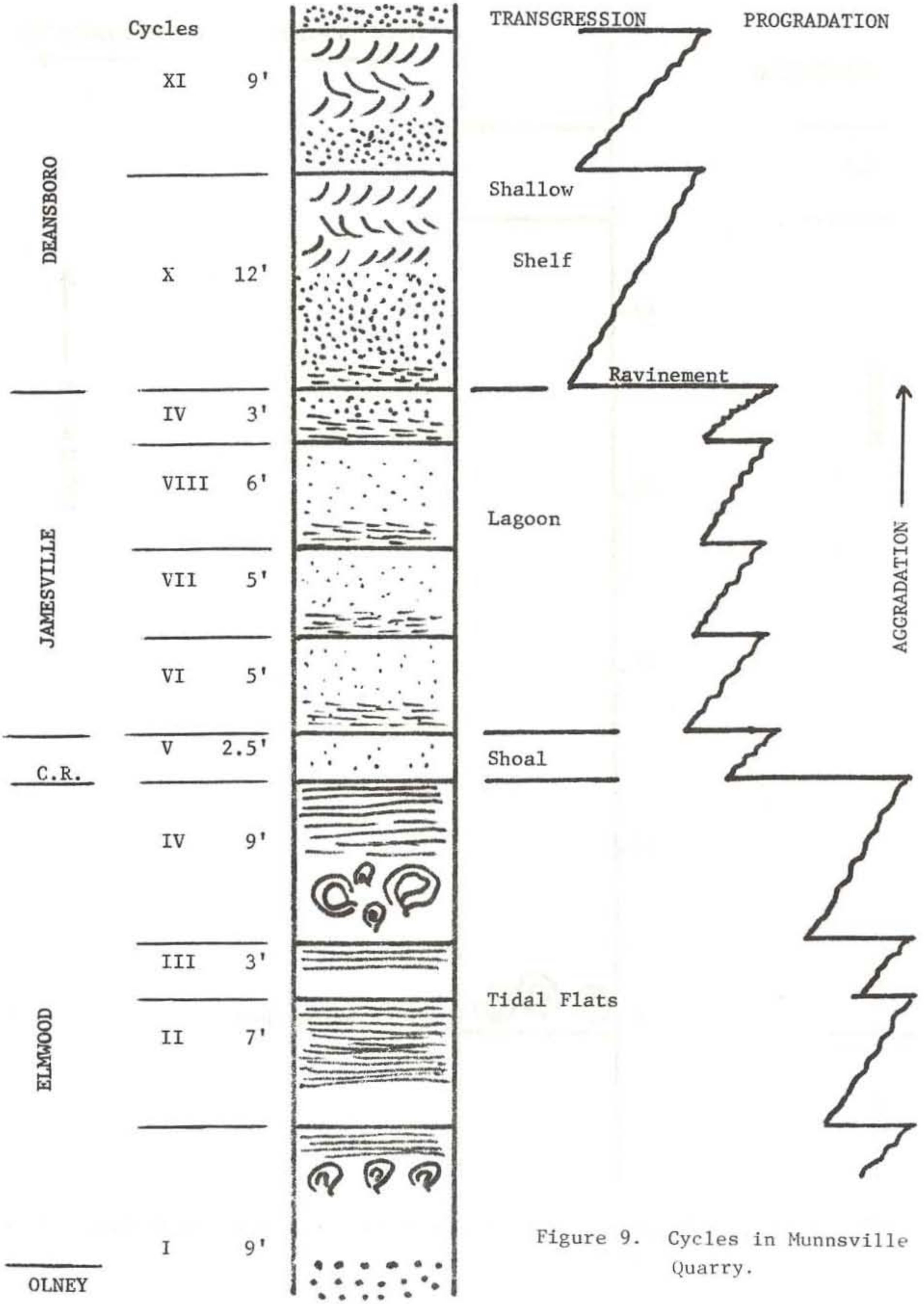

Figure 9. Cycles in Munnsville Quarry.

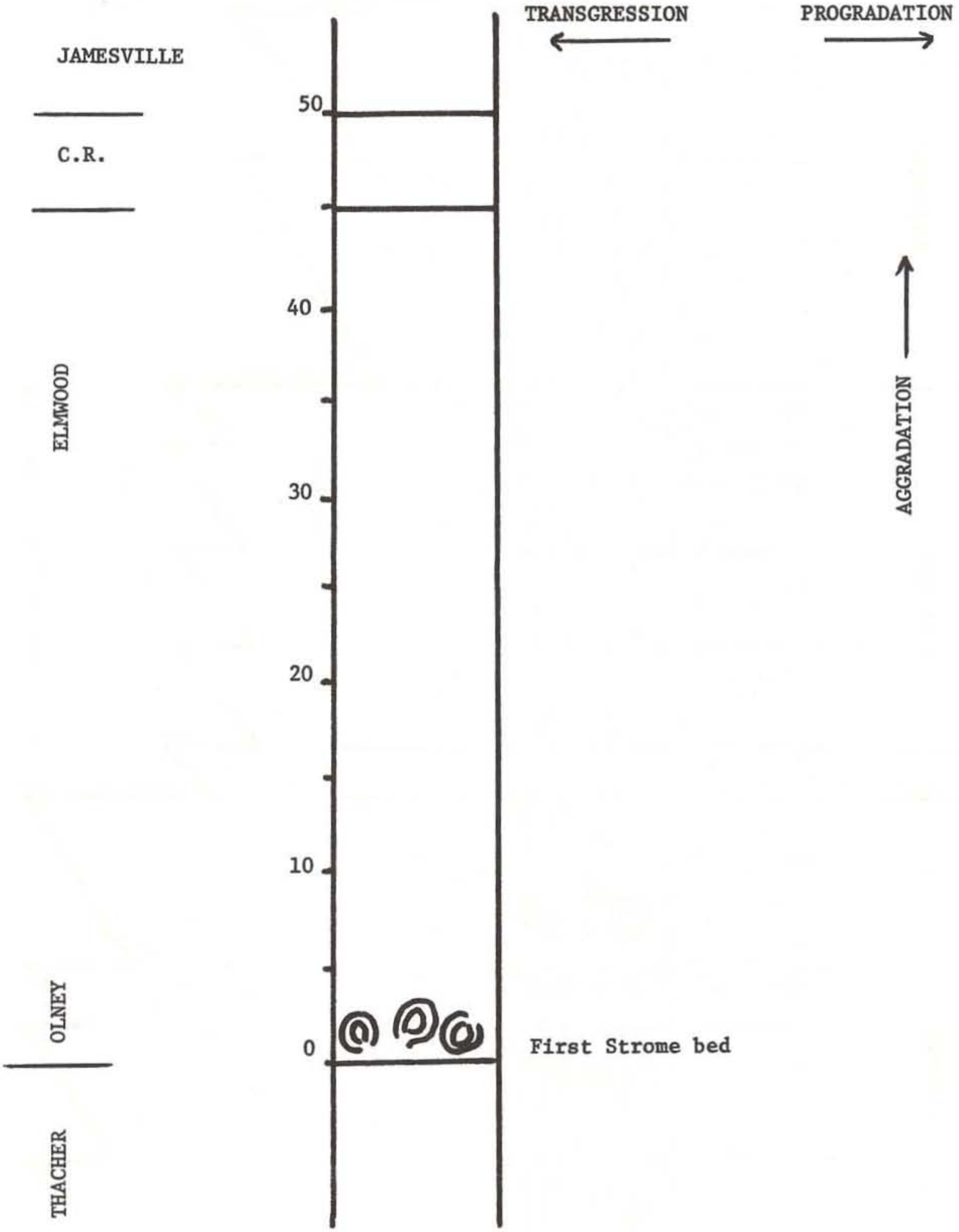

Figure 10. Cycle worksheet for north quarry wall lower Helderberg section at Perryville.

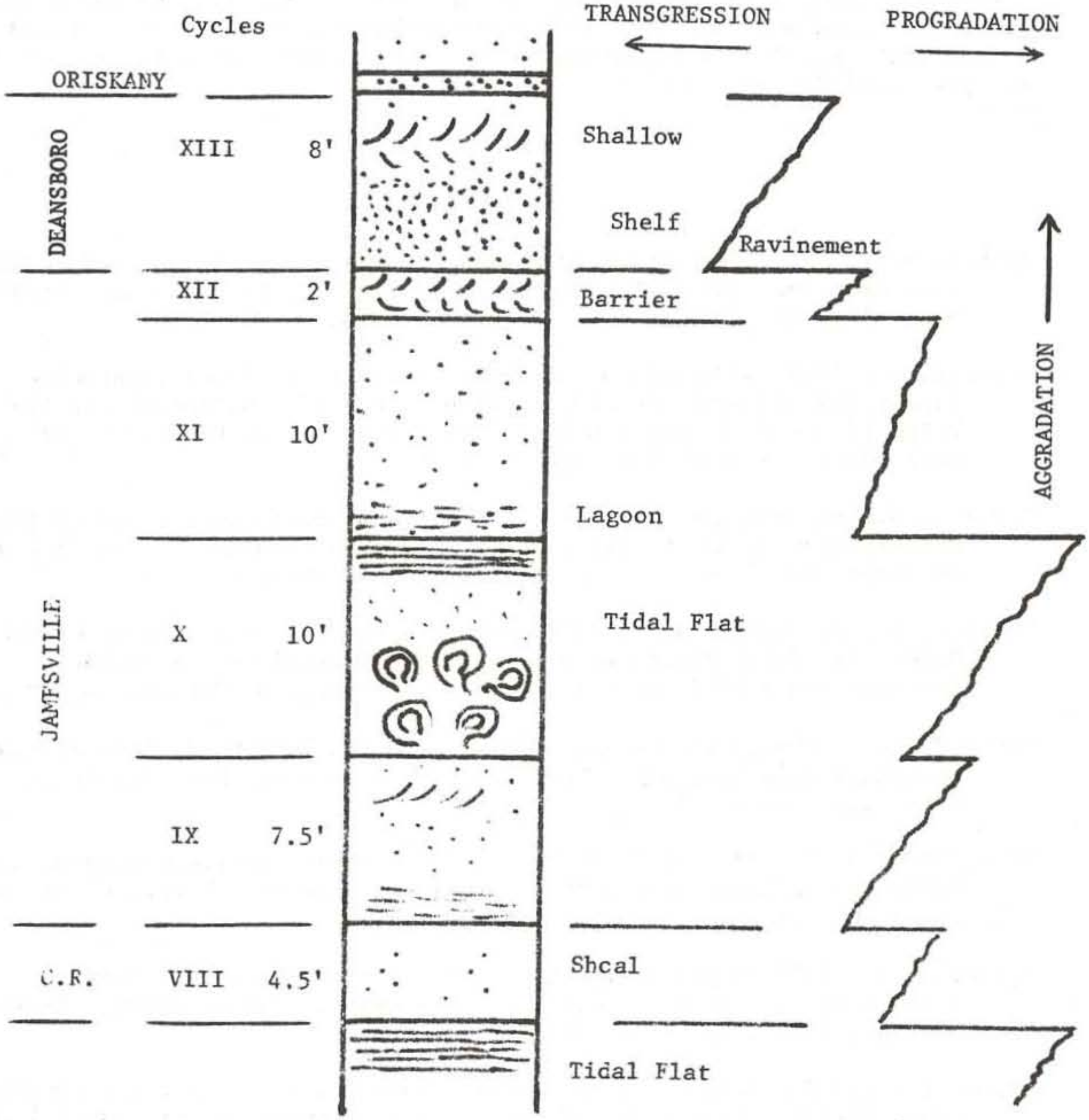

Figure 11. Cycles in upper Helderberg at Perryville south quarry wall.

The same situation is seen at the same stratigraphic position in the Jordanville Quarry. Cycle XIII, like the other Deansboro cycles seen at Jordanville and Munnsville, is represented by a bioturbated fossiliferous open shelf calcarenite grading up into a current-stratified calcarenite. Above the Deansboro, the Oriskany is represented by a quartz-rich trace (< one foot thick) of a migrating barrier island which in turn is overlain by open shelf Onondaga calcarenites.

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MILEAGE LOG (SATURDAY)

InMi	CumMi*	
0.00	0.00	New York Thruway exit 30; start mileage log at intersection with Route 28. Turn right (northeast).
0.25	0.25	Traffic light. Turn left continuing north on Route 28.
0.2	0.45	Traffic light at intersection of Routes 28 and 5. Turn right (east) onto combined Routes 5 and 28.
0.7	1.15	Traffic light. Turn left (north) onto Route 28 and proceed to Middleville.
8.15	9.30	Bear right, continuing on Route 28 towards the bridge.
0.2	9.50	Traffic light after crossing bridge over West Canada Creek. Turn left and continue north on Route 28 towards Newport.
4.4	13.90	Flashing yellow traffic light in Newport. Turn left onto Bridge Street (=Old State Road).
0.15	14.05	Crossing bridge over West Canada Creek.
0.1	14.15	"T"-intersection with West Street (=Newport Road). Turn right (north).
0.75	14.90	Turn right into gravel road leading to a large, old quarry. Park in front of gate, but do not block the entrance for trucks.
		<u>Stop #1</u>: Northwest Newport Quarry (locality NPQ): Walk about 300-400 feet along the gravel road and then descend carefully the southeast section of the quarry where the lower and middle Lowville Limestone is well-exposed. Then walk west around the treed promontory to the southwestern part of the quarry where the middle upper Lowville can be examined along with fallen blocks of the Watertown Limestone. Stay away from the southern wall which is about to collapse! Ascend the grassy slope here or walk back around to the center of the treed promontory and walk up the overgrown old "roadway" to examine the Watertown Limestone at the top of the quarry. The contact with the overlying lower Trenton Kings Falls Limestone is exposed in a quarry southwest of Newport (Kay, 1953), but not here.
0.0	14.90	Turn around in quarry driveway and head back to Newport.

*InMi = Incremental Mileage; CumMi = Cumulative Mileage.

0.75	15.65	Turn left (west) onto Bridge Street.
0.2	15.85	Flashing red traffic light at "T"-intersection with Route 28 (Main Street of Newport). Turn right (south) onto Route 28 South.
4.4	20.25	Traffic light in Middleville. Proceed straight ahead onto Route 169 south.
6.3	26.55	Bear left at fork in road, taking secondary road east (Route 169 bears right). You are on Rockwell Road.
0.75	27.30	Intersection with Cole Road. Continue straight. Rockwell Road changes its name to Top Notch Road here.
1.5	28.80	Intersection with dirt road. Bear left, continuing on paved road.
0.7	30.20	Intersection with Burrell Road. Turn left (north).
0.3	30.50	Intersection with Bronner Road. Turn right (east).
1.4	31.90	Intersection. Bear right, continuing on Bronner Road.
0.2	32.10	Bear left where Bronner Road turns left. David Road is to the right.
0.6	32.70	Intersection with Murphy Road. Continue straight on Bronner Road.
0.65	33.35	Turn right (south) onto Route 167.
0.4	33.75	"Y"-intersection with secondary road. Bear left onto East Creek Road.
2.15	35.90	Intersection with Inghams Mills Road. Turn left.
0.75	36.65	After coming down hill, continue straight onto dead end dirt road. Poor exposures of lower Trenton Group (Napanee Limestone) on left. (Do <u>not</u> turn right onto the large bridge over East Canada Creek. However. if the power company (Niagara-Mohawk) does not permit your trespassing, park and walk across the large bridge. Descend the left (upstream) side to the large limestone exposures at the inside of the meander to see all but the base and top of the Lowville Limestone. The 4 foot thick, Watertown-like, burrow-reworked, massively bedded subtidal facies caps the exposure).
0.05	36.70	Turn right and cross small wooden bridge.
0.04	36.74	After crossing bridge, take right fork in dirt road.

0.02	36.76	In front of building, turn left.
0.02	36.78	Turn left, back onto dirt road.
0.05	36.83	Park on grass along right side of dirt road.
		Stop #2: Walk to right, through the grass, and proceed to the right of the wire fence, walking beneath the power lines. At the stone wall along the edge of the field, bear left and walk along the wire fence. CAUTION: Poison ivy often grows in abundance along this path. Opposits the brick building, turn right and proceed very carefully over to the boulders and across the creek toward the base of the outcrop. The boulders you will have to walk over to get to this exposure are sometimes unstable and tend to move when stepped or climbed upon. Be careful! Traverse at your own risk.
0.0	36.83	Return to cars and drive straight ahead on the dirt road.
0.02	36.85	Turn left onto dirt road leadint from the power plant.
0.05	36.90	Bear right, crossing small wooden bridge. Then bear left.
0.05	36.95	Intersection with Inghams Mills Road. Proceed straight, uphill.
0.8	37.75	Intersection with East Creek Road. Proceed straight ahead.
0.75	38.50	Intersection before small bridge. Bear right onto Dockey Road.
0.4	38.90	Intersection with Bidleman Road. Proceed straight ahead.
0.15	39.05	Proceed straight ahead, joining Route 167 (south) and passing Exxon Station on your left.
2.65	41.70	Blinking traffic light. Stop. Turn right and take Route 167 to Little Falls.

Directions to Jordanville Quarry: (Stop #3):

Follow Route 167 through Little Falls and south to Jordanville, crossing Route 168 at Paines Corner after about 6 miles south of Little Falls, and reaching Jordanville after about 11 miles south of Little Falls. In Jordanville, take the secondary road north about ½ mile north to the quarry.

Return to Syracuse:

Return to Route 167, turn right and continue straight onto Jordanville Road (west) where Route 167 bears sharply left (south). After about 2 miles, turn right (north) onto Route 28 and proceed about another 6 miles through Mohawk to the New York State Thruway in Herkimer. Take the Thruway back to Syracuse.

Mileage Log (Sunday)

InMi	CumMi	
0	0	New York Thruway exit 36, Syracuse; go east on Thruway to exit 34.
21	21	Exit 34, go south on Route 13 through Canastota to route 5.
2	23	Turn east on Route 5, go to Route 46.
6	29	South on Route 46 to Munnsville, the quarry is a mile south of the town on the east side of the valley.
9	38	Munnsville Quarry Return north on Route 46 to Route 5.
9	47	Turn west on Route 5 and go to intersection with Quarry Road.
9	56	Turn south on Quarry Road and drive to entrance of Warlock Quarry.
2.5	58.5	Paved Road into quarry on west side of Quarry Road. Return north on Quarry Road to the intersection with Route 5.
2,5	61	Turn west on Route 5 and return to Syracuse.
16	77	Syracuse University.