Trip A-5

SEQUENCE STRATIGRAPHY OF PLATFORM CARBONATES: DEVONIAN LIMESTONES OF JOHN BOYD THACHER STATE PARK, SOUTHWEST OF ALBANY, NY

In Honor of Dr. Gerald M. Friedman, a distinguished Geologist, educator, and a mentor.

The Text of this trip is adapted and revised from a paper written by **Dr. Gerald M. Friedman** which was published in the Field trip Guide for the 67th Annual Meeting of New York State Geological Association (October 13-15, 1995) and edited by John I.Garver and Jacqueline A. Smith.

Trip Leader: Mossbah M. Kolkas, Certified Professional Geologist (CPG-10180)
Department of Engineering Science and Physics, The College of Staten Island of the City University of New York (CUNY), 2800 Victory Boulevard, Staten Island, New York 10314, mkolkas@gmail.com

Figure *1. A plaque erected in 1933 in memoriam of those pioneer geologists whose researches in the Helderbergs in the nineteenth century*

ABSTRACT

The Lower Devonian strata that crop out on the Helderberg Escarpment illustrate the characteristics of marine platform parasequences in carbonate rocks. In the hierarchy of stratigraphic units, parasequences are a relatively conformable succession of genetically related strata bounded by surfaces of erosion. The parasequences exposed in this escarpment, which include stromatoporoid reefs, stromatolites, and lithified lime mud (micrite) show regressive fades separated by unconformities representing transgressive episodes. The lowermost part of the section exhibits classical karst-generated solution collapse breccia of the kind that hosts oils and gas in the subsurface. The Middle Devonian Onondaga fades at this site are full of coral-reef debris. In the subsurface, Onondaga reefs form gas reservoirs and now serve as reservoirs for gas storage. Sir Charles Lyell visited this classic site, part of the Helderberg Mountains, in 1841 and a monument commemorates his visit and that of Sir William Logan, James Hall, Amos Eaton, and others of the heroic age of Geology.

INTRODUCTION

In the hierarchy of stratigraphic units, parasequences are a relatively conformable succession of genetically related strata bounded by surfaces of erosion. The Lower Devonian parasequences exposed in this escarpment, which include stromatoporoid reefs, stromatolites, and lithified lime mud (micrite) show regressive fades separated by unconformities representing transgressive episodes. The Middle Devonian Onondaga fades Stratigraphically above the rocks at this site is full of coral-reef debris.

HISTORY

This classic site is on hallowed ground. A plaque erected in 1933 in memoriam of those pioneer geologists whose researches in the Helderbergs in the nineteenth century (Fig.1) made this region classic ground includes not only almost all American pioneer geologists, but in addition, lists pioneers of British and Canadian geology. Among those listed are Amos Eaton (1776-1842), the John Gebhards Sr. and Jr. (life-cycle dates not available), James Hall (1811-1898), William W. Mather (1804-1859), Lardner Vanuxem (1792-1848), James Eights (1797- 1882), Sir Charles Lyell (1797-1875), Benjamin Silliman (1779-1864), Edouard de Verneuil (1805-1873), James D. Dana (1813- 1895), Henry D. Rogers (1808-1866), William B. Rogers (1804- 1882), Ferdinand Roemer (1818-1891),
Louis Agassiz (1807-1873), and Sir William E. Logan (1798-1875). Sir Charles Lyell visited the "Helderberg Mountains", as he called them, in September 1841 and although he rejoiced, noting that "the precipitous cliffs of limestone, render this region more picturesque than is usual where the strata are undisturbed" (Lyell, 1845, p. 67), he was

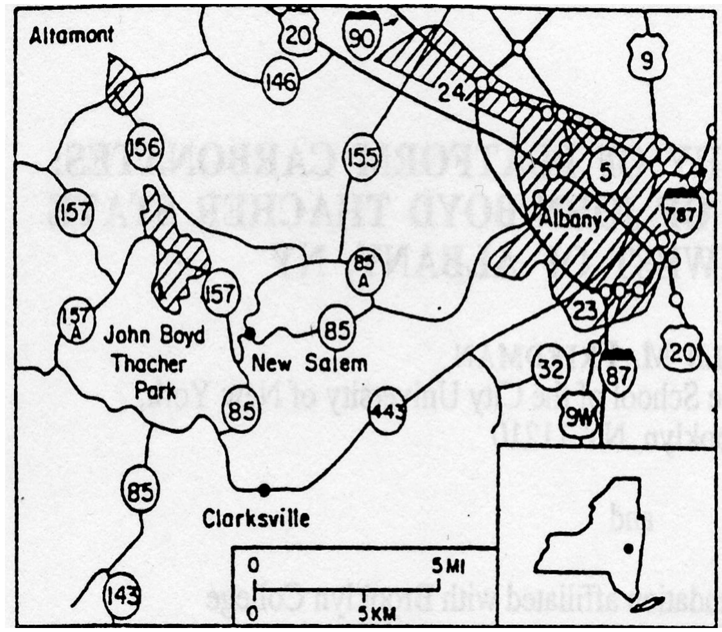
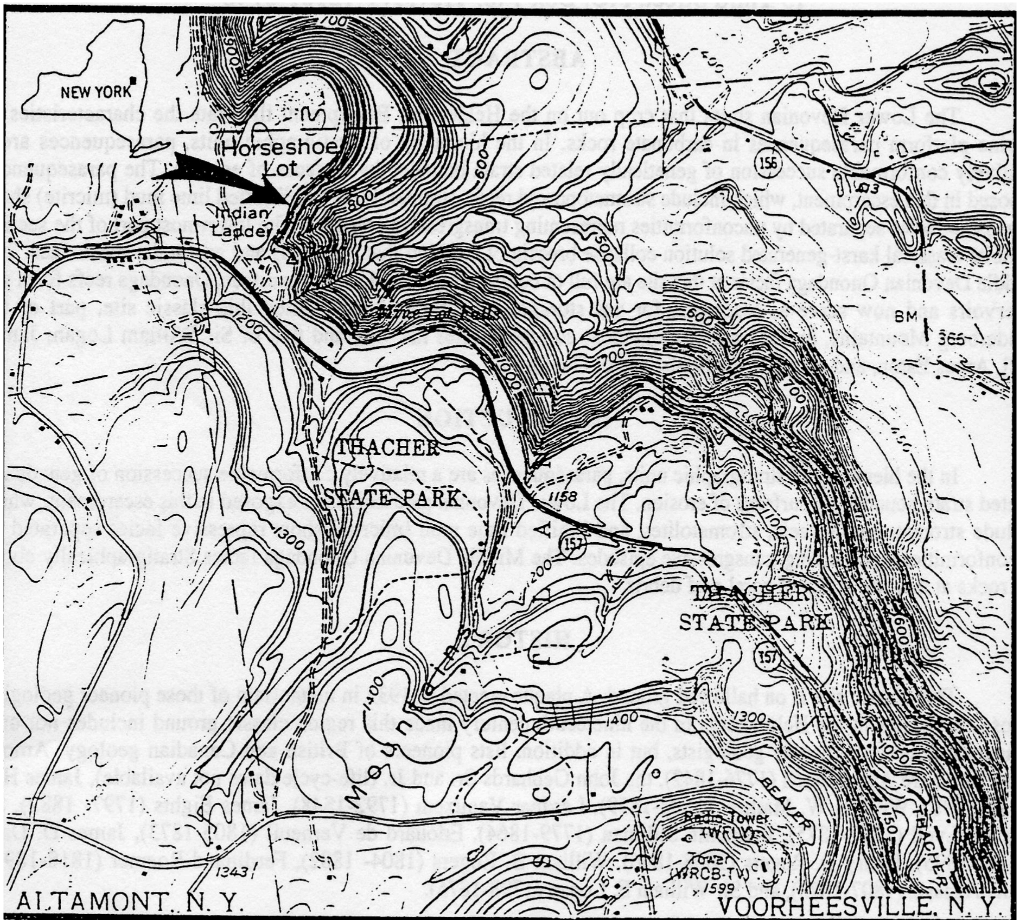


Figure 2A. Location of John Boyd Thacher-State Park (Fisher, 1987). The Indian Ladder Trail is located on Route 157.

more concerned in his account with the "Helderberg war" between Van Rensselaer and his tenants. On his return to the "Helderberg Mountains" in May 1846 the "Helderberg war" absorbed him again because he states that "the anti-renters have not only set the whole militia of the state at defiance, but have actually killed a sheriffs officer, who was distraining for rent." (Lyell, 1849, p. 260). The definitive studies of the Lower Devonian carbonates of the Helderberg Escarpment exposed at John Boyd Thacher Park date to the early New York State Geological Survey and were written by Vanuxem (1842), Mather (1843), and Hall (1843). Their reports were supplemented and complemented later in the nineteenth century.



SCALE 1:24000 CONTOUR INTERVAL: 10 FEET

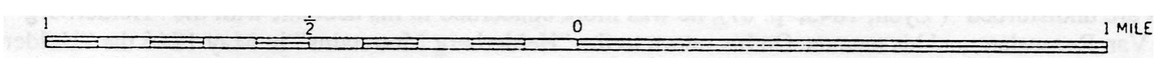


Figure 2B: Topographic map of John Boyd Thacher-State Parking showing location of Indian Ladder Trail.

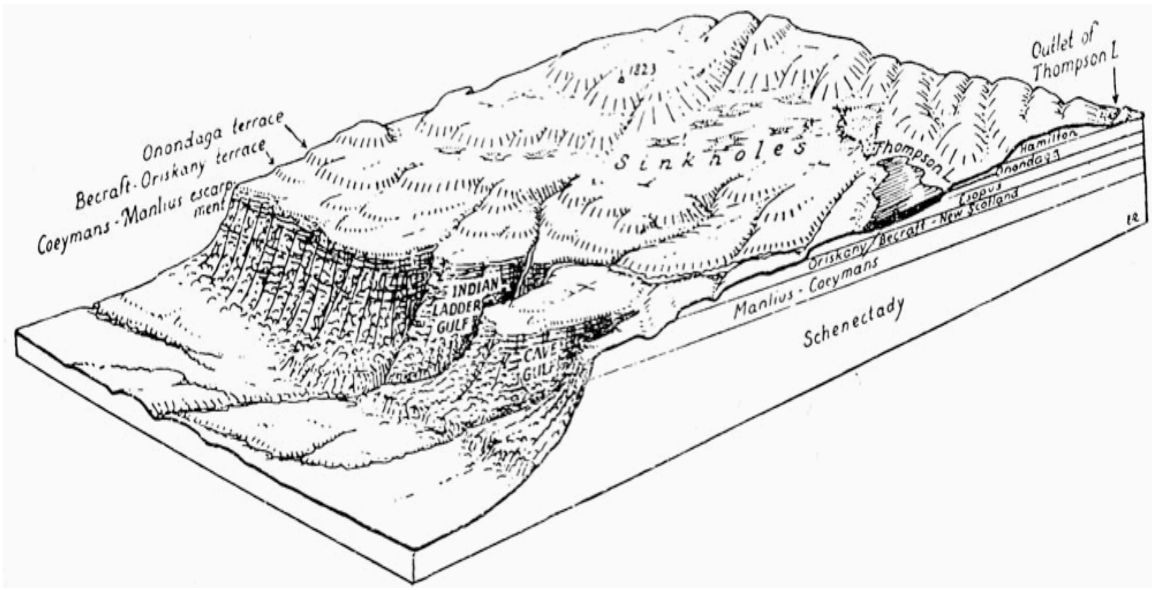


Figure 3. Block diagram of Helderberg Escarpment showing Indian Ladder location (labeled Indian Ladder Gulf), dip slope of Paleozoic strata, prominent terraces, and sinkhole topography (H.F. Cleland, 1930: modified by Winifred Goldring, 1935).

The Indian Ladder Trail site provides an unusual opportunity to study a vertical cliff of limestone strata: a vertical exposure of approximately 80 ft or 24 m exposed in the cliff is accessible by stairway and footpath; hand railings assure safety. One can view the entire sequence of the rocks at close quarter, including by hand lens; comparable physical settings in quarries never allow such close inspection.

Why the name Indian Ladder? Verplanck Colvin, one of the earliest men to write about the Helderbergs, in 1869 wrote:

"What is this Indian ladder so often mentioned? In 1710 this Helderberg region was a wilderness; nay all westward of the Hudson River settlement was unknown. Albany was a frontier town, a trading post, a place where annuities were paid, and blankets exchanged with Indians for beaver pelts. From Albany over the sand plains ... "Schenectada " (pine barrens) of the Indians ... led an Indian trail westward. Straight as the wild bee or the crow the wild Indian made his course from the white man's settlement to his own home in the beauteous Schoharie valley. The stern cliffs of these hills opposed his progress; his hatchet fells a tree against them, the stumps of the branches which he trimmed away formed the round of the Indian ladder."

The trail ended where the cliff did not exceed twenty feet in height. Here stood "the old ladder." In 1820 this ladder was still in daily use (Goldring, 1935). The modem stairway crosses the old Indian ladder road which ran to the top of the escarpment where the trail begins.

LOCATION

Figure 2 shows the location of the John Boyd Thacher State Park, where the Indian Ladder Trail reveals the vertical sequence of Lower Devonian limestones that rest unconformably on the Ordovician Indian Ladder beds and Schenectady Formation which can be seen, locally, in gullies below the escarpment (Fig. 3). Entering Thacher State Park from Albany on Route 157 stop at the "Cliff Edge Overlook" for a view of the Taconic and Berkshire Mountains, Adirondacks, Hudson River, and City of Albany; then drive to the next parking lot which has a sign La Grange Bush Picnic Area - Indian Ladder Trail. The trail is open from May 1 to November 1, weather conditions permitting. Descend here for study of the Lower Devonian carbonate fades. Examine also the memorial plaque near the cliff edge at the Mine Lot Creek parking lot which has been attached to a vertical rockwall. It says "in memory of those pioneer geologists whose researches in the Helderbergs from 1819 to 1850 made this region classic ground." The names of these pioneers have been cited under History.

THE SEQUENCE STRATIGRAPHIC COLUMN OF THE HELDERBERG GROUP

The cliff face exposes an excellent case history of sequence stratigraphy. Lower Devonian limestone of the Helderberg Group reveal sets of parasequences which may be recognized among the exposed formations (Rondout, Manhus, and Coeymans formations) (Fig. 3). Parasequences are the building blocks of vertical sequences. A parasequence is defined as a relatively conformable succession of genetically related beds bounded by surfaces (called parasequence surfaces) of erosion, nondeposition, or their correlative conformities (Van Wagoner, 1985). Each sequence is initiated by a eustatic fall in sea level rapid enough to overcome subsidence (Van Wagoner, 1985) or by epeirogenic upward motion. A parasequence surface commonly is an unconformity surface. Below the Indian Ladder Trail, where a waterfall known as Minelot Falls spouts across the path, sandstones and shales of the Middle Ordovician Schenectady Formation are mostly concealed beneath a cover of blocks of Devonian limestone forming a talus slope. At the waterfall, a major unconformity just below the trail separates the Ordovician strata from the Rondout Formation, exposed at the base of the cliff. The nonfossiliferous Rondout Formation is latest Silurian or earliest Devonian (Fisher, 1987). The rocks of this formation consist of brecciated dolostone cemented by gypsum. They display spectacular karst-generated solution-collapse features of the kind that hosts oil and gas in the subsurface. Evaporite minerals, now all dissolved, were present in this deposit. Note the concentration of springs which relates to the pore space created by ground-water dissolution of the evaporites.

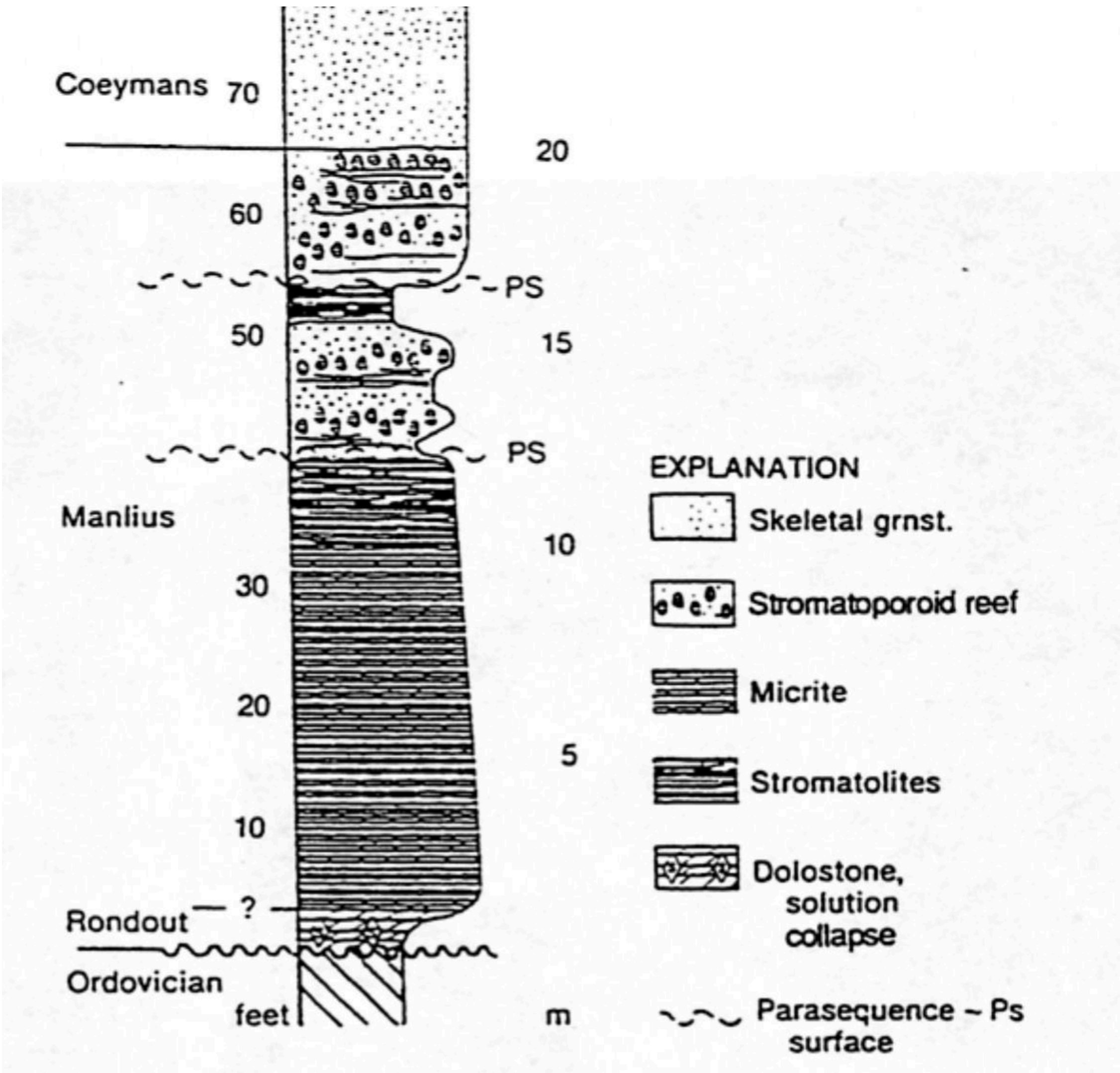


Figure 4a. Columnar stratigraphic section, parasequence surfaces, and facies distribution of the Lower Devonian carbonates. The Rondout Formation at the base is overlain by the Manlius Formation, and the top of the section extending to the break in slope at the top of the cliff is occupied by the Coeymans Formation. The stratigraphic section exposed on this trail is the type locality for the Thacher Member of the Manlius Formation, proposed by Rickard (1962). The Ordovician deposits at the base of the section are Indian Ladder beds- Schenectady Formation (see Fig. 3).

The Lower Devonian strata that crop out on the escarpment at John Boyd Thacher State Park illustrate the characteristics of marine parasequences in carbonate rocks (Figure 4). Two of the several parasequences are constituted as follows: a skeletal grainstone is overlain by stromatoporoid reefs and these, in turn, are overlain by interreef grainstone [interval between the upper PS (parasequence surface) and the scale mark for 20 m on Figure 4]. An underlying parasequence consists of skeletal grainstone that grades up into stromatolites (algal-laminated mudstone). Each of these two parasequences consists of strata that were formed when a depositional slope prograded seaward. The surfaces bounding the parasequences (labeled PS in Figure 4) are inferred to have resulted from rapid submergence. A set of several repeating parasequences, as shown in Figure 3, is known as a parasequence set, defined as "a relatively conformable succession of genetically related parasequences bounded by surfaces (called parasequence set boundaries) of erosion, non-deposition, or their correlative conformities."

Concepts identical to those just set forth, and developed independently of the definition of parasequence in seismic stratigraphy were formulated under the name of Punctuated Aggradational Cycles (PACs). What have been named PACs are thin (1-5 m) upward-shoaling cycles whose boundaries are defined by the depositional products of episodes of rapid submergence (Goodwin and Anderson, 1982).

OUTCROP GUIDE

Studies of vertical sequences should normally be worked from the base of the section upward. However, at this exposure it is best to work the section downward following the stairway from the edge of the cliff.

The top of the section is composed of skeletal grainstone (locally skeletal packstone) in which fossils, especially brachiopods, and crinoids, are evident (Fig. 4a); the pentamerid Gypidula coeymanensis is prevalent. This facies is part of the non laminated Coeymans Formation (Fig. 4b). Its lower contact is sharp and obvious in the field. Below this contact is the Manlius Formation which underlies most of this escarpment. A stromatoporoid reef with locally intercalated skeletal grainstone represents the top of this formation (Fig. 3). The stromatoporoids show their distinctive globular concentric structures resembling cabbage heads. Previous authors (Fisher, 1987; Rickard, 1962) have termed this reef facies a biostrome, presumably because its geometry in outcrop is sheetlike rather than mound- shaped. In my experience with reefs of all ages, I have observed that most large reefs are Hat on top and bottom, especially on the scale of this exposure. Other geologists share this experience, thus Shaver and Sunderman (1989) note "virtually all large reefs seen on outcrop have eroded, flattened tops, whereas smaller reefs that were not naturally aborted and that were unaffected by erosion as seen on outcrop have convex-upward rounded tops."

Figure 4b. This facies is part of the non laminated Coeymans Formation.

Close examination of the reef facies reveals a fine-grained matrix between the ramework-building stromatoporoids. This matrix resembles micrite, a lithified lime mud; hence this facies may be misinterpreted as representing a low-energy setting. However, in modern reefs, cement forms millimeters to centimeters beneath the living part which, in thin section, is finely crystalline (cryptocrystalline) and semi-opaque. Hence the matrix in such reefrock looks just like low-energy micrite (Friedman et al., 1974). Case histories abound where unwary geologists have confused high-energy reefrock with a supposed "low-energy" lime-mud facies (Friedman, 1975). Therefore, the observation of a fine-grained matrix between the framework builders does not deter, in fact confirms, the interpretation that this part of the section formed as a high-energy reef facies, and not in a low-energy setting. The stromatoporoids are massive which in the ecologic zonation of Devonian reefs represents the shallowest-water zone of a subtidal setting. Below the reef facies occurs a stromatolitic (finely laminated) facies which is recessed back creating a near cavelike morphologic feature (Fig. 5). This recessed feature can be traced throughout Thacher State Park and is known as "Upper Bear Path". By analogy with modem environments the stromatolitic facies represents a low-energy mtertidal or supratidal setting. The sharp contact between the intertidal or supratidal low-energy stromatolitic facies and overlying subtidal high-energy reef facies represents a parasequence surface (Fig. 4a).Downward from the stromatolites, a stromatoporoid reef facies is present, separated by bedded skeletal grainstone from the stromatolites.
in fact, the reef facies is present twice (Fig. 6). Hence downward the setting changes from intertidal or supratidal to subtidal shallow water. Below this double-reef section, the

change is again interpreted to be intertidal or supratidal stromatolites. Hence, once again, a parasequence surface separates the subtidal high-energy reef facies from the underlying intertidal to supratidal stromatolites (Fig. 4a). Interestingly, this stromatolitic facies is resistant to erosion (Fig. 6). and it projects outwards in the cliff face, whereas the upper stromatolite facies is recessed almost cavelike Below this lower stromatolite facies the lithology and facies are that of a low-energy, thin-bedded micrite with local

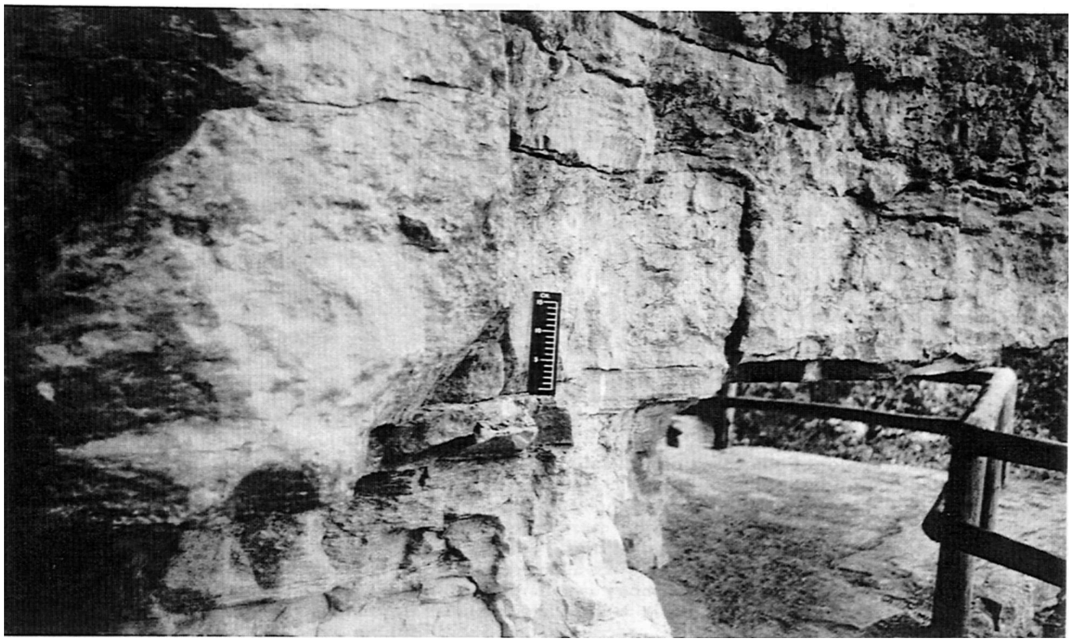


Figure 5. Photograph showing recessed underlying stromatolitic (finely-laminated) facies and overlying stromatoporoid reef facies of the Manlius Formation. Sharp contact between the two facies on which scale rests is parasequence surface (see Fig.4).

skeletal grainstone occurring as finely interbedded couplets, scour-and-fill structures, local cross-bedding, and some beds containing abundant spiriferid brachiopods, tentaculitids, ostracodes, and bryozoans. Near the base of the Manlius Formation occur several thicker beds, up to about 20 cm in thickness. Near the base of the section is the Rondout Formations, a recessed zone at the base of the cliff characterized by breciated carbonate rock cemented by gypsum. Its exact contact with the overlying Manlius Formation is subject to debate. In the columnar section (Fig. 4a) the Rondout Formation is identified where solution-collapse features are prominent and the lithology changes to dolomitic, especially dolomitic stromatolites, with sporadic intercalated calcitic laminae and shale laminae, an interpreted supratidal facies. Clasts of solution-collapse breccia are prominent together with gypsum-filled veins. The angular clasts of the collapse breccia may have resulted from collapse and brecciation of overlying carbonate strata when evaporites underlying them were dissolved. It represents a karst setting. Springs and caves, which are present here, are a function of dissolution of evaporites by groundwater. Karst- type openings were created during subaerial emergence. The Rondout Formation is commonly known as Rondout Waterlime. Its base is at or below the trail.

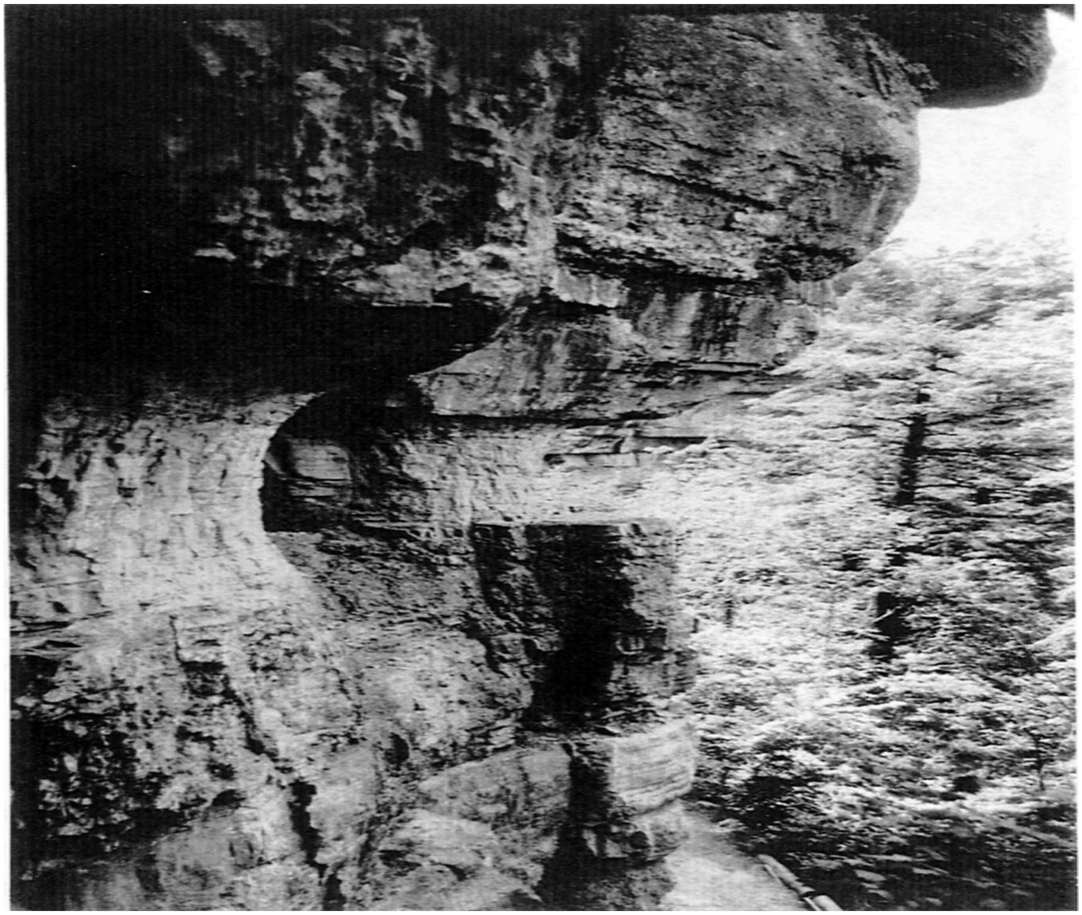


Figure 6. Photograph showing from top downward: massive projection reef separated by parasequence surface from underlying recessed stromatolites ("Upper Bear Path"). Below recessed stromatolite facies note in descending order bedded skeletal grainstone, non-bedded reef, bedded skeletal grainstone, reef, parasequence surface, and non-recessed stromatolite fades recognizable as a well-bedded fades. For detail compare with Figure 3.

THE ONONDAGA FORMATION

In John Boyd Thacher State Park the Onondaga Terrace (Fig. 3) exposes carbonate rocks of the Onondaga Formation which in the subsurface produces gas and serves as gas-storage reservoirs. Take Rt. 157 southwest to exit of park and continue to Indian Ledge Road (right turn-off before NY 85) (Fig. 1). Turn right on to Indian Ledge Road and drive 0.7 mile, park on right of road just above uppermost limestone outcrop. The outcrop exposes the Edgecliff Member of the Onondaga Formation. This limestone in not reefal. It is a skeletal limestone and ranges in this exposure from micrite to skeletal gramstone. Cnnoids and coral fragments are abundant. Of interest in this outcrop is the coarse-grained moldic facies in mid-section. Dissolution of fossils has led to high-porosity fades of a kind that would make excellent reservoirs for oil or gas. Decide for yourself whether this high-porosity zone continues into the subsurface or is only a surface feature. This porous facies vies in its porosity with the best of reservoir facies in the subsurface The accumulation of this coarse debris resulted from an episodic event, perhaps a storm or even a tsunami Note the prominent erosional surface which underlies this deposit (Fig. 7). Lindemann (1979) described the biofacies of this exposure.

Figure 7. Photograph of exposure of Onondaga Formation, Indian Ledge Road, Onondaga Terrace (Fig. 2). Note prominent erosional truncation on mid-section. High-porosity moldic storm coquinite overlies surface of truncation

Driving Directions To John B. Thacher State Park

You may use Google Maps to get the directions to John B. Thacher State Park, New Scotland, New York.

Park Information Telephone Number: (518) 872-1237

TRIP LOG

From: Syracuse University, NY 13202

To: John B. Thacher State Park, New Scotland, NY 12186

Total 139 Miles about 2 hours and 46 minutes.

1. Head north on Crouse Dr toward University Pl	0.4 mi
2. Take the 1st left onto University Pl	381 ft
3. Take the 1st right onto Irving Ave	0.3 mi
4. Turn left onto Harrison St	0.2 mi
5. Take the 1st right onto Almond St	59 ft
6. Merge onto I-81 N via the ramp on the left to I-690 W	4.2 mi
7. Take exit 25A to merge onto I-90 E toward Albany	
Toll road	89.4 mi
8. Take exit 29 toward US-10/Canajoharie/Sharon Springs	
Toll road	0.2 mi
9. Continue straight	
Toll road	0.2 mi
10. Turn left onto NY-5S E/E Main St	
Continue to follow NY-5S E	2.5 mi
11. Take the NY-162 N ramp	0.2 mi
12. Merge onto NY-162 S	13.8 mi
13. Continue onto New York 30A S	3.8 mi
14. Turn left onto New York 30A S/NY-7 E	1.1 mi
15. Turn right onto New York 30A S/Zicha Rd	
Continue to follow New York 30A S	1.2 mi
16. Continue onto NY-30 S	1.4 mi
17. Turn left onto NY-443 E	10.5 mi
18. Keep left at the fork	413 ft
19. Turn right to stay on NY-443 E/Helderberg Trail	3.4 mi
20. Turn left onto Co Rd 252/Thacher Park Rd	
Continue to follow Thacher Park Rd (157)	5.1 mi
21. Turn right onto John Boyd Thacher State Park	75 ft
22. Take the 1st right to stay on John Boyd Thacher State Park	0.3 mi
23. Continue to the main entrance to the Indian Ladder Trail	

REFERENCES

Cleland, H.F., 1930, Post-Tertiary erosion and weathering: American Jour. Sci., v. 19, p. 289-296.

Colvin, V., 1869, The Helderbergs: Harper's New Monthly Magazine, v. 39, p. 652-657.

Fisher, D.W., 1987, Lower Devonian limestones, Helderberg Escarpment, New York: Geol. Soc. America Centennial Field Guide, Northeastern Section, p. 119-122.

Friedman, G.M., 1985, The problem of submarine cement in classifying reefrock: an experience in frustration: p. 117-121 in Schneidermann, N. and Harris, P.M., eds.. Carbonate Cements, Soc. Economic Paleontologists and Mineralogists, Special Publ. No. 26, 379 p.

Friedman, G.M., 1990, Vertical parasequences of Lower Devonian limestone, Helderberg Escarpment: the Indian Ladder Trail at the John Boyd Thacher State Park near Albany, New York: Northeastern Geology, v.l2, p. 14-18.

Friedman, G.M.. 1991, The founders of American geology: a visit to their tombs, labs and their favorite exposures: The Devonian limestone of the Capital District; a study of sequence stratigraphy of these limestones: p. 55-70 in Ebert , J.R., editor. Field Trip Guidebook, New York State Geol. Assoc., 63rd Annual Meeting, 488 p.

Friedman, G.M., Amiel, A.J. and Schneidermann, N., 1974, Submarine cementation in reefs: example from the Red Sea: Jour. Sedimentary Petrology, v. 44, p. 816-825.

Friedman, G.M., Sanders, J.E., and Kopaska-Merkel, D.C., 1992, Principles of Sedimentary Deposits: Stratigraphy and Sedimentology. New York, Macmillan Publishing Company, 717 p.

Goldring, W., 1935, Geology of the Beme Quadrangle: New York State Museum Bulletin 303: 238 p., map scale 1:62,500.

Goldring, W., 1943, Geology of the Coxsackie Quadrangle: New York State Museum Bulletin 332, 374 p., map scale 1:62,500.

Goodwin, P.W. and Anderson, E.J., 1982, Punctuated aggradational cycles and carbonate facies, Helderberg Group (Lower Devonian), New York State, p. A-l to A-12 in Friedman, G.M., Sanders, J.E., and Martin, I.P., Sedimentary facies: products of sedimentary environments in a cross section of the classic Appalachian Mountains and adjoining Appalachian Basin in New York and Ontario: Eleventh International Congress on Sedimentology, Field Excursion Guidebook, McMaster Univercity, Hamilton, Ontario, Canada.

Goodwin, P.W. and Anderson, E.J., 1985, Punctuated aggradational cycles: a general hypothesis of episodic stratigraphic accumulation: Jour. of Geology, v. 93, p. 515-533.

Gumey, G.G. and Friedman, G.M., 1986, Transgressive-regressive cycles in vertical sequences: an example from Devonian carbonates in Cherry Valley, New York: Northeastern Geology, v. 8, p. 201-217.

Hall, J., 1843, Geology of New York. Part IV, Comprising the Survey of the Fourth Geological District: Can-oil and Cook Albany, New York, 683 p.

Laporte. L.F., 1967, Carbonate deposition near mean sea-level and resultant facies mosaic: Manlius Formation (Lower Devonian) of New York State: Am. Assoc. Petroleum Geologists Bull., v. 51, p. 73-101.

Laporte. L.F., 1969, Recognition of a transgressive carbonate sequence within an epeiric sea: Helderberg Group (Lower Devonian) of New York State: in Friedman, G.M., editor, Depositional environments in carbonate rocks, Soc. Economic Paleontologists and Mineralogists, Spec. Publ. No. 14, p. 98-119.

Lindemann, R.H., 1979, Stratigraphy and depositional history of the Onondaga Limestone in eastern New York; in Friedman, G.M., editor, p. 351-387, Joint Annual Meeting of New York State Geological Association 51st Annual Meeting and New England Intercollegiate Geological Conference 71st Annual Meeting, Troy, New York Guidebook for Field Trips, 457 p.

Lyell, C., 1845, Travels in North America in the Years 1841-1842; with Geological Observations in the United States, Canada, and Nova Scotia. Wiley and Putnam, New York: v. 1, 251 p. ,v. II, 221 p.

Lyell, C., 1849, Second visit to the United States of North America: Harper and Brothers, New York, John Murray London v. 1, 273p., v.2, 287p.

Mather, W.W., 1843, Geology of New York. Part 1, Comprising the Geology of the First Geological District- Carroll and Cook, Albany, New York, 653 p.

Rickard L.V., 1962, Late Cayugan (Upper Silurian) and Helderbergian (Lower Devonian) stratigraphy of New York- New York State Museum Bull. 386, 157 p.

Rickard L.V., 1975, Correlation of the Silurian and Devonian rocks of New York State: New York State Museum Map and Chart Series 24, 16 p.

Shaver, R.H. and Sunderman, J.A., 1989, Silurian seascapes: waterdepth, clinothems, reef geometry, and other motifs – A critical review of the Silurian reef model: Geol. Soc. America, v. 101, p. 939-951.

Van Wagoner, J.C., 1985, Reservoir facies distribution as controlled by sea-level change: Soc. Economic Paleontologists and Mineralogists, Abstracts, Annual Midyear Meetings, v. 11, p. 91.

Vanuxem, Lardner 1842, Geology of New York. Part III, Comprising the Survey of the Third Geological District- White and Visscher, Albany, New York, 306 p.