

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

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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 facies 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 facies 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 facies separated by unconformities representing transgressive episodes. The Middle Devonian Onondaga facies 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 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 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 sheriff's 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

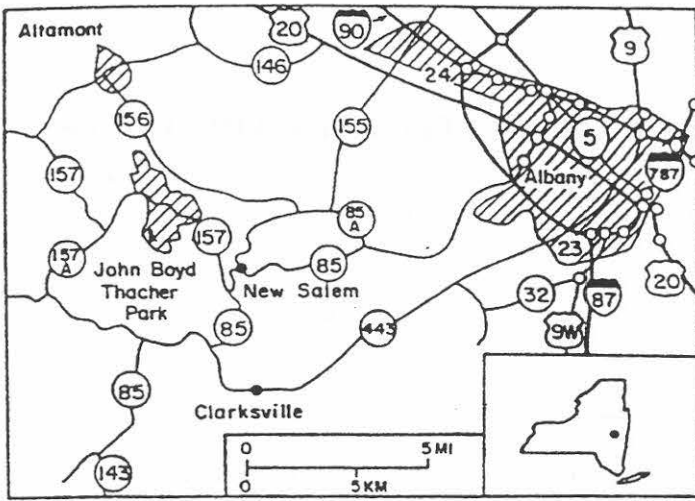


Figure 1A. Location of John Boyd Thacher-State Park (Fisher, 1987). The Indian Ladder Trail is located on Route 157.

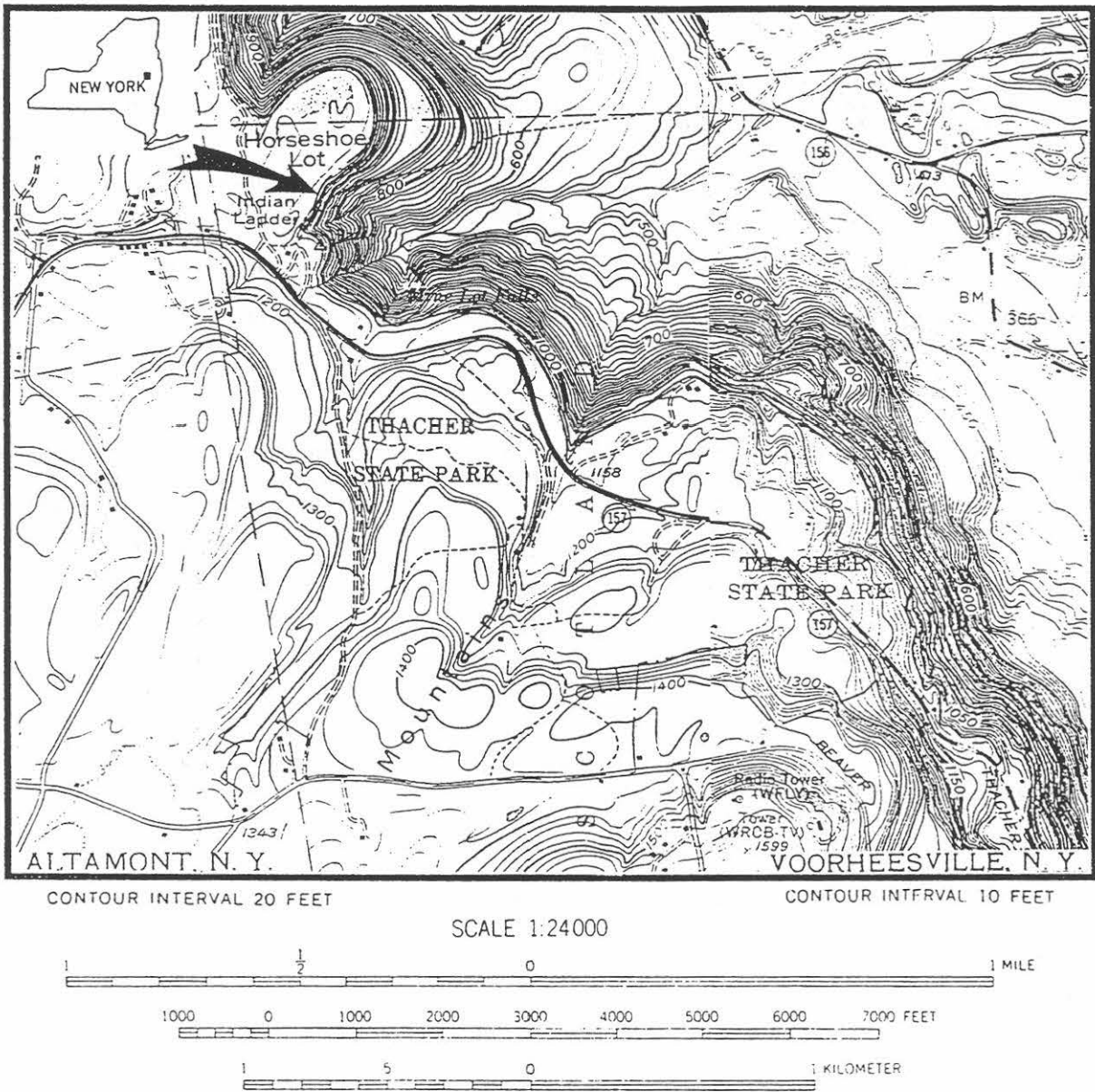


Figure 1B: Topographic map of John Boyd Thacher-State Parking showing location of Indian Ladder Trail.

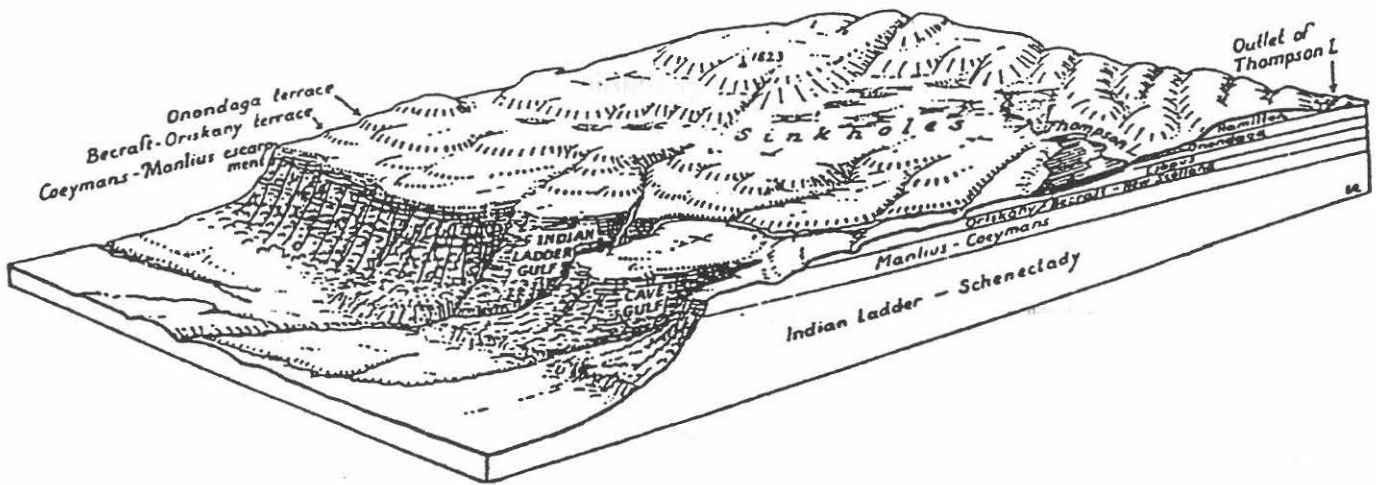


Figure 2. Block diagram of Helderberg Escarpment showing Indian Ladder location (labeled Indian Ladder Gulf), dip slope of Paleozoic strata, prominent terraces, and sinkhole topography (H.F. Cleland, 1930: modified by Winifred Goldring, 1935).

by the many volumes and papers by James Hall detailing stratigraphy and paleontology, followed in this century by many others, including Fisher (1987), Goldring (1935, 1943), Goodwin and Anderson (1982, 1985), Laporte (1967, 1969), Rickard (1962, 1975) Friedman, (1990;1991), and Friedman et al. (1992, p.180). Gurney and Friedman (1986) described vertical parasequences of Lower Devonian limestones as transgressive-regressive cycles in Cherry Valley, approximately 35 miles west of Thacher Park.

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 beautiful Schoharie valley. The stern cliffs of these hills opposed his progress; his hatchet fell 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 modern stairway crosses the old Indian ladder road which ran to the top of the escarpment where the trail begins.

LOCATION

Figure 1 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. 2). 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 facies. 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, Manlius, and Coeymans formations) (Fig. 2). 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 3 shows the columnar stratigraphic section, the 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).

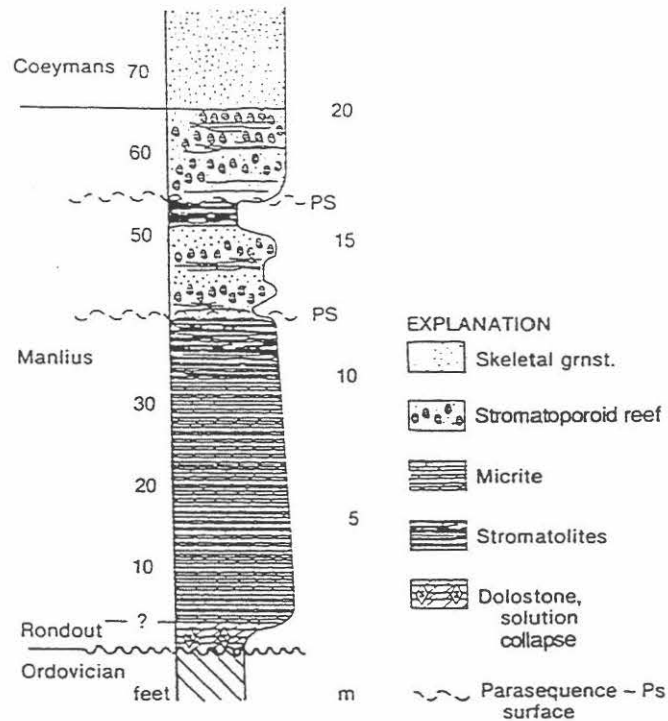
The Lower Devonian strata that crop out on the escarpment at John Boyd Thacher State Park illustrate the characteristics of marine parasequences in carbonate rocks (Figure 3). Two of the several parasequences are constituted as follows: a skeletal grainstone is overlain by stromatoporoid reefs and these, in turn, are overlain by interreef grainstone [interval between the upper PS (parasequence surface) and the scale mark for 20 m on Figure 3]. 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 3) 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.

Figure 3. 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. 2).



The top of the section is composed of skeletal grainstone (locally skeletal packstone) in which fossils, especially brachiopods, and crinoids, are evident (Fig. 3); the pentamerid *Gypidula coeymanensis* is prevalent. This facies is part of the Coeymans Formation. 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 flat 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."

Close examination of the reef facies reveals a fine-grained matrix between the framework-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. 4). This recessed feature can be traced throughout Thacher State Park and is known as "Upper Bear Path". By analogy with modern environments the stromatolitic facies represents a low-energy intertidal 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. 4). 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. 5). 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. 3). Interestingly, this stromatolitic facies is resistant to erosion (Fig. 5), 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

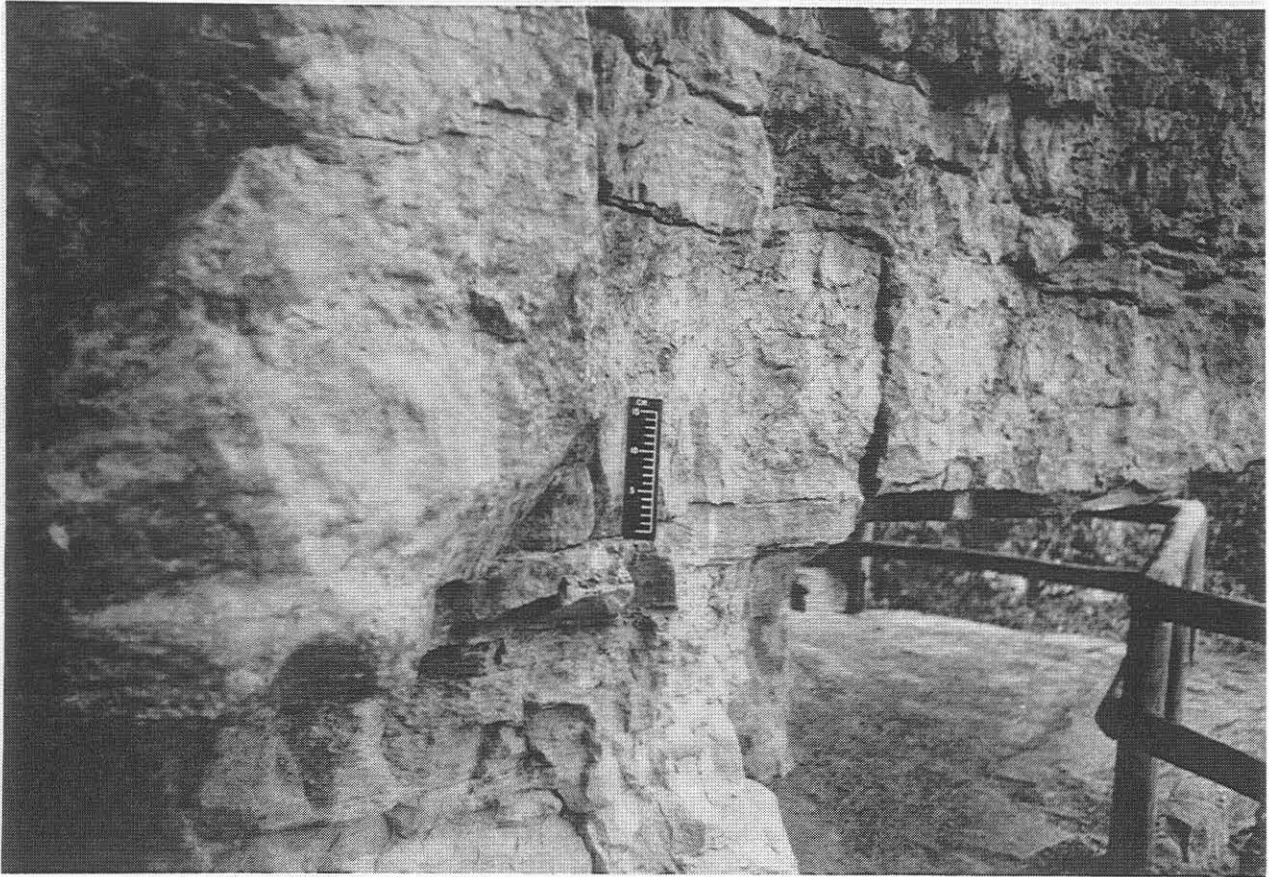


Figure 4. Photograph showing recessed underlying stromatolitic (finely-laminated) facies and overlying stromatoporoid reef facies of the Manlius Formation. Sharp contact between the two facies on which scale rests is parasequence surface (see Fig. 3).

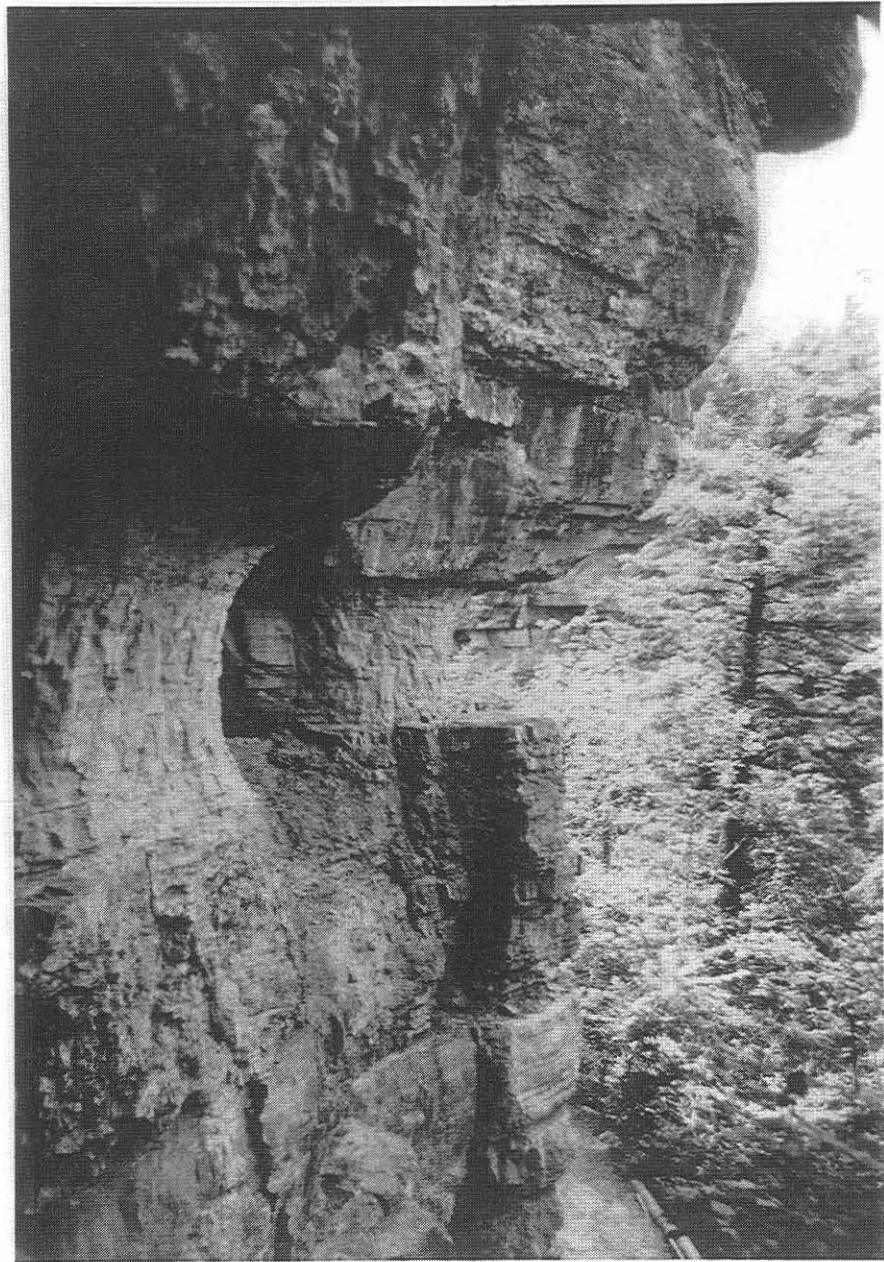
skeletal grainstone occurring as finely interbedded couplets, scour-and-fill structures, local cross-bedding, and some beds containing abundant spiriferid brachiopods, tentaculitids, ostracodes, and bryozoans. Near the base of the Manlius Formation occur several thicker beds, up to about 20 cm in thickness.

Near the base of the section is the Rondout Formations, a recessed zone at the base of the cliff characterized by brecciated carbonate rock cemented by gypsum. Its exact contact with the overlying Manlius Formation is subject to debate. In the columnar section (Fig. 3) 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.

THE ONONDAGA FORMATION

In John Boyd Thacher State Park the Onondaga Terrace (Fig. 2) 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.

Figure 5. 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, nonbedded reef, bedded skeletal grainstone, reef, parasequence surface, and non-recessed stromatolite facies recognizable as a well-bedded facies. For detail compare with Figure 3.



This limestone is not reefal. It is a skeletal limestone and ranges in this exposure from micrite to skeletal grainstone. Crinoids 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 facies 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. 6). Lindemann (1979) described the biofacies of this exposure.



Figure 6. 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.

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