Gypidula-bearing calcarenite of the Coeymans Formation (figure 20).

Figure 20:
Transition from strophomenid-bearing calcarenite to coarse, crinoidal calcarenite at the Manlius-Coeymans boundary, John Boyd Thacher State Park.

PAC CORRELATIONS

A fundamental tenet of the PAC hypothesis is that PAC boundaries are correlative. They are produced by punctuation events, abrupt base-level rises of allogenic origin. As products of punctuation events, upper Thacher PACs can be correlated by the combined use of the following methods: 1) tracing of PACs with distinctive facies between closely spaced sections; 2) correlating major facies changes produced by large punctuation events; and 3) matching vertical patterns in the magnitude of punctuation events between sections.

Two PACs in the Thacher Member of the Manlius Formation contain distinctive algal laminite horizons that, because of their lateral persistence, provide a means of correlating sections (figure 21). The stratigraphically lower laminite horizon occurs at the top of PAC 5 at localities between Thacher Park and Alsen Quarry, a distance in excess of 40 miles. The stratigraphically higher algal laminite horizon occurs at the top of PAC 8. This marker bed has been traced from the Hudson Valley into central New York. The PAC 8-9 boundary, placed at the top of this algal laminite horizon, serves as the major chronologic and environmental datum for the upper Thacher sequence (figure 7). It can be found at all localities between Cherry Valley and East Kingston, a distance of approximately 90 miles along the outcrop belt (figures 22-27).

Correlation of sections by the PAC 5 and PAC 8 algal

Figure 21:
The two distinctive algal laminite horizons occurring in the Manlius at South Catskill.

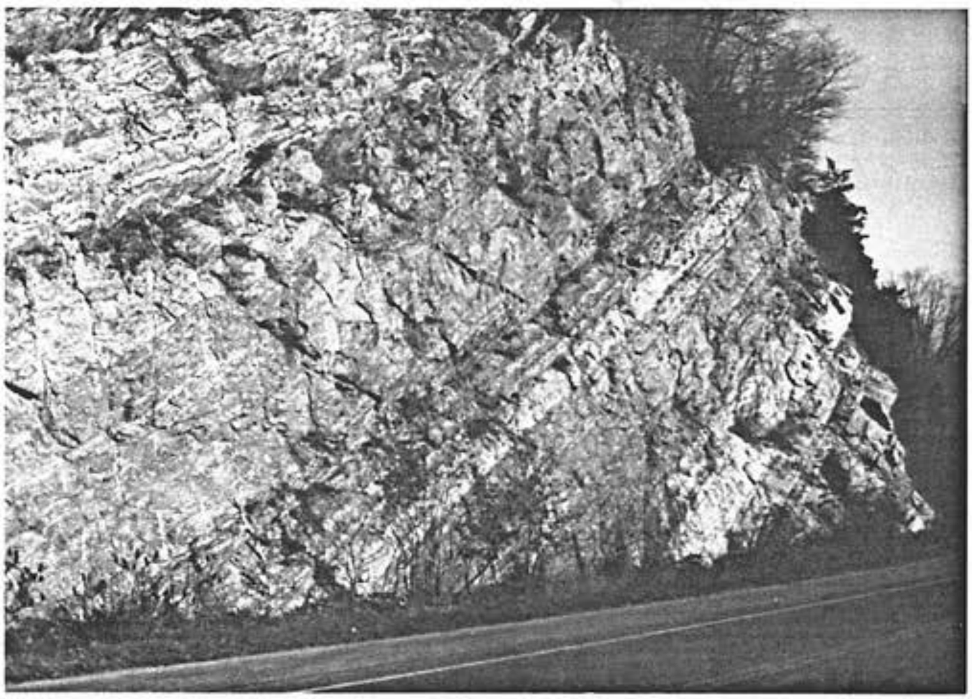


Figure 22:
The PAC 8 algal laminite horizon at Cherry Valley. Note 4 foot measuring stick for scale.

Figure 23:
The PAC 8 algal laminite horizon at Schoharie.

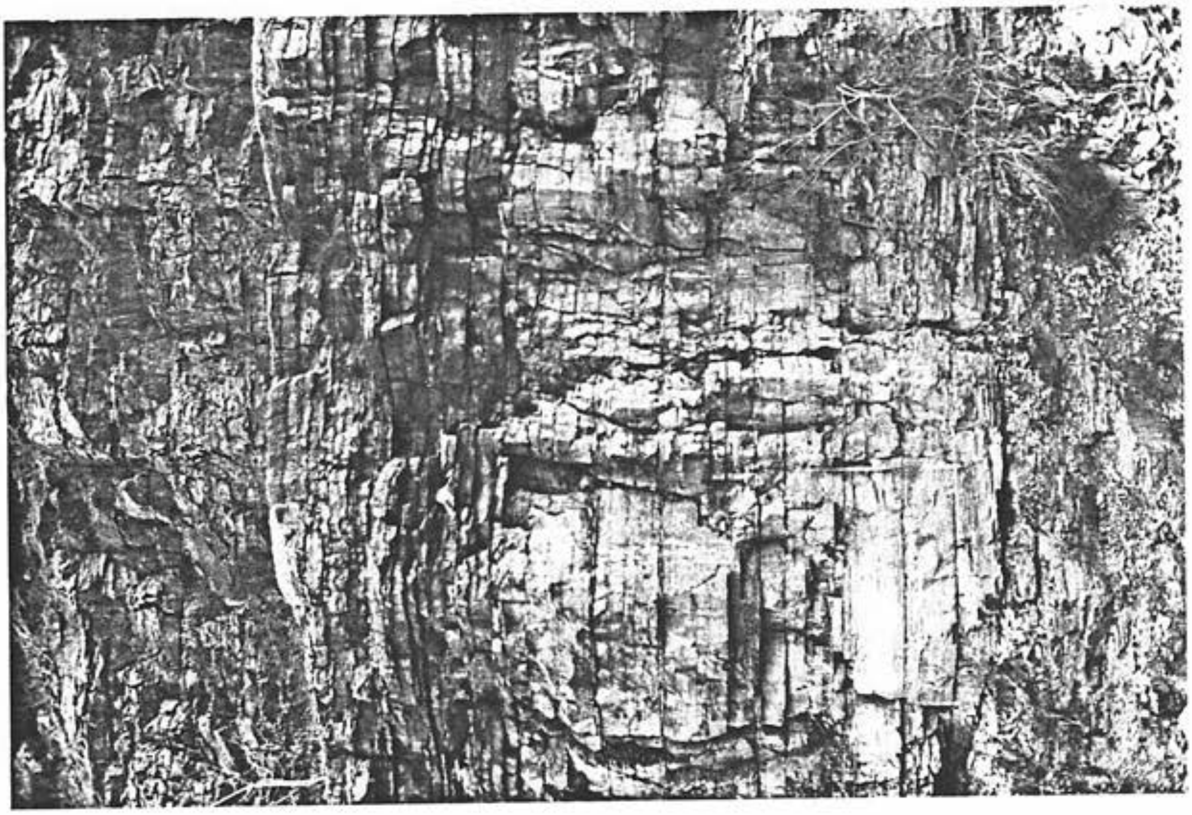
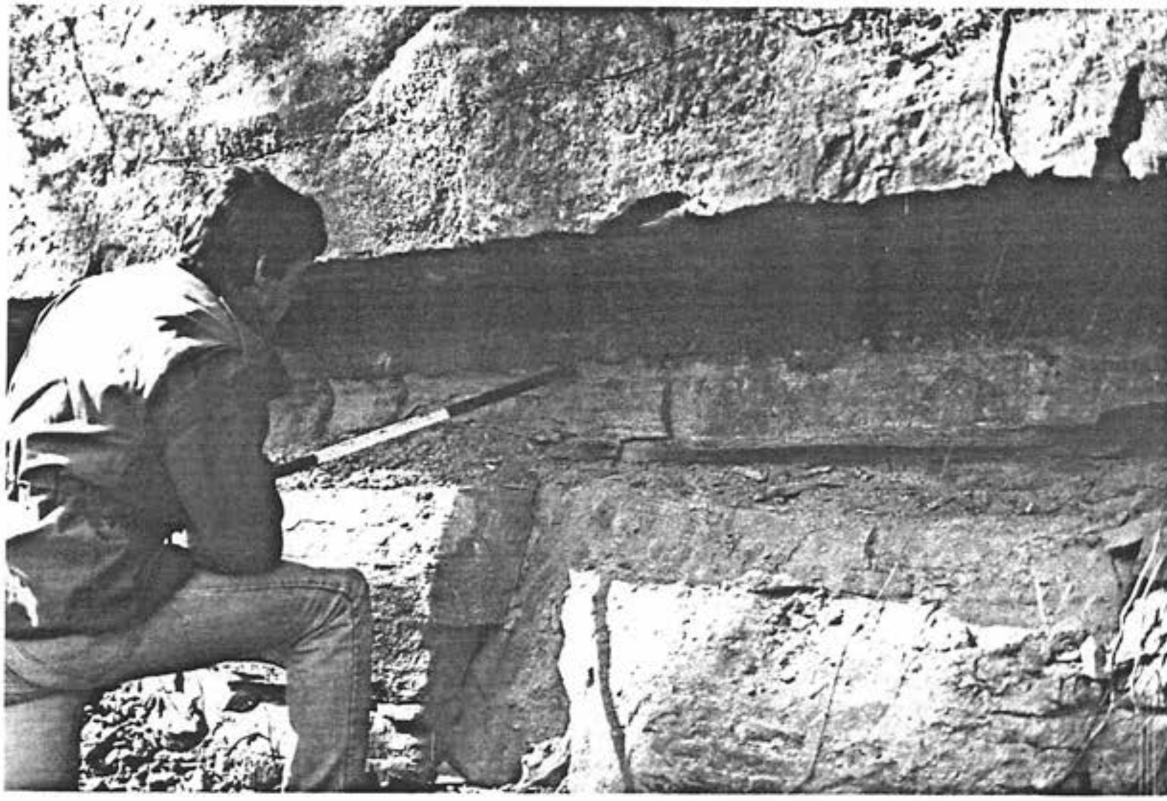


Figure 24:
The PAC 8 algal laminite horizon at New Salem.

Figure 25:
The PAC 8 algal laminite horizon at Climax Quarry.



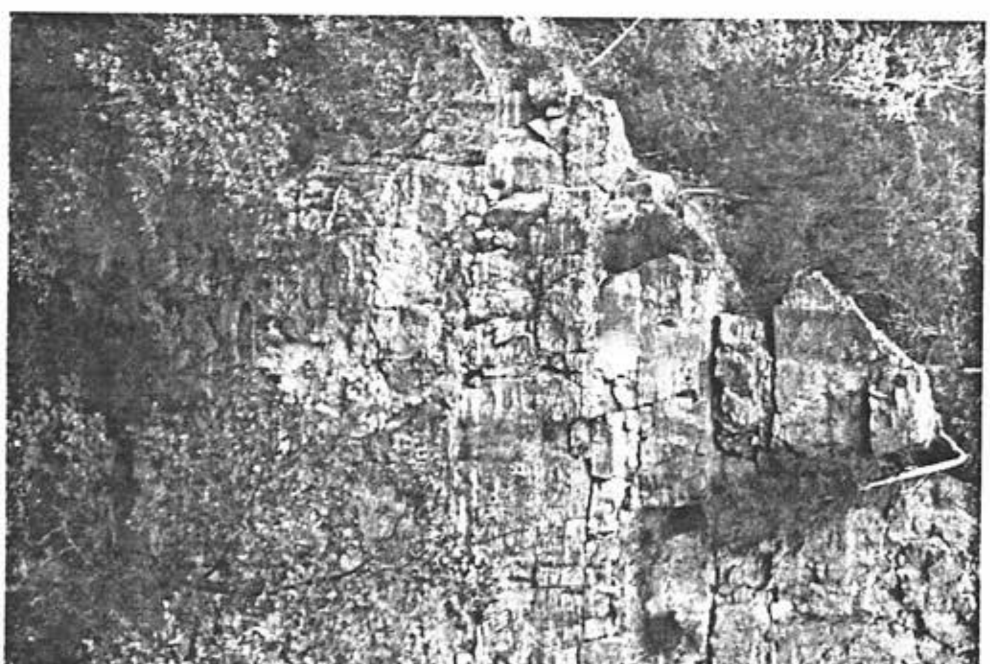
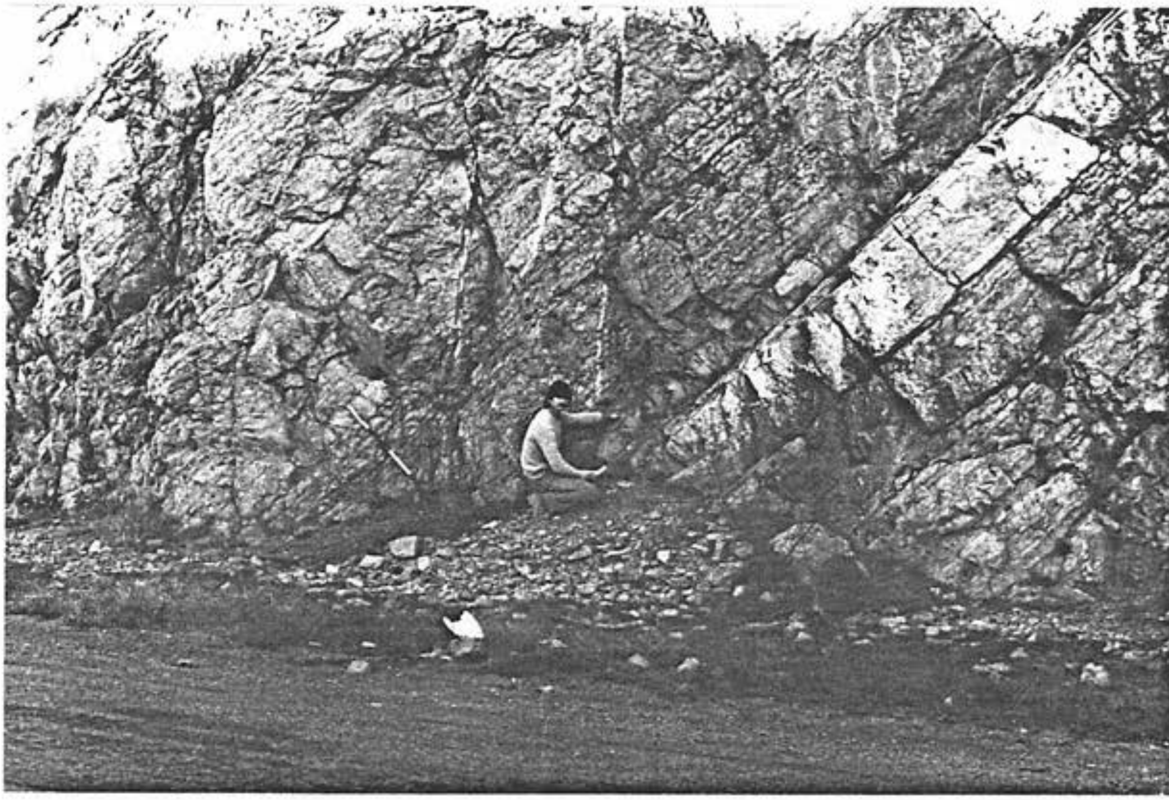


Figure 26:
The PAC 8 algal laminite horizon at North Catskill.

Figure 27:
The PAC 8 algal laminite horizon at Kingston.

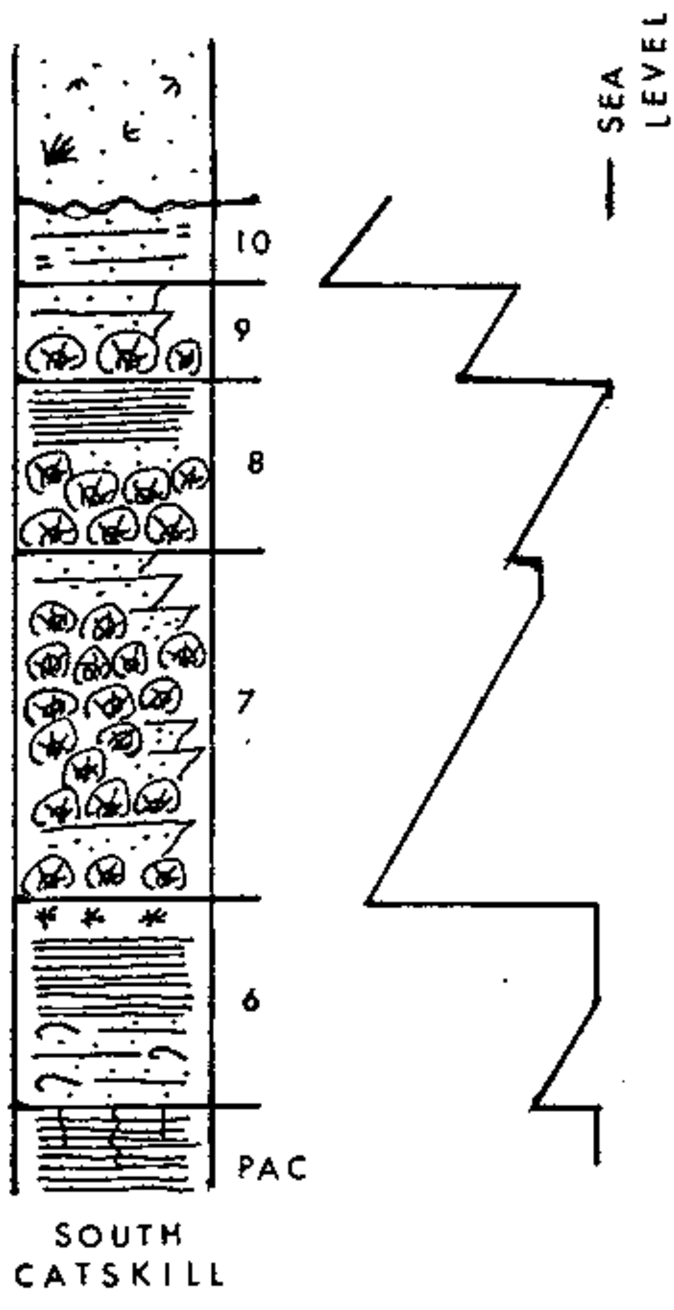


laminite horizons reveals the apparent time-stratigraphic nature of four upper Thacher stromatoporoid horizons which occur in Manlius PACs 7-10. As distinctive lithological units which can also be traced between sections, biostromes also provide data on which to base PAC correlations. The most extensive stromatoporoid horizon occurs in PAC 7. Stromatoporoids in varying concentrations ranging from single rolled heads to well-developed biostromes occur in PAC 7 at all localities between Sharon Springs and Kingston, a distance of nearly 80 miles (figure 7). The widespread occurrence of stromatoporoids in PAC 7 marks a major deepening event which resulted in basin-wide facies changes.

The occurrence of major deepening events in the Thacher Member provides a means of correlating sections which is used in conjunction with tracing PACs containing distinctive lithologic units. Major punctuation events produce basin-wide facies changes that result in well-defined PAC boundaries at all localities. Major deepening events, indicated by large deflections to the left in the relative water depth curve, occur in the upper Thacher at the PAC 6-7 and PAC 9-10 boundaries.

The major facies changes initiated by the two major deepening events in the upper Thacher can be identified at any locality. For example, at South Catskill (figures 21 and 28), the PAC 6-7 boundary marks a change from the supratidal birdseye mud facies capping PAC 6 to the stromatoporoid facies at the base of PAC 7. The large deflection to

Figure 28:
Stratigraphic column and interpreted relative water-depth curve for the upper Thacher section at South Catskill.


SEA LEVEL
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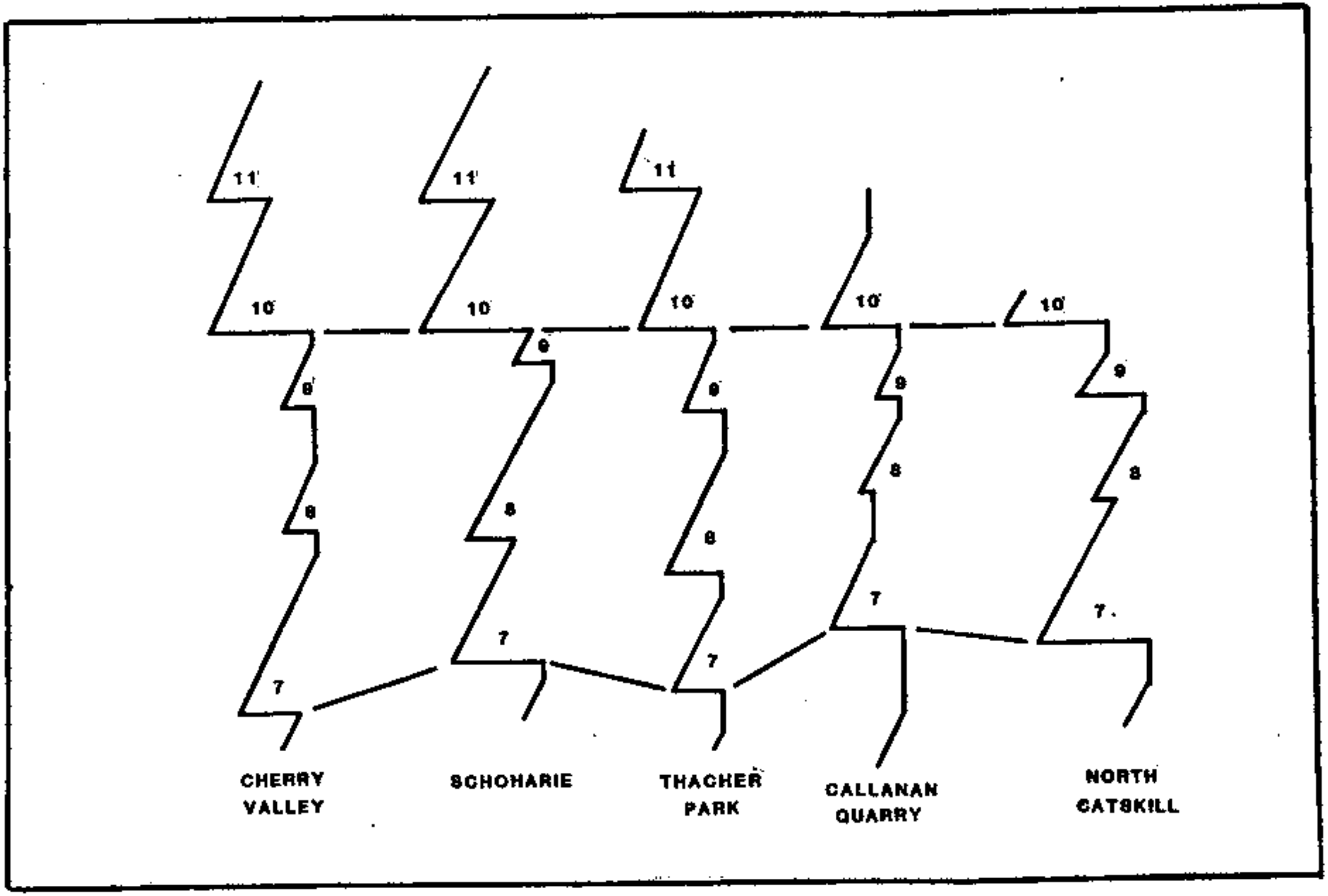
9
8
7
6
PAC
SOUTH CATSKILL

the left in the relative water depth curve at this PAC boundary indicates that the magnitude of the PAC 7 deepening event is the greatest of all Thacher punctuation events. The PAC 9-10 boundary marks a change in the Thacher depositional environment from a restricted biostrome-dominated platform to a more open marine, calcarenite-dominated shallow shelf environment with only minor biostrome development. The major facies changes at these PAC boundaries provide a means of correlating central New York sections including Schoharie with sections in the Hudson Valley.

In addition to tracing distinctive lithologic units and correlating major punctuation events, matching of vertical patterns of punctuation events provided a means to correlate sections. This method was particularly useful when applied in conjunction with other methods for the correlation of all PACs, even those produced by smaller-scale punctuation events. For example, beginning with the correlations already established by tracing algal laminite and stromatoporoid horizons and large punctuation events, all other PACs were then correlated between sections by comparison of patterns in the magnitude of punctuation events (figure 29). For example, PAC 6 and PAC 9 are both thin cycles which occur immediately below major facies changes. In contrast, PAC 10 and PAC 11 are produced by large-scale events which occur above the major facies change at the PAC 9-10 boundary. Thus, PACs 6, 9, 10 and 11 can be correlated by their relative magnitudes and by their stratigraphic position in relation to other cor-

Figure 29:
Correlation of the upper Thacher sequence by comparison of patterns in the magnitude of punctuation events.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CHERRY VALLEY
SCHOHARIE
THACHER PARK
CALLANAN QUARRY
NORTH CATSKILL

relation data.

In conclusion, the correlation presented in this study (figure 7) is the product of three different methods of PAC correlation. The correlations resulting from independent applications of each of these methods have proven consistent. Because the correlation of the upper Thacher based on PAC methods is supported by several lines of evidence, it can be used to evaluate the stratigraphic dynamics responsible for the formation of the Manlius-Coeymans contact.

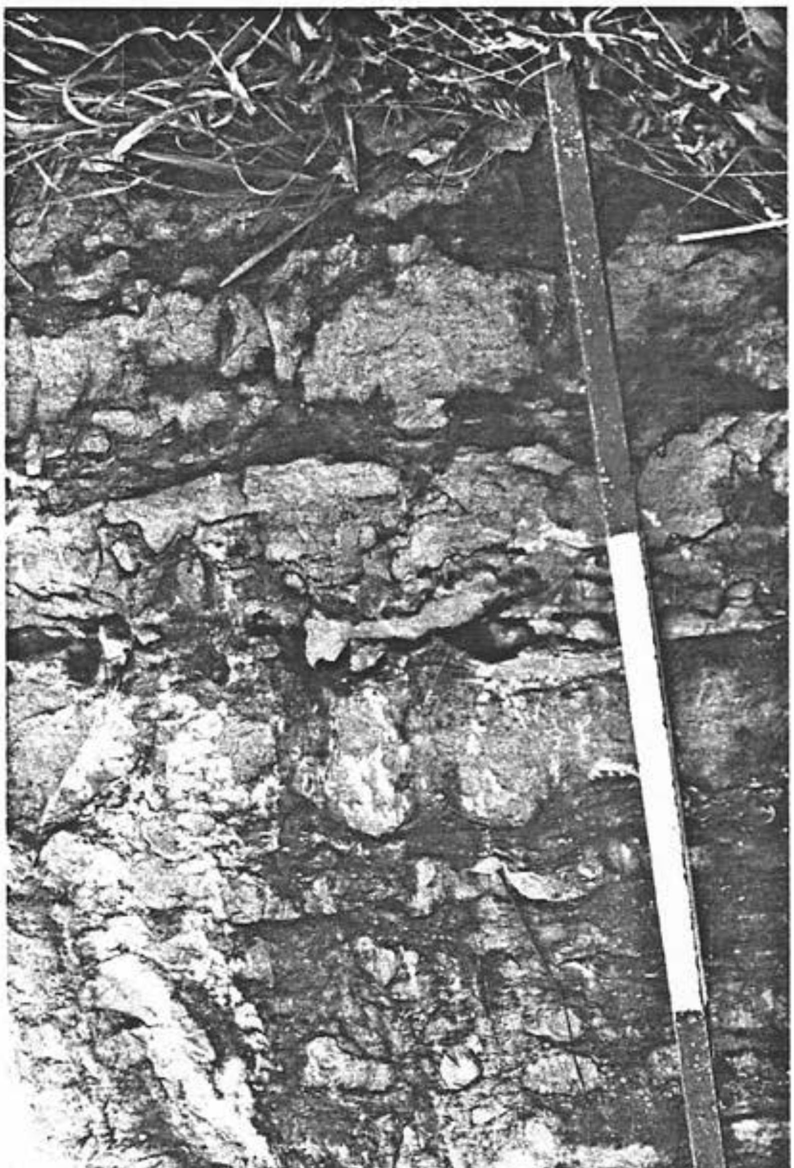
THE MANLIUS-COEYMANS FORMATIONAL BOUNDARY

The physical characteristics of the surface marking the Manlius-Coeymans formational boundary suggest that some erosion had occurred prior to deposition of Coeymans facies. Karstic features present at the contact at some localities in the Hudson Valley suggest that the erosion was due to subaerial exposure. For example, v-shaped solution pits commonly up to 8 centimeters deep occur at the contact at South Wilbur (figure 30). A crust possibly formed by the concentration of less soluble iron-rich constituents of Thacher limestone lines the solution pits. The basal foot of Coeymans section at South Wilbur is composed of mottled argillaceous calcarenite. The high content of buff-weathering clay in this facies may indicate that a soil horizon existed atop the pitted surface and was subsequently reworked during deposition of the first Coeymans PAC. At North Catskill the uppermost beds of the Thacher contain large solution cavities which are filled with coarse crinoidal calcarenite of the Coeymans Formation (figure 31). These cavities are identifiable on the outcrop because of the contrast in grain-size between the host Thacher beds and the infilling Coeymans sands.

The correlation achieved by application of the PAC hypothesis to upper Thacher strata by this author indicates that erosion of uplifted upper Thacher deposits resulted in a disconformity of major lateral, but minor vertical propor-

Figure 30:
V-shaped solution pits on the Manlius-Coeymans formational boundary at South Wilbur. Note penny on contact for scale.

Figure 31:
Large solution cavities filled with Coeymans sediment in the uppermost Thacher beds at North Catskill. Stick is divided into one foot increments.



tions. The decrease in the number of PACs from eleven to eight between Cherry Valley and Kingston indicates a progressive increase in the amount of section missing to the southeast. This conclusion is based primarily on tracing the algal laminite horizon at the top of PAC 8 and observing the progressive loss of Manlius PACs above it from Schoharie to Kingston.

At Cherry Valley, the westernmost locality in the study area, Manlius PACs 9-11 are fully preserved and comprise 17 feet of section above the PAC 8 datum (figure 32). PAC 9 is approximately 4 feet thick and consists of vuggey, current-washed, strophomenid brachiopod and ostracode-bearing calcarenite. PAC 10 is 7 feet thick and contains 4.5 feet of fine-grained crinoidal calcarenite which grades upward into 2.5 feet of medium-bedded calcarenite containing strophomenid brachiopods, rugosan corals, gastropods and ostracodes. PAC 11 is 6 feet thick and consists of medium-bedded strophomenid and and crinoidal calcarenite.

PACs 9-11 can be traced eastward to Thacher Park where the amount of section above the PAC 8 datum decreases to 15 feet. At Thacher Park PAC 9 is approximately 4.5 feet thick and contains 2.5 feet of stromatoporoid-bearing calcarenite overlain by 2 feet of fine-grained, laminated stracode calcarenite (figure 33). PAC 10 is 7.5 feet thick and contains 2.5 feet of medium-bedded calcarenite at its base (see figure 17). A stromatoporoid biostrome nearly five feet thick rests on the medium-bedded calcarenite. Rickard (1962, p.

Figure 32:
The 17 feet of Thacher section which occurs above the PAC 8 algal laminite horizon at Cherry Valley. Note measuring stick for scale.

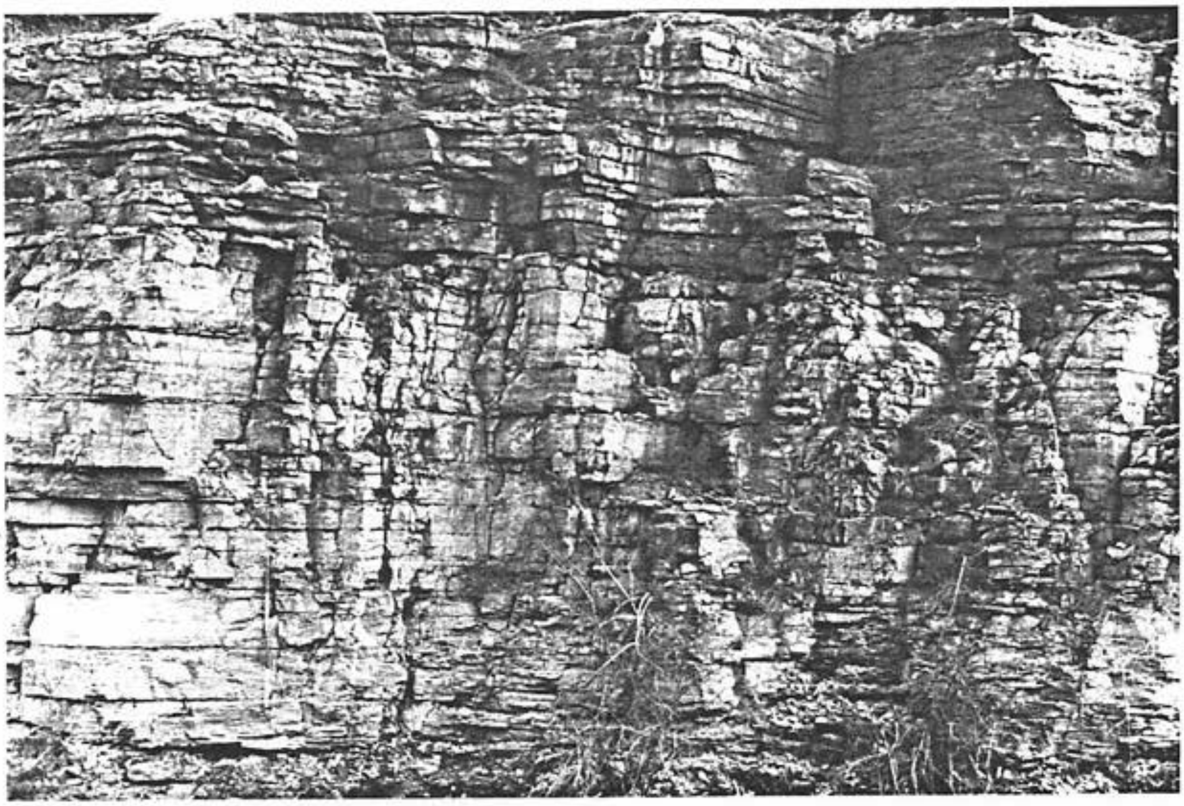
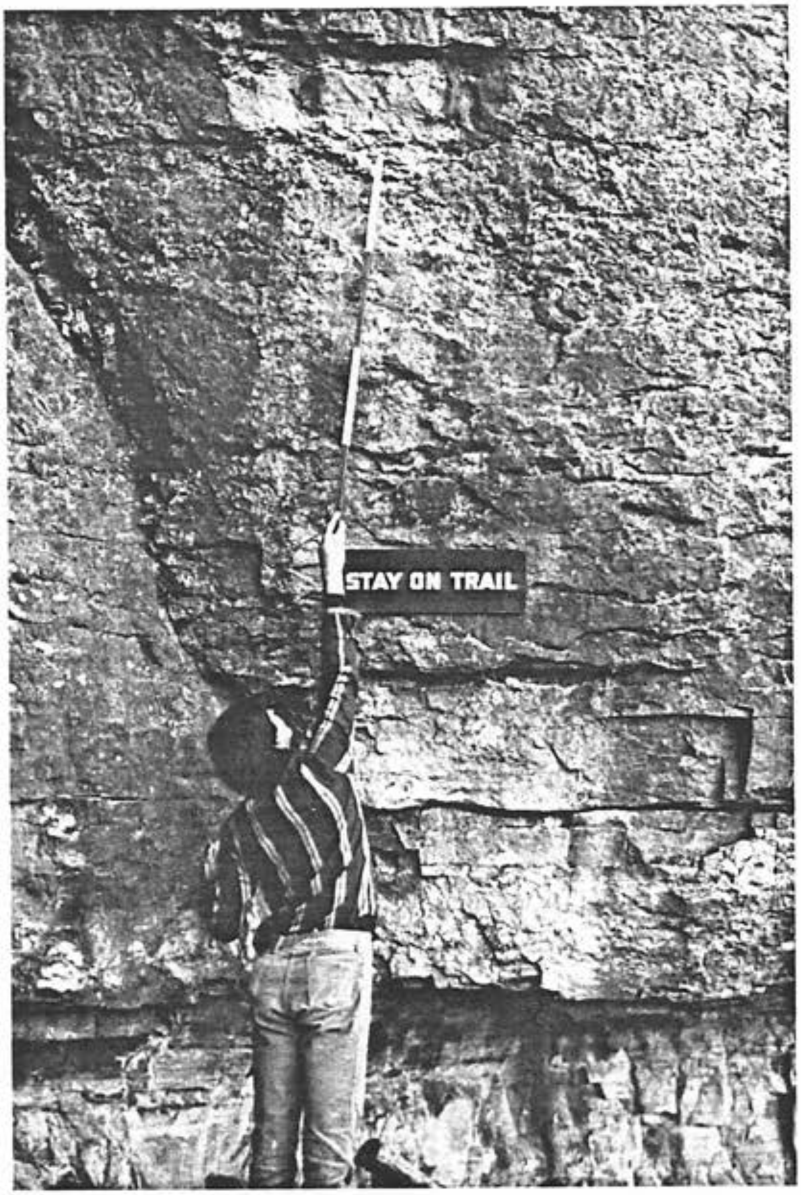


Figure 33:
Manlius PACs 9 and 10 at the Thacher type section, John Boyd Thacher State Park.


STAY ON TRAIL

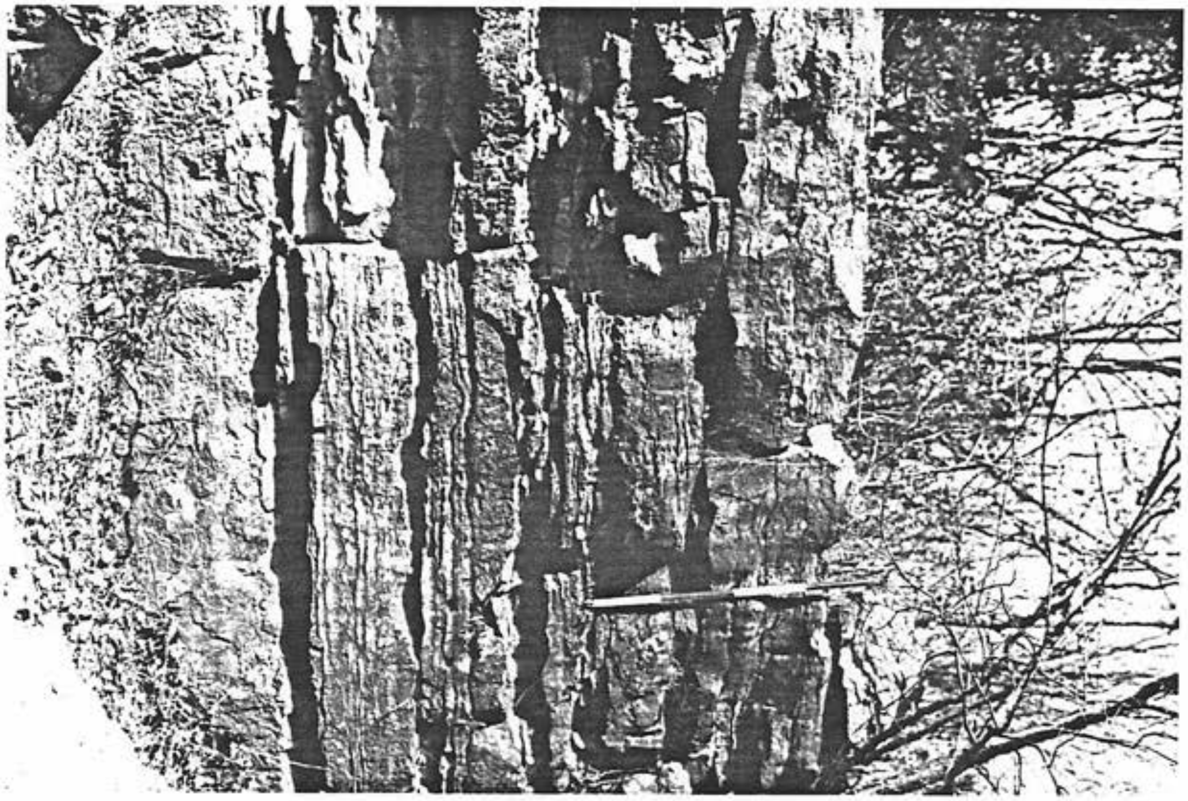
134) placed the Manlius-Coeymans contact at the top of the PAC 10 biostrome at Thacher Park. This author places the contact slightly more than three feet above this surface. This additional unit comprises Manlius PAC 11 and consists of bioturbated crinoidal calcarenite containing rolled-over stromatoporoids and strophomenid brachiopods but notably lacking Gypidula coeymanensis, the Coeymans marker fossil.

At New Salem, 5 miles east of Thacher Park, PAC 11 is missing entirely. The amount of section above the PAC 8 waterlime has decrased to 10 feet. This 10 feet of section comprises Manlius PACs 9 and 10. PAC 9 is 4 feet thick at New Salem and contains a 2.5 feet thick stromatoporoid biostrome which is overlain by 1.5 feet of thin-bedded calcarenite. PAC 10 is 6 feet thick and contains interbedded stromatoporoids and thin-bedded calcarenite (figure 34). At New Salem Coeymans facies directly overlie the stromatoporoid facies of Manlius PAC 10. While the irregular nature of the boundary surface at this locality may be, in part, attributable to relief on the biostrome, the occurrence of Manlius lime mud and stromatoporoid clasts in the basal beds of the Coeymans Formation (figure 35) suggests that the formational contact is erosional in nature.

PAC 9 and PAC 10 can be traced eastward from New Salem to Climax Quarry where the amount of section above the PAC 8 datum decreases to 7.5 feet. At Climax, PAC 9 is three feet thick and consists of thin-bedded calcarenite containing rolled-over stromatoporoid heads. PAC 10 is 4.5 feet

Figure 34:
Manlius PACs 9 and 10 at New Salem. Measuring stick is 4 feet in length.

Figure 35:
Clast consisting of Manlius stromatoporoid fragments and lime mud in basal Coeymans bed at New Salem. Scale in millimeters.



thick and consists of medium-bedded calcarenite. Some beds contain disarticulated strophomenid valves oriented convex-up (figure 36). These coquina-like beds are significant stratigraphically, because they are exclusive to PACs 10 and 11 throughout the study area. The occurrence of this facies at Climax provides evidence that Manlius facies recognized as transitional between Manlius and Coeymans facies at central New York localities by early workers (e.g. Grabau, 1907; Davis, 1953) extend eastward into the Hudson Valley.

At Catskill, approximately 10 miles south of Climax, the PAC 10 remnant becomes so thin and pitted that its identity as a unit discrete from PAC 9 as opposed to representing a regressive cap on PAC 9 becomes difficult to discern. At North Catskill, the amount of section above the PAC 8 laminite totals only 5.5 feet. PAC 9 is 4 feet thick and consists of mottled-bedded calcarenite. PAC 10 is less than 2 feet thick and consists of medium-bedded calcarenite which show signs of leaching. The irregular bedding planes (figure 37) indicate that PAC 10 strata have been distorted by dissolution as opposed to bioturbation. Lenses of coarse-grained shell hash mostly composed of valves of <u>Gypidula</u> occur immediately above the leached zone. At South Catskill PAC 10 facies are less pitted; recognition of 1.5 feet of section as a separate PAC from PAC 9 is easier than at North Catskill. The formational boundary at South Catskill is marked by a thin veneer of encrusting bryozoans which can be found in a thin calcareous black shale at the base of the

Figure 36:
Medium-bedded calcarenite containing disarticulated strophomenid valves oriented convex-up at the top of PAC 11 at Climax Quarry.

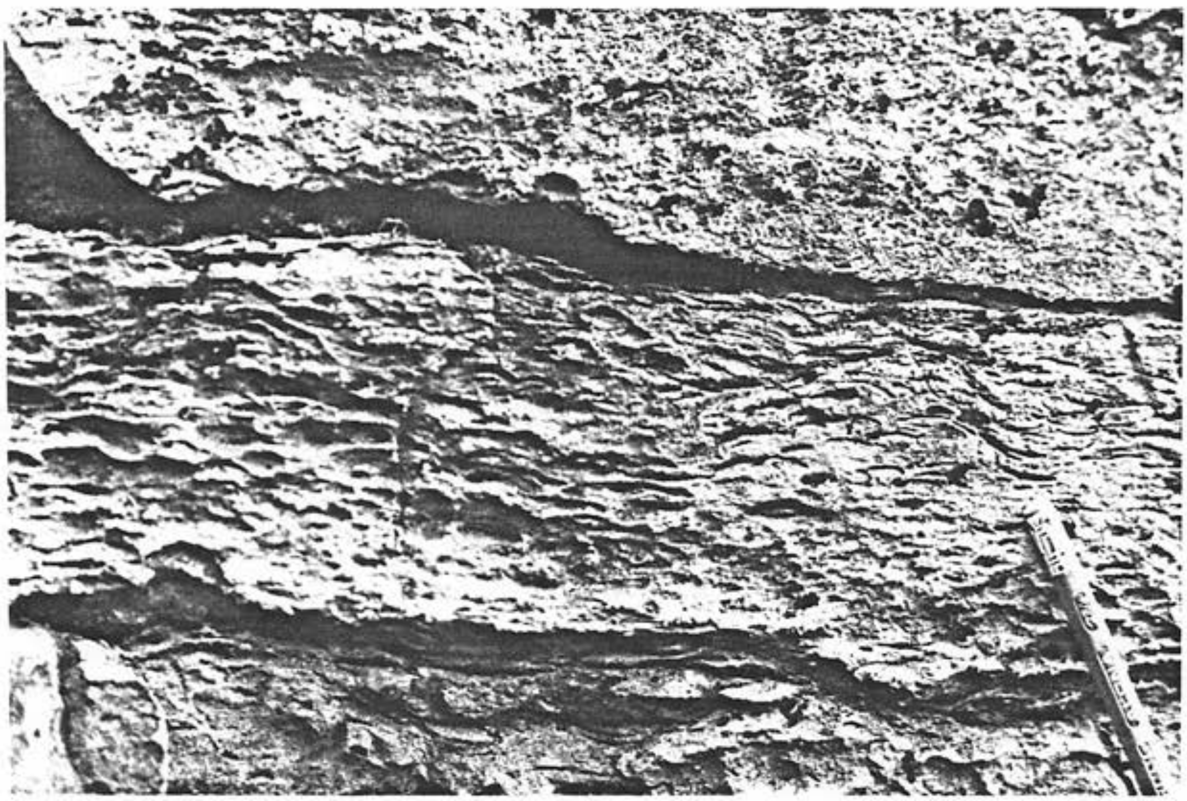
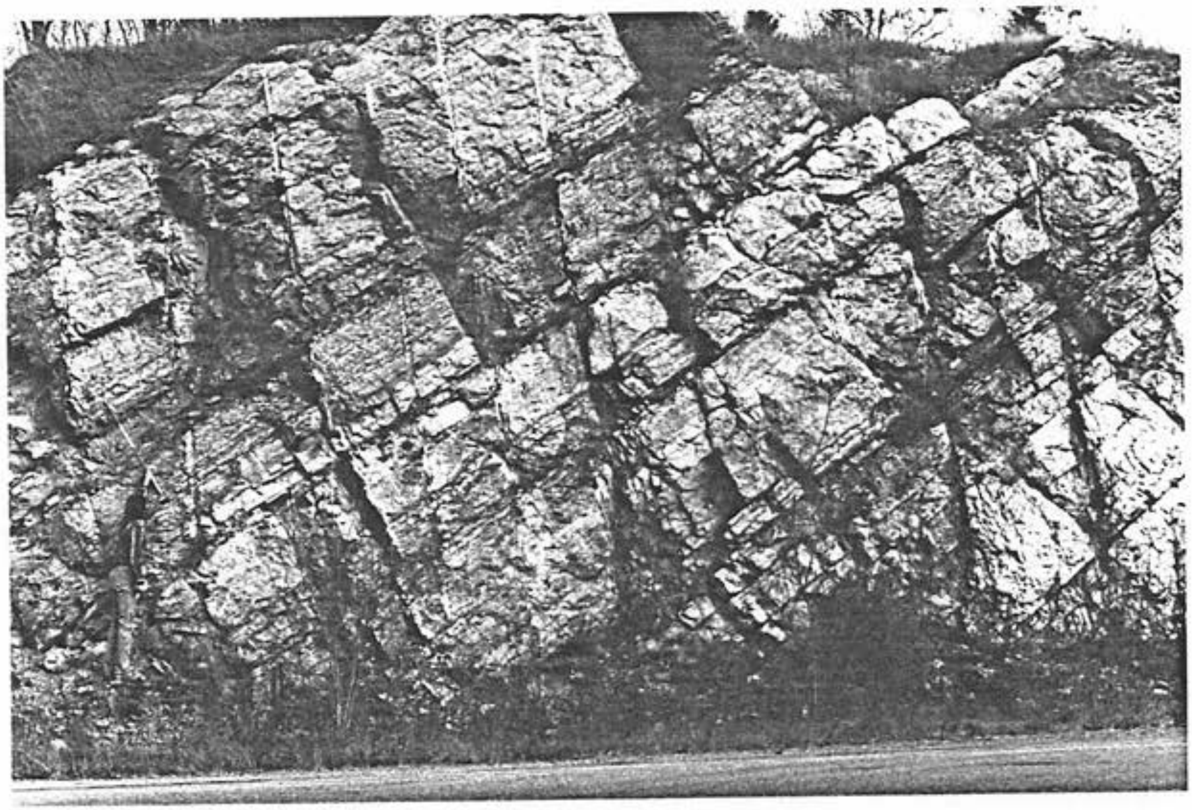


Figure 37:
The upper Thacher sequence at North Catskill. Top of stick is at the formational contact. Note relief on the top of the PAC 8 algal laminite at geologist's waist and distorted bedding at the top of PAC 10, the uppermost Thacher PAC.



Coeymans Formation.

Between Cherry Valley and Kingston, a distance of nearly 93 miles, the amount of Manlius section found above the PAC 8 laminite horizon decreases from 17 feet to zero. At Kingston, approximately 30 miles south of Catskill, Coeymans facies rest directly on the PAC 8 algal laminite (figure 38). The laminites are dissected by v-shaped pits which show evidence of both dissolution and scour (figure 39.). A clast of Manlius lime mud can be seen on the outcrop in the basal foot of the Coeymans. This suggests that the top of the Manlius was lithified prior to Coeymans deposition. This may indicate that a relative sea-level drop occurred late in Manlius time.

Kingston appears to mark the point of greatest erosion. At East Kingston Quarry, 2.5 miles south of the Kingston locality, 1.5 feet of PAC 9 remain atop the PAC 8 waterlime. At South Wilbur, the southernmost locality in the study area, 3.5 feet of PAC 9 are preserved. At this locality, PAC 9 consists of medium-bedded calcarenite containing large loaf-shaped stromatoporoids. PAC 9 is capped by a pale gray, fine calcarenite on top of which is the pitted surface marking the formational contact (figure 40).

The progressive loss to the southeast of Manlius PACs 9-11 suggests uplift and erosion along the eastern basin margin (figure 41) Tectonic uplift could explain the differential loss of 17 feet of section between Kingston and Cherry Valley. Uplift of the eastern basin margin seems consistent

<u>Figure</u> 38:
The Manlius-Coeymans contact at Kingston. The contact occurs at the top of the PAC 8 algal laminite marked by arrow.

<u>Figure</u> 39:
Close-up of the Manlius-Coeymans contact at Kingston. Note Manlius-derived clast at the base of the Coeymans.

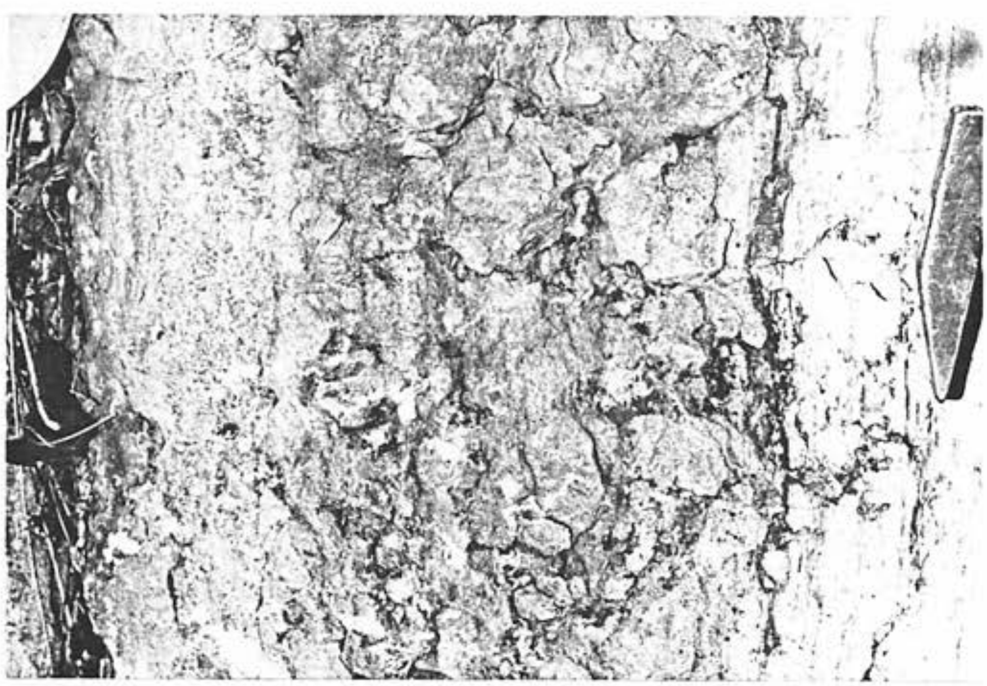


Figure 40:
The top of PAC 8 and the entire PAC 9 at South Wilbur. Stick is four feet in length.

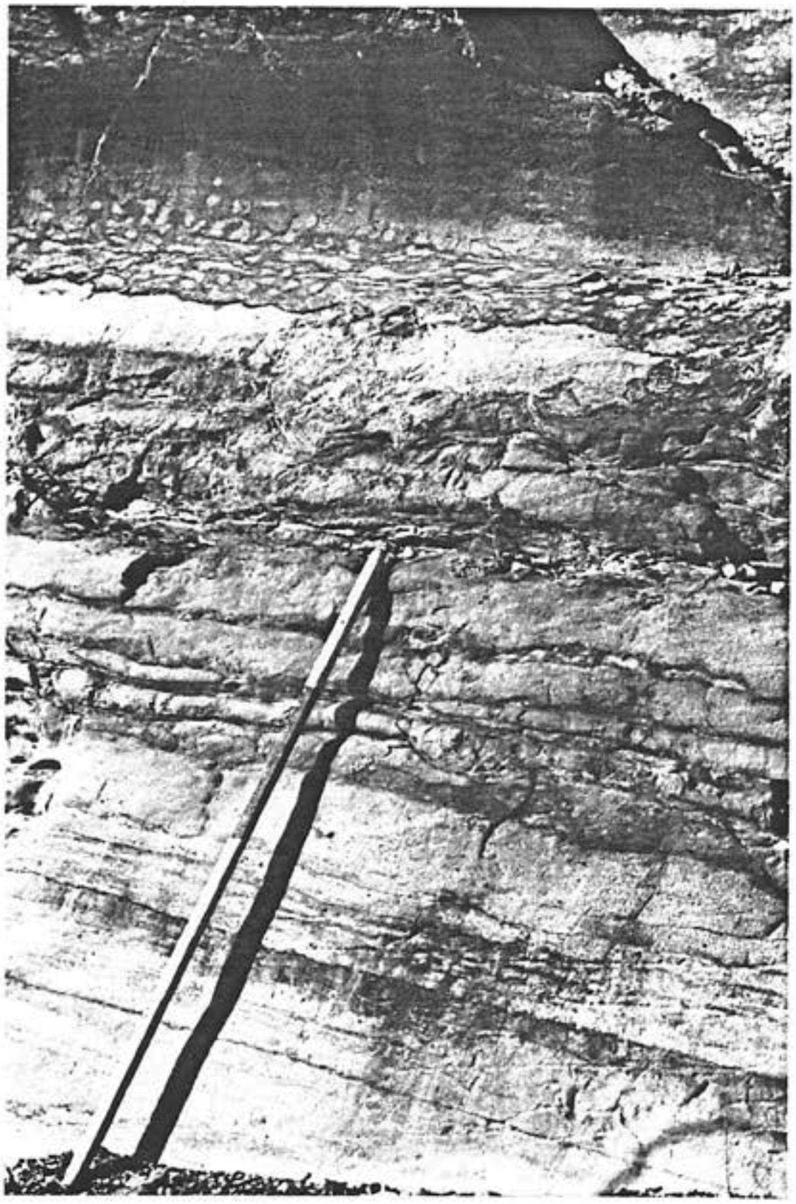
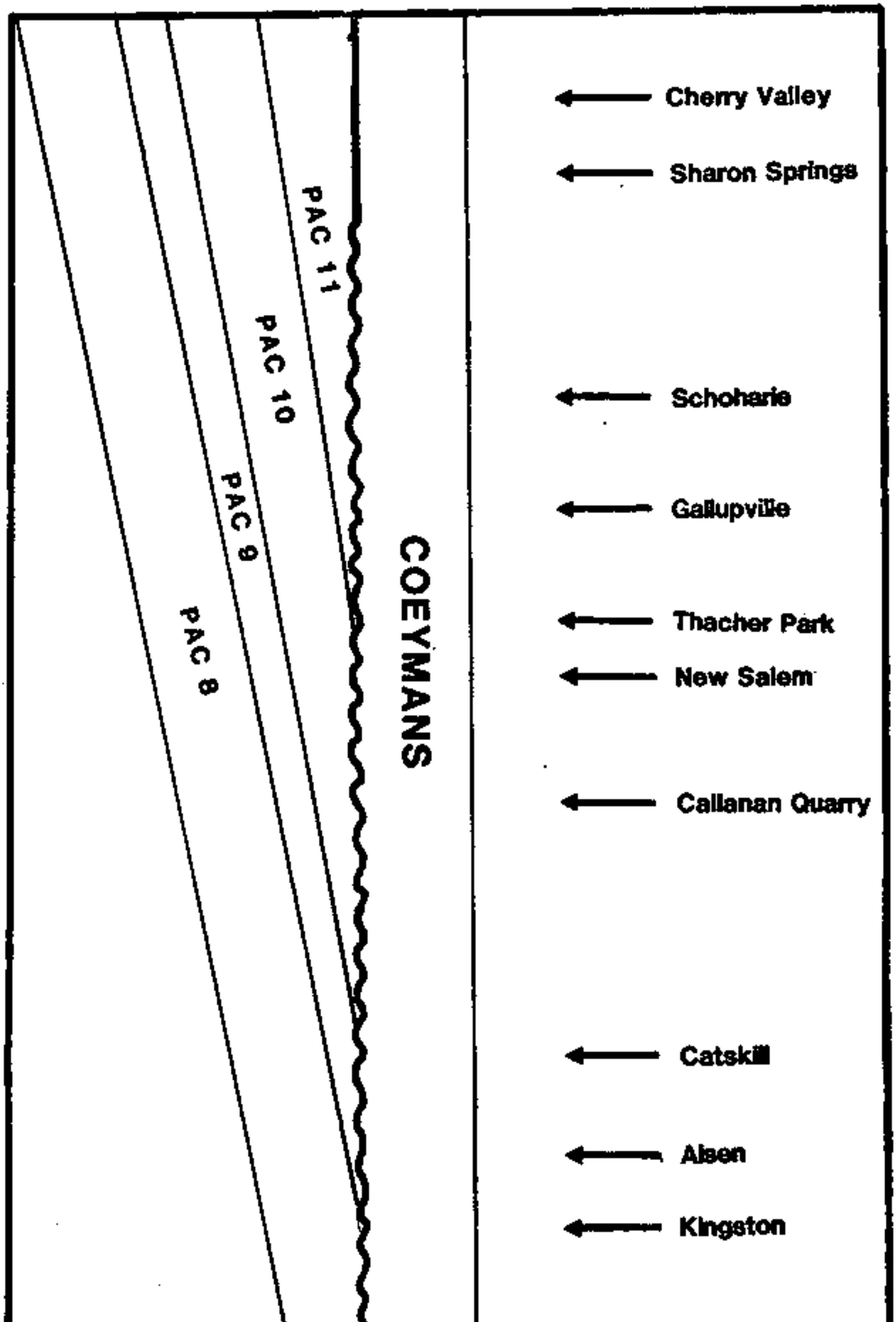


Figure 41:
Stratigraphic relationships between upper Thacher PACs and overlying Coeymans Formation across study area.



Cherry Valley
Sharon Springs
Schoharie
Gallupville
Thacher Park
New Salem
Callanan Quarry
Catskill
Alsen
Kingston
COEYMANS
PAC 11
PAC 10
PAC 9
PAC 8

with the regional tectonics during Late Silurian and Early Devonian time and may have been responsible for other minor disconformities found at the Binnewater-Rondout contact by Buggey (1985) and at the Roundout-Manlius contact by Osborn (1983).

CONCLUSIONS

Application of the PAC hypothesis to the Manlius-Coeymans formational boundary in central New York and the Hudson Valley yields the following conclusions:

1) The Manlius-Coeymans formational boundary is a disconformable contact.
2) Three different Manlius PACs (PACs 9-11) were subjected to pre-Coeymans erosion.
3) Manlius PACs 9-11, which comprise the "transition" beds of Davis (1953), extended throughout most of the study area prior to erosion.
4) The greatest amount of erosion occurred near Kingston where only eight of the eleven Manlius PACs are preserved.
5) Tectonic uplift of the eastern basin margin is responsible for the differential loss of 17 feet of section between Kingston and Cherry Valley, New York.
6) All Thacher depositional environments temporally preceded the Coeymans depositional environment.

APPENDIX: FIELD GUIDE TO LOCALITIES

<u>Cherry Valley</u>
Roadcut along Route 166 in vicinity of Judd Falls, 1 mile north of Cherry Valley, Sprout Brook 7½" quadrangle.

<u>Sharon Springs</u>
Abandoned quarries in residential Sharon Springs along Route 10, ½ mile north of intersection with Route 20 in the Sharon Springs 7½" quadrangle.

<u>Gallupville</u>
Roadcut along Fox Creek, 1 mile southeast of Gallupville, in the Gallupville 7½" quadrangle.

<u>Schoharie</u>
Roadcut into Schoharie Hill along Route 88 in the Schoharie 7½" quadrangle.

<u>New Salem</u>
Roadcut and abandoned quarry approximately ½ mile past the intersection of Rock Hill and North Roads, two miles southeast of New Salem.

<u>Thacher Park</u>
Indian Ladder in John Boyd Thacher State Park in the Altamont 7½" quadrangle.

<u>Callanan Quarry</u>
Active quarry owned and operated by the Callanan Road Improvement Company, 0.3 miles south of South Bethlehem town center in the Delmar 7½" quadrangle.

<u>Climax Quarry</u>
In town of Climax, behind Quarry Steak House on Route 81, 1.2 miles west of intersection with Route 9W in the Hudson North 7½" quadrangle.

<u>North Catskill</u>
Roadcut along Route 23 on the westbound Leeds off-ramp, 1.5 miles south of Leeds in the Cementon 7½" quadrangle.

<u>South Catskill</u>
Roadcut along Route 23A, 0.4 miles west of intersection with 9W just southwest of Catskill, in the Cementon 7½" quadrangle.

<u>Alsen Quarry</u>
Quarries along Route 9W o.5 miles south of Alsen in the Cementon 7½" quadrangle.

<u>Kingston</u>
Roadcut along Route 199, o.25 miles west of intersection with

Route 32 in the Kingston East 7½" quadrangle.

East Kingston Quarry
Inactive quarry owned by the Hudson Cement Company, o.5 miles south of East Kingston on Route 32 in the Kingston East 7½" quadrangle.

South Wilbur
Abandoned quarry/gravel pit one half mile south of Wilbur, west of Route 213.

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