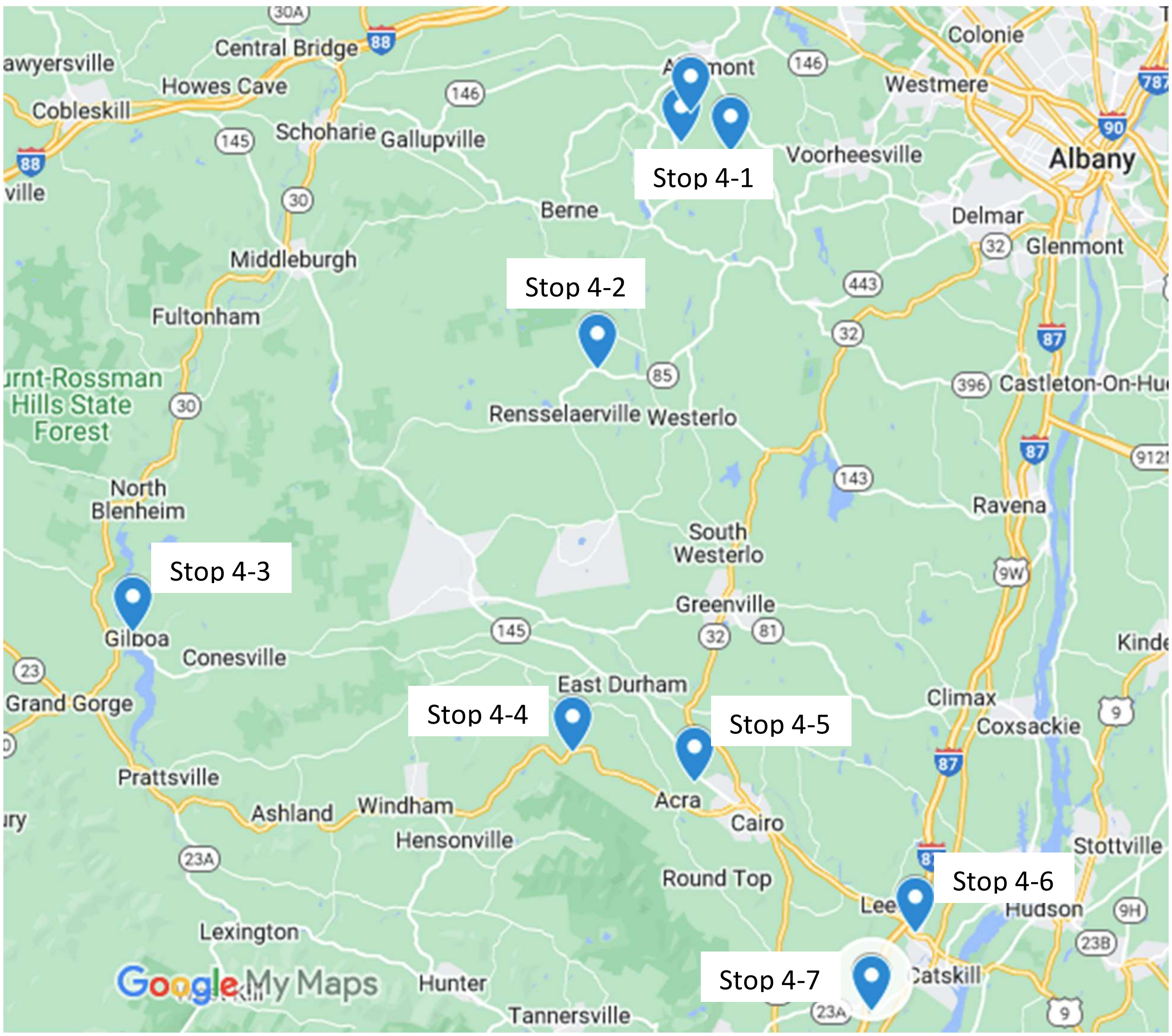
Field Trip Day 4 – 8/5/2023

Stop 4-1a	Thacher Park – Visitors' Center
Stop 4-1b	Thacher Park – Carrick Road Quarry
Stop 4-1c	Thompsons Lake Reef
Stop 4-2	Shell Inn Quarry
Stop 4-3	Gilboa Museum
Stop 4-4	East Windham Cuts
Stop 4-5	Cairo Town Highway Department Quarry
Stop 4-6	Rte. 23 Cuts
Stop 4-7	Rte. 23A Abandoned Thruway Exit Cuts



Howe's Caverns to Thacher Park:

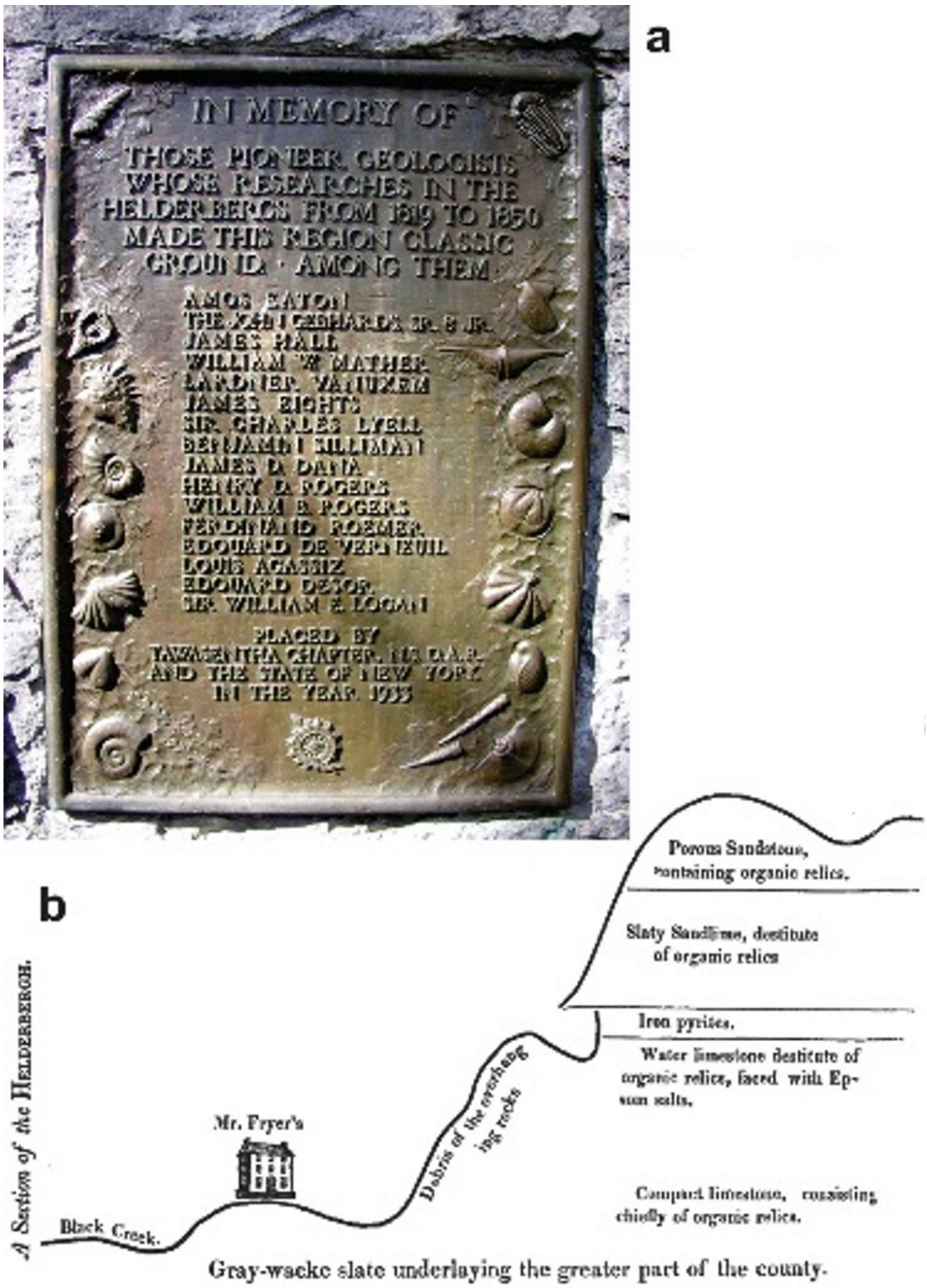
0.0 mi	Head southeast on Discovery Dr.
0.68 mi	Turn Left onto Caverns Rd.
0.27 mi	Stay Left to stay on Caverns Rd.
1.19 mi	Slight Left to stay on Caverns Rd.
259 ft	Turn Left onto NY-7 E
4.62 mi	Turn Right onto NY-30A S
1.1 mi	Continue onto NY-30 S
1.5 mi	Turn Left onto NY-443 E
5.18 mi	Turn Left onto Sholtes Rd.
1.1 mi	Turn Right onto Knox Rd.
1.66 mi	Continue onto Knox-Gallupville Rd.
2.15 mi	Slight Left to stay on Knox-Gallupville Rd.
260 ft	Continue Straight onto NY-156 E
3.15 mi	Turn Right onto NY-157 E
1.78 mi	Turn Left onto Ketcham Rd.
1.66 mi	Turn Left onto NY-157 E
0.45 mi	Turn Left onto Hailes Cave Rd. into Thacher Park
180 ft	Turn Right into Visitor Center Parking Area

Thacher Park:

Stop 4-1a: John Boyd Thacher State Park
Stop Author: Ver Straeten
Stop Leader: Ver Straeten

Location: John Boyd Thacher State Park, western Albany County

Introduction:
In 1820, pioneering geologist Amos Eaton (1776-1842) published a first geological survey of Albany County, New York (Eaton, 1820). The report concludes with an early cross-section of the rise from the valley below to the Indian Ladder cliffs, in what is now John Boyd Thacher State Park (Text-fig. 4-1a.1b).



Text-fig. 4-1a.1: a: Plaque listing names of important 19^{th} century geologists and paleontologists who visited and worked in the Helderbergs. b) 1820 cross-section from valley below Indian Ladder Cliffs to the top of the cliffs by Amos Eaton.

Beginning in the late 1830s, Albany, New York became a very significant North American center for geological and paleontological research. This was associated with the scientific efforts of the New York State Geological Survey/State Museum, most notably the geologist and paleontologist James Hall. In 1856, Louis Agassiz said: "*The Geological Survey of New York has given a new nomenclature to science. Hereafter no geologist can venture to bring his theories* *before the world unless he first consult its beautiful volumes. When European men of science come to this country their first question is: 'Which way is Albany?'*" (Clarke, 1923, pp. 320-321).

A visit to the geologists and collections at the New York State Museum in the mid to late 19th century was soon accompanied by a horse or buggy/wagon ride to the well exposed and highly fossiliferous Lower to Middle Devonian rocks of western Albany County, in the Helderberg escarpment and hills. A plaque in the park notes a number of the significant geologists/paleontologists who made the trip to the Helderbergs in the mid to late 19th century (Text-Fig. 4-1a.1a).

As early as 1841 the "father of modern geology", Sir Charles Lyell of England, made his first of visits to New York and its geologists. Mrs. Chris Hartnagel, wife of an early 20th Century New York State Geologist, wrote that Lyell said "*The Helderberg outcrops must be known to every geologist if he were to understand his science*." (Hartnagel, 1936).

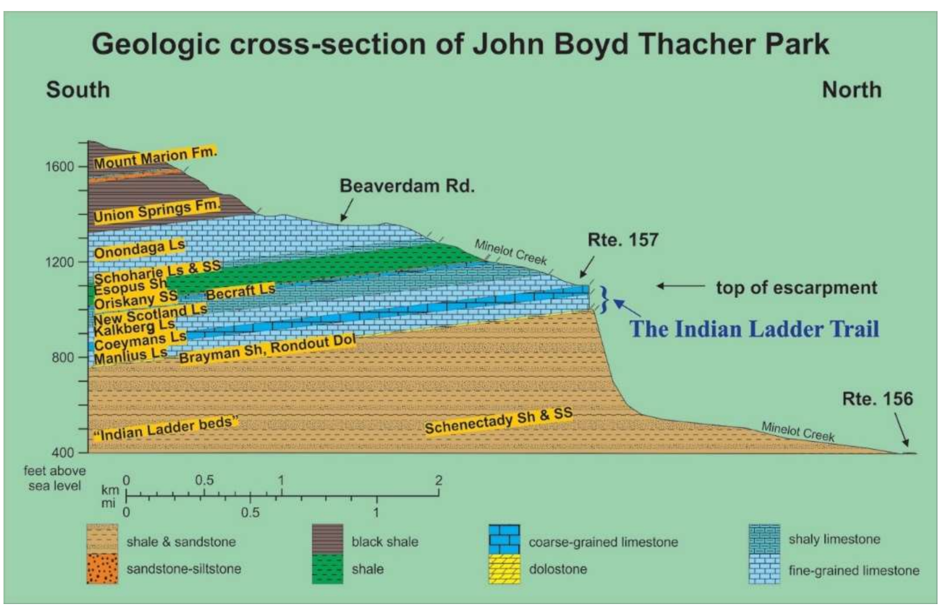
The Helderberg rock outcrops Lyell spoke of are the cliffs and hills of Helderbergs,. Most of the Helderberg rocks are from the Devonian Period, from about 420 to 390 million years old. Historian and politician John Boyd Thacher of Albany, while traveling in Europe in the late 19th or early 20th centuries, heard so much about the Helderbergs and their rocks and fossils from Europeans that he decided to preserve a portion of the famous cliffs and hills for their "natural beauty and extraordinary scientific interest".

Since the 1840s, the Helderbergs and today's Thacher Park were and remain the site of many visits by geologists and paleontologists - from the state, the region, and around the world. It can be considered to be "hallowed ground", geologically and paleontologically. New York State Paleontologist Winifred Goldring wrote a guide to the classic geology and paleontology of John Boyd Thacher State Park (Goldring, 1933).

John Boyd Thacher State Park in western Albany County comprises 2,155 acres (872 hectares; 8.7 km^2/3.4 mi^2) of the Helderbergs, with extensive forests, ravines, cliff escarpments and sometimes broad flats. Most of the park is free of Pleistocene and recent sediment cover beyond thin soils, leaving extensive bedrock exposures. Rocks exposed in lower parts of the park, below the famous Indian Ladder cliffs (Text-Fig. 4-1a.2), are Late Ordovician synorogenic shales and sandstones derived from the Taconic Orogeny. These are overlain by a "Taconic Unconformity, which is overlain by latest Silurian supratidal to tidal facies (Rondout and most of the overlying Manlius limestone formations). The Silurian-Devonian boundary is currently interpreted to occur in the middle of the Indian Ladder cliffs, in the upper Manlius Formation (Ebert and Matteson, 2023). Overlying limestones of the latest Pridoli to Lochkovian Helderberg Group are well exposed through parts of the park. Units, low to high, are the Manlius, Coeymans, Kalkberg, New Scotland and Becraft formations (Text-fig. 4-1a.3). Overall, their litho- and biofacies outline a tidal (Manlius) to deep ramp transgression (New Scotland), followed by regressive shallowing back to shoal (Becraft). Overlying Helderberg strata seen to the south in New York are absent here at the Slossian supersequence-scale Wallbridge Unconformity (Sloss, 1963), overlain by fossiliferous quartz arenites of the upper Pragian Oriskany Sandstone Formation.

Text-fig. 4-1a.2: Indian Ladder cliffs at Minelot Falls, Indian Ladder Trail, John Boyd Thacher State Park.

Overlying lower Emsian shales and silty mudstones with fine-grained sandstone sequence caps comprise the Esopus Formation, which are succeeded by mixed siliciclastic and carbonate strata of the upper Emsian Schoharie Formation. The Esopus Formation is best exposed in the gorge of Mine Lot Creek, where numerous thrust faults complexly cut through the succession.



Text-fig. 4-1a.3: Geologic cross-section of John Boyd Thacher State Park. Lower part on right is the same as Eaton's cross-section of 1820 (Text-fig. 4-1a.1b)

A second major carbonate, higher in the park, is the Middle Devonian (lower Eifelian) Onondaga Limestone. It is the highest major limestone in New York, correlative with same-age limestones from southeastern Quebec to the Illinois Basin in the U.S. Midwest. Highest strata in the park belong to the Marcellus subgroup, in the lower part of the classic Hamilton Group. A thick succession of black "Marcellus Shale" facies (Bakoven Member, Union Springs Formation) climbing up the southern slopes of Thacher Park pass into a gradation of more calcareous strata, culminating in the central Marcellus limestone-dominated strata of the Hurley and Cherry Valley members (Mount Marion Formation). Highest strata in the park are uppermost Eifelian shales (East Berne Member). The Eifelian-Givetian boundary occurs not far above the southern Thacher Park boundary, higher up on the southern slopes of the park.

This trip to Thacher Park will first go to the Visitor Center, where some exhibits examine mostly Lower to lower-Middle Devonian-related topics, accompanied by a short walk to a plaque honoring major 19th century geologists and paleontologists who visited the Helderberg Plateau/Hills, including Sir Charles Lyell, James Hall, Louis Agassiz, and others. We will then drive to an old quarry in the park, followed by a stop at an Onondaga Limestone coral reef (Thompsons Lake reef of Oliver 1956b), immediately adjacent to the park.

The John Boyd Thacher State Park Visitor Center opened in 2017. Exhibits on the geology and paleontology of the park were produced by Moey Inc., an exhibits design and production company; a number of their staff came from the American Museum of Natural History in New York City. They worked with geologists Chuck Ver Straeten and Thom Engel on exhibit planning and obtaining specimens, who know the park's geology and paleontology from long and detailed experience.

The plaque (Text-fig. 4-1.1a) noting significant mid to late 19th century geologists and paleontologists who visited +/- studies strata of the Helderbergs was placed by the Daughters of the American Revolution organization near the west end of the famous Indian Ladder Trail. The trail eastward from the plaques platform passes below the approximately 30 m (100 ft) high cliffs, passing through the Rondout, Manlius Coeymans, and in some areas the Kalkberg formations. These strata represent supratidal to tidal to shoal facies, respectively, low to high. Ebert and Matteson (2023) interpret the Silurian-Devonian boundary to occur in the upper part of the Green Vedder Member, upper part of the Manlius Formation, or closer to the overlying contact with the Coeymans Formation.

0.0 mi	Exit Thacher Park Visitors' Center Parking area. Turn Right onto NY-157 W.
0.54 mi	Turn Right onto Ketcham Rd.
1.66 mi	Turn Right onto NY-157 W
0.54 mi	Slight Right onto Old Stage Rd.
0.74 mi	Turn Right onto Carrick Rd.
0.35 mi	Pull into Carrick Rd. parking area.

Stop 4-1b: Carrick Road quarry, John Boyd Thacher State Park

The Carrick Road quarry, in the northwest part of Thacher Park, features a broad platform on the top of the Oriskany Sandstone (Text-fig. 4-1b.1), interpreted to be upper Pragian. The surface is covered by the swirls of *Zoophycos* ichnofossils. Chunks of the Oriskany Sandstone, with its classic "Big Shell Community" of Boucot and Johnson (1967), can be found in spoil piles around the site; however, collecting in not permitted in the state Park.

Text-fig. 4-1b.1: Large *Zoophycos* trace fossil on top surface of Oriskany Sandstone at Carrick Road Quarry.

In one area of the quarry, a roughly 2.5 m-high wall exposes the Oriskany Sandstone and the underlying Becraft Limestone formations. Some degree of subtle relief is seen at their contact. This is the Slossian supersequence boundary of the Wallbridge Unconformity, notably below the Oriskany Sandstone. Some Appalachian geologists still mistakenly think that the Wallbridge Unconformity overlies the Oriskany. The upper surface of the Oriskany or its correlative limestone facies (Glenerie Limestone in New York) is a major flooding unconformity, marking a significant sediment-starved surface during a major lower Emsian transgression (Devonian Depositional Sequence Ib1/Ems-1; Ver Straeten 2007, 2009, 2023). Especially in areas of the central Appalachian Basin, significant authigenic phosphate, glauconite and hematite deposits occur at this surface, formed during the time of strong sediment starvation over the top of the Oriskany Formation and correlative strata.

The Becraft Limestone in the lower part of the wall, is highly fossiliferous, with abundant crinoidal columnals and other parts, along with abundant brachiopods (Text-fig. 4-1b.2) Notably, many of the fossils are silicified. The timing of this replacement is not known. However, lowermost strata of the Esopus Formation, overlying the Oriskany Sandstone, features multiple altered air fall volcanic tephras, the Sprout Brook Tephras cluster (Ver Straeten, 2004a,b). Volcanic "ash", essentially silica glass/pumice shards formed from busting of gas bubbles as silicic magma rushes up through the neck of a volcano, in not stable under surface conditions on earth. The "devitrification" of the glass shards, alters the glass to clays, releasing large amounts of dissolved silica. This may be the source of the silica which replaced the original calcite of the fossil material here. Note also the sedimentary structures in the Becraft, indicative of the high energy setting of Becraft shoal facies.

Text-fig. 4-1b.2: Becraft Formation in lower wall below Wallbridge Unconformity. Coarse shell material and sedimentary layers imply dynamic, high-energy environment.

Carrick Rd. Quarry to Thompsons Lake:

0.0 mi	Head west on Carrick Rd. toward Old State Rd.
0.35 mi	Turn Left onto Old Stage Rd.
0.74 mi	Slight Left onto NY-157 E
0.54 mi	Turn Left onto Ketcham Rd.
902 ft	Pull over on Right side of Rd. Outcrop is across the road.

Stop 4-1c: Thompsons Lake reef
Stop Author: Ver Straeten
Stop Leader: Ver Straeten

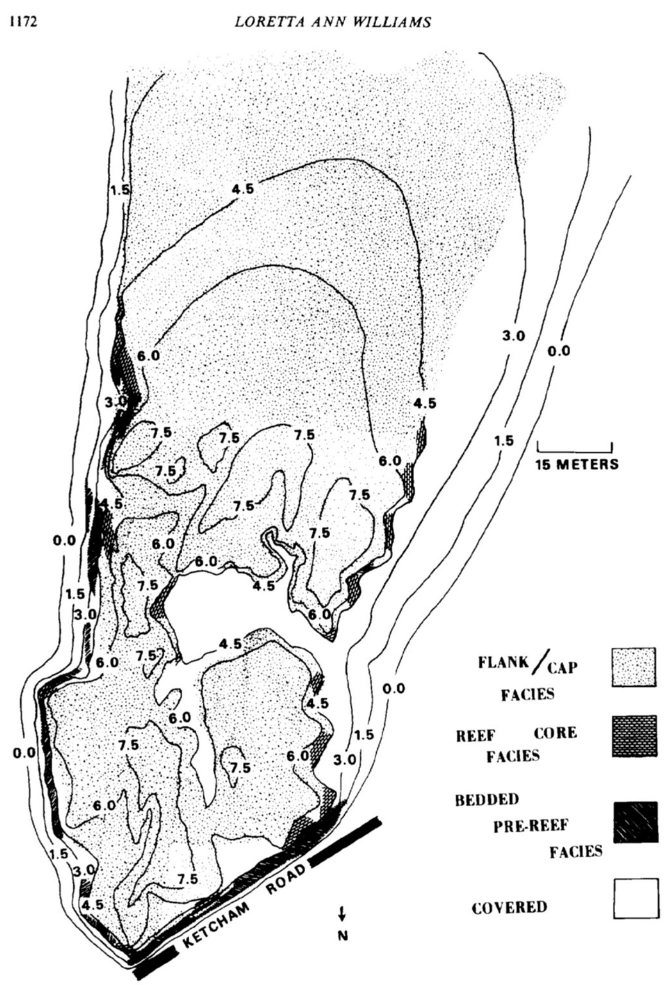
Locality: Outcrop along the north side of Ketcham Road. Visitation allowed only by permission of owner. Collecting is not allowed.

Unit: Lower Onondaga Formation, Edgecliff Member.

Description: The Thompsons Lake reef is one of a number of coral reefs in the Edgecliff Member, lower part of the lower Eifelian Onondaga Formation, in eastern New York (Oliver, 1956b; Text-fig. 4-1c.1). It occurs on private property, immediately adjacent to a part of Thacher Park, in the Town of Knox, western Albany County. The north end of the reef is visible on the south side of Ketcham Road. It forms an elongate bedrock hill that is overall elliptical is shape, with a south-southwest/north-north east orientation (Text-fig. 4-1c.2). Williams (1980) reports a length- and width of 150 m by 70 m; relief on the structure is up to nine meters relative to

Text-fig. 4.1c.1: Corals from the Thompsons Lake Reef.

Ketcham Road, but she states that reef thickness is no more than 4.5 m across the structure. The upper surface of the reef is knobby, partly related to erosion over the surface. However, Wolosz (1992) supported by Oliver's (1956b) observation of knobs of reef rock across the top of the reef, also noted the presence of separate coral mounds within the Thompsons Lake reef structure. He interpreted this to be indicative of patch-reef type development within the hill of the Thompsons Lake reef. Based on sedimentologic data, Williams (1980) interpreted the geometry of the structure to reflect the original depositional history of the reef; and that the preserved surface is likely close to the original top of the reef. The current author notes that lidar imagery of the area shows that the orientation of the Thompsons Lake reef structure is directly parallel to the trend of broadly adjacent glacial drumlins around it. The parallel alignment of the features may be coincident, or there may be more glacial erosion modification of the reef hill that previously recognized.



Text-fig. 4-1c.2; Figure 3 of Williams, 1980. "Isopachous map of Thompsons Lake reef, with superimposed facies relations. Map is contoured at 1.5 meter intervals above the top of the Schoharie Formation.

Toward the east side, Oliver (1956b) reported that on the east side of the hill, the reef gradually transitions southward to normal bedded Edgecliff facies across the southern slopes of the structure. These beds are visible in an old abandoned quarry farther south on the property.

Older, traditional views of the Onondaga reefs in eastern and western New York formed under tropical conditions. However, multiple lines of evidence point to a warm temperate climate during deposition of the Onondaga Limestone (in sharp contrast with the overlying Union Springs Formation, with its more equatorial Stony Hollow fauna, found in Manitoba and Saskatchewan, Canada during Onondaga time; Koch and Boucot, 1982).Wolosz and Paquette (1995) pointed out: 1) stromatoporoids and calcareous algae, associated with warm water conditions, are rare in Edgecliff reefs in New York, and more so in eastern New York; 2) Isotopically heavy δO^{18} values suggested relatively cooler water conditions; 3) faunal taxa patterns from Koch and Boucot (1982, brachiopods) and Blodgett et al., (1988) gastropods, absence of stromatoporoids and algae) were separately interpreted to indicate cooler water temps. This evidence strongly suggests that the Thompsons Lake reef, and other Edgecliff Member reefs, formed under warm temperate water conditions.

Other lines of evidence have pointed out to various researchers that the Thompsons Lake reef structure formed in shallow marine water, including Williams (1980), Wolosz (1992), and Wolosz and Paquette (1995). Sedimentologic evidence of currents, normal wave activity, storm activity within the reef, and coarse-grained crinoids grainstones in the normal background Edgecliff Member in the area strongly support a shallow water setting for the Thompsons Lake reef (the current author also wonders about the impacts of small-scale, Milankovitch-band cyclicity on development of this shallow water reef). Williams (1980) suggested that the reef formed in waters less than 20 m in depth, in what she termed a "shallow, open water carbonate shelf. In modern terms, this may be more interpreted to be on the shallow portion of a carbonate ramp; which based on evidence from Oliver (1956a), Williams (1980), Wolosz (1992) and Wolosz and Paquette (1995) sloped gradually downward from the area of the Thompsons Lake reef to the south and to the west. Wolosz (1992, p. 11) states: "*The Thompson's Lake bioherm mounds are located north- west of the New Salem reef (a successional mound) and due north of a (no longer accessible) coral-rich (reef) exposure at the southern end of Thompson's Lake (reference in Goldring, 1935, p. 144), which suggests that these small mounds grew in a shallow-water environment landward of larger reef structure*."

The base of the Onondaga Limestone is coincident with a major, 3rd order depositional sequence, alternately termed Devonian Sequence Ic or Eif-Giv. Edgecliff reef formation in eastern and western New York was initiated in the early stages of the Ic/Eif-1 lowstand or basal transgressive systems tract.

In summary, studies indicate that the Thompsons Lake reef, in the Edgecliff Member, lower part of the lower Eifelian Onondaga Limestone, formed as a patch reef, under warm temperate water conditions, in a shallow carbonate marine setting. Initiation of reef construction occurred at or proximal to the basal lowstand or basal transgression of Devonian Sequence Ic/Eif-1.

Further details of this reef structure, including its stages of development and construction, are available in the references above, and references within them.

Thompson's Lake Reef to Shell Inn Quarry:

0.0 mi	Turn around and head west toward NY-157 W. Turn Left onto NY-157 W.
1.73 mi	Slight Right onto NY-157A W
253 ft	Slight Right onto NY-157A W
2.5 mi	Turn Right onto NY-443 W
0.74 mi	Turn Left onto Cole Hill Rd. Note type section of East Berne Mbr. of the Mount Marion Fm. and Halihan Hill Bed (units exposed at Stop 5-3) at town Highway Dept. going uphill.
4.8 mi	Continue onto Switzkill Rd.
0.97 mi	Turn Right onto NY-85 W
2.11 mi	Turn Right into Shell Inn and park on west end of parking lot. Carefully cross road and walk up driveway into quarry.

Stop 4-2: Shell Inn Quarry
Stop Author: Bartholomew
Stop Leader: Bartholomew, Ver Straeten

Locality: Quarry across the road and uphill from the Shell Inn, northeast of Rensselaerville. State Rte. 85 42.53952, -74.11558

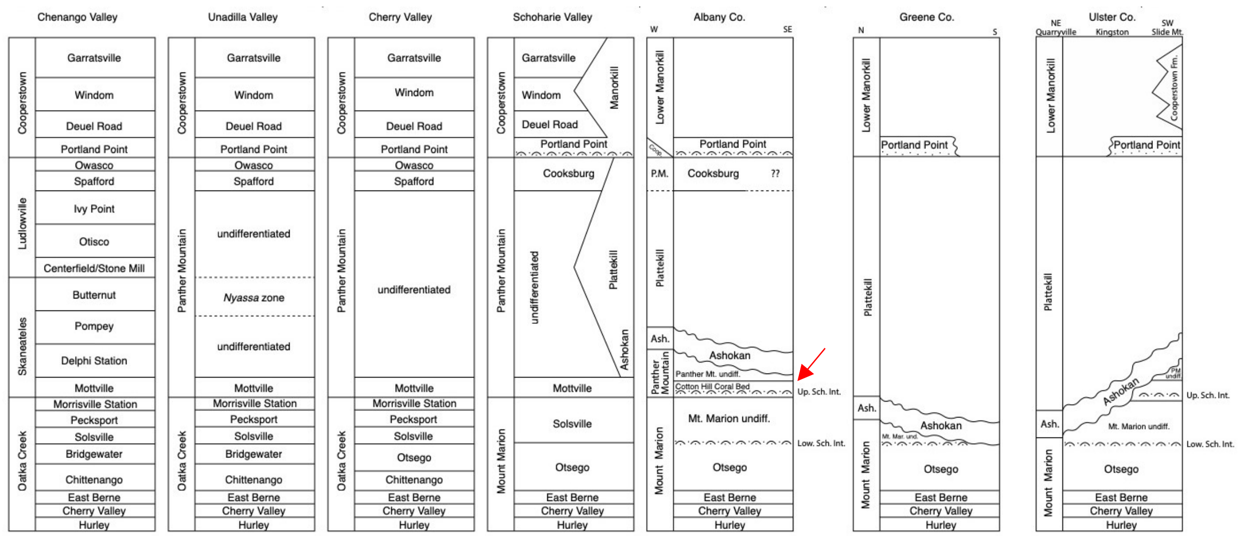
Units: Cotton Hill Coral Bed at base of Panther Mountain Formation, hypothesized to be equivalent to the Mottville interval at the base of the Skaneateles Formation to the west.

Reference: Brett, C.E., and Landing, E, 1988

Description: This small quarry (Text-fig. 4-2.1), across the road to the south of the Shell Inn along Rte. 85 ~3.2 km (2 mi) northeast of Rensselaearville, exposes ~6.5m of Middle Devonian (lower Givetian) strata, including the Cotton Hill Coral Bed (named for exposure along Cotton Hill Rd., west of Middleburgh, about 15.25km to the northeast of the Shell Inn Quarry), an anomalous rugose and tabulate coral-rich interval within the thick clastic-dominated succession of the lower to middle Hamilton Group in eastern New York State. Previously suggested by Brett and Landing (1988) to represent the "Meristella Coral bed" (now Halihan Hill Bed) of the Mount Marion Formation, this bed has recently been interpreted (Bartholomew and Ver Straeten, 2023) to represent the interval at or just above boundary of the Eif/Giv and Giv 1 (Ie-If) depositional sequences, marking locally the base of the revised Panther Mountain Formation, roughly equivalent to the Mottville/Stafford interval at the base of the Skaneateles Formation in central and western New York State (Text-fig. 4-2.2).

Tex-fig. 4-2.1: View of Shell Inn Quarry looking west.

Beginning about 6m above the level of Rte. 85, the lowest exposed beds are jointed 'bluestone', homogenous, fine-grained quartz arenite with rippled tops. Above this is about 4m of highly fossiliferous dark grey, brown-weathering silty shales and siltstones with small sideritic/ankeritic nodules. This unit contains abundant brachiopods including *Tropidoleptus*, *Spinocyrtia*, small productids, and chonetids, along with fenestellid and *Taeniopora* bryozoa, crinoid ossicles, and bivalves including *Ptychopteria*, *Grammysia*, and *Goniophora*. About 1.5m above the base of the exposure is the coral-rich interval dominated by large rugose corals including *Cystiphylloides* and *Heliophyllum* (Text-fig. 4-2.3), along with scattered heads of *Favosites*, some of which are quite large (>0.75m across). Above the coral-rich interval are more silty shales and siltstones with a dwindling fauna of brachiopods and bivalves, capped by sparsely fossiliferous, flaggy siltstones that are rather pyritic with rare carbonized plant fragments.



Text-fig. 4-2.2: Stratigraphic correlation chart for the Hamilton Group (minus the strata of the Union Springs Formation, the lowest strata of the Hamilton Group) from the Chengango Valley in the west to Albany County in the east and then south to Ulster County. The Cotton Hill Coral Bed exposed here at the Shell Inn Quarry (marked by the red arrow) is interpreted to be the local manifestation of the basal Panther Mountian/Skaneateles formation transgressive interval. Note that to the east and south this interval is correlated to the upper of the two *Schizophoria*-rich intervals.

Overall, this section records a major deepening and subsequent shallowing in the shallow-water, siliciclastic dominated facies of eastern New York State. This outcrop is the easternmost known occurrence of a coral-rich horizon within the Hamilton Group above the Halihan Hill Bed lower down in the Mount Marion Formation, representing a major sediment starvation event in the eastern facies area allowing for the colonization of the sea floor by the abundant rugose and tabulate corals. Of note are the presence here of the abundant rugose and tabulate corals, along with abundant small productids and large *Tropidoleptus* brachiopods, and associated large crinoid columnals, that form a distinctive association that marks the Mottville interval farther to the west and can be traced eastward from Otsego County, along with the distinctive large brachiopod *Paraspirifer* (notably absent here). Further east, this interval is correlated with an interval rich in the rare brachiopod *Schizophoria* (with rare *Paraspirifer* in one locality), along with the common small productids, large *Tropidoleptus*, and large crinoid columnals, offering tentative correlation of the base of the Panther Mountain Formation into southern Albany and northern Greene Counties and perhaps southward into eastern Ulster County as well.

Text-fig. 4-2.3: Cotton Hill Coral Bed fossil picture composite (hammer head ~14 cm long.) A, B, *Favosites* sp. (Lamarck, 1816) from Shell Inn Quarry. C, Nuculid bivalve nestled into the calyx of a *Cystiphylloides* (Edwards and Haime, 1851) coral from Cotton Hill Quarry, (actual size). D, E, *Cystiphylloides americanum* (Edwards and Haime, 1851) from Shell Inn Quarry, (scale bar in D is 2 cm.) F, Two *Cystiphylloides americanum* corals growing off a *Favosites* sp. coral, Cotton Hill Quarry. G, *Cystiphylloides americanum* in life-position in Cotton Hill Quarry. From Bartholomew and Ver Straeten, 2023, with permission of PRI.

Shell Inn Quarry to Gilboa Visitor's Center:

0.0 mi	Leave Shell Inn parking lot. Head west on NY-85 W
2.41 mi	Turn Right onto Albany Co. Rte. 353/Delaware Tpk.
4.83 mi	Continue onto Hauverville Rd.
3.37 mi	Turn Right onto NY-145 N
0.675 mi	Slight Left onto Stone Store Rd.
1.79 mi	Turn right to stay on Stone Store Rd. at Federal City
2.5 mi	Turn Left onto Keyserkill Rd.
0.9 mi	Turn Right onto Flat Creek Rd.
2.5 mi	Turn Left onto Back Rd.
2.8 mi	Continue onto Wyckoff Rd.
1.38 mi	Slight Right onto NY-990V W. NYC Drinking water Schoharie Reservoir on left.
0.9 mi	Cross Schoharie Creek. Famous Riverside Quarry was to left.
0.1 mi	Turn Right onto Stryker Rd. Gilboa Museum immediately on right.

<u>Stop 4-3: Gilboa Museum and Gilboa Forest</u>

Stop Author: Ver Straeten, Bartholomew
Stop Leader: Ver Straeten, Stein, Terry, Bartholomew

The Gilboa Museum is a small local museum, with both local history and fine paleobotany fossil specimens from the Gilboa fossil forests, along with other fossil and rock specimens. For over 100 years, Gilboa was the site of the oldest known fossil forest globally, until the discovery of the older Cairo fossil forest in 2009 (Stop 4-5).

Fossil stumps (Text-fig. 4-3.1) of the primitive tree *Eospermatopteris* have been found at five different levels in the upper part of the Middle Devonian (middle Givetian) Cooperstown Formation in the Gilboa area. The Cooperstown is the shallower water, more sandstone-rich correlative of the shale-dominated Moscow Formation seen at some previous stops in western to central New York. These fossil forest occurrences do not occur in the overlying Gilboa Formation, a common fallacy. They are found in the upper part of the Cooperstown Formation around Gilboa. This places them in later/higher parts of Depositional Sequence Ih, and perhaps also Sequence Ii. The Gilboa fossil forests occur in strata above/younger than the faunas at the Cairo site.

Text-fig. 4-3.1: Casts of *Eospermatopteris* tree stumps on exhibit at the Gilboa Museum, from Riverside Quarry at Gilboa.

Early discoveries of *Eospermatopteris* tree stump casts around Gilboa was reported in 1869 (Goldring 1928?). Extensive subsequent discoveries occurred during building of a large dam at Gilboa, to create an added reservoir to supply additional water the New York City. A large quarry downstream, the "Riverside Quarry" was opened to obtain large blocks of sandstone for construction of the dam. It yielded many additional stumps and other paleobotany fossils. Winifred Goldring of the New York State Museum published papers on the Gilboa Forest (Goldring, 1928). In addition, a large major exhibit at the museum reconstructed the setting of the Gilboa Forests. *Eospermatopteris* stumps of mid Givetian forests have been found at least five different levels in the Cooperstown Formation around Gilboa.

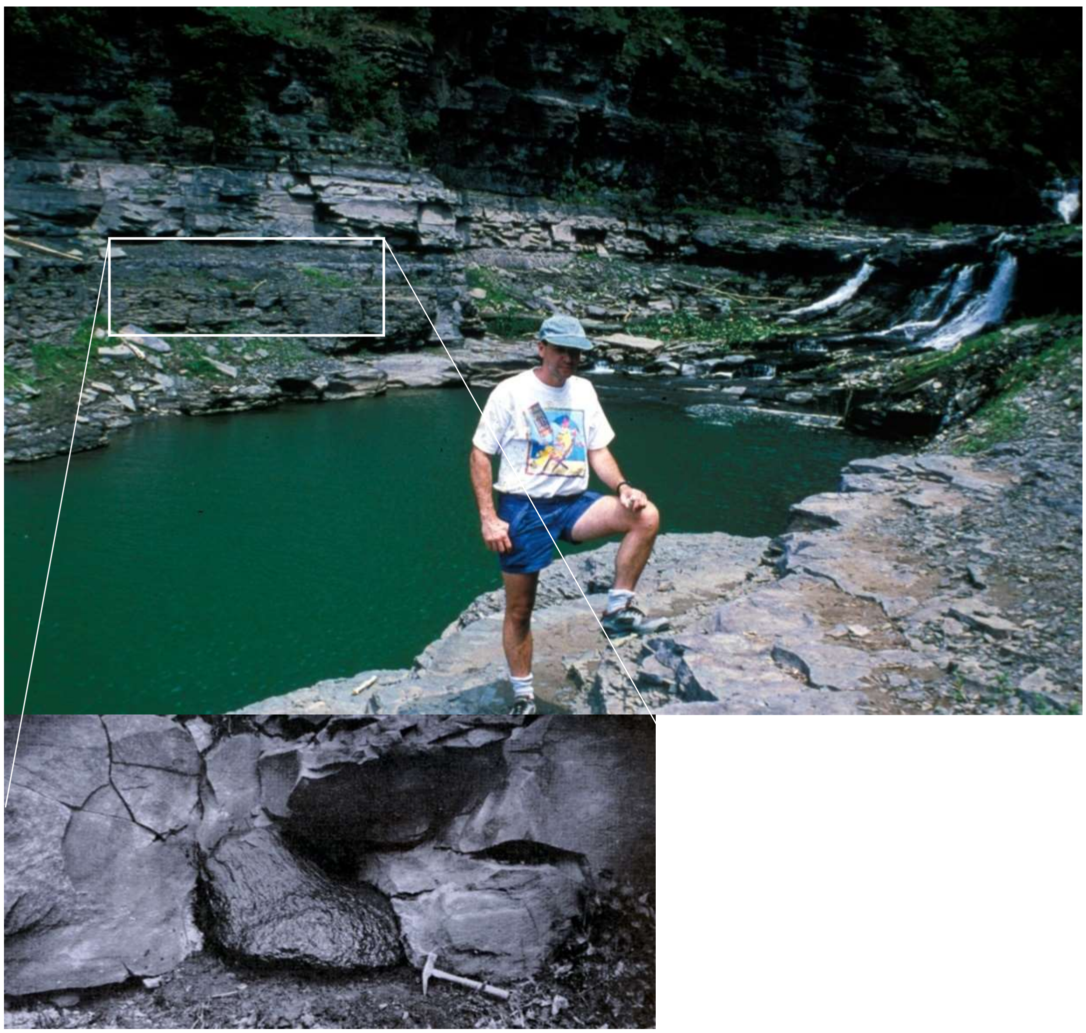
The old Riverside Quarry was reopened in 2010, which led to a third major paleobotanical discovery at Gilboa. Based on discovery of ichnofossil root molds of fossil trees on a quarry floor near Cairo, Greene County in 2009, 35 km (22 mi) to the east-southeast, an analogous forest floor was found in the original floor of the Riverside Quarry (Text-fig. 4-3.2). Through special permission from the New York City Department of Environmental Protection, the paleobotany crew of Bill Stein, Linda Hernick Van Aller, and Frank Mannolini, mapped out the distribution of three types of trees. In contrast with the Cairo Fossil Forest seen later today, the Riverside Quarry forest floor preserves the ichnofossils of a more *Eospermatopteris*-dominated forest. Prominent crater-like structures across the quarry floor represent the “seats”, where the bulbous bases of *Eospermatopteris* trees sat in the Devonian paleosols (Text-fig. 4-3.3).

In addition to the *Eospermatopteris* stump casts, and the trace fossils of various other plant fossils have been found in the Gilboa area, as described by Stein in his text accompanying the Devonian terrestrial overview earlier in this fieldtrip guide.

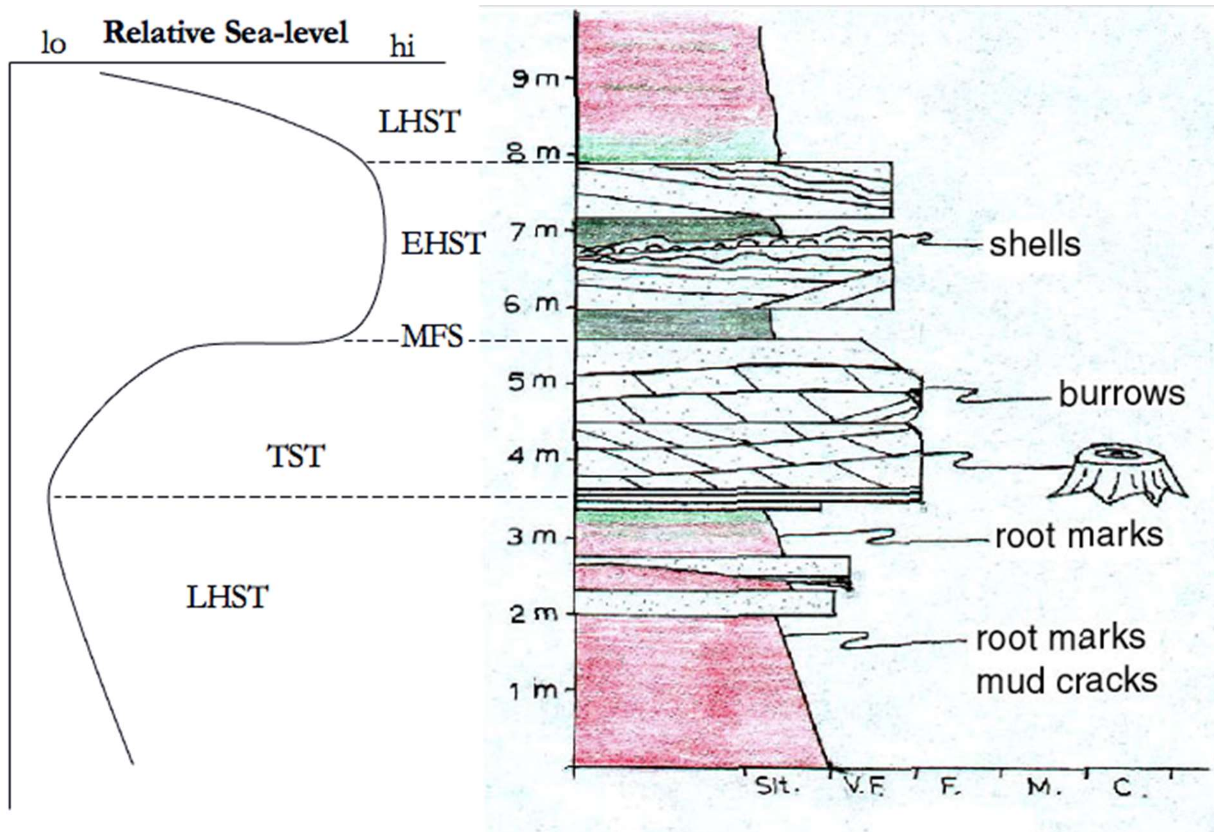
Text-fig. 4-3.2: View of forest floor at Riverside Quarry during 2010 excavation.

Text-fig. 4-3.3: “Seats” of Eospermatopteris trees on forest floor in Riverside Quarry.

A tongue of marginal marine and marine beds thought to be equivalent to the South Lansing Beds of the Garratsville Member of the upper Cooperstown Formation in the Schoharie Valley region is represented by the stump-bearing sandstone beds lying above the lowest 4-m-thick dominantly red mudstone interval near the base of the Manorkill section along the east side of the Schoharie Reservoir (Text-fig. 4-3.4). The stump bearing sands here are ~2 m thick and overlie a thin interval of green mudstone at the top of the underlying mudstone interval. Rooted in this green mudstone are small- to medium-sized stumps of *Eospermatopteris* trees. The trees are contained within steeply crossbedded, coarse-grained sandstones that also contain rare eurypterid fossils in association with the tree stumps. These beds are interpreted to represent catastrophic crevasse-splay deposits along the deltaic floodplain that formed during drowning of the river mouths during this transgressive interval. Immediately above the stump bearing sandstone are rippled sandstone beds bearing a marine fauna containing brachiopods, bivavles, bryozoa, and crinoid stem pieces. These units records a small-scale, fourth-order transgression across the basin and in the near-shore/onshore environment would be represented by a time of drowning of tidal channels and proximal river mouths along the delta front, resulting in episodic, catastrophic flooding of floodplain areas by crevasse-splay deposits that entombed the lower portions of the *Eospermatopteris* trees growing next to the rivers (Text-fig. 4-3.5).



Text-fig. 4-3.4 View of outcrop at mouth of Manorkill Creek gorge where it empties into the Schoharie Reservoir. This exposure is normally underwater. Outcrop exposes a stump-bearing horizon with a tongue of marine Cooperstown Formation strata within the terrestrial Manorkill Formation.



Text-fig. 4-3.5: Diagram of Manorkill Creek section with interpretation of sea level change.

Gilboa Visitor's Center to East Windham Cut:

0.0 mi	Depart Gilboa Museum. Turn Left onto NY-990V E
1.64 mi	Turn Right onto Prattsville Rd. Immediately cross the Manorkill Gorge. Gilboa Forest stump level in upper Cooperstown Fm. tongue at mouth of gorge exposed during low water levels in Schoharie Reservoir.
4.85 mi	Turn Left onto NY-23 E
1.45 mi	Turn Left onto NY-23 E
17.4 mi	Pull over on Right at long Manorkill Fm. section

Stop 4-4: Rte. 23 East Windham roadcut at 5 State Overlook, below East Windham
Stop Author: Ver Straeten
Stop Leader: Ver Straeten, Terry

Location: Southeast side of NY Rte. 28, just southwest/uphill of Five State Lookout pulloff.

Units: Middle Devonian Manorkill Formation

Description: Over 60 m of mudrocks including paleosols, sandstones, thin limestone beds and lenses, and an interval of charcoal from Devonian forest fire event(s) up-river of the site are a few of many features found in the upper Manorkill Formation at Stop 4-3. Overall, the site records processes and events active in fluvial floodplain and channel environments on a subaerial alluvial plain.

This fluvial system was draining from mountains of the Acadian (Acadian-Neoacadian) Orogen in New England westward into the Acadian Foreland Basin. Vast amounts of sediment eroding off of the mountain belt were carried by rivers basinward, into the marine seaway. This resulted in gradual progradational overfilling of the seaway to above sea level in the east of the foreland basin sea. On these lands, some of the oldest known forests and forest ecosystems were developing, as seen at forest sites at Gilboa (Stop 4-3) and near Cairo (Stop 4-5). Currently, the Cairo Fossil Forest is the oldest known Devonian forest site known globally.

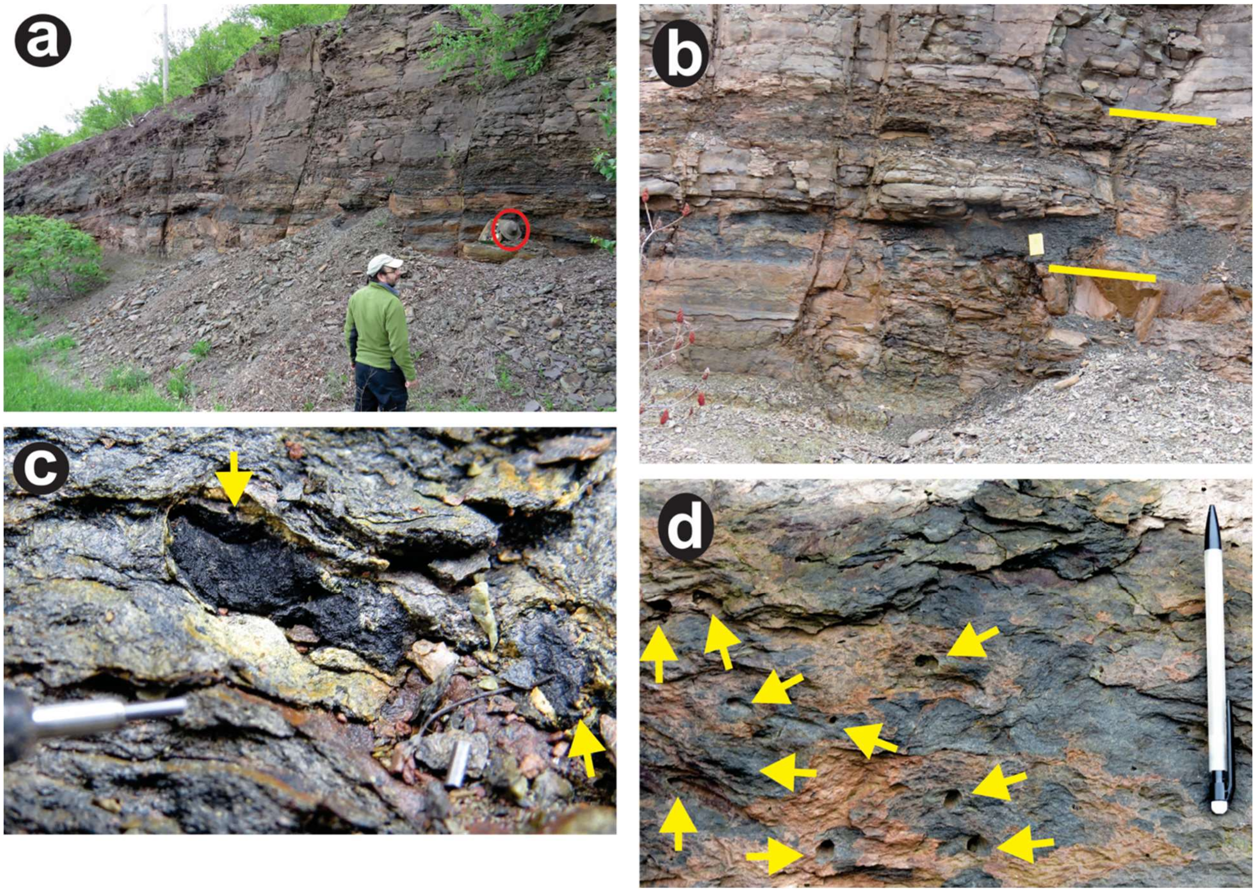
This outcrop, along New York Route 23, as adjacent to the Five State Lookout below East Windham, Greene County. It is approximately 1.25 km (0.8 mi) stratigraphically above the Silurian-Devonian boundary along Route 23 east of this stop, near Catskill. The strata here are mid Givetian, in the upper part of the Manorkill Formation, which is correlative with the Tully Limestone of central New York, seen at Stop 1-3. Around the bend of Route 23 uphill of this site, dark shales/mudstones hidden back under the trees are suggested to correlate with maximum flooding of the upper Givetian Geneseo Formation in central New York. Johnson (1968, 1972) along with Johnson and Friedman (1969) did key work on this site and others, correlating marine strata of the coeval Gilboa and Tully Formations through the shallow marine to marine-terrestrial transition, and into the terrestrial strata here. Their interpretations were supported by Rickard (1975).

Low in the part of the outcrop facing the parking area, several well-developed paleosols are seen. One of the red paleosols features green, cm-scale diameter traces of root of a possible cladoxylopsid tree (e.g., *Eospermatopteris*; Text-fig. 4-4.1). The green color in the redbeds is related to reduction of the red, oxidized iron in the sediments during decay of the roots. Additional paleosols along the outcrop show varying development (Mintz et al., 2006). In some areas, small pockmarks, or small, off-white “pebbles” are visible. These are small calcareous soil peds (concretions). Theseform associated with alternating wet and dry seasons, an indicator of monsoonal-type climates in the Catskills region at times during the Middle to Late Devonian. Further up the outcrop, floodplain deposits vary between red, green, yellow-tan and dark gray/black mudstones and lesser fine-grained sandstones. Several sandstone bodies occur along this stretch of the outcrop also, though few are thicker than 1-2 m.

Text-fig. 4-4.1: Reduction halos marking decayed root traces of apparent *Eospermatopteris* tree in lower part of Rte 23A cut, across from 5 State Lookout parking area.

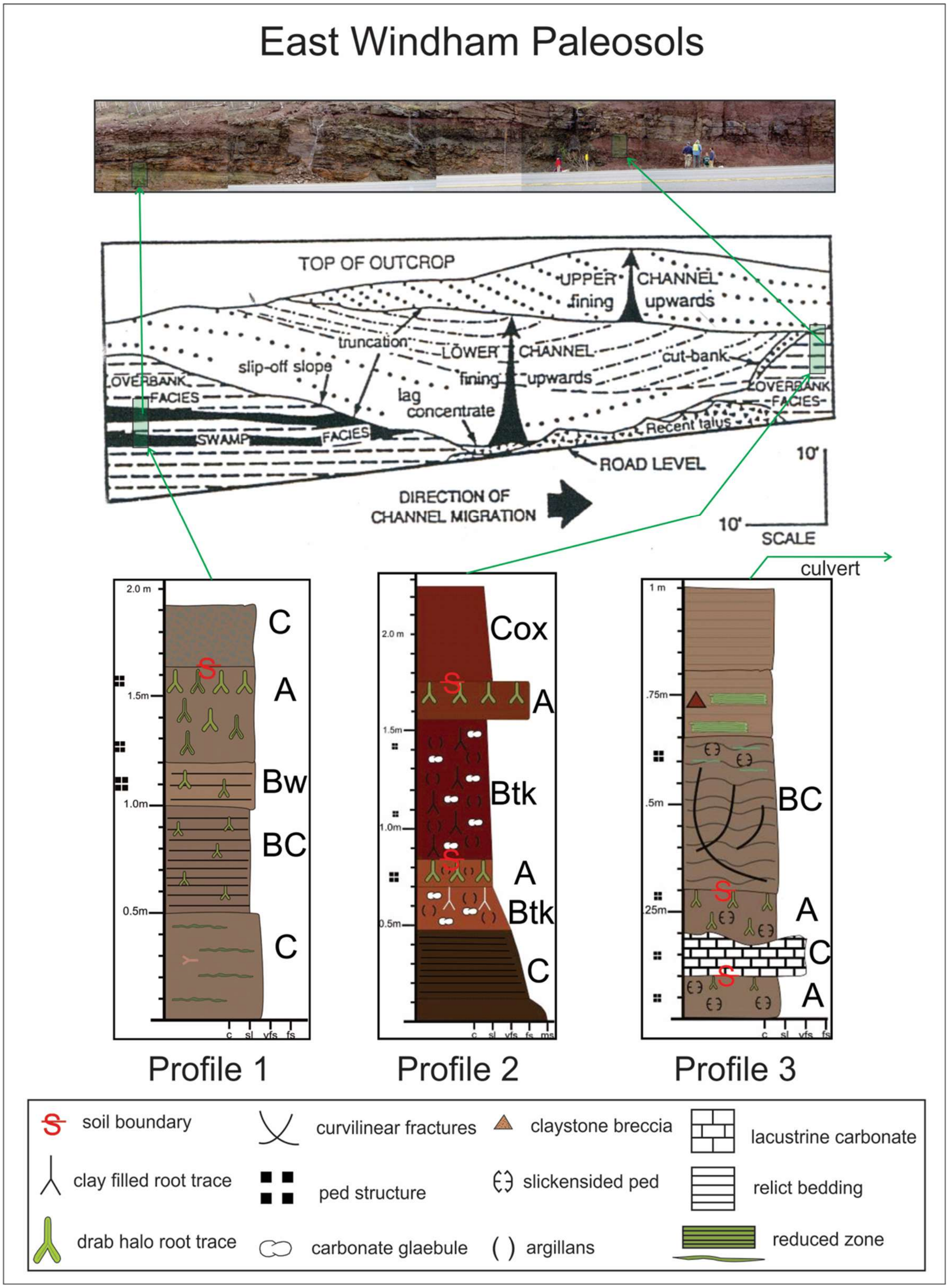
Around the bend and uphill from the parking area, a prominent sloping-to-the-right interval of yellowish-green strata is succeeded by a zone of thin sandstones and dark gray mudrocks, at a distinctly different angle to the underlying beds. A number of isolated soft sediment deformation pillows occur along the outcrop within the lower approximately 1-3 m of the upper unit.

In one interval, there is a distinctive interval of dark strata. A close examination of the interval shows small, hollow pockmarks. Small dark pebbles of black material are also found. These are rounded, fluvially transported and abraded pieces of charcoal, from mid-Givetian wildfires in some of Earth's oldest forests (Text-fig. 4-4.2).



Text-fig. 4-4.2: a) Overview of outcrop including interval with charcoal from Devonian wildfires. b) Yellow lines bracket interval with charcoal. c) close-up view of pieces of charcoal (yellow arrows). 0.7 mm pencil lead for scale. d) Arrows point to pock-marks where charcoal has decayed out of the outcrop. Pencil for scale.

In the upper part of the outcrop (above charcoal layer and below the driveway) several prominent paleosols are encountered. At least three different types of paleosols are present in this interval (Text-fig. 4-4.3)



Text-fig. 4-4.3: Cross-section with paleosol profiles from outcrop between charcoal interval and driveway (from D. Terry).

Higher in the section, downhill from the first driveway uphill of the bend, a prominent, thin ledge of limestone sticks out from the outcrop (Text-fig. 4-4.4). Fallen slabs of the bed can be seen in the talus. Light gray to brown-gray, varyingly smooth to knobby in appearance, the fauna noted in the bed consists of ostracodes. Mintz et al. (2006) state that the bed appears to have been pedogenically modified and brecciated. It is over and underlain by red to green paleosols.

Text-fig. 4-4.4: Discontinuous lenses of pedogenic limestone layer in upper part of outcrop below driveway.

A short distance above the limestone, along the lower part of a driveway, an interval of olive-colored, mudrock-dominated strata above the limestone, best seen along the lowest part of a driveway, features fish bone material, ostracodes and desiccation cracks. Also found in the interval are *Spirophyton* trace fossils, which have been interpreted by some to have lived in freshwater setting (Bridge and Gordon, 1985; DeMicco et al., 1987), but by others (Gordon, 1988; Miller, 1991) to indicate brackish water conditions. Miller (1991) proposed that the animals producing *Spirophyton* lived in ephemeral ponds on the coastal floodplain, with fluctuating fresh- to brackish water salinities, perhaps tied to floods of brackish water that flowed upstream and spread across floodplains during major storms.

In addition to the fossils found along the driveway, a number of thin ledges of impure limestones occur, best seen low in the outcrop at to upslope of the base of the driveway. These limestones, like the one mentioned above, appear to also be pedogenic limestones. Some appear to be relatively continuous, laterally. Due to their continuity, these might be considered to be calcretes, forming “hardpans” in Devonian soils.

As in other fluvial-dominated strata of the Catskills, Manorkill Formation sandstones analyzed by Gale (1985; 3 samples) feature common mono- and polycrystalline quartz (29.6-60.0%), and foliated metamorphic and sedimentary rock fragments (30.4-41.8% and 9.3 to 22.0%, respectively). lesser amounts of chert (0.2-0.7%), plagioclase and orthoclase feldspars (1.6-4.3%), along with chlorite and micas, illite and kaolinite are found in Manorkill sandstones (Gale, 1985). This represents a subtle shift toward increased quartz content from the underlying Plattekill Formation. With the exception of a single bed at or near the base of the Manorkill Formation, conglomerates known to the author at this point are intrabasinal ones, with reworked mud or pedogenic carbonate nodules.

East Windham Cut to Cairo Quarry:

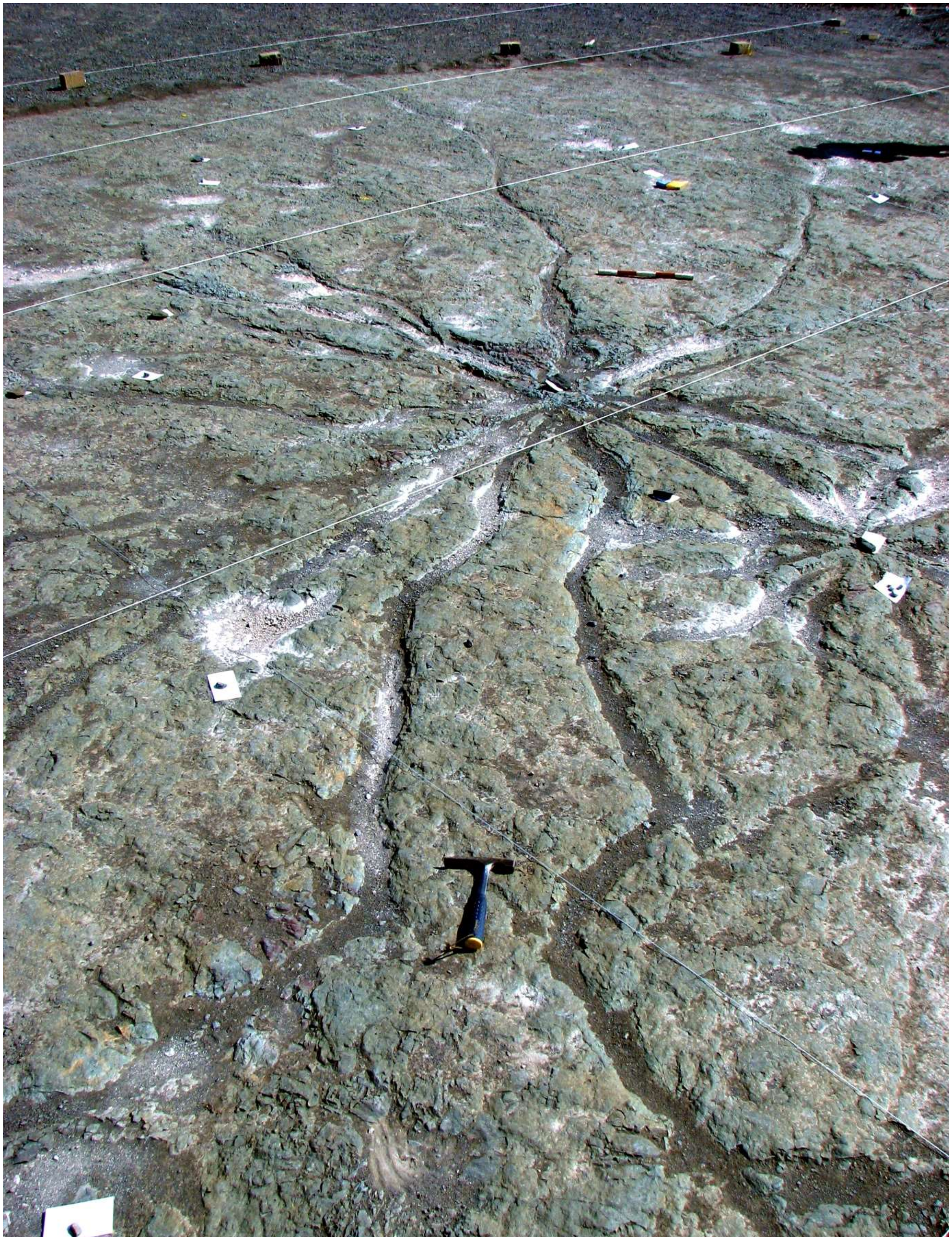
0.0 mi	Continue downhill (east) on NY-23 E
3.2 mi	Turn Left onto Edison Timmerman Rd.
2.37 mi	Turn Left onto Roosevelt Ave.
165 ft	Turn Right onto NY-145 S
0.77 mi	Turn Right into Town of Cairo Highway Dept. Continue west into quarry.

Stop 4-5: Cairo Quarry, Town of Cairo Highway Department, Greene County
Stop Author: Ver Straeten
Stop Leader: Ver Straeten, Stein

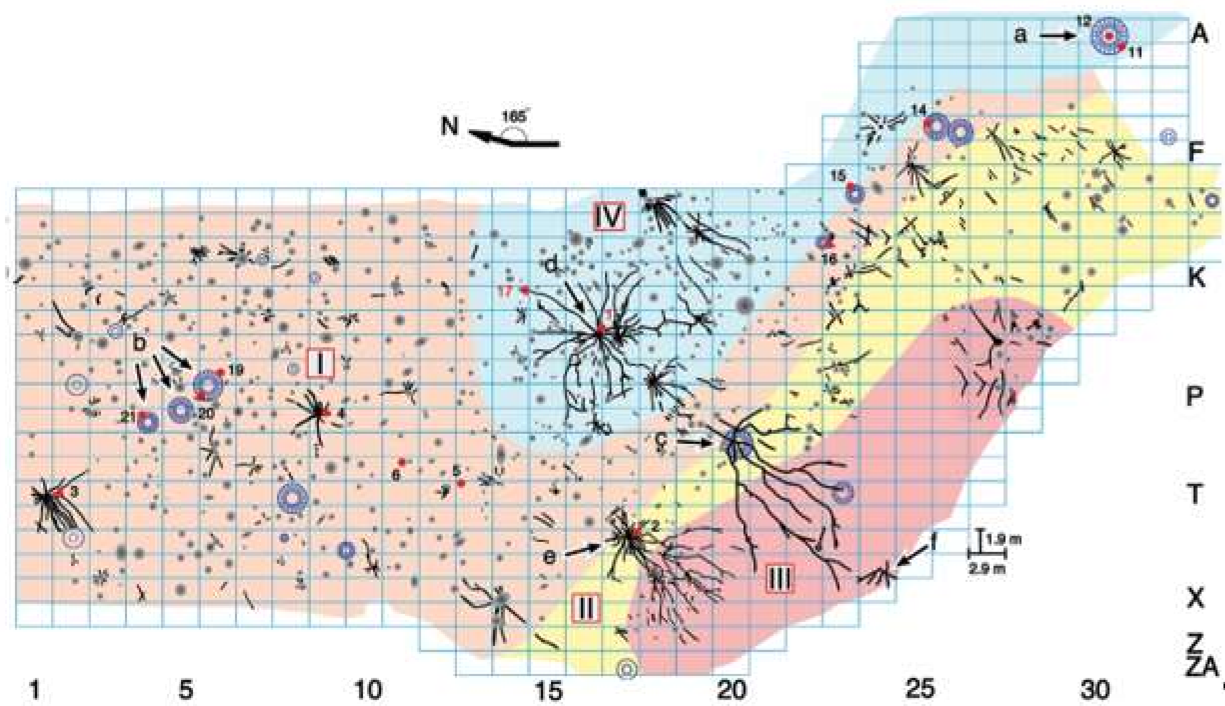
Locality: Inactive quarry on property of the Town of Cairo Highway Department, Greene County, NY

Units: Strata appear to occur in the middle of the early to mid Givetian terrestrial Plattekill Formation.

Description:
The Gilboa Fossil Forest was considered to be Earth's first forest for nearly a century. As noted at Stop 4-3 earlier today, *Eospermatopteris* tree-stump casts marked the level of multiple forests in the Middle Devonian Cooperstown Formation near Gilboa. In 2009, an older fossil forest was discovered near Cairo, Greene County. In contrast with the Gilboa forests, tree fossils of the Cairo Fossil Forest are preserved as moldic impressions of the root systems of multiple trees, scattered across the surface of a paleosol, on an inactive quarry floor (Text-figs. 4-5.1,2).



Text-fig. 4-5.1: Root systems of 2 *Archaeopteris* trees, the original 'find' at the Cairo Quarry.



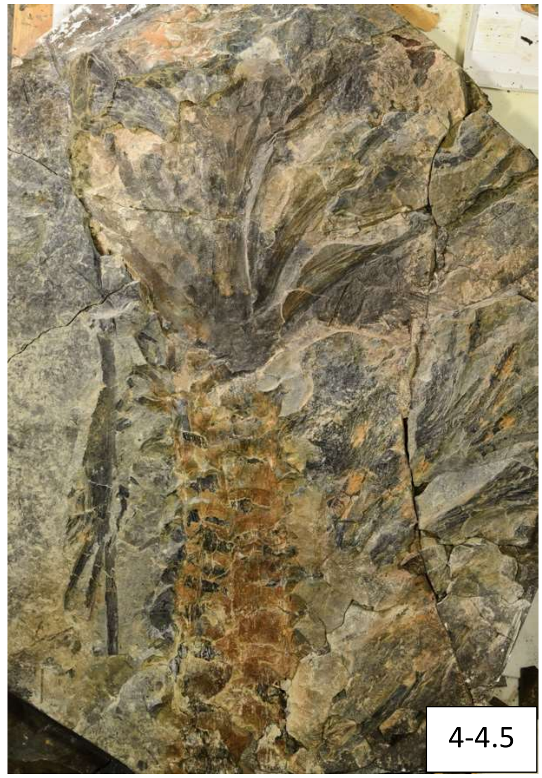
Text-fig. 4-5.2: Map of distribution of trees in the Cairo Fossil Forest. Three types of trees are found here: *Archaeopteris* (shown with long 'spidery' roots), *Eospermatopteris* (shown as concentric circles with connecting lines), and apparent lycopod (marked by Roman numeral III). Small circles with dot in center are unknown structures (possibly trees?).

The Cairo quarry has been the focus of a number of paleobotanical studies since the 1950s. The strata consists of fluvial sandstone bodies and varying colored mudrocks and paleosols, also with dark shales to mudstones and a lens of dark, impure limestone. The stratigraphic position appears to occur coarsely proximal to the lower-middle Givetian boundary and the contact of lower upper divisions of the Plattekill Formation. Characters related to sequence stratigraphic trends, and reports by Stein et al. (2020) suggest some possible influence of marginal marine- to brackish-water conditions at least temporarily, along with lacustrine influences. No shelly marine fossils have been seen by this author or the others, including no lingulid brachiopods, tolerant of brackish water conditions. This line of study needs additional attention.

Variations in the color of mudrocks, shales, and paleosols range from red to green to dark gray and black, with some mixed red and green. Stein et al. (2020) also note red vertisols indicative of a monsoonal climate regime, noted in other areas of the Catskills region.

The key fossils of significance are the impressions of rooting systems of three types of trees: *Archaeopteris* (Text-fig. 4-5.3), *Eospermatopteris* (Text-figs. 4-5.4,5), and an unknown, apparent lycopsid tree (Stein et al., 2020). They are spread around an area that totals approximately 3000 m^2 of the forest floor, which has been mapped in detail. A transect, east to west, starts in red to red and green mottled to green mudrocks, succeeded downward through dark mudstones down to rusty gray shales; the rusty stains indicate decay of pyrite approaching apparent anoxic water conditions.

Text-fig. 4-5.3: Fossil frond from *Archaeopteris* with leaves.



Text-fig. 4-4.4: Stump of Eospermatopteris tree from Gilboa, NY.
Text-fig. 4-4.5: Upper portion of Eospermatopteris tree from Durham, NY.

Archaeopteris root systems dominate the quarry floor at Cairo (Text-figs. 4-5.2). They have an appearance similar to that of modern trees – multiple broad roots that extend outward, narrowing from a central point where a tree stood (Text-fig. 4-5.1). At least one root trace extended 7.3 m (24 ft) outward from the position where the tree stood (Text-fig. 4-5.1). Cores taken down through the forest paleosol indicate that root traces in the cores extended down into the soil as much as 1.6 m (Stein et al. 2020). They also note that shallow bowl-like depressions with mounded rims characterize the "seats" where *Eospermatopteris* trees stood (Text-fig. 4-4.3). Some of the "seats" show the infilled trace fossils of *Eospermatopteris* finger-like roots that extend downward from the tree trunk, as seen at the Gilboa Museum earlier today, into the underlying paleosol.

Archaeopteris root systems up on the main forest floor area radiate outward in all directions (Text-fig. 4-5.6). In contrast, on the gently sloping transition from green to dark gray to rusty pyritic paleosol transitions, roots of an *Archaeopteris* and the one apparent lycopsid trees distinctly trend in the downslope direction (Text-fig. 4-5.2, yellow to red zones).

Text-fig. 4-5.6: Radial extension of roots from large *Archaeopteris* tree. Tree would have been situated at location of white bucket.

A group of Town of Cairo citizens have been working to protect the Cairo Fossil Forest site, with a plan in mind to turn it into an educational center and scientific preserve. A successful step forward is the protective fencing around the bulk of the study area seen here today.

Cairo Quarry to Rte. 23 Exit Ramp Cut:

0.0 mi	Depart Town of Cairo Highway Dept. Turn Right onto NY-145 S
1.93 mi	Continue Left onto NY-23 E
8.1 mi	Take Exit for Leeds/Jefferson Heights
1,000 ft	Turn Right onto Main St. at end of Exit ramp
1.36 mi	Turn Left onto Allen St.
610 ft	Slight Left to stay on Allen St.
265 ft	Turn Right onto Rte. 9W N
0.4 mi	Turn Right onto NY-23 ramp
0.3 mi	Turn Right onto NY-23 W
1.15 mi	Take Jefferson Height Exit toward Leeds. Pull over on Exit ramp along outcrop.

<u>Stop 4-6: Rte. 23 exit ramp Jefferson Heights</u>
Stop Author: Ebert
Stop Leader: Ebert, Brett, Bartholomew

RTE. 23 LEEDS: AUSTIN GLEN FORMATION, RONDOUT FORMATION, LOWER HELDERBERG GROUP, INCLUDING THE MANLIUS, COEYMANS, KALKBERG, NEW SCOTLAND AND BECRAFT FORMATIONS

Strata of the middle and upper Helderberg Group attain their maximum thicknesses in the Hudson Valley. We will visit three road cuts in the iconic Hudson Valley Fold-Thrust Belt: two near Catskill/Leeds and one near Kingston to see these units as well as thinned presentations of the lower Helderberg formations.

STOP 4-6A: LEEDS RTE. 23 ON RAMP: AUSTIN GLEN FORMATION, RONDOUT FORMATION, LOWER HELDERBERG GROUP, INCLUDING THE MANLIUS, COEYMANS, AND KALKBERG FORMATIONS

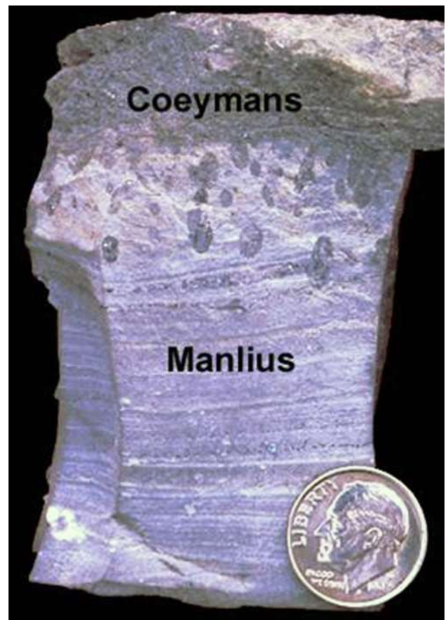
Text-fig. 4-6.1: The angular Taconic Unconformity separates the Ordovician Normanskill Formation on the right from the Silurian Rondout Formation on the left. The Normanskill was folded initially in the Middle Ordovician Taconic Orogeny. The entire sequence was folded a second time in the Devonian Acadian Orogeny.

This outstanding outcrop displays two episodes of deformation from a) the middle Ordovician Taconic Orogeny and b) the Early to Middle Devonian Acadian Orogeny. The section begins in the Middle Ordovician Austin Glen Formation, which represents flysch shed from the rising Taconic Mountains to the east. Beds of the Austin Glenn are nearly vertical as a result of experiencing two orogenic episodes, with the initial folding occurring in the Taconic Orogeny. The Austin Glen flysch is cut by the angular Taconic Unconformity (Text-fig. 4-6.1). Above the unconformity is a thin representation of the Fuyk Sandstone, overlain by dolomitic beds of the Rondout Formation. The contact between the Rondout and the overlying Manlius Formation is not well exposed. The Manlius Formation here is somewhat enigmatic. Rickard (1962) assigned these beds to the Thacher Member. The lower beds correspond to the Thacher Member as it occurs in the west. However, there is a thin representation of the Green Vedder Member that is overlain by higher Manlius strata, which may correspond to units such as the Elmwood, Clark Reservation and Jamesville members of Central New York.

The contact between these higher Manlius strata and the overlying Coeymans Formation is marked by borings (Text-fig. 4-6.2) and rare lithoclasts along the Howe Cave Unconformity. Unlike outcrops to the west where this surface was probably developed by subaerial erosion, the Howe Cave Unconformity in the Hudson Valley may have developed under fully marine conditions and likely represents a transgressive flooding surface.

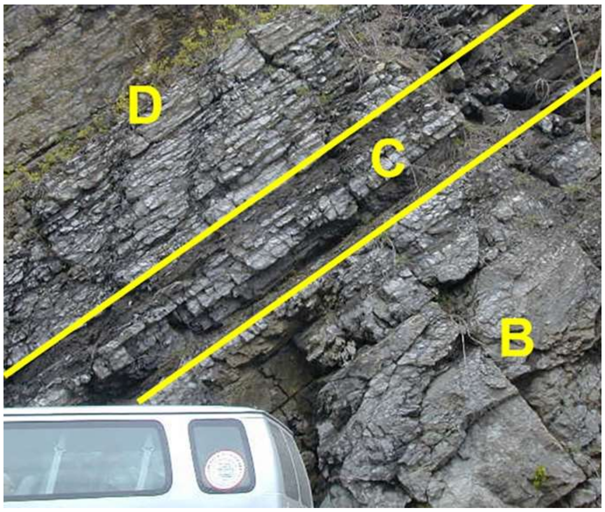
The Coeymans Formation is capped by a subtle disconformity (Punch Kill Unconformity), which displays weak mineralization in the form of sparse pyritic crusts. Overlying the Punch Kill Unconformity is the Kalkberg Formation.

Here in the Hudson Valley, the Kalkberg Formation is divisible into four informal subunits referred to as Kalkberg A, B, C and D (Text-fig. 4-6.3). The lowest subunit (A) is characterized by nodular to continuous beds of black chert developed in skeletal wackestones to packstones. The overlying B subunit is a skeletal rich packstone to grainstone with an abundant and diverse fauna. The A and B subunits represent mid- to late highstand conditions.



Text-fig. 4-6.2: Borings along the Howe Cave Unconformity at Stop 3a. This photo was included in the 2003 NYSGA Field Trip Guidebook. Used with permission from NYSGA.

The thin (< 1 m) C subunit is a dark gray to black shaly mudstone to wackestone that bears a sparse, diminutive fauna of pyritized brachiopods. The C subunit also includes a thin tephra bed. Subunit C developed under sediment-starved, dysoxic to anoxic conditions and likely represents the transgressive systems tract. The succeeding highstand systems tract is recorded by the D subunit, a richly fossiliferous packstone to grainstone. The D subunit includes the *Mariacrinus stoloniferous* epibole, which is an important marker for correlations to the west of the Hudson Valley



Text-fig. 4-6.3: Subunits B, C, and D of the Kalkberg Formation. A thin tephra occurs in Subunit C.

STOP 4-6B RT. 23 LEEDS: AUSTIN GLEN FORMATION, RONDOUT FORMATION, HELDERBERG GROUP, INCLUDING THE MANLIUS, COEYMANS, KALKBERG, NEW SCOTLAND (LEEDS GORGE AND JEFFERSON HEIGHTS MEMBERS) AND BECRAFT FORMATIONS
Stop Author: Ebert
Stop Leader: Ebert

This outcrop repeats the succession of the Austin Glen Formation, the Taconic Unconformity, the Rondout, Manlius, Coeymans and Kalkberg A, B, C and D. The D subunit of the Kalkberg Formation is overlain by dark calcareous siltstones to fine sandstones of the Jefferson Heights Member of the New Scotland Formation (Text-fig. 4-6.4). The Jefferson Heights Member records the most significant influx of siliciclastic sediment into the Helderberg Sea. These silts and sands, along with tephras within the New Scotland represent the earliest phase of the Acadian Orogeny, which precedes Tectophase I of Ettenson (1985). The highstand responsible for accumulation of the Jefferson Heights Member also signals a connection with the flysch basin of New England to the east, which allowed siliciclastic sediments to overflow into the Helderberg Sea.

Text-fig. 4-6.4: Jefferson Heights and Leeds Gorge members of the New Scotland Formation at the type section for these units on Rte. 23 near Catskill, NY.

Above the Jefferson Heights Member, the wackestones, packstones and less common grainstones with shaly interbeds of the Leeds Gorge Member record later highstand conditions and the restoration of carbonate deposition. Grainstone interbeds increase upward in the Leeds Gorge Member and become more crinoidal in composition. This marks the transition to the Becraft Formation in what is likely the only gradational contact within the Helderberg Group.

The Becraft Formation is a crinoid-brachipod grainstone that is divisible into three distinct facies termed B-1, B-2, and B-3 by Ebert (1983, 1987). The B-1 facies exhibits herringbone cross stratification, and silty and peloidal interbeds that commonly drape the stoss sides of dunes made up of coarse, crinoidal grainstone. Some of these finer interbeds display reversed paleocurrents compared to the coarser beds. Abundant, shield-like holdfasts of *Aspidocrinus scutelliformis* (Text-fig. 4-6.5), representing the eponymous epibole are characteristic of this facies. Ebert (1983, 1987) interpreted the B-1 facies as recording asymmetric tidal sand waves. The overlying B-2 facies is similar lithologically, but lacks the finer interbeds. This facies was interpreted as deposits of tidal sand waves in a more symmetrical tidal regime (Ebert, 1983, 1987). The B-2 facies accumulated under late highstand conditions.

The B-3 facies is absent at the top of this outcrop but is exposed below in the gorge of Catskill Creek. The overlying Alsen and Port Ewen formations are also exposed in Catskill Creek. These units will be seen at the Kingston outcrop (Stop 4) to the south.

Text-fig. 4-6.5: Lower bedding plane of a block of the Becraft Formation showing abundant holdfasts of *Aspidocrinus scutelliformis*. This block is a part of the historic (1775) Leeds Bridge over Catskill Creek, north of Rte. 23.

Leeds Cuts to Abandoned Thruway Exit

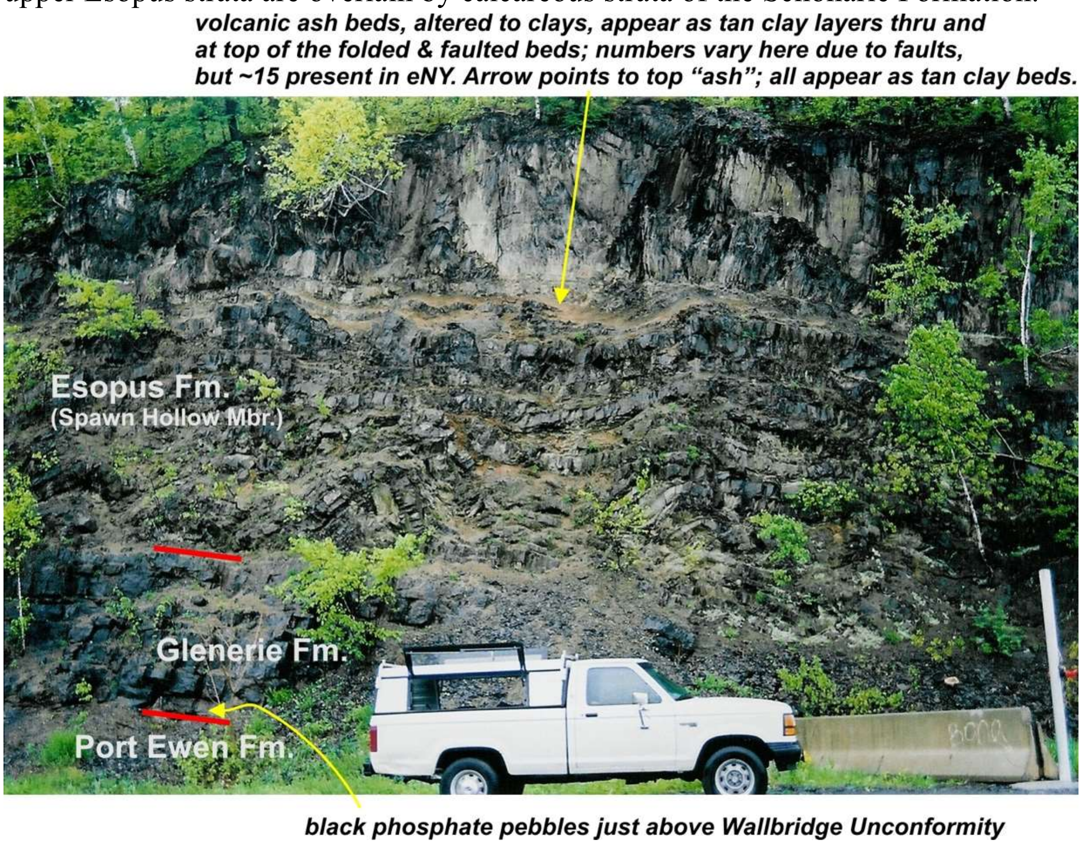
0.0 mi	Continue northwest on NY-23 W
0.8 mi	Turn Left onto Cauterskill Rd.
2.6 mi	Turn Right to stay on Cauterskill Rd.
0.7 mi	Continue Straight onto Cauterskill Rd.
0.9 mi	Turn Left onto Ulster Co. Rd. 47B
910 ft	Slight Left onto NY-23A E
0.2 mi	Pull over on Righ along outcrop. Be sure not to block access gate.

Stop 4-7: Rte. 23A Abandoned Thruway Exit
Stop Author: Ver Straeten
Stop Leader: Ver Straeten

Locality: High roadcut, south side of New York Route 23a, southwest of Catskill, Greene County, at abandoned New York State Thruway/I-87 exit. There are two parts to this outcrop: the first is the area adjacent to a large parking area off Route 23a; the second is continuing exposures beyond a gate. This latter part of the outcrop is along the New York State Thruway and should only be observed with written permission of the Thruway Authority.

Stratigraphic Units: Lower Devonian Port Ewen Formation (Lochkovian/Pragian?, Wallbridge Unconformity, Glenerie Formation (Pragian), Esopus and Schoharie formations (Emsian)

Description: The first part of this Lower Devonian outcrop exposes uppermost strata of the Helderberg Group Port Ewen Formation), the Wallbridge Unconformity, the Oriskany-equivalent Glenerie Limestone, and the lower part of the Esopus Shale (Text-fig. 4-7.1). The exposure extends southward ~300 m along the New York State Thruway, where middle and upper Esopus strata are overlain by calcareous strata of the Schoharie Formation.



Text-fig. 4-7.1: Photo of outcrop along Rte. 23A at eastern end of abandoned NY Thruway exit.

The Wallbridge Unconformity, one of six major North American Phanerozoic unconformities (Sloss, 1963) caps argillaceous limestones of the Port Ewen Formation. The unconformity is marked by a thin (-10 cm-thick) phosphate pebble-rich conglomeratic lag at the base of the Glenerie Formation. This bed lies at the base of Sloss' (1963) Kaskaskia Supersequence, which extends from the upper Lower Devonian through the Mississippian Period, and marks the base of Depositional Sequence 1 of this paper. The Glenerie Formation at Rt. 23A (3.5 m-thick) consists of relatively fine-grained, fossiliferous, drab brown limestones and dark gray cherts. Oriskany-age brachiopods are visible in cross-section in some limestone beds; the highly diverse and abundant fauna known from the Glenerie Limestone locally, however, appears absent at this outcrop.

The limestones and cherts of the Glenerie Formation are gradationally overlain by strata of the Esopus Formation at Stop 2. In general, the lithology of the Esopus consists of silty mudstones with lesser sandstones at the caps of three members, the Spawn Hollow, Quarry Hill, and Wiltwyck member, low to high. The lower member of the Esopus, The Spawn Hollow consists, of a tripartite subdivision of strata: 1) a lower interval of interbedded, thin siltstones, cherts, shales, and K-bentonites. This interval includes the Sprout Brook Tephras of Ver Straeten (2004a,b; Ver Straeten et al., 2005, 2020), which at this outcrop consist of up to 15 thin, altered, air fall volcanic tephra layers; 2) a middle subunit of dark gray to black, banded shale with scattered medium-size (~ 10-20 cm diameter), dark blue-gray calcareous-phosphatic concretions; and 3) an overlying coarsening-up interval of medium dark gray silty shales to buff-gray weathering, slightly calcareous siltstones. Small brachiopods *(Atlanticocoelia* and/or *Leptocoelia)* and other uncommon fossils occur in the upper subunit, with scattered glauconite.

The lower submember (-6.6m-thick) of the member is highly deformed at this outcrop; disharmonic folds, shear zones, and prominent fractures and cleavage are associated by Marshak (1990) with movement of a detachment fault between the Glenerie and Esopus Formations. Bentonite beds along the outcrop pinch and swell between more resistant beds and form horizons along which faults slide. The overlying middle dark gray-black shale subunit (2.0 m-thick) in the upper part of the cliff shows prominent slaty cleavage. Subunit 3 of the lower member of the Esopus Formation along Rt. 23A totals 4.0 m in thickness; its capping buff-gray siltstone bed forms a prominent ledge around the comer from the anticlinal exposure.

The overlying middle and upper members of the Esopus Formation extend southward along the outcrop and consist of rusty, dark gray silty mudstones to argillaceous siltstones that total over 40 m in thickness (Text-fig. 4-7.2). The upper member of the Esopus, unlike the previous stop, consists of the laminated unit and -2.9 m of strongly *Zoophycos-churned* siltstones to fine sandstones. The base of the Schoharie Formation is marked by a prominent glauconite-rich bed with quartz pebbles. The overlying unnamed member of the Schoharie Formation is 9.2 m-thick along the Thruway cut and shows distinctive banding, as does the overlying Aquetuck Member (10.7+ m exposed; thicknesses for the Schoharie Formation reinterpreted from Johnsen, 1957); this banding may be related to Milankovitch cycles.

Text-fig. 4-7.2: Middle Esopus Formation (Quarry Hill Member, lower part) south of gate at abandoned NY Thruway outcrop. Note distinct banding, possibly related to Milankovitch cyclity.

The basal Glenerie phosphate pebble bed marks initial transgression during deposition of the first post-Wallbridge depositional sequence, Continued transgression, coupled with the onset of tectonically induced foreland basin subsidence (Acadian Tectophase 2 of Ver Straeten, 2023a, which replaces Tectophase I of Ettensohn, 1985) marks the change into the overlying Esopus Formation.

At this stop, the Glenerie Formation and Spawn Hollow Member of the Esopus Formation comprise Devonian Sequence Ib_1, or alternatively, Sequence Ems-1. Devonian Sequence Ib_2 ins contained within the overlying Quarry Hill Member of the Esopus Formation, here at its type section. Shallowing and siliciclastic progradation through the upper part of the Esopus Formation is truncated by apparent erosion of upper strata of the Wiltwyck Member of the Esopus, below an unconformity at the base of the Schoharie Formation. The Wiltwyck Member, where complete elsewhere, comprises the whole of Devonian Sequence Ib_3.

Overlying strata of the Schoharie Formation represent calcareous mudrocks with minor chert. Along the more distant part of the outcrop along the NYS Thruway, two intervals with glauconite are found. The lower one may mark the transgression in the lower Wiltwyck Member of the Esopus; the upper one may represent the base of the Schoharie Formation and the lower member of it, the Gumaer Island Member. The Gumaer Island comprises strata of Devonian Sequence Ib_4 (Ems-4). None of the overlying Aquetuck and Saugerties members, of Devonian Sequence Ib5 (Ems-5) are thought to be present at the far end of this stop. Some of it, at least, is exposed on the west side of I-87 a short distance south of this.

Abandoned Thruway Exit to Saugerties Comfort Inn

0.0 mi	Turn around and head northwest on NY-23A W. Cross over I-87.
0.41 mi	Turn Left onto Old Kings Rd. Many outcrops of Onondaga Fm. along this road.
7.11 mi	Turn Left onto NY-32 S
1.4 mi	Turn Left into Saugerties Comfort Inn

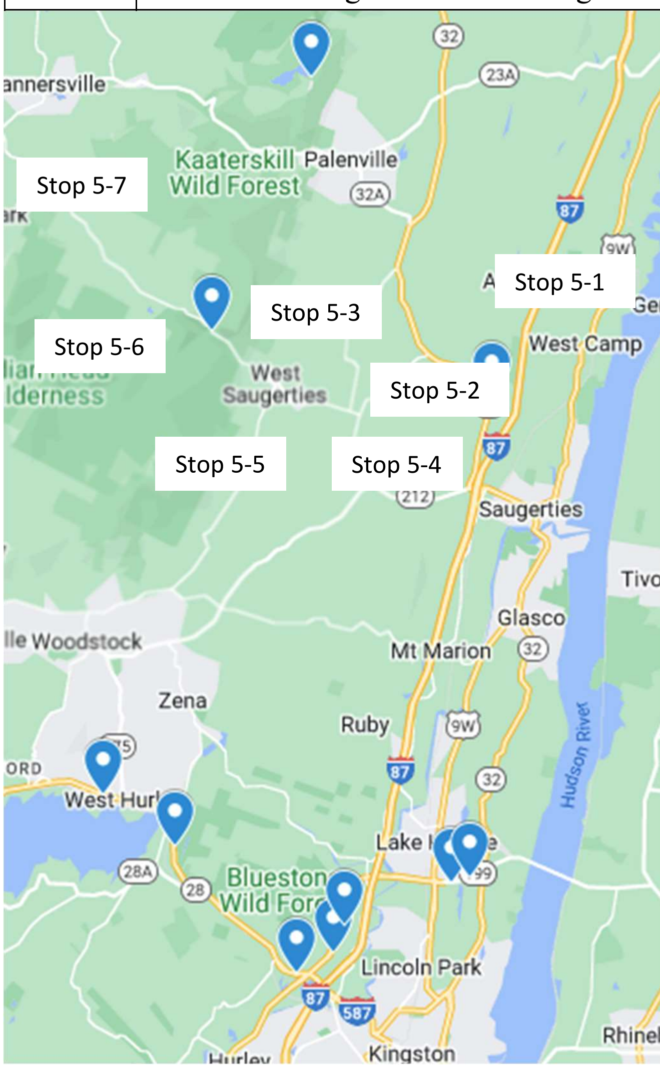
END DAY 4

<u>Field Trip Day 5 – 8/6/2023</u>

Stop 5-1	Rte. 199 Anticline – Upper Helderberg Group
Stop 5-2	Rte. 199 Syncline – Upper Tristates Group
Stop 5-3	Rte. 209 – East Berne and Halihan Hill Bed
Stop 5-4	Rte. 209 – Stony Hollow and Cherry Valley members
Stop 5-5	City View Terrace
Stop 5-6	Rte. 28 – Ashokan Formation
Stop 5-7	Rte. 28 – Plattekill Formation
Stop 5-8	Rte. 32 – Schoharie/Onondaga formations
Optional Stop	Platte Clove Corner
Stop 5-9	North-South Lake

Stop 5-9

0.0 mi	Depart Saugerties Comfort Inn. Turn Left onto NY-32 S.
0.42 mi	Turn Left onto NY-32 S
0.34 mi	Turn Right onto Kings Highway
3.2 mi	Turn Left onto Tower Dr.
925 ft	Turn Left onto Glasco Tpk.
0. Optional Stop	rn Right onto Rte. 9W S. This is the type section of the Pragian/Emsian Esopus l Glenerie formations.
3.73 mi	Turn left onto Tuyten Bridge Rd. Immediate slight left to stay on Tuyten Bridge Rd.
1.22 mi	Turn Right onto NY-3 Stop 5-8
200 ft	Turn left onto NY-199 W entrance ramp toward Ellenville. Merge onto NY-199 W
0.4 mi	Pull over on Right shoulder at large anticline outcrop.

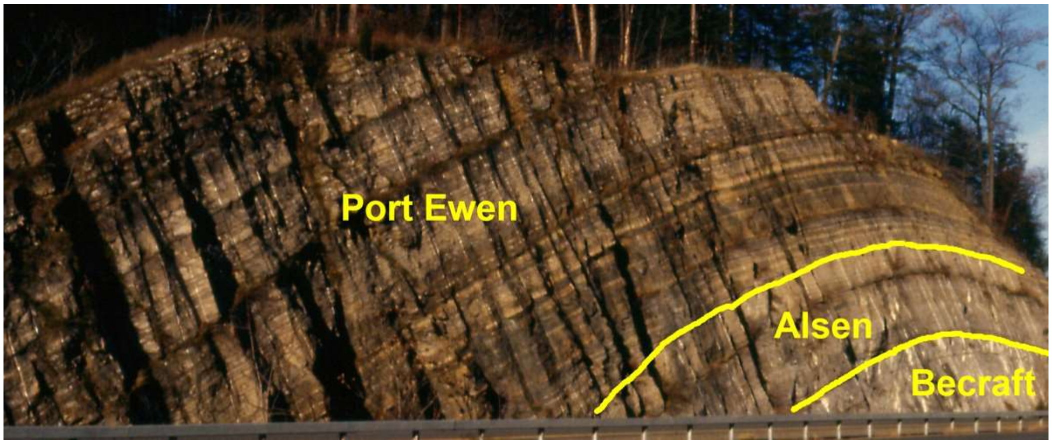


SAUGERTIES COMFORT INN TO RTE. 199/209 CUTS:

STOP 5-1: RTE. 199/209 KINGSTON: BECRAFT, ALSEN AND PORT EWEN FORMATIONS OF THE HELDERBERG GROUP AND THE GLENERIE FORMATION OF THE TRISTATES GROUP

Stop Author: Ebert

Stop Leader: Ebert



Text-fig. 5-1.1: Stop 4 Anticlinal exposure of the upper formations of the Helderberg Group.

This anticlinal exposure reveals the top of Becraft Facies B-2, the overlying B-3 facies, the Alsen Formation and the Port Ewen Formation (Text-fig. 5-1.1). In the brush at the western end of the outcrop, a portion of the Glenerie Formation is also exposed.

Becraft Facies B-2 comprises coarse skeletal grainstones deposited under late highstand conditions. Sedimentary structures are difficult to see owing to the coarseness of the skeletal gravels. Cross stratification with some paleocurrent reversals have been observed elsewhere.

Approximately one meter at the top of the Becraft is represented by the B-3 facies. This coarse grainstone lacks any apparent sedimentary structures. The *Clonocrinus* (?) epibole is present in the form of holdfasts of root-like clusters. This epibole is also present at the top of the Becraft in the Schoharie Valley. The position of the B-3 facies suggests that it represents the transgressive systems tract at the commencement of the final phase of Helderberg deepening.

The sharp contact between the Becraft and Alsen formations is a minor disconformity. The Alsen comprises bioturbated, fine skeletal grainstones and packstones. A few, remnant ripples and small-scale cross stratification have been observed in other outcrops. In thin section, most bioclasts in the Alsen Formation are pervasively micritized, indicating relatively long residence on the sea floor with low rates of sedimentation. The Alsen records highstand deposition.

Text-fig. 5-1.2: Bored phosphatic nodules near the base of the Port Ewen Formation.

The Alsen – Port Ewen contact is sharp and records a disconformity that resulted from sediment starvation. Rare, bored, phosphatic lithoclasts occur above this surface in the lowest decimeter or two of the Port Ewen Formation (Text-fig. 5-1.2).

Text-fig. 5-1.3: Nodular bedding in the Port Ewen Formation. These early-cemented nodules exhibit a variety of uncompacted ichnofossils, including *Chondrites* and *Zoophycos*.

There are few body fossils in the Port Ewen, but ichnofossils are abundant. Lithologically, the Port Ewen is a shaly wackestone to carbonate mudstone with nodules of limier mudstones to peloidal grainstones (Text-fig. 5-1.3). Uncompacted burrows in these nodules indicate early cementation and subsequent differential compaction around nodules. The upper surfaces of some nodules display thin pyritic crusts, suggesting exposure of patchy hardgrounds on the sea floor. The Port Ewen records highstand conditions with dysoxia interrupted by episodes of more oxygenated waters. Cycles of nodule development were interpreted by Ebert (1983, 1987) as the result of episodic fluctuations of the position of the pycnocline in a stratified basin.

A portion of the Glenerie Formation, which rests on the Wallbridge Unconformity, is exposed to the west of this outcrop. This sandy, skeletal grainstone to sandstone is likely correlative with the Oriskany Sandstone in the west.

Helderberg Anticline to Tristates Syncline:

0.0 mi	Continue west on NY-199 W
0.35 mi	Pull over on Right shoulder at next synclinal outcrop

Stop 5-2: Rte. 199 Syncline: Esopus/Schoharie formations
Stop Author: Ver Straeten, Da Silva
Stop Leader: Ver Straeten

Locality: Large outcrops on the north and south side of NY Rte. 199 just east of US Rte. 9W junction.

Units: Emsian Esopus and Schoharie formations (parts)

Overview - Chuck Ver Straeten
The third set of roadcuts westbound on New York Route 199 north of Kingston exposes the upper part of Esopus Formation strata and all except uppermost strata of the Schoharie Formation on both sides of the highway (Text-fig. 5-2.1 5144). Visible is the typical development of these strata in the Catskill to Kingston area. Strata young from the west side of the outcrops eastward.

Text-fig. 5-2.1: Outcrop along north side of NY Rte. 199 just east of US Rte. 9W exposing uppermost Esopus Formation on far left, and most of the Schoharie Formation younging to the right.

The lower to middle parts of the Esopus Formation (Spawn Hollow and Quarry Hill members) in the area are not visible at this site. Those two are characterized, respectively, by 1) interbedded cherts, shales and altered air fall volcanic tephras, overlain by shales and a fine-grained sandstone cap; and 2) siliciclastic mudstones, often silty and highly burrowed/bioturbated, is also capped by a fine-grained sandstone unit. Visible here along Route 199 are sandstones in the upper part of the Wiltwyck Member; a distinctive marker in the lower part of the Wiltwyck Member is an interlaminated shale-siltstone bed. The entire Esopus Formation, within the Zlíchovian substage of the Emsian Stage, is composed of non-calcareous, poorly fossiliferous siliciclastics. With uppermost strata of the Oriskany-correlative Glenerie Cherty Limestone, the Esopus Formation is comprised of three third order depositional sequences, Ib_1, $1b_2$ and $1b_3$ (alternatively Ems-1, Ems-2, and Ems-3). The late highstnd/falling stage of the upper Esopus sequence represents a more significant shallowing that the two underlying Esopus sequences, and the overlying lower Schoharie Formation sequence (Ib4/Ems-4).

Most of the Schoharie Formation (Dalejan substage, Emsian State) is exposed along the New York Route 199 outcrops here. Uppermost Schoharie strata are visible in two sections around Kingston, at the New York Route 32 Delaware Avenue exit south-southeast of this site, and in a railroad cut north of West O-Reilly Street, in southwest Kingston.

Three of the four members of the Schoharie Formation are found here and through the Hudson Valley to the north. A lower “Gumaer Island” Member consists largely of calcareous mudstones, sometimes silty, and burrowed to bioturbated, generally weathering brownish. Shelly fauna through the member are generally uncommon, typified by relatively small *Atlanticocoelia* brachiopods. A prominent, roughly meter-thick dark/black chert unit is seen partway up through the unit ("black bed" of Johnsen and Southard, 1962). In some areas to the north, cherty tongues occur locally at other levels of Schoharie strata. The Gumaer Island Member comprises the previously mentioned Schoharie 3rd order Depositional Sequence Ib_4 (Ems-4). Two members occur in upper Schoharie strata in the Hudson Valley, a lower Aquetuck Member and an upper Saugerties Member, which together comprise Depositional Sequence Ib_5 (Ems-5). At this site, the contact between the Gumaer Island and Aquetuck members occurs proximal to the lowest continuous white limestone band, underlain by uncommon, scattered quartz pebbles which are visible from here north to the Helderbergs in western Albany County. The Aquetuck Member consists of mudstones with a greater calcareous content, with bands of decimeter-scale whitish limestone concretions. Partway up through the upper Schoharie Formation here, decimeter-thick white limestone bands appear – this marks the base of the lithostratigraphically-defined Saugerties Member. Increasingly diverse faunas occur through this upper Schoharie sequence. Northward and then west from here to the Schoharie Valley, the top of the Schoharie is characterized by increasing sandstone content and diversifying faunas of the Rickard Hill facies, culminating in a diverse cephalopod and coral-rich cap of the Schoharie Formation, below the Onondaga Limestone Formation.

The interval of maximum flooding in the lower part of the Gumaer Island Member, in Depositional Sequence Ib_4 (Ems-4) should correlate with or be proximal to the Emsian Stage Zlíchovian-Dalejan substages boundary in the Czech Republic. This stratal position is correlatable through some areas of the Appalachian Basin, from the eastern New York to central Pennsylvania (Needmore Formation, middle Hares Valley Member); to near Wytheville, southwestern Virginia (Huntersville Chert), 823 km (511 mi) from this outcrop, near the southern margin of the Emsian outcrop belt in the basin (Ver Straeten, 2007, 2023).

A very distinct, often roughly decimeter scale cyclicity is visible in the Schoharie. It is very distinct in the calcareous mudstones of the upper Gumaer Island Member on the south side of Route 199 here; in the overlying Aquetuck to Saugerties members, cyclicity is often visible as alternations of mudstones and bands of limestone concretions to beds (Text-fig. 5-2.2 7525). This is discussed more in a following section by Anne-Christine Da Silva.

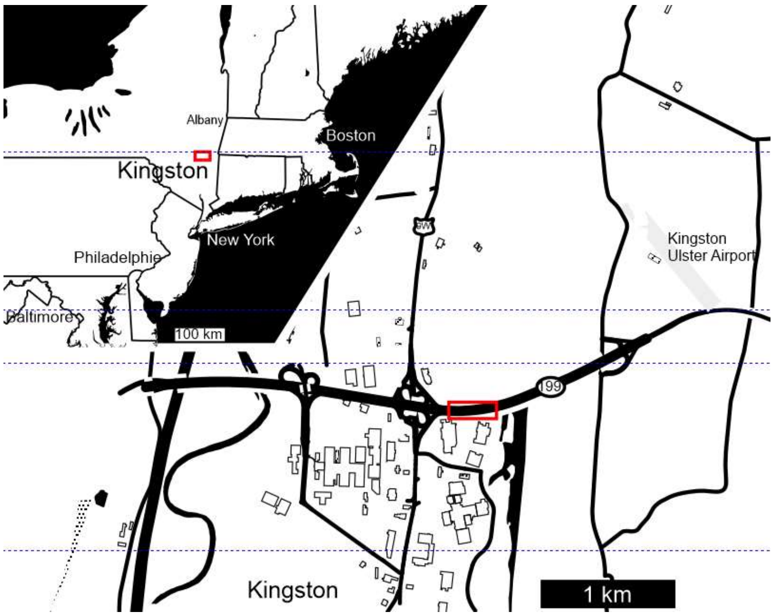
Interestingly, some light tan claystone beds have been found in upper Schoharie strata in the Kingston area, up to perhaps a couple decimeters in thickness. One or two perhaps occur high in this outcrop. They are best developed and accessible in the railroad cut in southwest Kingston. These beds appear to represent altered airfall volcanic tephra beds. They have not as yet been confirmed to be tephras, but have the distinct character of many such beds in the Appalachian Basin – clay to claystone beds light tan color, a greasy/soapy/waxy feel when rubbed between finger and thumb, and that form distinct recession in outcrops. The position of the Emsian-Eifelian boundary is not clearly known in the Appalachian Basin yet; however, these beds do occur in some proximity to the Emsian-Eifelian boundary, and merit further investigation.

Text-fig. 5-2.2: Outcrop of Schoharie Formation along southside of NY Rte. 199 just east of US Rte. 9W showing lower Gumaer Island (GI) and upper Aquetuck (Aq) members, boundary marked by distinct white band.

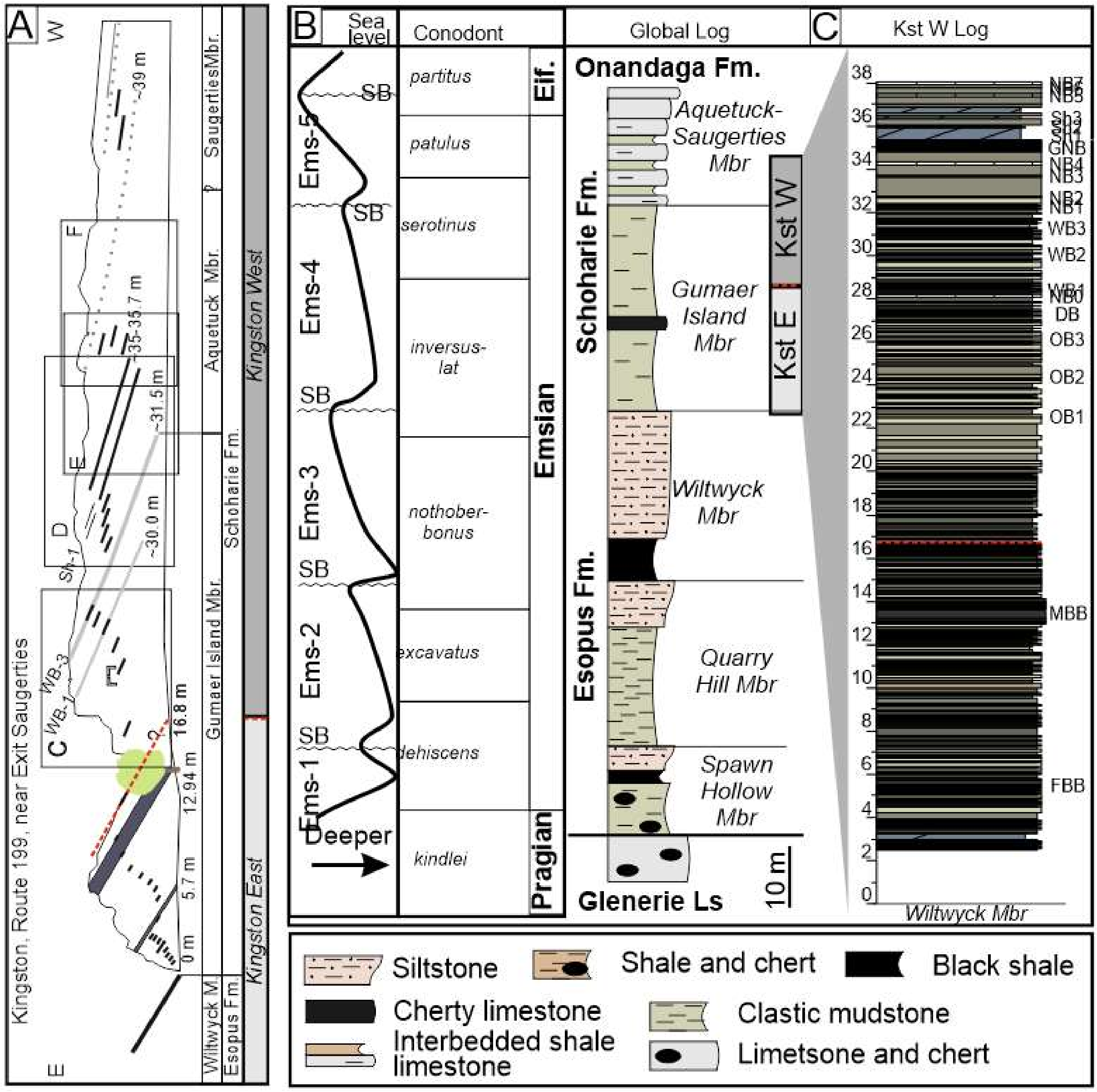
Cyclicity: - Anne-Christine Da Silva

Eastern North America was located approximately 30° of southern Latitude during the Early-Middle Devonian (Scotese & McKerrow, 1990). From the early Silurian to the Late Devonian, the Acadian orogeny led to the formation of a large mountain belt, with associated large-scale erosional products coming into the foreland basin. The Pragian to Eifelian succession deposited in the Appalachian basin includes the Pragian Oriskany Formation, with quartz sandstones and carbonates, the Emsian Esopus and Schoharie Formations made of mixed siliciclastics and carbonates, followed by the lower Eifelian Onondaga limestones and Union Springs siliciclastic deposits (Ver Straeten, 2007).

The Rte 199 outcrop is located along the Route 199 State Highway from the Hudson Valley (coordinates 41.974213, -73.983377; 500 m East of the highway interchange with 9W; Text-fig. 5-2.3). The outcrop on both side of the Route 199 exposes a succession, which starts with the top of the Esopus Formation (lower Emsian) shales and sandstones, followed by a sharp surface corresponding to the transition to the upper Emsian Schoharie Formation with mixed clastics and carbonates (Text-fig. 5-2.4A,B). The Esopus and Schoharie Formations are both strongly bioturbated and rich in *Zoophycos* and *Planolites*, are mostly silty argillaceous limestones with few fossils (trilobites, brachiopods, etc.) and are interpreted as deposited in an epeiric sea/distal foreland basin.

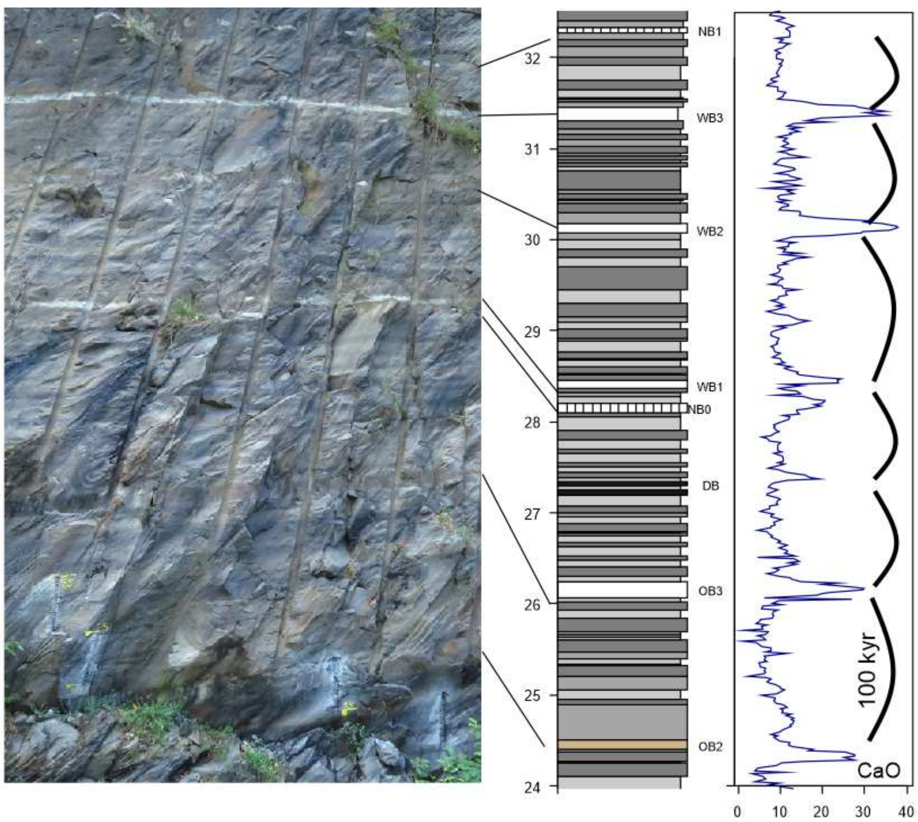


Text-fig. 5-2.3 – Location of Kingston Rte 199 outcrop in New York State.



Text-fig. 5-2.4: Kingston Rte 199 record. A. Schematic visualisation of the Kingston Rte199 outcrop, on the northern Side of Rte 199, with the corresponding altitude and marker beds on the lithological column (C). B. Local regional geology (Ver Straeten, 2007), with identified sequences, sea level changes, stages and formations and their respective lithologies. C. Lithological column of the Rte 199 Kingston record, with marker beds. The red line corresponds to a surface on the outcrop, which is a suspected fault.

The Schoharie Formation starts with Gumaer Island Member corresponding to silty shales, with light beige and dark beige alternating colors and including two distinctive dark layers (around 5.5 m and 14 m, Text-fig. 5-2.4), as well as distinctive orange and white beds (between 20 until 32 m, Fig. 2). The second and most remarkable white bed corresponds to the transition to the Aquetuck Member (31.2 m, Text-fig. 5-2.4). The Aquetuck Member is formed by nodular white beds alternating with carbonate dark beds, followed by a shaly interval alternating with carbonate beds (35.4-37 m; Text-fig. 5-2.4). The boundary with the Saugerties Member is unclear. These Formations were subdivided into sequence stratigraphic systems tracks (Ver Straeten, 2007) with third-order sedimentary cycles corresponding to the Gumear Island (Ems-4, transgression in the first few meters and shallowing upward for most of the Member), and the Aquetuck and Saugerties Members (Ems-5), with the second and most distinctive white bed at the transition with the Aquetuck Member interpreted as a sequence boundary. These two cycles, together with the three cycles from the lower Emsian are correlatable from eastern New York to central Pennsylvania (Ver Straeten, 2007). The Gumaer Island Member corresponds approximately to the *inversus* conodont zone, while the Aquetuck and Saugerties members correspond roughly to the *serotinus* and base of the *patulus* conodont zone (Text-fig. 5-2.4).



Text-fig. 5-2.5 – *Visualisation of the lithological changes and couplets and of the interpreted orbital cycles.*

At the outcrop, through the record of silty calcareous shales of the Schoharie Formation, three main type of alternations styles or cyclicities can be identified (Text-fig. 5-2.5):

- <u>*LD Couplets*</u> - The smaller scale cycles range in thickness between ten centimeters and half a meter and are characterized by silty calcareous shales alternating as light beige and dark beige couplets (Text-fig. 5-2.5). The dark part of the cycle is sometimes a little bit more recessive than the light part and indeed, the light layers are characterized by stronger CaO values (between 3-7 % in the dark layers and 5-12 % in the light layers).

- *Intermediate scale cycles and marker beds* - The "LD couplets" are grouped by 6-8 to form a second scale of cycle ranging between half a meter and two meters. These groups of couplets are separated by distinctive marker beds (Text-fig. 5-2.3,2.4), which are of a different color than the LD couplets themselves, appearing as orange-brown, white or as white nodular layers. Those marker beds (Text-fig. 5-2.4,2.5) show classically a sharp increase in CaO and a sharp decrease in Al_2O_3, SiO_2, Fe_2O_3, K_2O, MS. CaO is below 10 % in most couplets but reaches 20-30% for these marker beds; SiO_2 higher than 40% in the couplets and lower than 40 % in the marker beds; K_2O around 2 % for the couplets and around 1 % for the marker beds; MS around 5.10^{-8} for the couplets and around 3.10^{-8} for the marker beds; L* around 35 for the couplets and 40 for the marker beds.

- *Long scale cycles*- correspond to a change in the expression of the LD couplets and associated marker beds (Text-fig. 5-2.4,2.5) and range between 2 to 8 m. The marker beds are of different color than the dominant light beige and are and much richer in limestone. Three orange-brown sharply demarcated beds are visible between 18-27 m (called OB1, OB2, OB3, Text-fig. 5-2.4). At 27.3 m the marker bed does not appear as clearly marked and it is a slightly darker bed (DB) and then between 28-32 m, three white sharply marked beds can be counted (WB1, WB2, WB3, Text-fig. 5-2.5). Between 32-35 m four white nodular beds can be counted (NB1-NB4). However, NB1 is discontinuous on the southern side and does not appear on the northern side. Between 35-37 m there are three argillaceous beds (Sh1-Sh3) and marker beds are nodular again between 37-38 m (NB5-7). The LD couplets expression also evolves through the record. Indeed, they are clearly visible between 26 and 32 m but below and after this, they fade or disappear completely.

The couplets are interpreted as precession cycles (~17kyr in the Devonian), the marker beds are interpreted as separating the short eccentricity cycles (~100 kyr), while the change of expression of the marker beds and couplet cycles through the record (long scale cycles) are interpreted as corresponding to the long eccentricity cycles (405 kyr).

Tristates Group Syncline to Mount Marion Formation:

0.0 mi	Continue west on NY-199 W. Cross Rte. 9W, road becomes US-209 S
2.7 mi	Pull over on Right shoulder at pull-off. Walk to outcrops along Rte. 209 S

Stop 5-3: East Berne and Halihan Hill Bed along Rte. 209, Kingston

Stop Author: Bartholomew

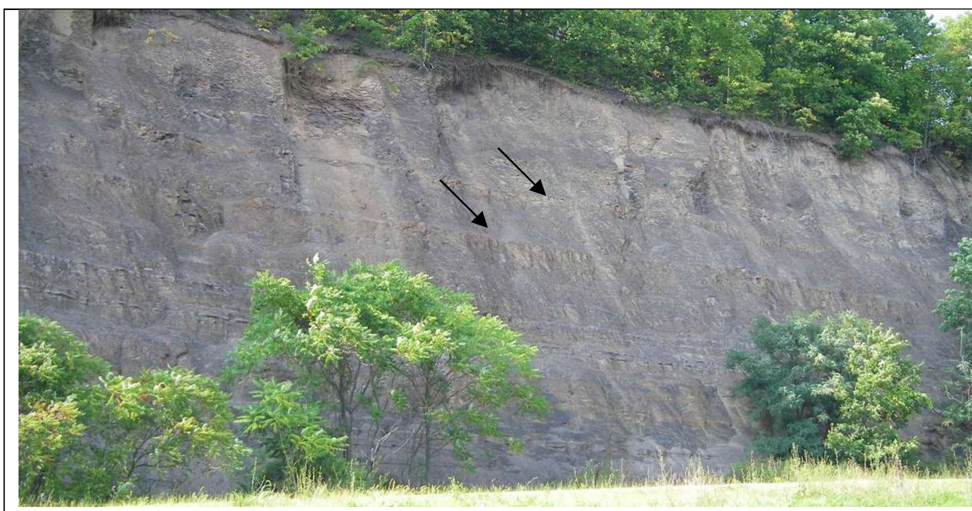
Stop Leader: Bartholomew, Ver Straeten

Locality: Large outcrops along the east and west side of US Rte. 209 just south of Sawkill Road junction.

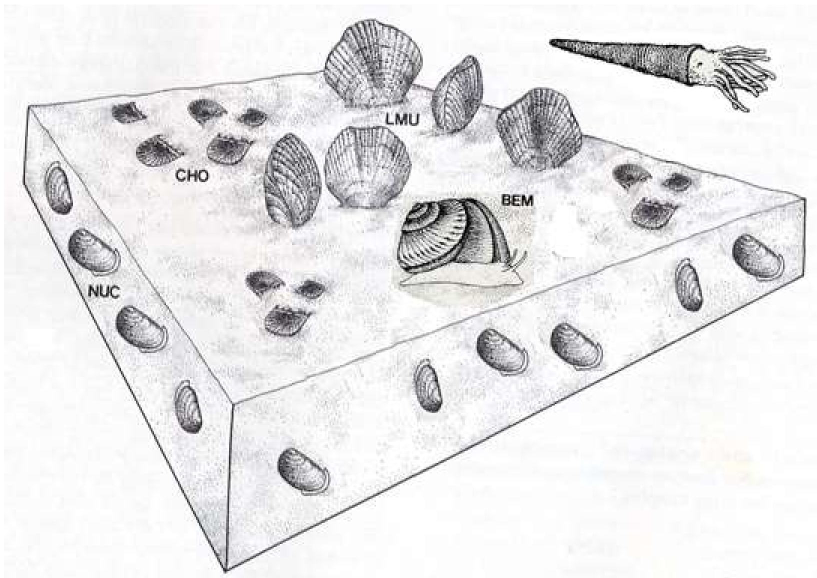
Units: Eifelian/Givetian East Berne and Otsego members of the Mount Marion Formation

Description: The upper portion of the Cherry Valley Member and lower portion of the overlying East Berne Member of the Mount Marion Formation is covered along the southern end of the large outcrop here, but only for ~10m or so. The lowest exposed portions of the East Berne Member are medium-gray, fine-grained, very fissile shales that grade upwards with more and more silts. Near the middle of the member, we see the entrance of thicker-bedded siltstones and fine-grained sandstones. These beds are very homogenous inside and show little to no burrowing in nearly every instance at this outcrop and are interpreted to be storm-derived sediments that were most likely deposited nearly instantaneously into deep, dysoxic waters.

At this locality the East Berne Member consists of dark-gray shale grading upward into fine-grained silts with interbedded thin- to medium-bedded fine-grained sandstones. The bulk of the East Berne Member is relatively barren here with very rare, scattered infaunal bivalves and pyritic thread-burrow. There are two ~5cm thick, compact, pyritic fossiliferous beds exposed near the middle-upper portion of the member separated by ~5m of barren silty-shale (Text-fig. 5-3.1). Both beds are faunally similar, being dominated by large numbers of nuculid bivalves with rare leiorhynchid brachiopods, gastropods, and cephalopods (Text-fig. 5-3.2).



Text-fig. 5-3.1: Outcrop of East Berne Member of the Mount Marion Formation along Rte. 209 west of Kingston. Dark arrows point to two thin fossiliferous horizons. The upper horizon is the Dave Elliot Bed, underlaing by vertial burrows. The lower bed is thought to correlate to the Hannacrois Ravine Bed to the north. Both are characterized by very abundant infaunal bivalves with rare leiorhynchid brachiopods and goniatite cephalopods.

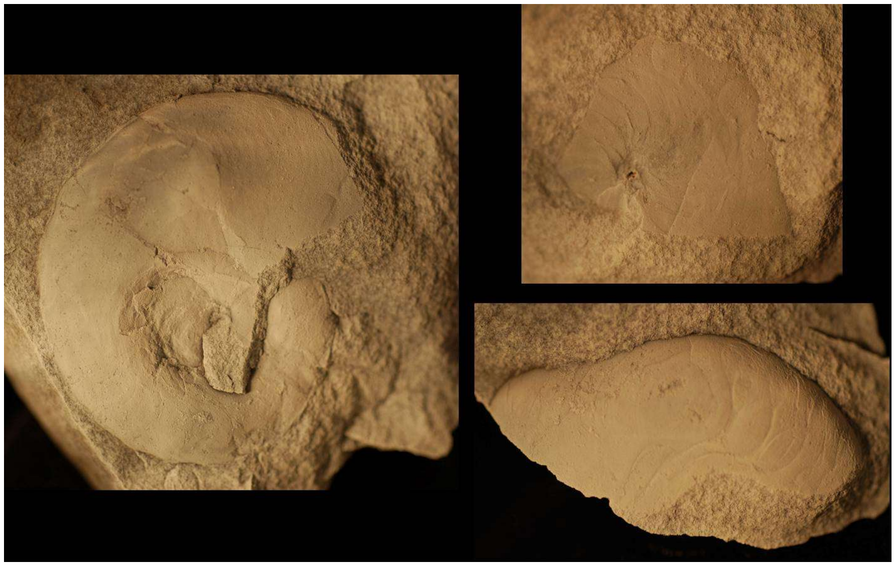


Text-fig. 5-3.2: Paleoecological reconstruction for Rte. 209 locality. LMU: *Eumetabolotoechia*, NUC: *Nuculoidea*, BEM: *Bembexia*, CHO: chonetids

The first distinct rusty horizon that contains a great abundance of infaunal nuculid bivalves (*Nuculoidea*) and rare goniatites. This bed is interpreted to be equivalent to the Hannacrois Ravine Bed to the north. Approximately 2m above this bed is a distinctive horizon of vertically-oriented concretions formed around tubular pyritic burrows. This bed is ~1m below the Dave Elliot Bed, another rusty horizon with abundant nuculid bivalves and rare leiorhynchid brahiopods and cephalopods. This bed represents a 'dirtier' water version of the leiorhynchid biofacies of Brett et al. (2007). Bartholomew and Schramm (2013) undertook an examination of this interval from this outcrop through sections north to Albany County, recording faunal counts from the Dave Elliot Bed at multiple sections. They determined that the Dave Elliot Bed represents the lowest known occurrence of the Hamilton Evolutionary-Ecological Subunit within the Appalachian Basin, preserving facies from deep water, as here at Kingston, to shallow-water coral-rich facies in northern Greene County, showing a full suite of Hamilton EE-SU biofacies. This interval in the upper East Berne Member is interpreted to represent a small-scale, 5^{th} or 6^{th}-order transgressive event.

Of great importance was the discovery at this site, and in the Hannacrois Ravine section to the north, of the zonally important goniatite *Tornoceras* aff. *mesopleuron* (Text-fig. 5-3.3, graciously identified by Dr. R. Thomas Becker of Muenster, Germany). At the standard section for the base of the Givetian in Morocco, this taxon first appears just above the base of the *P. hemiansatus* conodont zone that marks the base of the Givetian Stage and the occurrence of this taxon in the Dave Elliot Bed here marks its lowest record in eastern North America to date and helps to establish the base of the Givetian Stage as occurring somewhere below this bed and above the top of the Cherry Valley Member which contains conodonts indicative of the upper Eifelian

(*T. kockelianus* Zone) and puts the lower East Berne in the *P. ensensis* Zone (Bartholomew and Scrhamm, 2013).



Text-fig. 5-3.3: Goniatite *Tornoceras* aff. *mesopleuron* from the Hannacrois Ravine Bed. Full specimen is ~5cm across.

About 13 meters up section to the north is the horizon of a distinctive coral-rich horizon known as the Halihan Hill Bed. This well-known and widely traced coral be marks the base of the Otsego Member of the Mount Marion Formation and has been traced westward to western New York as well as into sections in Pennsylvania, Ohio, Ontario, Michigan, and Illinois. The Halihan Hill Bed marks a medium-scale, 4^{th}-order transgressive interval in eastern North America, marking a major 'cleaning event' within the water column allowing for colonization of the sea floor by abundant rugose corals across wide areas of the basin. This horizon marks the lowest full complement of Hamilton Fauna within the basin, containing an overall more abundant fauna than the smaller Dave Elliot Bed transgressive interval below, including such rare forms as *Fimbrispirifer* and *Meristella*. At this exposure (Text-fig. 5-3.4 and 5-3.5), the Halihan Hill Bed sits upon a thin, ~10cm, silty sandstone with corals in life position including *Enallophrentis* (formerly *Heterophrentis*), *Heliophyllum*, and *Eridophyllum* as well as abundant *Mediospirifer* brachiopods. Rare phacopid trilobites have also been found here.

Overlying dark gray shale-dominated strata above the coral bed represent offshore delta platform environments near to or below storm wave base. Cyclically-occurring shell beds, generally separated by 3-8 m of unfossiliferous mudstones, feature distinctive brachiopod-dominated faunas that in general increase in diversity upward through the interval. The strata also feature packages of thin sandstone beds; recent work shows that most of the shell beds and clusters of thin sandstones are correlative along the eastern New York outcrop belt (> 110 km, Kingston to Schoharie; Ver Straeten, 1994). The shell bed-mudstone alternations represent parasequence-scale cycles of greater thickness than analogous western New York Hamilton cycles due to greatly increased sediment rates near the proximal margin of the basin in the early progradational stage of Acadian tectophase C.

Text-fig. 5-3.4: Small rugose corals in life position in the Halihan Hill Bed interval.

Text-fig. 5-3.5: Thin silty-sandstone above which Halihan Hill Bed corals can be found.

Stop 5-4: Stony Hollow, Hurley, and Cherry Valley Members, Rt. 209, Kingston
Stop Author: Ver Straeten
Stop Leaders: Ver Straeten, Bartholomew

Location: Large outcrops along the east and west side of US Rte. 209 just south of Stop 5-3

Units: Eifelian Stony Hollow and Hurley members of the Union Springs Formation and the Cherry Valley Member of the Mount Marion Formation.

Description: Outcrops on the northwest and southeast sides of U.S. Route 209 here, north of Kingston, expose the upper 43 m of 71 m of the Stony Hollow Member (Union Springs Formation) in this vicinity; and 8.3 m of the Hurley and the lower 2.7 m of the lower part of the 10 m of the Cherry Valley members, assigned to the Mount Marion Formation in this area.

The Stony Hollow Member along Route 209 in the late 1980s, along with the Hurley and Cherry Valley members, was ideally weathered with little cover, and the author recorded a very detailed log of this section at this time. Strata here comprise middle to upper portions of the member. The lower ~28 m of the member are not exposed here; the section begins in the middle Stony Hollow. Lower strata are faunally barren, and little disturbed by burrowing. Strata 28 m below the top of the member feature an unusual fauna, consisting of *Coleolus* tubes, dacryoconarids/styliolinids, gastropods, nuculid bivalves, hyoliths, and cephalopods. The next notable fossiliferous interval features common auloporid tabulate and common small rugose corals, *Guerichiphyllum*? cf. *echoense*, along with a small chonetid (?) brachiopod, nuculid bivalves, and cephalopods. The first normal benthic fauna, of the Stony Hollow Fauna, appears in a limestone bed immediately below the 4 m-thick capping sandstone of the Stony Hollow Member.

This same lithology and other characters of the Stony Hollow Member is developed in intermediate depths down through the central to southern Appalachian Basin. This includes at Stroudsburg, Selinsgrove Junction and Cooks Mills/Hyndman, eastern, central and southern Pennsylvania; Keyser, northern West Virginia; and Jordan Mines, western Virginia, 703 km (437 mi) southwest of this stop. The same strata from the Hudson Valley in New York to Stroudsburg, Pennsylvania are assigned to the Stony Hollow Member; at the subsequent sites, Stony Hollow time-correlative strata, all of the same facies, are assigned to the lower part of the Purcell Member of the Marcellus Formation.

The Stony Hollow Member along Route 209 at this location is overlain by 8.3 m of the Hurley Member, at its type section. As noted elsewhere, the base of the Hurley in this part of eastern New York marks the base of the Mount Marion Formation, and the base of Devonian Sequence Ie/Eif-Giv. In sharp contrast with the Hurley Member seen at Stop 3.X, near Cherry Valley, the thick section here represents the siliciclastic lithosome of the member, largely composed of fossiliferous siliciclastic mudstones, with lesser siltstones and sandstones. The lower Chestnut Street submember in the Kingston area features three highly fossiliferous zones, featuring the highest diversity occurrence of the Stony Hollow fauna known in New York and the Appalachian Basin. Taxa include the brachiopods *Spinatrypa* cf. *borealis*, *Variatrypa* (*V*.) *arctica*, *Cyrtina*, *Warrenella* cf. *maia*, *Nucleospira*?, *Gypidula*, *Atlanticocoelia acutiplicata*?, *Spinulicosta*, *Schizophoria* cf. *macfarlanei*, *Leptaena*, *Pentamerella* cf. *wintereri*, and "*Productella*" (n. gen.). Other faunal elements include the minute crinoid *Haplocrinites clio*, the trilobite *Dechenella haldemani*, auloporid corals and the small rugose coral *Guerichiphyllum*? cf. *echoense*. Best access to this interval is along an abandoned railroad cut north of Hurley Mountain Road nearby. The overlying Lincoln Park submember, also at its type section here, largely consists of mudstones and a prominent ledge-forming, 0.7 m-thick sandstone with *Agoniatites nodiferus* goniatites (Text-fig. 5-4.1. This is the same event/marker bed as the siltstone in black shales seen near Cherry Valley in the upper part of the Hurley Member there. In the upper part of the Lincoln Park submember along Route 209, rusty mudstones with common spherical pyrite concretions extend up to the first sandstone ledge at the base of the Cherry Valley Member, also in its siliciclastic lithesome (Text-fig. 5-4.2).

Text-fig. 5-4.1: *Agoniatites nodiferus* from 0.7m thick sandstone bed in Lincoln Park submember of the Hurley Member.

Text-fig. 5-4.2: Middle to upper Hurley Member of Mount Marion Formation at its type section along northwest side of U.S. Rte. 209 northeast of NY Rte. 28. Base of Cherry Valley Member of Mount Marion Formation marked by white line. 0.7m thick sandstone beds with in *Agoniatites nodiferus* is behind person in photo.

Along Route 209 here only the lower 2.7 m of the 10 m-thick Cherry Valley Member in the Kingston area is exposed. Visible are two rusty, highly bioturbated sandstones ledges, separated by a rusty mudrock interval. A complete, overlapping composite section of the Cherry Valley Member is visible in a pair of outcrops nearby, on the west side of New York Route 28 and a railroad cut behind it. is visible in an abandoned railroad cut immediately behind the highway exposure. Five highly bioturbated arenaceous units, separated by sandy mudstone intervals, comprise the 10 m-thick siliciclastic lithosome of the Cherry Valley Member along Route 28 and the adjacent railroad cut.. Note that the upper sandstone is missing in the highway cut and the lower sandstone is exposed down-section to the south in the railway cut.

In the siliciclastic lithosome of the Cherry Valley Member near Kingston, body fossils are relatively uncommon in the sandstones. However, carbonate-rich concretions feature shelly to styliolinid-rich hashes with abundant quartz sand. *Cherryvalleyrostrum*, other small brachiopods, and auloporid corals may be present near the tops or bases of the sandstone units. Uncommon to rare nautiloid and goniatite cephalopods may also be found. *Teichichnus* is the most prominent ichnofossil in the sandstones. The intervening sandy shales feature numerous limonitic burrows, accompanied by small brachiopods and bivalves.

0.0 mi	Continue Southwest along US-209 S
0.5 mi	Take Exit ramp for NY-28 W toward Pine Hill
0.5 mi	Turn Right onto Forest Hill Dr.
200 ft	Turn Right onto City View Terrace. Pull over on Right.

Stop 5-5: City View Terrace roadcut, off NY Rte. 28
Stop Author: Ver Straeten
Stop Leader: Ver Straeten

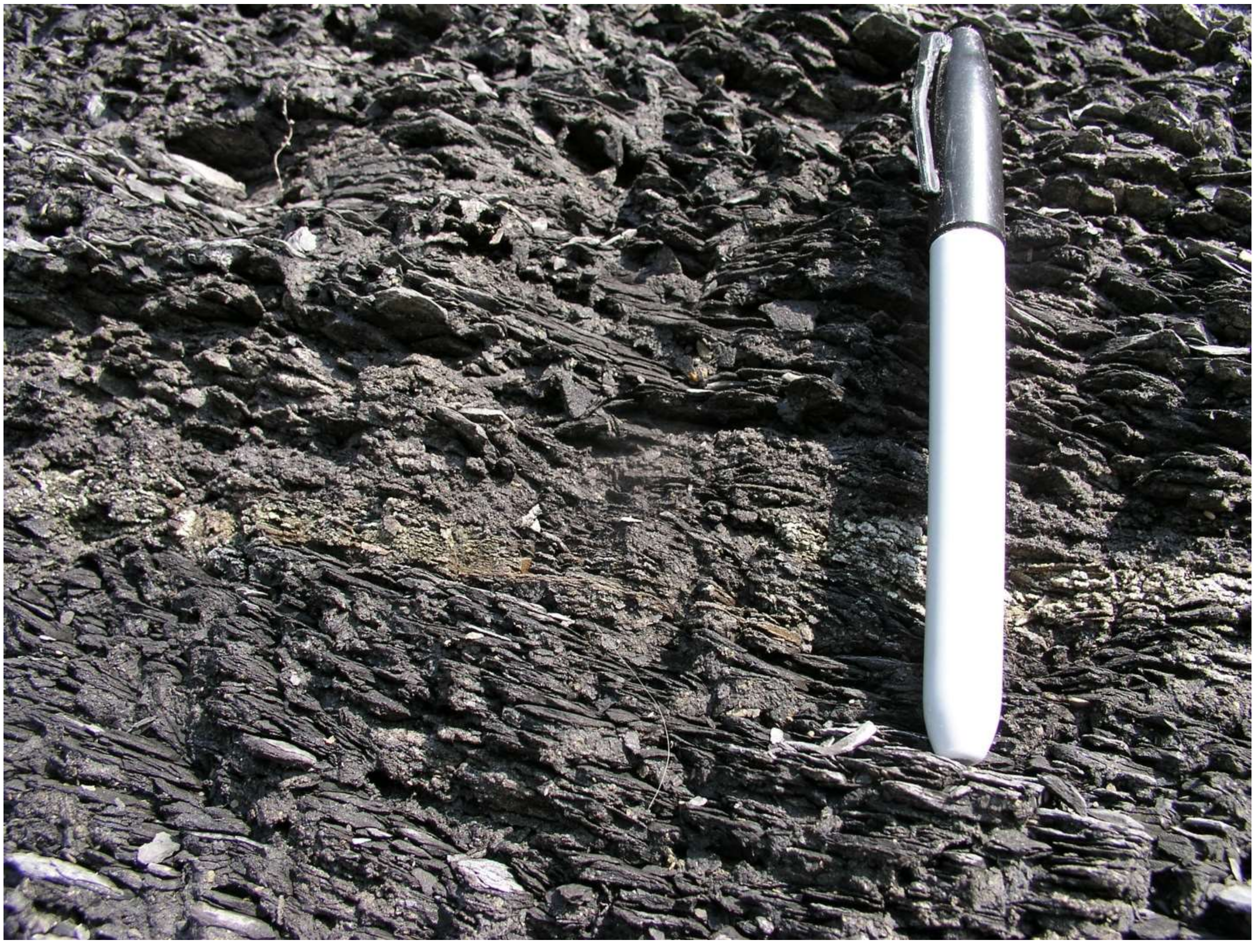
Locality: Contiguous roadcuts along New York Route 28, City View Terrace, and Forest Hill Drive, northwest of Kingston, Ulster County.

Units: Bakoven and Stony Hollow members of the Union Springs Formation, lower part of the Marcellus subgroup, lower Hamilton Group, Eifelian Stage, lower Middle Devonian.

Description: Lowest Hamilton group strata in New York State, dominated by black shale facies are assigned to the Union Springs Formation. Black shales to dark gray mudstone faices are termed the Bakoven Member. In the Hudson Valley to Port Jervis, where New York, New Jersey, and Pennsylvania meet, resistant, buff-colored, calcareous, silty shale that grades up to a capping sandstone comprises as much as the upper half of the formation. These strata are termed the Stony Hollow Formation.

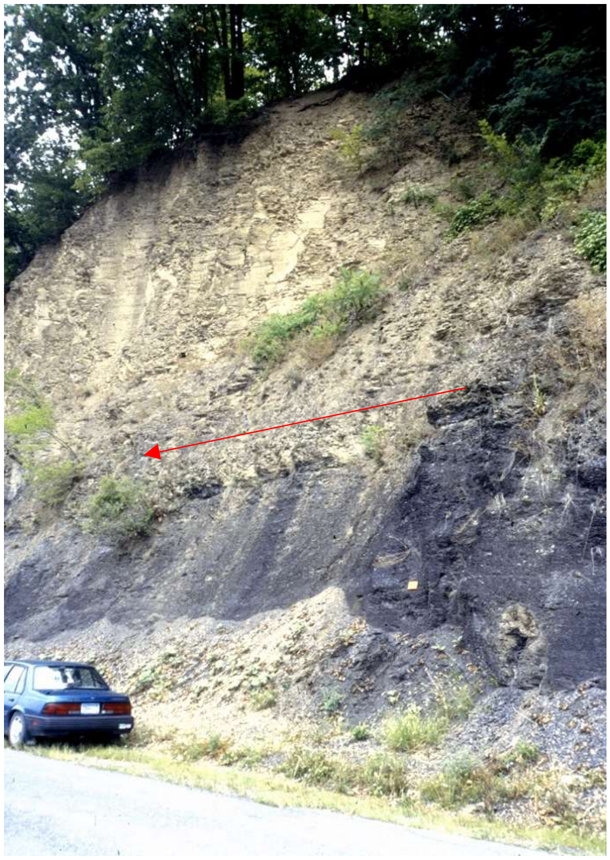
Near Kingston, Ulster County, the Union Springs Formation is on the order of 150 to 160 m-thick. Rickard (1989) estimated a thickness for the Bakoven Member to be 80 to 90 m in thickness around Kingston; the overlying Stony Hollow Member is 71 m-thick.

Roadcuts at this stop along Route 28, City View Terrace, and Forest Hill Drive expose the upper 10 m of the Bakoven Member and the lower 23 m of the overlying Stony Hollow Member. The Bakoven Member is nearly barren of fossils; styliolinids, cephalopods, and *Panenka* bivalves comprise the dominant forms found here. Upper strata of the Bakoven Member here feature numerous deformational structures, most notably below the Stony Hollow Member in the lower part of the City View Terrace exposure. Several zones of sheared and mesoscopically-folded shales are seen below the overlying resistant strata of the Stony Hollow Member. In addition, a basin-wide thin, correlatable altered airfall tephra is visible a short distance below the top of the Bakoven – along part of the outcrop, it appears as a cm-scale pyritic bed (5-5.1).



Text-fig. 5-5.1: Mid-Union Springs tephra. This bed can be found in the mid-Union Springs and correlative strata throughout the Appalachian Basin.

The Bakoven-Stony Hollow contact is gradational at Kingston (Text-fig. 5-5.2). Calcareous, buff-weathering, thinly laminated to burrow-mottled lower Stony Hollow strata also feature a low diversity, anaerobic to dysaerobic fauna of dacryoconariids and rare, small bivalves and brachiopods. Grain size increases upward through the Stony Hollow Member from laminated claystone mudstone couplets in the lower part to fine-grained sandstones near the top of the unit, as seen at the previous stop. The Stony Hollow Member along City View Terrace continues uphill along adjacent Forest Hill Drive. The top of this section, at least as exposed around 1990, correlates into the lower part of the Stony Hollow Member, 15 m above the base of the next roadcut, a high bluff along Route 28.



Text-fig. 5-5.2: Contact between Bakoven and Stony Hollow members of the Union Springs Formation along City View Terrace. Arrow marks the boundary.

City View Terrace to Rte. 28 Plattekill Outcrop:

0.0 mi	Turn around and turn Left onto Forest Hill Rd.
200 ft	Turn Right onto NY-28 W
3.5 mi	Pull over on Right across from Woodstock Harley-Davidson dealership

<u>Stop 5-6: Ashokan Formation along NY Rte. 28</u>
Stop Author: Ver Straeten
Stop Leader: Ver Straeten

Locality: Roadcuts along west side of New York Route 28, just past Woodstock Hurley Davidson

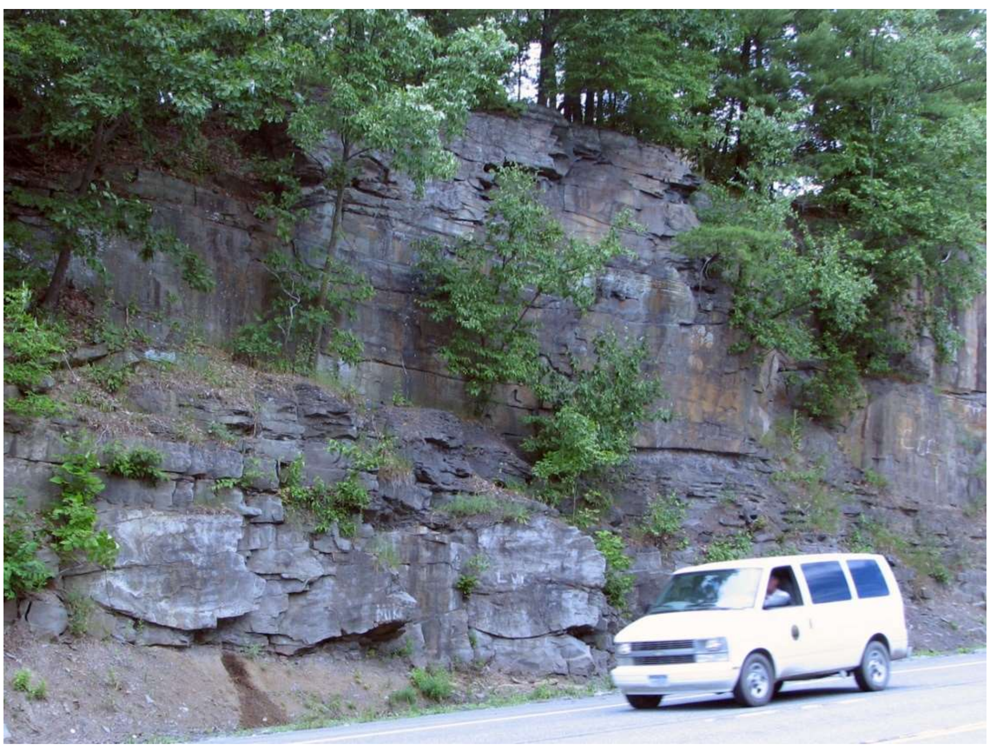
Units: Ashokan Formation, upper unnamed submember, lower part of the Hamilton Group at this site

Description: The Ashokan Formation is a two-part unit – the lower part encompasses strata marine-terrestrial transition zone, succeeded by lower, pre-redbed terrestrial strata. Unlike other Middle Devonian Hamilton Group formations, which are time-correlative/allostratigraphic units, the base and top of the Ashokan Formation are diachronous, and progressively rise into higher Hamilton Group strata, associated with the westward progradation and overfilling of the sea, creating new land.

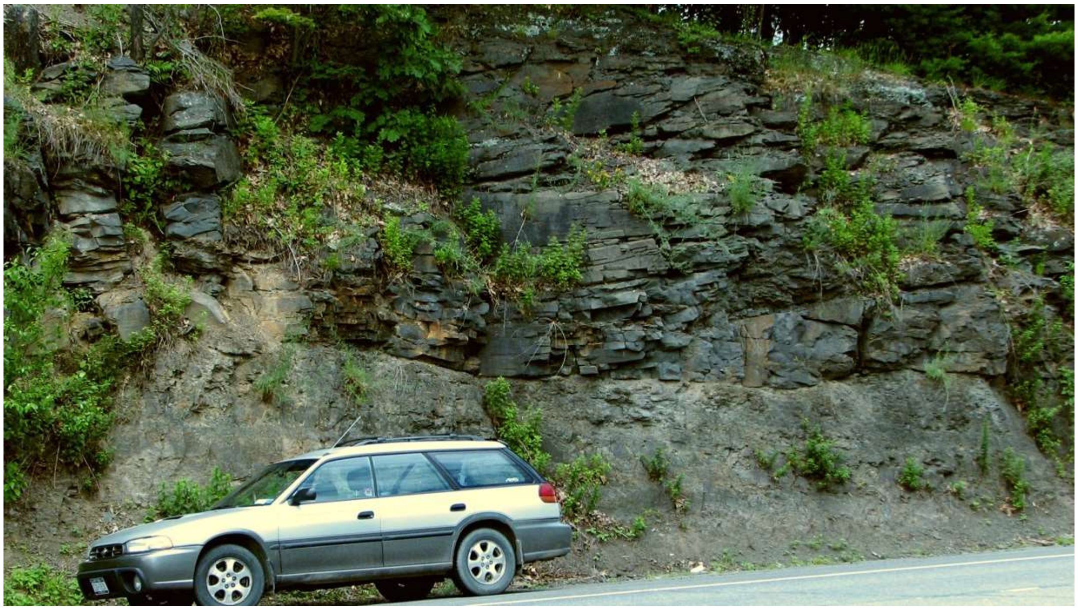
The lower part of the Ashokan Formation, as newly defined in Ver Straeten (2023c) consists of contiguous alternations of marine facies and terrestrial facies within the range of small scale cycles. Along the Route 28 corridor, this member lower part of the Ashokan occurs in a road cut on the northeast side of the highway as it descends to the road to Onteora Lake. No name has been assigned to this member-level unit.

The upper part of the Ashokan Formation, as seen at this stop, is characterized by fluvial channel sandstones, and greenish mudrock-dominated flood plain deposits, and a third facies, dark shales, apparently associated with lower coastal plain wetlands. The first two are exposed along the Route 28 roadcuts; the latter are visible along a railroad cut beyond these cuts, accessed off of ______ Road, ….

Marine shelly fossils have been found on both sides of Route 28, across from along a small road on the south side of Woodstock Harley-Davidson. The tall roadcut immediately northwest of it feature an odd yellowish-tan clay bed at its base, overlain by multiple stacked sandstone bodies (Text-fig. 5-6.1). Upper sandstones, if not all, appear to be normal, cross-bedded channel sandstones.



Text-fig. 5-6.1: Great stack of channel sandstone bodies in the upper Ashokan Formation immediately north of Woodstock Harley-Davidson dealership, west side of NY Rte. 28.



Text-fig. 5-2: Green-mudstone facies of upper Ashokan Formation erosionally overlain by channel sandstone facies. This exposure is farther north of Woodstock Harley-Davidson dealership, west side of NY Rte. 28.

Further northwest on Route 28, channel sandstones alternate with flood plain mudrocks (Text-fig. 5-6.2). Some sandstones show distinct sub-channel erosion down into underlying floodplain deposits. Some flood plain deposits are largely undisturbed, and preserve depositional layering. In other intervals, subtle to well-developed paleosols are visible (Text-figs. 5-6.3,4,5 … AshokanRt28_3295,md; GreenFloodplainSed-2; Ashokan,Rt28_3287md; IMG_3294,md), characterized by disturbed layering, blocky textures, pedogenic slickensides associate with vertisols, and mixed dark organic material and green mudstones.

Text-fig. 5-6.3: Upper Ashokan paleosol showing disturbed layering and blocky weathering.

Text-fig. 5-6.4: Upper Ashokan paleosol showing pedogenic dish structures (convex-up) associated with vertisols.

Text-fig. 5-6.5: Upper Ashokan paleosol mixed with dark organic material and green mudstone.

In contrast with the channel and green, non-red floodplain facies along Route 28, the abandoned railroad cut mentioned features thick dark gray shale and mudstones, alternating with sandstones. At one place along the cut, Ver Straeten found small lycopsid mats folded over, as if buried in the dark shales during a mud depositional event (Text-fig. 5-6.6).

Text-fig. 5-6.6: Dark shales to mudstones of upper Ashokan facies representing waterlogged facies likely associated with coastal plain wetlands. Yellow bar denotes length of hammer for scale.

0.0 mi	Continue northwest along NY-28 W.
2.0 mi	Pull over on Right at northwest end of outcrop

Stop 5-7: Plattekill Formation along NY Rte. 28
Stop Author: Ver Straeten
Stop Leader: Ver Straeten

Location: Cuts along N.Y. Rt. 28, 0.7 mi. west of intersection with NY Rt. 375.

Units: Givetian lower Plattekill Formation

Description: This outcrop of red, green, and olive mudstones (lower part) and medium-gray, cross-bedded sandstones (upper part) occur in the lower part of the Plattekill Formation (Text-fig. 5-7.1). They present a basic, generalized set of facies that characterize the remainder of Middle and Upper Devonian terrestrial strata (lower Givetian to lower Frasnian) at the Catskill Front. The mudstone-dominated facies represent subaerial floodplain deposits; the sandstone in the upper part of the outcrop represents fluvial channel deposits. The lower 5 m consist largely of green, green and red mottled, and red mudstones, including paleosols. Small calcareous soil peds/concretions occur in some intervals. Plant fossils and root traces are visible throughout much of the section; distinctive weathering styles appear to characterize different paleosol units along the outcrop. The overlying olive-weathering mudstones (-1.5-3.0 m-thick) are erosively capped by -4 m of planar cross-bedded, lithic arenites that represent deposition within a migrating fluvial channel. Pedersen et al. (1976) reported a zone of structural deformation in a paleosol horizon - 2.5 above the base of the section. On close examination, these structures appear to resemble separate, low angle, basin- or bowl-shaped structures - 0.5 to 1.0 m in diameter. Slickenlines on the bottom-side of the structures visibly radiate outward and upward on the outcrop. Pedogenic slickensides form in modern vertisols associated with seasonal wetting and drying of expansive smectitic (e.g., montmorillonite) clays in the B soil horizon (Gray and Nickelsen, 1989; Ciolkosz et al., 1979).

Text-fig. 5-7.1: Floodplain mudrocks overlain by fluvial channel sandstone body along north side of NY Rte. 28 just east of Laurel Lane.

In the channel sandstone above, a thin sandstone at its base is overlain by an amalgamations of generally flattened-appearing, multicolored clasts, with some more sub-spherical, light colored pebbles. These largely represent rip-up “intraclasts” (“clasts from within the environment”) of muddy sediments and the small calcareous soil peds noted above – all pieces of flood plain deposits torn up and transported during a high energy event, and deposited at the base of the river channel sandstone. The thinner sandstone below the intraclast conglomerate may be the remnant of a previous channel deposit, deeply eroded beneath the overlying channel. Alternatively, it may represent a “crevasse splay”, a thinner sandy deposit that spread out over the flood plain when a breach opened up in a levee along a river channel. The intraclasts bed likely formed as the river channel shifted out of its old channel, which had filled above the level of the flood plain – and shifted to the lower level during an avulsion event (Text-fig. 5-7.2).

Text-fig. 5-7.2: Mixture of rip-up clasts eroded from floodplain during flood or avulsion event and deposited near base of channel.

Several other interesting points can be gathered from this outcrop. The presence of the small calcareous soil peds/concretions are indicative of an alternating wet and dry monsoonal climate. Colors of the mudrocks are associated with position of the floodplain sediments relative to Devonian water tables. Above a water table, iron in the sediments is oxidized, yielding the red color (Text-fig. 5-7.3). Below a water table, iron in contact with water is reduced, producing a green color. Mottled green and red generally relates to a fluctuating water table; however, it is also associated with the decay of organic matter in red paleosols, such as roots, and can reduce the surrounding clays, producing green root haloes. Finally, dark to black shales in terrestrial settings, which were not seen at the previous stop in the Ashokan Formation, are associated with wetlands, where “soils” are supersaturated, and the waters and/or sediments may be anoxic, analogous to marine black shale depositional settings.

Text-fig. 5-7.3: Redbed floodplain deposits, including paleosols, in lower part of outcrop.

A rare but increasingly noted floodplain deposit is found 2.5 km (1.6 mi) to the west-northwest of this site. A decimeter scale limestone bed, first reported by Goldring (1943), occurs within green, red, and mottled red and green floodplain deposits just below the crest of Ohayo Mountain Road, north of Route 28 (Text-fig. 5-7.4). The bed is a 15 cm-thick red, relatively pure limestone bed, the latter indicated by strong karstification of the bed along narrowly-spaced vertical joints. It is bounded below and above by mostly green floodplain deposits. An unidentified fish plate was found, suggesting this was one of several freshwater limestone beds found by the author in recent years. Some of these beds feature fossil fish bone material and ostracodes. Fossil branchiopod crustaceans (*Estheria*) sometimes also occur, which are generally interpreted to indicate freshwater conditions.

Text-fig. 5-7.4: Karstified, decimeter-scale red limestone bed on Ohayo Mountain with aquatic, freshwater organism fossils.

However, also rarely but increasingly found in the Catskills terrestrial succession are pedogenic limestone lenses to beds, in the sense of calcrete horizons where soil concretions laterally amalgamated to form irregularly layered beds, with sometimes a complex, chaotic appearance. Both types around found in redbed successions.

Some of the apparent freshwater limestones appear to be relatively pure, others are argillaceous to sandy, or become calcareous, diluted by a high concentrations of siliciclastic sediments. They range from several to approximately 30 centimeters in thickness. They occur scattered through the Plattekill, Manorkill, and Oneonta formations. The Catskill Front limestones appear to have been deposited far out on floodplains beyond mud deposition where water tables rise above the land surface, as described by Gierlowski-Kordesch et al. (2013).

Where found, these occur within relatively continuous and sometimes very thick redbed successions, with mature paleosols and few sandstone bodies. Following additional field research on these thin limestones in summer 2019, possibly as many as 15 or more have been found within redbed successions in the Plattekill and Manorkill formations. Some of these clearly appear to form in freshwater lacustrine/ palustrine settings; others may be associated with pedogenic processes.

Plattkill Fm. along Rte. 28 to Schoharie/Onondaga along NY-32

0.0 mi	Turn around at Laurel Ln. at northwest end of outcrop and head southeast on NY-28 E
0.5 mi	Turn Left onto NY-375 N toward Woodstock (village, not site of festival)
2.9 mi	Turn Right onto NY-212 E
8.36 mi	Turn Left onto NY-32 N
1.85 mi	Pull over on left at junction with Kings Highway

Stop 5-8: New York Route 32, Kaatsbaan
Stop Author: Ver Straeten
Stop Leader: Ver Straeten

Locality: exposures along both sides of New York Route 32 at Kaatsbaan, northern Ulster County, and in woods back of west side of Route 32.

Units: Upper strata of the upper Emsian Schoharie Formation and overlying exposures of the Eifelian Onondaga Limestone (Note: the position of the Emsian-Eifelian boundary is unknown; it should be positioned between the top of the Schoharie Formation and the top of the lower member of the Onondaga Formation, Edgecliff Member).

Description: This set of outcrops exposes uppermost strata of the Saugerties Member of the Schoharie Formation, previously seen Stop 5-2 earlier today, and overlying strata of the Onondaga Limestone. The contact of the Schoharie and Onondaga formations is well exposed on the west side of Route 32, 0.3 km (0.2 mi) south of its intersection with Old Kings Highway.

Saugerties Member strata consist of alternations of calcareous mudrocks and limestones/limestone concretions (Text-fig. 5-2.1). At this site, only the uppermost Saugerties Member is exposed, which consists of fossiliferous light brownish sandstones (Rickard Hill facies), seen at the base of Text-fig. 5-8.1, overlain by buff- and light gray-weathering limestones with thin quartz sand stringers.

Text-fig. 5-8.1: Upper Saugerties Member of Schoharie Formation overlain by overhanging ledge of Edgecliff Member, base of Onondaga Formation. Note standard fieldbook for scale.

Light gray, clean limestones of the Edgecliff Member mark the lower portion of the Onondaga Formation here. The entirety of the member is well seen at the north end of Old Kings Highway, 10.9 km (6.7 mi) north of here. At that site (Text-fig. 5-8.2), the lower 2.0 m of relatively chert-free, coral, brachiopod, and crinoid-rich pack- and grainstones are capped by a thick section of medium-grained, cherty, crinoidal packstones. Similar alternations of cherty and chert-free strata characterize the Onondaga Limestone in this area; chert-dominated facies are predominant locally, however.

Text-fig. 5-8.2: Lower non-cherty Edgecliff Member strata overlain by upper cherty Edgecliff Member strata. North end of Old Kings Highway, 10.9 km to the north of Stop 5-8.

Upper Edgecliff and overlying Nedrow members strata are exposed back from the road a distance. The Nedrow Member is recognized by its more argillaceous and recessive character. The distinctively more recessed interval in the upper middle part of Text-Fig. 5-8.3 represents the maximum flooding position of Depositional Sequence Ib (Eif-1). This same maximum flooding, termed the Nedrow Black Beds (Brett and Ver Straeten, 1994, Ver Straeten et al. 2023, 2006), occurs just above the base of the *Pol. costatus costatus* Zone. This marker unit is recognizable as the relative deepest litho- and biofacies throughout Onondaga and corelative strata not only in the Appalachian Basin, but has been seen at the same position close above the base of the *costatus* zone by Ver Straeten and Brett in the Anti-Atlas and Moroccan Meseta in Morocco, the Barrandian Basin in the Czech Republic, and the Austrian Alps. Lower strata of the overlying Moorehouse Member form a flat vertical face above the Nedrow Black Beds interval.

Text-fig. 5-8.3: Middle to upper Nedrow and lowermost Moorehouse members of the Onondaga Formation. Recessed interval at top of Nedrow Member is the Nedrow Black Beds of Brett and Ver Straeten (1994) and Ver Straeten et al. (2023).

At the northern end of this set-back outcrop, return to the roadside, and continue to follow the northward trend of the outcrop. More of the Moorehouse Member is visible on both sides of the highway (Text-fig. 5-8.4). Compared with the Edgecliff Member in the lower Onondaga is the Moorehouse Member by finer-grained, cherty, wacke- to packstones characterized by brachiopod-dominated faunas. Overall, the Moorehouse Member is characterized by finer-grained, cherty, wacke- to packstones, with brachiopod-dominated faunas.

Text-fig. 5-8.4: Moorehouse Member west side of NY Rte. 32 outcrop just north of junction with Old Kings Highway.

It is doubtful any Seneca Member occurs at the top of the outcrop. However, in Kaaterskill Creek, 10.5 km (6.5 mi) to the northeast, a decimeter-scale apparent altered air fall tephra, possibly the Tioga B tephra bed, can be found up a small ravine just downstream of the Onondaga-Marcellus contact, with a small amount of limestone above it. Normal erosion over time, or glaciation, would have removed the Seneca Member off of the outcrop.

The member level subdivisions of the Onondaga Limestone that are well-defined and easily recognized in central New York (see Brett and Ver Straeten, 1994) are less readily detectable in Hudson Valley outcrops. They can tentatively be separated by changes in chert and argillaceous content, and in bedding thickness.

Fifty meters of Onondaga strata are reported from outcrops along the NYS Thruway at Saugerties, 13.7 km (8.5 mi) to the south (Feldman, 1985). The top of the Onondaga section the is thought to be relatively close to the contact of the Onondaga Limestone and overlying clastics of the Union Springs Member.

Kaatsbaan Schoharie/Onondaga outcrop to Platte Clove Corner Outcrop:

0.0 mi	Continue North on NY-32 N
1.5 mi	Turn Left onto Harry Wells Rd.
1.94 mi	Turn Right to stay on Harry Wells Rd.
225 ft	Merge onto Blue Mountain Rd.
2.89 mi	Continue onto Platte Clove Rd. Steep road, no maintenance in November-April
0.5 mi	Pull over just past right turn. Be careful of cars on narrow road.

Optional Stop: Platte Clove road Corner outcrop
Stop Author: Bartholomew
Stop Leader: Bartholomew, Ver Straeten

Having driven up into the Catskill Front via the steep, narrow road through Platte Clove, we are now several hundred feet up into the Middle Devonian terrestrial succession. As we go up section, we see an increase in thickness and incidence of sandstone river channel facies and a thinning and decrease in number of related mud-dominated overbank, floodplain deposits. At this stop we will see a relatively thin red to green mudstone paleosol package overlain by a thick coarser-grained sandstone river channel succession. Within the muddy, overbank deposits we see a common pattern in coloration change preserved here, with lower, slightly coarser-grained, blocky-weathering red mudstone overlain by slightly finer-grained, somewhat fissile, olive-green colored mudstone that sits directly below the sandy river channel deposits (Text-fig. 5Opt-1). This change in color is interpreted to represent a rise in the Devonian water table, as seen in the lower Plattekill Formation exposure along Rte. 28, associated with the approach of the river channel system as it migrated across the floodplain. The fine-grained, overbank deposits below the base of the river channel deposit here at this outcrop is eroded back into the outcrop, allowing us to examine the base of the river channel deposit and we find preserved in the base of the channel several large fossil logs aligned with paleo channel flow direction. (Text-fig. 5Opt-2).

Text-fig. 5Opt-1: View of upper portion of muddy, overbank deposits showing color change from lower reddish mudstone to overlying olive-green mudstone.

Text-fig. 5Opt-2: Close-up view of underside of sandy river channel deposits showing at least, aligned three large tree trunk fossils (arrows) with carbonization of woody material.

Kaatsbaan Schoharie/Onondaga Outcrop to North/South Lake:

0.0 mi	Continue North on NY-32 N
4.14 mi	Continue Straight onto NY-32A N
1.9 mi	Slight Left onto NY-23A W. Be careful on windy road up Kaaterskill Clove.
4.87 mi	Turn Right onto N Lake Rd., bear right at Y immediately after
2.3 mi	Enter North/South Lake State Park. Follow signs to North Lake Parking area

Stop 5-9: Catskill Escarpment, at North-South Lake, Catskill Mountains
Stop Author: Ver Straeten
Stop Leader: Ver Straeten, Bartholomew

Locality: North-South Lake State Park, Catskill Front, east of North Lake Beach Parking. Walk east to Catskill Front escarpment to Catskill Mountain House site and then walk south up hill to outcrops.

Units: Givetian Oneonta Formation including the greater Twilight Park member.

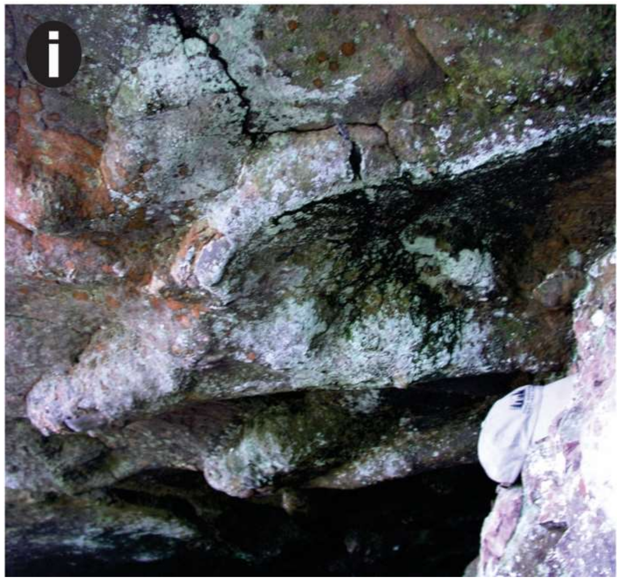
Description: At this site, we are standing at the top of the Catskill Escarpment, rising 480 m (1575 ft) above the valley floor below. In the distance to the east are the Appalachian Mountains as they are today, visible, left to right, in Vermont, Massachusetts, and Connecticut. They are the remnants of three Paleozoic collisional events during the Ordovician, Devonian and Upper Carboniferous-Permian. Continent-continent collision of eastern "Laurentia" and other terranes during the Late Silurian and throughout the Devonian resulted in the Acadian Orogeny – split by some into separate Acadian and Neoacadian orogenies (Pridoli to Emsian, Eifelian to post-Devonian, respectively). The orogen progressively built upward and cratonward into a major mountain range during the Devonian. Massive volumes of synorogenic sediments were shed off the orogen from western New England into eastern New York through the Devonian Period.

The north to south flowing Hudson River is visible in places in the valley. West of it, Ordovician siliciclastics are unconformably overlain by very thin Upper Silurian strata, succeeded by Devonian strata. The latter extend westward from here to Lake Erie, western New York (seen at stops on Day 3 of the pre-meeting Fieldtrip and the Niagara mid-meeting Fieldtrip). Two ridges west of the Hudson River are composed of marine Lochkovian carbonates and lower Givetian siliciclastics, respectively. Strata in the flats below the escarpment are overlying lower Givetian terrestrial strata. The Middle-Upper Devonian boundary apparently lies at a position not far above us, near the conglomerates on South Mountain, to the right and upslope. The thickest succession of Devonian strata in New York State are from the Silurian-Devonian boundary here in the Hudson River Valley (Stop 4-6) to the high peaks of the Catskill Mountains southwest of here, for a total thickness estimated of at least 2.7 km (1.7 mi) (Text-fig. 5-9.1).

Text-fig. 5-9.1: Aerial view of Catskill Escarpment looking west. Arrow points to Catskill Mountain House site at edge of escarpment. Photo credit: Joe Gianelli.

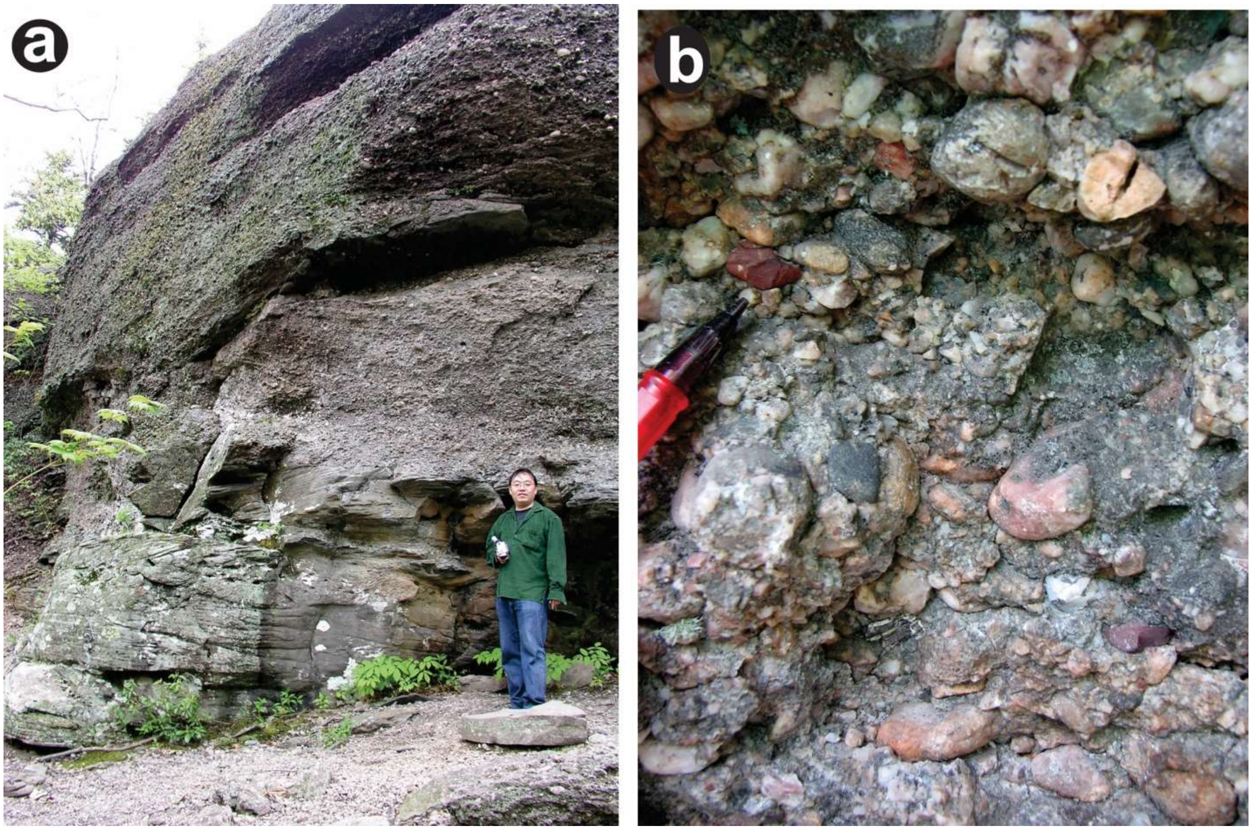
The area of North-South Lake and the canyon of Kaaterskill Clove to the south was very significant in the origin and evolution of the Hudson River School of American landscape painters in the 19th Century. At that time, there was much interaction between geologists and artists, including painter Thomas Cole, father of the Hudson River School of painters (Bedell, 2001). One of the great Catskill Mountain hotels, the Catskill Mountain House, sat on this ledge of sandstones.

From the Catskill Mountain House site, a trail leads southward, up the east side of South Mountain. The first outcrop along the trail exposes a channel sandstone body with a prominent overhang, where underlying floodplain deposits have eroded away. On the underside of the sandstone, a number of decimeter-scale, tunnel-like horizontal burrows extend downward (Text-fig. 5-9.2). At least some of them end in an elongate, perhaps chamber-like mass. These are understood to be lungfish burrows leading to aestivation “nests”, where during droughts, the lungfish would reside in a state of torpor until monsoonal rains would return. The underlying muds would create an aquiclude, above which water in the base of the channel sands would remain longest. A red mudstone outcrop is visible nearby.



Text-fig. 5-9.2: Lungfish burrows extending to aestivation chambers on underside of channel sandstone along trail heading uphill to southwest from Catskill Mountain House site, North-South Lake State Park.

A thick conglomerate is found farther up along the trail. This is one of two thick conglomerate bodies in the lower part of the Oneonta Formation, along the crest of the Catskill Escarpment (Text-fig. 5-9.3). The two thick conglomerate bodies on South Mountain here mark the central part of an approximately 200 m-thick interval of gravel-based fluvial fining-upward cycles (Ver Straeten, 2023d). These 2 beds were first noted in a 1794 paper by a general naturalist as granite (De La Bigarre, 1794), reflecting the early stage of geology in North America, and the colorful character of the conglomerates from the variously white, hematite-stained red, and chlorite-veined green and white milky quartz, red jasper and general sandstone pebbles in the conglomerates. This roughly 200 m-thick, currently informal “greater Twilight Park member” (gTwlPk; Ver Straeten 2023d), is more substantial than the interval including the two ca. six m-thick conglomerates within 30 m used to define the Twilight Park Member by Bridge and Nickelsen (1985).



Text-fig. 5-9.3: a: Overview of lower thick Twilight Park Conglomerate at Sunset Point, North-South Lake State Park. b) Close-up view of pebble in the Twilight Park Conglomerate, Sunset Point, North-South Lake State Park.

The gTwlPk member represents the first major progradation of gravels into the easternmost segment of the Devonian outcrop belt in New York. Conglomerates of similar thickness are not reported in the Catskills terrestrial succession until roughly 400-500 m higher in the succession. Lesser conglomerates occur lower in the succession, including in upper marine strata seen on the closer, low ridge noted above, with a distinctly different suite of milky quartz and chert pebbles. Studying the gTwlPk on Plattekill Mountain, several km/mi to the south, Ver Straeten (2023d) found a distinct trend of upward-thickening gravels at the base of fluvial cycles in the lower part of the unit, building up to the two ~6 m-thick conglomerates. Above there, conglomerate thickness trends reverse, and basal gravels thin to the top of the interval where, as at the base of the Twilight Park member, conglomerates only occur as lenses.

Progradational cyclicity under relatively high sedimentation rates, as seen in the greater Twilight Park interval, could be the result of three major processes: downstream-controlled base-level changes in the Acadian Foreland Basin seaway, orogenic thrusting and uplift up in the mountain belt, or climate-controlled changes in precipitation. One additional process that could lead to similar patterns would be related to river avulsion, when a river migrates from its current channel to another area on the flood plain. However, this would result in more localized features. Ver Straeten (2023d) examines these potential causal mechanisms in more detail. Considering the probable position of the Catskill Escarpment area as still on the relatively lower part of the Acadian alluvial plain proximal to the Middle-Late Devonian change, the trend may better be explained by sea level change in the marine portion of the Acadian foreland basin. Within medial scale depositional sequences (ca. 100 kyr or 405 kyr) cycles, on the order of deposition of the entire gTwlPk, gravel would be transported further basinward during marine falling stage to lowstand systems tracts; and through transgression to maximum floodings, conglomerate deposition would migrate up the alluvial plain. Similarly, at the scale of individual fluvial fining-upward cycles, conglomerate deposition would occur during regressions to lowstands of sea level and would migrate up slope during transgressions.

Bedding features/sedimentary structures, well seen along the extensive outcrop of the upper thick conglomerate, indicate strong hydrodynamic flows at times during deposition. This includes trough crossbedding or plow and fill structures, and other features.

This position in the coarsely estimated 1.9 km (1.2 mi)-thick Catskill Mountains terrestrial succession is below the midway point, vertically. In the upper half of the succession, mudrock-dominated flood plain deposits decline to largely disappear, replaced by a greater percent of sandstones, including as flood plain deposits. This is related to ongoing deposition, leading to higher positions on the Acacian alluvial plain. In upper units (upper Walton and Slide Mountain formations), thick conglomerate bodies increasingly occur. Depth of burial studies, discussed in Ver Straeten (2023d), indicate as much as four to five km (2.5 to 3 miles) of rock has been eroded off of the highest peaks in the Catskills Mountains today. How much of that thickness was Devonian in age is totally unknown.

North/South Lake to Saugerties Comfort Inn

0.0 mi	Head West on N Lake Rd.
2.3 mi	Turn left onto NY-23A E. Be careful on windy road down Kaaterskill Clove.
4.87 mi	Slight Right onto NY-32A S
1.9 mi	Continue Straight onto NY-32 S
5.55 mi	Turn Left into Saugerties Comfort Inn

End of Day 5

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