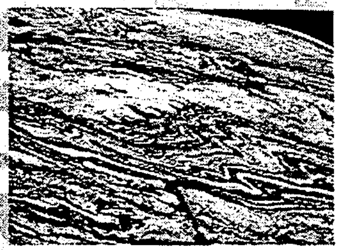
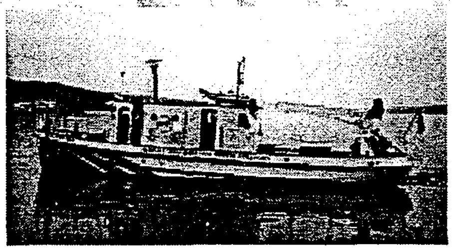
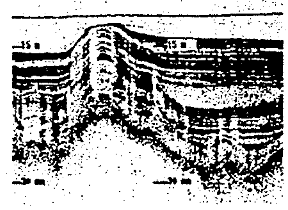
NYSGA 2000

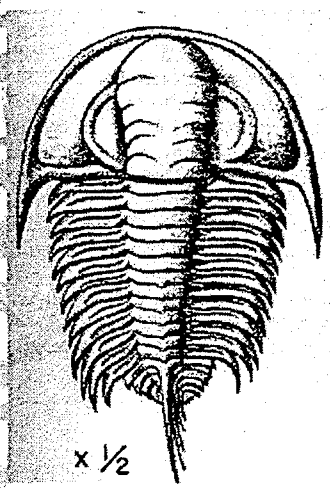
FIELD TRIP GUIDE

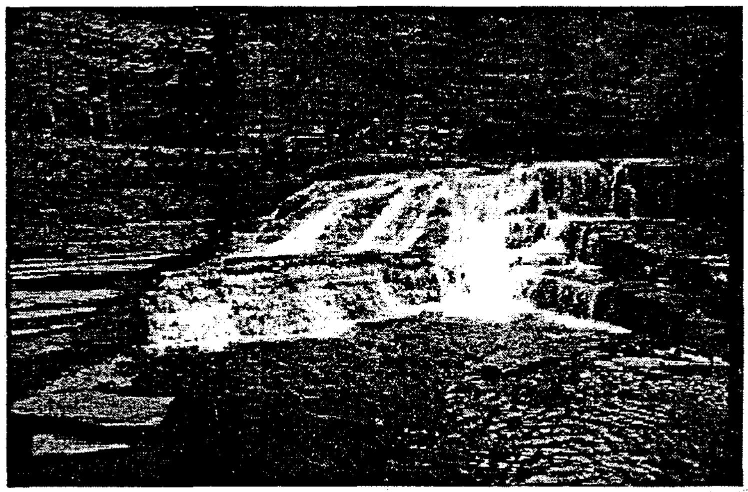
72nd Annual Meeting of the New York State Geological Association











September 29 - October 1, 2000

HOBART AND WILLIAM SMITH COLLEGES
GENEVA, NEW YORK

HOBART
AND
WILLIAM SMITH
COLLEGES
Geneva, New York

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Field Guide Compiler:
D. Brooks McKinney

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SURVEY OF THE GEOLOGY OF THE NORTHWESTERN ADIRONDACK MOUNTAINS AND BLACK RIVER VALLEY

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DEPARTMENT OF GEOSCIENCES

And

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DEPARTMENT OF GEOLOGY
SUNY AT CORTLAND

INTRODUCTION

The geological history of New York State may be conveniently divided into four major phases, each represented by rocks or sediments or geomorphic features. These major phases include:

- Proterozoic orogenesis (represented primarily by exposed mid-crustal metamorphic and igneous rocks of the Adirondack region)
- Paleozoic events (represented by exposed and deformed sedimentary rocks throughout the state)
- Early Mesozoic crustal extension (represented by basaltic dikes and sills, and by sedimentary rocks in southeastern NY)
- Pleistocene glaciation and subsequent events (represented by sediments and geomorphic features throughout the state).

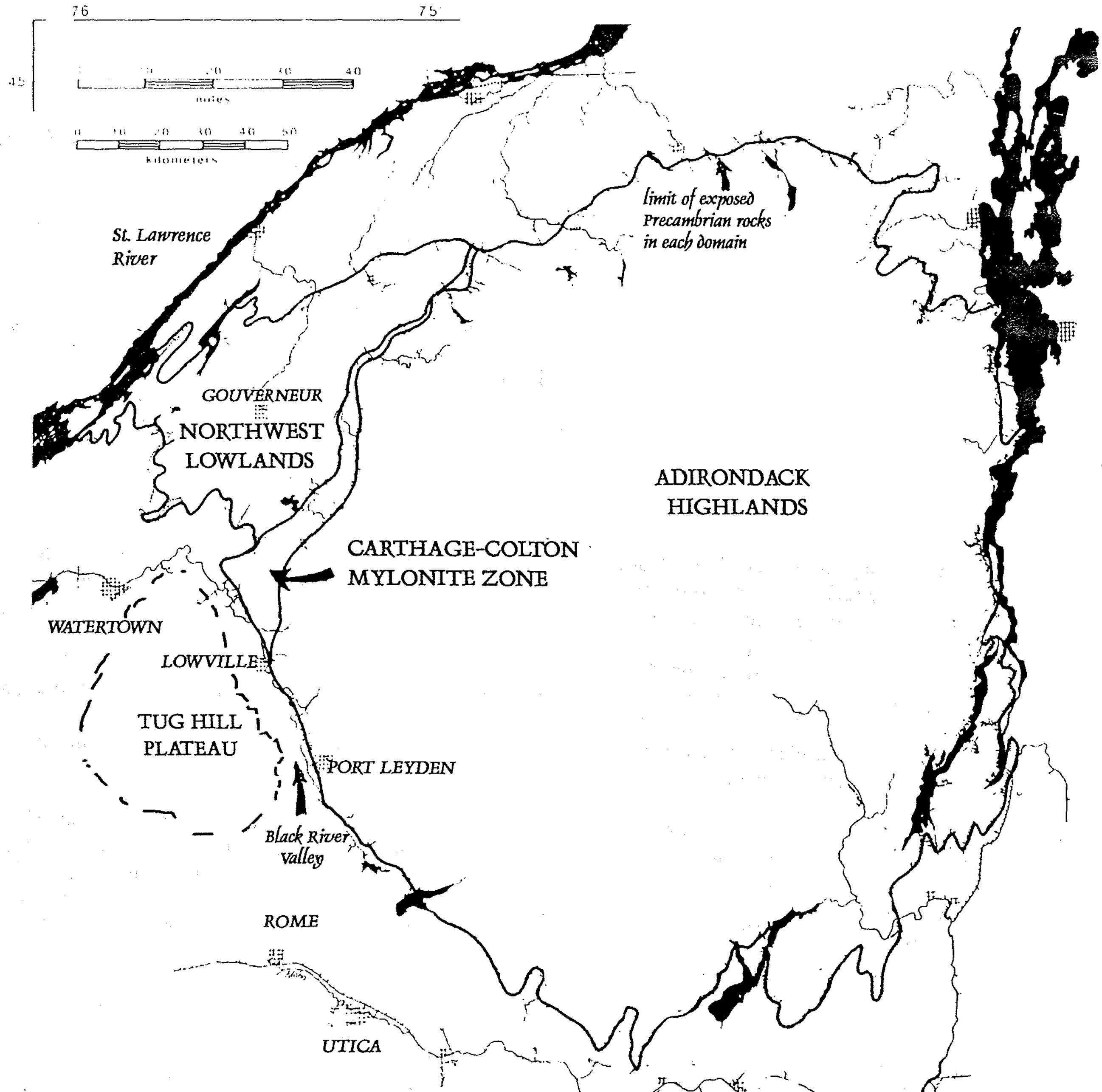
Exposures in the northwestern Adirondacks and the Black River Valley permit the examination of relics of most of these events, although Mesozoic events are represented poorly at best The current trip is designed as a north-south transect from the Northwest Lowlands, across the Carthage-Colton Mylonite Zone into the Adirondack Highlands at their western margin, up onto the Tug Hill Plateau, and along the Black River Valley (Figures 1 and 2). The Black River Valley, which separates the Tug Hill Plateau from the Adirondack Highlands, provides a wonderful opportunity to examine rocks, sediments, and structural features with ages ranging over a billion years.

PROTEROZOIC OROGENESIS

Proterozoic metamorphic rocks of New York State are all part of the Grenville orogen, which welded together a supercontinent that predated Pangaea. This supercontinent 1.09 billion years ago contained a mountain range to rival the modern Himalayas (Mezger and others, 1991). The collisional events that produced this range occurred over a period 150-200 million years long, and left a complicated record composed primarily of highly deformed metamorphic rocks. The complete story may be deciphered with difficulty, using field relationships, interpretation of rock types, isotopic studies and dating, and chemical petrologic methods.

Various workers, especially Bohlen and others, (1985), and Mezger and others (1991), have shown that metamorphic grade is not equal across the Adirondacks. Rocks exposed in the Northwest Lowlands (Stops 1-6) were metamorphosed at generally slightly lower pressures and temperatures than those of the Adirondack Highlands (Stops 10- 11 and Stops 14-16). Additionally, there are more rocks of sedimentary origin, such as marble (Stops 1 and 2), in the Northwest Lowlands than in the Highlands, and metamorphism in the Lowlands ended before that in the Highlands (Mezger and others, 1991). All of the rocks currently at the surface in the Lowlands and the Highlands were metamorphosed at mid-crustal depths, with nearly 20 km of rock now missing from above the Lowlands, and at least 28 missing from above the Highlands.

The Carthage-Colton Mylonite Zone (CCMZ), a broad (3-5 km wide; Geraghty and others, 1980) belt of intensely deformed gneisses (stops 7-9) separates the Lowlands to the northwest from the Highlands to the southeast. Rocks within the shear zone have penetrative foliations and well developed lineations that plunge to the northwest. The interpretation is that the Lowlands were once over the Highlands, but essentially slid off along the Carthage-Colton


76
75
45
0 10 20 30 40
miles
0 10 20 30 40 50
Kilometers
St. Lawrence River
limit of exposed Precambrian rocks in each domain
GOUVERNEUR
NORTHWEST LOWLANDS
ADIRONDACK HIGHLANDS
CARTHAGE-COLTON MYLONITE ZONE
WATERTOWN
LOWVILLE
TUG HILL PLATEAU
PORT LEYDEN
Black River Valley
ROME
UTICA

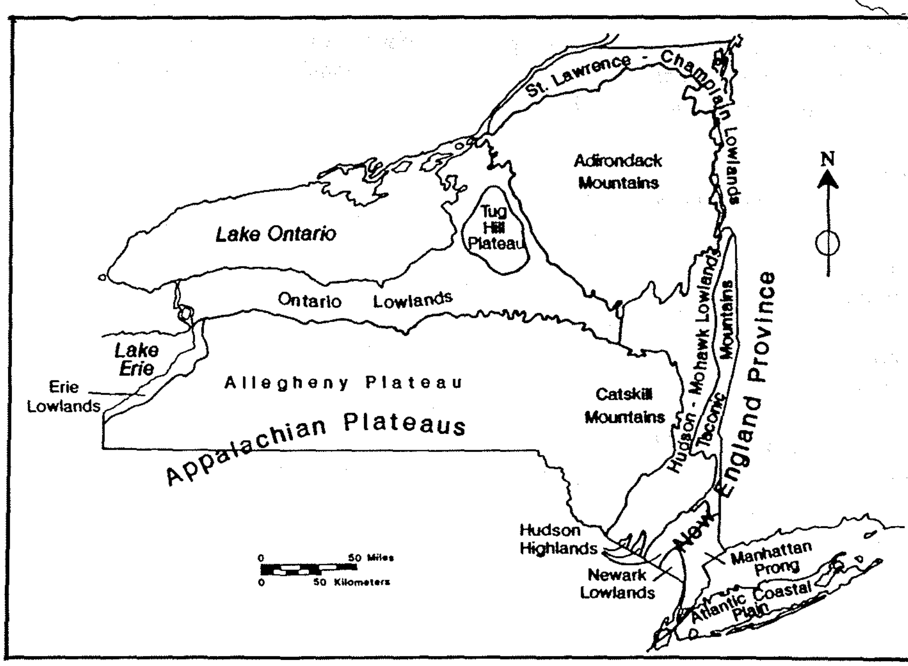

St. Lawrence - Champlain Lowlands
Adirondack Mountains
Tug Hill Plateau
Lake Ontario
Ontario Lowlands
N
Lake Erie
Erie Lowlands
Allegheny Plateau
Appalachian Plateaus
Catskill Mountains
Hudson - Mohawk Lowlands
Taconic Mountains
New England Province
Hudson Highlands
Newark Lowlands
Manhattan Prong
Atlantic Coastal Plain
0 50 Miles
0 50 Kilometers

Figure 1. Map showing major geographic and geologic features of the State of NY. The current field trip runs fro outside Gouverneur south to the village of Port Leyden. Figure is modified from figures in Isachsen and others, 1991.

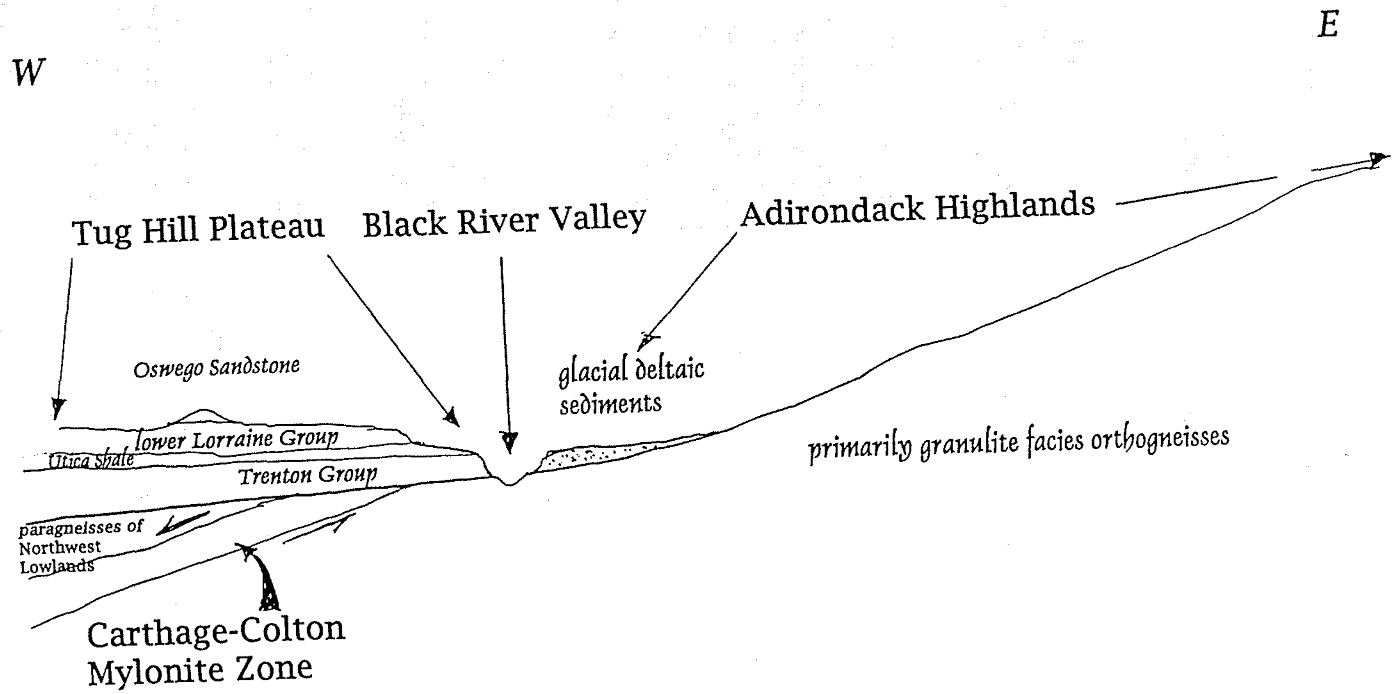


Figure 2 Schematic cross-section from west to east across the Black River Valley, between Lowville and Port Leyden. The figure is meant only to illustrate gross relationships between features and units; vertical scale has been grossly exaggerated, and the horizontal scale is not reliably linear. Note that rocks of the Northwest Lowlands are exposed only well north of the line of section.

Mylonite Zone shortly following high-grade metamorphism. This model accounts for the structural features of the CCMZ, as well as the differences between the Highlands and the Lowlands.

At some time after Grenville orogenesis and before Paleozoic sedimentation, sub vertical basaltic dikes were emplaced in the gneisses, perhaps as a response to the break up of the supercontinent. An example of one of these dikes may be seen at Stop 1.

PALEOZOIC EVENTS

Over much of the Adirondack region, the oldest preserved Paleozoic unit is the Late Cambrian Potsdam sandstone. It is a relatively near-shore passive margin deposit of quartz sandstone. We will see only erosional remnants preserved in sinkholes in Proterozoic marble at Stop 1. Originally more extensive deposits, along with any Early Ordovician sediments were eroded away in Middle Ordovician time (and/or in Mesozoic time), as the seas retreated from the area.

In the Late-Middle and Upper Ordovician, sedimentation resumed over the entire Adirondack region (Rickard, 1969; 1973). In the Black River Valley, limestones of the Black River Group were laid down directly onto exposed Precambrian granitic gneisses. The unconformity is well exposed in Roaring Brook, at Stop 12. The unit here is conglomeratic, with pebbles of crystalline rocks in a sandy matrix. The depositional environment of the Black River Group is thought to be shallow to intertidal. The Trenton Group limestones were deposited over the Black River Group. Deeper water conditions followed, in response to loading of the eastern edge of proto-North America at the onset of the Taconic Orogeny. Thick (up to hundreds of meters), black, sulfidic, shales of the Utica Formation were deposited. The contact between the Trenton and the Utica is sharp. In the Black River Valley and Tug Hill Plateau region, the Utica Shale in turn grades upward into the Lorraine Group, a stack of siltstones and shales, beautifully exposed in Whetstone Gulf. The siliciclastic nature of this unit reflects filling in of the basin and westward transgression of the incipient Queenston delta.

MESOZOIC EVENTS

While the Mesozoic rifting, intrusion, and deposition seen elsewhere in New York State had little effect on the western Adirondacks and the Black River Valley, the terrain was still affected by Mesozoic events. Recent work by Roden-Tice and others (2000) proves that denudation of the Adirondack Mountains occurred in Mesozoic time. Apatite fission-track ages for the Northwest Lowlands range from 135-126 Ma, slightly younger than those from the High Peaks region of the Highlands.

The actual age of the current domal form of the Adirondack Mountains, and the dips on the unconformity which overlies them, may be still younger. According to Isachsen (1975, 1981), doming is Tertiary.

GLACIAL EVENTS

Nearly two million years ago the northern hemisphere underwent an Ice Age. There is evidence in North America for four major pulses of ice advance. In New York most of the features we see are related to the last ice advance, called the Wisconsin. By about 20,000 years ago nearly all of New York (although probably not the Adirondack Highlands, which were elevated by then, and were affected by valley glaciers) was under the Wisconsin ice sheet. About 10, 000 years ago, the ice retreated again.

The remains of this ice sheet in the Northwest Lowlands consist of polished and striated rock surfaces, and widespread, relatively small sand and gravel deposits. In the Black River Valley, there are deltas of sediment shed off the Highlands into proglacial Lake Port Leyden, at a time when ice blocked both the Mohawk Valley and the St. Lawrence Seaway.

ROAD LOG FOR GEOLOGY OF THE NORTHWESTERN ADIRONDACK MOUNTAINS AND BLACK RIVER VALLEY

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0	0.0	Parking Lot of Day's Inn, Watertown on Rte.3. Turn east on Rte. 3.

1.3	1.3	Turn north on Rte. 11.
37.0	35.7	Pass McDonalds on Rte. 11, village of Gouverneur.
37.1	0.1	Turn north (left) on Rock Island Street.
41.4	4.3	STOP 1, Roadcuts on either side of Rock Island Road, immediately south of bridge over Oswegatchie River.

STOP 1. ROCK ISLAND ROADCUT

This large roadcut is one of the best places to observe the contact between Proterozoic marbles of the Adirondack lowlands and the Cambrian Potsdam sandstone. The marbles were highly deformed, intruded by basalt dikes (also exposed here), and deeply eroded. The Potsdam sandstone here was apparently deposited into sinkholes formed on the pitted marble surface. A clear and detailed description of this outcrop is provided in Van Diver (1976).

Turn around and head back south on Rock Island Road

45.65	4.3	Turn south on Rte 11, village of Gouverneur.
45.95	0.3	Turn south on Route 58, toward Fowler.
47.4	1.45	STOP 2. Large white roadcut at intersection with Hailesboro entry road

STOP 2 HAILESBORO ENTRY ROAD ROADCUT

This outcrop exposes white marble of the Northwest Lowlands, enclosing trains of dark amphibolite blocks. The rocks are complexly folded. According to Shoenberg (1974), the sequence of events that accounts for the features of this outcrop is:

foliation formation
folding
intrusion of basalt as dikes and sills
further folding and metamorphism, converting basalt to amphibolite, and folding and dismembering the dikes

Marble and basalt have considerably different mechanical properties, accounting for the difference in behavior during deformation; marble can flow at conditions that cause silicate materials to break.

There is also abundant evidence for chemical interaction between the two rock types. The grain-size in the marble increases toward the dikes, and minerals such as tourmaline and feldspar, absent elsewhere, occur there.

Continue south on Rte. 58

51.15	1.0	STOP 3. Large dark roadcut on either side of Rte. 58 at intersection of Poplar Hill Rd.

STOP 3. Popple Hill Gneiss

The Popple Hill Gneiss is a widespread unit in the Northwest Lowlands. It is locally migmatitic formation extensively studied by Carl (1988). This exposure on Rte 58 is the best example of the migmatitic phase of the unit. Here the dominant rock type is a dark gray quartzofeldspathic gneiss with biotite; subordinate rock types include concordant amphibolite layers, and leucosomes. As at Stop 2, the amphibolites as well as the leucosomes behaved differently from the surrounding gneiss and became folded and boudinaged in this case. Structural relationships demonstrate that the leucosomes formed in situ before or during major folding events.

Based on extensive chemical analysis, Carl (1988) proposed that the Popple Hill Gneiss originated as a dacitic volcanic rock.

Continue south on Rte. 58

52.1	1.05	Turn south on Rte. 812 toward Harrisville
53.4	1.3	Pass Gouverneur Talc mines.
62.2	8.8	Junction of Rte 3 and 812, turn west, staying on both 3 and 812.
66.7	4.5	Turn south on Rte. 812
69.0	2.3	STOP 4. Small brown outcrops, either side of 812

STOP 4 Deformed anorthosite in Carthage-Colton Mylonite Zone

The rock here is a brown-weathering, pink, very coarse-grained gneiss with large bluish-gray relict phenocrysts of plagioclase. The pink mineral which resembles K-feldspar is also plagioclase, colored pink for the same reason that K-feldspar appears pink: its cleavages are decorated by small inclusions of earthy hematite. Foliation is defined by parallel alignment of wisps and stringers of dark minerals. Also parallel to this crude layering are large somewhat irregular oxide schlieren.

70.5	1.5	STOP 5. Small outcrops either side of 812.

STOP 5. Mylonitic Gneisses of the Carthage-Colton Mylonite Zone

In these outcrops, mineral lineations are so well developed that lineation can easily be mistaken for trace of foliation. Lineation is defined by rods of quartz and K-feldspar, the latter occasionally forming rounded porphyroclasts. It is this moderately plunging, NNE-bearing lineation that is thought to represent the direction of tectonic transport, which slid lower-temperature rocks from the southeast and higher in the crust, down and to the northwest, and left them juxtaposed against deeper, higher-temperature rocks.

Continue south on Rte. 812.

73.2	2.7	STOP 6. Pink outcrops west side of Rte. 812.

STOP 6 Coarse-grained massive granitic gneiss.

The pervasive foliation and lineation present in rocks exposed along Rte 812 for 5 miles to the north is simply not present here. The rocks here are much coarser grained, and clearly have not experienced mylonitization in the CCMZ. You have crossed the southeastern edge of the CCMZ and are looking at rocks of the Adirondack Highlands.

76.9	3.7	Village of Indian River. Continue south on Rte. 812
82.9	6	Village of Croghan. Continue south on Rte. 812.
84.7	1.8	STOP 7. Long low pink and gray roadcut on either side of Rte. 812

STOP 7. Granitic gneiss and amphibolite of the Adirondack Highlands.

Rocks southeast and under the CCMZ are predominantly orthogneisses, and are at higher metamorphic grade than those northwest and above the CCMZ. The difference in grade is expressed primarily in the mineral chemistry and assemblages. Foliation here has fairly low dip and is defined primarily by the presence of amphibolite layers in coarse-grained pink granitic gneiss. While the rocks are not part of the CCMZ, they are still intensely deformed and contain lots of evidence for shearing, including: offset dikes, refolded folds, and augen feldspars, and local truncation of layering within the amphibolite against the granite.

There is fairly nice glacial polish with striae on the tops of outcrops on the east side of the road. Climb to top of outcrops on east side of road, and look to the east. There is a good-sized sand and gravel quarry, in a glacial deposit.

Continue south or Rte. 812.

88.2	3.5	Village of N. Bremen. Continue south on Rte. 812.
92.1	3.9	Large quarry on east side of Rte. 812. Unconformity with Precambrian rocks is at base of hill
93.2	1.1	Lowville. Stay on Rte 812. Turn south at the light where Rte. 26 intersects Rte. 812.
94.2	0.9	Intersection of Rte 12 with Rte. 26. Bear west, staying on Rte. 26.
94.3	0.1	McDonalds. Stop for drinks.
95.1	1.4	If weather is clear, glance out to east, across Black River Valley.
99.9	4.3	At sign for Whetstone Gulf State Park, turn to northwest onto West Road.
102.7	2.1	Turn west onto Corrigan Hill Road, which is unpaved.
104.1	2.3	STOP 8. Immediately beyond intersection, pull into grassy area and park. Cross Corrigan Hill to marked trailhead, and follow trail to brink of Whetstone Gulf

STOP 8. Overlook of Mid- to Late Ordovician Utica Shale and Lorraine Group in Whetstone Gulf

From this point at the brink of Whetstone Gulf, you can see a stack of late-middle to late Ordovician rocks, with the Utica shale at the bottom grading up into finely bedded shales and siltstones of the Lorraine Group on the top. These rocks represent early sediments shed from the Taconic Orogen 150 km to the east. Also, note the fracture sets shown in the canyon walls.

Note the large Pleistocene glacial erratics perched on the rim.

Return to cars. Turn around and head back down Corrigan Hill Rd.

105.6	1.5	STOP 9. Pull off to right as far as possible. Overlook of Black River Valley

STOP 9. Black River Valley Overlook

If the weather is clear, pull as far as possible of the road. Look out to east over the Black River Valley. You are standing on the Tug Hill escarpment. The valley below marks the boundary between Tug Hill and the western Adirondack Highlands. The Tug Hill escarpment consists of two distinct benches. The one on which you are standing is underlain by sandstones and siltstones of the upper Lorraine Group. The lower bench, marked by numerous dairy farms below you, is underlain by the Trenton and Black River Groups (limestones). Low in the valley and on the far (east) side, you may be able to distinguish a relatively level surface, created by the tops of deltas shed into glacial lake Port Leyden, during the Wisconsin deglaciation. Better views may be had further south, between Lyons Falls and Boonville. Beyond these and to the far horizon, metamorphic rocks of the Adirondack Highlands are exposed.

Continue down Corrigan Hill Rd.

106.2	0.6	STOP 10. Small borrow pit on south side of Corrigan Hill Rd.

STOP 10. Fossils in Utica Shale.

By gently prying open bedding surfaces, many samples of fossils may be collected. Fragments of trilobites, and pyritized cephalopods are common, whereas graptolites are rare.

Continue down Corrigan Hill Road

106.4	0.2	Turn south on West Rd.
106.8	0.7	Turn east on Lee Road.
107.5	0.4	Cross Rte. 26 on Lee Road.
108.5	1.0	Bear left at fork, staying on Lee Road.
109.1	0.7	Cross Glendale Road.
110.5	1.2	Cross Rte. 12 onto Cannan Road, at enormous dairy operation.
110.7	0.2	STOP 11. Pull over immediately before small bridge.

STOP 11. Unconformity between middle Ordovician sedimentary rocks and pink quartz-feldspar gneisses of Adirondack Highlands.

If the creek is high, then this outcrop is not accessible. If the creek is low, drop down and walk upstream until you encounter nearly flat-lying sedimentary rock lying directly on top of pink quartz-feldspar gneiss in which the foliation dips steeply. Notice the pebbles of gneiss enclosed in the basal sedimentary rocks. These sedimentary rocks are part of the middle Ordovician Black River Group (rather than the upper Cambrian Potsdam sandstone as at Stop 1), which means that the difference in age between the rocks above and below the unconformity is roughly 600 million years. Notice the evidence for spheroidal weathering in the pink quartz-feldspar gneisses directly below the unconformity. The evidence decreases downstream (i.e. farther structurally below the unconformity),. Consequently, we interpret this to be the result of middle Ordovician chemical weathering.

Continue north on Cannan Road.

111	0.25	Take first available left turn, onto unmarked road (Williams Road intersects on right)
111.1	0.1	Intersection with Rte 12. Turn south on Rte. 12
121	10.1	Turn left onto ramp for Rte 12D, at Stewarts Shop, toward village of Lyons Falls. Proceed into village.
121.2	0.2	Turn right on McAlpine.St.
121.4	0.3	Turn right again, following signs to Lyon's Falls. Pass paper mill
121.8	0.4	Turn left on Lyonsdale Rd. Cross bridge over Black River.
124.3	2.5	Turn left into Ager's Falls Park. Bear left.
124.5	0.2	STOP 12. Parking lot below Ager's Falls.

STOP 12. Dated locality of Lyon Mountain Gneiss at Ager's Falls.

The origin of the rock exposed at Ager's Falls Park is somewhat controversial. The country rock is a pink, medium-grained and equigranular granitic rock, which is host to abundant quartz-sillimanite "nodules", veins, and stringers. These elongate bodies have a set of preferred orientations that make the rock appear to have a tectonic foliation. It was mapped as metapelite by Florence and others (1995). However, the interpretation of Orrell and McLelland (1996), following arguments originally made by Vernon (1979) is that the rock formed as a granitic melt which created its own hydrothermal system as it crystallized, such that fluid flow was channelized. In areas of high flow, alkalis were leached away, leaving behind the relatively immobile silica and alumina, as quartz and sillimanite. Orrell and McLelland (1996) state that the origin of the quartz-sillimanite features of the rock are thus metasomatic rather than tectonic and the rock is therefore interpreted as undeformed and post-tectonic, and McLelland includes the rock with the Lyon Mountain granitic gneiss of the northern and eastern Adirondacks. Evidence in support of an igneous origin for this rock is provided by zircons, which are typically finely oscillatory zoned.

A sample from Ager's Falls has been dated, with a concordant single zircon grain giving an age of 1031 +/- 8 Ma (Orrell and McLelland, 1996).

Turn around and head back out of park.

124.7	0.2	Turn east on Lyonsdale Road.
125.1	0.4	Turn north, cross Lowdale Road bridges.
125.3	0.2	Stop 13. Pull over and park immediately after bridge.

STOP 13 Dated locality of undeformed pegmatite cross cutting Lyon Mountain Granite

Leave cars and head south across the northern bridge, and drop down into the Moose River bed on the western, downstream side. Staying fairly close to road, locate roughly one-half meter wide, steeply-dipping, undeformed white pegmatite dike, trending N35W. The dike is zoned, with quartz-albite rims and granitic, magnetite-rich interiors. Sillimanite is an accessory phase. Such undeformed pegmatites are generally rare in the Adirondacks. This particular example cross-cuts the Lyon Mountain Granite with abundant quartz-sillimanite nodules, as at Ager's Falls. This dike has been dated (Orrell and McLelland, 1996). Zircons give a well-defined upper intercept of 1034 +/- 8 Ma. Monazites give a well-defined intercept age of 1027 +/- 8 Ma. Because of the undeformed and hence post-tectonic character of the dike, this is considered to represent a minimum age for the end of Grenville orogenesis in the region.

Turn around and recross bridges.

125.5	0.2	Turn east on Lyonsdale Road.
125.9	0.35	Bear east at fork, onto Marmon Road
128.8	2.9	Turn west, following signs into village of Port Leyden
129.3	0.5	Turn north on Lincoln Road, just past the school.
129.8	0.5	Turn right on North Street
129.9	0.1	STOP 14. Pull into grassy area in front of Cataldo Electric and park.

STOP 14 Nelsonite ore body. Note! There is both poison ivy and barbed wire in the woods. Proceed only with extreme caution!

Cross North Street, heading south and east, to outcrop visible from parking area. This gray rock is a pelitic gneiss with the assemblage quartz + plagioclase + garnet + sillimanite + biotite. Walk over the outcrop and down to the left. Proceed for about 40 meters downhill toward a few prospect pits and ultimately toward the water filled mineshaft at the base of the hill. The prospect pits are in weathered exposures of the nelsonite; fresh samples can be collected near the mineshaft. The nelsonite is described and interpreted by Darling and Florence (1995). It is a rare igneous rock commonly associated with rocks of the anorthosite-suite. Its mineralogy is dominated by fine-grained magnetite, fluorapatite, and ilmenite. Pyrite and pyrrhotite occur as well. Chlorite, pyrite and biotite are abundant near contacts with the country rock. Darling and Florence (1995) suggest the occurrence of this rock indicates anorthosite-suite rocks were once present in the western Adirondack Highlands.

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Lake Ontario Coastal Geology and Land Management: Processes, Products and Policy

Donald L. Woodrow, Hobart and William Smith Colleges, Charles E. McClennen, Colgate University, Sandra Bonanno, The Nature Conservancy

This field trip carries us to some of the most dramatic freshwater scenery to be found in New York State. From the broad sand beaches of the eastern shore to the bedrock shelves, gravel beaches and till bluffs of the southeastern shore, geomorphology, sedimentary processes and human activity are manifest. Balancing the needs of citizens with those of the natural world so that the region can be both enjoyed and nurtured is an ongoing issue. We will look at examples of various shoreline geomorphologies, explain as best we can the processes shaping them and consider some of the policy questions involved.

Along the eastern shore of Lake Ontario, sand is arrayed offshore and on broad beaches backed by dunes. The extensive beaches are separated by a few, low till bluffs. Beach/dune barriers protect extensive wetlands and bays. Obvious human impacts are limited to only a few areas of the shore. Determined efforts by governmental agencies, citizen groups, and individuals have had a marked positive effect on preservation, conservation, and low-impact recreational utilization.

The southeastern shore is marked by bedrock shelves, gravel beaches and high till bluffs. Wetlands and bays are less extensive than in the east. Evidence of human activities is ubiquitous: industrial sites, harbors, houses, farms and orchards, state and local parks. Efforts at conservation by government and various citizen groups are less in evidence along the southeastern shore which is not surprising given its greater extent and history of exploitation. Southeastern shore residents most often express concern about lake level and its effects on property, shore-related activities, and boating activities.

Glacial and post-glacial sediment in this region rest on Ordovician strata which is locally exposed along the shore.

Stop #1. Chaumont Barrens (We will not visit this locality but it will be discussed at the Friday evening briefing.)

Chaumont Barrens Preserve is a global ecological rarity: 1630 windswept acres of an intact alvar landscape. "Alvar" comes from the term coined by Swedish geologists to describe expanses of level, exposed limestone bedrock found on islands off the southeastern coast of Sweden. Northwestern Jefferson County features a chain of similar outcrops of level, exposed limestone, which supports a characteristic mosaic of rare ecological communities. Jefferson County is the southeastern limit of the alvar mosaic, which occurs in fewer than 100 scattered locations in New York, northern Michigan, Ontario and along an escarpment of Cambro-Ordovician limestone and dolomite at the edge of the Canadian Shield. Chaumont Barrens is the best preserved occurrence in New York.

The Chaumont Limestone and other units of the Ordovician Black River Group are the rocks on which the Chaumont Alvar is based (Isachsen and Fisher, 1970). They are light gray, fine-grained and rich in cephalopods, corals, stromatoporoids, gastropods, brachiopods, trilobites and burrows. Cephalopods, in particular, are commonly seen in outcrops on the preserve. Rectilinear joints, some of which are enlarged by solution, break the rock surfaces. Strata dip to the southwest at less than one degree.

There is some controversy about the origin and fate of the very thin, discontinuous soil cover. During glacial retreat, some 10,000 years ago, pro-glacial Lake Iroquois covered the area of the present-day barrens to depths of at least tens of feet. Wave-driven currents probably winnowed away sediments overlying the bedrock. This alone may be enough to account for the thin, discontinuous soils. Another idea holds that, during glacial retreat, ice dams formed to the northeast of this area. With further melting, the ice dams burst, loosing enormous volumes of water which exploded across the bedrock clearing any sediments which may have been deposited there whether on the surface or in solution-widened joints. Finally, some of the soil materials may have been washed into joints over time as they were widened by solution.

Whatever the cause, soils throughout northern Jefferson County are thin and alkaline. At Chaumont Barrens and other alvar sites, soils are often just a few inches thick. The areas with thinnest soils and few fissures flood deeply during heavy rains and spring runoff, then bake dry throughout the summer and early fall. Water movement is thought to be predominantly sheet flow across the landscape, mostly NE to SW, across a very subtle 1% slope. Artesian features are known in the area, however, so upwelling may be a partial source of flood waters. The hydrology of this region is not well understood but it is clear that the annual cycle of flooding and drought greatly limit the variety of life that can survive here.

The alvar mosaic at Chaumont includes three rare natural communities: limestone woodland, calcareous pavement barrens, and the rarest of all, alvar grassland. Limestone woodlands occur on shallow soils over limestone. The canopy may be entirely deciduous, entirely coniferous, or a mixture of the two. Ground cover can include a delightful array of wildflowers under deciduous stands, which tend to have a rather open canopy. The conifer stands are dense and dark, with only scattered spongy moss colonies beneath.

At Chaumont the calcareous pavement barrens community is made up of variable-sized patches of barren rock; platy gravel colonized by mosses, lichens, and a few small wildflowers; deep fissures sculpted into the joints, and patches of shallow soil inhabited by shrubs, a few trees, and open grassy areas. The arrangement of patches feels very random on the ground, but an aerial view reveals a striking NE/SW arrangement of alternating woody and open areas parallel with the regional joints. The pattern occurs because shrubs and trees frequently sink roots into the fissures where moisture and protection allow them to survive.

Alvar grasslands are the rarest part of the community mosaic, both in number and size of occurrences. In the U.S., there are only a handful of occurrences and those are found in northwestern Jefferson County, and northern Michigan. Extremes of flooding and drought alternate in the alvar grasslands every year. The resulting vegetation looks like a prairie, and contains prairie species rarely found in the northeastern United States. Prairie plants may have migrated here during a mid- to late-Holocene warmer/drier interval some 5000 years ago. Then, as the climate became more moist, prairie plants were replaced almost completely throughout the Northeast by plants attuned to more moist conditions.

Stop #2. Black Pond – El Dorado Beach

A newly built road, parking area, and boardwalk allow easy access to a set of contrasting ecosystems that have been subjected to minimal human impact over the last century or two. The outlet from Black Pond to Lake Ontario is a geomorphic boundary for Lake Ontario coastal classification. Sandy beaches extend to the south and bedrock coast to the north. Black Pond with surrounding sedge, scrub and forested wetlands is protected from wave attack by the dune-capped barrier beach and offshore shoals. The size and age of the trees on the dune tops and eastern faces demonstrate the stability and relict nature of the highest dune crests. Along the lake or western dune faces, grasses and scrub (sand cherry) growth prevail. Recent snow fence installation, dune-grass planting and walking path demarcation including a walkover to the beach face and conservation signage have encouraged a recovery of local vegetation and dune sand accumulation.

Beach sand at this locality contains rock fragments, quartz, magnetite and garnet (among other grains) and masses of shells and shell debris of Zebra- and Quagga-mussels. Beach berms, runnels and other ephemeral features of sandy shores are seen here as a result of changing lake level and storm waves. Reworking of previously accumulated sediment prevails since there is no source of sand other than limited long-shore drift, minor erosion of till and exchanges with the subdued nearshore sandbars.

Offshore, to the south of this location, side-scan sonar records and sub-bottom profiles collected in conjunction with surface sediment samples and vibracoring reveal a one to several meter thick sheet of very well sorted sand. On it are scattered meter-scale, circular and elongated patches of what appear to be mussel colonies (Figure 1). Side scan sonar records disclose exposed bedrock just offshore from this locality (Figure 2). The bedrock looks to be festooned with mussels and is marked by fracture patterns like those seen on land in Henderson and adjacent townships to the north and east and at the Chaumont Barrens. The boundary seen on shore between the unconsolidated sediment surface cover to the south and exposed bedrock to the north continues offshore to depths of roughly 30 m (100 feet).

Captions for Figure 1 and 2.

Figure 1. Bottom features thought to be patches of zebra mussels on very fine sand. North is to the left. Half, side-scan tracks are illustrated. Orientation of elongation is roughly east/west perpendicular to the shoreline. Location is approximately 3 km south of Stop #2 at a depth of approximately 15 m. These features have not been sampled but their very low relief, numbers, location on a relatively stable sediment surface opposite beaches with large amounts of mussel shells makes it likely that they are clumps of zebra/quagga mussels.

Figure 2. Bedrock. North is to the left. Water depth approximately 10 m. Located approximately 1 km southwest of stop #2. Rock surface has on it boulders. Rock mass is fractured and pitted. Fractures and pits look to be populated by large numbers of mussels. Orientation of fractures approximates that seen in bedrock on shore to the north

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Stop #3. Southwick Beach State Park.

The sweeping extent of this low relief beach offers one of the best known vistas in eastern Lake Ontario. Sands on the beach, in the dunes and on the gently sloping foreshore are fine- to very fine grained. A history of intensive recreational use, sand mining and exploitation by private groups and government management agencies has significantly modified this section of formerly dune-capped barrier beach.

The adjacent marsh was once a fen. Evidence for the prior existence of a fen comes in two forms. First, this is the type locality for a very rare moth, Hemileuca sp. (bog buckmoth), known from only 10 localities, world-wide and all of them fens. Hemileuca has not been seen in this wetland since the 1960's. Second, the site is now marsh but it has a "false bottom" – underlain as it is by a deeper peat mat. It is reasonable to assume that the fen was flooded and that the present marsh developed over it. The marsh is now valued as habitat for a variety of uncommon breeding waterbirds and migrating waterfowl.

Waves during the summer months are either southerly or face-on to the beach while in winter, they are more northerly. Sand-bars formed under each of those regimes serve as sand reservoirs with some transport onshore and off with little net movement. Sand is extracted from the system as dunes accrete and migrate and as barrier bars are breached and new inlets form with their bay-mouth bars. Dune accretion is likely greatest during times of low lake level and least when it is high.

Cooperative restoration efforts by The Nature Conservancy and New York State over the last three years have seen the installation of two dune walkovers and snow fencing to protect the transplanted and very rare Ammophila champlainensis (Champlain beachgrass). This grass is found only here, a few sandy beaches on Lake Champlain and at a few sites along the St. Lawrence River in Quebec.

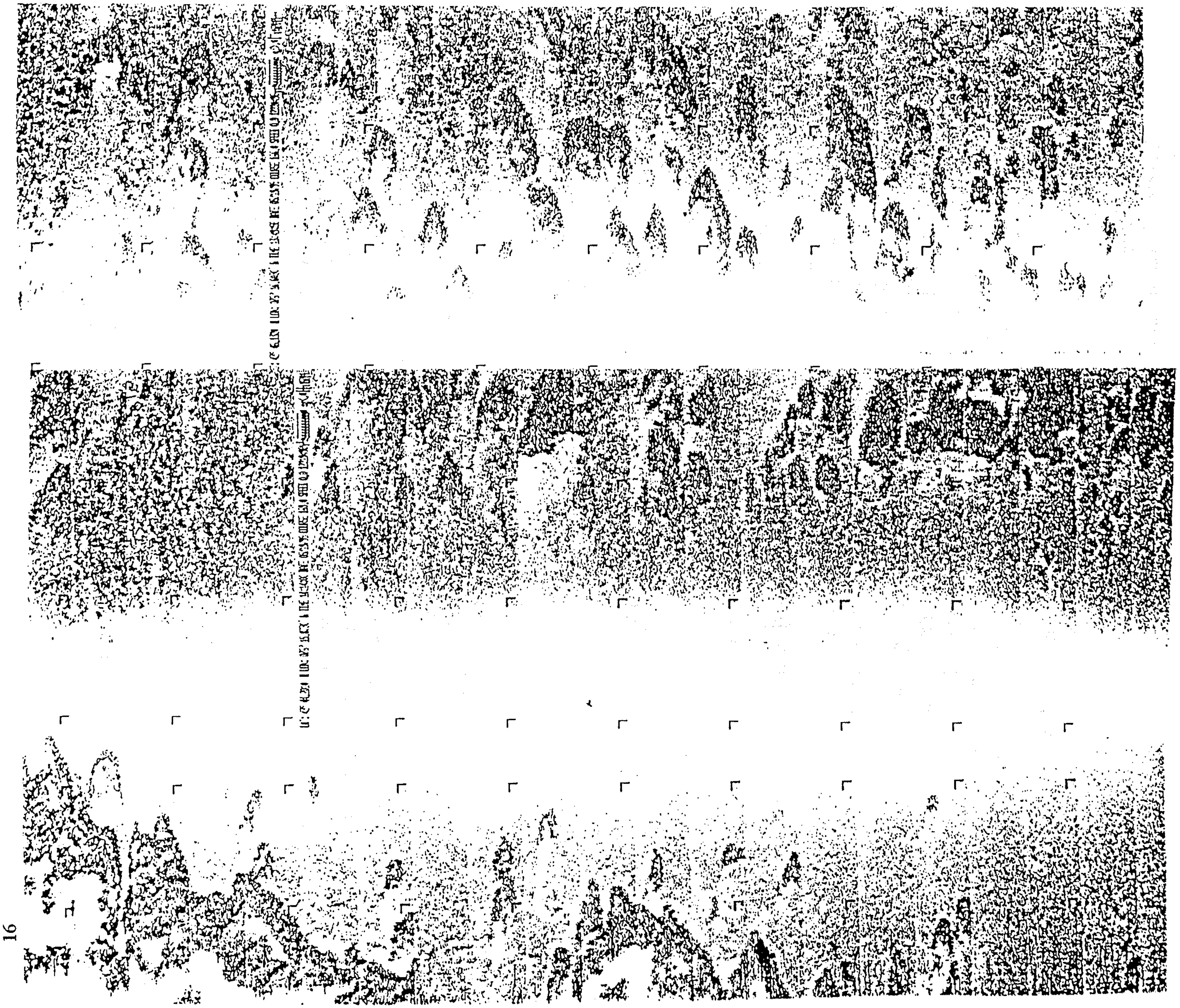

FIGURE 1.

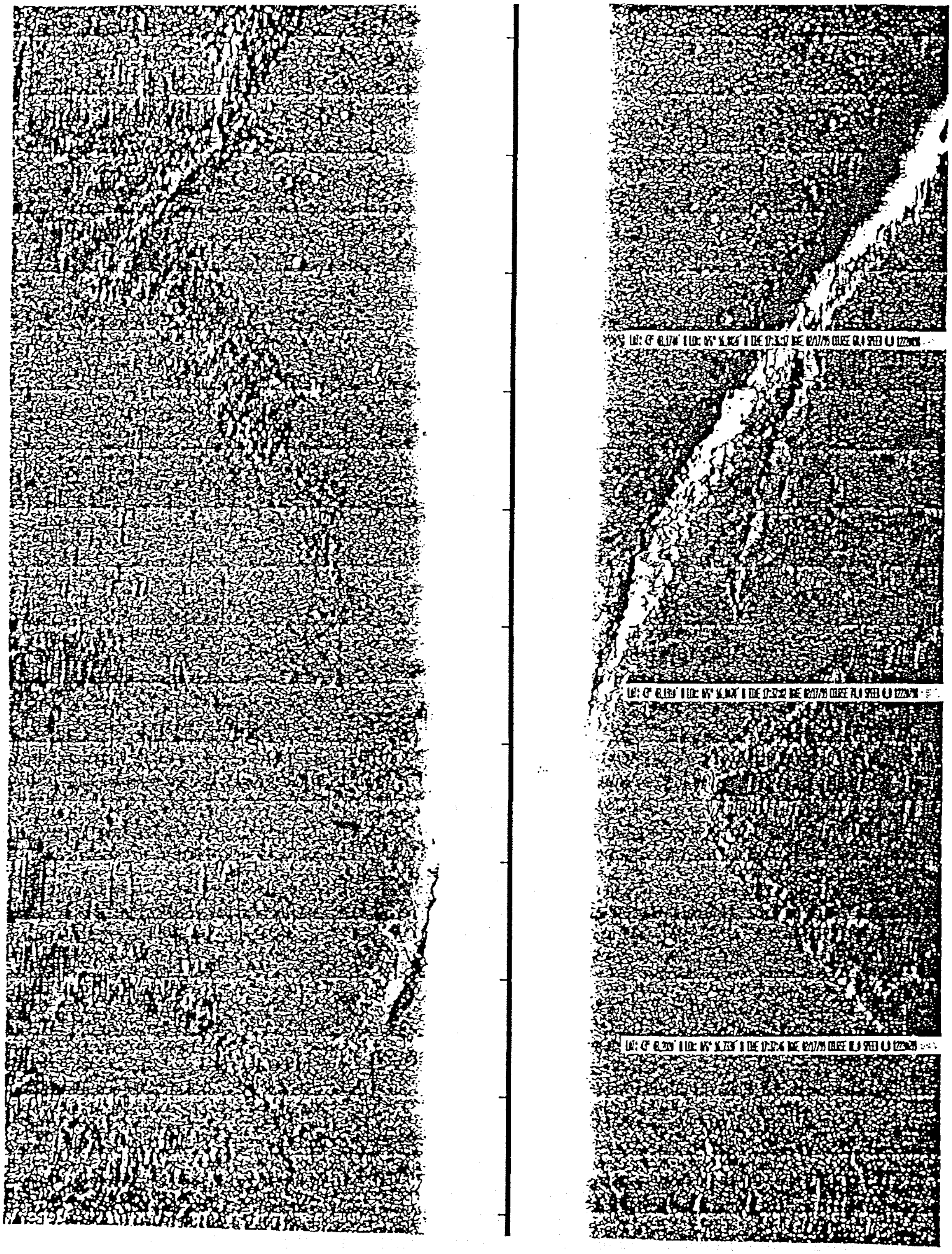

FIGURE 2.

Sand dune accumulation has already begun along with natural propagation of the dune grass and self-sown wormwood. Proposals for restriction or exclusion of camping from the lakeshore along a former dune line met with intensive public resistance. Campers clearly enjoy parking their vehicles between the access road and beach where there used to be a well developed natural dune ridge. The prevailing westerly winds of summer as well as the sight and sound of breaking waves make this section of the park very attractive.

Stop #4. Sandy Island Beach: Dune Reconstruction and Planned Development.

At this location, an early 20th century inlet through the barrier into Sandy (North) Pond was abandoned and became the locus of a dune. In more recent decades, a blowout formed at the dune site carrying sand from the beach into Sandy Pond and thereby almost duplicating the earlier inlet. The barrier and its dunes extend about two miles to the north where another a modern-day inlet opens into Sandy Pond. Other inlets that have opened and closed along the barrier in this century are recorded in aerial photography starting with a series in 1938 and continuing through 1988.

Until this year, crumbling and abandoned facilities, debris of all kinds and a cobble beach made this a much-degraded site. We will view new developments on the lakefront where Oswego County has constructed day-use park facilities. Beginning with land acquisition, The Nature Conservancy has supported both this development and that of NYSDEC as it "restored"the dune flanking the park to the north. To restore the dune meant that first, 44,000 ft3 of sand were moved from landward edge of the advancing blowout back to the beach/dune line. Plantings on the restored surface are now well established and are protected by fencing. Another significant volume of sand was moved to the beach face from the rear of what is now the parking lot to cover what had become the cobble surface of the beach. Finally, a gated, fenced, and cobbled access roadway has been established from the new parking lot north along the dune/beach line to ensure vehicular access for those home owners north of the site along the barrier. The addition of upland sand to this beach provides the opportunity for an experiment in sand movement along this section of shore.

Offshore just south of this location, seismic and side-scan records indicate that the sand sheet is patchy on an eroded till and/or bedrock surface (Figure 3). Vibracores taken in the sand sheet nearby disclose a layer of 2-10 cm diameter gravel resting either on well-sorted sands very much like those presently found on the beaches or on organic-rich peaty clays and silts. This gravelly surface is apparent in the seismic records where it marks the top of seismic Unit #2 (Figure 4). We take this gravelly sand to be a beach deposit which indicates that post-glacial Lake Ontario water levels were as much as 25 meters (80 feet) below present. This lower stage may be the "Dune Stage" of Sutton, Lewis and Woodrow (1970), a lower lake level whose existence was postulated on a much more limited data set. Carbon 14 AMS dating analysis results for the peaty deposits below the gravel may be ready by the time of the NYSGA 2000 field trip and should help to date the lower lake stage.

Captions for Figures 3. and 4.

Figure 3. Side-scan sonar record of patches of sand on till on hard substrate. North is the left. Location is 4-5 km southwest of stop #4 in water depth of approximately 15 m. Sand patches fill low areas on the substrate surface. Edges of patches often are "finger" on to the substrate in irregular patterns. Seismic records show the patches to be less than 1 m thick.

Figure 4. Seismic record of strata at and below the lake bottom. East is to the left. Individual seismic units are noted. Depth markers on the record approximate unit thicknesses. Unit 1 appears to merge with Unit 2 toward the east end of the record and with Unit 3 toward the west end of the record. This suggests that part of the modern sand sheet is derived from a sand mass emplaced earlier at this location and Unit 2 is likely to be discontinuous over this region.

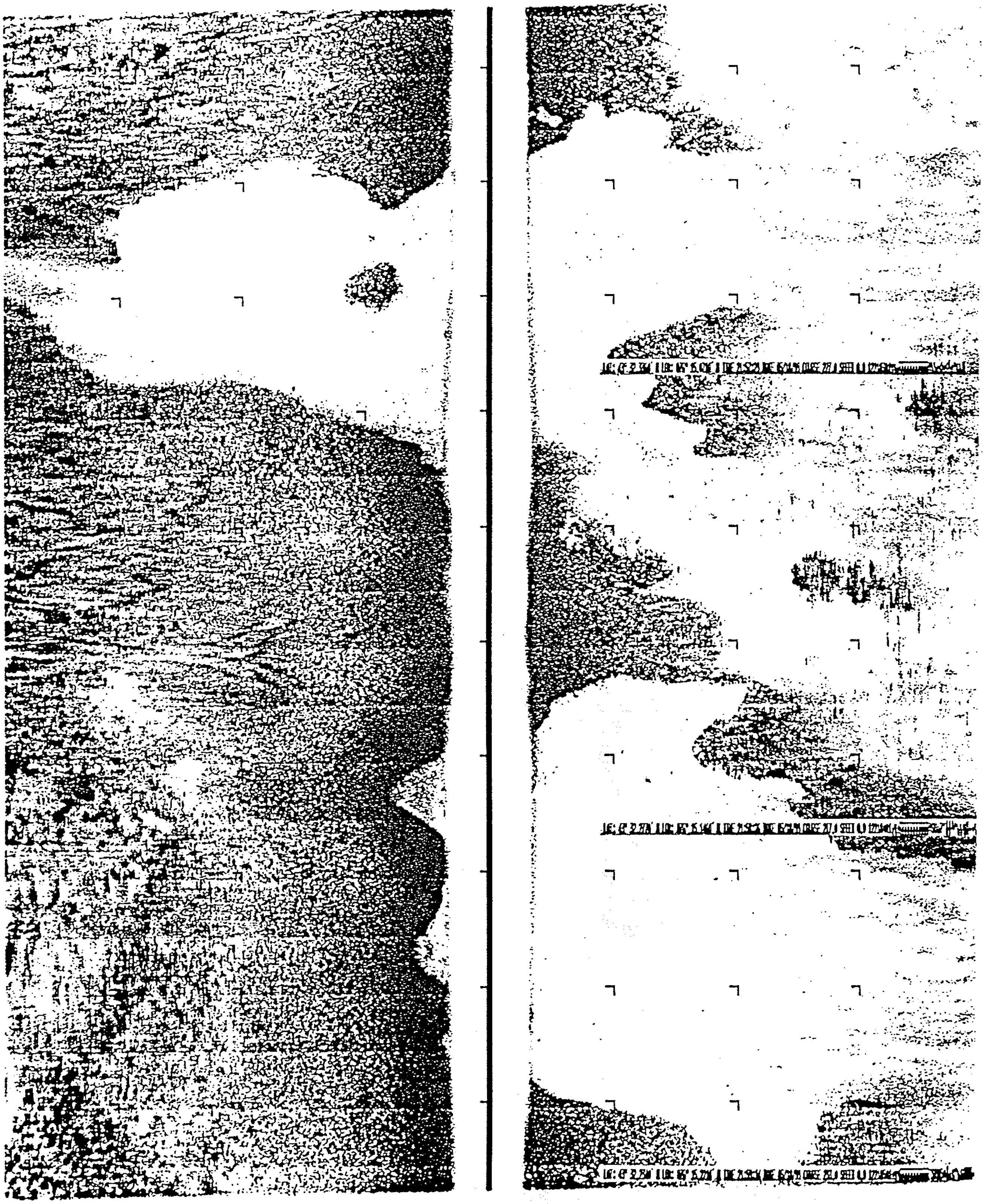

FIGURE 3.

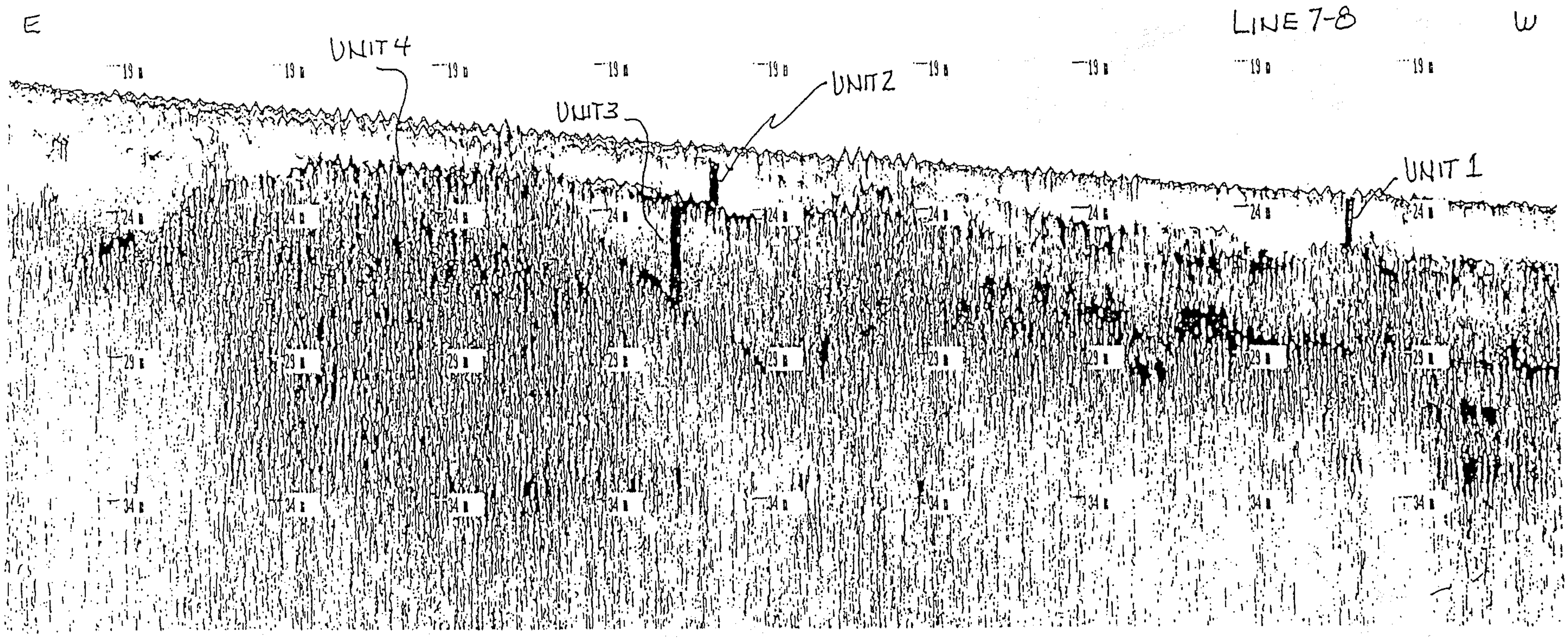

FIGURE 4.

Stop #5. Shoreline at the Energy Center, Nine Mile Point.

Driving around to the southeastern shore of Lake Ontario, instead of dune-capped, sandy, barrier-beaches and adjacent wetlands and bays we see bluff exposures of till over bedrock. This location provides an example. The "beach" here is made up of minimally rounded boulders and slabs. The beach is developed on bedrock. The overlying till is exposed where continued erosion prevents establishment of vegetation. The steep bluff face and lack of trees on it suggest that erosion events recur on a decadal frequency, a frequency less than that seen further to the west. The presence of glacial-scour marks on the exposed bedrock indicates resistance to erosion and suggests an explanation for lesser erosion rates of the till at this locality.

The bedrock seen here is the Late Ordovician Oswego Sandstone (Isachsen and Fisher, 1970). Bedding planes exhibit light greenish-gray, fine-grained sandstones marked by low-angle, trough cross-strata and parting lineations. Rip-up clasts are found at the base of sandstone beds and some units display sole marks. Fossils are not seen at this locality. At other locations nearby, the Oswego is arrayed in fine-upward sequences typical of fluvial and/or tidal channels. The Oswego is part of a thick Late Ordovician basin-fill sequence the base of which is the Black River Group carbonates of Stop #1. Between that location and this more than 500 m of clastics from black shale to this sandstone are covered by the glacial and younger sediments. Next above the Oswego and not exposed on the south shore of Lake Ontario until the Genesee River Gorge in Rochester, is the red and green Queenston Shale which marks the top of the basin-fill.

Just east of this location are three nuclear power plants, a concentration of such plants greater than that found at any other location in the country. Siting the plants on stable bedrock near an abundant supply of cooling water and distant from large population centers made the location environmentally and politically attractive. In a linked location-decision, an aluminum-can production plant, located just to the west of here, also uses Lake Ontario waters for cooling and draws on the power grid for electricity. Cooling ponds at the plant required modification of many acres of wooded coastal wetlands. The ponds provide an expanded habitat, yielding some impressively large carp and other species.

For several miles east of the power plants, the coast consists of bedrock cliffs with a shallow bedrock platform just offshore. The cliffs, although accessible by road, are dangerous to scale because of groundwater seepage, clay-rich soils and slimy overgrowths. Cliff-edge trees at these locations often have roots exposed and locked into cracks suggesting a very slow rate of erosional retreat.

Stop #6. McIntyres Bluff: Drumlins and adjacent barrier-beach fronted wetlands.

West of the city of Oswego in the township of Sterling, the bedrock is no longer exposed along the lakeshore. Here are a series of north-south trending drumlins and connecting barrier beaches in front of ponds and wetlands, a geomorphic pattern which persists for about 30 km to the west. The drumlins have been truncated by storm-wave undercutting, particularly during periods of high lake level, and further eroded by a combination of mass wasting, streamlet runoff and wind erosion. The nature of the spring thaw, snow cover and rain-event sequencing generates a lot of inter-annual variability in the amount and style of slumping and sliding as well as gully washout and alluvial fan development. Long-shore wave-driven transport, which moves predominantly toward the east, redistributes the eroded till of the drumlins and deposits a progressively more rounded sand and gravel barrier. The fines are redeposited in the deeper waters of the lake or in the lows of inter-drumlin ponds and wetlands. The bluffs of drumlins show a variety of heights and morphologies, which are measured to be more and less steep, with and without gully development, and multiple kinds of alluvial fans and scarps at the toe of the bluffs along the beach.

The model (Pinet et al, 1998; Pinet and McClennen, 1997) that goes a long way to explain many of the observed patterns (Pinet et al, 1992), has a focus on the causal changes in bluff morphology as the erosion processes cut through the drumlin hills. Groundwater-flow and run off keep the bluff faces wetter in the initial stages of bluff retreat. After the crest portion of the drumlin has been removed the bluff faces are generally drier due to the landward direction of runoff and water table gradients, and exposure to wind. The local bluff height and retreat rates control to some extent the volume of drumlin till deposited on the beach. In combination these factors seem to explain the early, youthful, mature and old age stages of bluff retreat morphologies. They are modulated by inter annual weather and lake level variations. The last stop of the field trip at Chimney Bluffs State Park will show a more fully developed example of the coastal retreat patterns and interpretations introduced at McIntyres Bluff.

Stop #7. Chimney Bluffs State Park (under development).

At this location, we see an unusual landscape cut into a flat-topped drumlin. The landscape, like that at McIntryre's Bluff, is made up of spires, pinnacles and razor-edge ridges, some ending at lake-edge in sheer cliffs and all separated by steep-sided valleys. The drumlin is flat-topped (as are all of the other drumlins near the lake shore in this region) as the result of beveling by wave erosion in proglacial Lake Iroquois. Its crest stands about 50 m above the lake.

This landscape is the product of groundwater seepage (sapping), erosion by flowing water and wind, and solifluction. The solifluction effects are dramatic. In the spring, frozen cliff surfaces thaw over large areas in a matter of hours. Masses of till are loosed into the valleys as dense mudflows. The flows easily raft along boulder-sized clasts delivering them as part of a muddy slurry to the beach where the flows dewater and deposit their sediment load in fans. Valley surfaces are denuded as much as several cm in a day with the southwest, more fully exposed, faces experiencing the highest rates of loss. Once on the beach, waves erode the fans in several weeks or months. The biggest boulders are left at the fan head and form boulder-trains on the floor of the lake as the cliffs retreat. Cobbles and coarse sand are moved along the beach to the east and finer sediments are carried into the open lake. Ridge-ends are undercut by waves during lake high-stands and cliff-collapse is common at that time, adding to the rate of retreat. At the west end of Chimney Bluffs, faulting in the till has led to differentially rapid erosion along fault surfaces and the development of ephemeral caverns and clefts.

The west end of the Chimney Bluff drumlin is especially instructive. There, varved clays, apparently derived from the top of the drumlin as it was eroded by Lake Iroquois waves, are exposed in a 3-6 m cliff. The varves lap on to the till of the drumlin, thin up-section, are coarser toward the drumlin and show soft-sediment deformation caused by masses of gravelly sediment sliding down side of the drumlin.

New York State is slowly developing the park and, unlike developments at most lakeshore locations, is working to make a virtue of rapid erosion. However, the issue is joined because the edge of the low bluff just north of the lot in which we parked has retreated approximately 10 m in 35 years. Permanent structures at this location will have a finite lifetime independent of the life of the materials used to build them.

Observations on management policy for the lake shore

The effects of wave erosion and changing lake levels when combined with the desire to protect and preserve various shoreline habitats and at the same time utilize the lake shore for recreation and year-round living leads inevitably to conflicting views of management. We offer these observations on the situation.

*<u>Patterns of erosion and coastal retreat over the 20th Century have motivated numerous lakefront property owners to build defensive structures, a losing proposition</u>. The obvious lack of substantial sediment input from land and coastal erosion at some locations leading to gravel- rather than sandy shores has decreased the attractiveness of the beaches. Property owners and land managers must deal with this pattern of coastal evolution often at considerable private or public expense. The desire for shoreline stability around private lands is in unavoidable conflict with the patterns of change so prevalent on unconsolidated sediment coasts of large water bodies. Even without tides, the storm waves, winds and flood level patterns of Lake Ontario cause rapid and substantial changes in coastal configurations. It is clear that preparing fixed shore defenses

against the unending and highly variable wave regime of Lake Ontario is not likely to succeed. Even massive stone emplacement structures show signs of undermining and collapse in the course of only decades, as seen along the protected but beachless section of shore in Fair Haven Beach State Park or just east of the jetties at Sodus Bay.

*Rates of erosion are highly variable from place to place along the shore and with time. Rates of a few feet per year are generated during intense weather events experienced every decade or so, making prediction and management decisions very challenging. Public understanding of the erosion processes and patterns appears to be quite limited based on some of the engineering attempts made in the name of saving coastal property. At McIntrye's Bluff and Chimney Bluff, for example, reducing groundwater flow and runoff to the top of the bluff face appears to be much more effective and economical strategy for erosion control. In other areas, local governmental bodies may decide that zoning of shorelines will be necessary to reduce the cost of inevitable property loss.

*Lake levels have a critical impact on the extent of erosion and changes in habitats experienced in an individual storm or season and deserve particular attention in any management analysis and planning. High lake levels greatly increase the rate of drumlin erosion by waves, for example. Lower lake levels broaden beaches but make inlet and river channel shallow reducing access to the open lake. Habitat extent and character vary with lake level with often profound effects. The Prairie Plover nested on the eastern shore sandy beaches until 1984 but since then has not been seen. Has the regulation of lake levels narrowed the eroded dune zone at the back of the beach sufficiently to exclude these former residents?0

*Our experience of wave effects and lake levels over the last century may not provide a solid basis for management if climate were to change. However, over the long term all should accept the predominant and persistent patterns of erosion and coastal retreat along most of the unconsolidated sediment sections of eastern and southeastern Lake Ontario. The fluctuations and occasional depositional building of the shore while natural will eventually be counteracted by a return of erosional patterns.

*To conserve a natural setting may require that it be permitted to change naturally. This simple concept has important implications for all of those who would take advantage of Lake Ontario's resources. Letting nature have its way may be a goal but it is likely to be a difficult concept to include in a management plan.

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Road log in miles. Distances are approximate.

0.0 Exit 45 I81. Proceed north on I81 to Exit 47.
2.3 Exit 47 I81. Proceed to NY 12 north.
13.9 Turn left (south) to DePauville Road.
15.5 Turn right (north) to Van Alstyne Road.
16.5 Chaumont Barrens on the right.

STOP #1 Chaumont Barrens. (not visited on this trip)
Return to I81 and proceed south to Exit 41.
31.7/0.0 Junction I81/NY 178. Proceed west on 178.
8.8 Village of Henderson, continue on 178.
9.6 Junction of NY 178 and NY 3. Turn left (south) on NY 3
12.4 Turn right (west) on Bolton Road to entrance of NYSDEC Black Pond Wildlife Management Area.(BPWMA)
13.8 Entrance to BPWMA with parking. Follow boardwalk through wetland, across the leeward side of the dunes and then through the dunes to the beach.

STOP #2. ElDorado/Black Pond Natural Area.
Most northerly part of the Eastern Shores expanse of open beach, shore backed by 15-20 m dunes, mussel shells as clasts, bedrock visible to the north.
Retrace route to NY 3 and proceed to the right (south.)
18.1 Entrance road to Southwick Beach State Park.

STOP #3. Southwick Beach State Park.
Proceed to southernmost part of beach front camping area. Expanse of open beach backed by low dunes.
Retrace route to NY3 and turn south. NY 3 passes War of 1812 Sandy Creek battlefield and swings east around Sandy Pond, the largest of the bays along the eastern shore.
30.5 Turn right on Oswego County 15 at Lindsey Restaurant and proceed to the end of the road.
32.8 Sandy Island Beach parking lot. Walk to beach along resident's access road.

STOP #4. Sandy Island Beach.
Southern end of expanse of sandy beach. Restoration of dune blowout and beach. Gravel berm with sand offshore and dunes behind. Armored section of beach visible to south.
Retrace route to NY3. Turn to right (south).
44.1 Turn right (west) on 104B, toward Oswego.
47.1 Bear right (west) on Oswego County 1.
51.8 Turn right (north) on Nine Mile Point Road.
53.5 Turn left (west) on Lake Road .
55.4 Turn right (north) on access road to Nuclear Learning Center parking lot. Walk past front of Nuclear Learning Center and down the lawn to the beach.

Stop #5. Beach west of nuclear power stations.
Ordovician Oswego Sandstone overlain by till. Glacial grooving of bedrock. Till exposed in bluff.
Retrace route to Lake Road (Oswego County 1A). Turn right on 1A
56.4 Turn right (west) on Oswego County 1. Proceed on 1 into City of Oswego.
62.6 Turn left (south) on Fourth Street.
62.8 Turn right (west) on Bridge Street (NY 104). Cross over the Oswego River and NYS canal.
64.8 On the right, note the entrance to SUNY College at Oswego main campus.
68.2 Bear right on NY 104A.
71.7 Junction with Old State Road at a 5-points. Bear half-right (west) to McFarland Road which is unnamed at this junction.
73.2 Bear left on Farden Road.
74.1 Turn right on Center Road.
74.2 Turn right on McIntyre Road and proceed to parking area on side of road just before steep incline. Note: the road to the lake shore is often washed out and may be impassible to all but fourwheel drive, high-clearance vehicles.

Stop #6. McIntyre's Bluff.

Till exposure with erosional topography. Gravel beach and barrier across wetland to east, alluvial fans, wave erosion.

Return to 104A by turning right on Center Road at beginning of McIntyre and then right to NY 104A at thefirst stop sign.

84.9 Straight ahead to NY38 (104A curves off to right (west)).

89.3 Turn right (west) on NY 104.

103.6 Turn right (north) on Lake Bluff Road. Proceed north on Lake Bluff Road

106.6 Continue north on Garner Road.

109.6 Turn very sharp left on East Bay Road.

110.6 Parking lot at Chimney Bluffs State Park.

Stop #7. Chimney Bluffs State Park (under development).

Extreme examples of erosional (badlands) topography. Wave-bevelled drumlin capped by lag gravel; faulting in till, varved clays, boulder trains in lake.

Return to NY 104 by following East Bay Road south

113.4 Lummisville Road. Turn right (west) and proceed to junction with Lake Bluff Road.

114.4 Turn left (south) on Lake Bluff Road.

119.5 Turn right (west) on NY 104

137.0 Lyons, NY. Junction with NY 31. Continue south on NY

144.6 New York State Thruway, Exit 42.

151.3 Hobart and William Smith Colleges, Scandling Center.

STRATIGRAPHY, SEDIMENTOLOGY, AND GEOCHEMISTRY OF SENECA LAKE, NEW YORK

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INTRODUCTION

This field trip investigates the stratigraphy, sedimentology and geochemistry of Seneca Lake. The field trip is aboard the H-WS Explorer, and focuses on representative sediments that have accumulated in the northern part of the lake since deglaciation, which are typical of the other Finger Lakes. The trip also highlights ongoing efforts to collect and interpret high-resolution (2 - 12 kHz) seismic reflection profiles that image down to the glacial drift, and our recent understanding of the chloride and calcium concentrations/budgets in Seneca Lake in comparison to the other Finger Lakes.

The Finger Lakes of central New York State consist of 11 elongated, north-south trending basins just south of Lake Ontario (Fig. 1). The basins are glacially scoured into the northern edge of the Appalachian Plateau (Coates, 1968, 1974). At Seneca Lake, the bedrock is primarily Devonian shales (Hamilton Group in the northern end of the lake), and lesser amounts of sandstones and carbonates that gently dip to the south-southwest. Silurian carbonates, shales and most importantly evaporites (mostly halite) are found below the Devonian section.

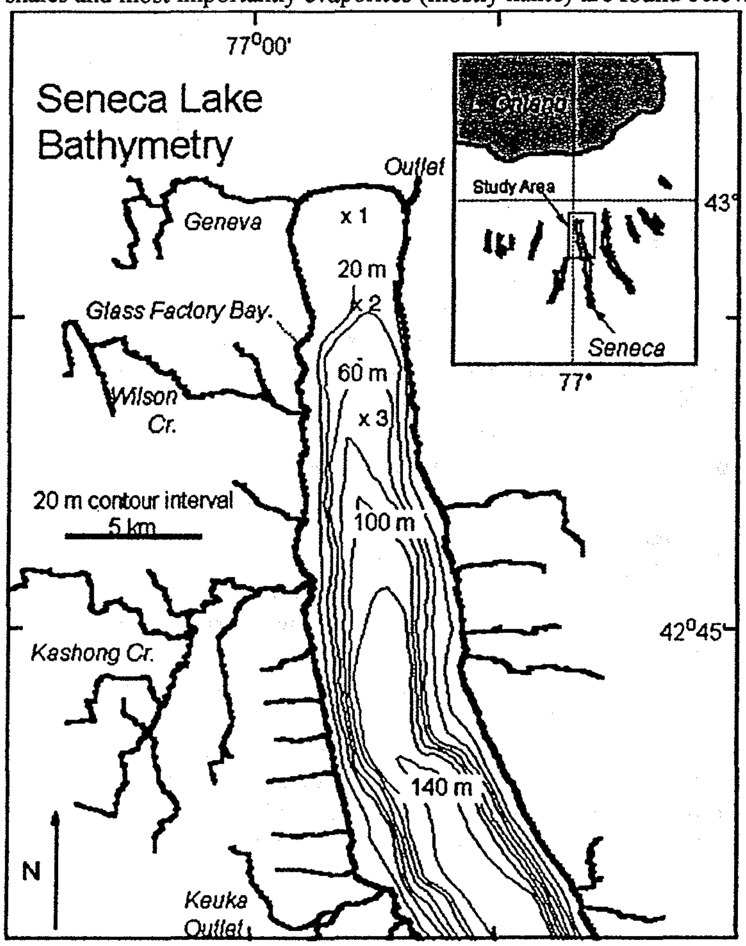


Fig. 1. Bathymetric map of northern Seneca Lake with station locations for this field trip (e.g., x 1). Th insert shows the location of Seneca Lake in relation to the other Finger Lakes.

Seneca Lake is the largest (by volume) and deepest of the Finger Lakes (Fig. 1, Table 1). Only Cayuga Lake immediately to the east of Seneca is longer (61 km) and almost as deep (132 m). The other basins are smaller, ranging in length from 5 to 32 km and maximum water depth from 9 to 84 m. The present day lake is fed by over 30 streams and major creeks and drains to the north-northeast through the Seneca River (New York State Cayuga-Seneca Barge Canal).

DEGLACIATION OF THE FINGER LAKES REGION

Deglaciation of the Laurentide Ice Sheet, as recorded by recessional moraines and kame deposits, is linked to the present day erosional and depositional geomorphology of the Finger Lakes Region (Fig. 2, Muller and Cadwell, 1986), and specifically, the excavation and subsequent filling of the Finger Lake Basins. The best developed moraines are the East-West trending moraines near Geneva (north of Geneva near the Freeway and south of Geneva intersecting the lake near Glass Factory Bay), and the kame moraines immediately to the south of each Finger Lake. The kame moraines are collectively known as the Valley Heads Moraine that dams each lake at their southern margins, are restricted to the valleys and reveal evidence for deposition by moving water. It suggests that glacial erosion aided by large volumes of glacial meltwater during the occupation of the Valley Heads Moraine were the erosional agents for the Finger Lake Basins (Coates, 1968) and is consistent with Mullins' interpretations of recent Uniboom seismic reflection profiles of the basins.

Table 1. Seneca Lake Statistics (Bloomfield, 1978)	
Length	57 km
Maximum Width	5.2 km
Surface Elevation	136 m above mean sea level
Water Volume	15.54 km^3
Surface Area	175 km^2
Maximum Water Depth	186 m
Water Residence Time	18-20 years

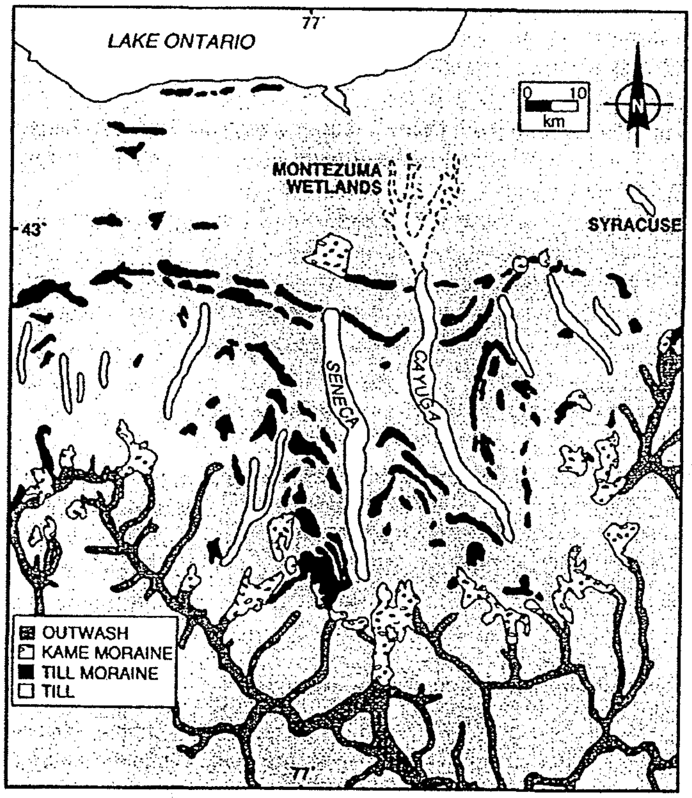


Fig. 2. Generalized geomorphology of the Finger Lakes region (redrawn from Muller and Cadwell, 1986 by Mullins et al., 1996).

In Seneca Lake, Uniboom seismic reflection profiles reveal a deep V-shaped notch cut into the bedrock with up to 270 m of sediment fill onlapping onto the erosional bedrock surface (Mullins and Hinchey, 1989; Mullins et al., 1996). It is deep enough to erode into the Silurian evaporites, which is important to the Chloride geochemical story presented below. Mullins proposed that pressurized meltwaters flowing under the ice excavated the basin when the ice occupied the Valley Heads moraine. Mullins links the majority of the sedimentary fill to deglaciation of the region. The seismostratigraphy of the sediment fill is interpreted as late glacial sediments with a thin cover of postglacial sediments based on acoustic character and correlation to short piston cores and on-land drilling. Mullins and coworkers differentiated 3 lower seismic sequences of ice-contact and water-lain sands and gravels fining upward to ice-proximal lacustrine muds that are related to the retreat of the Laurentian Ice Sheet from the Valley Heads moraine at the southern margin of the lake to the Geneva Moraine at the northern extent of the lake. The upper sequences are relatively thin and are interpreted to correspond to the proglacial rhythmites, locally known as pink clays, which were deposited during a proglacial, high, lake-level phase of Seneca Lake when the ice front blocked the present day outlet to the north, massive brown muds, which are related to the rapid lowering of lake level when the lower, modern-day outlet opened to the north, and profundal postglacial, black to gray, stratified muds, which have accumulated in the lake since deglaciation. Timing of these events is not well constrained. Limited number of radiocarbon dates suggest that the Valley Heads moraine was occupied about 14.4 ka, and the brown mud - postglacial transition was 13.9 ka and suggests that the retreat of the ice sheet and deposition of the ice-related sediments occurred in a rapid period of time (Mullins et al., 1996).

The basin bathymetry is similar to a steep-sided (bedrock cut), flat-floored trough (sediment fill). The lake floor gradually deepens from north to south before shoaling at the southern end of the lake near Watkins Glen. East/West profiles gently deepen to the central portion of the lake, north of Glass Factory Bay. Farther south, the lake bottom gently deepens in nearshore locations, then quickly descends to a flat lying basin in the central part of the lake. A grade of 10% or more is not uncommon on the steepest slopes south of Wilson Creek. Farther to the south, the nearshore areas are narrower and the steep slopes are steeper.

STRATIGRAPHY - ICE-CONTACT, ICE-PROXIMAL AND POSTGLACIAL SEDIMENTS
(after Woodrow et al., 1969 & Woodrow, 1978)

Short cores and surface grab samples reveal a number of sediment types within the basin (Woodrow et al., 1969; Woodrow, 1978; Mullins et al., 1996; Halfman and Herrick, 1998). Glacial drift (ice-contact and ice-proximal) fine sands and silts underlie proglacial rhythmites (pink clays). Both outcrop in the northern and other shallow water margins of the lake. Lacustrine marls, muds with photosynthetically-induced microcrystalline carbonate with fossil mollusk layers and macroscopic plant fragments are also sporadically observed in water depths shallower than 20 m. The deep profundal zone contains olive-gray to black, laminated, fossil poor, organic rich muds. Massive brown muds are found between the younger postglacial muds and older pink clays. Halfman and Herrick (1998) recently detected evidence for basin-scale mass movements of the pink clays during the waning stages of pink clay deposition (see below).

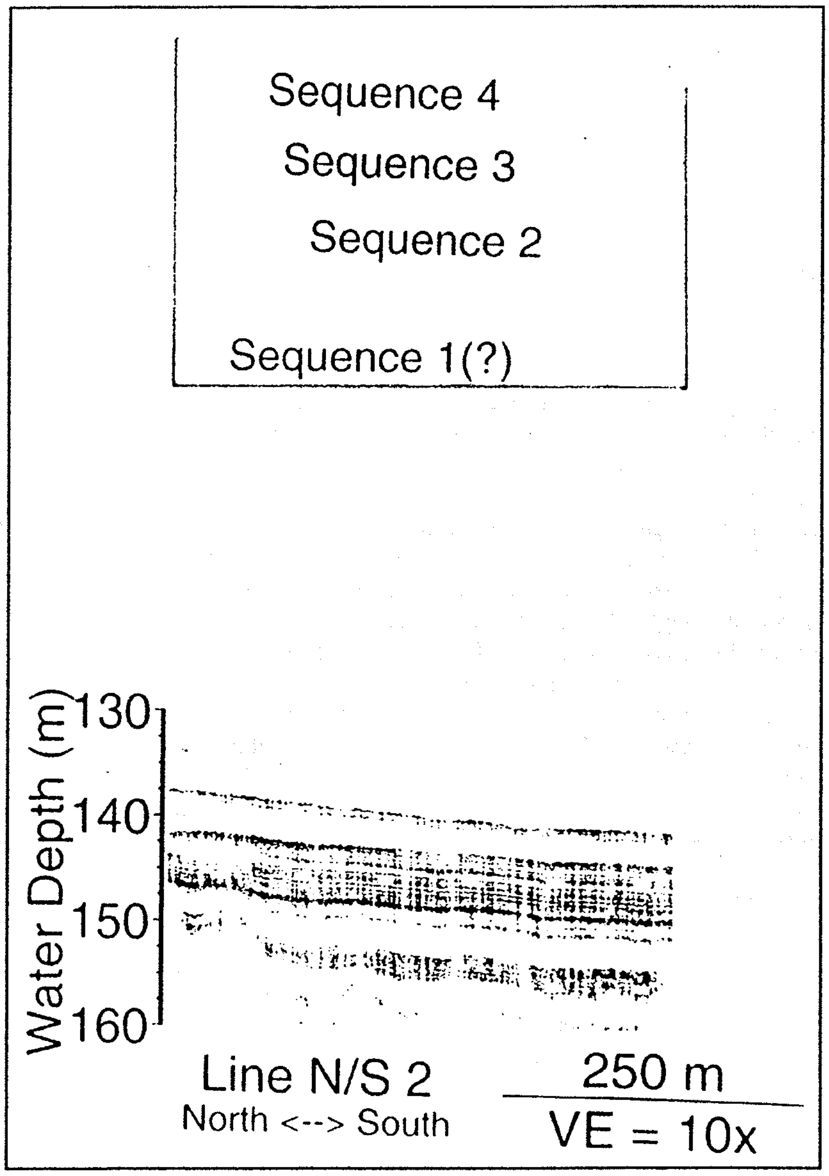


Fig. 3. An example of the acoustic stratigraphy of the upper 30 m of sediment in the deeper portion of Seneca Lake (from Halfman and Herrick, 1998). The line drawing outlines the major sequences identified in the text.

SEDIMENTOLOGY - HIGH-RESOLUTION SEISMIC REFLECTION PROFILES
(after Halfman and Herrick, 1998)

Over 100 km of high-resolution (2 - 12 kHz) seismic reflection profiles, collected from the northern end of the lake delineate the upper stratigraphy and investigate the depositional and erosional processes in the basin (Halfman and Herrick, 1998). The seismic system images up to 30 meters of section. Four major acoustic sequences encompassing the upper part of the glacial drift to the postglacial sediments were identified based on acoustic character and correlation with short (1 to 3 m) piston cores and surface grab samples (Fig. 3, Table 2).

The high-resolution seismic reflection profiles shown in this field guide focus on evidence for: (1) mass movement of the pink clays, and (2) sediment reworking to water depths of 60 m by wind-driven surface waves and currents, wind-driven internal waves and currents associated with seiche activity along the thermocline, and a possible 20 m lowstand of the lake during the Holocene.

Table 2. High-Resolution Seismostratigraphic Sequences (from Halfman and Herrick, 1998)

Sequence	Acoustic Character and Interpretation
4	Low amplitude surface and internal reflectors that onlap onto older sequences. Postglacial laminated muds & underlying brown muds
3	Two and locally more transparent units with surface reflectors similar to sequence 2. Mass movement deposits of pink clays
2	High-amplitude surface and parallel to subparallel internal reflectors on decimeter scale. Proglacial rhythmites (pink clays)
1	High-amplitude surface and occasional internal point reflectors. Glacial drift
Others	Transparent section, the seismic signal is typically attenuated by gas (biogenic methane?). Lacustrine early-Holocene marls (detected in isolated nearshore areas, water depths < 20 m)

MASS MOVEMENT OF THE PINK CLAYS

Sequence 3 is a previously unidentified seismostratigraphic unit, and is interpreted as two main and locally more mass movement deposits of the pink clays. A number of observations support our hypothesis. The sequence is found abruptly between and above the pink clays, filling the bathymetric lows in the lake (Fig. 4). The sequence thins to the south, and slowly gains additional high-amplitude internal reflectors that are characteristic of the older pink clays. Isolated "pods" of pink clays are laterally encased in a package of sequence 3 and suggests that the pods are parent material caught in a flow of proglacial rhythmites (Fig. 5). Woodrow and coworkers (1969) described folded and faulted pink clays recovered from the margins of the deep basin. They hypothesized that the deformed strata were the product of down slope movement of pink clays from the neighboring steep sides of the basin. Halfman and Herrick (1998) hypothesize that sequence 3 is a subaqueous, down slope movement of upper portions of pink clays. Movement was towards the center of the basin and towards the south along the long axis of the lake. They infer that the movement was intense enough to disturb the internal stratigraphy of the pink clays but the intensity of disturbance decreased to the south. Timing of the two main flows is stratigraphically restricted to the waning stages of pink clay deposition in the basin about 14 ka. The triggering mechanisms could be pulses of meltwater or meltwater sediments, rapid drawdown of the lake as a lower outlet was opened to the north, melting of stagnant ice within the glacial drift along the central portion of the basin, and/or earthquake activity.

SEDIMENT REWORKING AND POSSIBLE LOWER LAKE LEVELS

The postglacial muds are 5 to 8 meters thick and blanket the profundal portions of the basin. The thickness of postglacial sediments decreases rapidly on the steep slopes, where normal faults, slumping, accurate glide planes, and other evidence for episodic down slope movement of sediments is evident. The postglacial muds only form a thin veneer of material that unconformibly covers pink clays and glacial drift in shallow water areas, down to water depths of 60 m in the northern part of the lake. Surface waves and associated currents rework shallow-water sediments. Theoretical calculations for Seneca Lake suggest that surface waves from sustained 50 kph winds can erode fine sands at water depths up to 20 meters in the lake (Johnson, 1980). This 20-meter depth is a maximum estimate because parameters like effective fetch were deliberately overestimated in the calculations.

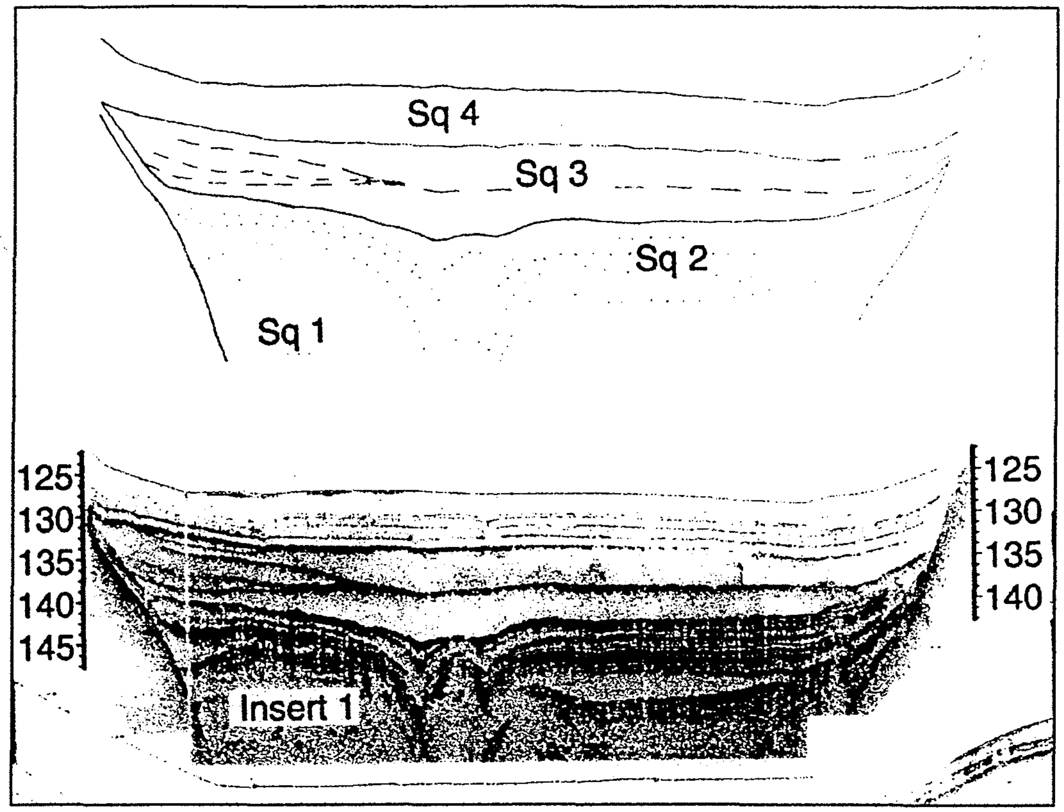


Fig. 4. East/West seismic profile from the lake with Sequence 3 found between and above the pink clays (after Halfman and Herrick, 1998).

Twenty years of current meter data collected by Bill Ahrnsbrak (Hobart and William Smith Colleges) indicate that currents and internal waves associated with seiche activity are significant in Seneca Lake (e.g., Ahrnsbrak, 1974; Ahrnsbrak et al., 1996). For example, current velocities of 30 cm/s have been recorded 1 meter above the lake floor at a water depth of 66 m this past Fall (1996) but only immediately after strong southerly wind events associated with the passage of a front. These currents must impact sedimentation in the lake at water depths deeper than 20 m, apparently down to 60 m. The strong seiche activity is probably enhanced by the elongated nature of the basin.

A lake-floor scarp, where the lake bottom quickly descends from approximately 15 to 20 meters, is observed in Seneca Lake (Fig. 6). We are presently investigating the following hypotheses for its origin (1) The scarp may be the result subaqueous sediment redistribution and deposition by the reworking processes mentioned above, and the reworked sediments have prograded lakeward with time. (2) The scarp could be the lakeward extent of marl deposition. (3) The scarp may be a wave-cut feature, i.e. the result of sediment truncation by surface, wind-driven waves during a lowstand of the lake sometime after the deposition of the early-Holocene marls. The preliminary data favor the later hypothesis but additional data are required to confirm our tentative hypothesis.

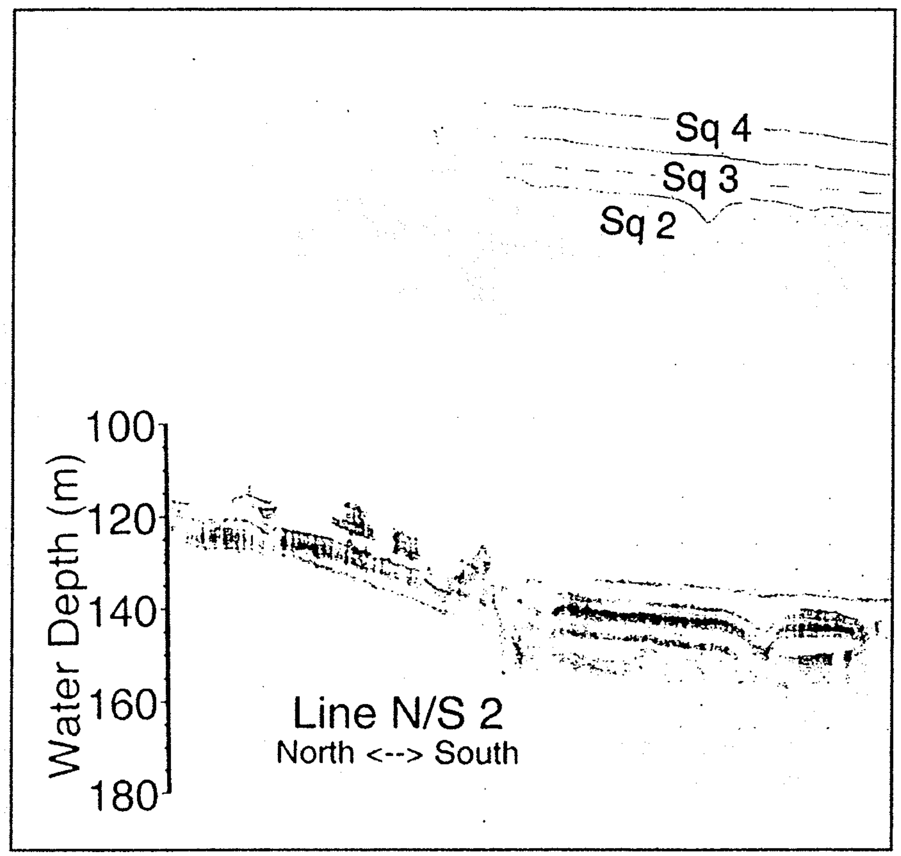


Fig. 5. Pods of pink clay encased in a package of Sequence 3. It suggests that Sequence 3 is a mass movement of pink clays during the waning stages of deglaciation in the basin (after Halfman and Herrick, 1998).

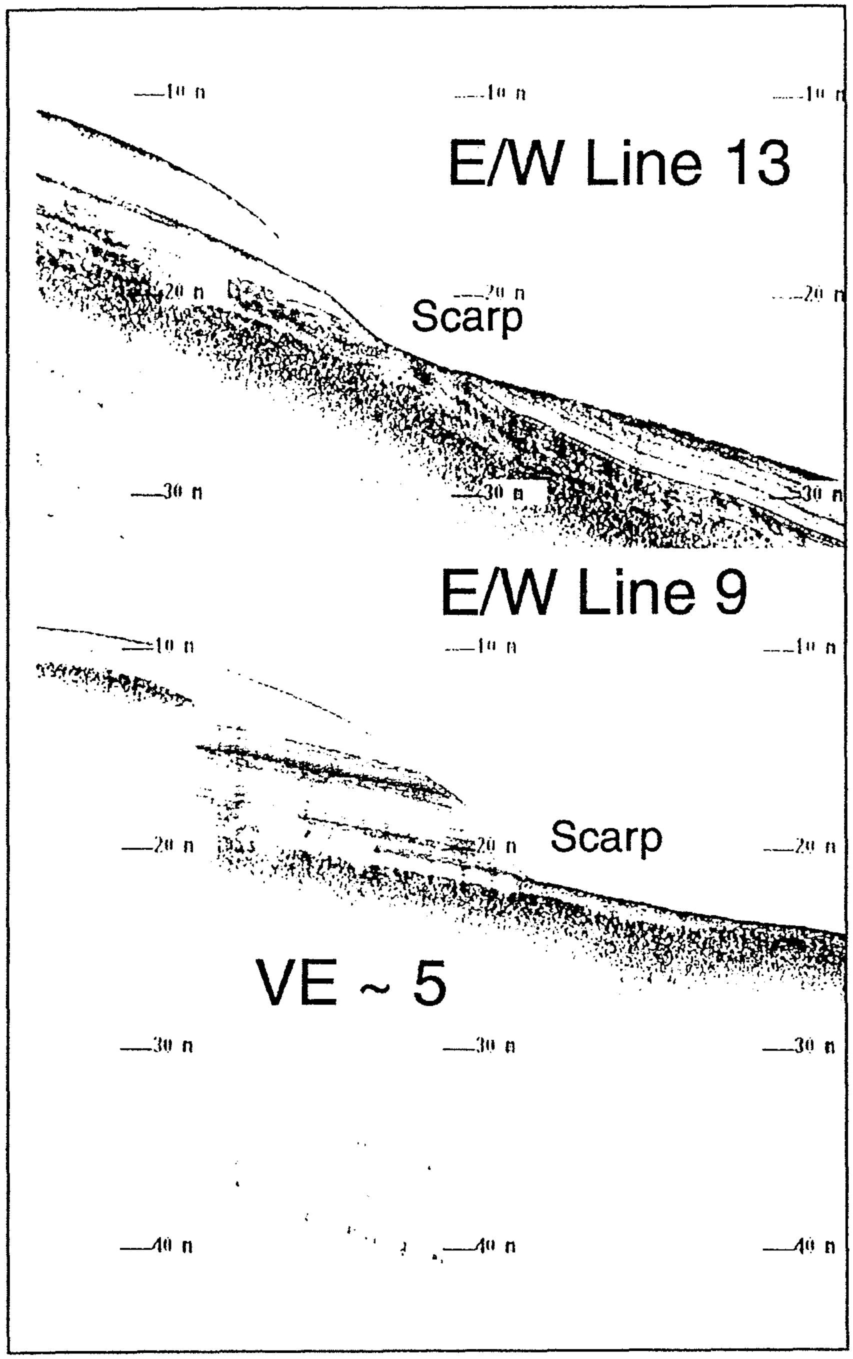


Fig. 6. A scarp at 20 meters of water is found through out the basin. Its origin is currently being investigated.

GEOCHEMISTRY - SENECA LAKE CHLORIDE AND CALCIUM CONCENTRATION

CHLORIDE
(after Wing et al., 1995)

Seneca Lake is the water supply for many of the inhabitants within its drainage basin. Thus, water quality of the lake is a concern to many. Chloride concentrations are 8 to 10 times higher in Seneca Lake (approximately 150 ppm) than they are in the other Finger Lakes (5 to 20 ppm, and 80 ppm in Cayuga Lake), high enough to pose a long-term health hazard for individuals prone to heart disease and newborns who use Seneca Lake water for drinking. The higher concentration is not the result of landuse or mining practices in the basin, because the annual chloride loading to Seneca Lake by streams and local mines is similar to those found at the other Finger Lakes, and more importantly, is deficient by an estimated 170 x 10^6 kg of salt. The deficiency suggests an interesting hypothesis. Seneca Lake is the only Finger Lake (with the partial exception for Cayuga Lake) with a deep enough basin to intersect the Silurian evaporites. Thus, the great depth of the bedrock floor provides a conduit to an extra source of Chloride, which is not available to the other shallower Finger Lakes. Cayuga Lake is the exception to this rule. Wing and coworkers (1995) propose that its second deepest status is consistent with its second highest chloride concentrations among the Finger Lakes.

Field data support this hypothesis. Chloride concentrations were observed to increase in the hypolimnion, the water mass below the thermocline, during the summer. The saltier water was mixed into the rest of the lake in early winter when the lake became isothermal (isopycnal). Sediment pore waters reveal large regions of higher salinity water several meters below the sediment-water interface, where chloride concentrations as high as 30 ppt have been found. Analysis of pore waters from piston cores reveal increasing Chloride concentrations with increasing burial depth.

CALCIUM HARDNESS
(After Halfman et al., submitted)

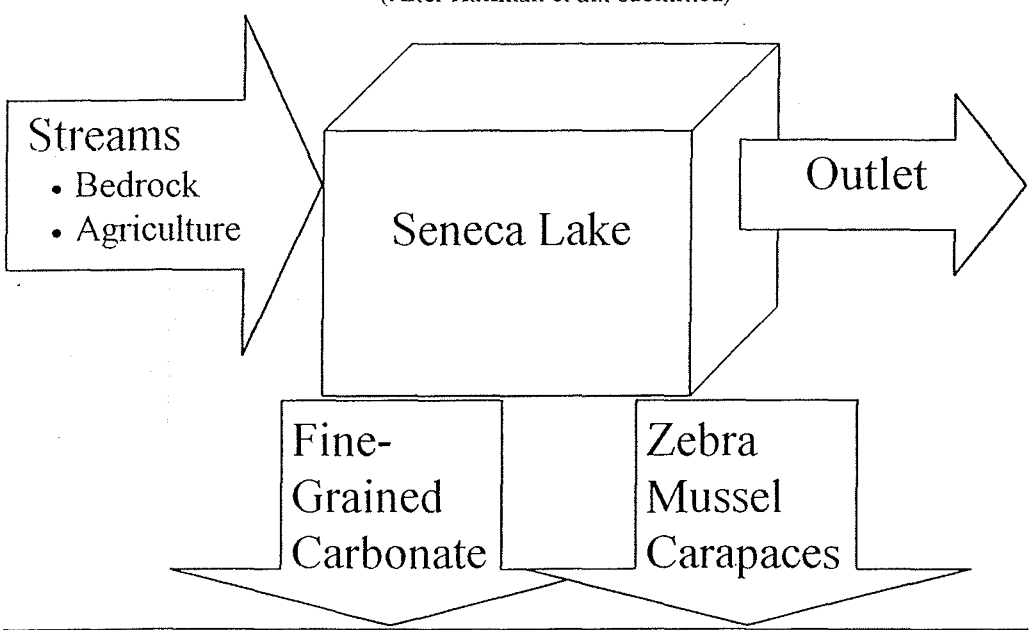
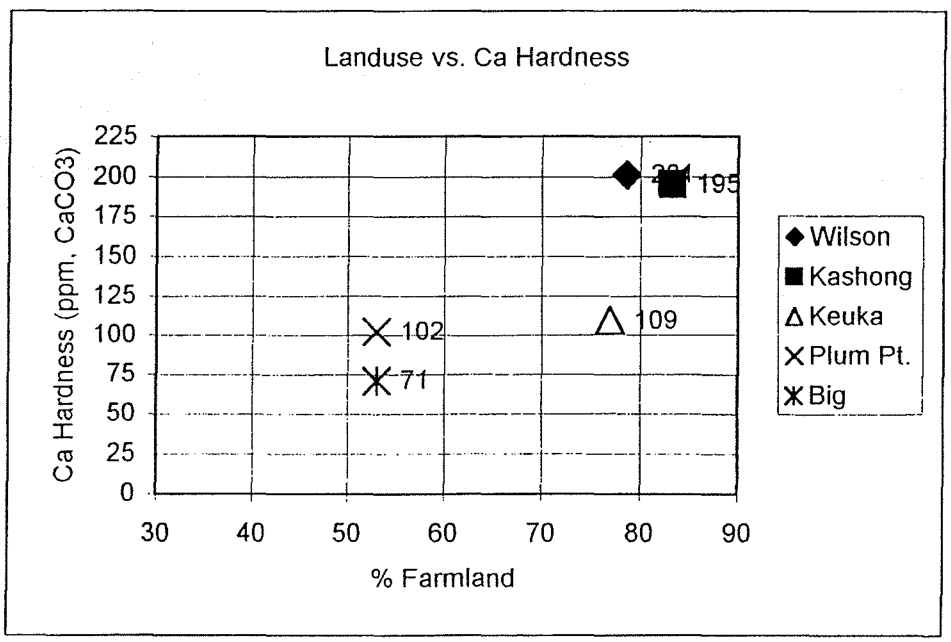


Fig. 7. A first-order calcium mass balance model for Seneca Lake showing the major source and sinks of calcium to and from the lake.

Calcium hardness concentrations average 95 ppm (as $CaCO_3$), and total hardness concentrations average 150 ppm (as $CaCO_3$). These values approach the 80 (100) ppm concentration minimum that defines the boundary between soft (lower concentrations) and hard water (higher concentrations). Hard water is a nuisance in domestic water supplies because is prevents the lathering of soaps and deposits a whitish scum on pots, pans and plugs plumbing in hot water heaters. Calcium is also a vital "nutrient" for the zebra mussel (*Dreissena polymorpha*), a recent exotic. It first appeared in Seneca Lake during the summer of 1992. Since then, it has quickly invaded all of the suitable habitats in the lake, and significantly impacted water clarity, plankton concentrations, nutrient concentrations and other facets of the lake's limnology. Here we will report on the zebra mussel's impact on the calcium budget of the lake.

Stream, sediment and limnological data are sufficient for back-of-the-envelop calculations on the calcium budget in the lake and to assess the impact by the recent invasion of zebra mussels. The primary source of calcium to the lake is from streams whereas the primary removal mechanisms of calcium from the lake are precipitation of an authigenic carbonate (whiting), flow through the outlet, and precipitation of zebra mussel shells. We assume that groundwater has a negligible impact (Fig. 7).

The calcium input by streams was extrapolated from the available stream discharge and calcium concentration data collected from 6 streams since 1995. We extrapolated the different fluxes of calcium by each stream to the entire watershed after assuming stream discharge is proportional to subwatershed area and calcium concentration is proportional to bedrock geology and a lesser extent agricultural activity in the subwatershed (Fig. 8). It yields an annual influx of 34,400 metric tonnes of calcium per year. The outflow removes 31,000 metric tonnes of calcium/year by multiplying the Ca concentration in the lake by the annual discharge through the outlet. The pre-zebra mussel efflux by authigenic calcite precipitation was estimated from the mean concentration of calcium in the sediments (0.03 g Ca/g mud), the sediment porosity (0.82), sediment accumulation rates over the entire lake floor (0.20 cm/year) and sediment density (2.65 g/cm^3). The result is 4,000 metric tonnes / year. The estimated pre-zebra mussel inputs (34,400) balance the pre-zebra mussel outputs (31,000 + 4,000). The flux of calcium to zebra mussels was estimated from the average mass of calcium in the zebra mussels collected in a number of sediment dredge samples (1.2 g Ca/dredge), a zebra mussel average life span of 3 years, and extrapolating this result over the entire lake floor where zebra mussels accumulate (50 km^2). This yields a flux of 200 metric tonnes/year or 5% of the total calcium flux to the lake floor. This redirection of calcium from the authigenic carbonate fraction to the zebra mussel fraction is confirmed by a most recent decrease in carbonate content in the uppermost 1 or 2 cm of sediment.



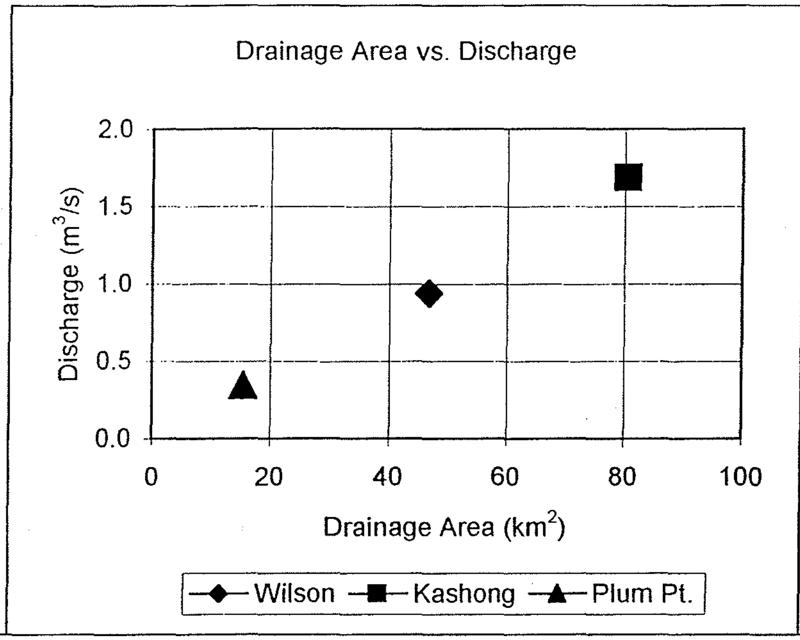


Fig. 8. Mean annual discharge and mean calcium concentrations vs. subwatershed area for selected streams. The data suggest that stream discharge is proportional to watershed area, whereas calcium concentration must reflect other factors besides watershed area. Landuse and bedrock geology are two plausible options. Mean annual calcium concentrations vs. percentage of agricultural land do not reveal a linear trend. Limestone and calcium rich soils underlie Reeder, Wilson, and Kashong Creeks than other creeks in the survey and the bedrock correspond to the high calcium concentrations.

H-WS EXPLORER

H-WS Explorer is a steel hulled, single screw, diesel powered vessel built in 1954 for the United States Navy. Hobart and William Smith Colleges acquired the vessel in 1976 after it had also been used in, e.g., the lobster and fishing industries. The vessel is documented "Oceanographic" by the United States Coast Guard and meets all of the standards applicable to such a vessel. In 1989, major renovations resulted in the construction of a 20 by 10 ft laboratory on the main deck to compliment the growing list of standard oceanographic/limnologic equipment including 2 Sea Bird CTD's (Conductivity, Temperature, Dissolved Oxygen, pH, Turbidity and Depth sensors), EdgeTech (EG&G) X-Star high-resolution seismic reflection system, EdgeTech sidescan sonar, computers, flume hood, weather station and other equipment. The pilothouse has a full compliment of safety, navigation and communication equipment including up-to-date radar, satellite navigation, marine radio-telephone, cellular phone and other equipment. Most importantly, a licensed captain and mate operate the vessel. It provides a safe, well-equipped platform useful under most weather conditions experienced on Seneca Lake.

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CRUISE LOG

This field trip starts and stops aboard the H-WS Explorer, and investigates the sediment character and water chemistry at selected locations (Fig. 1). We will look at the X-Star seismic stratigraphy of the sediments while underway between stations. Surface grab samples will be collected at the first two stops, and a short piston core at the third stop. We will also deploy the CTD and collect water samples to analyze at the third station as well. We will not concern ourselves with the lacustrine marls because they compose a small fraction of the sediments in the lake. A road log is not provided for obvious reasons.

STATION #1. SHALLOW-WATER SANDY SILTS - NORTHERN END OF SENECA LAKE

The lake floor is covered by sandy silts, with the coarsest sediments in the northwest margin of the lake. Shell and plant debris and the occasional ice-raft pebble make up the other minor components. We believe that these sediments must be derived from the reworking of and erosion of glacial drift. Subbottom images suggests that the sand forms a thin wedge of sediment above the pink clays and/or glacial drift. In many places the seismic images are attenuated by gas (biogenic methane?).

Suitable substrate (coarse materials) is covered by zebra mussels. Zebra mussels are an exotic species that has been introduced in the lake during the past decade. They are prolific filter feeders, filtering, on average, a few liters of water each day, extracting the plankton from the water column. One possible measure of their impact is historical Secchi disc data. Secchi discs are used to measure water clarity. To a first approximation, deeper Secchi disc depths correspond to less turbid water (e.g., smaller plankton concentrations). Historical Secchi disc data have shown increasing Secchi depths over the past decade from a few meters to over 5 meters deep during the productive early summer months. This change is consistent with a decrease in chlorophyll concentrations. The exact reasons for the increase in water clarity (and decrease in chlorophyll) are not completely understood but the Secchi disc data suggests two hypotheses: that the burgeoning population of zebra mussels has become large enough to significantly reduce the standing crop of plankton, and/or an increase in the quality of sewage treatment by lake-shore residents has reduced the anthropogenic nutrient loading to the lake.

STATION #2. PROGLACIAL RHYTHMITES – MID-LAKE OFFSHORE OF BELHURST CASTLE

To the south of station 1, pink clays may be found below a thin veneer of postglacial material. The pink clays are well stratified, very cohesive and exhibit light red to pink colors. Single pebble to granule sized grains and ostracode shells are found widely scattered in the sequence. Well defined, parallel to subparallel reflectors characterize these clays in the subbottom profiles. The reflectors commonly outcrop onto the lake floor in shallow water. We interpret these clays as proglacial rhythmites, typical of many proglacial lakes. It is unclear whether the couplets are annual events (varves). In the northern part of the lake, the pink clays are folded. The subbottom profiles suggest that the pink clays collapsed into ice-block holes in the underlying drift and/or the ice front experienced small re-advances.

STATION #3. POSTGLACIAL MUDS & LAKE GEOCHEMISTRY – OFFSHORE OF CLARKS POINT

Moving south across exposures of glacial drift, the lake floor descends to a flatter floor typical of the deeper parts of the lake. At this location the uppermost sediments are very fine grained, black to gray, stratified and rich in organics. These sediments blanket the older materials with thicknesses up to 8 meters in the subbottom profiles. The sequence thins rapidly in water depths shallower than 60 meters and on the steep slopes on either side of the basin. They contain no shell material, a few coarse grains of silt and sulfide minerals. These muds are interpreted as the postglacial sediments deposited since deglaciation. The source is the suspension of fine material carried into the lake by streams and/or erosion of older, shallow-water bottom sediments by surface and internal waves.

We will also deploy the CTD and analyze the surface water for its chloride and calcium concentrations at this site to discuss the unique source of the "extra" chloride to Seneca Lake and the recent depletion of calcium from the lake by zebra mussels.

ANATOMY OF A COMPOSITE SEQUENCE BOUNDARY: THE SILURIAN-DEVONIAN CONTACT IN WESTERN NEW YORK STATE

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INTRODUCTION

Unconformities form the basis for sequence stratigraphy (Vail et al., 1977, 1991; Wilgus et al., 1988; Van Wagoner et al., 1988; Emery and Meyers, 1996). Widespread disconformities have long been recognized and Sloss (1963) used such major gaps – which typically expand cratonward – to delineate six major intervals, now termed supersequences, in the Phanerozoic record of North America. The boundary between the middle Ordovician – Lower Devonian – Mississippian Kaskaskia sequence was drawn at a major, if cryptic, disconformity that was later named the "Wallbridge Unconformity" (Sloss, 1963; Dennison and Head, 1975). The temporal significance of unconformities stems from a key assumption – fundamental to relating sequence stratigraphy and chronostratigraphy – all strata below an unconformity are everywhere older than all strata above the surface.

In addition to their importance in sequence stratigraphy, unconformities may have other far-reaching implications. Topographic features of the surfaces may provide insight into processes active during the hiatus in which the surfaces formed. Presence of early jointing may signify tectonic regimes. Sinkholes and collapse breccias may point to karstification, and paleosols may provide some hints as to climatic regimes. Three-dimensional study of unconformities – the production of paleogeologic maps along these key surfaces may yield very important insights, as to paleotopography and aid in defining the positions of relative highs (domes, arches) and lows (local basins).

Correlation of unconformities involves outcrop to outcrop tracing and/or independent data on biostratigraphy, event beds, etc. Such correlations may point to significant widespread lowering of relative sea level. Ultimately, intercontinental correlations may aid in identification of eustatic lowstands. Conversely, the localization of unconformities in otherwise continuous successions may lead to recognition of local tectonic effects (e.g., Ver Straeten and Brett, 2000). Commonly, two or more disconformities may merge laterally to form a much larger unconformity. This to may point to localized diastrophic or far field tectonic effects (Ettensohn, 1991).

Finally, as erosion surfaces are later onlapped by shallow seas they become transformed temporarily into rocky shorelines and rockground seafloors that may exhibit distinctive morphologies and faunas that typify the intertidal to shallow subtidal zone. Such rocky shorelines have received considerable attention of late (see Kobluk et al., 1977; Johnson, 1988, 1992; Johnson and Baarli, 1999).

In this paper we document details of widespread sub – Middle Devonian (Onondaga Formation) unconformities in western to west-central New York (map, Figure 1). We recognize up to three disconformity surfaces (sequence boundaries) in western to central New York that locally merge to form one. The true Wallbridge Unconformity may erosionally truncate three older, post-Bertie sequences.

These results point to widespread erosion in the Late Silurian – Early Devonian west of Cayuga Lake. This surface was subsequently transgressed in the middle Early Devonian (Pragian) and draped with basal quartz sands of the Kaskaskia transgression (Oriskany Formation). A subsequent period of erosion removed much of the Oriskany and probably all of the overlying Esopus Formation during mid-Emsian time. This erosion surface was transgressed by late Emsian (Schoharie-Bois Blanc) shallow seas, which reworked sand and clasts of older units. Finally, another period of erosion, immediately preceding the deposition of latest Emsian-early Eifelian Onondaga Limestone removed much of the Bois Blanc and further modified the exhumed erosion surface.

Finally, we describe what appears to be a rocky shoreline with small sea stacks, submarine cavities, and fissures in Silurian dolostones, which are draped and filled with Devonian bioclastic sediment.

STRATIGRAPHY

In the following section we briefly discuss each of the stratigraphic units synjacent to the Devonian unconformities, commencing with the oldest. An overview of the stratigraphy of the uppermost Silurian and Lower Devonian, presenting preliminary modifications of Rickard (1975), is displayed in Figure 2.

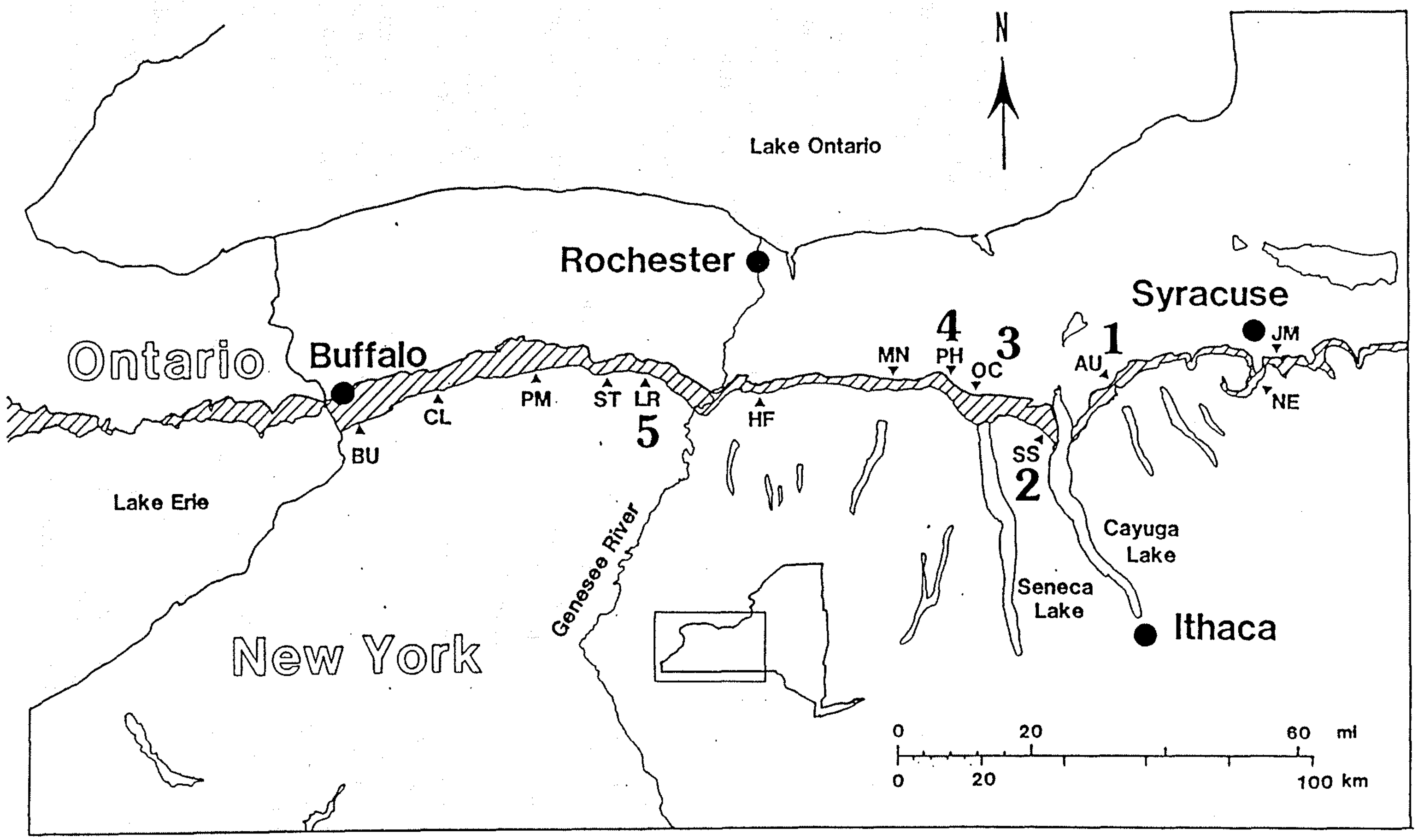

Figure 1. Outcrop map of the Onondaga Formation in west-central to western New York (modified after Rogers et al., 1990). Unconformities interval at and below Onondaga Formation examined on fieldtrip occur at north side of outcrop belt. Key localities include (east to west): JM=Jamesville, NE=Nedrow and Onondaga Indian Nation, AU=Auburn (Stop 1 of fieldtrip), SS=Seneca Stone quarry (Stop 2 of fieldtrip), OC=Oaks Corners (Stop 3 of fieldtrip), PH=Phelps (Stop 4 of fieldtrip), MN=Manchester, HF=Honeoye Falls, LR=LeRoy (Stop 5 of fieldtrip), ST=Stafford, PM=Pembroke, CL=Clarence, BU=Buffalo.

Silurian and Devonian Units below the Wallbridge Unconformity

Upper Silurian (Pridolian) Bertie Group. The oldest strata, below the lower or Wallbridge Unconformity are dolostone and dolomitic shales of the Upper Silurian (Pridoli) Bertie Group. The Bertie has long been famous for its eurypterid fauna and details of Bertie stratigraphy have been documented by Clarke and Ruedemann, 1912; O'Connell, 1913, 1916; Ruedemann, 1916; Alling and Briggs, 1961; Leutze, 1961; Rickard, 1962, 1969, 1975; Kjellesvig-Waering and Heubusch, 1962; Kjellesvig-Waering, 1963, 1964; Craft, 1964; Treesh, 1972; Ciurca, 1973, 1978, 1982, 1990; Hamell and Ciurca, 1986; Ciurca and Hamell, 1994; Belak, 1980; Tollerton and Muskatt, 1984). The details of Bertie stratigraphy will only be briefly summarized here. In broadest outline, the Bertie comprises three shallowing - deepening cycles.

Oatka Formation. Lowest Bertie strata have been assigned to the Oatka Formation. The Oatka comprises approximately three meters of medium – dark gray dolomitic shale and shaly dolostone. It is unfossiliferous and probably represents sabhka-type dolomitic mudstone-shale facies.

Fiddlers Green Formation. The overlying Fiddlers Green Formation (ca. 10 m-thick) has been subdivided into a series of members by Ciurca (1973, 1990). Lowest strata are assigned to the Morgansville Member, which consists of approximately 1.5 m of buff-weathering, conchoidally-fracturing, massive dolostone. This is the first unit referable to as a "waterlime", a fine-grained dolostone, formerly used as a naturally-setting cement rock.

The Morganville Member carries rare eurypterids and sedimentary structures such as vaguely crinkly laminae (cryptalgal?), ripples, and salt hoppers, indicative of shallow subtidal (lagoonal?) to intertidal deposition. Here the Oatka – Morganville succession is inferred to represent a deepening – shallowing peritidal succession.

The upper surface of the Morganville Member is an irregular discontinuity surface with relief of up to 0.5 m; it is well displayed in cuts along the New York State Thruway at Phelps. It is interpreted as a flooding surface, a minor discontinuity at which the irregular upper contact of the Morganville hosts thrombolitic mounds. These mounds extend upward into thin bedded, light gray- to white-weathering, 6 m-thick Victor Limestone Member of the Fiddlers Green Formation. This is the most strongly marine-influenced part of the Bertie; the Victor A submember (ca. 0.6 m-thick) typically contains articulate brachiopods (*Whitfieldella*). It is overlain by the thick Victor B (brownish gray, thinly-bedded, vuggy and bioturbated dolostone) and thin Victor C (limestone, 0.6 m-thick) submembers.

The upper portion of the Fiddlers Green Formation displays a series of facies that resemble the Morganville Dolostone and comprises the second shallowing upward cycle of the Bertie Group. It commences with pale brownish-gray, conchoidally-fracturing, finely-laminated dolostone of the Phelps Member (1 m-thick). This unit is noted for its finely preserved eurypterids, especially *Eurypterus remipes remipes*, most notably at Passage Gulf, Herkimer County, New York. The upper portion of the Phelps Member contains a suite of sedimentary structures including crinkly cryptalgal laminae, ripples, salt hopper casts, and desiccation cracks, that, again, point to an inter– to supratidal depositional setting. The highest unit of the Fiddlers Green Formation is the 1-2.5 m-thick, stromatolitic Ellicott Creek Breccia Member. Ciurca and Hamell (1994) proposed that the breccia may represent a tsunamite deposit that tore up stromatolitic-bound sediments. The member is interpreted as evidence for further shallowing, associated with the transition into the Scajaquada Formation.

Scajaquada Formation. The succeeding Scajaquada Formation (ca. 3 m-thick) consists of dark gray, greenish-gray, and rarely reddish-streaked shaly dolostone and thin-bedded platy dolostone. Desiccation cracks and small halite crystal molds are present. Fossils are lacking; chert nodules occur locally. The unit is very similar to the Oatka Member and is likewise interpreted as a muddy sabkha facies.

Williamsville Formation. The Williamsville Formation constitutes pale gray, fine-grained, slightly argillaceous dolostone, or waterlime, similar to the Phelps Member of the Fiddlers Green (though grayer in color rather than brownish-gray). This unit is approximately 2 m-thick and has been subdivided into four subunits by Ciurca (1990). The first and third units (A and C) comprise conchoidally-fracturing waterlimes; the B unit features the articulate brachiopod *Eccentricosta*. Unit D is also a waterlime, transitional into the overlying Cobleskill/Akron Formation. The Williamsville Formation contains a moderately diverse assemblage of fossils, including molluscs, lingulid brachiopods, ostracodes, and the eurypterid *Eurypterus remipes lacustris*.

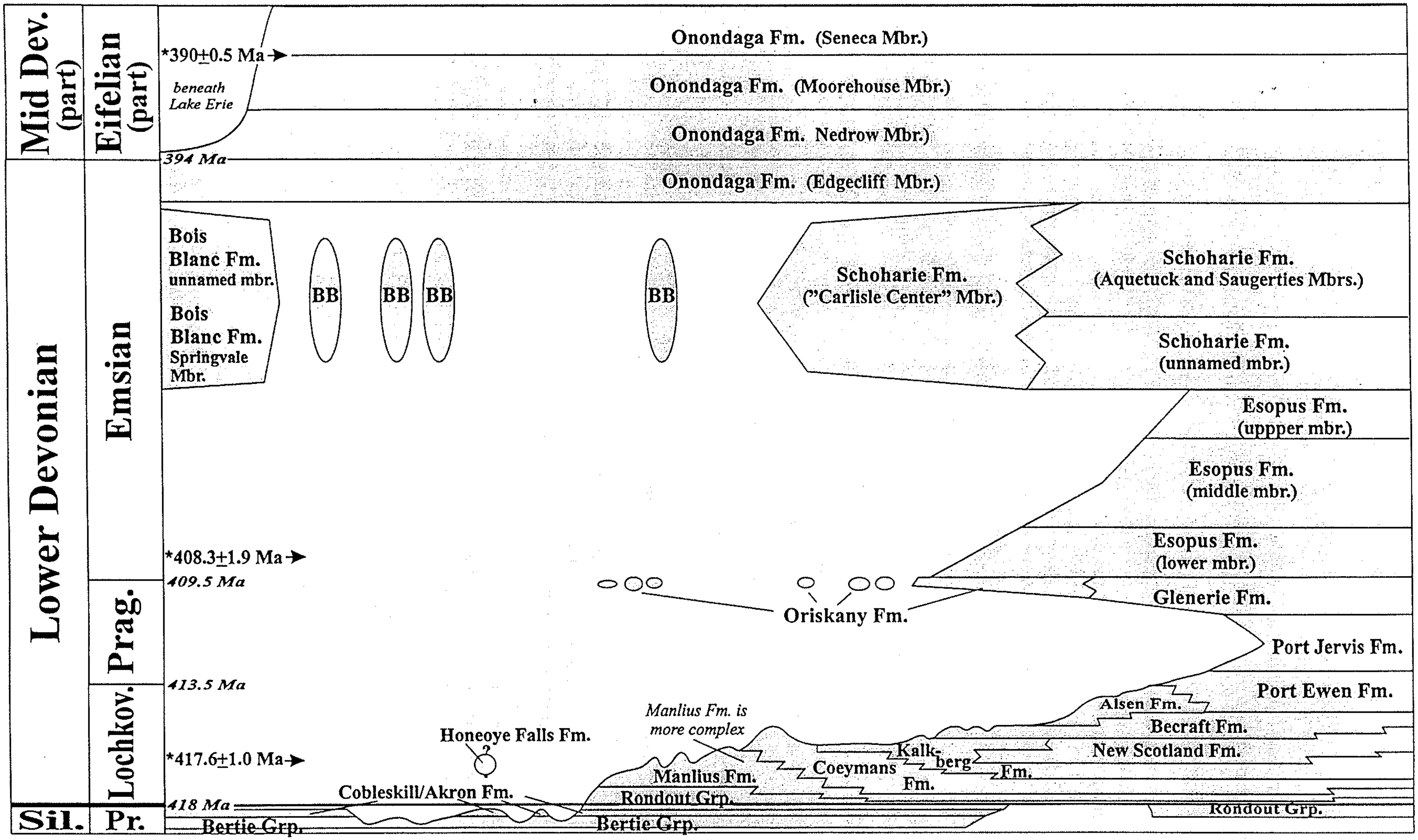

Figure 2. Revision by C.A. Ver Straeten (in process) of the Lower Devonian portion of Rickard's (1975) Stratigraphic Chart of the Devonian. One of the significant components of this revision is the adaption of the revised Devonian time scale of Tucker et al. (1998), wherein the Late Silurian Pridolian Stage comprises one million years, and the Lochkovian, Pragian, and Emsian stages of the Lower Devonian comprise 4.5, 4.0, and 15.5 million years respectively. The revised, longer estimate for duration of the Emsian (previously estimated between 3.6 to 8 m.y. by previous time scales) is reflected in the expanded vertical dimension of the Emsian age Esopus and Schoharie formations. Recent geochronologic dates from Tucker et al. (1998) in bold, regular letters to left in figure; their estimates for dates of the stage boundaries in bold italic lettering. Zircons from the two older dated horizons come from K-bentonites in the Kalkberg and Esopus formations at Cherry Valley, NY. The upper dated K-bentonite is the Tioga B (=Onondaga Indian Nation Ash) at the base of the Seneca Member of the Onondaga Formation, dated from samples in central Pennsylvania.

Upper Silurian (Pridolian) - Lower Devonian (Lochkovian) Rondout Formation.

Cobleskill/Akron Formation/Member. The Cobleskill (or Akron) Formation (Member of Rickard, 1975) is the highest Silurian formation fully exposed in western and central New York. It is a massive, vuggy, and heavily-bioturbated dolostone and dolomitic limestone. The latter has been referred to as Cobleskill, while more fully dolomitized facies have been identified as Akron. Belak (1980), showed that the units are merely diagenetic facies of one another, and Ciurca (1990) advocated the use of Cobleskill Formation throughout New York and southwestern Ontario. He also suggested inclusion of the Cobleskill within the Bertie Group. Herein we follow Rickard (1975) and keep the Cobleskill/Akron Formation in the Silurian-Devonian Rondout Formation. Rare rugose and tabulate corals and a few species of brachiopods (including *Eccentricosta*) have been identified from this unit in western New York. This interval probably represents a return to more open subtidal and less saline conditions.

Moran Corner Waterlime Member. Capping the Cobleskill Formation is a 1 m-thick unit fine-grained, conchoidally-fracturing waterlime described by Ciurca (1982, 1990). The unit features a eurypterid (Eurypteris sp.), and postulates an unconformity marked by distinct mudcracked upper contact. The Moran Corner Waterlime appears to represent a small outlier of the Chrysler Member (Rondout Formation) recognized by Rickard (1975).

Chrysler Member. The Lower Devonian (Lochkovian to lower Pragian) Helderberg Group is represented in central New York by strata assigned to the upper part of the Rondout Formation and the Manlius Formation. Basal strata of the Chrysler Member are comprised of conchoidally-fracturing, buff dolostones interpreted to represent supratidal facies.

Ciurca (1973) recognized massive and thin-bedded dolostones and waterlimes at one locality in western New York, which he termed the Honeoye Falls Formation. The formation features the eurypterid *Erieopterus microphthalmus*, otherwise known from the Manlius Formation of central New York. The unit appears to represent a local outlier of Chrysler Member. Ciurca (1982) correlates the Honeoye Falls with Lochkovian strata in southwestern Ontario assigned to the Clanbrassil Formation. The unit is characterized by approximately 7.6 meters of fine-grained dolostone and also features *Erieopterus*. The Clanbrassil Formation has been correlated with the Chrysler Member and part or all of the overlying Manlius Formation (Ciurca, 1982, 1990; Ciurca and Hamell, 1994). Ciurca (1990) also projects an unconformity between the Upper Silurian Moran Corner and Honeoye Falls formations.

Manlius Formation. The Manlius Formation of the Lower Devonian Helderberg Group comprises a mixture of thinly-laminated, stromatolitic to mudcracked micrites, fossiliferous thin-bedded packstones with low-diversity normal-marine faunas, and stromatoporoid-rich bioturbated wackestones. The Manlius Formation is the highest unit exposed below the Wallbridge Unconformity in central to western New York; it is considered to be of Early Devonian, Lochkovian-age. Six members are recognized, including five in the central New York region. These five units are considered to be lateral, shallow water equivalents of the Coeymans, Kalkberg, and New Scotland formations to the east (Rickard, 1962, 1975; see Figure 2of this paper). Rickard (1962, 1975; Figure 2 of this paper) also shows the Chrysler Member of the Rondout Formation as correlative with the Manlius (Thacher Mbr.), Coeymans, and lower Kalkberg formations of eastern New York.

These correlations suggest that the westward thinning and eventual loss of the Helderberg Group (Figures 3, 4) is in part attributable to depositional pinchout onto the craton. We might further suggest that the westward extension of the Chrysler/Honeoye Falls/Clanbrassil formations is laterally equivalent to the maximum transgressive part of the lower Helderberg depositional sequence (i.e., New Scotland Fm.) of eastern New York.

Rickard (1975) shows the Olney and Elmwood members of the Manlius Formation underlying the major Wallbridge Unconformity in the eastern Finger Lakes area (Localities 1-2 of this field trip). The Olney Member comprises lowest strata of the Manlius Formation west of the Syracuse area. The unit consists of blue-colored, fine-grained, even-, thin- to thick- or massive-bedded limestones, sometimes internally laminated, with minor, thin grainstone beds (Rickard, 1962). Excepting stromatoporoids, which are widespread, fossils are uncommon in the Olney Member. The succeeding Elmwood Member in the study area is composed of non-fossiliferous, drab yellow-weathering, thin-bedded waterlimes with desiccation cracks (Rickard, 1962).

Southeastward of the study area, successively higher units of the Helderberg Group appear beneath the Wallbridge Unconformity (Figures 2, 3). These units comprise two large deepening upward cycles; A) Rondout, Manlius, Coeymans, Kalkberg, New Scotland, and lower Becraft; and B) upper Becraft, Alsen, Port Ewen, and Port Jervis formations. Closure of the unconformity occurs in the Tristates area of New York, New Jersey, and Pennsylvania (i.e., Port Jervis, NY; Figure 2).

Devonian Units above the Wallbridge Unconformity

Oriskany Sandstone. The oldest unit exposed above the major Wallbridge Unconformity in New York is the Oriskany Sandstone, tentatively dated as late Pragian age (Oliver and Hecht, 1994). The Oriskany Formation is a pale gray to white weathering quartz arenite. Locally, this sandstone is highly fossiliferous with a moderate diversity fauna, including thick-shelled brachiopods (i.e., *Costispirifer arenosus, Acrospirifier murchisoni, Megastrophia, Hipparionyx,* and *Rensselaeria* ("Big Shell" or *Hipparionyx* Community; see Boucot, 1975). At the Seneca Stone quarry south of Seneca Falls (Stop 2), a thin lens of the Oriskany Sandstone contains abundant brachiopods, spheroidal *Favosites (Emmonsia)* sp. and very rare rugose corals (Oliver and Hecht, 1994).

Although the Oriskany locally attains a thickness of 3 m at the type section (Oriskany Falls; Baker, 1983), it has a very patchy distribution in central New York and generally absent in the western part of the state (Figures 2, 3. 4). As noted, the unit is up to 60 cm thick in Seneca Stone quarry (Stop 2) but pinches out within the quarry.

Across much of the west-central to western New York outcrop belt the Oriskany Formation is missing, although neptunian dikes and cracks filled with quartz grains that may represent Oriskany sands occur just below the Wallbridge unconformity at several localities (e.g., Stops 3 and 5).

Bois Blanc Formation. At several localities through central to western New York State, the Oriskany Formation, or the Wallbridge Unconformity where the Oriskany is missing, is unconformably overlain by a thin, highly condensed interval that has been variously termed "Bois Blanc Limestone" or "Springvale Sandstone" (Figures 2, 3).

Ehlers (1945) originally defined the Bois Blanc as approximately 30 meters of cherty and arenaceous to shaly chert-rich limestone on Bois Blanc Island, Mackinac Straits area of Michigan. Sanford and Brady (1955) traced the unit eastward through southern Ontario where it thins from 30 m near Woodstock to less than 2 m near Buffalo, where small erosional remnants of the unit were identified by Oliver (1954). Near Hagerstown, Ontario, where the Bois Blanc is approximately 6.0 m-thick, the lower 2.5 m are massive sandstones assigned to the Springvale Sandstone of Stauffer (1913).

In New York the unit ranges in thickness from zero to approximately five meters, and is preserved as localized lenses. Apparently, the unit has been removed across most of the western to central New York region by a period of late Emsian erosion, prior to deposition of the Onondaga Formation.

The stratigraphy and faunas of the Bois Blanc Formation in the western New York area have been described by Oliver (1967, 1976), Oliver and Sorauf (1981), and Boucot and Johnson (1968). Coral and conodont biostratigraphy indicate a late Emsian age (probably *serotinus* zone) for the Bois Blanc (Oliver and Pedder, 1979; Oliver, 1967; Oliver and Sorauf, 1981; Klapper, 1981). This unit is a lateral equivalent of the Schoharie Formation of the eastern New York and perhaps also of sandy beds rich in *Meristina* and small *Amphigenia*, informally termed "Springvale" near Syracuse.

The term "Springvale" was proposed by Stauffer (1913) for a thin (<1 m) fossiliferous, glauconitic and phosphatic sandstone that locally overlies the true Oriskany Sandstone. The Springvale fauna was found to post-date the Oriskany and to have affinities with that of the Schoharie Formation of eastern New York State. The Springvale is presently considered to be the basal member of the upper Emsian Bois Blanc Formation in Ontario (Chadwick, 1919; Oliver, 1967).

Use of "Springvale" for basal Bois Blanc glauconitic sandstones in Ontario and western New York follows Oliver (1967), Boucot and Johnson (1968), and Oliver and Hecht (1994). As thus construed, Springvale represents the lower member of the Bois Blanc Formation, and is overlain by a presently unnamed carbonate-rich member, the main thickness of the Bois Blanc.

Near Buffalo, NY, Oliver (1966, 1967) recognized lenses of the carbonate-rich unit, which he described as a dark gray, fine-grained limestone with a brachiopod-dominated fauna. Small lenses of Bois Blanc have also been recognized near LeRoy. The furthest eastward outcrop at which the typical Bois Blanc carbonate lithology has been recognized is at Phelps (Stop 4).

At the Neid Road quarry near LeRoy (Stop 5), the Bois Blanc is a two-part succession up to about 1.4 m thick. A thin (ca. 0- 25 cm) interval of dark brownish-gray, glauconitic and phosphatic sand and sandy mudstone, attributed

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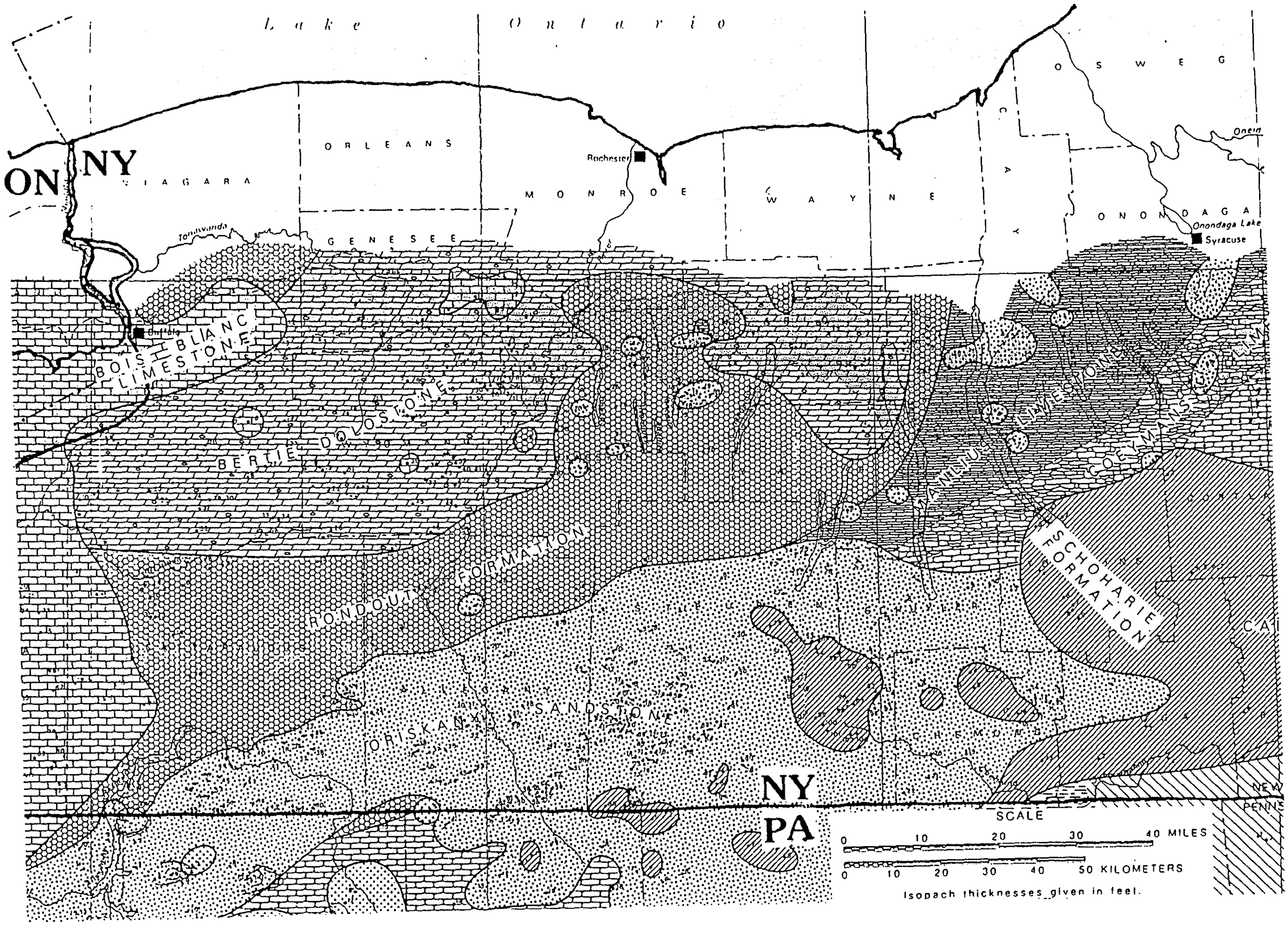
Figure 3. Paleogeologic map of Silurian and Devonian strata below the sub-Onondaga unconformity, northern Appalachian Basin (from Rickard, 1989). Note the progressively older strata exposed below the unconformity into western New York, from the west and especially from the southeast. Recent work discussed in this paper indicates a greater amount of Schoharie-Bois Blanc (sandstone facies), previously interpreted as basal Onondaga, underlies the unconformity in central New York.


Lake Ontario
ON
NY
ORLEANS
MONROE
Rochester
WAYNE
GENESEE
ONONDAGA
Onondaga Lake
Syracuse
Buffalo
BOIS BLANC LIMESTONE
BERTIE DOLOSTONE
RONDOUT FORMATION
MANLIUS LIMESTONE
SCHOHARIE FORMATION
ORISKANY SANDSTONE
NY
PA
SCALE
0 10 20 30 40 MILES
0 10 20 30 40 50 KILOMETERS
Isopach thicknesses given in feet.

to the Springvale Member, is present below carbonates of the unnamed upper limestone member. The sandstone features meristellid and spiriferid brachiopods and small rugose and favositid corals that resemble forms in the overlying Bois Blanc carbonate beds. A pebbly bed about 10 cm above the base contains rounded clasts of brown dolostone and chert, apparently derived from underlying Bertie Group strata, as well as small, sandy phosphatic nodules. The upper third of the 25 cm interval features two to five centimeters of thin lensing beds of wackestones and shales. This lower "Springvale" interval in turn is sharply overlain by two or three ledge-forming, light gray limestone beds, totaling about one meter in thickness. The lower one or two beds are fossiliferous, bioturbated wackestones with thin layers of brachiopod rich packstones. The upper bed is a wackestone with scattered solitary rugose corals (*Heterophrentis*, cystiphyllids and other forms). Adjacent to knobs of Cobleskill Formation that extend upward along the Wallbridge unconformity surface the Bois Blanc appears to form a single bed of highly fossiliferous, medium gray, iron stained pack- and grainstone. (See further details below).

At the roadcut on NY Rt. 88 just west of Phelps, NY (Stop 3), the Bois Blanc is a little less than 5 m thick (see Oliver, 1967, for discussion of nearby outcrop along the NY State Thruway). It still exhibits a basal sandy zone (ca. 1.6 m-thick at Phelps) that, at its base, contains phosphatic clasts of Bertie and sandstone; this apparently represents the Springvale Member. The upper member, about 2.9 m thick locally, consists predominantly of fine-grained, brownish-gray, cherty, dolomitic, limestone (sparse biomicrite or lime mudstone). The unit shows some tendency toward upward coarsening, with grains of crinoidal debris and small corals becoming more common toward the top. This unit is overlain by a pale pinkish gray crinoidal grainstone that represents the basal Edgecliff Member, but the contact is poorly exposed. As previously noted, this is the farthest east lens of typical Bois Blanc strata. The formation is absent altogether at the next major locality to the east at Oaks Corners Quarry (Stop 3).

<u>Undifferentiated Bois Blanc/Schoharie Strata in Central New York.</u> East of Phelps, typical carbonate facies of the Bois Blanc Formation are absent. Farther east, in the Auburn to Syracuse area and eastward, the equivalent of Bois Blanc and Schoharie is represented by a thin (centimeters to over 3 m), two part succession. A thin, lower, dark-gray muddy sandstone (Springvale Member), is overlain by calcareous, yellow- to white-weathering quartz arenite, locally greenish-gray to reddish and argillaceous, with large spheroidal (2-10 cm in diameter) bluish-white-weathering, black phosphatic sandstone concretions ("cannonballs"). Near its top, this unit becomes a sandy limestone that is locally hematitic, and contains fairly abundant large brachiopods, bryozoans and other fossils. We suggest that the main upper body of sandstone may be equivalent to the unnamed carbonate member of the Bois Blanc formation to the west. At its thickest, along Rt. I-81 south of Syracuse, the interval is almost 3.5 m-thick. To the east of Syracuse the phosphatic sandstone extends at least Oriskany Falls, where it overlies typical Oriskany Sandstone (Baker, 1983). Beyond there it thickens, and is continuous with what been called the Carlisle Center Formation, now informally recognized as a member of Schoharie Formation, laterally equivalent to the whole of the Schoharie Formation in the Hudson Valley of eastern New York (Ver Straeten, 1996, in prep.). West of and even near Syracuse, however, its thickness and presence/absence is very localized, and the white quartz arenite-cannonball facies is absent west of Cayuga Lake. In many places where it is absent, reworked phosphatic sandstone clasts, apparently derived from the unnamed member, indicate its widespread occurrence previous to erosional truncation below the Onondaga Formation.

<u>Onondaga Formation</u>. The highest stratigraphic unit involved in the unconformable contacts in western to central New York is the Edgecliff Member of the (Onondaga Formation Figure 2). Brett and Ver Straeten (1994) recognized two predominant facies in the Edgecliff Member: crinoidal, commonly coral-rich grainstones (Jamesville Quarry facies) and cherty, finer-grained wackestone to mudstone (Clarence facies). In nearly all outcrops from Fort Erie, Ontario eastward to past Syracuse, New York the basal Onondaga is formed by a 0.3 to 1.5 m thick interval of non-cherty crinoidal pack- to grainstone. This interval is locally developed as a series of small bioherms. In the study area the basal Edgecliff grainstones variably overlie the Bois Blanc/Springvale, Oriskany, Manlius (Olney or Elmwood mbrs.), Chrysler, or various units of the Upper Silurian Bertie Group (Figures 3, 4).

West of the Syracuse area, and especially from the Oaks Corners quarry west, the higher parts of the Edgecliff Member are generally developed in Clarence facies, a cherty micrite (lime mudstone to wackestone) that displays common light gray to bluish gray chert. In places, the Clarence facies may comprise up to eighty percent chert, with minimal carbonate. The cherty unit rests directly on sub-Onondaga strata in a very few, localized occurrences (e.g., Stop 5, Neid Rd. quarry).

The age of the Edgecliff Member of the Onondaga Formation remains poorly constrained, as it has at present only yielded non-diagnostic conodonts of shallow water icriodid biofacies. The overlying Nedrow Member, however, has yielded forms diagnostic of the *partitus* zone and the overlying P. *costatus costatus* zone, representative of lower

Eifelian age (Klapper, 1971, 1981). In the absence of further data, the Edgecliff is tentatively placed within the latest Emsian *patulus* conodont zone (Klapper, 1971, 1981).

UNCONFORMITIES

At least three unconformities intervene between the uppermost Emsian (Lower Devonian) Edgecliff Member and the Pridolian (Late Silurian) Bertie Group. Each of these is described in some detail below, and are presented in Figures 3, 4, and 5.

Sub-Oriskany (Wallbridge) Unconformity

The most significant of the unconformities is the sub-Oriskany Wallbridge Unconformity, which marks the base of Sloss' (1963) North American-wide Kaskaskia Supersequence. Evidence for the unconformity across the region can be found in many sections where Oriskany Sandstone (or sand grains) overlie an erosion surface. Careful studies in central New York to southwestern Ontario by Ciurca (1973, 1982, 1990), Ciurca and Hamell (1994), and Kobluk et al. (1977) indicate that this unconformity is complex and regionally variable.

Ciurca (1973, 1982, 1990) carefully traced out the stratigraphy of the top Silurian – Lower Devonian erosion surface in Ontario and western New York. His cross-sections (combined into Figure 5 of this paper) show substantial regional relief on this surface. A maximum of 18 meters of stratigraphic separation is redognized from highest areas that expose Lower Devonian Honeoye Falls and Clanbrassil Formations to lowest depressions exposing Silurian Bertie Dolostone units downward to the Victor Member of the Fiddlers Green Formation. Because it is overlain by Pragian-age Oriskany Sandstone, the Wallbridge erosion is bracketed between Lochkovian and upper Pragian. At a smaller scale the unconformity shows a relief of up to three meters in a single quarry (e.g., Stop 5, Neid Rd. quarry), but, in these cases, the erosion surface is actually the combination of two or more unconformity-forming episodes.

At Seneca Stone quarry (Stop 2) the Wallbridge Unconformity is a nearly planar, slightly irregular contact of Oriskany Sandstone on older Lower Devonian (Lochkovian) Manlius Formation. The contact displays small clastic dikes and what appear to be large (up to 1 cm in diameter) organism boreholes. In places angular clasts of the Manlius occur as much as twenty centimeters up into the Oriskany and a few have been encrusted with corals. Rarely, *Favosites* directly encrust the unconformity itself.

Kobluk et al. (1977) describe an irregular sub-Oriskany unconformity in southern Ontario that features sand-filled, solution widened joints, and a *Trypanites* bored rock ground. The widened joints ("klufkarren" or grikes) were interpreted to have formed under subaerial conditions; however, a lack of vugs suggested insufficient meteoric water circulation in contrast to later pre-Bois Blanc conditions. Borings were produced during initial transgression of shallow seas over the eroded surface (Pemberton et al, 1980).

Sub-Bois Blanc / Springvale Unconformity

In most localities where the Bois Blanc Formation (or equivalent sandstone) is present (Figure 6), it rests directly upon the Silurian – Lower Devonian erosion surface with at most only a few sand grains in fractures below. However, in certain localities from the Seneca Stone quarry eastward to Syracuse the Bois Blanc/Springvale can be seen to rest unconformably upon the Oriskany Formation, thereby demonstrating the existence of an Emsian unconformity, distinct from the Wallbridge (see also Oliver, 1966, 1967; Hodgson, 1970, Baker, 1983). This erosion surface was characterized by phosphatized clasts of subjacent units, including Bertie dolostone, Manlius, and sandstones with thick-shelled brachiopods resembling those in the Oriskany Formation.

In those areas where the Oriskany Sandstone is absent and the Bois Blanc/Springvale is present, a combined Wallbridge – sub-Schoharie unconformity exists. This contact is generally flat to slightly undulose. However, at the Neid Road quarry near LeRoy, New York, Bois Blanc strata locally mantle a highly irregular surface on the Silurian Bertie dolostones. The sub-Bois Blanc surface is commonly irregularly pitted, bored, and impregnated with glauconite. In a few places along the quarry walls the Bois Blanc overlaps neptunian dikes filled with clean quartz sands. These are presumably remnants of the Oriskany that were not exhumed during the pre-Bois Blanc/ Schoharie erosional interval. In other cases phosphate- and glauconite-rich quartz sands fill crevices and dikes, and appear to represent later Emsian-age ("Springvale") deposits. Fossiliferous upper Bois Blanc sediment fills karstic hollows up to several meters across, as well as thin cracks, fissures, and even horizontal crevices within the eroded Silurian. We interpret this contact as the exhumed and slightly modified Wallbridge Unconformity.

In southern Ontario Kobluk et al. (1977) described a bored rock ground surface immediately below the Bois Blanc. They also noted the development of solution pits, vugs, and a second generation of joints containing clasts of Oriskany Sandstone. Minute solution pitting was inferred to indicate the presence of algae, lichens and/or mosses, while dendritic etchings on this surface were interpreted as land plant rhizome etchings. *Trypanites* borings below

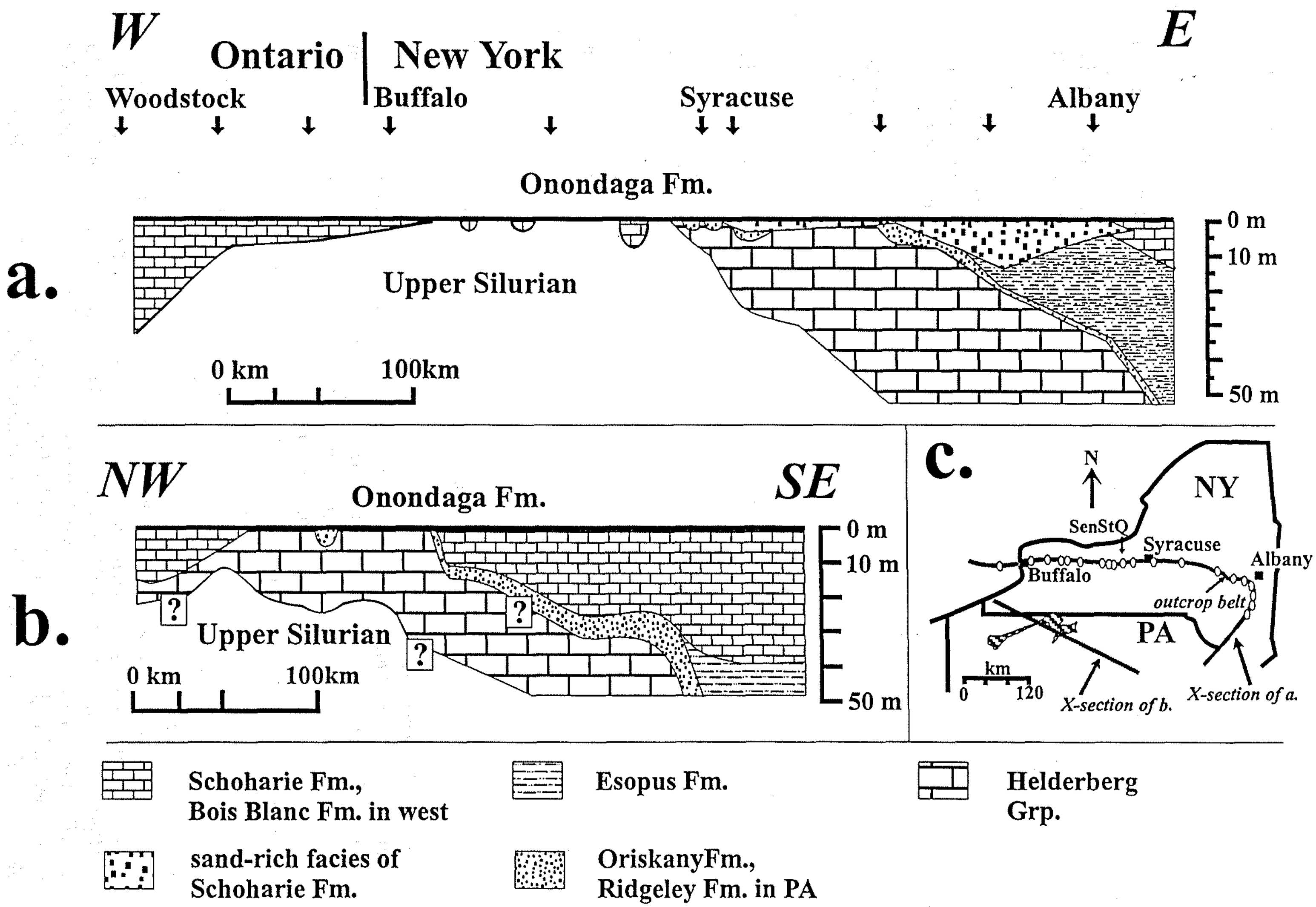


Figure 4. Cross section of Devonian strata below the sub-Onondaga unconformity along the New York outcrop belt (a) and in the subsurface of southwestern New York and northwestern to central Pennsylvania (b). Map (c) shows distribution of cross-sections. From Ver Straeten and Brett, 2000; data for cross-section b from Rickard (1989).

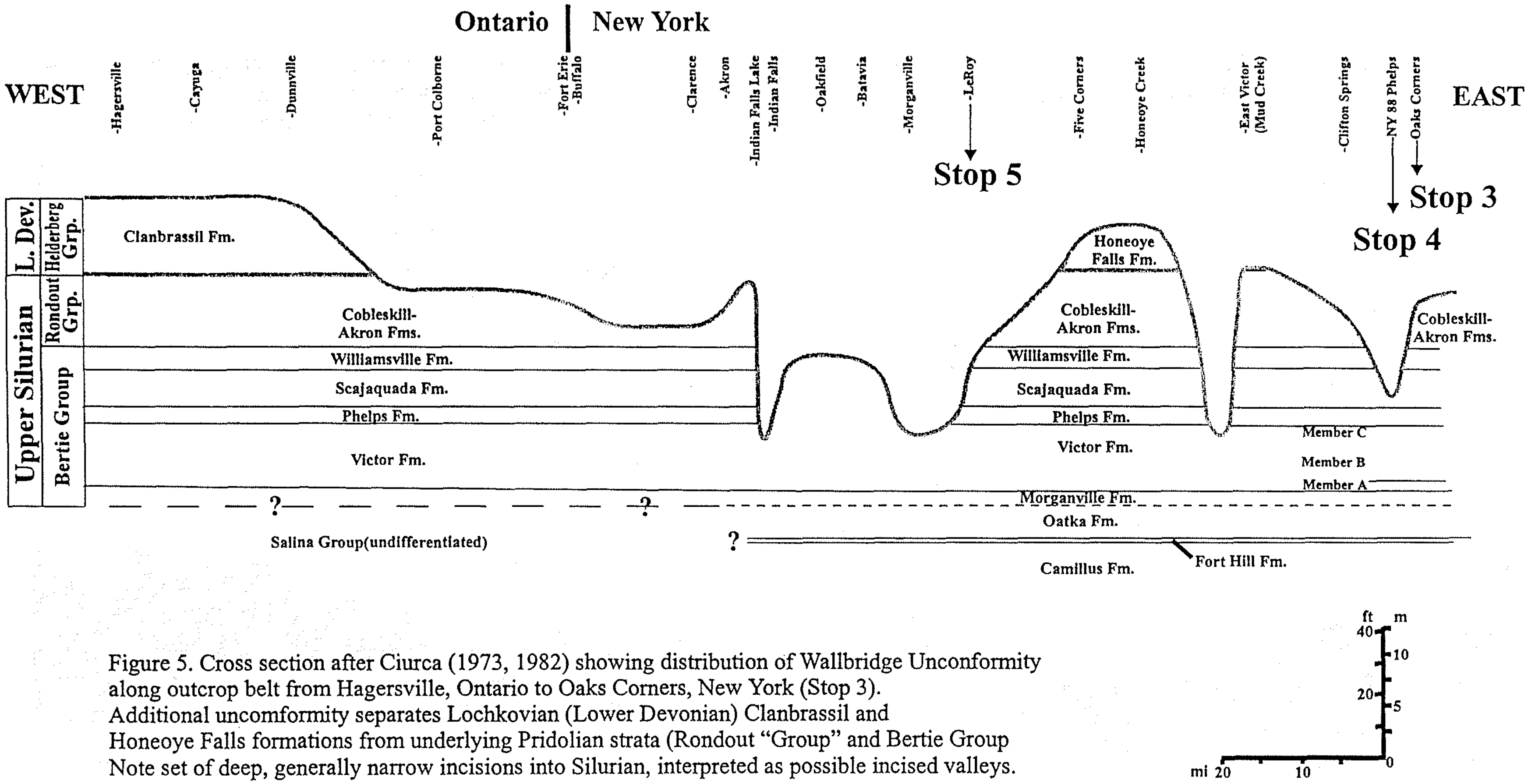


Figure 5. Cross section after Ciurca (1973, 1982) showing distribution of Wallbridge Unconformity along outcrop belt from Hagersville, Ontario to Oaks Corners, New York (Stop 3). Additional uncomformity separates Lochkovian (Lower Devonian) Clanbrassil and Honeoye Falls formations from underlying Pridolian strata (Rondout "Group" and Bertie Group Note set of deep, generally narrow incisions into Silurian, interpreted as possible incised valleys.

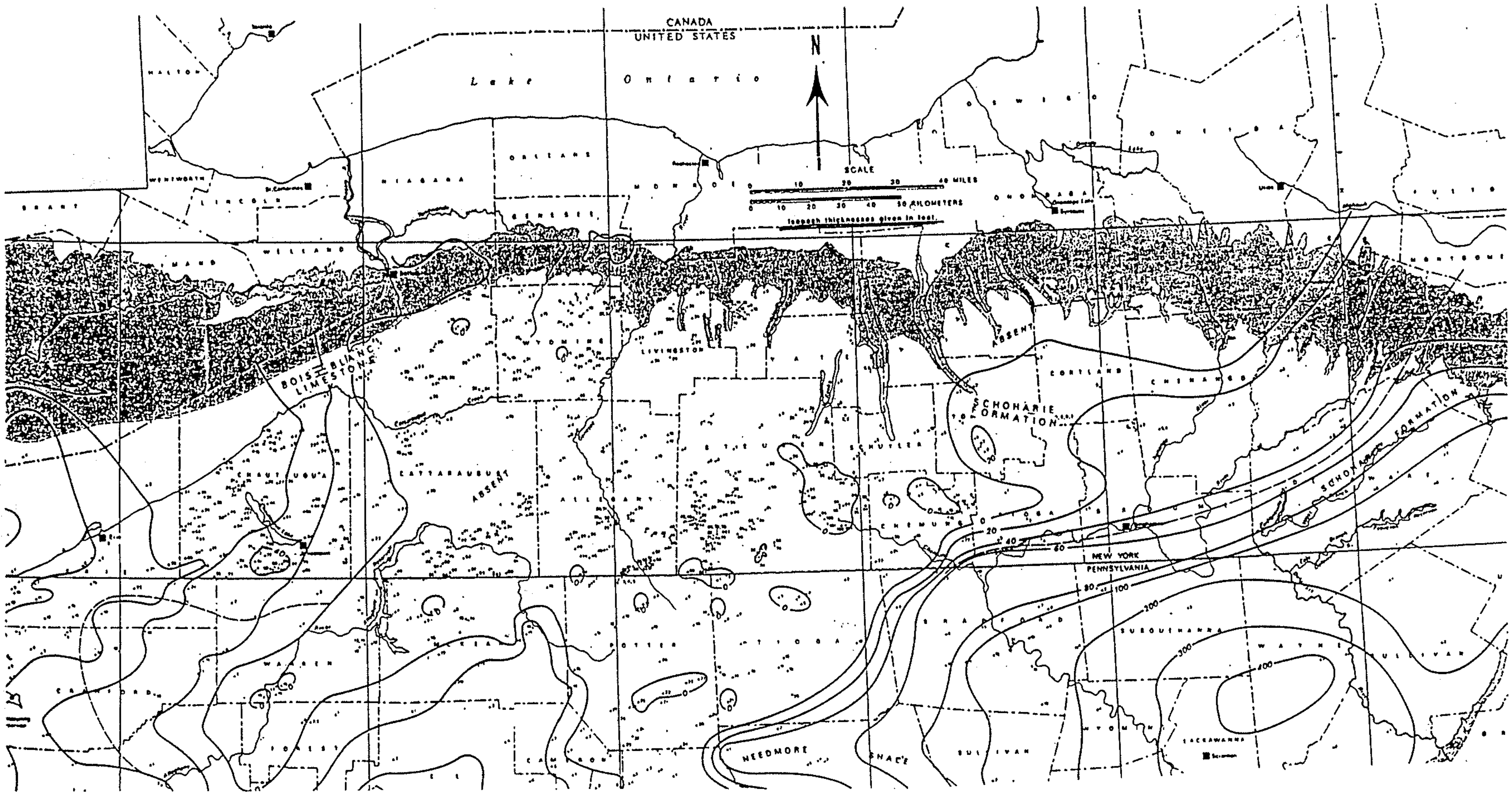


Figure 6. Isopach map of Bois Blanc and Schoharie formations in northern Appalachian Basin (after Rickard, 1989). Note broad pinchout of strata across western to central New York, with isolated lenses preserved across the area. Outcrop-based recognition of Bois Blanc-Schoharie sands across central New York (east of Cayuga Lake) indicates a greater, though locally spotty, distribution of these strata occurs over the area. Isopach thickness given in feet.

the Bois Blanc were infilled with quartz silt/sand and glauconite (Pemberton et al., 1980). We have similarly observed glauconite and silt-filled borings beneath and above Bois Blanc in cavities at Neid Road quarry and the NY Route 88 roadcut near Phelps (see below).

Sub-Onondaga Unconformity

Oliver (1966) and Oliver and Sorauf (1981) noted a faunal break between the Bois Blanc and Onondaga formations that he interpreted to result from a significant unconformity. The contact of the Onondaga (Edgecliff Member) and underlying Bois Blanc formations is also marked by a thin lag of quartz sand, glauconite, and phosphate grains, further suggesting the presence of an unconformity (Hodgson, 1970; Oliver and Hecht, 1994).

In outcrops where the Bois Blanc is present, such as the Neid Road quarry (Stop 5, near LeRoy), it is separated from the overlying Edgecliff grainstones by a sharp, typically planar to gently undulating contact. This unconformity is set off by rust staining at or closely below the contact. It is immediately overlain in some sections by a thin layer of sticky clay that may be a K-bentonite or residual soil. In some outcrops (e.g. Neid Road Quarry, northeast wall [Stop 5], and Goodrich Road near Clarence, NY) the Bois Blanc occurs as a series of lenses. This indicates preservation only in patches. Presumably, the unit has been removed in intervening areas. At both the Auburn and Seneca Stone quarries (Stops 1 and 2), the basal bed of the Edgecliff Member at the base of the Onondaga, shows a flat and seemingly conformable contact with underlying beds. However, it also contains clasts of older units, including phosphatic sandstone nodules (apparently reworked from the older Emsian-age, Schoharie- and Bois Blanc-equivalent "Springvale Sandstone", as well as oxidized (subaerially-weathered?) clasts of the Lochkovian-age Manlius Limestone. Some phosphate-impregnated clasts also contain valves of thick-shelled brachiopods, resembling those of the underlying Oriskany Sandstone. These clasts were reworked during deposition of the first Onondaga sediments (latest Emsian?) as they are associated with (and rarely encrusted by) Onondaga, rather than Schoharie, rugose corals (W. Oliver, 1981, pers. commun.). Ver Straeten and Brett (2000) infer that a number of these clasts were locally derived from previously deposited "Springvale" strata that were eroded over the crest of a migrating topographic high (Figure 7; see further discussion below).

Combined Wallbridge, Sub-Bois Blanc, Sub-Onondaga unconformities.

At many localities in western New York the Onondaga Formation rests directly on eroded upper Silurian strata. In such cases, the crinoidal grainstone of basal Edgecliff tends to fill hollows on the irregular karstic surface. This surface appears to have been "inherited" from the karstification episode of the Wallbridge unconformity (i.e. Late Silurian to earliest Devonian erosion interval). We suspect that during the intervening time interval the surfaces may have been mantled with thin deposits of Oriskany, probably Esopus, and Bois Blanc, but that these beds were subsequently removed by the pre-Onondaga erosion.

Figure 7. Composite figure of facies and time-rock relationships, high resolution correlations, and model for bulge and back-bulge basin migration across central to western New York, Bois Blanc-Schoharie and Onondaga formations (from Ver Straeten and Brett, 2000). 7a) Facies and time-rock relationships in Bois Blanc-Schoharie and Onondaga formations, Buffalo to Syracuse area. Upper part of figure 7a displays an idealized onshore-offshore transect for Onondaga facies across the Appalachian Basin (1 = shallow coral biostromal facies, 9=basinal black shales). Lower part of 7a is a chronostratigraphic facies transect across western to central New York. Vertical axis represents time. Note unconformity at base. FB and BBB areas outline envelopes of eastward migrating bands of relatively shallower and deeper facies through time, interpreted to represent a flexural bulge and back-bulge basin. 7b) High resolution correlations of Bois Blanc-Schoharie strata and Edgecliff, Nedrow, and Moorehouse members of the Onondaga Formation, western to central New York (including Stops 2, 3, and 5 of this fieldtrip). Correlated units include bentonites, a widely recognized pair of black shale beds, and small- to media-scale cycles. Note absence of entire lower medial-scale cycle (parasequence set) at Seneca Stone quarry. 7c) Map and cross section of interpreted peripheral bulge,showing eastward motion of bulge and model of pinnacle reef development in deeper facies in southern New York and northwestern Pennsylvania. BBB = back-bulge basin, FB = forebulge, and FLB = foredeep of Appalachian Basin at that time. LHS = late highstand, LST = lowstand, TST = transgressive, and EHS = early highstand systems tracts of sequence stratigraphic terminology; arrows indicate relative sea level fall to rise. Reef development model shown for upper Bois Blanc-Schoharie (t1) through middle Onondaga (t4).

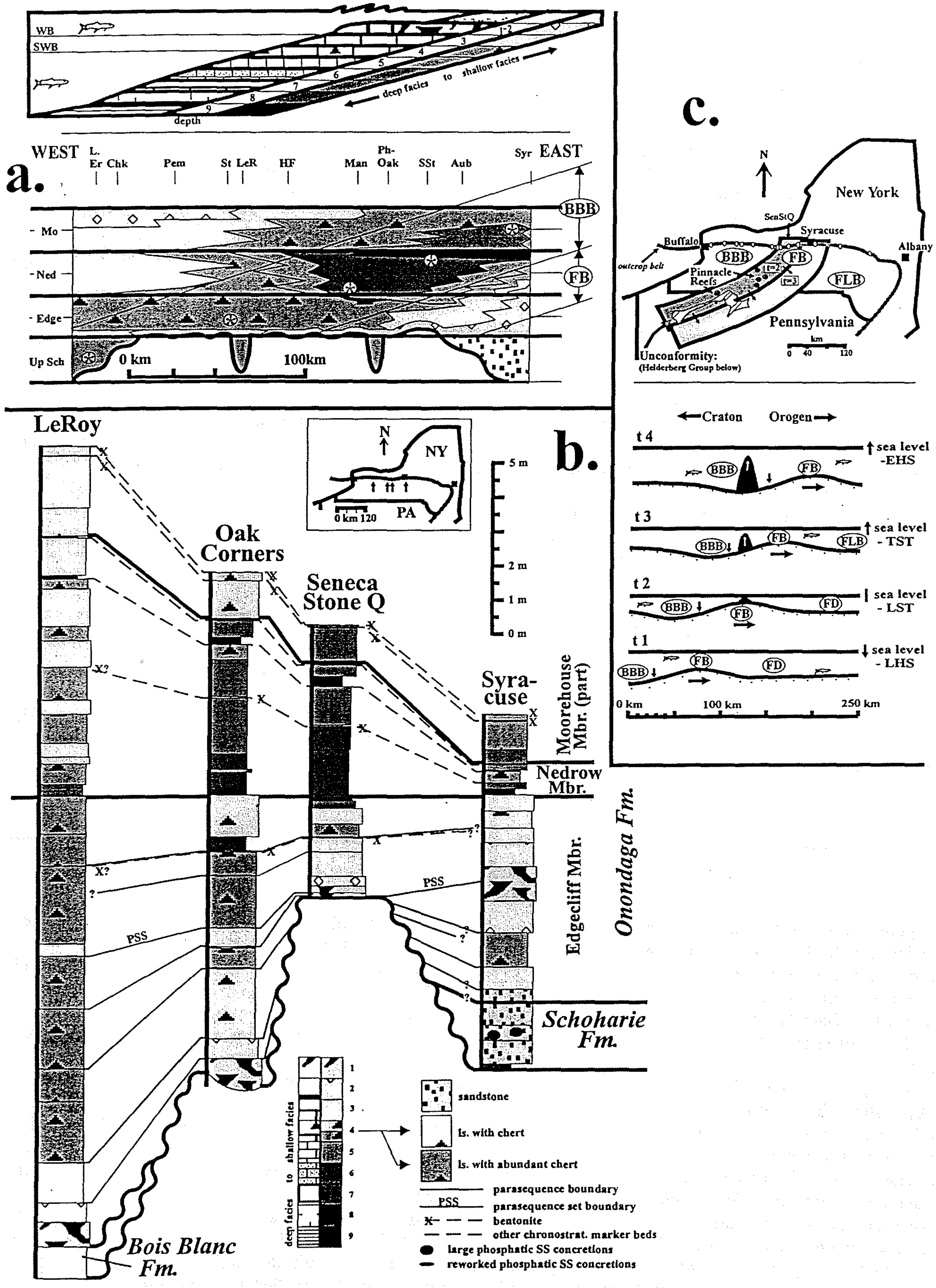
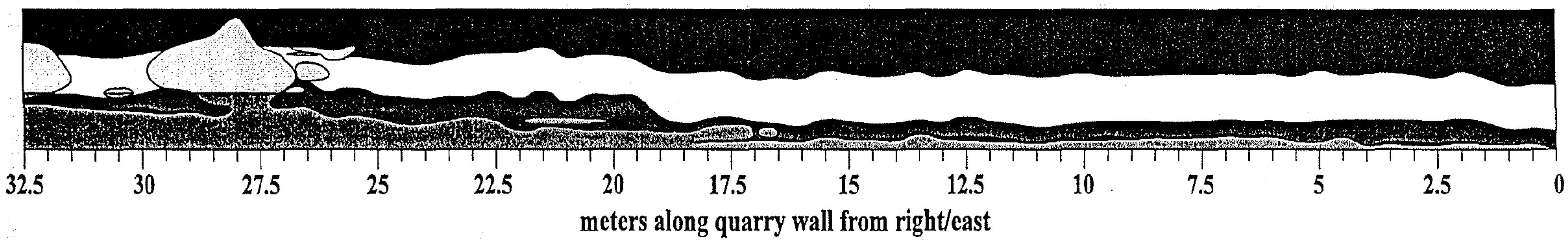

a.
WB
SWB
deep facies to shallow facies
depth
WEST
EAST
L. Er
Chk
Pem
St
LeR
HF
Man
Ph-Oak
SSt
Aub
Syr
Mo
Ned
Edge
Up Sch
BBB
FB
0 km
100km
b.
LeRoy
Oak Corners
Seneca Stone Q
Syra-cuse
NY
PA
0 km 120
5 m
2 m
1 m
0 m
Moorehouse Mbr. (part)
Nedrow Mbr.
Edgecliff Mbr.
Onondaga Fm.
Schoharie Fm.
Bois Blanc Fm.
PSS
deep facies to shallow facies
sandstone
ls. with chert
ls. with abundant chert
parasequence boundary
parasequence set boundary
bentonite
other chronostrat. marker beds
large phosphatic SS concretions
reworked phosphatic SS concretions
c.
New York
Buffalo
SenStQ
Syracuse
Albany
outcrop belt
Pinnacle Reefs
FLB
Pennsylvania
Unconformity:
(Helderberg Group below)
km
0 40 120
Craton
Orogen
t 4
sea level -EHS
t 3
sea level - TST
t 2
sea level - LST
FD
t 1
sea level - LHS
0 km
100 km
250 km

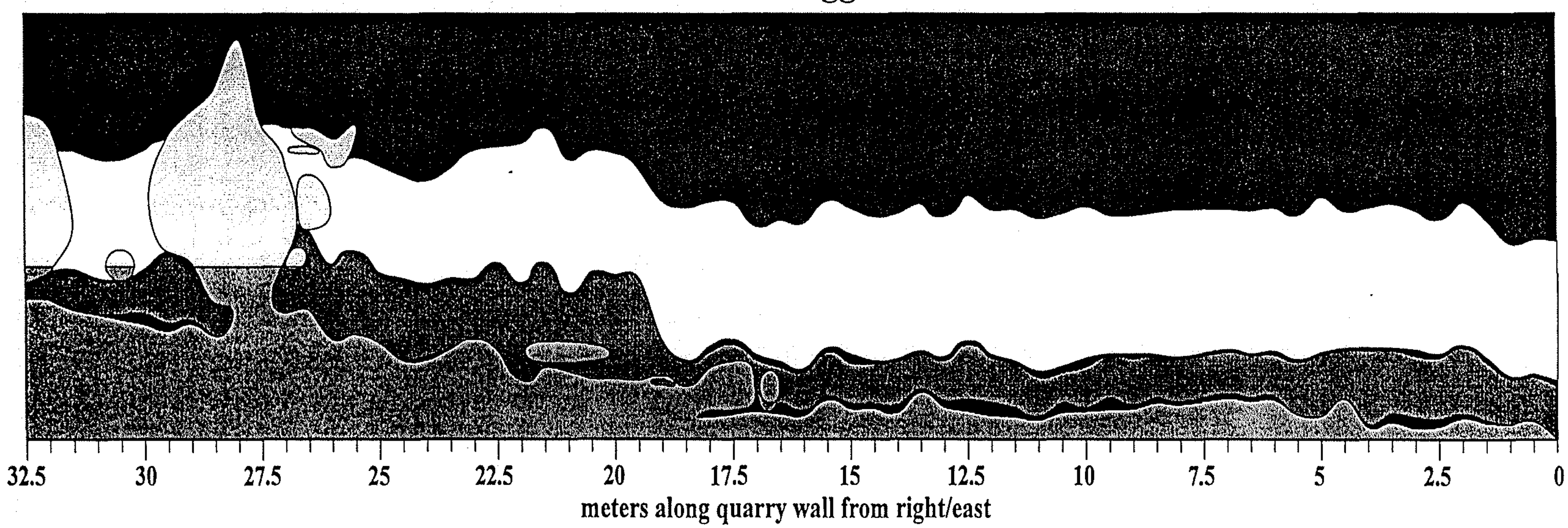
Figure 8. Partial cross-section of northeast wall of Neid Road quarry, LeRoy, New York, showing complex stratigraphic relationships over remnant Silurian bedrock highs. Relief on Silurian = three meters. Note prominent knobs and undercut cavities in Silurian strata, progressively filled in, around, and over by Bois Blanc Formation (coral-crinoid rudstones), basal Edgecliff Member (chert-free grainstones), and middle Edgecliff Member (cherty wacke- to packstones). Two significant disconformities present: 1) an amalgamated Wallbridge & sub-Bois Blanc unconformity; and 2) a sub-Onondaga unconformity.

Lower Devonian Edgecliff Mbr., Onondaga Fm. - cherty facies
Lower Devonian Edgecliff Mbr., Onondaga Fm. - non-cherty facies
Lower Devonian Bois Blanc Fm., limestone facies
Lower Devonian Bois Blanc Fm., lower & upper SS lenses
Upper Silurian Cobleskill-Akron Fm.
Upper Silurian Williamsville Fm.

No vertical exaggeration



3x vertical exaggeration



The Silurian – Devonian contact at Neid Road Quarry: A Possible Rocky Shoreline.

Restudy of an abandoned limestone quarry north of Gulf Road and west of Neid Road in the town of LeRoy (Stop 5) has yielded evidence for a complex, irregular rock ground with possible sea stacks.

The contact between the Silurian Bertie Group and Devonian carbonates is exposed almost continuously around the eastern and northern rim of this quarry. At most stations along the eastern and northwestern quarry walls a thin (ca. 0.8 to 1.4 m-thick) interval of the Bois Blanc Formation rests on beds of the Williamsville Formation. About 10-30 cm of dark gray, glauconitic/phosphatic pebble-rich sandy mudstone (Springvale Mbr.) is overlain by about a meter of brachiopod, coral and gastropod-rich wackestone to packstone (unnamed upper Bois Blanc mbr.). Oriskany Sandstone is absent except for minor fracture fillings in the Bertie that are visible down to at least 0.9 m below the unconformity. Additional fracture fills of, quartz sand with phosphate, glauconite, and abundant fossil hash appear to be Emsian-age. A slight amount of channeling and positive relief of at least 50 cm is observed at this contact. The Bois Blanc, in turn, is sharply overlain by a 70 to 110 cm interval of fine- to medium-grained crinoidal grainstone – the basal Edgecliff Member. This contact also displays a very minor amount of relief, is stained orange from the leaching of sulfides and is, at least locally, overlain by a thin clay layer. The higher beds of the Onondaga are developed in chert-rich Clarence facies of the Edgecliff Member (Figure).

Particularly interesting features occur at the northeast corner of the quarry (Figures 8, 9). Here the normal, nearly horizontal basal contact of the Bois Blanc is greatly modified. First, obvious mounds to pinnacles of Upper Silurian Williamsville and Cobleskill dolostone rise up to three meters above the normal, sub-horizontal contact. These knobs are variously draped by coarse coral- and crinoid-rich Bois Blanc strata, or the lower Edgecliff Member. However, in places, the Bois Blanc and basal beds of the Edgecliff terminate abruptly against the Silurian paleobedrock knobs. Thus, over highest parts of the Silurian knobs the contact is overlapped by cherty Clarence facies (Figures 8, 9).

The knobs themselves are composed of medium-bedded dolostone of the Williamsville Dolostone (Bertie Group), and locally the overlying burrow-mottled, coral-bearing Cobleskill-Akron Formation. They stand above the main "peneplane" surface in the Bertie Group. We infer that these knobs are erosional remnants and possibly sea stacks that were elevated on the Devonian sea floor.

The most intriguing feature of these erosional masses is that they have been undercut near their bases. Subhorizontal notches as much as 1.5 m deep and 5-50 cm high occur near the base of at least one such a mound. Erosion may have been focused along the contact between the softer, thinner bedded Williamsville and overlying, harder Cobleskill dolostone (Figures 8, 9).

In one particularly intriguing situation, along the northeast wall the vertical succession of beds at the edge of one of the pinnacles is as follows: Williamsville (Upper Silurian) – Bois Blanc (Lower Devonian) –Cobleskill (Upper Silurian) – Edgecliff (Lower Devonian). The Bois Blanc here is filling in an undercut notch (possible karstic cavity); where this filling has crumbled away on a single area the ceiling and sidewall of the crevice are visible. They have been extensively bored by *Trypanites*, the dwelling sites of probable sipunculid worms (Pemberton et al., 1980) in the cavity ceiling (Figure 9).

This and other cavities and adjacent areas are infilled by coarse, coral-rubble rudstone to grainstone facies (Figures 9,10) that are directly traceable along the outcrop into the normal, brachiopod-rich mudstones to wackestones of the Bois Blanc Formation. The coarse material is exceptionally rich in solitary and colonial rugose corals (many of them overturned, highly corroded remnants) as well as tabulates and echinoderm debris. The coral content of the Bois Blanc gradually decreases and grades into that typical of the fossiliferous wackestone-packstone facies of the Bois Blanc within 100 to 150 meters from the knobs.

DISCUSSION: IMPLICATIONS OF THE SILURIAN-DEVONIAN UNCONFORMITIES FOR REGIONAL GEOLOGIC HISTORY

The unconformity capping Upper Silurian (Pridolian)/Lower Devonian (Lochkovian) strata in western New York is a complex surface, in places representing the superposition of two to three or more major disconformities, each with distinctive geometries and characteristics. Details of the geometry and topography of these erosion surfaces, together with the sediments that overlap them aid in reconstructing the broad outline of a regional history during the Early Devonian, a history characterized more by erosion than deposition.

Latest Silurian- Earliest Devonian Background

It should be noted that a significant unconformity may also exist between the uppermost Silurian Cobleskill-Akron dolostones and overlying Lower Devonian Clanbrassil-Honeoye Falls Formation (Ciurca, 1990; Ciurca and Hamell, 1994). This unconformity is poorly known due to the fact that it is poorly exposed and overstepped in many areas by the subsequent Wallbridge Unconformity. As far as known, it is a nearly planar paraconformity.

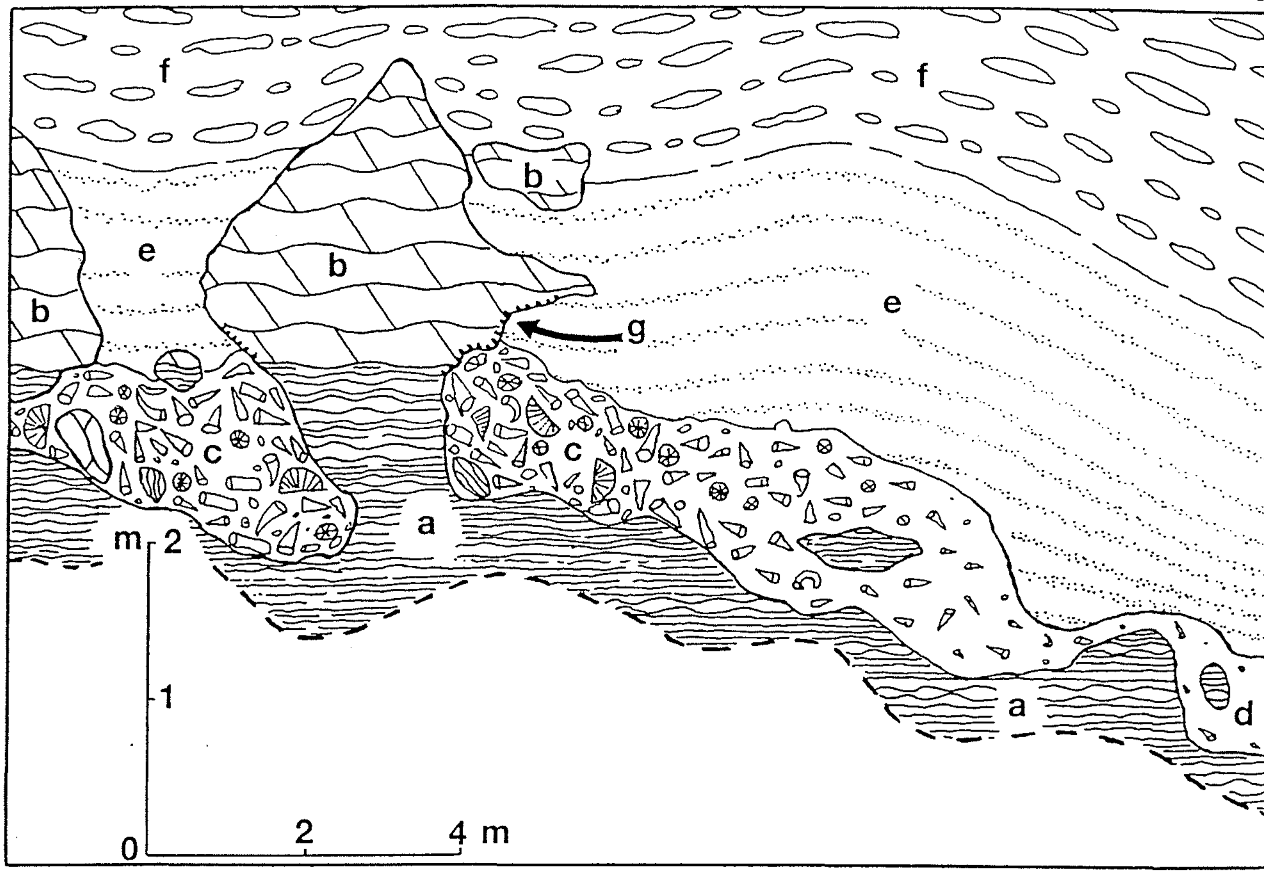
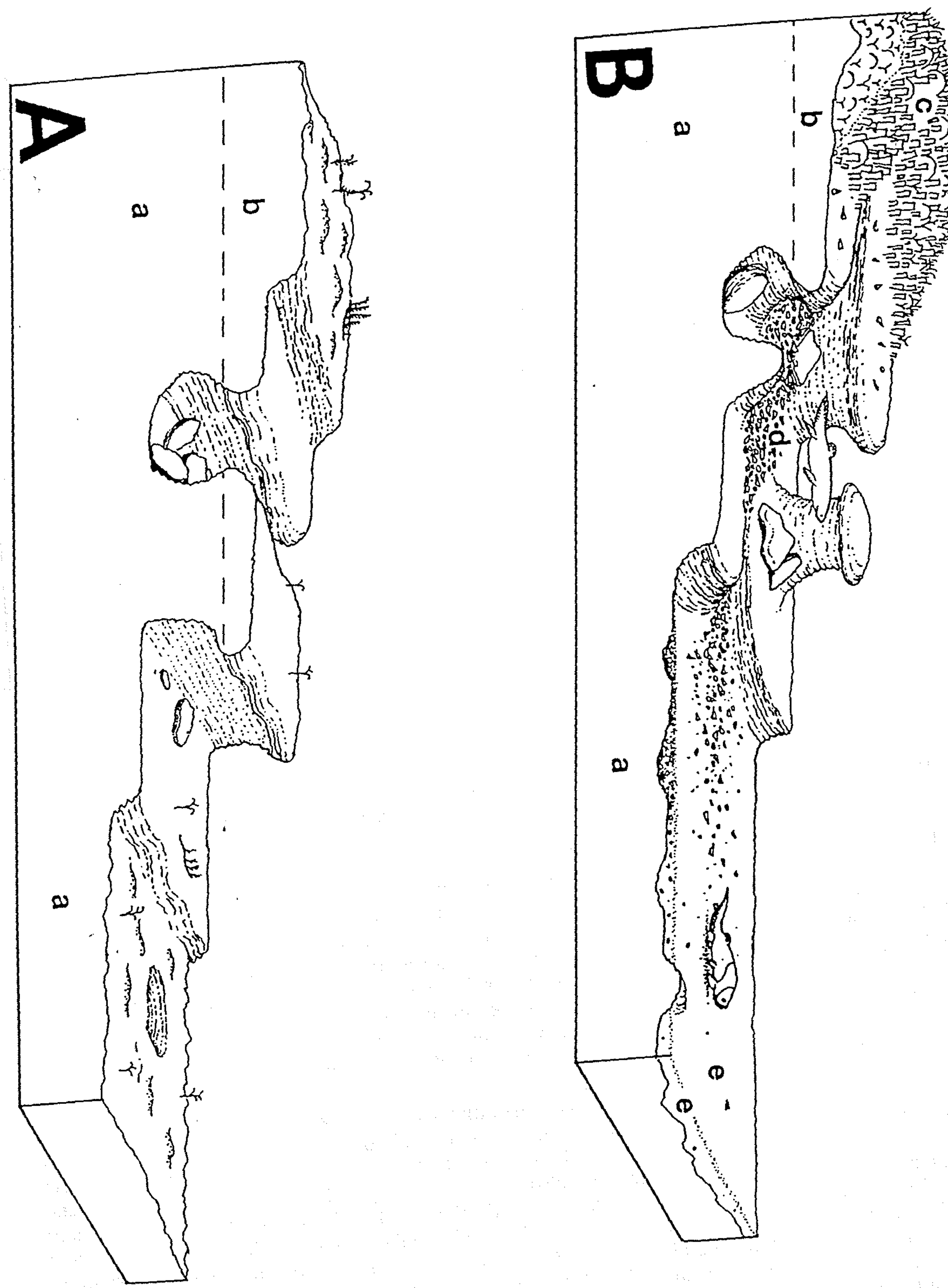


Figure 9. Diagrammatic view of irregular erosional contact (Wallbridge Unconformity) of Silurian Bertie-Cobleskill dolostone and Devonian Bois Blanc and Onondaga limestones, at Neid Road Quarry, LeRoy, Livingston County, New York. Note irregular knob ("sea stack") of dolostone and onlapping relationship of the overlying Devonian skeletal carbonate sediments; also note Devonian skeletal debris filling in pockets below projecting ledges of Silurian dolostone. Lettered features include: a) Williamsville Dolostone (Upper Silurian, Pridoli, Bertie Group): rhythmically laminated, light gray dolostone("waterlime"); b) Cobleskill/Akron Formation (Upper Silurian); massive, mottled dolostone with rare corals; c) Bois Blanc Limestone (Lower Devonian, Emsian) note coarse, coral-rich packstone and grainstone, with some dolostone clasts near bedrock knob; note that this unit terminates against Silurian bedrock and grades laterally into d) finer grained packstone-wackestone typical of Bois Blanc in surrounding exposure; e, f) Edgecliff Member (Lower to lowest Middle Devonian; Emsian-Eifelian; Onondaga Limestone); e) lower submember; medium grained, well sorted pinkish gray crinoidal grainstone; note that this unit also terminates against bedrock knob; f) upper submember, "Clarence" facies, light gray, bioturbated lime mudstone with abundant dark, bluish gray chert nodules; note that this unit drapes the bedrock knob; g) *Trypanites* borings in ceiling of overhanging ledge.

Figure 10. (See next pages)Series of schematic diagrams illustrating sequential development of the composite Wallbridge-sub-Onondaga unconformity, as exposed at the Neid Road quarry near LeRoy, New York. A) Early Pragian: development of the sub-Oriskany (Wallbridge) karstic unconformity; subaerial conditions, note development of small sink holes and solution hollows, also small tracheophyte plants on the surface (evidenced by rhizome etchings on the unconformity in Ontario; see Kobluk et al., 1977). B) middle-late Emsian: deposition of Bois Blanc sediments on old erosion surface flooded by shallow seas; note hypothetical growth of corals on elevated bedrock knob and coral rubble in adjacent hollows. C) latest Emsian: eroded surface of Silurian and veneer of Bois Blanc skeletal rich sediment during relative lowstand associated with the sub-Onondaga unconformity; again, note small vascular plants growing on subaerially exposed carbonate surface. D) latest Emsian-earliest Eifelian: composite erosion surface reflooded and accumulating crinoidal sand and gravel during initial Onondaga transgression. Letters: a) Williamsville Dolostone, Bertie Group; b) Cobleskill/Akron Dolostone; c, d) Bois Blanc Limestone coarse facies and fine facies; e) basal Edgecliff sediments.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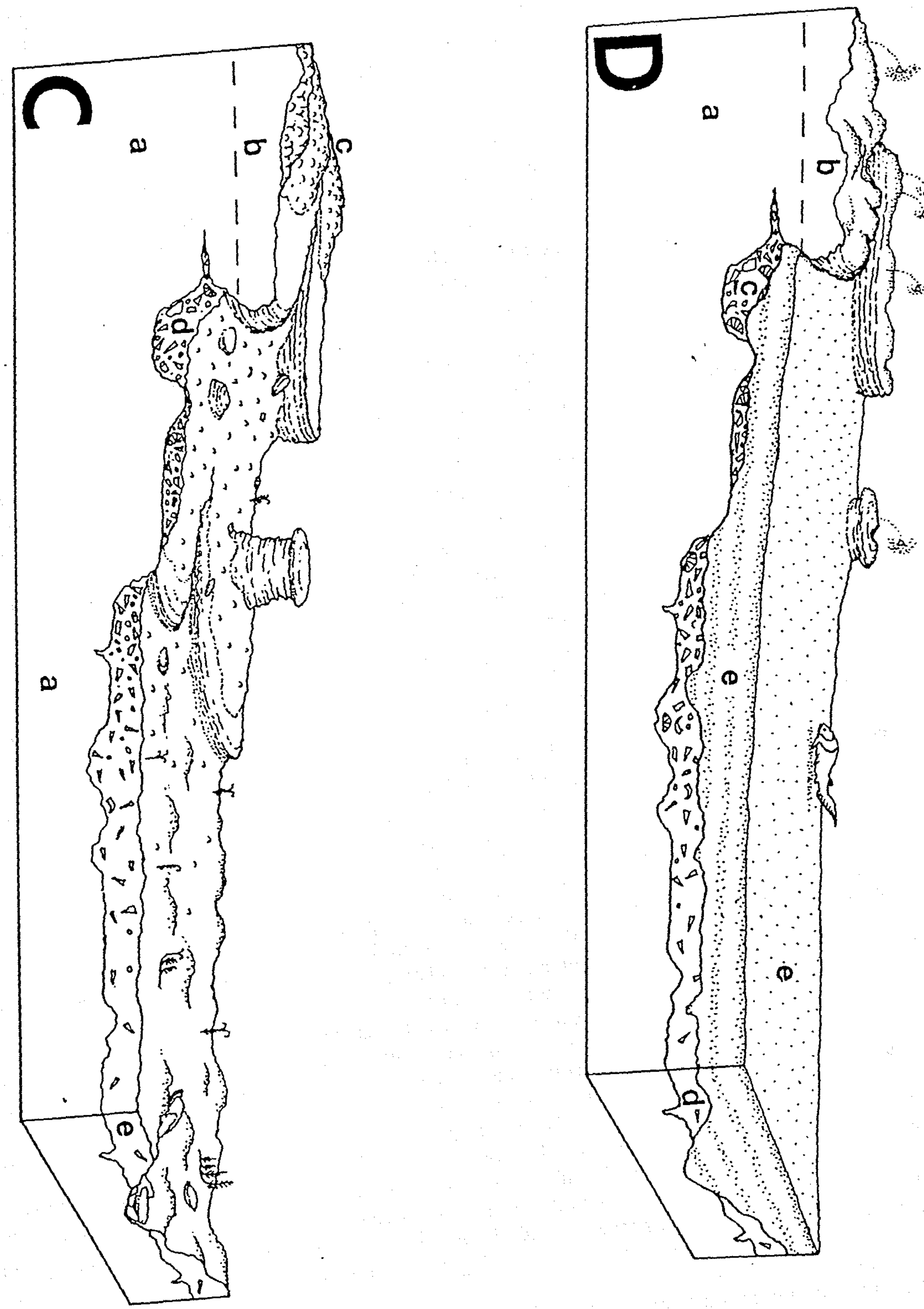
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We infer that it developed in areas west of the northwestern shoreline of the eastwardly-restricted foreland basin during relative sea level lowstand in latest Silurian to earliest Devonian time, probably coeval with deposition of peritidal Rondout (Chrysler) and Thacher carbonates in south eastern to central New York. We suggest, but can not prove that the shallow water Clanbrassil and Honeoye Falls carbonates are slightly younger deposits that accumulated during an Early Devonian highstand, perhaps coeval with the deposition of shallow subtidal upper Manlius limestones in central New York and deeper water Kalkberg-New Scotland strata to the east (Hudson Valley; see Figure 2).

Pre-Oriskany Events

The most significant unconformity is the sub-Oriskany (Wallbridge) disconformity. This unconformity appears to emanate from the contact between the Glenerie-Oriskany and the underlying Port Jervis Formation in southeastern New York (Figure 2), where the Glenerie (or Oriskany in nearby eastern Pennsylvania) is approximately 50 m-thick. Preliminary investigation across the basin indicates that the Wallbridge Unconformity in central New York may already represent an amalgamation of two sequence-bounding discontinuities; a lower one, locally underlying the thick Oriskany-Ridgeley sandstones in the deeper central portion of the basin (e.g., central Pennsylvania and adjacent areas), and an upper one underlying the New York Oriskany. More work is pending on this.

To the northwest across New York the sub-Oriskany Wallbridge Unconformity bevels successively lower Helderberg units and eventually cuts downward into the underlying Bertie Group west of the Cayuga Lake meridian. Only very minor remnants of Lower Devonian Helderberg Group rocks remain in western New York, but studies by Ciurca (1973, 1982; see Figure 5) indicate that a more continuous preservation of the Lower Devonian Clanbrassil Formation occurs west of Hagersville, Ontario. The unconformity shows maximal relief and cuts most deeply into the Silurian (Victor Member of Fiddlers Green Formation) at localities in Genesee and Livingston Counties in western New York. The overall pattern of greatest cutout in western New York and decreasing hiatus both to the east and west suggests that the lowstand erosion may have been focused on a relatively high area, possibly a broad arch or dome lying partly in western New York. It should be noted that erosion is even more extensive to the southwest of New York. For example, in south-central Ohio the base of the Columbus Limestone, tentatively correlated with the upper Emsian Bois Blanc or lower Onondaga limestones, rests on medial Silurian dolostones.

The detailed cross section of the unconformity surface in Ontario-western New York delineated by Ciurca (1973, 1982; Figure 5 herein) shows a series of four "deep" incisions along the Wallbridge unconformity , separated by highs on the Silurian-Lowest Devonian paleobedrock surface. The cross section has a high degree of vertical exaggeration. In fact, the lows are relatively broad (5 to 15 miles) and shallow (15-20 m deep). We suggest that these represent a series of incised paleovalleys that may have been cut by a combination of solution and erosion during a mid Early Devonian (late Lochkovian to Pragian) lowstand. It is tempting to speculate that these were temporarily occupied by broad, low gradient rivers that emptied into the Appalachian foreland basin to the southeast. Unfortunately, data at present are insufficient to constrain the orientation of the lows. It is also noteworthy that the unconformity becomes more nearly planar (lacking in distinct highs and lows) both east and west of the study area where it is developed on Lower Devonian Helderberg carbonates. This too may indicate that those areas were not subject to so prolonged a period of subaerial exposure.

A further interesting fact is that these paleovalleys do not contain thick fills of Oriskany Sandstone. However, in each of these areas at least minor veneers, neptunian dikes, and crack fillings of clean, white quartz sand, possibly attributable to the Oriskany, indicate that the irregular unconformity was cut prior to deposition of the latter unit (i.e. by no later than late Pragian time). If the lows or putative paleovalleys were ever filled by Oriskany Sandstone it has subsequently been removed almost completely. Strangely, thicker areas of clean quartz arenite, with typical Oriskany faunas occur both to the west (in southern Ontario) and to the east (in central New York State) of the area of maximal erosional incisement as depicted in Figures 3 and 5.

This observation and the pattern of onlap of the Helderberg Group into central New York suggests that the region of incisement in western New York may have been locally elevated during early to mid Early Devonian (Lochkovian to Pragian) time. The fact that the sub-Oriskany unconformity in Ontario (Kobluk et al., 1977) and in western New York (Oliver, 1966; personal observation) shows solution enlarged joints with sandstone "dikes" indicates that the Silurian rocks had undergone a period of fracturing in the pre-Oriskany interval. Possibly, this early jointing episode was related to stresses associated with gentle arching of the crust. Such joints, in turn, may have focused later erosive incision.

Details of the unconformity in some areas, as at the Neid Road quarry (Stop 5), also suggest that it may have had a more intricate topography (Figures 9, 10). However, the degree to which that topography was modified by later erosive and transgressive events is presently unknown (but see below).

Oriskany-Schoharie Interval

In eastern New York up to 100 m of dark gray silty to siliceous shale and fine-grained sandstones, the Esopus Formation, intervene between the Oriskany Sandstone and the overlying Schoharie Formation. If this unit was ever deposited in the west it has been removed by sub-Schoharie/Bois Blanc erosion. The fine-grained, dark gray, deep-water nature of middle Esopus strata in westernmost outcrops (e.g., Cherry Valley), indicate that the Esopus should have originally extended far to the west, but was later erosionally truncated below the sub-Schoharie sequence-bounding unconformity. That erosional episode has also stripped away Oriskany Sandstone across west-central to western New York except in some local lenses. These may represent pockets of sand that were preserved in low spots on the unconformity. We do note, however, that the Oriskany is not always present in the lowest depressions in local quarry sections.

The fact that Oriskany Sandstone (and overlying Esopus mudstone, if ever present) has been removed, except in local lenses and pods throughout western and west central New York indicates a period of post-Oriskany erosion. Moreover, Kobluk et al. (1977) found evidence for a second episode of jointing beneath the Bois Blanc, indicating possible renewed tectonic stresses during this time.

At Cherry Valley, in east central New York, the Esopus Formation is sharply and erosionally overlain by argillaceous siltstones to fine-grained sandstones of the Carlisle Center Member (Schoharie Fm.; Figure 2). This sequence-bounding unconformity, which can be traced beyond Catskill in the Hudson Valley, contains some reworked phosphatic clasts and firmground burrows indicative of erosional truncation down into overcompacted muds (Miller and Rehmer, 1982; Ver Straeten, 1996). We surmise that this is the leading edge of the unconformity that underlies the Bois Blanc/Springvale Sandstone in western New York.

As noted, the "lows" or paleovalleys on the Wallbridge Unconformity generally lack thick Oriskany deposits and only fissure fillings point to the former existence of the sand in these areas. We suggest that the incised areas may have been re-occupied by streams during the pre-Schoharie lowstand and their sands flushed out. Alternatively, all accommodation space in the older paleovalleys may have been filled during the Oriskany-Esopus sequence, and new paleovalleys cut during the sub-Schoharie/Bois Blanc lowstand. If so, then the fissure fillings are actually from later, Emsian-age sands.

It is certainly noteworthy that the lower part of the Schoharie Formation throughout the Hudson Valley, and westward to Cherry Valley, shows layers of large quartz grains near its base. Perhaps these are, in part, cannibalized Oriskany sands. It does appear, however, that minor amounts of sand remained on the unconformity surface and were reworked along with terrigenous muds (reworked Esopus?) during the initial Schoharie-Bois Blanc transgression to form the so-called Springvale sands.

In contrast to the Oriskany, the Bois Blanc/Schoharie does appear to be preferentially preserved in lows or paleovalleys. A notable example is the outlying lens of Bois Blanc Formation at Phelps, NY (Stop 5). Here as much as 4.5 m of phosphatic, cherty sandstones and fine-grained, somewhat cherty, sparsely fossiliferous limestone overlies the Scajaquada Shales (Bertie Group). As elsewhere, the basal beds are sandy and contain reworked phosphatic nodules and clasts. Conversely, nearby at the Oaks Corners Quarry (Stop 3) no hint of the Bois Blanc is present; and here a relative high ("interfluve") brings Cobleskill (Akron) Formation into direct contact with lower Onondaga Limestone.

However, it is also notable that Bois Blanc in intervening lenses, most notably in the sections near LeRoy, 45 miles west of Phelps, and again near Buffalo, have a distinctly coarser texture (wackestones to grainstones at Neid Road Quarry). These areas also display more diverse, brachiopod, bryozoan, and even coral-rich biotas. Hence, the Bois Blanc facies at the farthest east outcrop presently recognized are distinctly deeper water in aspect and more comparable to Canadian Bois Blanc in southern Ontario than these intermediate sections. It is notable that the Phelps exposures lie in one of the deeper low areas or "paleovalleys" on the Wallbridge Unconformity (Figure 5). We suggest that Bois Blanc thicknesses and facies were controlled by the local irregular topography of the seafloor. Near Phelps (Stop 4) a relatively thick succession of deeper water aspect accumulated as part of a paleovalley fill, whereas near LeRoy (Stop 5) the seafloor was shallower over a relative high on the unconformity and thinner, shallower water facies accumulated.

Termination of the Bois Blanc onto local highs is directly observable in a single outcrop at the Neid Road quarry (Stop 5; Figures 9, 10). Here the Bois Blanc forms a semi-continuous band 60 centimeters to about 1.4 meter thick around most of the quarry. The bed thins and drapes the inclined erosion surface near a knob and thin pinches out for a distance of five meters. The first beds of the overlying basal Edgecliff Member likewise wedge out against the bedrock high (Figures 9, 10). This evidence demonstrates that the Bertie bedrock high persisted through deposition of the Bois Blanc and beyond (see below) through the time of the pre-Onondaga hiatus and remained a high during the initial deposition of Onondaga transgressive grainstones. We suggest that this pinnacle of rock represents a sea stack or small bedrock island on the Bois Blanc-Schoharie seafloor.

Notches near the base of this and other bedrock knobs in the Neid Road quarry are filled with coarse skeletal debris that grades laterally into the lower (Springvale) and upper (unnamed) members of the Bois Blanc Formation (Figures 9,10). The undercut areas were thus in existence during Bois Blanc-Schoharie deposition. We suggest that they mark the position of a wave cut (or bioerosional) notch, comparable to those seen on many present day carbonate rock coast lines. It would mark a temporary stand of sea level during the Bois Blanc-Schoharie transgression. The notch and the knob itself were probably "drowned" during subsequent sea level rise (Figure 10b). Relict crevices (some probably enlarged joints) and notches then became infilled with debris of normal marine biotas that infiltrated from higher ground (Figure 10). As noted, the coarseness of debris and the anomalously high abundance and diversity of corals relative to normal Bois Blanc near the bedrock knobs at the Neid Road quarry, may indicate that the bedrock high provided an elevated substrate for colonization of shallow water coral-dominated biotas that were normally excluded from the surrounding slightly deeper (~3 m deeper) and more muddy Bois Blanc sea floor (Figure 10b). Unfortunately, thus far, we found no direct evidence of corals cemented in place nor any holdfasts or other encrusters on more elevated portions of the knob. This is not surprising in view of the fact that the knob was probably re-exposed and subjected to an abrasive environment during the later Onondaga transgression.

The phosphatic-glauconitic, bioturbated, locally muddy sandstones that characterize the "Springvale" in central New York, represent a highly condensed Bois Blanc/Schoharie-equivalent that accumulated in a moderate energy sandy to muddy shelf setting. Fossil brachiopods and bryozoans are found in this unit. It is not entirely clear whether this biofacies represents deeper or shallower conditions than those of the western Bois Blanc. The extraordinarily high concentration of phosphatic nodules and coated clasts may suggest that nutrient-rich waters upwelled onto the margin of the eastern shelf during this time, or may alternatively be related to very low sedimentation rates across a starved, sandy shelf-type environment across central New York.

Schoharie-Bois Blanc to Edgecliff Events

In the Hudson Valley, the basal Edgecliff Member of the Onondaga Limestone overlies upper strata of the Schoharie Formation (Figure 2). The abrupt contact and upward change to coarser-grained facies are the only hints of a minor sequence-bounding disconformity. Likewise, in southern Ontario, Canada, the contact between the Bois Blanc and Onondaga is abrupt but seemingly nearly conformable. This contact in Ontario and at least one western New York outcrop (Neid Road quarry) is marked by a thin, recessive weathering, sticky greenish gray clay that may represent a K-bentonite. However, over most of western New York, the Edgecliff grainstones rest directly on Oriskany Sandstone or Bertie Group strata. The fact that rather typical cherty facies of the Bois Blanc are found as far east as Phelps (some 120 km east of the last continuous outcrop of Bois Blanc in southern Ontario, indicates that these deposits were at one time relatively widespread. Evidently, they have been removed over much of the area by a short-lived erosive episode, prior to deposition of initial Edgecliff sediments. The erosion was not too severe, so that remnants of Bois Blanc were preserved in hollows or paleovalleys. It is noteworthy that, with the exception of these depression fillings, the Bois Blanc is absent over western New York. The incorporation of reworked phosphatic concretions and other clasts derived from Schoharie-Bois Blanc into the base of Onondaga indicates that a short period of pre-Onondaga erosion took place in this area, even as deposition continued almost unbroken to the west and east.

A significant factor in the development of the sub-Onondaga unconformity across western to central New York has recently been discussed by Ver Straeten and Brett (2000). Detailed litho- and biofacies trends (Figure 7a), the correlation of small scale cycles/parasequences and marker beds through the lower to middle Onondaga (Figure 7b), and the distribution of the unconformity (Figure 4) point to anomalous lateral migration of adjacent shallower- and deeper-water facies belts through upper Bois Blanc-Schoharie and Onondaga time. A fall and rise of sea level through the interval should have resulted in predictable vertical changes of facies, in which all areas of central to western New York showed the same relative trends as is seen across the rest of the Appalachian Basin for that time. However, the pinchout and absence of lower Edgecliff cycles into the central Finger Lakes area (focused at Seneca Stone quarry, Stop 2; Figure 7b), differing water depth trends for individual localities across the area, and the eastward shift of distinct, adjacent bands of shallow and deep-water facies through time (Figure 7a) can be tied to the migration of a bulge-like feature and an adjacent, cratonward back-bulge basin across western to central New York during the Late Emsian to early Eifelian (Figure 7c).

This interpretation is supported by, and appears to provide an explanation for, the distribution of Onondaga pinnacle reefs within the deeper water facies in the subsurface of south-central New York and northwestern Pennsylvania (Figure 7c; see Ver Straeten and Brett, 2000 for further discussion). The migration of the bulge, combined with a eustatic sea level lowstand at the base of the Onondaga Limestone, resulted in the cutout or non-deposition of progressively younger Edgecliff strata into the area of Seneca Stone quarry (Figure 7b).

What this means relative to the development of the sub-Onondaga unconformity is that there was additional time during the latest Emsian to modify the pre-existing landscape over a broad topographic high across west-central to central New York. This, in part, must account for the very patchy distribution of at least the late Emsian Bois Blanc Formation and its equivalents, if not progressively older strata of the Esopus and Oriskany Formations and the underlying Helderberg and Bertie Groups.

This strongly suggests a period of tectonically-induced arching during or following final phases of Bois Blanc-Schoharie deposition. This broad truncation surface, spanning over 150 km, may be due regional erosion of a gently uplifted arch. Such an arch might have resulted from tectonic thrust loading during a late part of the first tectophase of the Acadian Orogeny; this notion is supported by the appearance of a probable K-bentonite locally, along the unconformity. This bentonite is only one of many bentonites in the Onondaga and might seem to herald the onset on increased magmatism previous to the onset of Acadian Tectophase II. Alternatively, following flexural models of Quinlan and Beaumont (1984) and Beaumont et al. (1988) the arching might represent thrust load relaxation and accentuation of the basin and forebulge. But that should have occurred earlier than approximately 15 million years after the early, tectonically-active stage at the onset of Tectophase I. Indeed the pattern of deep truncation of lower Emsian Esopus clastics might lead to speculation that the sub-Schoharie unconformity is more associated with relaxation and uplift of a flexural forebulge. Nonetheless, the sub-Onondaga unconformity has the aspect of a tectonically generated sequence boundary in that it fades both west and east of the erosive area in western New York. However, erosion was also concentrated at the sub-Onondaga unconformity during a widespread, apparently eustatic lowstand interval immediately prior to Onondaga deposition.

It may be that the sub-Onondaga unconformity represents the one that finally levels out the basin topography that was initiated with the onset of tectonism in the early Emsian. Initial thrust load-induced subsidence of the proximal foredeep at that time resulted in deposition of relatively deep water muds and sands of the Esopus Formation. Subsequent uplift of a flexural bulge in central New York by Schoharie time, and possibly even during mid to upper Esopus time, and a top Esopus/basal Schoharie sea level lowstand, began the process of eroding and leveling the high, accompanied by infilling available accommodation space in the foredeep with predominantly orogen-derived sediments. The following Bois Blanc-Schoharie transgression resulted in widespread deposition over the high. Ensuing lowstand conditions resulted in another erosive beveling over the bulge, followed by the eventual complete blanketing of the region with the Onondaga carbonates.

The Edgecliff sandy grainstones seem to record a basal transgressive lag of phosphatic clasts, and sand reworked from the Springvale or possibly Oriskany Sandstone, together with crinoidal and coralline sand and gravel. This material spread as a sheet-like unit and appears to have nearly leveled out any residual topography. Locally, as at Oaks Corners quarry (Stop 5), this sandy, crinoidal grainstone thickens by tens of centimeters into low erosional hollows on the Silurian unconformable surface. The first beds of the basal Edgecliff Member actually wedge out against the bedrock highs at Neid Road quarry, as do the underlying Bois Blanc beds (Figures 8, 9, 10c,d). This evidence demonstrates that the Bertie bedrock highs persisted through deposition of the Bois Blanc and beyond through the time of the pre-Onondaga hiatus. If any residual Bois Blanc sediments mantled the bedrock highs, it was removed during this time. The highest knobs remained exposed during deposition of the initial Onondaga transgressive grainstones and were finally overlapped by cherty Clarence facies of the second Edgecliff cycle (Figure 10c,d). At this point the legacy of the Wallbridge Unconformity was completed and the irregularities of the old contact finally ceased to have any influence upon sedimentation patterns.

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ROADLOG AND STOP DESCRIPTIONS

0.0	0.0	Start field trip at the junction of U.S. Rte. 20/NY Rte. 5 with NY Rte. 14 south. Proceed ahead on U.S. Rte. 20/NY Rte. 5
0.6	0.6	Junction with NY Rte. 14 north. Continue ahead on U.S. Rte. 20/NY Rte. 5.
2.6	2.0	Junction with NY Rte. 96A. Continue east on U.S. Rte. 20/NY Rte. 5.
7.3	4.7	Cross NY Rte. 96 in city of Waterloo.
8.7	1.4	Proceed straight through intersection with NY Rte. 414, which joins with U.S. Rte. 20/NY Rte. 5 into the village of Seneca Falls. We will later pass through this intersection going from Stop 3 to Stop 4. Enter the village of Seneca Falls approximately 1.5 miles ahead, and pass by Women's Rights National Park.
14.0	5.3	Cross NY Rte. 89. We will later drive south on this road to get to Stop 3.
15.8	1.8	Cross over Seneca River. Enter Cayuga County.
16.0	0.2	Intersection with NY Rte. 90.
23.6	7.6	Low cuts of Manlius on left (south) side of highway, Manlius and Onondaga Fms. on right (north) side of highway. Reworked concretions of phosphate-cemented sands of the "Springvale Sandstone" of Schoharie age occur in the base of the Edgecliff Member.
23.7	0.1	Entrance to Finger Lakes Mall on right.
24.3	0.6	Junction with Cayuga Co. Rte. 326.
25.2	0.9	Cross Washington St.
25.6	0.4	NY Rte. 38 turns north.
25.8	0.2	Turn left (north) onto NY Rte. 34
26.9	1.1	Cross railroad tracks
27.2	0.3	South entrance to abandoned "Schooley" Quarry.
27.3	0.1	Leave city of Auburn.
27.4	0.1	Turn right (east) into entrance of NFR Northeast Inc.

27.5	0.1	Turn right and proceed a short distance to the abandoned "Schooley" Quarry in Manlius to Onondaga Fms. Park car and walk in.

STOP 1. ABANDONED QUARRY ("SCHOOLEY QUARRY"), NORTH OF AUBURN.

This abandoned quarry pit and a larger one to the east expose Lower to Middle Devonian strata of the Manlius, "Springvale Sandstone," and Onondaga (Edgecliff, Nedrow, and Moorehouse members) formations. The regional complexity of multiple unconformities is reflected at the small scale here by the local thickening and thinning, including pinchout, of the "Springvale" Sandstone along the quarry walls.

The lower walls of the quarry feature buff to gray, fine-grained limestones to dolostones, with local stromatoporoid buildups, assigned to the Manlius Formation. Two members appear present in the quarry; upper buff-weathering, mud-cracked dolomites to limestones of the Elmwood Member, and lower, gray weathering limestones with local stromatoporoid buildups of the Olney Member. Ciurca (1978), however, shows Olney at the contact in the area of Auburn. The upper contact of the Manlius Formation appears sharp.

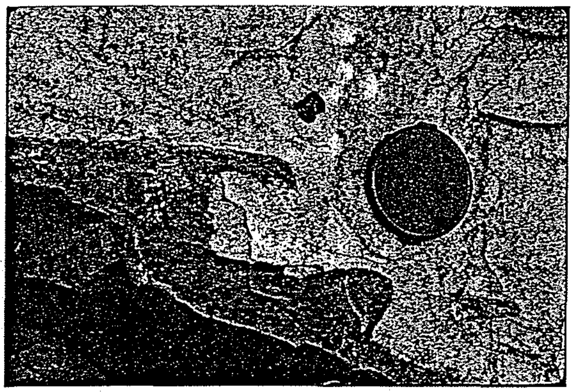
A photograph (Figure 11) shows the succession through the units in the northwest corner of the "Schooley" quarry, along a ramp road. The top surface of the Manlius appears irregular and knobby. The overlying approximately 0.7 m consists of dark, argillaceous, phosphate-rich and locally glauconitic sandstone, with phosphatic concretions. A gray- to buff- to blue-colored resistant ledge of sandstone caps the "Springvale." Medium- to large-sized sandy phosphatic concretions occur at two horizons within; similar and smaller concretions in the upper part of the bed appear fragmented and reworked, possibly indicative of a time of erosion and unconformity between "Springvale and basal Onondaga strata.

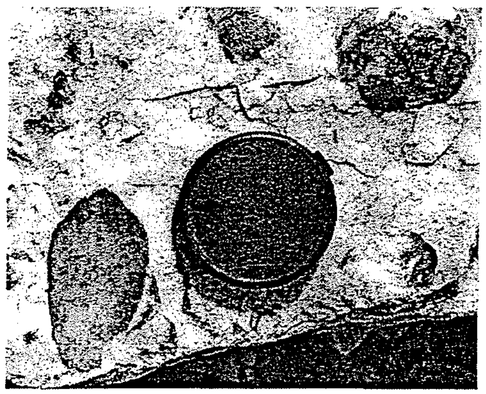
The overlying 3.7 m-thick Edgecliff Member (Onondaga Fm.) is characterized by a lower non-cherty interval (0.3 m-thick) with common corals; the corals are mostly restricted to the lower 0.8 m of the member. Three cherty intervals (Clarence facies) occur up through the Edgecliff in the "Schooley" quarry.

Examination around the walls of the quarry indicates local pinching and swelling of the "Springvale" sandstones. In at least one area on the south wall, the Springvale is absent for a distance; sandy phosphatic concretions from the unit are seen reworked into the base of the Edgecliff Member.

27.6	0.1	Proceed back to NY Rte. 34 and turn left (south), proceeding back through Auburn to U.S. Rte. 20/NY Rte. 5.
27.7	0.1	Enter city of Auburn.
28.1	0.4	Cross railroad tracks.
29.1	1.0	Turn right (west) onto U.S. Rte. 20.
29.7	0.6	Cross Washington St.
30.6	0.9	Junction with Cayuga Co. Rte. 326.
31.2	0.6	Entrance to Finger Lakes Mall on right.
31.3	0.1	Low cuts of Manlius on left (south) side of highway, Manlius and Onondaga Fms. on right (north) side of highway. Reworked concretions of phosphate-cemented sands of the "Springvale Sandstone" of Schoharie age occur in the base of the Edgecliff Member.
38.9	7.6	Intersection with NY Rte. 90. A short distance ahead cross into Seneca County and pass through Montezuma National Wildlife Refuge, at head of Cayuga Lake, in valley ahead.
40.9	2.0	Turn left (south) onto NY Rte. 89.
41.7	0.8	Cross Seneca River.
44.8	3.1	Entrance to Cayuga Lake State Park.
45.0	0.2	Fayette town line.
46.6	1.6	Enter village of Canoga.
46.8	0.2	Turn right (west) onto Canoga St.
47.0	0.2	Verge right onto Seneca Co. Rte. 121.
47.7	0.7	Sharp left bend on Seneca Co. Rte. 121.
47.9	0.2	Sharp right bend on Seneca Co. Rte. 121.
48.8	0.9	Entrance and office of Seneca Stone Corporation quarry. Check in at the office, and then proceed straight (north) into quarry.
49.2	0.4	<u>Fork left</u> onto ramp road, beyond sheds on left. Proceed to lower level.

Figure 11. Top Manlius, "Springvale", and Onondaga strata at abandoned ("Schooley") quarry, Auburn. Note resistant top ledge of Manlius (Elmwood Mbr.) low in photo, overlain by phosphate-rich, relatively friable sands, which are in turn succeeded by resistant top ledge of "Springvale" sandstones. Medium to large phosphatic sandstone concretions in top Springvale bed. Basal Edgecliff Member at top of photo.

a. 

b. 

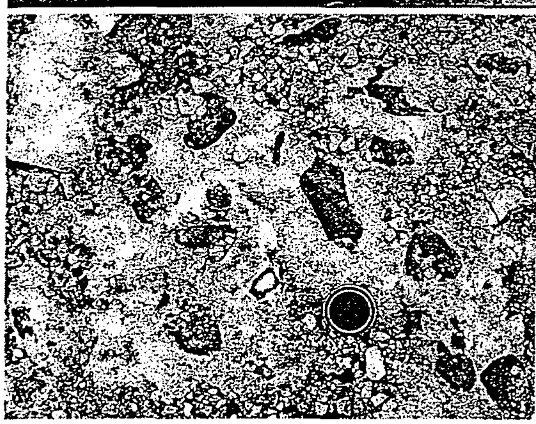
c. 

Figure 12a-c. Manlius, Oriskany and basal Onondaga formations at Seneca Stone quarry. Camera lens caps for scale. a) Small-scale bedrock ledges of Manlius Formation (Olney Mbr.) overlain and filled in around by Oriskany Sandstone, from base of quarry. b) Characteristic large brachiopods of Oriskany Formation, including *Renssalaeria* (lower left). c) Basal thin reworked sand and cobble bed at base of Edgecliff Member on floor of quarry. Cobbles composed of phosphatic-cemented sandstones locally eroded from previously deposited "Springvale" sandstone and colonized by corals.

Figure 13. Irregular topography on sub-Onondaga Unconformity, overlying Upper Silurian Cobleskill-Akron Formation at Oaks Corners Quarry (south wall).

STOP 2. SENECA STONE QUARRY.

The classic Seneca Stone quarry exposes a succession of Lower to Middle Devonian strata from the upper part of the Manlius Limestone to the top of the Cherry Valley Member of the Oatka Creek Formation (Marcellus subgroup of Brett and Ver Straeten, 1994). Two prominent, north-directed thrust faults occur in the upper part of the Onondaga Formation within the quarry. One of the faults has been long known, and is visible in the east and west walls toward the south end of the quarry. An additional, recently exposed fault occurs in the northwest wall. The section at Seneca Stone is otherwise relatively undisturbed.

Fine-grained, micritic limestones of the Lower Devonian Manlius Formation (Olney Mbr.) of the Lochkovian Helderberg Group are found in a small sump pit in the bottom of the quarry, overlain unconformably by quartz arenites of the Lower Devonian Oriskany Formation (Pragian Tristates Group). The intervening break between the Olney, which is mid-Lochkovian, and the Oriskany, interpreted to be late Pragian represents on the order of four to six million years (based on Rickard, 1975 and new geochronologic dating by Tucker et al., 1998). This break represents the true Wallbridge Unconformity at the base of the Sloss's (1963) Kaskaskia Supersequence. Clasts of the older Manlius Limestone occur in the base of the Oriskany, sometimes overgrown by tabulate coral colonies. Small (cm-scale) undercut ledges of the Manlius may also be found at the unconformity, with the intervening space filled by quartz arenite (Figure 12a).

The Oriskany Formation is characterized by white quartz arenites that occur locally as pods or lenses across central New York. The spottiness of these occurrences is shown well within the base of the Seneca Stone quarry. Approximately 0.6 m of quartz sandstone is found near the central sump pit of the quarry; however, the whole unit pinches out a short distance to the south (visible in the quarry walls). The classic "big brachiopod community" of the Oriskany Formation is well shown in the sandstones at Seneca Stone quarry (Figure12b), with numerous large, robust brachiopods (including *Costispirifer arenosus*, *Rensselaeria*, and *Hipparionyx*), platyceratid gastropods, and favositid and rare rugose corals (Oliver and Hecht, 1994).

The Emsian-age, phosphate- and locally glauconite-rich sandstone strata noted at Auburn during the previous stop are absent at Seneca Stone quarry. They do appear, however, to be represented, as phosphatic-cemented sandstone clasts in a lag of reworked conglomeratic sands in the base of the Onondaga Formation (Figure 12c; sourced from the Springvale Mbr., as seen in situ at Stop 1). Based on the recent Devonian time scale revision of Tucker et al. (1998), the gap between basal Onondaga strata (uppermost Emsian) and the Oriskany Formation (upper Pragian) represents approximately 15 million years.

49.6	0.4	Return to the office of Seneca Stone Corporation and turn right (west) onto Seneca Co. Rte 121.49.90.3 Sharp right bend on Seneca Co. Rte. 121.
50.1	0.2	Sharp left bend on Seneca Co. Rte. 121.
50.7	0.6	Cross NY Rte. 414 and continue west.
51.4	0.7	Turn right (north) onto Disinger Rd.
53.3	1.9	Intersection with County House Rd. Jog slightly left (west) and proceed north on Kingdom Rd.
55.0	1.7	Turn left (west) onto Seneca Co. Rtes. 116/119.
55.6	0.6	Turn right (north) and cross over Seneca River.
55.7	0.1	Junction with NY Rtes. 5 and 414 and U.S. Rte. 20. Proceed straight through stoplight onto NY Rte. 414.
56.1	0.4	Turn left (west) onto Ballsley Rd.
56.4	0.3	Cross railroad tracks.
57.0	0.6	Intersection with Swift Rd. Proceed ahead on Ballsley Rd.
57.5	0.5	Intersection with Virginia Rd./NY Rte. 96. Proceed straight ahead onto Rte. 96.
61.7	4.2	Vegetable stand on left.
62.4	0.7	Fork left (almost straight ahead) onto Cross Road at right bend of NY Rte. 96.
62.8	0.4	Cross Town Line Rd. and enter Ontario Co.
63.4	0.6	Cross railroad tracks.
63.5	0.1	Cross NY Rte. 14.
64.5	1.0	Elderlee Sand and Gravel operation on right and 0.6 miles ahead.
65.3	0.8	Turn right onto Pre-Emption Rd./Ontario Co. Rte. 6.
65.4	0.1	Entrance to Oak Corners Quarry (owned and operated by Hanson Aggregates). Check in at office.
65.7	0.3	Proceed to the old south wall of the quarry

STOP 3: OAKS CORNERS QUARRY

The walls of the Oaks Corners quarry displays strata of the upper Silurian Akron Formation and the Lower to Middle Devonian Edgecliff, Nedrow, and part of the Moorehouse Members of the Onondaga Formation. The unconformity between Silurian and Devonian strata is well exposed in the quarry walls (Figure13), and commonly exhibits an irregular topography of small mounds and adjacent lows that are filled with basal Onondaga limestones or locally-occurring patches of quartz sandstone.

On the south wall at Oaks Corners, basal Onondaga strata of the Edgecliff Member generally rest directly on beds of the Upper Silurian Akron Formation, a massive, dark brownish buff-weathering saccharoidal dolostone. Thin, locally-occurring quartz arenite lenses occur in the quarry, as well as quartz-sandstone filled karstic cavities that extend down as far as the quarry floor (D. Woodrow, pers. commun.). The age of the sandstones (Oriskany, Bois Blanc, or reworked at the base of the Onondaga) is presently unresolved. In the absence of the sandstones, weathered pyritic crusts leave distinct rusty stains along the Akron-Onondaga contact. The unconformity is approximately six meters lower in the Silurian section four miles to the northwest (Rte. 88-Phelps cuts, Stop 4), where the unconformity surface is cut down to the level of the older Scajaquada Shale. At the Oaks Corners quarry, large channel-like depressions, up to several meters across and with a relief of up to one meter, occur along the unconformity.

Basal, chert-free beds of the Jamesville Quarry facies of the Edgecliff Member (Brett and Ver Straeten, 1994) occur within hollows on the combined Wallbridge, sub-Bois Blanc-Schoharie (?), and sub-Onondaga unconformities. These lowest Edgecliff strata comprise fine- to medium-grained crinoidal grainstone, typically pinkish-weathering, which range from 40 to 120 centimeters in thickness as a result of the irregular topography over the unconformity. Immediately overlying chert-rich strata (Clarence facies) consist of cherty, crinoidal pack- to wackestones. The remainder of the approximately 8.5 m-thick Edgecliff Member at the Oaks Corners quarry is dominated by the Clarence cherty facies, and consists predominantly of pale gray-weathering, micritic limestone with 20 to 30% dark gray chert.

66.0	0.3	Return to the quarry entrance and turn left (north) onto Pre-Emption Rd./Ontario Co. Rte. 6.
66.3	0.3	Town picnic park on left. **LUNCH STOP.**
66.4	0.1	After lunch, continue north on Pre-Emption Rd./Ontario Co. Rte. 6.
66.9	0.5	Turn left (west) onto NY Rte. 96.
68.9	2.0	Enter village of Phelps.
69.5	0.6	Cross over Flint Creek.
70.3	0.8	Turn right (north) onto NY Rte. 88.
70.7	0.4	Outcrops on both side of road of Edgecliff Mbr., Bois Blanc Fm., "Springvale Sandstone," Oriskany Fm., and Upper Silurian Scajaquada and Fiddlers Green Fms. Park along side of road.

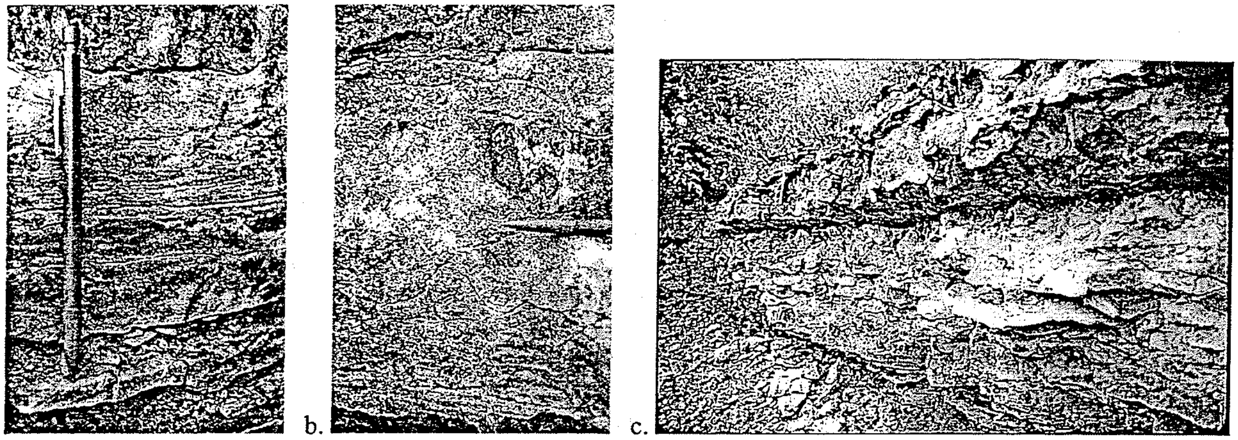
STOP 4: ROADCUTS ALONG NEW YORK RTE. 88, NORTH OF PHELPS.

Roadcuts along NY Route 88, immediately south of the New York State Thruway, display Upper Silurian strata of the Bertie Group (Pridolian, Scajaquada Formation) and Lower Devonian rocks interpreted here to represent the Emsian Bois Blanc Formation, a lateral equivalent of the Schoharie Formation of eastern New York.

Medium to slightly reddish-gray shales and argillaceous dolostones of the Scajaquada Formation characterize the lower part of the succession here and to the east along the Thruway. Small salt crystal casts may be found in the formation.

The Wallbridge Unconformity lies at the top of the Scajaquada Formation. The new Devonian time scale of Tucker et al. (1998) indicates that the unconformity between the Bois Blanc and the Scajaquada represents on the order of 16 million years.

The contact of the Scajaquada Formation with overlying Devonian strata is sharp. However, a record of unconformity-related processes is visible in the upper part of the Silurian strata. Thin fissure fillings of Oriskany quartz sand are seen to extend 30 to 40 centimeters downward below the upper surface of the Scajaquada Shale. The upper 10 -20 cm also show an indistinct mottled texture (Figure 14a), and the upper surface of the dolostone features common *Trypanites* hardground borings, infilled with quartz sands. The contact is overlain by a conglomeratic sandstone bed with pebbles to cobbles of dolostone, sandstone or phosphate (Figure 14b). Some of the clasts even show an interior core of dolostone that may be up to 2-3 cm thick, surrounded by 2-3 additional centimeters of lithified sandstone that may also feature a thin exterior rind of phosphate.



a. b. c.

d.

Figure 14a-d. Upper Silurian Scajaquada Formation and Lower Devonian (Emsian) Bois Blanc Formation, NY Rte. 88 cut at Phelps. a) Fine-grained dolostones of uppermost Scajaquada Formation capped by coarser sandstones of Bois Blanc (Springvale Mbr.). Note mottled texture of Scajaquada, with increasing disruption of primary layering up to the contact. b) Irregular contact of Scajaquada and Springvale, at pen on right and descending to left. Note reworked phosphatized pebble in sandstone bed. c) Strata of 1.45 m-thick Springvale Member above Scajaquada Formation. Contact on top of small ledge at bottom center of photo. d) Knobby, cherty, wacke- to packstones of upper carbonates of Bois Blanc Formation at Phelps roadcut.

Recent study of the Devonian strata at the Phelps cut indicates a distinct two-part lithologic subdivision: a lower, only slightly calcareous sand-rich unit (1.6 m-thick) and an upper carbonate interval above (4.2 m-thick). The character of the much of the outcrop, including lithology and fauna, appears strikingly different from the Edgecliff Member of the Onondaga Formation across the region. We interpret the outcrop to represent the easternmost known outlier of the Emsian-age Bois Blanc Formation in New York State. This is supported by Oliver's (1963) report of low exposures of cherty, micritic Bois Blanc limestones along the New York State Thruway near Phelps, 1.7 miles west of the Rte. 88 cut. Pending a revision of Emsian strata across the region, we assign the lower sand-rich unit to the "Springvale Member" of the Bois Blanc Formation, and the lower 2.9 m of the upper carbonates to an unnamed, upper member of the Bois Blanc.

The lower part of the Bois Blanc Formation ("Springvale Member") here is relatively sand-rich. Three subdivisions can be recognized, consisting of a lower coarse sandstone unit with a basal conglomerate-rich bed, overlain by finer-grained, knobby-bedded/nodular strata, with thin shaly drapes between layers (Figure 14c). Local lenses of "salt and pepper" quartz and phosphate sandstones occur at the contact of the lower and middle units. The upper unit is coarser-grained again, although still knobby-bedded. Irregular nodules of apparent phosphatic and/or cherty composition occur in both the middle and upper subunits of the sand-rich interval. Phosphate appears to be especially common in the middle, finer-grained unit, although it also commonly occurs as reworked concretions in the basal lag bed.

The upper sand-rich subunit features common fossils, including medium- to large-sized brachiopods, uncommon small rugose corals (one larger rugosan seen), cephalopods, and a conularid. Little to no crinoidal material is visible. Of interest is the appearance of large brachiopods, including a spiriferid, in the sand-rich facies of the Springvale. Similar large brachiopod assemblages are seen in the apparent Bois Blanc-Schoharie-age sandstone facies across central New York (e.g., Jamesville and vicinity).

Limestones comprise the succeeding 4.2 m of the section at Phelps. Much of the interval is characterized by relatively fine-grained, knobby-bedded, cherty limestones (Figure14d), with coarser-grained beds noted near the base and especially about a meter below the top. The lower to middle beds generally appear poorly- to non-fossiliferous, again excepting the basal bed and another approximately 1.2 m above the base of the carbonate section. Of note, the topmost bed on the east side of the road at Phelps is a relatively coarse limestone bed with scattered rugose corals. The presence of the corals, and the relative coarseness of the bed is similar to the lower part of the Edgecliff Member of the overlying Onondaga Formation across New York, and across the Appalachian Basin. On the west side of the road, it is overlain by two additional limestone beds. The upper of these features small, light gray chert nodules, analogous to the lowest occurrence of chert in the Edgecliff Member. We interpret the coral bed to represent the base of the Edgecliff Member. The horizon of the Bois Blanc-Edgecliff contact is not exposed well in the cuts; following the regional trends, we could project it to be unconformable.

Four miles to the southeast, at the previous stop (Oaks Corners quarry), basal strata of the Edgecliff Member directly overlie the Cobleskill-Akron Formation of the Upper Silurian. This is in sharp contrast to the cuts here at Route 88. Regional study shows an additional six meters of erosional truncation of Silurian strata here relative to Oaks Corners. This local topographic low appears to have provided accommodation space for deposition of the Bois Blanc, in addition to providing a shield against erosional truncation of Bois Blanc preserved in the low. The unconformity is approximately four to five meters higher in the Silurian section than at the Rte. 88 exposures (Stop 3), where the unconformity surface is cut down to the level of the older Scajaquada Shale. The geographic extent of the area of the low is not known, but Oliver's (1963) report of additional local exposure of the Bois Blanc indicates a feature of some extent. We project that the relatively deeper water, cherty non-fossiliferous carbonates and the finer-grained sand-rich unit of the Bois Blanc, along with the additional strata were deposited in a locally incised valley that developed during one or more of the sea level lowstands associated with the Wallbridge and sub-Bois Blanc unconformities.

70.7	0.0	Proceed ahead (north) on NY Rte. 88.
70.8	0.1	Overpass of New York State Thruway.
71.1	0.3	Turn around at broad driveway on right, just before McBurney Rd. Return south on NY Rte. 88.
71.8	0.7	Turn right and continue west on NY Rte. 96.
72.4	0.6	Outcrop of Nedrow Mbr. of Onondaga Fm. in bed and bank of Flint Creek, to left (south) of NY Rte. 96 (opposite ice cream shop).
72.9	0.5	Cross NY Rte. 448.
79.9	7.0	Turn right (north) onto NY Rte. 21.
80.0	0.1	Turn left and proceed to toll booth of NY State Thruway/I-90.
80.2	0.2	Fork to left and take NY State Thruway west towards Buffalo.
81.0	0.8	Merge onto NY State Thruway.
90.2	9.2	Seneca Service Area on NY State Thruway.
91.6	1.4	Exit ramp for I-490 to Rochester. Proceed ahead (west) on Thruway. Cross into Monroe Co. approximately 2.5 miles ahead.
102.9	11.3	Exit ramp for I-390 to Rochester. Proceed ahead (west) on Thruway.
107.0	4.1	Cross over Genesee River.
116.1	9.1	Ontario Service Area on NY State Thruway. Cross into Genesee County
119.0	2.9	Exit from of NY State Thruway at Exit 47/LeRoy.
119.4	0.4	Exit 47 toll booth. Pay toll and proceed ahead.
119.7	0.3	Exit to right to get to NY Rte. 19 and LeRoy.
120.1	0.4	Intersection with NY Rte. 19. Proceed straight ahead onto Rte. 19.
120.6	0.5	Cross over NY State Thruway.
121.0	0.4	Turn left (east) onto Parmalee Rd. Road will bend to right (south).
121.4	0.4	Turn left (east) on Oatka Trail Rd.
122.3	0.9	Turn right (south) onto Circular Hill Rd.
122.4	0.1	Cross over Oatka Creek.

122.6	0.2	Base of the Onondaga escarpment. Exposures of Upper Silurian strata on left (east) bank of road toward top of escarpment.
122.9	0.3	Top of Onondaga Escarpment.
123.7	0.8	Dolomite Products Corporation, Rochester Asphalt Products plant.
124.0	0.3	Turn left (east) onto Gulf Rd.
124.4	0.4	Pullover and view of abandoned quarry in Onondaga Fm. Top of Edgecliff Mbr. exposed in quarry floor; Nedrow and lower Moorehouse mbrs. form the quarry walls.
124.6	0.2	Bridge over abandoned quarry road. Upper part of Edgecliff Mbr. and Nedrow Mbr. exposed below bridge.
124.9	0.3	Dolomite Products Corporation quarry entrance on right; old quarry scoop shovel seen on left.
125.1	0.2	Front entrance to Neid Rd. quarry on left. Proceed ahead on Gulf Rd.
125.4	0.3	Turn left (north) onto Neid Rd.
125.7	0.3	Turn left (west) onto extension of Neid Rd.
125.8	0.1	Proceed to gate of abandoned Neid Rd. quarry and park. Walk ahead, following old quarry road and proceed down the ramp to the quarry road.

STOP 5. ABANDONED NEID ROAD QUARRY, EAST OF LEROY

This large abandoned quarry exposes Upper Silurian (Pridolian) strata of the Bertie Group and Cobleskill-Akron member of the Rondout Formation, and Lower Devonian (Emsian) strata of the Bois Blanc Formation and Edgecliff Member of the Onondaga Formation. Adjoining quarries along Gulf Road expose additional strata of the Edgecliff, Nedrow, and Moorehouse members of the Onondaga Limestone. At this stop we will focus our attention to the northeast corner of the quarry, examining relationships between the top Silurian, Bois Blanc, and basal Onondaga units.

One of the most significant features of the Neid Road quarry is the locally complex topography of Upper Silurian strata, which in one area features prominent knobby pinnacles and undercut cavities through the fine-grained dolostones. The overlying Devonian units are variously draped over the highs and settled into the cavities below. In addition, the Bois Blanc undergoes dramatic lithologic changes between a relatively low, level background topography and the adjacent highs, from relatively fine-grained, brachiopod wacke- to packstones to coarse, rubbly, coral- and crinoid-rich rudstones and grainstones.

The quarry is floored by thinly bedded dolostones of the Fiddlers Green Formation of the Bertie Group. Characteristic salt hopper casts are locally common in the formation. The overlying Scajaquada Formation is poorly exposed in the lower sides of the quarry walls and extends up into fine-grained waterlimes of the overlying Williamsville Formation. Across most of the quarry the Williamsville is erosionally truncated by a composite Wallbridge Unconformity; generally about 0.8 m of the unit remains below the erosional surface. The surface of the unconformity along most of the quarry wall is generally relatively planar, with local humps up to approximately a half meter high and a couple meters across. The uppermost dolostone layers show subtle features associated with unconformity development, including a weathered, spongy appearing appearance in the upper few centimeters, and sand-filled *Trypanites* hardground/rockground borings. Quartz sand-filled neptunian dikes are visible down to at least 0.7 m below the Silurian-Devonian contact locally.

Along the quarry walls on the east and west, the unconformity is overlain by the late Emsian (upper Lower Devonian) Bois Blanc Formation. Two divisions are recognizable in the Bois Blanc along the east wall (Figure 15a): a lower, recessive-weathering interval of argillaceous sandstone with reworked clasts, phosphate, and glauconite, and lensing, nodular limestones ("Springvale" Member); and a more resistant ledge of fossiliferous, fine- to medium-grained limestones (unnamed member).

The "Springvale" Member at the Neid Road quarry consists primarily of approximately 30 cm of argillaceous siltstone to sandstone (Figure 15b); the unit locally thins over low mounds on the Silurian and thickens in topographic lows. A yellow clay occurs locally at the contact. Different layers internal to the Springvale may feature reworked clasts of dolostone or phosphate, or even chertified favositid corals. Glauconite is present in some beds, along with a few meristellid and other brachiopods. A transitional cap to the Springvale comprises alternating lenses of fossiliferous micritic limestones and thin shales.

The upper (unnamed) limestone member of the Bois Blanc along the eastern wall (Figure 15a) consists of a ledge, approximately 0.8 to one meter thick, of relatively tabular, gray wacke- to packstones. The lower interval, generally weathering as two beds (ca. 30 cm-thick each) show a fauna of predominantly small to medium-size brachiopods with ambocoelids and a meristellid, along with platyceratid gastropods, and some small rugose corals. The upper bed features scattered medium-sized rugosans (*Heterophrentis* and a cystiphyllid) and medium to large brachiopods.

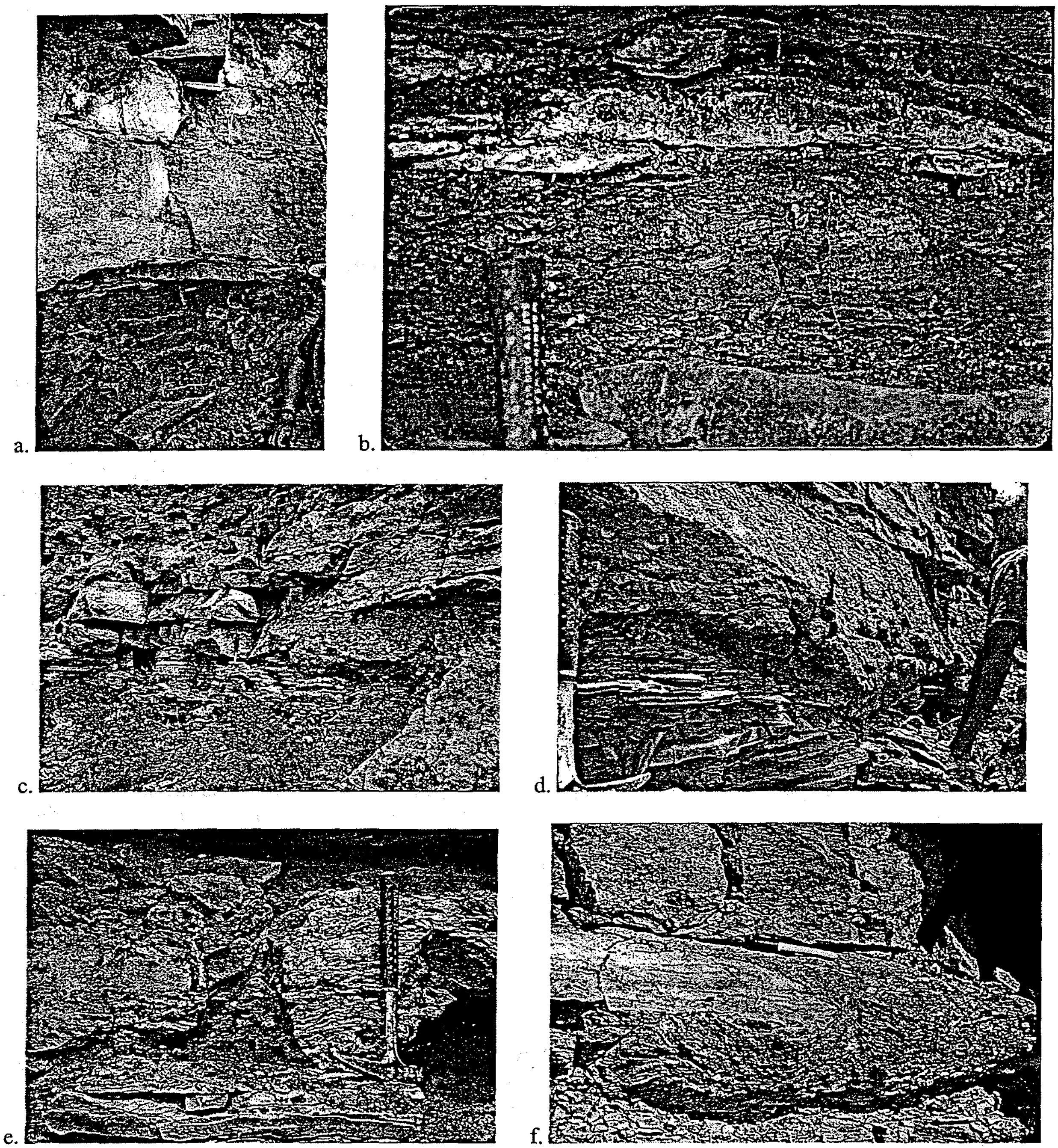


Figure 15a-f. Silurian-Devonian unconformities interval, Neid Road quarry, LeRoy. a) Topmost Bertie Group (Williamsville Fm.), Bois Blanc, and basal Onondaga formations on east wall of quarry. Hammers on sub-Bois Blanc unconformity, overlain by argillaceous, phosphatic Springvale Member. Upper Bois Blanc limestones extend up to horizontal field book (upper center). b) Detail of sub-Bois Blanc unconformity and Springvale Member on east wall. c) Mid-distance view of north quarry wall (east end), showing Williamsville, Bois Blanc, and Onondaga formations. Note irregular topography on sub-Bois Blanc unconformity. d) Close-up photo of center of previous photo, showing truncation of Silurian strata below Bois Blanc Formation. Note rough, coarse-grained rudstones of Bois Blanc carbonates on north wall relative to smoother-textured grainstones of basal Onondaga above (upper right). e) Close up of north wall at 17 meters of cross-section (Figure X of this paper), showing karstic cavity fill of apparent terra rosa soil within Silurian bedrock. f) Karstic fill of coarse-grained Bois Blanc limestone into cavities within fine-grained Williamsville dolostones, overlain by basal Edgecliff Member above pen.

Faunally and lithologically, the Bois Blanc limestones appear to represent relatively offshore, shelf-like facies, with a general coarsening-up/shallowing-up trend into the upper bed.

The top of the Bois Blanc is marked by an irregular topography and a thin crevice, which features a yellowish clay (< 1 cm-thick); the clay may represent a bentonite bed. A similar clay has been seen at the Bois Blanc-Onondaga contact in Ontario.

The contact is overlain by approximately 0.9 m of relatively coarse non-cherty grainstones (Jamesville Quarry facies) of the Edgecliff Member. The contact is relatively horizontal along the eastern wall, although it can be seen to rise subtly above the crests of the low paleobedrock mounds on the Silurian. The basal Jamesville Quarry facies of the Edgecliff is succeeded by a thick succession of Clarence chert-rich facies. The Edgecliff Member totals 12.9 m and is fully exposed in the Neid Road and adjacent Gulf Road quarries.

These patterns are representative of the Silurian and Lower Devonian transition zone around much of the Neid Road Quarry. However, immediately adjacent to the ramp road, in the northeast corner of the quarry, the stratigraphy becomes much more complex.

On the northeast wall we find some remnant topographic highs on the Silurian bedrock; localized knobs, or pinnacles, that extend at least 3 meters up above the normal, background topography of the Silurian bedrock (cross-section, Figure 8). In places the full 2.9 m of the Williamsville are preserved, with overlying Cobleskill/Akron Formation visible with its small, recrystallized corals. The paleotopographic highs, which may have functionally been "seastacks" along the Bois Blanc to Edgecliff coastlines, are locally undercut by cavities. The pinnacles, and isolated chunks of the Williamsville and Cobleskill/Akron that apparently attached back into the wall, stand surrounded by a matrix of Devonian strata. In a few places, thin, continuous fill of Bois Blanc is observed in elongate narrow cavities that are open at both ends. These various features may be due to karstification, or possibly be related to widening of joints (grikes) and physical cutting/erosion during sea level advance over a rocky coastline. Kobluk et al. (1977) reported etching over the Silurian bedrock that they interpreted to be associated with land plants, indicating subaerial exposure of the bedrock during lowstand events. They also reported indications of marine erosion processes, including bioerosive activity associated with *Trypanites* rockground borings. We have not at present identified plant related etchings. No borings were noted on the top surface of the Williamsville along the outcrop, away from the pinnacles. However, on some of the isolated pods that would have been standing above the sea floor and on the adjacent pinnacles, *Trypanites* borings are notable. In addition, to the west of the measured section, toward the far end of the "pinnacles outcrop (away from the ramp), a channel-like feature also occurs, infilled with Bois Blanc limestones.

Draped over this topography, across the lower parts of it, are coarse coral- and crinoid-rich rudstones with some grainstones (Figures 15c, 15d). This facies, which might generally be associated with the basal Edgecliff in New York, can be seen to grade laterally to the northwest and the southeast into the normal, generally brachiopod-rich wacke- to packstones, and even the basal muddy phosphatic sands and lenticular carbonates, of the Bois Blanc Formation. The coarse facies features a relatively diverse fauna, including a number of different solitary and colonial rugose corals, and *Pleurodictyum* and *Favosites* , along with abundant echinoderm debris, medium to large brachiopods, and rostroconchs. In places there is a finer-grained unit at the top, that locally even becomes shaly. A thin recessed interval of muddy, phosphatic sandstone to shales with glauconite also occurs locally at the bottom of the Bois Blanc on the northeast wall, and locally infills cavities, as seen at 17 m on the cross-section (cross-section Figure 8 and photo Figure 15e). The coarser, coral- and crinoid-rich facies can also be seen to infill around knobs and cavities in the underlying Silurian strata (Figure15f). The Bois Blanc ranges in thickness along the northeast wall from 0 to 72 cm, and terminates against the highest Silurian pinnacles/knobs.

Where the knobs stand above the top of the Bois Blanc, they are typically draped by the chert-free basal Edgecliff strata (Jamesville Quarry facies). However, in a few places the knobs stand up over the basal Edgecliff unit and are draped by cherty strata of the overlying Clarence facies of the Edgecliff. A distant view of the outcrop shows that the various lower Edgecliff layers appear to rise locally over the pinnacles.

Development of the coral-rich facies over the topographic high appears to be varied. Across the ramp road, approximately 100 m to the southeast, two thin wedges of coral-crinoidal rudstones pinch out locally into the thin limestones interval at the top of the lower, recessive Springvale unit. The lower part of the upper limestone ledge appears coarser than the upper part locally also. In the opposite direction, across a covered distance of more than 100 m, there appear to be three intervals of coarser, coral-rich facies, separated by finer-grained, almost calcisilt-type facies. So it appears that development of the coralline communities occurred repeatedly during deposition of the Bois Blanc Formation.

The abrupt changes in litho- and biofacies between the relatively deeper shelf, brachiopod-rich wacke- to packstones along the sidewalls of the quarry and the coarse rudstones of corals echinoderm debris of the pinnacles area imply a sharp ecological gradient locally during deposition of the Bois Blanc. A visible relief of approximately three meters in the quarry walls would not appear to account for enough depth change to support this gradient. It may be that the coral rudstone facies was developed either during relative lowstands of sea level, or that the positive topographic relief exposed in the quarry is only the margin of a more elevated feature that is developed back of the wall, or was destroyed during quarrying. The presence of tongues of rudstone to grainstone facies through a significant portion of the upper limestone ledge in the first outcrop to the northwest, and its presence in the top of the lower (Springvale) unit across the ramp road implies that a coral-rich community was developed locally during deposition of much of Bois Blanc. This appears to support a suggestion that a greater topographic high, not seen in the quarry wall, existed locally, and that coral bioherm communities, reflected here in off-reef debris aprons draping the topography, may have existed locally over the high during much of Bois Blanc deposition. Curiously, reef development did not continue above the sub-Onondaga unconformity, as reflected by the relative finer-grained and coral-poor grainstones of the basal Onondaga, which is well known for its local biohermal buildups.

This is also very interesting in light of recent work by Wolosz (1992) and Wolosz and Paquette (1988, 1994) on the nearby LeRoy Bioherm. They provide evidence that the lower core of the bioherm was subjected to extensive erosion prior to deposition of the upper cap of the feature. Recent regional to basinwide study of the Onondaga Formation indicates that the Edgecliff Member comprises two and a half medial-scale sea level cycles (parasequence sets). The erosion over the core could have occurred during one of the relative lowstands of sea level within the Edgecliff. However, in light of the discovery of Bois Blanc biohermal facies locally, another possibility is that the dark-colored, fine-grained, *Cladopora*-rich core of the reef also could be Bois Blanc. Oliver (pers. commun., 8/00) states that Cladopora is a long-ranging Silurian-Devonian form; its presence in the lower part of the bioherm does not necessarily indicate an Edgecliff age. The diagenetic character of the partially-silicified Cladoporids, unique among Edgecliff reefs (Wolosz and Paquette, 1994), is also consistent with the high degree of silicification of fossils in the Bois Blanc in western New York (Boucot and Johnson, 1968). Reworked clasts of Cladoporid mound facies and otherwise absent lithologies in the base of the overlying biohermal unit and in fissure fills cut down into the inner reef core reported by Wolosz and Paquette (1994) appear to indicate a relatively significant break, consistent with exposure and erosion at a sequence-bounding unconformity. It is possible, then, that the erosion surface within the LeRoy Bioherm may actually represent the sub-Onondaga unconformity, and that the inner reef core is Bois Blanc in age, as tentatively suggested by Wolosz (1988).

END OF TRIP. To return to Hobart and William Smith Colleges, backtrack to the NY State Thruway and follow it eastward toward Albany. Get off at Exit 42 and proceed south on NY Rte. 14 to Geneva. Follow signs to Hobart and William Smith Colleges.

PROGLACIAL LAKES, SOUTHERN CAYUGA AND SENECA VALLEYS

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INTRODUCTION

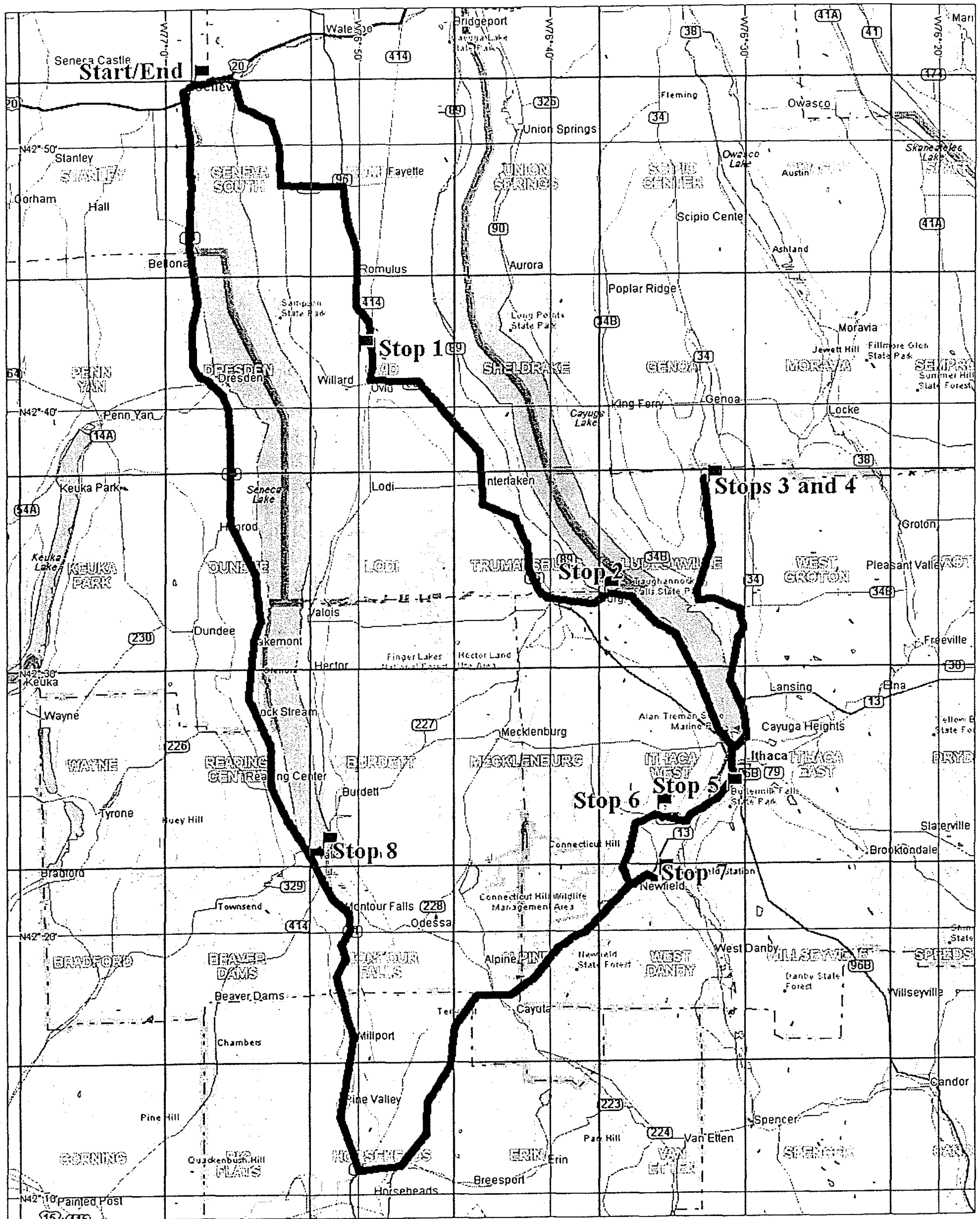
The modern Finger Lakes troughs of central New York developed by a combination of glacial scouring and the action of high-pressure sub-glacial meltwater (Mullins and Eyles, 1996). Seismic stratigraphic relationships suggest that the stratigraphic and morphologic record left behind by this event–including the Valley Heads Moraines (VHM) as well as much of the infill of the Finger Lakes troughs themselves--must have occurred between (and including) VHM time, around 14.9-14.4 ka ^{14}C yr. B.P. (Muller and Calkin, 1993). Late-stage trough-fill sediments were deposited until 13.6 ka ^{14}C yr. B.P. (Wellner et al., 1996), by which time ice had retreated north of the modern Finger Lakes and the lakes probably had dropped to near their current elevations. This sedimentologic development in the troughs themselves was produced by pro-glacial lakes that dropped in height above the modern lakes as ice retreated north through the troughs. Early in this late-glacial history, local high-level lakes were impounded in many tributary valleys as ice retreated from the uplands but persisted in the main north-south troughs. Our goals on this field trip (Figure 1) are to examine some of the evidence of high-level and pro-glacial lakes in the southern parts of the Cayuga and Senaca troughs, as these areas illustrate many of the relationships that are characteristic of the other Finger Lakes as well.

LATE-GLACIAL EVOLUTION OF THE FINGER LAKES TROUGHS

The reflection data obtained by Mullins and his co-workers (Mullins and Hinchey,1989; Mullins and Eyles, 1996) have provided a fundamentally new view on the formation of the Finger Lakes troughs. An ice-erosion origin for the troughs had long been recognized (Mullins et al., 1989), and indeed there is scattered evidence (such as the Fernbank site, described by Bloom in 1972) for pre-late Wisconsin lakes and ice advances through the region. Thus, the modern troughs have a long-term history. However, the recent seismic data have shown convincingly that the present shape and sub-lake sediment relate to the latest glacial period, during retreat of the Laurentide ice sheet from the Valley Heads Moraines position. Indeed, it wasn't until extensive seismic reflection studies had penetrated the sub-lake stratigraphy that the full nature of sub-glacial erosion could be recognized. We summarize here what we consider to be the most important observations and conclusions of this work, leading to a more detailed discussion of the pro-glacial lakes that produced much of this deposition. We take this mostly from Knuepfer and Lowenstein (1998).

(1) Deep bedrock scour occurred below each of the Finger Lakes, as great as 306 m below sea level beneath Seneca Lake. The depth of scour, coupled with seismic stratigraphy of the deepest sediments that fill these basins, is most consistent with erosion by high-energy, high-pressure sub-glacial meltwater (Mullins and Hinchey, 1989; Mullins et al., 1996). It is certainly no coincidence that this interpretation is consistent with the argument by Shaw and Gilbert (1990) that subglacial meltwater flood(s) played a major role in development of the drumlin field of the Ontario lowland to the north. However, the problem of finding convincing evidence of major, catastrophic meltwater flows south through the Susquehanna remains. Braun (1994) argued that the lack of preserved slackwater sediments and preserved pre-latest Quaternary terraces and deposits along the Susquehanna upstream of water gaps in Pennsylvania shows that no major, catastrophic flows occurred through the Susquehanna in latest glacial time. Shaw (1996), on the other hand, argues that potholes and residual islands in the lower Susquehanna resulted from catastrophic meltwater flooding. Mullins and Hinchey (1989) suggest that the VHM were deposited by the water from the Finger Lakes scour event(s), and it is sufficient for our purposes to accept this idea.

(2) The oldest sediments preserved in any of the Finger Lakes troughs correlate with and onlap sediment preserved in the Valley Heads Moraines deposits. Assuming synchroneity of the VHM deposits, the best estimate of the age of this event is supplied from the Nichols Brook site in western New York. Muller and Calkin (1993) conclude that ice retreat at this site had begun by 14.4 ka ^{14}C yr. B.P., with radiocarbon dates as old as 14.9 ka ^{14}C



3-D TopoQuads Copyright © 1999 DeLorme Yarmouth, ME 04096 1 mi Scale: 1 : 350,000 Detail: 9-1 Datum: WGS84

Figure 1. Route map. Base from U.S. Geological Survey 1:250,000-scale map, reformatted by DeLorme 3-D TopoQuads program.

yr. B.P. obtained from this site. This provides a constraining upper age for initiation of all of the pro-glacial lakes of the Finger Lakes troughs that have left the hanging deltas of the Finger Lakes glens.

(3) Sub-glacial scour apparently removed any pre-existing sediment within the bottoms of the troughs, although some sediment of likely last interglacial age is preserved locally within or near hanging valleys on the margins of troughs. The principal site that has been well studied is the "Fernbank" exposure on the west margin of Cayuga Lake (Maury, 1908; Bloom, 1972; Karrow et al., 1990). Interglacial deposits, assumed to be of Sangamon age, were reported from this location, providing direct evidence that a Cayuga Lake trough of some sort existed prior to Wisconsin glaciation (Bloom, 1972, 1986). The lack of interglacial sediment as interpreted from seismic stratigraphy from the Cayuga Lake trough proper indicates that the present depth of excavation of the trough is a late-glacial feature.

(4) Sedimentation in the troughs was substantial in late-glacial time, up to 270 m total (Mullins et al., 1996). The bulk of this sedimentation occurred under proglacial lake conditions while ice was retreating northward in the troughs. The deposition initially was largely from the north, consistent with subaqueous outwash (Mullins et al., 1996). A reversal in direction of inwash into the proglacial lakes occurred around 13.9 ka ^{14}C yr. B.P., which Mullins et al. (1996) interpret as an indicator of substantial lake-level drop. Perhaps this marks the time of retreat of the ice margin into the Ontario lowlands, although Mullins et al. (1996) infer that a sedimentation event immediately prior to this reversal represents deposition from an ice margin that terminated at the north end of the present Finger Lakes. In any event, Mullins et al. (1996) indicate that sedimentation in the period 13.9 ka ^{14}C yr. B.P. to 13.6 ka ^{14}C yr. B.P. consisted predominantly of sand and gravel deposits from lateral and southern sources, marking the first significant influx of sediment from these sources into the troughs. Alternatively, one could interpret the available evidence to indicate that prior to 13.9 ka ^{14}C yr. B.P. debris influx from the southern and lateral drainage systems was relatively minimal; we consider this interpretation below. There need not have been a regional change in the influx from lateral tributaries. However, boreholes south of both Canandaigua Lake and Cayuga Lake record the burial of lacustrine sediments by sand and gravel at this time, suggesting a lake level comparable to the modern and progradation of deposition from the south. Thus, the lowering of lake level must have been complete by this time. This constrains most of the history of the pro-glacial lakes to within a very short interval.

(5) Post-glacial infill of the lake troughs is relatively minor. Maximum interpreted thickness of post-glacial lake sediments (their Sequence VI) in Cayuga Lake is only about 12 m (Mullins et al., 1996) to perhaps greater than 15 m (Mullins, 1998).

Thus, the modern Finger Lakes troughs, including Cayuga Lake, owe their present morphology and sedimentation to late-glacial and post-glacial processes. Three morphologic characteristics are particularly notable: the troughs themselves, particularly dramatic at their south ends; the tributary gorges, called glens, that descend from handing valleys into the main lakes; and the numerous small hanging deltas preserved alongside the glens due to changing lake (base) level during the progressive lowering of the pro-glacial lakes. We will consider first the major pro-glacial lakes, concentrating on the Cayuga Lake trough, then discuss some of the high, local lakes that were impounded earlier in the retreat of ice from the VHM position.

MAJOR PRO-GLACIAL LAKES OF THE CAYUGA AND SENECA TROUGHS

Fairchild (1899a,b; 1909; 1934) mapped the extent of pro-glacial lakes in the Cayuga trough and throughout central New York. He recognized that progressive northward retreat of the Laurentide ice sheet opened progressively lower outlets for lake overflow (such as Grasso, 1970, and Hand, 1978, have described in detail for the Onondaga Valley lakes in the Syracuse area). This produced a series of distinct lake levels, progressively lower, into which tributaries built deltas (e.g., Fairchild, 1934). Most tributaries preserve morphologic and stratigraphic evidence of these pro-glacial lake deltas. Available exposures into these surfaces that we have visited in the Cayuga Lake trough generally display foreset beds, in some cases overlain by topset beds or even till. As many as 7 or more delta surfaces are preserved above some of the gorges.

Fairchild and other workers (e.g. von Engeln, 1961) named the various lakes that they mapped from the distribution of hanging deltas and other shoreline indicators as well as outlets. Many of the lakes are named for famous geologists (e.g. Lakes Hall and Dana), whereas others are named for localities (e.g. Lakes Ithaca and Watkins). Fairchild (1916) recognized the effect that isostatic rebound had had on elevating individual shorelines to the north, although von Engeln (1961) continued to reject the rebound model. We principally follow Fairchild (1934) in this summary, as his work remains the most complete treatment of the pro-glacial lakes.

The Cayuga and other troughs were covered by ice when Valley Heads Moraine deposition was occurring at 14.9-14.4 ka ^{14}C yr. B.P. Upon ice retreat from the Valley Heads position, ice dammed meltwater escape to the north, the VHM deposits limited meltwater escape to the south, and local divides and cols controlled meltwater escape to the east and west. Thus, a series of proglacial lakes was impounded, with local streams (such as Enfield Creek) forming deltas into these lakes. Initially, lakes were local and confined to areas adjacent to the ice sheet and/or the VHM; the lakes of this sort in the Cayuga trough are considered later. As the ice retreated north, lakes expanded, controlled by both ice position and potential overflow points. Lake Ithaca developed in the Cayuga trough, with overflow across the VHM at White Church north of Willseyville at an elevation (modern) of 985 feet (300 m). (In keeping with past practice, we will use the lake names and outlets described by Fairchild except in cases where more recent studies supply alternative interpretations.) Simultaneously, a lake was impounded in the Seneca trough (called Lake Watkins), but at a much lower elevation, constrained by the 900-foot (275-m) Horseheads outlet (which we will visit during the field trip). Northward retreat of the ice sheet eventually uncovered the Tully escarpment at Ovid (Figure 2), and Lake Ithaca drained into the Seneca trough (Figure 3a). This abandoned the White Church outlet, and Lake Ithaca merged with Lake Watkins to form what is called Lake Newberry (Figure 3b). The Horseheads outlet persisted and controlled this lake, which eventually occupied most of the Finger Lakes troughs in central New York. The Horseheads outlet wasn't abandoned until ice retreated north of the Batavia area in western New York, opening an outlet to the west into the Lake Erie/Huron and ultimately Mississippi drainage (Fairchild, 1934; von Engeln, 1961). This impoundment, called Lake Hall (Figure 3c), had an outlet at a modern elevation of 825 feet (250 m).

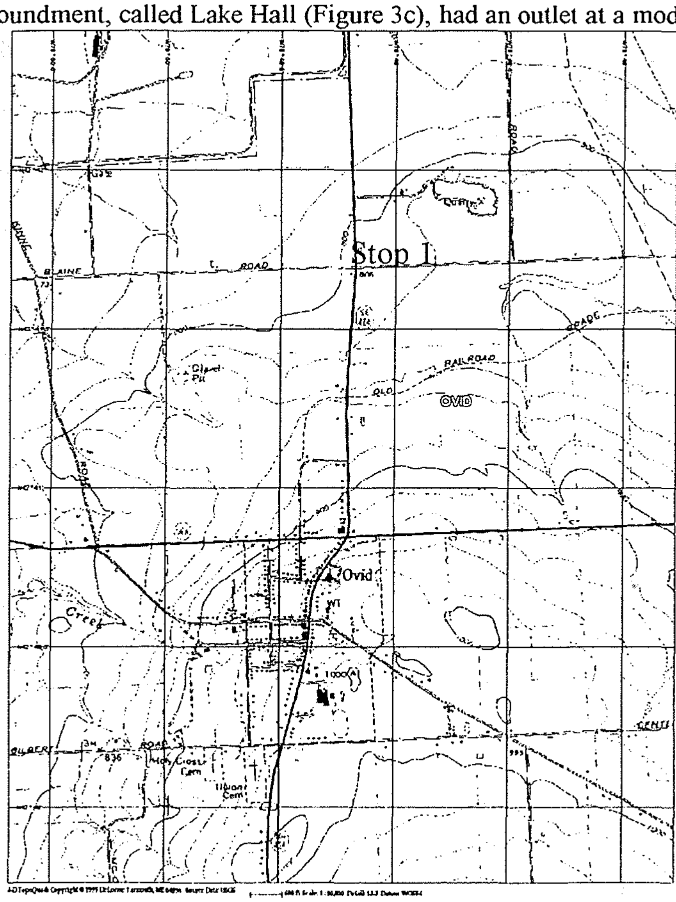


Figure 2. Topographic map of Ovid area and location of Stop 1. USGS Topographic map produced from DeLorme 3D TopoQuads program. Note flat surface at Ovid at elevation of approximately 1000 ft (305 m), which we interpret as scour surface and/or shoreline from overflow of Lake Ithaca into Lake Watkins (Figure 3a). Also note flat surface at location of Stop 1, marked by quarries, at elevation around 820 feet (250 m), which we interpret as the shoreline and scour of the drop to the Lake Hall elevation (Figure 3c).

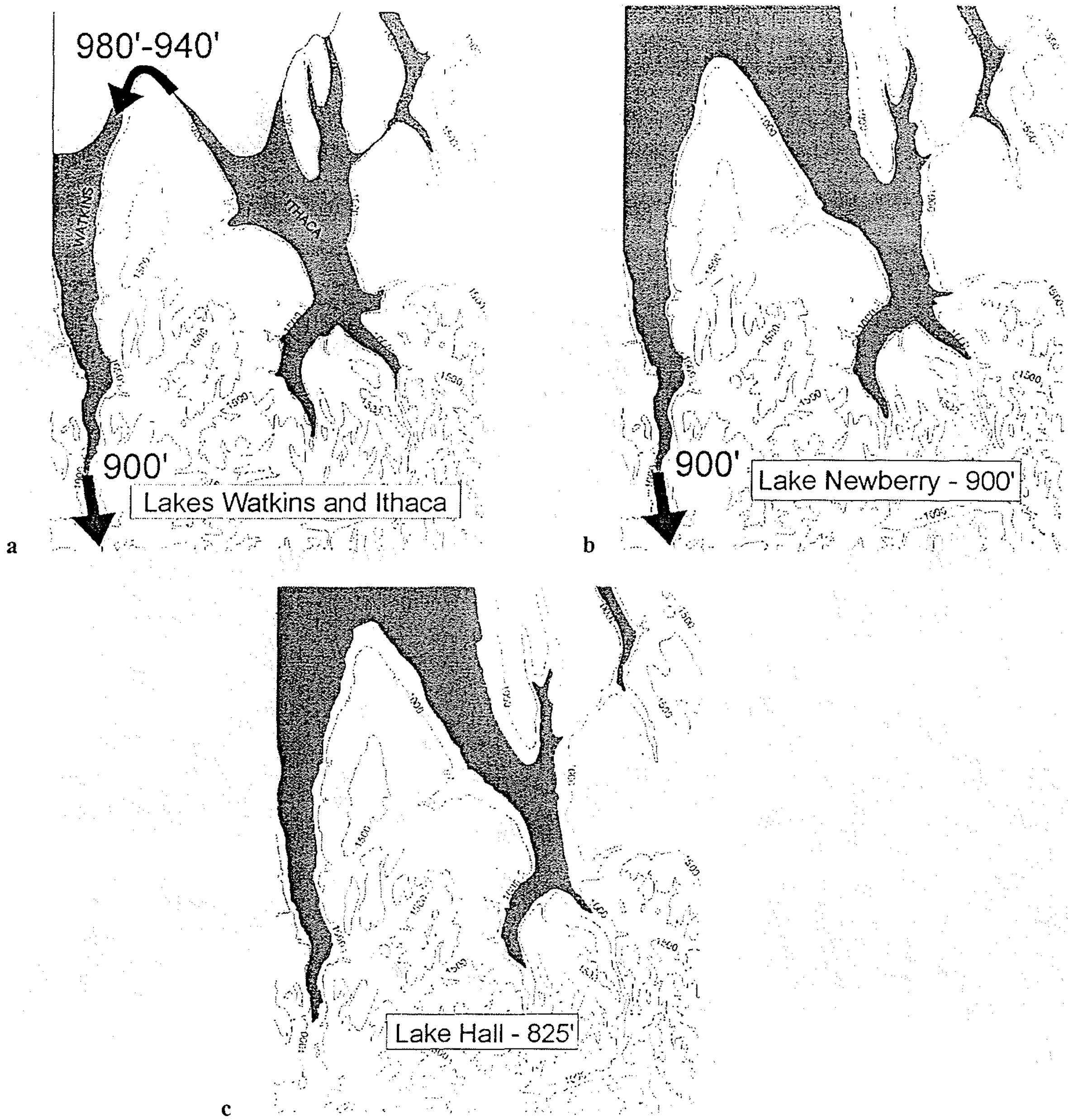


Figure 3. Evolution of pro-glacial lakes in the Cayuga and Seneca troughs. **a**. Initial overflow of Lake Ithaca into Lake Watkins at Ovid when spillway opened due to ice retreat. **b**. Amalgamation of Lake Newberry at common elevation between Cayuga and Seneca troughs after spillover complete. Outlet of combined lakes controlled at Horseheads. **c**. Drop to Lake Hall level when Batavia outlet opened. Note that shoreline is between Cayuga and Seneca troughs is just north of present location of Ovid.

As noted previously, these lakes left behind a dramatic morphologic and stratigraphic record in hanging deltas (Figure 4). However, at least some of the deposits are more complicated, involving interactions between glacial, lacustrine, and probably fluvial processes (Figure 5). Deltas are more numerous along the tributaries of southern

Cayuga trough than southern Seneca trough because of the persistence of the Horseheads outlet. Thus, the Lake Watkins delta at places like Watkins Glen Creek or Hector Falls Creek (Figure 6) is extremely broad, whereas individual deltas along the Cayuga trough generally are much smaller (regardless of the size of the contributing upland drainage basin).

Another important point is to realize that this evolution of pro-glacial lakes was very rapid. Cayuga Lake and other Finger Lakes had apparently reached levels close to modern by 13.6 ka ^{14}C yr. B.P. Thus, base-level fall that triggered lowered deltas and tributary valley incision must have occurred within about no more than 1300 years. Indeed, Mullins et al. (1996) imply that gorge incision was accomplished only after sedimentation from lateral and southern sources is recorded in the Finger Lakes cores and seismic records, i.e. in the interval 13.9-13.6 ka ^{14}C yr. B.P. This seems unlikely; other seismic stratigraphic evidence indicates a largely ice-free Cayuga Lake trough by 13.9 ka ^{14}C yr. B.P. (Mullins et al., 1996), which means lake levels already would have lowered in response to ice retreat. Regardless of how short the time period was, formation of the deltas of the Finger Lakes, and at least some significant incision, was accomplished within a very brief interval of late-glacial time.

Figure 4. Exposure of foreset beds at Taughannock Falls State Park. Photo taken July, 2000. View west toward top of delta surface.

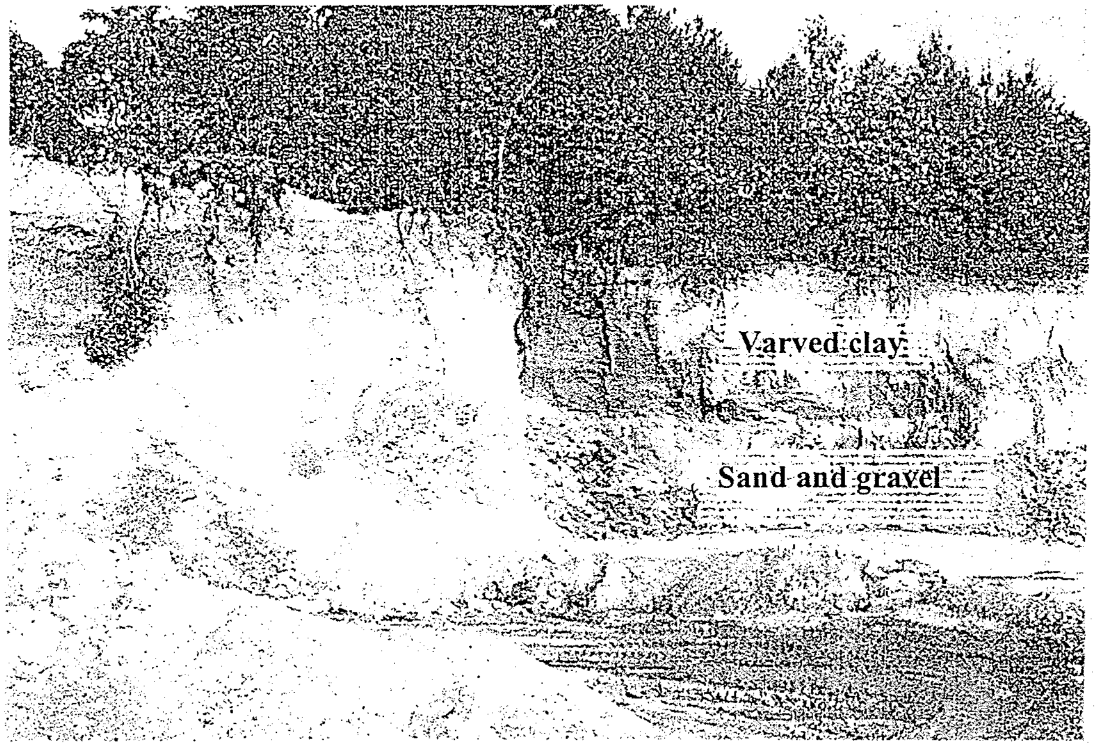


Figure 5. Exposures of stratified sand and gravel at Thompson and Genoa Sand and Gravel pits. Top: Exposure of stratified outwash(?) overlain by varved lacustrine clay (and locally diamict). View looking east at north end of pit wall. Photo taken 10 August 2000. Bottom: Exposure of faulted outwash(?) sediments overlain by till. Reverse faulting well exposed on left side of photo. View looking east in lowest exposed level of Genoa Sand and Gravel pit. Photo taken 10 August 2000.

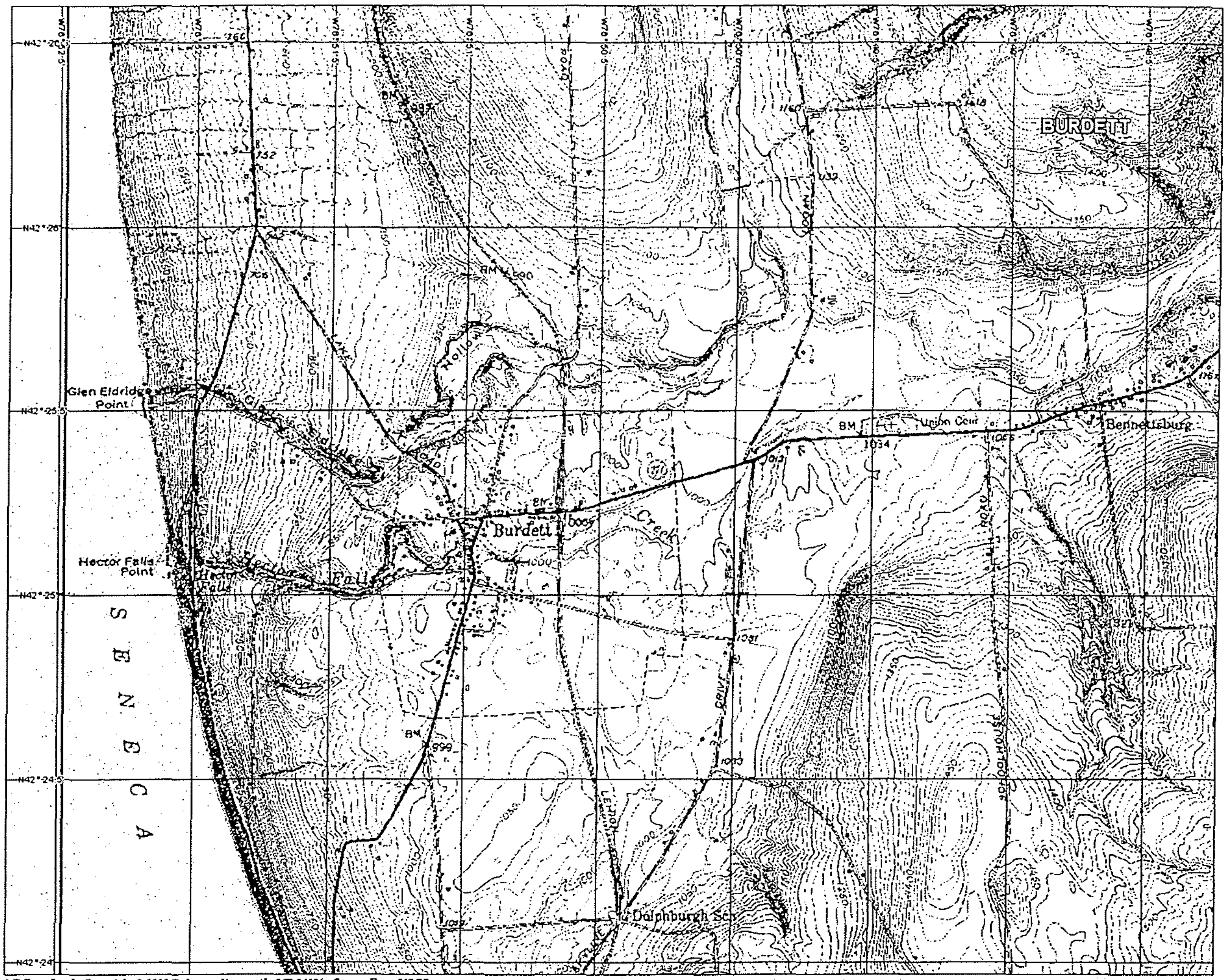


Figure 6. High delta surface at Hector Falls Creek, Burdett. Delta front 950-970 feet (290-295 m) at Burdett above Hector Falls Creek. This delta complex, representative of many at the southern end of Seneca Lake, graded to the stable Lake Watkins level controlled by the Horseheads outlet. Topographic map from U.S. Geological Survey quadrangles, produced by DeLorme 3D TopoQuads program.

HIGH-LEVEL LOCAL PRO-GLACIAL LAKES

Although it is the large lakes that have left the strongest imprint on the landscape, initial ice retreat from the Valley Heads Moraine position resulted in local impoundments in the Cayuga trough and elsewhere. Fairchild (1934) summarized many of these lakes in the Cayuga trough and surrounding areas. Again, our discussion begins with his work.

Fairchild (1934) concentrated on lakes that developed within the main Cayuga trough and to the east, where he and others had extensively studied the Six Mile Creek drainage and its lakes, such as Lake Dryden. The western tributary streams were not given such attention, as Fairchild thought their post-glacial genesis to be relatively straightforward and simple:

> "The divide at the head of Pony Hollow, three miles southwest of Newfield, with an elevation of 1240 feet, was not cut by drainage, judging by map contours... Well developed shore features--gravel bars--occur at elevation 1230-1240 feet, one and a half miles north by northeast of Enfield falls corners... one explanation of these high level beaches is to postulate an Enfield falls local lake for some phase when ice lay on the

of these high level beaches is to postulate an Enfield falls local lake for some phase when ice lay on the lower slopes. The difficulty here is that the Pony Hollow pass is too high, and uncut, and the swamp col west of Key Hill and one and a half miles west of Newfield is too low. Another explanation...is that the beaches represent the early phase of the West Danby Lake..." (Fairchild, 1934, p. 247-248).

We are unaware of any challenge to this hypothesis by previous workers, and therefore present our own.

It is very likely that the southern margin of the Laurentide ice Sheet was quite lobate when the VHM were deposited; indeed, Mullins and Hinchey (1989) suggested that the troughs may have been occupied by ice streams, and the pattern of upland moraines mapped by Muller and Cadwell (1986) clearly supports the notion of a lobate retreating ice front. Thus the glacier margin conformed to the valleys during both advance and retreat, similar to an alpine glacier, while the body of the ice sheet acted as a continental glacier to the north. The lobe in Cayuga Valley blocked the outlets of both Enfield Glen and West Branch Cayuga Inlet during initial retreat from the VHM position at West Danby. With access to the main valley trough eliminated, glacial meltwater flooded local highlands until the waters themselves topped the glaciers or another outlet was found. In the case of Enfield Glen and the West Branch Cayuga Inlet, their local high-level lakes found overflow across Valley Heads Moraines deposits southward down Pony Hollow towards Cayuta (Figure 7a), where it turned southeast towards Van Etten.

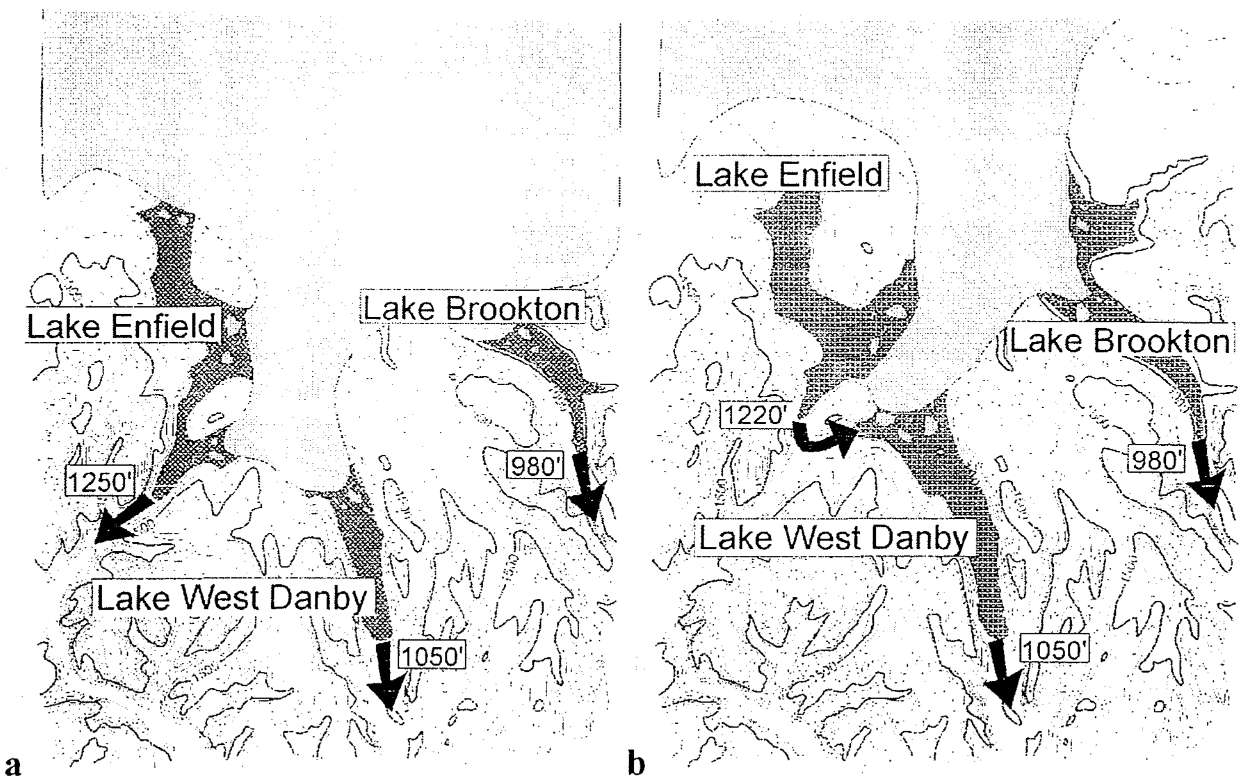


Figure 7. High-level lakes of the southern Cayuga trough during early stages of glacial retreat from the West Danby Valley Heads moraine position. a. Lake Enfield controlled by ice margin and Pony Hollow spillway. b. Lake Enfield drains to Lake West Danby through Fish Kill outlet, which is incised during this spillover. Large delta at Taber property (sediments viewed at Stop 7) formed by this event.

The Pony Hollow outlet lies near the middle of the valley, at a modern elevation of 1235 feet (375 m), passing under State Highway 13, 0.25 miles (0.4 km) east of the junction of State Highway 13 and Sebring Road. This 30-foot (9-m) wide, flat-bottomed trough is the modern north-south drainage divide in Pony Hollow that at one time drained the local high level lakes of the western Cayuga Trough tributaries. The combination of Cayuga Trough being blocked by the valley glacier and the outlet through Pony Hollow formed the initial high-level Lake Enfield, which existed at about 1250 feet (380 m). Note that differences in elevations of lake features and outlet geometry that exist along a north-south line are associated with incision of the outlet along with the isostatic rebound. Rebound curves for the region are between 1.5 and 3 feet/mile (0.28-0.57 m/km; e.g. Fairchild, 1916), which accounts for the 15-foot (5-m) difference in the elevations of the outlet through Pony Hollow and the deltaic and other deposits at stop 6 just north of Enfield Glen.

The Pony Hollow outlet was abandoned as the glacier occupying Cayuga trough retreated far enough north to allow water to escape between the glacier and the north side of Benjamin Hill immediately south of Newfield into the lower Lake West Danby (Figure 7b). The evidence of this escape lies at 1100-1180 feet (335-360 m), where a broad delta was deposited (Stop 7) and a bench was cut into the western flank of Cayuga trough. Along this bench are several kettles that formed as ice blocks, perhaps from Lake Enfield, grounded themselves in this outlet. As the elevation of Lake Enfield was being lowered, a drainage divide just south of the headwaters of Fish Kill developed about 1 mile (1.6 km) west of the junction of State Highway 13 and Trumble Corners Road. The Fish Kill drainage divide, at a modern (post-incision) elevation of 1175 feet (358 m), separated Lake Enfield into two separate bodies. We continue to use the name Lake Enfield for the northern body, and we apply the name Lake Newfield to a short-lived lake to the south. The surface of Lake Newfield gradually dropped to the 1130-foot (345-m) level though outlet drainage and quickly disappeared. After the extinction of Lake Newfield, water from Lake Enfield continued to use the Fish Kill outlet, carving a spillway which is clearly visible today, and which we will see on the field trip.

Thus the small high-level lakes commonly had complicated histories, strongly affected both by ice dynamics and local outlets and overflows. We have not investigated the history of early high-level lakes in the Seneca trough, but high deltas in places like Odessa may well relate to similar small lakes.

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ROAD LOG FOR PROGLACIAL LAKES, SOUTHERN CAYUGA AND SENECA VALLEYS

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0	0.0	Begin road log at intersection of Hwy. 14 and Hwys. 5 and 20, Geneva, NY. Drive east on Hwys. 5 and 20 to junction Hwy. 96A.
2.5	2.5	Turn right (south) onto Hwy. 96A. Continue south to junction with Hwy. 336.
8.3	5.8	Turn left (east) onto Hwy. 336 through MacDougall on to junction with Hwy. 96.
11.0	2.7	Turn right (south) onto Hwy. 96.
18.7	7.7	STOP 1. Stop at or near Blaine Road for an overview of the field trip and view of erosional/shoreline benches that connected Lakes Newberry and Hall between the Cayuga and Seneca troughs.

STOP 1. OVERVIEW OF CAYUGA TROUGH DRAINAGE OUTLETS

The highway continues south to Ovid from here. We are stopped on a bench at an elevation of approximately 820 feet (250 m), with a quarry into bedrock to our east (Figure 2). Ahead, Ovid sits on a surface on the nose of the Tully Escarpment cuesta (von Engeln, 1961) that has an elevation of 980-1000 feet (300-305 m), also seen on Figure 2. This level was likely scoured as the ice retreated northward, opening a drainage-way for spillover from Lake Ithaca into the Seneca Lake trough, forming Lake Newberry (Figure 3a). We interpret the lower level, marked at several nearby locations by rock quarries, as the bench/shoreline formed at the Lake Hall level (Figure 3b).

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
20.0	1.3	Continue south on Hwy. 96 to Ovid. Turn left onto continuation of Hwy. 96. As we drive southeast we descend from the Lake Ithaca to Lake Newberry and then Lake Hall levels. Continue on Hwy. 26 south to Trumansburg.
35.5	15.5	Turn left (southeast) onto Falls Road. Continue to Park Road.
36.7	1.2	Turn left (northeast) onto Park Road.
37.3	0.6	Pull over at the Falls Overlook parking area on the right.

STOP 2A TAUGHANNOCK FALLS OVERLOOK

The parking areas on both sides of the road are located on a delta surface hanging high above the modern Cayuga Lake. The elevation of the highest delta above the parking lot–at 820 feet or 250 m–was likely graded to the Lake Hall level. The view area affords an excellent perspective of the main Taughannock Falls, situated approximately 1.4 km (0.8 mile) upstream of the mouth of the gorge. Here the creek drops some 65 m through late Devonian Genesee Group sediments. The top of the falls is formed in resistant siltstone of the Sherburne member (Grasso et al., 1986); the notch at the lip of the falls has remained little changed since a rockfall in the late 1880s or early 1890s. One question to consider is how much the waterfall has retreated upstream and how much gorge incision has occurred in post-glacial time. The record of progressively lower deltas, coupled with the evidence of the rapid lowering of the proto-Cayuga Lake (Knuepfer and Lowenstein, 1998), all point to rapid incision during and immediately after ice retreat, while the Cayuga Trough was occupied by Lakes Ithaca, Newberry, Hall, Dana, etc.

STOP 2B GRAVEL QUARRY

Cross Taughannock Park Rd. from the Falls Overlook parking area and walk onto the unpaved road on the left side of the small parking lot northwest of the road. Walk about 100 m into a reactivated gravel pit. This pit is cut into the front edge of the most prominent high hanging delta of Taughannock Creek (the Lake Hall level). Recent working of the northeast wall of the quarry has resulted in a clear exposure of the delta-front foreset beds (Figure 4). Sediments include well stratified sands and gravels with some clayey and silty interbeds.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
37.3	0.0	Return to vehicles. Drive down Taughannock Park Rd. to Hwy. 89. Note the small delta surfaces across which we drive. The youngest delta, of course, is the active delta complex on which much of the developed area of Taughannock Falls State Park is located. This is one of the largest deltas on Cayuga Lake. If we use the analog from Canandaigua Lake and the evidence that Mullins and co-workers

38.0	0.7	have provided, we can assert that this delta probably began to form in latest glacial time, after base level for Taughannock Creek had dropped to approximately its modern position. Again, we can consider how much of the incision of bedrock occurred during this drop in lake levels, and how much is post-glacial.
47.9	9.9	Junction Hwy. 89. Turn right (south) to Ithaca.
55.1	7.2	Junction Hwy. 13 and 34 north in Ithaca. Turn left on Hwy. 13 north; follow the signs for Hwy. 34 north out of Ithaca.
58.0	2.9	Junction Hwy. 34 and 34B, South Lansing. Turn left onto Hwy. 34B. The easiest way to get to the next two stops is to turn right at Salmon Creek Road, but a bridge is currently under repair, and this route is unavailable.
59.1	1.1	Turn right onto Lansingville Road.
61.0	1.9	Turn right onto Lockerby Hill Road.
63.1	2.1	Turn left onto Salmon Creek Road.
		Gravel pit visible along bluff on right; pull off and climb onto spoil pile for STOP 3. STOP 4 is just north of this past the houses.

STOP 3. COUNTY GRAVEL PIT AT THOMPSON PROPERTY

Cayuga County has been removing sand and gravel from the lower part of the long exposure. This work has been continuing for some years, and the local property owner indicates that the bluff used to extend nearly out to Salmon Creek Road. The current excavation exposes several meters of sand and gravel (possibly outwash) overlain by varved clays, in turn overlain by a diamict (Figure 5a). The geomorphic surface above these exposures is at an elevation of only 700-720 feet (210-215 m), which could correspond to the Lake Warren level (von Engeln, 1961). The vaved clays likely were deposited by one of the earlier, deeper lakes (Hall or Newberry). The overlying diamict is problematic.

STOP 4. GENOA SAND AND GRAVEL PIT

A larger operation just north of the Thompson pit has been recovering sand and gravel from locally deformed outwash (?) deposits below the 700-foot (210-m) level. No foresets are exposed; all sediment is flat- or nearly flat-lying, indicating these probably are not deltaic deposits. Here thrust faulting has offset well bedded sands and gravels exposed in some of the active walls in the pit (Figure 5b). What we see during the field trip depends on the recent activity of the operators. We interpret these deposits as ice-proximal outwash, possibly overriden by a local re-advance, and the deformation likely occurred while the sediments were frozen (given the intact nature of most of the deformed beds).

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
63.1	0.0	Return to vehicles and return to Ithaca.
77.5	14.4	Junction Hwy. 13 south in Ithaca. Turn onto Hwy. 13 south and continue through Ithaca.
81.5	4.0	Entrance to Buttermilk Falls State Park on left. Turn in to Buttermilk Falls State Park and park in the lot. We'll eat lunch in the shadow of the falls.

STOP 5 (LUNCH). BUTTERMILK FALLS AND BUTTERMILK GLEN

Not only is the main waterfall here at the mouth of the gorge, which contrasts sharply with the situation at Taughannock Creek, but delta surfaces are not as well preserved here–perhaps because the drainage basin is smaller, but also because Buttermilk Creek probably did not re-excavate its pre-last glacial gorge. Instead, the morphology here is consistent with a pre-late-glacial "proto-Buttermilk Creek" gorge located about 300 m to the north and occupied by a small, unnamed modern creek. This situation–abandonment of the pre-glacial gorge–was suggested by Matson (1904).

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
81.6	0.1	Return to Hwy. 13 and turn left (south).
83.1	1.5	Turn right at Hwy. 327 toward Robert Treman State Park.
86.0	2.9	Drive uphill and turn into H&H Auto Sales to look at exposure. STOP 6.

STOP 6. H&H AUTO SALES GRAVEL PIT

This gravel pit exposes interbedded sands and gravels. When the main quarry north of (behind) the auto shop was operated by the Town of Enfield some years ago, it exposed foreset beds below a 1200-1230-foot (365-375-m) poorly preserved surface. These beds were overlain by a poorly consolidated, thin (less than 2 m exposed) till. Currently only part of the foreset beds are exposed, once again being worked for sand and gravel, although most of the active workings expose flat-lying sediments. We interpret the deltaic sediments as marking the input of local creeks into a high-level lake, which we informally name Lake Enfield. As noted previously, this lake drained southwest through the Fish Kill outlet (Figure 7b), through which we will drive next. We interpret the overlying till as indicating that a nearby ice margin overrode the sediments during a brief re-advance.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
86.0	0.0	Return to Hwy. 327.
86.3	0.3	Turn into the upper entrance to Robert Treman State Park. Although we won't go into the park, it preserves a spectacular example of joint-controlled erosion and re-excavation of a pre-glacial valley (a more detailed description is provided by Knuepfer and Lowenstein, 1998). We'll now drive into and through the outlet of the highest upland lake of Enfield Creek, though Fish Kill
86.9	0.6	Turn right onto Woodward Rd.
87.6	0.7	Turn left onto Stonehouse Road.
88.2	0.6	Turn right onto Douglas Road.
88.6	0.4	Turn left onto Fish Kill Road.
89.2	0.6	Turn left onto Millard Hill Road.
89.3	0.1	Turn right onto Horton Rd.
90.3	1.0	Turn left onto Trumbull Corners Rd. Note the marsh to the east, which is the head of Fish Kill and the outlet of Lake Enfield.
91.0	0.7	Turn left at the intersection of Sebring Road (straight ahead) and Turmbull Corners Road; you'll be continuing on Trumbull Corners Road. Gravel pits in this area and immediately to the south expose thick sections of sands and gravels. Most exposures show foreset-type dips, suggesting deposition into another upland lake (which we call Lake Newfield). The controlling outlet for this lake was at Pony Hollow to the southwest, at a modern elevation of about 1230 feet. However, small upland lakes persisted until ice completely retreated from the main Cayuga Trough to the east, as indicated by the thick foreset sequence at the next stop.
92.3	1.3	Turn left onto Hwy. 13.
93.6	1.3	Turn right at the north turn-off to Newfield (Main Street) then immediately left onto Taber Rd.
93.8	0.2	Drive on Taber Rd. to entrance to gravel pit (permission of the Taber family required). This is STOP 7

STOP 7. TABER GRAVEL PIT

This pit exposes a thick section (>70 ft or 21 m) of bedded sands and gravels. It is part of a lobe along West Branch Cayuga Inlet between 950 and 1050 feet (290-320 m) that we interpret these as a deltaic complex. This is most properly interpreted as a kame delta into Lake West Danby; the outlet extends to the southeast along a kame surface between the West Branch of Cayuga Inlet Creek (here) and Van Buskirk Gulf at the northwestern end of the Valley Heads Moraines sequence at West Danby (pictured and described by von Engeln, 1961).

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
93.8	0.0	Return to vehicles.
94.0	0.2	Left onto Hwy. 13.
98.0	4.0	Left onto Mazourek Rd.
98.2	0.2	Brief stop at Pony Hollow to view outlet of Lake Enfield-Lake Newfield complex.
98.5	0.3	Continue on Mazourek Rd. to Hwy. 13 and turn left.

111.7	13.2	Continue on Hwy. 13 to Hwy. 223 (Ithaca Road), north side of Horseheads. Turn right onto Hwy. 223.
112.4	0.7	Right onto County Road 21.
112.5	0.1	Left onto Wygant Road.
114.1	1.6	Right onto Hwy. 14 at north end of Horseheads. This area formed the outlet for Lake Watkins and Lake Newberry, as the Seneca Lake trough, later connected to the Cayuga Lake trough, maintained a stable lake level throughout retreat of the ice sheet from the Valley Heads Moraine position here to the north end of modern Seneca Lake and until an outlet to the west at Batavia was opened (Fairchild, 1899; von Engeln, 1961).
126.0	11.9	Junction Main St. in Montour Falls. Shequaga Falls, aka Montour Falls, is 0.3 mile (almost 0.6 km) west. An excellent view of the falls and the broad deltaic surface of Lake Watkins at Odessa are available from the bridge at the top of the falls. If time permits, we will detour to this viewpoint. Otherwise, continue north on Hwy. 14 into Watkins Glen.
127.9	1.9	Lower entrance to Watkins Glen State Park. This is certainly the most famous and most visited of all the Finger Lakes glens (gorges). Watkins Glen Creek descends some 450 feet (m) through a narrow gorge marked by cascades and falls and accessible along a spectacular gorge-bottom trail.
128.3	0.4	Junction Hwy. 409 (west) and 414 (east). Turn right onto Hwy. 414.
129.0	0.7	Turn left into Lakeside Park for a brief rest stop. STOP 8.

STOP 8. LAKESIDE PARK, WATKINS GLEN

Here at the south end of Seneca Lake we are afforded a spectacular view not only of the Cargill salt facility immediately to the west, but of the Seneca Lake trough. The lower slopes of the trough at its southern end are precipitous, and most tributary streams enter via waterfalls at or near the mouth of their incised glens. Tributaries are marked by hanging deltas, just as is the case in the southern Cayuga Lake trough. Here, however, the top delta tends to be very broad with thick sediments, the result of the relatively long-duration (at least compared to the other Finger Lakes) stable Lake Watkins pro-glacial impoundment. Particularly prominent examples are preserved at Hector Falls Creek, visible to the east (Figure 6), and at the upper parking area for Watkins Glen State Park.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
129.0	0.0	Turn right back onto Hwy. 414 towards Watkins Glen village.
129.7	0.7	Turn right onto Hwy. 14 north. We'll take this north all the way back to Geneva.
151.3	21.6	Bridge over Keuka Lake Outlet and junction Hwy. 54. Although the barbed shape of Keuka Lake, the next Finger Lake to the west, suggests an original southward drainage system, modern post-glacial drainage is to the northeast through this channel connecting Keuka Lake with Seneca Lake. We drop to Keuka Lake Outlet across a series of delta-like terraces, many with gravel pits. Although we have not studied this area, we suspect that the terraces record incision that mostly occurred during late-glacial lake-level drops below the Lake Hall level, as is most likely true for the other tributaries to Seneca Lake. Detailed study of these deposits could well yield a much more precise chronology for the early post-glacial lake evolution.
163.0	11.7	Bathurst Castle on right; entrance to Village of Geneva.
164.4	1.4	Junction Hwy. 14 and Hwys. 5/20 in Geneva and end of trip

GEOLOGY AND THE DEVELOPMENT OF UPSTATE NEW YORK'S DISTINCTIVE COBBLESTONE ARCHITECTURE

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INTRODUCTION

Cobblestone buildings are the most distinctive structures in upstate New York's regional architecture. Most of these handsome and durable buildings are farm houses built between 1825 and 1860, the prosperous years following the completion of the Erie Canal. Most of them are found in the glaciated lowlands bordering Lake Ontario in a belt that extends from Syracuse to Buffalo. Upstate cobblestone construction is characterized by 1-2 foot-thick, rubble-filled walls that are more than 50% by volume lime mortar, which are faced with a veneer of fist-sized cobbles laid in horizontal courses.[1] Individual cobbles are "framed" with hand-profiled mortar joints. The horizontal mortar joints separating the horizontal courses of stones are typically continuous across an entire wall and therefore more visually prominent than the vertical joints between adjacent cobbles within a course (Figure 1). Cobblestone construction techniques were used to build at least four of the architectural styles popular during the later half of the 19th century: Federal, Greek Revival, Gothic, and Italianate. Although U.S. examples of cobblestone buildings can be found from New England to Colorado, roughly 90% are located in upstate New York with the greatest concentrations are in Ontario and Wayne counties.

The development of cobblestone architecture and its prevalence in Ontario and Wayne counties is remarkable example of the interplay between the area's 19th-century human history and the bedrock and surficial geology of the area. The Erie Canal and the economic development it fostered was the impetus for constructing most of these buildings, but the lay of the land and the types of materials which were (and were not!) available to builders did much to determine how those buildings were constructed.

This paper and the accompanying field trip is designed primarily as an introduction to cobblestone architecture for geologists. Somewhat paradoxically, then, it focuses more on architecture and history, which most geologists will know less about, and less on geology, which most geologists will already know or easily learn. The first part of the paper is a cobblestone "primer" describing the technique and the types of materials it employs and the architectural styles to which it was adapted. The second part examines the cultural and geologic reasons for the development of cobblestone architecture in upstate New York.

Acknowledgements

The material in this paper is drawn from many different sources, but a few deserve special mention at the outset. Paul Briggs, a restoration mason working out of the Ithaca area, showed me how cobblestone masonry is done and infected me with his enthusiasm for cobblestone buildings. Much of my understanding of historical and architectural aspects of cobblestone buildings derives from a class that I co-taught with Professor Dan Ewing, formerly of the Hobart and William Smith Colleges Art department. In particular, I draw heavily in what follows from Dan's presentations on the architectural history and his analysis of the ways in which the Erie Canal was and was not important in the development of cobblestone structures. For those wishing to take up the subject for themselves, the Landmark Society of Western New York, in Rochester, has a superb collection of materials on cobblestones, including the amazingly comprehensive survey of upstate cobblestone structures compiled by Robert Roudabush in the

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[1] There is considerable debate about what should and should not be called "cobblestone construction" and the term may apply to very different styles of masonry walls in other places. This article deals only with upstate New York cobblestones where the stones are relatively small, less than 20 cm in largest dimension, and framed with mortar.

late 1970s and recently updated by Stephen and Marion Wolfish. Cynthia Howk of the Landmark Society is a patient, knowledgeable and helpful guide to these collections. My thanks as well to the property owners who have given permission for the group to visit their homes: Mrs. Bernard Harkness, Mr. Herb Aldwinckle, Steve and Jane Westfall, Mr. and Mrs. Jack Beilstein, Mr. Gregory Nunn, Mr. Roger Cunninham, and Mr. and Mrs. Calvin Van Derlike.

PART I: A COBBLESTONE PRIMER

Figure 1 shows the basic components of cobblestone construction: cobbles, mortar, and structural stone components such as quoins, sills, and lintels. Each of these is discussed in detail below. Though assembling these components has often been described as a "lost art," Paul Briggs has shown that there is little mystery to building a cobblestone wall. The author learned most of the techniques described below in cobblestone masonry workshops led by Briggs, and in the application of those techniques to the construction of two small cobblestone structures on his own property, including one under Briggs' direct supervision.

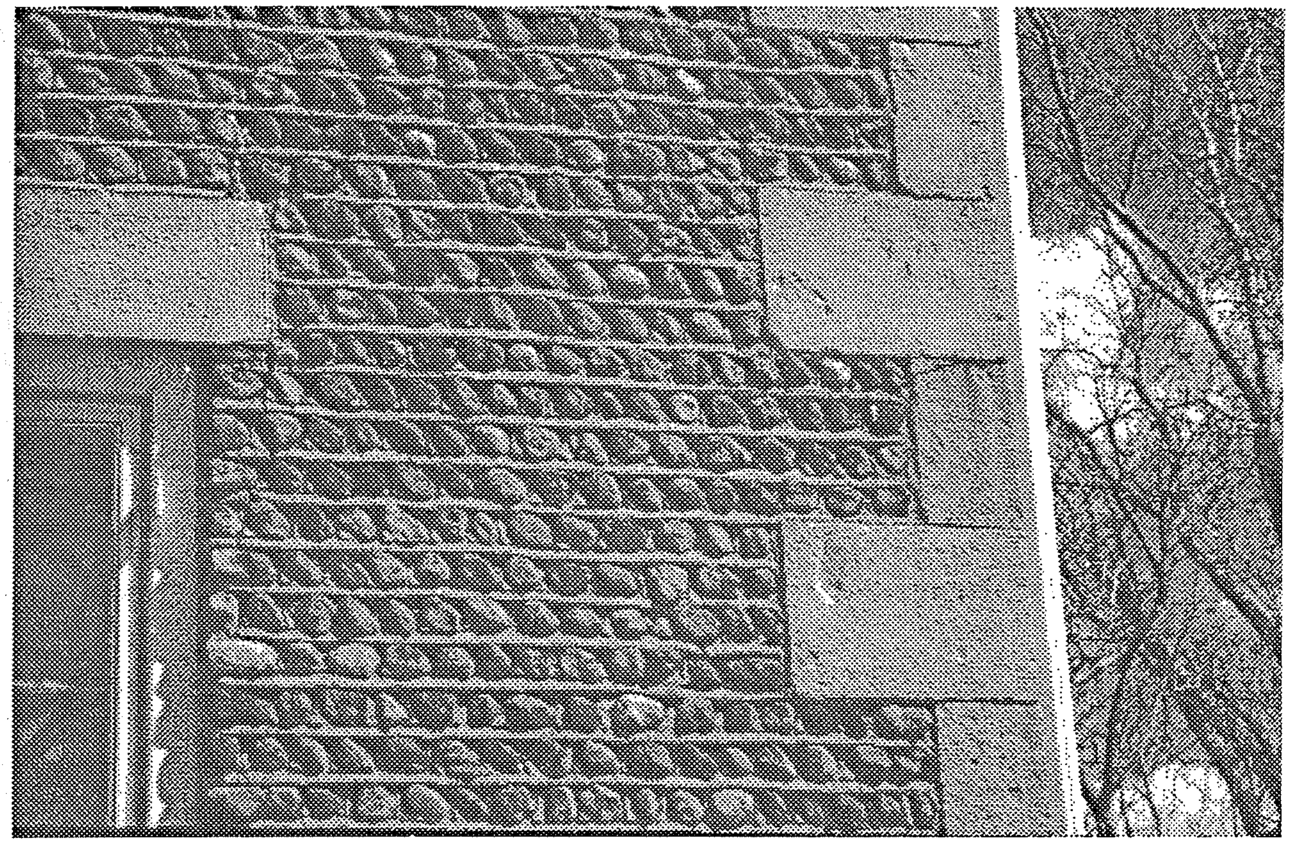

Figure 1. Part of a cobblestone wall. Note the rounded to subangular cobbles of varying lithologies, the prominent horizontal mortar joints, the cut stone blocks used to reinforce the corners (quoins), and the cut-stone lintel used to support the window opening. This wall is part of the Barnes House (STOP 2), a fieldstone type of cobblestone structure.

Cobblestone Materials

Cobbles

The cobbles themselves are simply fist-sized rocks. There are two basic types, "fieldstone" and "lake-washed." Fieldstone cobbles are subangular to rounded rocks that vary in average dimension from approximately 10 to 20 cm. These cobbles are derived from glacial till and outwash deposits and many lithologies are represented in a typical fieldstone wall: sandstone, limestone, quartzite, gneisses, and coarse and fine-grained igneous and metamorhpic rocks. Dark red to gray Medina sandstone cobbles are the most abundant type of cobble. Builders were careful to exclude shales and sulfide-bearing cobbles, but with those exceptions, fieldstone cobbles are samples of the locally available cobble-sized glacial debris. Fieldstone structures are the earliest cobblestone buildings. Though they continued to be built throughout the cobblestone era (roughly 1825 to 1860), fieldstone structures are less common among later cobblestone buildings.

"Lake-washed" cobbles are the same glacially-derived stones as found in fieldstone structures, but these cobbles are typically very well-rounded prolate ellipsoids. They are called lake-washed because many accounts describe collecting these stones along the shores of Lake Ontario, particularly near Sodus, N.Y., in Wayne County. While these wave-rounded cobbles are abundant on the Lake Ontario shore, similarly shaped cobbles can be found in tills and outwash deposits and may have been hand-picked for that reason, thus all so-called "lake-washed" cobbles may not have been rounded by wave action in a lake. Though lake-washed cobbles include the same sizes and range of rock types seen in fieldstone structures, many structures, particularly in the latter years of the cobblestone era, use only lake-washed stones of a similar size (usually 4-7 cm), shape (all prolate or all oblate ellipsoids), lithology (typically the Silurian Medina sandstone) and colors (overwhelmingly dark red).

Though less than 50% of a cobblestone wall is made up of cobbles, constructing a two story house still requires a large pile of rocks. Several accounts describing gathering the rocks for a structure survive. Boys were paid ten cents a day to walk beside a "stoneboat," a sled pulled by an ox or other draft animal, and throw cobbles turned up by plowing into the sled. Other accounts describe farmers who hauled wheat to Sodus for shipping returning with a wagon load of cobbles. Records of the construction of the Phelps Baptist Church (1845) indicate that the congregation supplied the cobbles, which were brought to the site by ox cart from the fields in the surrounding area. There are also accounts of community "bees," similar to barn raisings for the purposes of collecting and/or sorting the stones. Size sorting of the stones was clearly important. Schmidt (1966, p. 2) describes how the stones were sorted using an iron "beetle ring" or with a board or with appropriately sized holes. In some cases it took a period of a few years to gather the stones needed for a building and these were supplied by the future owner of the building, not the mason.

Mortar

Cobblestone walls use lime mortar, not the Portland cement mortars used in modern masonry construction. Lime mortars have been used since antiquity. Their main ingredients are lime and sand. Lime is produced from the "burning" of limestone, a decarbonation reaction:

$$CaCO_3 + \text{heat} \rightarrow CaO + CO_2(\text{gas})$$

This reaction is endothermic, requires sustained temperatures of 800-1100°C and results in a 44% weight decrease. The resulting product is quicklime, CaO, which was pulverized and either used immediately or sealed in casks for later use. The author knows of one large lime kiln that survives in South Sodus in Wayne County. This is a masonry "chimney" roughly six to eight meters square and approximately ten meters high. Limestone from a nearby quarry was loaded in from the top, and a fire was kept burning at the base until the reaction was complete. Probably there were many lime kilns operating in the area during the cobblestone era, some of which may have been little more than a pit with limestone piled on top of firewood. Phelps village historian John Parmalee suggests that many large farms had their own lime kilns (Parmalee 1986, p. 62). This might explain why a cursory survey of period classified advertising turned up ads for stone, nails, lumber, bricks and other construction materials, but not lime.

Regardless of its source, the quicklime was "slaked" or saturated with water. Slaking hydrates the lime and produces a lime paste or putty roughly two to three times the volume of the powdered quicklime.

Several accounts describe the slaking process as being done in a in a two meter square pit at the construction site. This pit was prepared and the slaking process begun in the fall prior to the summer in which a building project was to be undertaken. This extended "seasoning" is possible because, unlike Portland cement based mortars, lime mortars require air to cure and harden. Thus, as long as a layer of water remained on the lime putty, it would not set. Regardless of the extended "soaking" such a treatment would allow, a common feature of all cobblestone mortars is the presence of white chunks of unground quicklime in the mortars.

To make the final mortar, the lime putty is mixed with sand and other variously reported ingredients (clay, cow manure, and "secret ingredients"). Reported recipes give the ratio of lime to sand as varying from one part lime to four to seven parts sand by volume. The sands used in cobblestone buildings are typically glacial outwash sands that have abundant brown and red lithic clasts. Several cobblestone houses, particularly later ones with more refined mortar joints, show the use of two "grades" of mortar, a bedding mortar with coarse sands for use in the interior of the wall to better support layers of cobbles, and a finer jointing mortar that was used on the exterior. Clay was a common additive used to increase plasticity and provide some coloring. The resulting mortars are notable for their warm brown and tan colors which make them very distinct from the cool blue to gray tones of Portland cement-based mortars (this is painfully obvious where Portland mortars have been used to repair cobblestone structures).

Lime mortars are critical to cobblestone construction because they set more slowly, are more plastic and are easier to work. Paul Briggs has suggested that the attribution of cobblestone masonry as a "lost art" may in part result from attempts by modern masons to duplicate cobblestone techniques using modern mortars that set too quickly, are too stiff, and are to difficult to trowel. As an aside, synthetic Portland cements were developed in Britain in 1824, but did not become common in the U.S. until 1880. Naturally occurring cements capable of setting under water, which 19th-century builders called "hydraulic cements" or "water limes," were known in upstate New York during and were important in the construction of Erie Canal locks.

Structural Stone Components

Because lime mortars are porous, relatively soft and have low tensile strengths, corners and wall openings in cobblestone structures are potential areas of weakness. Most cobblestone masons address these weaknesses by reinforcing the corners and openings with another, stronger material. In the classic cobblestone, this is done with cut dimension stone, usually limestone or sandstone, but there are also examples that use rough stone blocks, brick, or even wood for these purposes. The soft lime mortar that might be exposed at an exterior corner would be easily abraded and could thus weaken the building. To overcome this difficulty, corners are typically formed using rectangular blocks of stone called "quoins" (the word is derived from the French word for "corner"). Window sills are potentially vulnerable because water shed by the window can percolate into the porous mortars of the sill and be degraded by subsequent freeze-thaw cylces. Thus the horizontal, upward facing surfaces of windows and doors require a sill to protect the underlying mortar. Lentils span wall openings such as windows and doors to support the wall above. A more decorative use of cut stone is a "water table," a line of sill-like cut stones that define the top of the foundation wall (often of very rough stone construction) and the cobblestone wall above.

In most cobblestones, the structural stone components are cut stones prepared by skilled stone masons (probably rarely the same mason who laid the cobblestone). Figure 2 shows a quoin from an 1853 school building in Gypsum, N.Y. (STOP 5), that is typical of cobblestone stone work. The block is dressed to an accurate rectangular shape on the exterior surfaces. A decorative tooled margin created by repeated chisel blows creates the decorative exterior band, while the interior has a dimpled surface created by repeated blows of a bush hammer (for more information on stone cutting and interpreting the tool marks left on cut stones, see Cramb, 1992). Though the techniques used to dress cut-stone vary little from cobblestone to cobblestone, the type of stone used for structural components does. All of the cobblestones the author is familiar with in the Ontario and Wayne county areas use a light-gray weathering, fine-grained, massive limestone, probably the Devonian Onondaga. Oral tradition for at least one cobblestone house, the Barnes House south of Geneva (STOP 2), identifies a quarry in the

Onondaga near Seneca Falls as the source of stone. Farther to the west, dark red Medina sandstone or Lockport dolomite is used for cut-stone components.

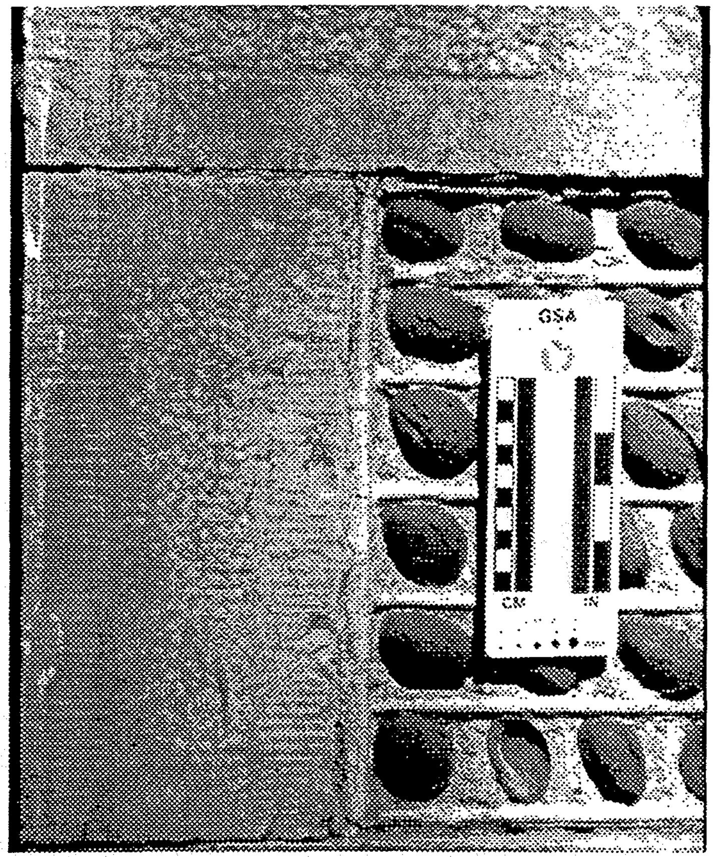

Figure 2. Cut-stone quoins in the 1853 Plainsville School (also known as Gypsum, STOP 5). These quoins have a "chisel-draughted edge" created by repeated chisel strikes and a dimpled central panel produced with a tool called a bush hammer—the stone mason's equivalent of a meat tenderizing mallet. This is a lake-washed cobble building as shown by the uniform color and size of the cobbles. Just visible in this photograph are the beaded mortar joints used between the courses.

Building a Cobblestone Wall

Figure 3 shows a small cobblestone wall under construction. Working from a foundation of large blocks, a set of backing stones for the inside wall is laid up and the quoins are laid true and square. To "fill" the space between the quoins with cobblestones, a thick bed of mortar is laid down. Individual size-sorted cobbles are then placed on this mortar bed so that their upper surfaces define a roughly horizontal line and the ends that project outward from the wall are flush with a guide string strung between the corners of the two quoins. These cobbles are placed so that they have approximately 2 to 4 cm gap between them. Once the stones are thus arranged, the mason fills the gaps between stones with mortar. As the mortar is thixotropic, this is best done by flinging a wad of mortar into the gap with a small trowel; repeated flings fill the gap up to the height of the stones on either side. With the gaps between cobbles filled, the joints are formed using a flat pointing trowel. The vertical joints across the entire wall are formed first. Using upward strokes, first on one and then the other side of the joint's center line, the mason creates vertical to inward sloping surfaces that meet as a broad V. Typically this is broader at the base than the top. Once all the vertical joints for a course have been formed, the mason shapes the upper surfaces of the two angled surfaces that will form the horizontal joint at the base of the course. This upper surface is created by running the trowel horizontally along the base of the stones, pressing inward and downward to create a mortar "shelf" that is angled down and away from the wall at roughly a 45° angle. Finally, the mason uses a slicing motion to cut away the excess mortar along this shelf and in the

Figure 3. A small cobblestone wall under construction. Note the "backing stones" that form the back of the wall and the line of cobbles along the front. In between is the "trough" which will later be filled with rubble and mortar in advance of starting the next course.

process forms the face of the lower part of the horizontal joint, a surface that slopes inward and down. The visual "line" of the joint is formed by the intersection of the two surfaces; while contact of the upper and lower surfaces of the joint with the cobbles may be very irregular, the line of the joint is produced by the intersection of the joint's upper and lower surfaces and its linearity and horizontality is limited only by the mason's skill.

Completion of the joint work for a course leaves an irregular trough between the backing stones and the stones laid up as the horizontal cobblestone course. This trough is important because it compensates for the different sizes of the cobblestones—larger stones can extend farther back into the trough than shorter ones. Such larger stones help to strengthen the final wall by "tying" the cobblestone work to the wall's interior. After one or two courses of cobblestone is laid, this trough is filled with mortar and waste stones, rocks that are not well sized shaped, or colored for the cobblestone exterior. Thus, cobblestone walls are a type of rubble-filled mortar construction.

Only two or three courses of cobblestones can be laid in a day. If more are attempted, the weight of overlying courses causes the slow setting mortar of lower courses to bulge and sag. And cobblestones cannot be laid during rain (unless the site is covered) or during freezing weather. Furthermore, it is the author's experience that cobblestones masonry laid up in the late fall (September or October) is very susceptible to spalling, probably because it does not dry and cure adequately before subjected to freezing temperatures. Given these constraints it is easy to understand why many large cobblestone houses took two or three years to complete.

There are important variations from the basic techniques discussed above. A few early cobblestones have mortar joints that form a hexagonal pattern around the cobbles, and some late, highly refined cobblestones have rounded bead mortar joints that must have been made with a special trowel (STOP 5). Schmidt (1966) and Shelgren and others (1978) have detailed drawings of these and other mortar techniques. Schmidt also identifies a few partially demolished cobblestone walls in which the cobblestones are a veneer applied to a much rougher rubble filled wall.

Development of Cobblestone Techniques

Cobblestones techniques show a progressive refinement over the cobblestone era. Schmidt (1966) has proposed division of cobblestone techniques into an early, middle and late periods based upon the nature of the mortar joints, the size of the cobblestones, and the sorting of the tones for color, shape, and size.

Early, 1825-1835: Early Period cobblestones are characteristically made of large fieldstones, typically with minimum dimensions greater than 10 cm. The horizontal joints of early cobblestones are commonly wavy and lack the striking horizontal lines of later cobblestones. Quoins may be dressed cut stones, but roughly shaped blocks are also common. Wooden or brick window sills and lintels are more common than in later structures.

Middle, 1835-1845: Middle Period cobblestones may be either fieldstone or lake-washed, or combine the two. Stones are typically smaller than in early cobblestones with minimum dimensions closer to 6 cm's. Some stones will show evidence of having been selected for shape, size or color, particularly on front wall of the structure. Stones may be set in color-selected rows, herringbone patterns, or bands of coarser and finer stones. Lake-washed stones first appear in the late 1830's and become the preferred stone type by 1845. Beaded mortar joints (see below) also first appear in this period.

Late, 1845-1860 and later: Late Period cobblestones carry the innovations of the Middle Period to extremes. Stone sizes become very small, less than 6 cm, and are selected for uniformity of color, size and shape. Mortar joints are highly refined and often beaded. Beaded joints emulate wood moldings; they are worked with a special tool that leaves a half-round ridge or "bead" protruding from the joint surface. The uniformity of the stones and the refined mortar work give late period cobblestone walls a uniformity that contrasts starkly with early and middle fieldstone walls.

The increasing refinement of cobblestone technique suggests some insights into late 19th century aesthetics. Given that the number of courses of cobblestone that can be laid at one time are limited, using smaller stones is much more labor intensive. This explains the frequently made observation that larger cobbles are used on the sides and backs of buildings. Add to the use of small stones the more refined, and presumably skilled, treatments of the mortar joints, and it is clear that the refined styles of late period houses must have been significantly more expensive. This is supported by the fact that even on refined late period houses, it is usually only the front wall that receives the most refined treatment. In an age when Americans were embracing the new technologies of the Industrial Revolution, it may well be that the much more uniform and mechanical nature of the refined late-period cobblestones was seen as more "modern." In many ways, one looks at these late period walls and gets the sense that they are really cobblestone walls imitating brick or some other more "uniform" and man-made material. Architect and cobblestone expert Carl Schmidt was the first to note and this phenomenon: "Small lake-washed stones had no structural feeling, they were merely veneer. The sparkle and life of the varicolored fieldstone walls disappeared because all the stones were of the same size and color. The machine-made appearance of such a wall is monotonous. The fieldstone walls of the Early Period and the first half of the Middle Period expressed a feeling of material correctly used; the did not make a display of the mechanical skill of the masons as did the cobblestone work of the Late Period" (Schmidt, 1966, p. 6).

Architectural Styles

While there are a few very plain and utilitarian cobblestone buildings, they are the exception rather than the rule. Most are cobblestones are highly stylized buildings that were built in one of the architectural styles that dominated the period: Federal (1780-1830), Greek Revival (1820-1850), Gothic Revival (1830-1880), and Italianate (1840-1880). The accompanying road log describes cobblestone examples of each style and notes some of the characteristic identifying features of these styles. These designs were adopted from pattern books that were common in the middle and late 19th century. For example, the *Wayne County Sentinel*, a weekly newspaper published in Palmyra contains the following advertisement in its Tuesday, October 18, 1831 (Volume 9, number 5) edition:

> *The Practical House Carpenter*
> *Being a complete development of the Grecian orders of Architecture, methodised (sic) and arranged in such a Simple, Plain and Comprehensive manner, as to be easily*

understood; each axample (sic) being fashioned according to the style and practice of the present order, three examples of the Doric order, three examples of the Ionic order, one example of the Corinthian order, and one example of the Cowpastie order, with all their details drawn to a large scale; to which are added a series of designs for Porticoes, Frontispieces, Doors, Windows, Caps and Sills, Frames, Sashes and Shutters, Base and Surces, Trusses for Roofs and Partitions, Stairs and &c. Engraved on Sixty-four large Quarto Copper Plates; by Asher Benjamin, Architect; Author of the "American Builders Companion" and "The Rudiments of Architecture" --Just received, and for sale at the Palmyra Bookstore, by E. B. Grandin, June 2, 1831

Beyond the fact that particular architectural styles, like the types of cobblestone work itself, allows us to roughly date cobblestone structures, these architectural styles are interesting again for what they tell us about the people who built these houses. Why, for example, would a farmer in upstate New York, build a house with elements taken from a Greek temple? Architectural historians have traced the origins of these fashions to American sympathies and national aspirations; for the Greek Revival these include pride in the American Revolution and democratic principles, as well as a desire to embrace an alternative to the British influences of the Federal Period. The roots of these styles and their symbolism are beyond the scope of this paper, but it is ironic that the people who built the upstate's cobblestone houses probably believed that these structures were and would be important more for the symbolism of these national styles rather than the local cobblestones with which they were built.

PART II: WHY DID COBBLESTONE ARCHITECTURE DEVELOP IN UPSTATE? WHY DID IT END?

Certainly the most widely circulated theory for the abundance of cobblestone structures in upstate New York is the "Erie Canal Theory." Though it may not be the earliest mention of it, this theory is well stated by Carl Schmidt in his 1966 volume on cobblestone masonry:

The building of the Erie Canal from Rochester to Buffalo between 1823 and 1825 provided the numerous masons necessary to build the scores of cobblestone structures in Western New York State......contractors realized that many more masons were needed to complete the canal within the specified time and that Western New York State could not supply them. Hence, they advertised for masons in New England and Pennsylvania. After the canal was completed many of these imported masons purchased farms and made Western New York their home. Consequently, there were many more masons than the building craft could normally assimilate. They needed masonry work to supplement their farm incomes. This is probably the principal reason for so many cobblestone houses on or near Ridge Road and the area paralleling the Erie Canal east and west of Rochester.
(Schmidt, 1966, p. 3)

Variants of this theory call upon English and/or Irish emigrants as the "imported masons." While it is certainly true that the beginning of cobblestone construction correlates well with the opening of the Erie Canal, correlation is distinct from causation and several lines of evidence call this theory into question.

Some cobblestones may predate the completion of the Erie Canal in 1825. There is no consensus on the age of the first cobblestone structure and many structures with construction details suggesting an early age are not reliably dated. Roudabush's survey of cobblestone structures identified one structure in Farmington, Ontario County, that has an 1810 inscribed on a portico. In a more in-depth survey of Ontario County cobblestones, Swartout (1980) questions the reliability of this date, but also reports a deed transfer record for this property dated 1825. While 1810 would be very early, this structure does seem to be pre-1825 and shows several interesting features suggesting an early date, including wooden lintels, pilastered front corners and cobblestone back corners without the use of quoins. There are several well-dated buildings constructed in the years 1825-1827 in widely separated areas of Ontario and Wayne counties; given that most buildings are undated, it seems likely that there are some pre-1825 cobblestones.

Roudabush (1980) points out that there are problems with the theory both in the location and the timing of the demand for masons during canal construction. The demand for masons in canal construction was primarily for the construction of locks and aqueducts, but 65% of the locks and 68% of the aqueducts on the original canal were east of Syracuse, while only 4% of cobblestone structures are found there. Roudabush's survey of dated cobblestones indicates that almost half of all the well-dated cobblestones, 47%, were built in the decade between 1836 and 1845. But the early success of the canal led to canal expansion projects that widened and deepened the canal. Reconstruction of the canal locks and other works began in 1832 and continued until 1862. Thus, during the peak years of cobblestone construction, there should have been sufficient employment for masons on the canal.

There is also a disparity between the masonry structures associated with the canal and cobblestone construction. Locks and other canal structures were built primarily with large, carefully cut and shaped limestone blocks (STOP 10). In contrast, cut stone was a relatively minor part of most cobblestone houses. A contract for the 1838 construction of the Tuttle house just west of Geneva (now the Cobblestone Restaurant) survives in the Ontario County archives and it calls for the stone components of that building, including "cut stone ready cut" to be delivered to the site by the owner, suggesting that the masons simply incorporated the precut blocks into the cobblestone walls, a task requiring care but little skill. In Lockport, west of Rochester, the canal crosses the escarpment of the Lockport Dolomite in a flight of five locks. Heralded in its day as one of the engineering feats of the world, this series of locks must have employed many masons. Interestingly, there are houses in Lockport that *were* made by canal masons (Plante, 1994). These are not cobblestone structures, but instead are made of cut stone blocks and much more closely resemble the type of stone work seen in canal locks and aqueducts.

Finally, there is little in the way of contemporary descriptions of cobblestone masons, but this silence may in itself be significant. For example, Schmidt's 1966 book reproduces the text of two accounts by farmers who had cobblestone buildings constructed for them. Both accounts are letters sent to local farm magazines and recommend these techniques to other farmers. In describing the benefits of cobblestone construction, they say nothing about "special" masonry skills being required. If cobblestone masonry was a difficult "art" requiring highly specialized skills, it seems likely that these accounts would have mentioned the necessity of finding a mason skilled in the technique, but they do not.

Given these above, it seems more reasonable that indigenous masons built these structures. How were cobblestone building techniques first introduced into the area? Shelgren and others (1978, p. 7-13) document cobblestone buildings in the southern part of England that predate upstate cobblestones and are similar in many ways. This could be the source, but structures built with rubble-filled cobblestone walls are known back into classical times and it may be that the technique developed independently in different areas at different times. It seems altogether possible that a capable 19th-century workman familiar with the basics of mortar and faced with an abundance of rounded cobbles and a scarcity of square or rectangular rocks would be able to invent the technique for himself.

Though Erie Canal masons may have played only a small role in the development of cobblestone buildings, the Erie Canal and the economic development it fostered are critically important. Begun in 1817, completed through Rochester by 1823, and fully operational by 1825, it is difficult to overstate the importance of the Erie Canal, both regionally and nationally. For farmers in rich agricultural counties such as Ontario, Wayne, and Monroe, the canal provided a way to transport their produce to larger markets. This fundamentally changed the nature of agriculture along the canal's route by allowing these farmers to shift from subsistence farming, to cash crops, particularly wheat. With the development of cash crops and markets in East Coast cities like New York, upstate farmers began to experience significant prosperity in the years following the canal's construction. Out of that same prosperity, came the desire to build more permanently, in effect to build a structure that was not only functional, but symbolically important as well. Masonry, and especially stone, have always been the preferred materials for such structures. Masonry construction is more permanent, has greater resistance to fire, does not have to be painted, and has always been associated with solidity and prosperity. These advantages were all the more persuasive because wood construction of the early and middle 19th-century used heavy timbers held together by mortise and tenon joints secured with wooden pins. This type of construction was much more expensive than the dimension lumber framing that we are familiar with today and required the services of a skilled carpenter. Board construction was uncommon because both boards (which had to be sawed from timbers, an additional step) and nails, which were individually handmade by a blacksmith, were expensive.

Geological Factors Important to the Development of Cobblestones

The geology of upstate New York is also critical to the development of cobblestone buildings. In the area in which cobblestones are most abundant, the weak shales and evaporites of the Silurian Salina formation are sandwiched between the more resistant Lockport Dolomite (below)and Onondaga Limestone (above). The slight south dip of these units (approximately 1°) produces a broad east-west strike belt that has been scoured by glaciation to produce an east-west trending lowland that has little topographic relief. It is across this lowland that most of the Erie Canal was constructed. The greatest expense in canal building is in the construction of locks. As the canal profile in Figure 4 demonstrates, the first 100 miles from the Hudson to the top of the Mohawk watershed Utica requires 51 locks and has an elevation gain of 406 feet. Just west of Utica, the canal enters the outcrop belt of the Salina formation and the "lowlands" south of Lake Ontario. For the next 225 miles, only 25 locks are needed to accommodate 210 feet of elevation change (up and down), with a net elevation gain of 86 feet to Lockport. These same lowlands were also excellent farmlands. Thus, the geology of upstate New York was critical to the development of the canal and thus to the prosperity and cobblestones houses which followed.

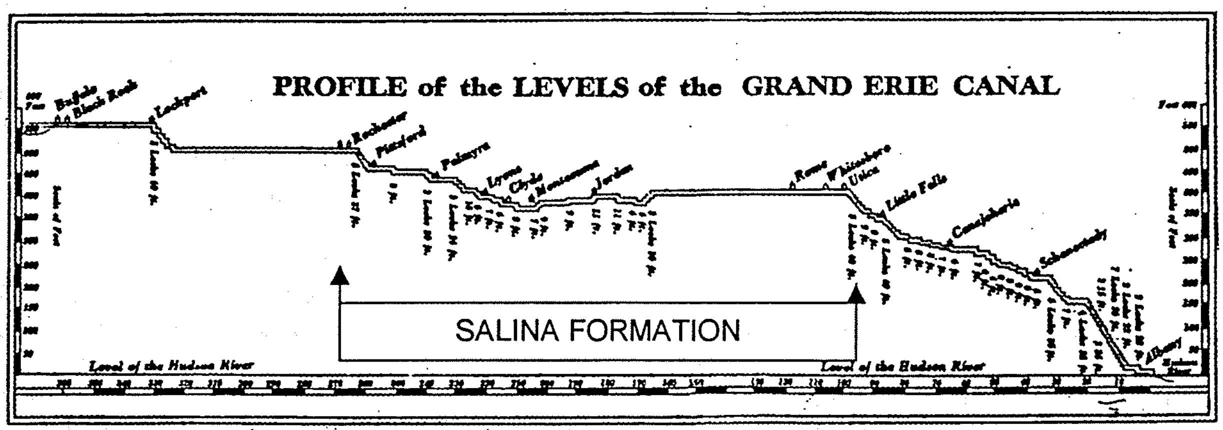

Figure 4. Profile of the original Erie Canal. The east-west trending outcrop belt of relatively weak Silurian rocks from Utica west helped to produce the subdued topography of the lowlands bordering Lake Ontario. Without this lowland, the Erie Canal would not have been feasible (Figure modified from

As middle- to late-19th- century upstate farmers began to consider building new masonry homes that would reflect their growing prosperity they faced one important problem. Good building stones crop out sporadically along the trend of the Onondaga Limestone and southward, and in scattered areas to the north of the Lockport Dolomite (Figure 5). But in most of the area in which cobblestone buildings are common, locally available stone consists chiefly of glacially deposited, potato-shaped cobbles. Limestone outcrops were sufficiently close to provide lime and cut-stone components, glacially deposited outwash sands were abundant and widespread. Using these materials that were at hand, cobblestone building techniques and cobblestone buildings emerged.

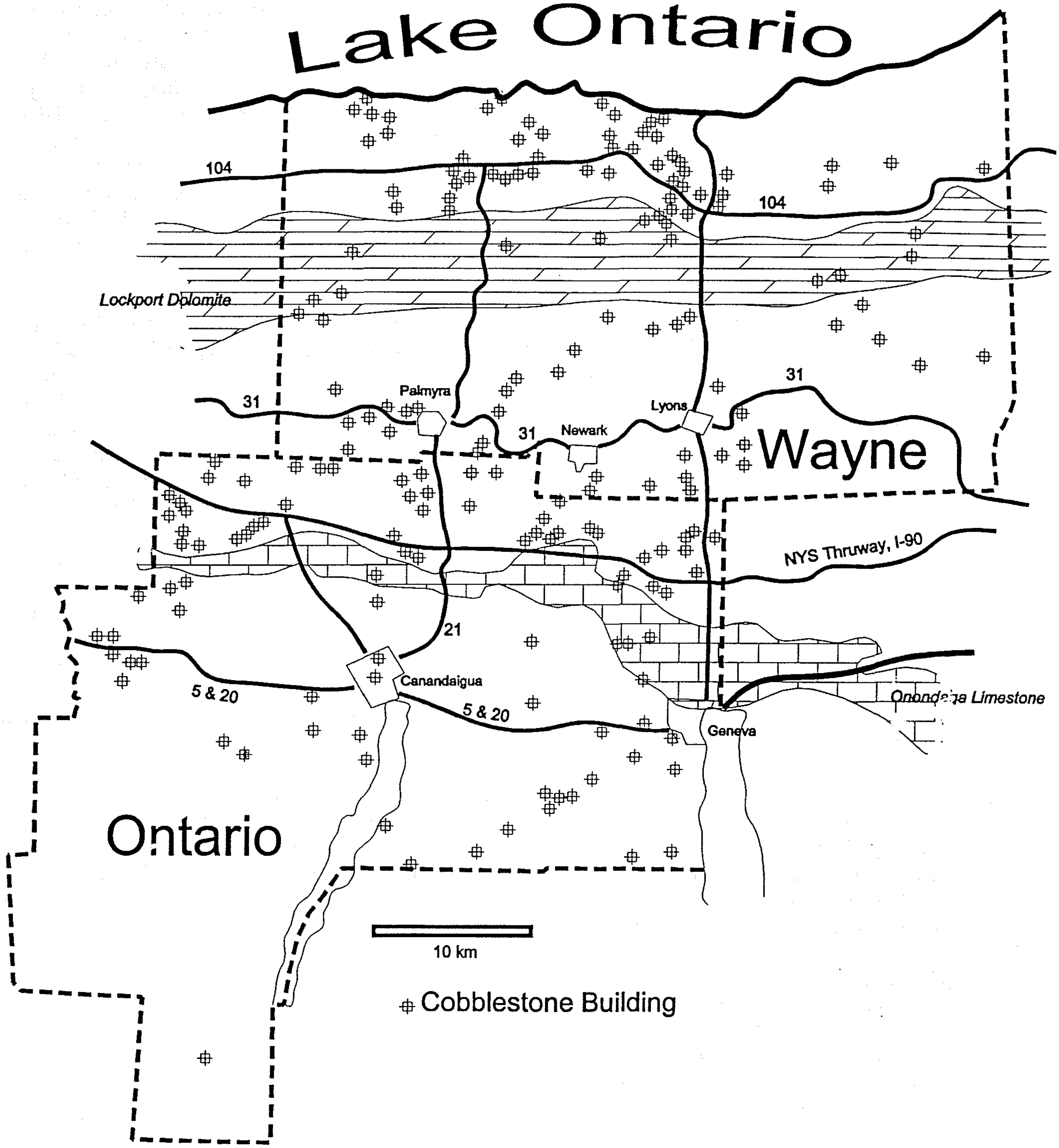

Figure 5. Map of Ontario and Wayne counties showing the distribution of cobblestone structures relative to the areas underlain by Onondaga limestone and Lockport dolomite. Outcrops of these units are sparse. Cobblestone structure location information compiled from Swartout (1981) and Wayne County Historical Society (1979).

If flat or block-shaped stones, ones easier to build with, had been widely available in the Ontario lowlands, they probably would have been used instead of cobblestone. Two lines of evidence support this assertion. First, as one moves south from the Onondaga outcrop belt, cobblestone houses become scarce and one sees instead stone structures built with dark-colored Devonian siltstones and sandstones taken from formations above the Onondaga. The nearly perpendicular intersection of bedding planes and joint surface in these rocks produce slab and block-like stones that would have been much easier to build with. Geneva Hall on the campus of Hobart and William Smith is a good example. It was constructed in 1822 of slabby silt and sandstones from outcrops along the lake to the south brought to the site by boat. There are a few stone buildings in the lowlands where cobblestones are dominant, but all of these that the author is aware of are within a mile or less of stone quarries. Given that Late Period cobblestone builders carefully selected cobbles for color, shape and size and strove for uniformity, it seems likely that they would preferred the more regular stone blocks had they been available at reasonable cost.

Only a few cobblestone structures were built after 1865. Why was cobblestone construction essentially abandoned after that date? A few authors have suggested that the construction of New York's roughly 700 cobblestone buildings may have exhausted the supply of cobbles. Hogwash. No geologist, and no person who has ever exercised a shovel in northern Ontario or southern Wayne County could accept this theory—there are probably enough cobbles in these areas to rebuild the great wall of China several times over. Instead, the demise of cobblestone construction likely was caused by a combination of technological and economic factors. The increasing prevalence of steam powered saw mills, the continuing development of machines that could make low-cost nails, and the ability to transport lumber and nails by rail all served to lower the cost of the materials for building a frame house. To take advantage of lower cost nails and dimensioned lumber, George Washington Snow invented the "balloon frame" house in 1832. Using this system, very much like modern frame construction, a few relatively unskilled men could quickly frame a house. Thus the labor costs for wood frame houses were also reduced, a particularly important factor in the inflationary labor markets that followed the Civil War (Tenney, 1987). All of these factors increased the cost differential between a cobblestone house and a frame house. The old advantages of cobblestone construction, durability, lack of maintenance, and fire resistance remained, but now that much cheaper alternatives were available, farmers began their transformation into consumers: they realized that they could buy other increasingly available goods rather then build these handsome structures.

HOW TO LOOK AT A COBBLESTONE HOUSE

With their understanding of the natural stone materials used in cobblestone houses, their experience in "reading" the visual clues of composition, texture, and pattern in outcrops, and their training in recording such details, geologists are well-adapted to looking at and understanding many of the subtleties of cobblestone construction. What follows is a brief checklist of observations that may be useful for those just beginning to look at these interesting buildings:

<u>The Building</u>

- Function? (home, barn, church, etc.)
- Architectural style and stylistic elements that support this designation?
- Presence of a date stone?
- Evidence that the house was built in stages? (Many are!)
- Quality of moldings, door facings, etc.?
- Later additions/modifications/renovations?
- Location relative to local geology? Were alternative materials readily available?

<u>Cobbles</u>

- Types of cobbles--field or lake-washed? Sizes? Colors? Variations within the structure?
- Patterns defined by color/size/orientation of cobbles? (e.g., herringbone, color bands, etc.)
- Number of cobble courses per quoin on front, side and rear walls?

Mortar
- Sand size ranges in the mortar? Bedding (coarse) and finish (fine) mortars?
- Presence, abundance of white lime "lumps?"

Joint Work
- Basic form of the joint work, both vertical and horizontal joints—V-shaped, beaded, etc.?
- Linearity and horizontality of joints?

Structural Stone Components
- Presence and types of materials used for quoins, sills, lintels, "water tables"?
- Tool markings on cut-stone components?
- Changes in quality of stone components from front, to side, to rear of building?
- Is this building representative of the early, middle, or late cobblestone period?

Having made these observations, one can then ask some of the more interesting questions—Who built this building and why? What factors influenced their choice of styles, techniques and periods? What does the building itself tell us about the people who built it? How does this building fit into the context of upstate cobblestones? Where did the materials come from?

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ROAD LOG FOR GEOLOGY AND THE DEVELOPMENT OF UPSTATE NEW YORK'S DISTINCTIVE COBBLESTONE ARCHITECTURE

PLEASE NOTE! ***All of the houses described below are private residences. Anyone wishing to visit these structures must obtain the permission of their owners! The description of these houses in this road log in no way implies the permission of the owners for others to trespass on these properties!***

STOP 1: COBBLESTONE TOOLS AND TECHNIQUES, HWS CAMPUS

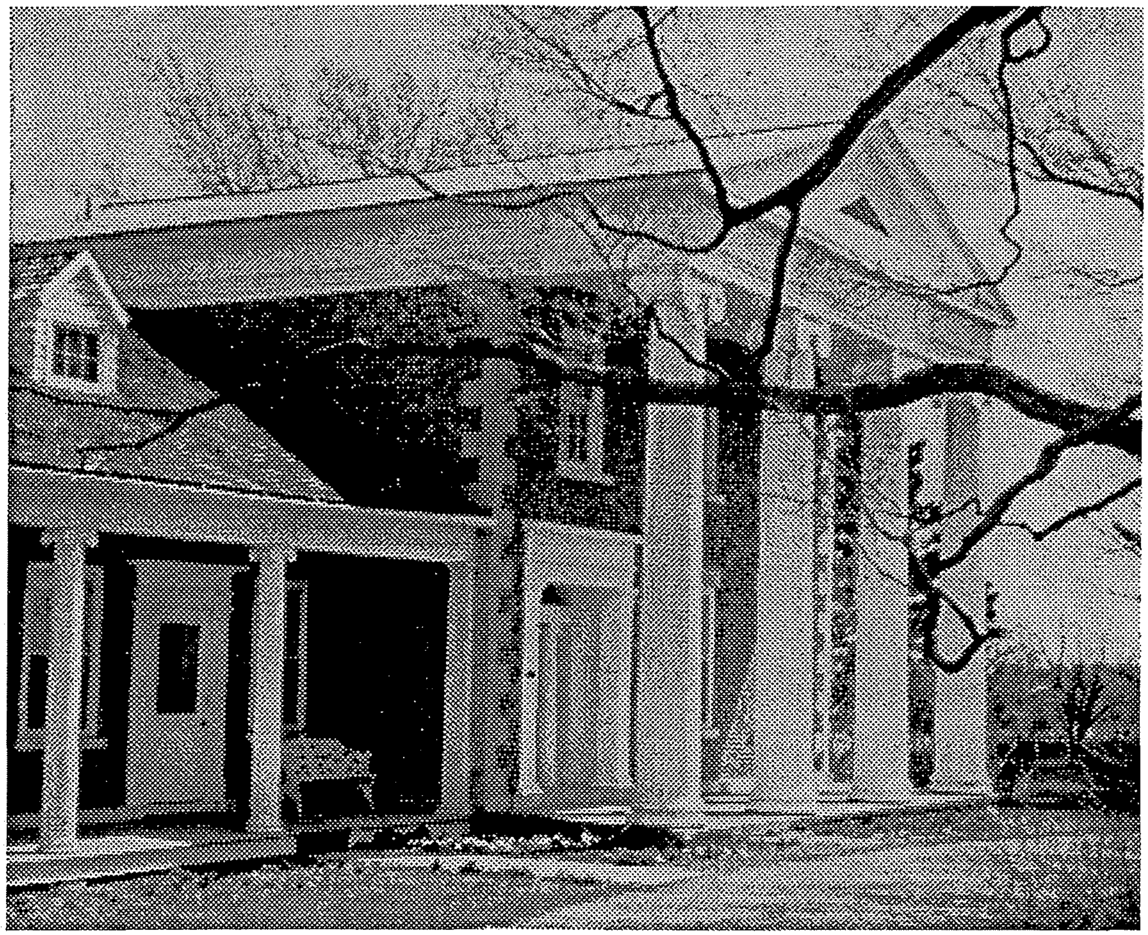
A demonstration of basic cobblestone techniques. Some cobbles, mortar, stone and basic masonry tools will be available and participants will have a chance to test their skills as cobblestone masons.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0	0.0	Intersection of Routes 5 and 20 (Hamilton St.) and Pulteney St. in Geneva, entrance to HWS campus. Head west toward Canandaigua (left if leaving HWS campus on Pulteney St.)
1.3	1.3	Stop light and intersection with Pre emption Rd., County Road 6. Turn left (south) onto Pre emption Rd. The Cobblestone Restaurant on the SW corner of this intersection was originally a single story cobblestone house built in 1838/39. The building contract for this house is preserved in the Ontario County Archives. The house was built by Clark Morrison, Amos Siglee, and Samuel O. Coddington for a price of $1550 excluding materials, which were supplied by the owner, Joseph H. Tuttle. The stucco second story was added in 1915.
7.0	5.7	Stop 2. Barnes House. Park on shoulder on left.

STOP 2. BARNES HOUSE, FIELDSTONE GREEK REVIVAL HOME, 1835 TO 1838.

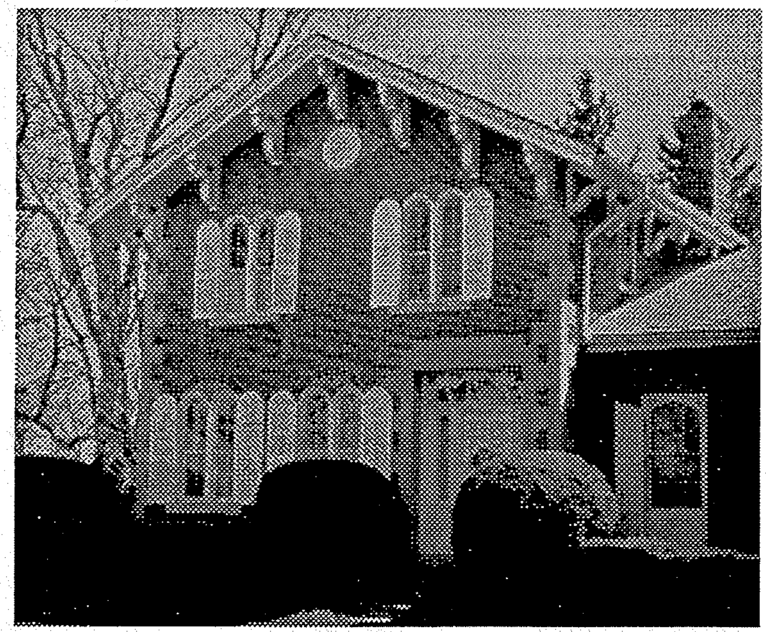
This house is an excellent example of a Greek Revival cobblestone (Figure 5). It was built over a period of three years, beginning with the north wing in 1835 and completed in 1838. Key features identifying this as a Greek Revival are the portico with Ionic columns, the wide cornice moldings which simulate the entablature of a Greek temple, the recessed doorway, and the massive lentil over the doorway. Features to examine and discuss: lithologies of the cobblestones, cut-stone components and their tool marks, character of mortar joints, variations in technique from the front to the back of the house, assignment to one of the cobblestone periods (early, middle, late).

Return to vehicles, turn around and head north on Pre emption Rd. Reset odometer to 0.



CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0	0	Stop 2, Barnes House
2.5	2.5	Turn left (west) at intersection with Billsboro Rd.
4.5	2.0	Billsboro Rd. (here called Lake to Lake Rd.) joins Route 14A, turn right (north) onto Route 14A

6.7	2.2	Rt. 14A turns sharply to the right (east), continue straight onto short access road to Leet Rd. STOP 3 is on the left. Park on the right shoulder of the access road.



STOP 3. RIPPEY HOUSE, LAKE-WASHED ITALIANATE HOME, 1854

This is home is made of lake-washed cobbles and was built in the Italiante style very late in the era of cobblestone construction. The features which identify it as Italiante are the shallow roof angles, the deep eaves, the decorative brackets supporting the eaves, and the paired windows with rounded arches. The Italianate style called for "compressed" vertical elements, tall and relatively thin windows, for example. After 1850, improvements in glass-making technology allowed these windows to have a few large panes of glass, in contrast to the small panes used in earlier styles. The other common Italianate style, though though rarely made of cobblestones, is the "cube and cupola," a two story box like house with a shallow-angled roof that rises in four panels to a central cupola. Features to examine and discuss: lithology, size and sorting of the cobblestones, nature of the mortar joints, quality of mortar work around the windows, comparisons with Barnes house, assignment to one of the cobblestone periods (early, middle, or late).

Return to vehicles and head north on Route 14A.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
10.7	4.0	Traffic light, intersection with Rt. 5 and 20. Turn left (west) on Rt. 5 and 20.
11.7	1.0	Baron House, a Greek Revival cobblestone house built in 1848, on the right (north) side of the road.
15.8	4.1	Intersection with County Rd. 20, turn right (north).
18.6	2.8	Stop sign, intersection with County Rd. 4. Continue straight.
19.9	1.3	Intersection with State Rt. 488, turn left (west) on 488.

20.8	0.9	STOP 4. Oliver Warner House (Landmark Farms). Park in driveways by the barn, on the left (south) side of road.

STOP 4. OLIVER WARNER HOUSE, FEDERAL STYLE FIELDSTONE HOUSE, 1840
This house was clearly built in stages; the front, west wing was built in 1840 in the Federal style. Features which mark this as a Federal style house the semicircular stone-trimmed fanlight, the door treatment, the shallow cornices, and the relatively thin, elegant moldings. Unlike the Greek Revival style, the Federal style uses thin vertical elements and shallow openings which accentuate the building's flat surfaces. Features to see and discuss: types and variety of cobbles, extraordinary cut-stone work, variations in construction techniques in different wings of the building, comparisons with other buildings we have seen. Can you hypothesize on the chronology of the wings?

Return to vehicles, turn around and head back (east) on Rt. 488. (Rt. 488 curves northward after intersection with County Rd. 20.)

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
21.7	0.9	Intersection with County Rd. 20, continue on 488.
25.1 (Reset mileage)	3.4	Intersection of Rt. 488 with Rt. 96. Reset odometer to 0 a this point. Turn left (west) on Rt. 96.
2.6	2.6	North of village of Clifton Springs, turn right (north) on County Rd. 25.
2.8	0.2	Cross NY State Thruway
3.1	0.3	Cross Canadaigua Outlet, bear right on far side of bridge
3.7	0.6	Village of Gypsum, intersection with County Rd 27 (Plainsville Rd, enters from the left, north). Turn left (north) onto County Rd 27
3.9	0.2	STOP 5. Plainsville School (east side of road), and Second Baptist Society of the Town of Phelps church (now both private residences).

STOP 5. PLAINSVILLE SCHOOL, 1853, AND SECOND BAPTIST SOCIETY CHURCH, 1835. COMPARISON OF EARLY AND LATE COBBLESTONE PERIODS

These two structures, now private residences but once public buildings, are on opposite sides of Plainsville Rd. in the village of Gypsum, also called Plainsville. They are excellent examples of the differences between early and late cobblestone construction. In examining the buildings, make sure to note the contrasts in quoins, lintels, sills and other structural components, sizes and lithologies of the cobblestones, mortar, and the tooling of the joints. The owner of the church building says that the building was built by the congregation with the help of a mason and relates the following story, the truth of which is difficult to assess: The mason showed the amateur builders how to lay cobblestones in the parts of the wall framing the front door, where the joints are relatively straight and horizontal. As the distance from the door increases and the amateurs took over, the joints bob and weave like drunken sailors. Features to examine and discuss: the contrasts in materials, techniques and architectural styles between these two buildings.

Gypsum is so named for gypsum deposits in the Salina formation that were discovered along the Canadaigua Outlet just south of town in 1812. The town was originally called Plainsville, but when it got its own post office the name had to be changed because there was already a Plainsville, N.Y. (Parmalee, 1986).

Return to vehicles, turn around and go back to County Rd. 20.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
4.1	0.2	Turn left (east) on County Rd. 20.
4.2	0.1	Intersection with McBurney Rd., turn right (south) on McBurney Rd.
6.2	2.0	Outcrop of Onondaga Limestone on the right (south) side of road
7.9	1.7	Intersection with Rt. 488, turn right (south) on 488.
8.2	0.3	Pass under NYS Thruway, outcrops of the lower portions of the Devonian Onondaga Limestone flank the road.
8.7	0.5	Traffic light and intersection with Rt. 96. Turn left (east) and proceed into the village of Phelps.

The village of Phelps is unusual in that it has both excellent cobblestones and 19th century buildings made with cut stone blocks. This reflects the fact that Phelps is located on the falls of Flint Creek as the creek cuts across the resistant Onondaga Limestone and exposes this good building stone. The town hall, a beautiful limestone block building that combines elements of both Greek Revival and Federal styles, was built in 1849 from limestone quarried just west of town (Parmalee, 1986).

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
9.5	0.8	Cross Flint Creek
9.7	0.2	Phelps Town Hall (see above)
10.0	0.3	Two cobblestones, an early and a late one, face each other across Main St. Note the off-color Portland cement mortar that was used to repair the structure on the left (north) side of the street. A few houses further down the street there is a small Greek Revival house built with cut stone.
11.6	1.6	STOP 6. Hawks House. Park on the right shoulder, cross Rt. 96 with caution!

STOP 6. HAWKS HOUSE, LAKE-WASHED GOTHIC REVIVAL HOME, 1848

This house is a great example of the Gothic Revival style. Features that identify this as a Gothic Revival style include the pointed arches of the windows, the steeply pitched roof, the cross gables, and the wall-dormer windows of the second story. Features to examine and discuss include: comparisons with other structures, use of arches instead of than lintels to support window openings, an contrast between the front and rear of the home. Careful examination of the east-facing gable reveals that this house was added on to with a latter cobblestone addition.

Return to vehicles, and continue east on Rt. 96.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
11.8	0.2	Large cobblestone home and barns, left (north) side of the road.
12.0	0.2	Federal style cut stone home—one of very few in this area.
12.2	0.2	Intersection with Pre emption Rd. Continue east on Rt. 96.
13.1	0.9	STOP 7, Hanson Aggregates Gravel Quarry, park on right shoulder.

STOP 7. GRAVEL QUARRY IN GLACIAL OUTWASH DEPOSITS
A brief "arm waving" stop to see some of the glacial outwash deposits being quarried here and to review local glacial geology. Just visible to the west of this site is the Onondaga Limestone escarpment and a large quarry (the Oaks Corners quarry). Just to the north, across the Canandaigua Outlet, is the morainal topography of the Waterloo recessional moraine. Discussion of the materials needed for cobblestone masonry and their abundance in the region.

Return to vehicles, turn around (WITH GREAT CAUTION!) and return west on Rt. 96.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
14.0	0.9	Intersection with Pre emption Rd., turn right (north) on Pre emption Rd. Cross bridge over Canandaigua Outlet.

Once one crosses the Outlet, the drive from this point northward is through some of the best developed drumlin fields in the area. The underlying tills are filled with cobbles!

14.1	0.1	Climb hill on the north side of the Outlet's floodplain and into the morainal topography of the Waterloo recessional moraine
14.6	0.5	NYS Thruway underpass. Morainal topography quickly gives way to drumlin fields from this point northward.
17.0	3.0	Stop 8. Vandevort House (Optional stop depending upon time). Park on right shoulder.

STOP 8. VANDEVORT HOUSE, LAKE-WASHED, GREEK REVIVAL HOME, 1847
We will make this stop only if time allows. This house is remarkable for the way in which the mason who built it used various shapes and sizes of stones to simulate moldings, particularly on the front of the house. It would be interesting to know what the mason and the Vandervort's thought about these "moldings." Is this a high-refinement of the technique? or has the technique been pushed to the beyond the limit of the materials being used? Discussion: What were these people thinking?

Return to vehicles, continue north on north on Pre Emption Rd.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
18.7	1.7	Wayne County line

19.3	0.6	Good view of drumlin on the left (west) side of road
20.7	1.4	Federal fieldstone cobblestone house, right (east) side of road
21.3	0.6	Junction with Old Pre Emption Rd., bear to the right.
21.7	0.4	Pre Emption Rd becomes Leach Rd (which enters from the right), continue straight
22.4	0.7	Cross RR tracks.
22.6	0.2	Traffic light and intersection with Rt. 31 in the village of Lyons. Continue straight on Leach Rd.
22.7	0.1	Cross bridge over NYS Barge Canal
22.8	0.1	Stop sign. Turn left.
24.0	1.2	STOP 9. Salina Formation. Turn around and park on left (south) shoulder or in canal work building lot.

STOP 9 SALINA FORMATION

Green, tan, and maroon shales of the Silurian Salina formation are exposed in a low road cut at this site. Casts of hopper-shaped salt crystals can be found in some of the weathered shales. The Salina formation is significant to this field trip because of the topographic control it exerts over the regional landscape, creating the east-west lowland that made it possible to construct the Erie Canal. Discussion: Topography and the feasibility of the Erie Canal.

Return to vehicles and head back toward the village of Lyons.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
24.1	0.1	Intersection with Dry Dock Rd. Turn right (south) on Dry Dock Rd and cross NYS Barge Canal. On the other side of the canal, follow Dry Dock Rd. to the right (west).
24.7	0.6	STOP 10. Old Lock 56 of the Erie Canal. Park on the right shoulder and follow trail along the barge canal to the west for approximately 100 meters.

STOP 10. OLD LOCK 56 OF THE ERIE CANAL

The significance of this stop is two fold. First, it provides a fine setting in which to review the importance of the Erie Canal to the economic prosperity it helped to produce, and of which cobblestone farm houses are one manifestation. Second, it is a good place to review the "Erie Canal theory," the idea that cobblestones were built by unemployed masons who had been imported to build the canal. The disparities between the type of construction used on this lock and cobblestone construction should be quite clear.

End of field trip. To return to Geneva, continue on Dry Dock Rd. which intersects with Rt. 31 less than a mile from this point. Turn left (east) toward Lyons on Rt. 31. In Lyons (approximately 2 miles), turn south on Rt. 14 and follow it to Geneva (approximately 15 miles).

GLACIAL FEATURES OF THE WESTERN FINGER LAKES LANDSCAPE

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INTRODUCTION

During the Pleistocene Epoch, repeated episodes of continental glaciation affected the Great Lakes region of eastern North America. The most recent ice advance, known as the Wisconsin Stage (65,000-12,000 years B.P.) is largely responsible for the appearance of our modern western Finger Lakes landscape, although there is little doubt that it followed the pattern left by earlier glaciations. During Wisconsin time, ice filled the Lake Ontario basin, split into sublobes and flowed southward across western New York. Distribution and movement of these sublobes has been deduced from the orientation of striae and drumlins (Dreimanis and Goldthwait 1973). As the ice margin retreated across the Finger Lakes region, glacially scoured valleys were filled with trapped meltwater. Drainage to the north was blocked by the ice sheet, and to the east and west by higher ground. The first proglacial Finger Lakes, with their southern drainage, had come into existence. Fairchild (1909) wrote about these glacial lakes. Their names are not as familiar as the modern Finger Lakes: Lake Hall near Dansville in the Genesee Valley, Lake Naples in the southern Canandaigua Valley, and Lake Italy in the Italy Valley to name a few. These lakes were short-lived, for as soon as the ice margin retreated farther north, lower spillways were uncovered. In the Canandaigua Valley, Lake Naples was replaced by Lake Middlesex as soon as an eastern drainage outlet was free of glacial ice. Today the signs of the historic presence of these lakes can be found in hillside shorelines (strandlines because these beaches are located some distance from the modern lake beaches) and gravelly delta deposits at the mouths of abandoned spillways. Perhaps, too, the fertile lacustrine sediments of a valley floor where no lake stands today will serve as a reminder of our recent glacial past.

The glacial geology of the western Finger Lakes region will be discussed at several stops on this field trip. The road log provides background figures and brief explanations for each stop. Two types of illustrations are presented for each stop: a photocopy reproduction of the relevant portion of a U.S.G.S. topographic quadrangle sheet and a digital elevation model (DEM) of the entire quadrangle sheet. For the former, the contour interval is 20 feet and north is at the top when the map is oriented to read. Map scale varies as each photocopy was enlarged in order to accentuate the glacial features. For the latter, DEM files were selected from Cornell University's geographic information resources library (search on the worldwide web for cugir). Relevant files were decompressed and extracted. For each DEM, the image file has been projected through ArcView's © Spatial Analyst Extension accepting the hillshade default settings.

ROAD LOG FOR GLACIAL FEATURES OF THE WESTERN FINGER LAKES LANDSCAPE
FULL DAY EXCURSION

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0	0.0	Intersection of Routes 5 and 20, Rte. 14 in city of Geneva, turn north on Rte. 14
6.4	6.4	Intersection of Rte. 14 and Rte. 318, turn east on Rte. 318
7.9	1.5	STOP 1, Junius Ponds

STOP 1. JUNIUS PONDS AS VIEWED ALONG ROUTE 318

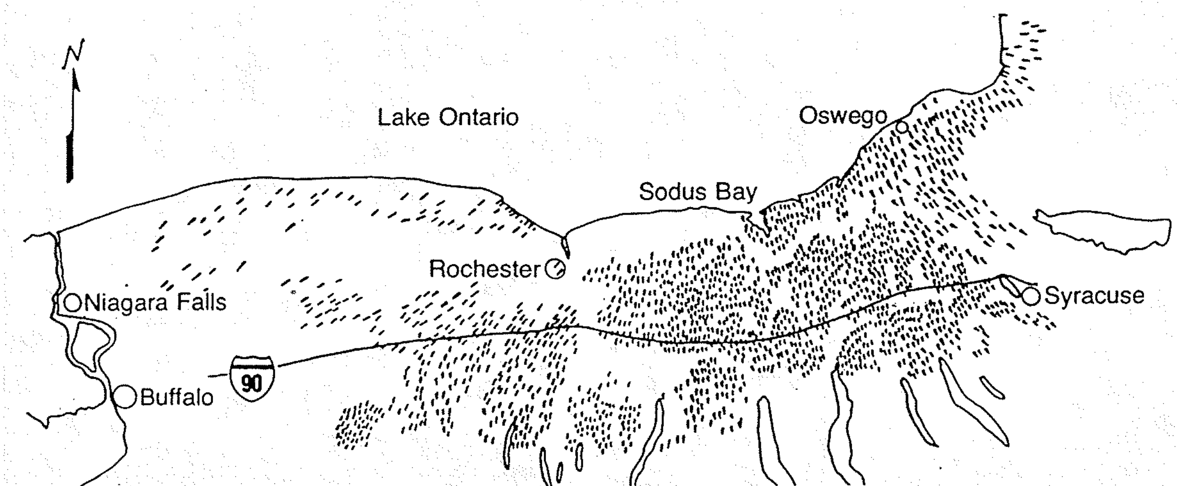
This disintegration landscape of stagnant ice features contains kettles and kettle hole lakes within a large and rather unique kame moraine complex. Chunks of glacial ice, varying in size, were buried here. When melting occurred, depressions were formed. Several basins are springfed today - the Junius Ponds complex. The complex consists of eight inter-connected basins separated by wetlands or sediment sills. The basins range in total depth from 8 to 17 meters, with the deepest basin exhibiting meromictic water circulation conditions. Original work on the limnology of the basins was published in 1931 by Burkholder. Since then, several unpublished graduate studies have been conducted (Principle 1981, Pendl 1982, Besse 1984 and Schloss 1985).

The surrounding kame moraine is composed of stratified (washed) sand and gravel that was deposited on, against, or immediately in front of the glacial margin. It is unusual and distinctive from other kame moraine complexes in New York State. Exposures in highway cuts and adjacent gravel pits indicate that portions of the moraine were affected by a major ice readvance. Sediment structure was distorted and the surface was remolded by the ice sheet overriding previously formed features. In addition to this site's unique glacial history, the natural communities here support several New York State rare species. Wetlands are particularly diverse, with some developing acidic bog-like conditions while others exhibit marly fen-like conditions apparently associated with calcareous seepage.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
9.4	1.5	West on Rte. 318, return to Rte. 14, turn north on Rte. 14
27.6	18.2	Intersection of Rte. 14 and CR 143 (Ridge Road) in hamlet of Alton, turn east on CR 143
31.4	3.8	Intersection of CR 143 and CR 154 (Lake Bluff Road), turn north on CR 154
33.0	1.6	Intersection of CR 154 and CR 155 (Lummisville Road), turn east on CR 155
33.8	0.8	Intersection of CR 155 and East Bay Road, turn north on East Bay Road
37.0	3.2	STOP 2, Chimney Bluffs parking lot at end of East Bay Road

STOP 2. CHIMNEY BLUFFS ALONG THE SOUTHERN SHORE OF LAKE ONTARIO.

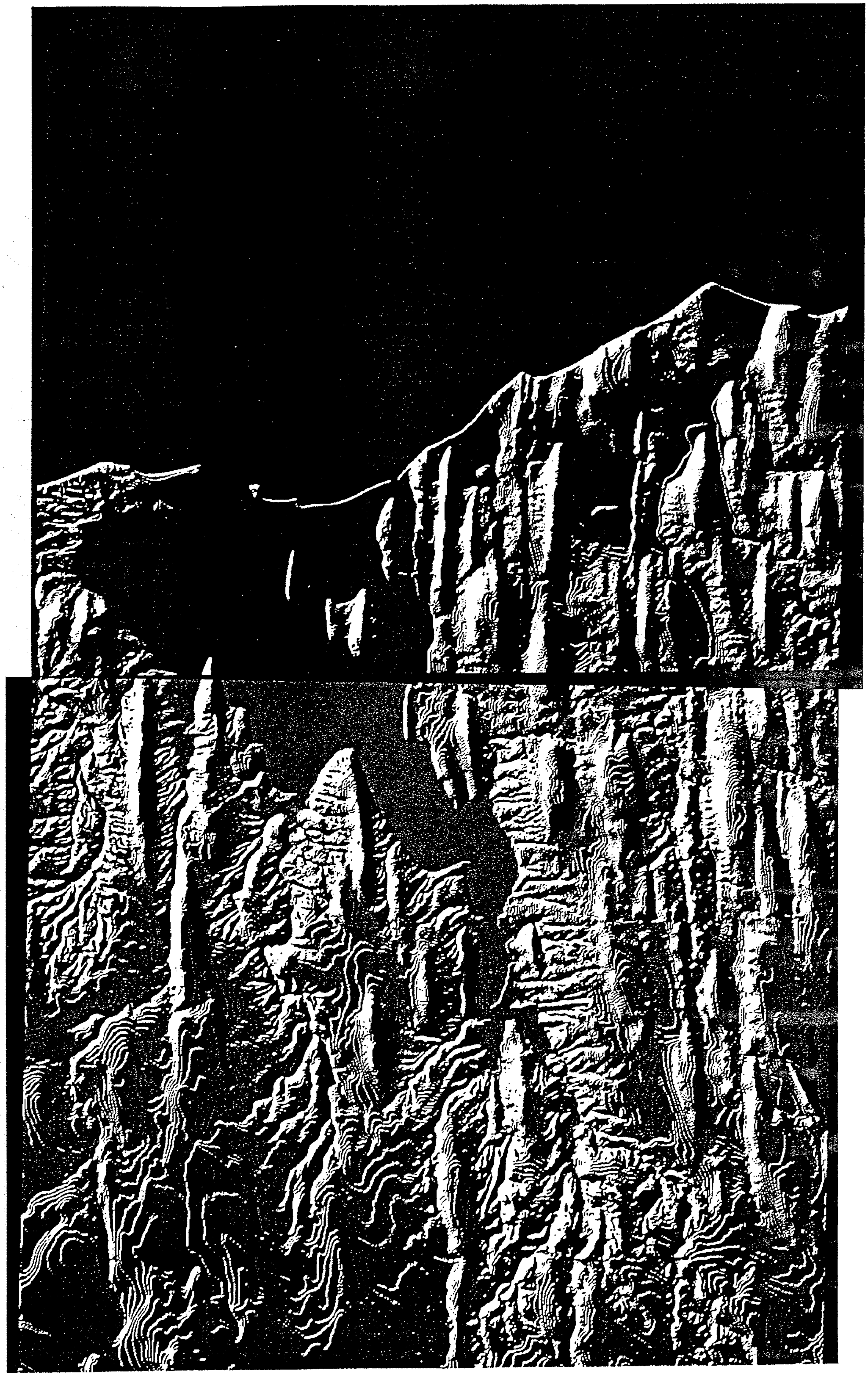
Over 10,000 drumlins lay in the plain between Lake Ontario and the Finger Lakes...the largest field of drumlins in the world!



(Source: VanDiver 1985)

The processes that form drumlins is complicated and involves a certain amount of rational guess work. Most drumlins are built up with concentric layers of gravel bound together by an excess of clay. It is widely agreed that drumlins are built by accretion, a subglacial plastering and lodgement of till as the ice sheet moved forward. A fairly flat landscape and thin ice are required. At this site, it is thought that a reduced lobe of ice occuping the future basin of Lake Ontario radiated out over the adjacent land. The basal debris in this ice was pulverized shale from the lake basin - hence the high content of clay. The thin ice margin was not exerting as great a pressure on the landscape as before. With a thrust from behind (a slight readvance), the ice tended to slip, or slide over the ground without digging in. Where it passed over a slight obstruction, the clay at the bottom adhered and was added to, layer by layer. The obstacle may have been a heap of glacial till or a small protrusion of bedrock. Later, when the Lake Ontario basin rebounded from the loss of ice mass, water levels began to rise. The bluffs were formed as the rising waters eroded the toe of the slope in the surf zone. Today, the "badlands" topography is maintained by several processes. Ongoing wave action loosens till fabric at the beach. Wind and rain combine to sculpture exposed bluff faces. Water that percolates downward near the rim of the drumlin contributes to slumping wherever it re-emerges along the bluff face. Freezing and thawing cycles may exacerbate these processes. It has been estimated that the bluffs erode up to five feet per year. Differences in composition and compression account for the more resistant strata features at the lakeshore.

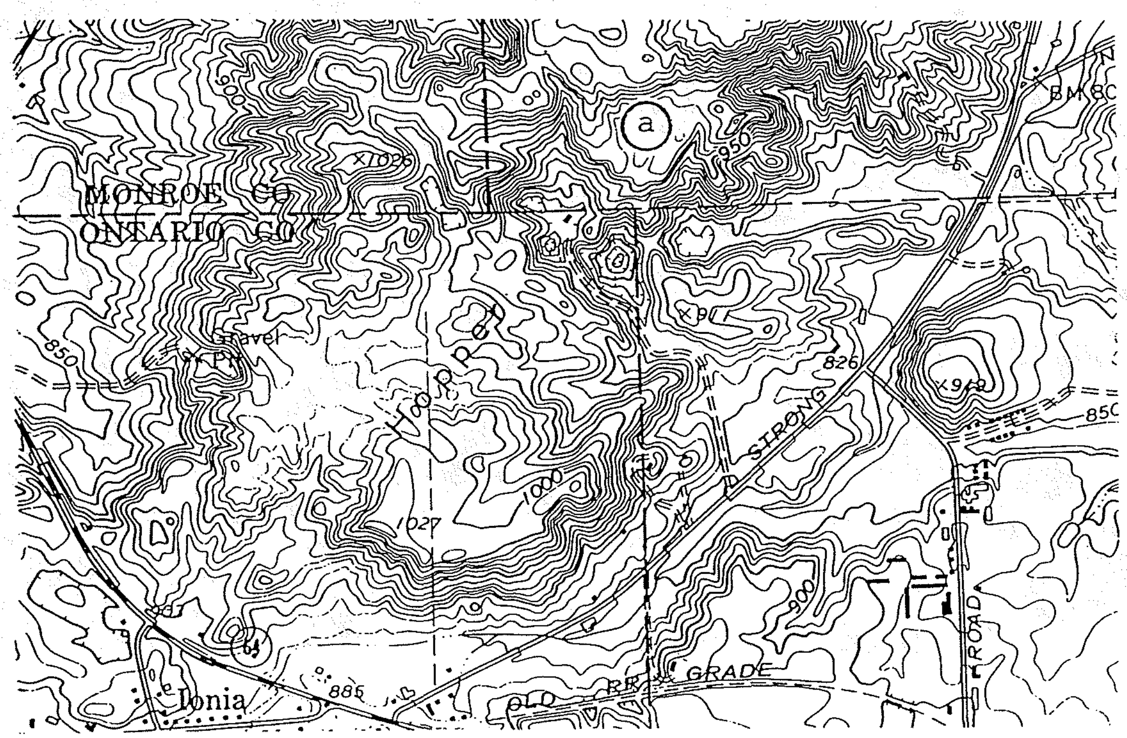
18
6
250
400
300
BM
281
ROAD
St Johns
Chapel
254
278
Root Swamp
e Bluff
GARNER
H U R
252
LAKE
350
396



CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
40.2	3.2	Leave parking lot heading south on East Bay Road to intersection with CR 155, turn west on CR 155
41.0	0.8	Intersection of CR 155 and CR 154, turn south on CR 154
42.6	1.6	Intersection of CR 154 and CR 143, turn west on CR 143
46.4	3.8	Intersection of CR 143 and Rte. 14, turn south on Rte. 14
65.0	18.6	Intersection of Rte. 14 and Rte. 96, turn west on Rte. 96, passing through the village of Phelps
71.2	6.2	Intersection of Rte. 96 and Rte. 488, turn south on Rte. 488, passing through hamlet of Orleans
80.7	9.5	Intersection of Rte. 488 and Rte. 21 in Chapin, turn south on Rte. 21
84.0	3.3	Intersection of Rte. 21 and Rte. 332 (Main Street) in Canandaigua, turn south on Rte. 332
84.2	0.2	Intersection of Rte. 332 (Main Street) and West Avenue, turn west on West Avenue
85.6	1.4	Intersection of West Avenue and Routes 5 and 20, continue west on Routes 5 and 20
92.8	7.2	Intersection of Routes 5 and 20 with Rte. 64, turn north on Rte. 64
96.0	3.2	STOP 3, Hopper Hills in hamlet of Ionia

STOP 3. KAME MORAINE, LOCALLY KNOWN AS THE HOPPER HILLS, VIEWED FROM STRONG ROAD NEAR THE HAMLET OF IONIA.

These kames were heaped upon the landscape during Lake Warren time (a predecessor to Lake Erie that extended across western New York) and their striking contrast to the flatter land surrounding them suggests an exceptionally debris laden ice front at this particular site. In adjacent sand and gravel pits, the internal structure of the kames can be seen. They are stratified and show evidence of land-water contact (ripple marks) throughout their layers but especially towards their base.



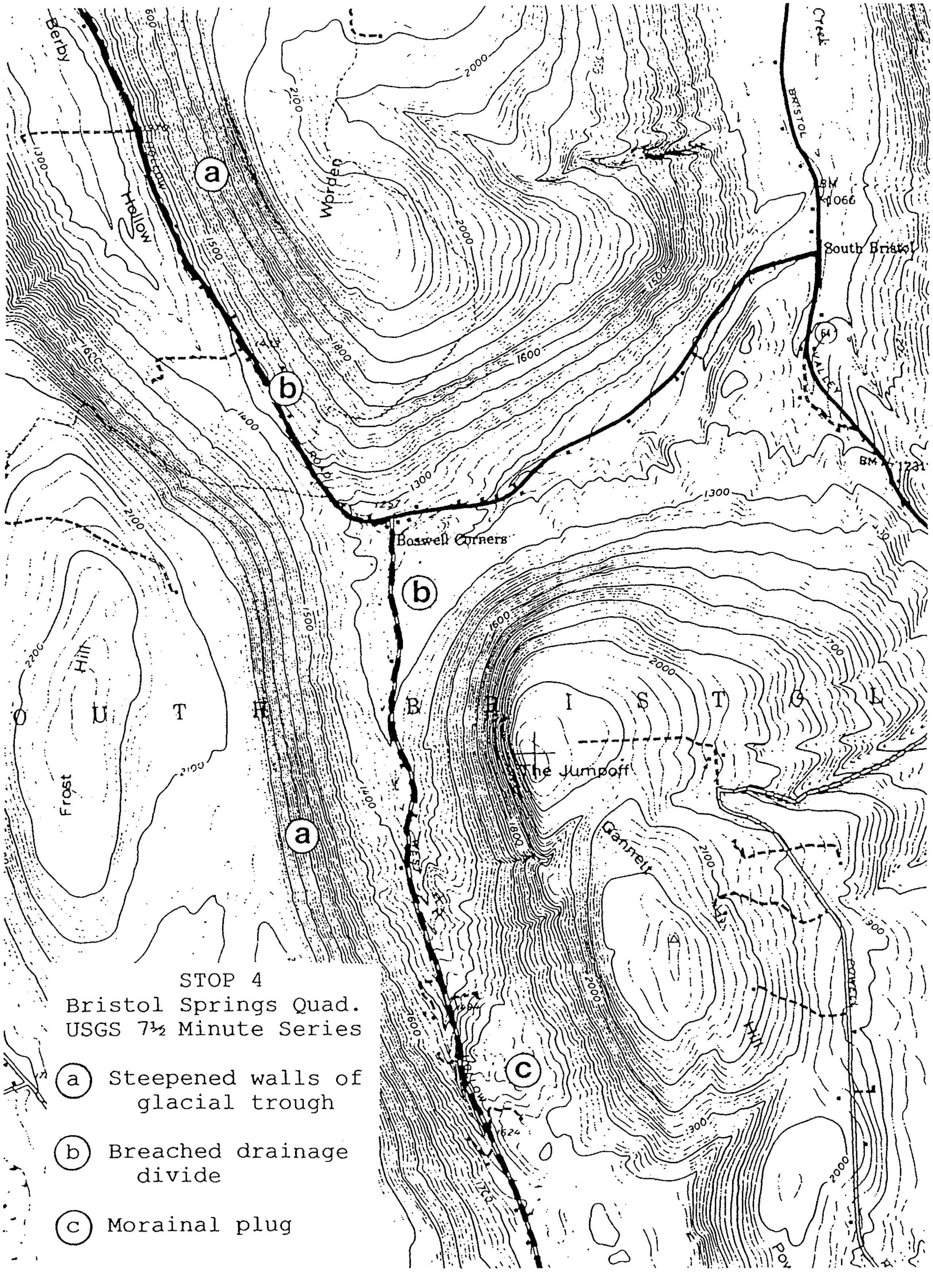
CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
103.2	7.2	Leave Hopper Hills, heading south on Rte. 64 to intersection with Routes 5 amd 20, turn east on Routes 5 and 20
106.3	3.1	Intersection of Routes 5 and 20 with Rte. 64, turn south on Rte. 64
119.2	12.9	Intersection of Rte. 64 and Gannett Hill Road, turn west on Gannett Hill Road
120.5	1.3	STOP 4, Entrance to Ontario County Park at summit of Gannett Hill Road, turn right to reach Jumpoff parking lot

STOP 4 THE JUMPOFF AT ONTARIO COUNTY PARK ON GANNETT HILL.

The main road to the Ontario County Park ascends up the west flank of the glacially carved Canandaigua trough (broad U-shaped valley). Along the road, a small stream has carved a ravine that exposes a thin glacial ground moraine underlain by Upper Devonian shales and sandstones. Looking southward from the top of the hill one can see the Appalachian Plateau with its near alignment of summits believed to have resulted from water erosion of the preglacial peneplain. The ice sheet then selectively eroded the pre-existing north-south streams into the wide troughs that separate these flat hilltops.

The Jumpoff overlook in the park is at an elevation of 2100 feet above sea level and almost 700 feet above the valley floor! Looking northwest (right) into Berby Hollow the graceful curved cross-section of a glacially carved trough can be seen. On clear days, the city of Rochester located on the Lake Ontario plain is visible in the distance. Below the Jumpoff and to the south (left) is a hummocky valley floor composed of a recessional moraine plug containing lower Silurian sandstones whose nearest source is in bedrock outcrops near Rochester. Glacial transport can be the only explanation. Other transported rocks and boulders, known as glacial erratics, are common in the woodlands of Ontario County Park.

Small glacial lakes once situated in Berby Hollow and the Bristol Valley had to drain eastward into the Canandaigua trough, breaching the drainage divide near Boswell Corners. Recall, the margin of the ice still blocked any northward escape of meltwater. At the bottom of the hill along the main entrance road to the park is a small hamlet known as Bristol Springs. Just beyond it is a gravelly delta, deposited where these small lakes drained into Glacial Lake Naples occupying the Canandaigua valley thousands of years ago. The delta deposit is stratified, clearly indicating sorting by glacial meltwater. Cross-bedding of the layers suggests that water altered its drainage pattern across the delta many times. The particle sizes and texture of the deltaic material is coarse; the finer silts and clays are absent. They were probably carried by the raging meltwater currents out into Lake Naples, eventually to become varve deposits along the bottom of the Canandaigua trough. Drifting icebergs along the lake surface added dropstones to the accumulating bottom sediment.



STOP 4
Bristol Springs Quad.
USGS 7½ Minute Series

(a) Steepened walls of glacial trough

(b) Breached drainage divide

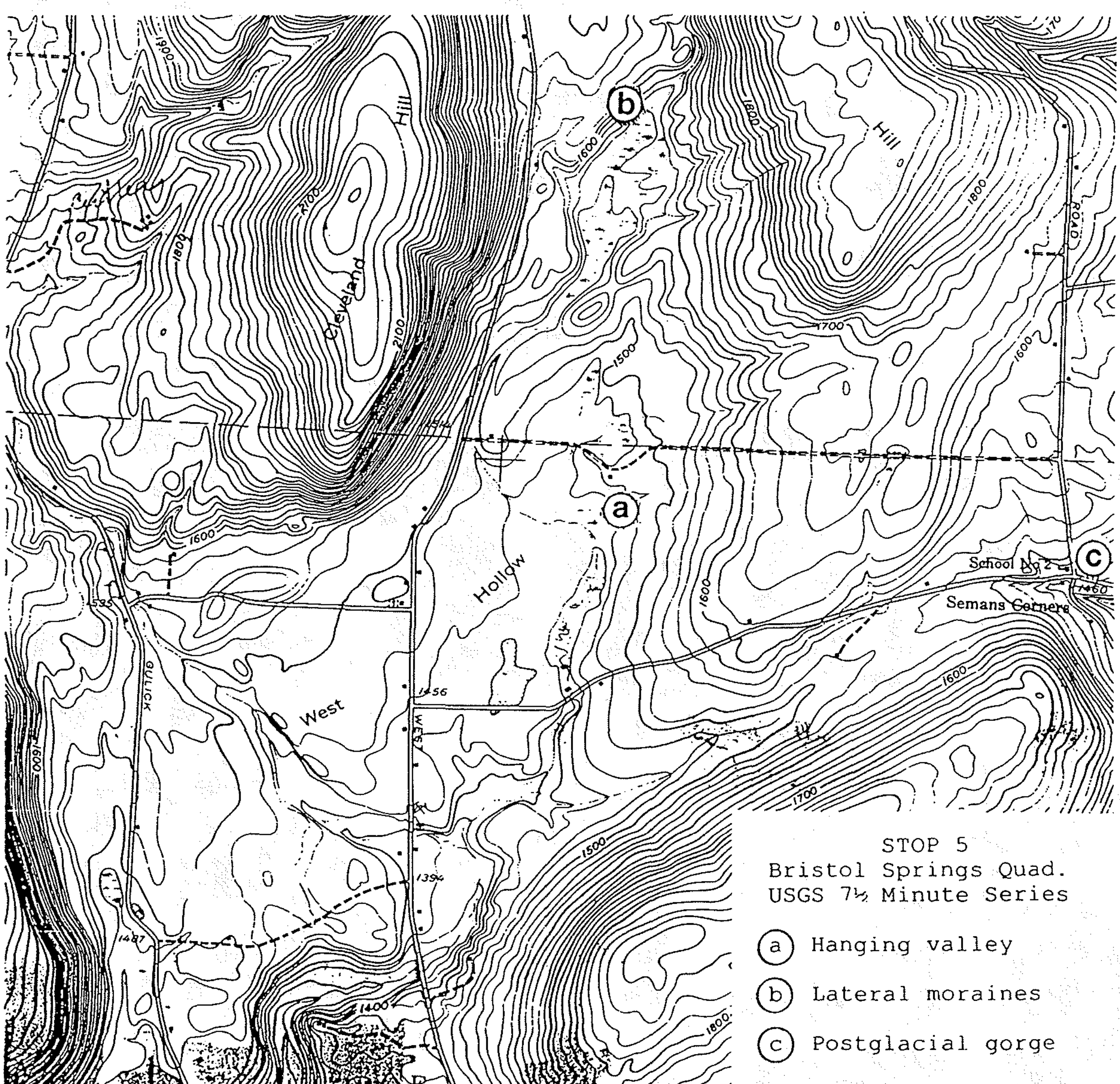
(c) Morainal plug

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
123.8	3.3	Leave Ontario County Park, turn south on Gannett Hill Road staying along top of hill to STOP 5

STOP 5 THE WEST HILL HANGING VALLEY VIEWED FROM GANNETT HILL ROAD NEAR THE INTERSECTION WITH SEMAN ROAD.

Glacial striations produced as the ice advanced over native bedrock in the western Finger Lakes landscape have a compass orientation within a few degrees of south. The ice sheet selectively eroded pre-existing north-south valleys because they aligned with the basal ice flow direction. In this regard, the Canandaigua Valley, originally V-shaped and occupied by the "Canandaigua River", was extensively scoured along its bottom and its sidewalls transforming it to a typical U-shaped glacial trough.

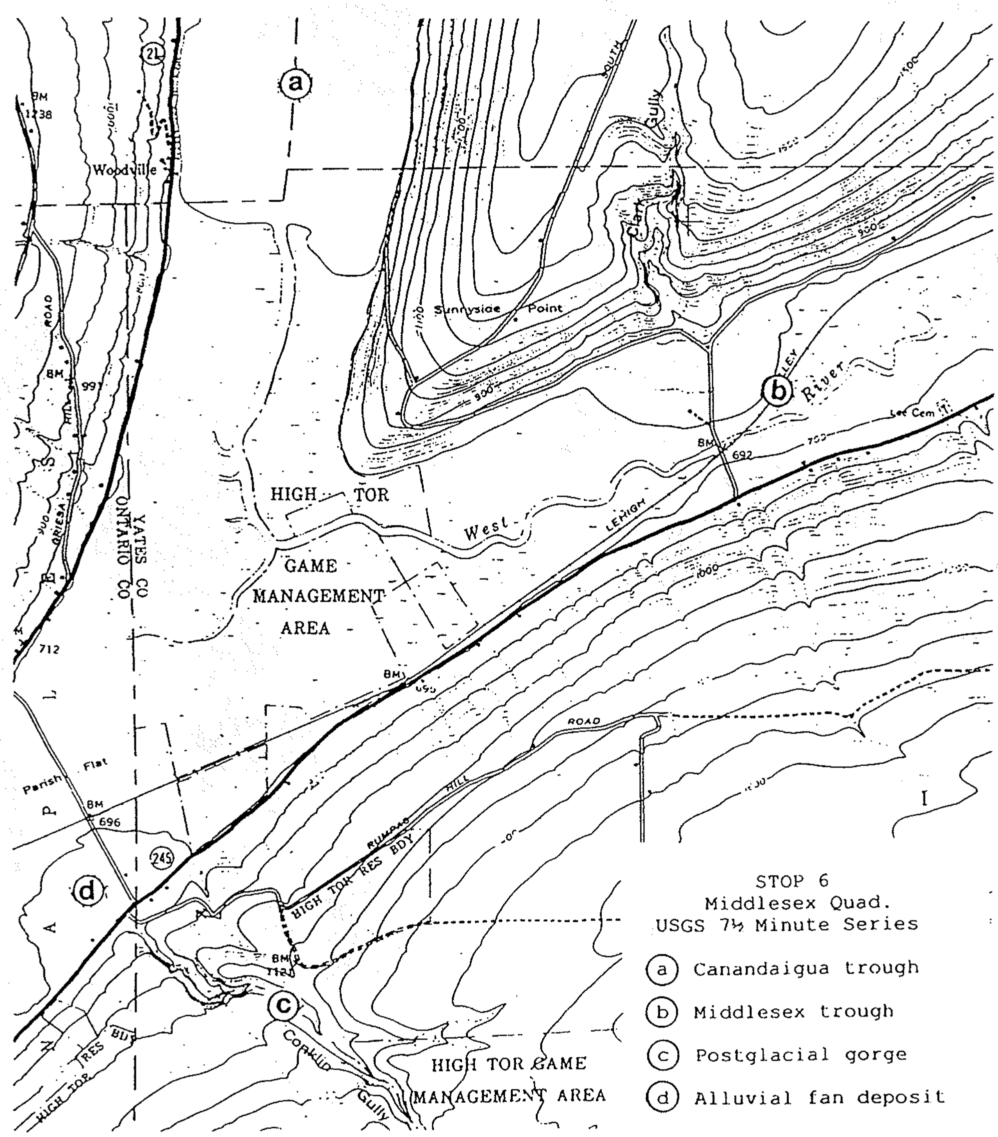
Preglacial, east-west tributaries were not as deeply scoured during the Pleistocene. After ice sheet retreat, these tributaries were left elevated above their preglacial outlets (the now deeply eroded north-south valleys). Spectacular, scenic gorges trace the course of these hanging valley streams as they cascade down into the over deepened glacial troughs (a gorge will be visited at stop 9).



CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
124.0	0.2	Gannett Hill Road changes name to Rhine Street at the intersection with Seman Road, continue south on Rhine Street
124.6	0.6	Intersection of Rhine Street and CR 12, turn south on CR 12
124.9	0.3	Roadside pull-off on CR 12 for STOP 6

STOP 6. CANANDAIGUA LAKE OVERLOOK AND BARBED TROUGH JUNCTION WITH THE MIDDLESEX VALLEY AS VIEWED FROM COUNTY ROAD 12.

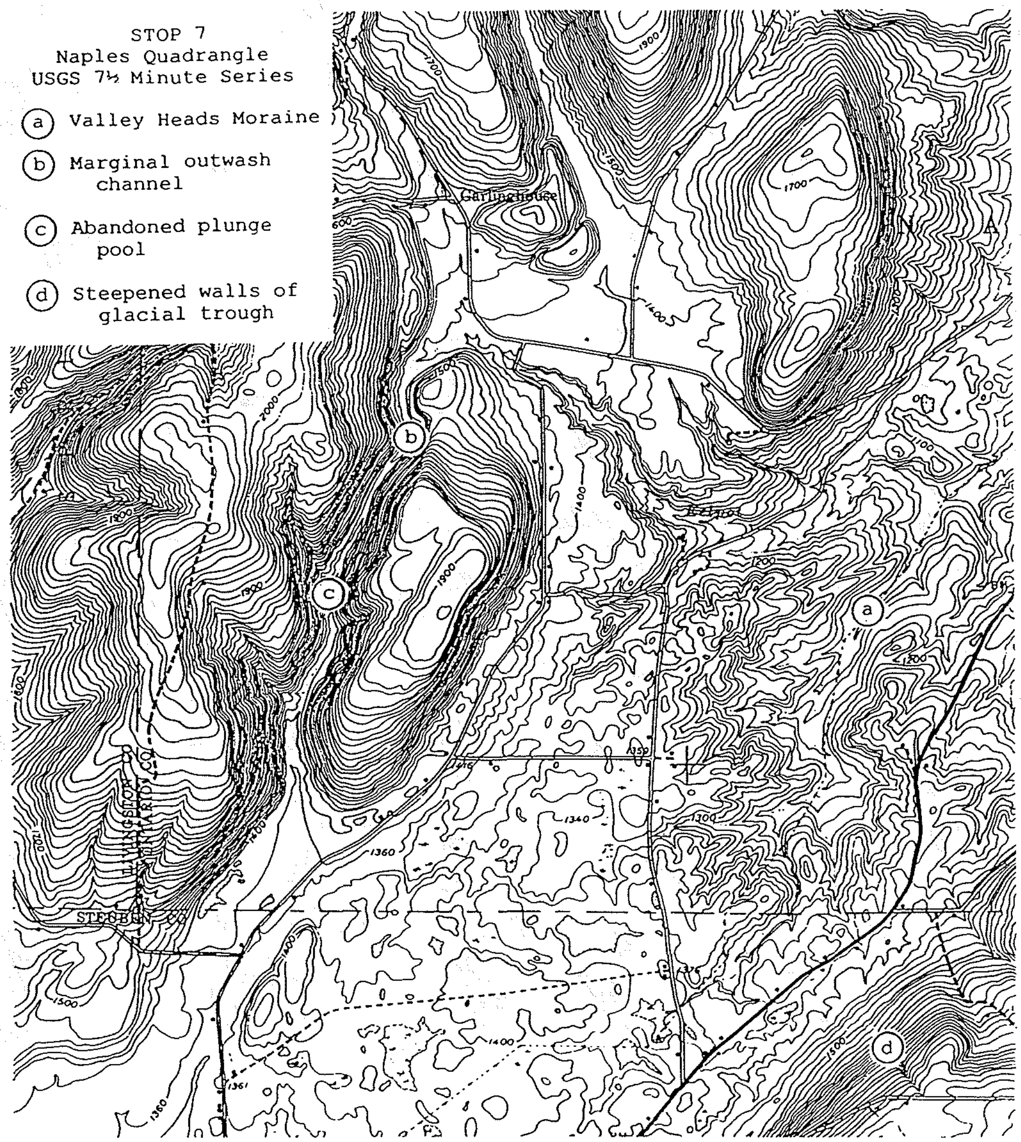
To the north (left) is the large, water-filled Canandaigua trough with its glacially scoured and steepened walls. Initially, erosion may have been enhanced simply due to faster ice flow but it soon was assisted by increasing thickness of ice as the valley was deepened. Joining the Canandaigua trough from the east is the Middlesex trough (today occupied by the meandering West River). This trough is also the product of glacial scour. The barbed trough junction at the confluence of the two valleys closely resembles the shape of modern Keuka Lake and supports the idea of a south flowing pattern for the western Finger Lake valleys during preglacial times (Fairchild 1909). Just south of Naples, a similar barbed trough junction is present where the Italy Valley joins the Canandaigua Valley. Some geologists theorize that the drainage then turned westward into the north flowing "Dansville River", an ancient predecessor of the Genesee River. Others suggest the drainage continued southward eventually joining the Susquehanna basin. Conklin Gorge may be seen along the far wall of the Middlesex trough. The gorge is postglacial and has built a considerable alluvial fan (locally known as Parish Flats) on the valley floor.

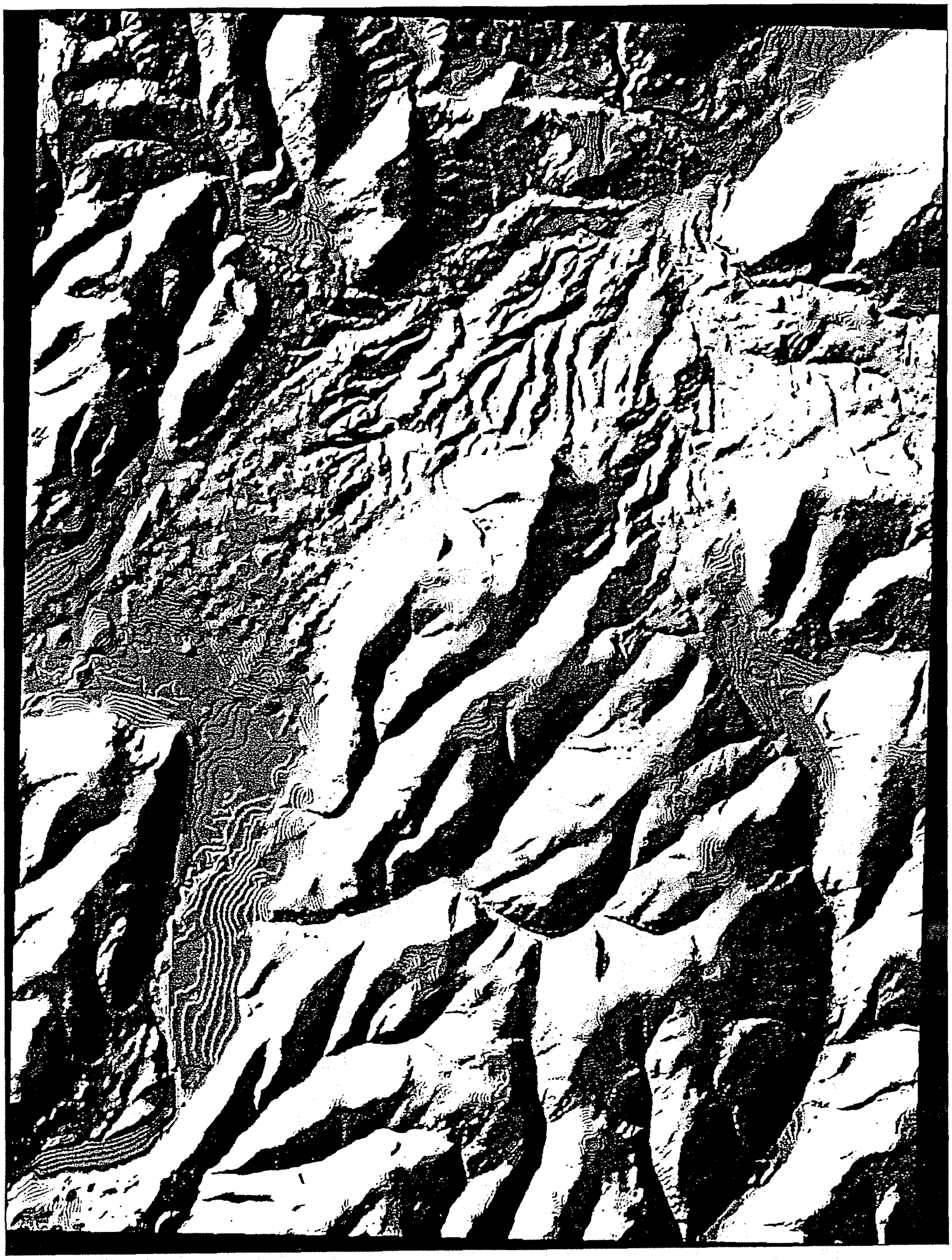


CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
126.7	1.8	Continue south on CR 12 to intersection with Rte. 21, turn south on Rte. 21
131.1	4.4	Pass through village of Naples, a few miles south watch for a safe roadside pull-off as Rte. 21 ascends the Valley Heads Moraine, STOP 7

STOP 7. THE VALLEY HEADS MORAINE AS VIEWED ALONG ROUTE 21 SOUTH OF THE VILLAGE OF NAPLES.

Just south of the village of Naples, Route 21 ascends from the valley floor of the Canandaigua trough. The landscape becomes hummocky, composed of small rolling hills and valleys, called a knob and basin morphology by glaciologists. This is a recessional moraine, a massive glacial deposit that accumulated from drainage off the Appalachian Plateau. It was banked up against the stagnant ice front reaching a thickness of over 600 feet! It is a somewhat stratified deposit, affected by the presence of trapped meltwater along the ice sheet margin. As the ice downwasted, kames and kettles were formed on the surface of the moraine. The Valley Heads recessional moraine is estimated to be between 13,500 and 15,000 years old. Today, the Valley Heads moraine marks the major drainage divide between the St. Lawrence Seaway and the Susquehanna River. It effectively dams the southern end of the Finger Lake valleys, trapping water in eleven of the glacial troughs, and forcing their modern drainage northward.





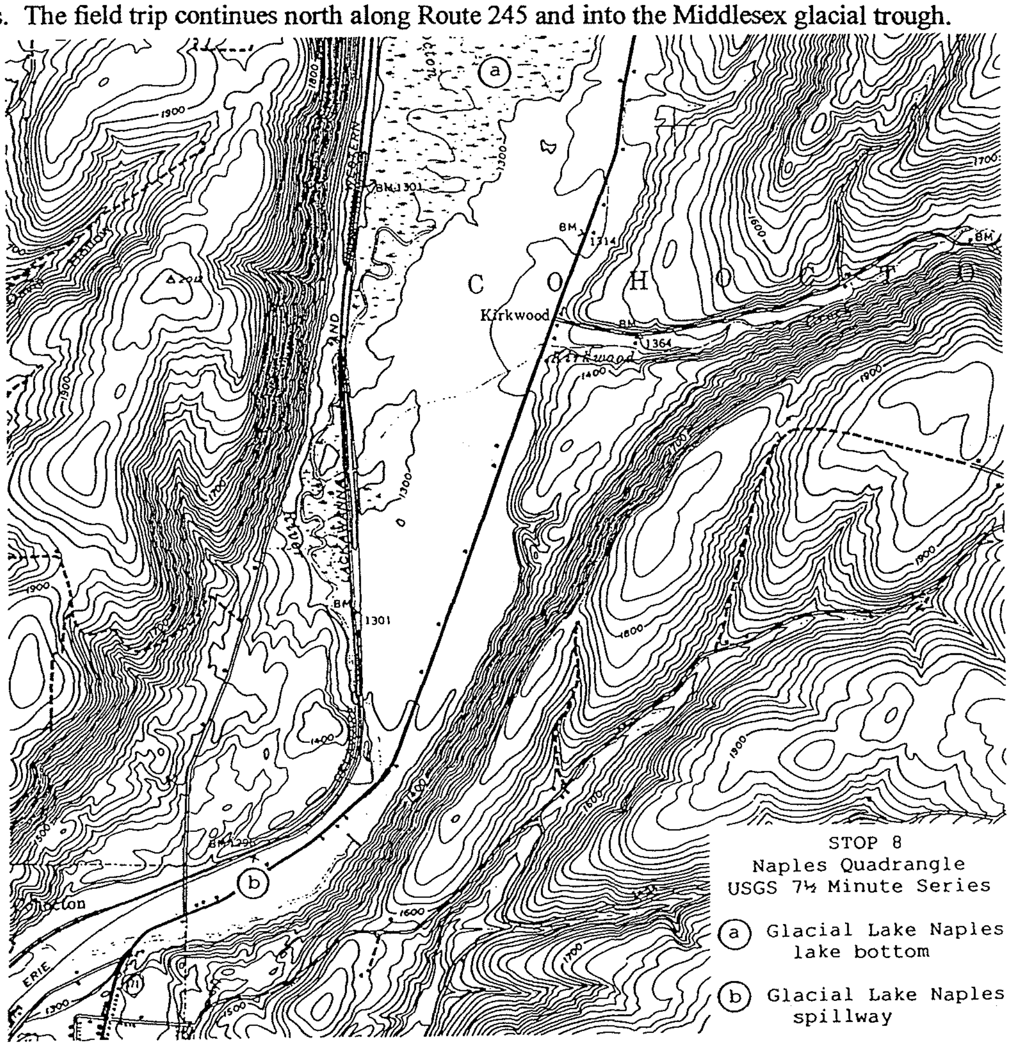
CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
133.1	2.0	Continue south on Rte. 21 to intersection with Rte. 371 in the village of North Cohocton, turn south on Rte. 371
137.1	4.0	As valley narrows, park in roadside lot to the left where river crosses beneath, STOP 8

STOP 8. THE GLACIAL LAKE NAPLES SPILLWAY ALONG ROUTE 371 BETWEEN NORTH COHOCTON AND COHOCTON.

Traveling farther south, the hummocky surface of the Valley Heads moraine gives way to a flat plain of virtually stone-free soils. This is the bottom sediment of Glacial Lake Naples! A silty and productive farm soil, coring would undoubtedly reveal buried varves that tell the story of seasonal accumulations of silt and clay. Lake Naples is estimated to have been 13 miles long, 2 miles wide and over 800 feet deep! It had a surface elevation of 1340-1350 feet above sea level. Glacial Lake Italy, at an elevation of 1370 feet above sea level, drained into Lake Naples forming the Tannery Glen delta.

Watch along the valley wall for evidence of this ancient lake's shoreline. Often small sand and gravel pits on local farms, or elevated deltas along tributary streams pinpoint the location. Travelling south and just before entering Cohocton, the lake bottom and valley floor suddenly narrow...the entrance to the Lake Naples spillway. This outlet is about 1000 feet wide and must have been impressive when torrents of water drained through it. Today, a much smaller Cohocton River slowly meanders southward to join the Chemung River.

On the return to Naples, take a moment to appreciate the view from the top of the Valley Heads moraine. Notice the barbed trough junction (STOP 6) where the Canandaigua and Middlesex troughs join just north of the village. Remember, this Y-shaped junction supports the idea of a south flowing preglacial drainage system for the western Finger Lakes. The field trip continues north along Route 245 and into the Middlesex glacial trough.

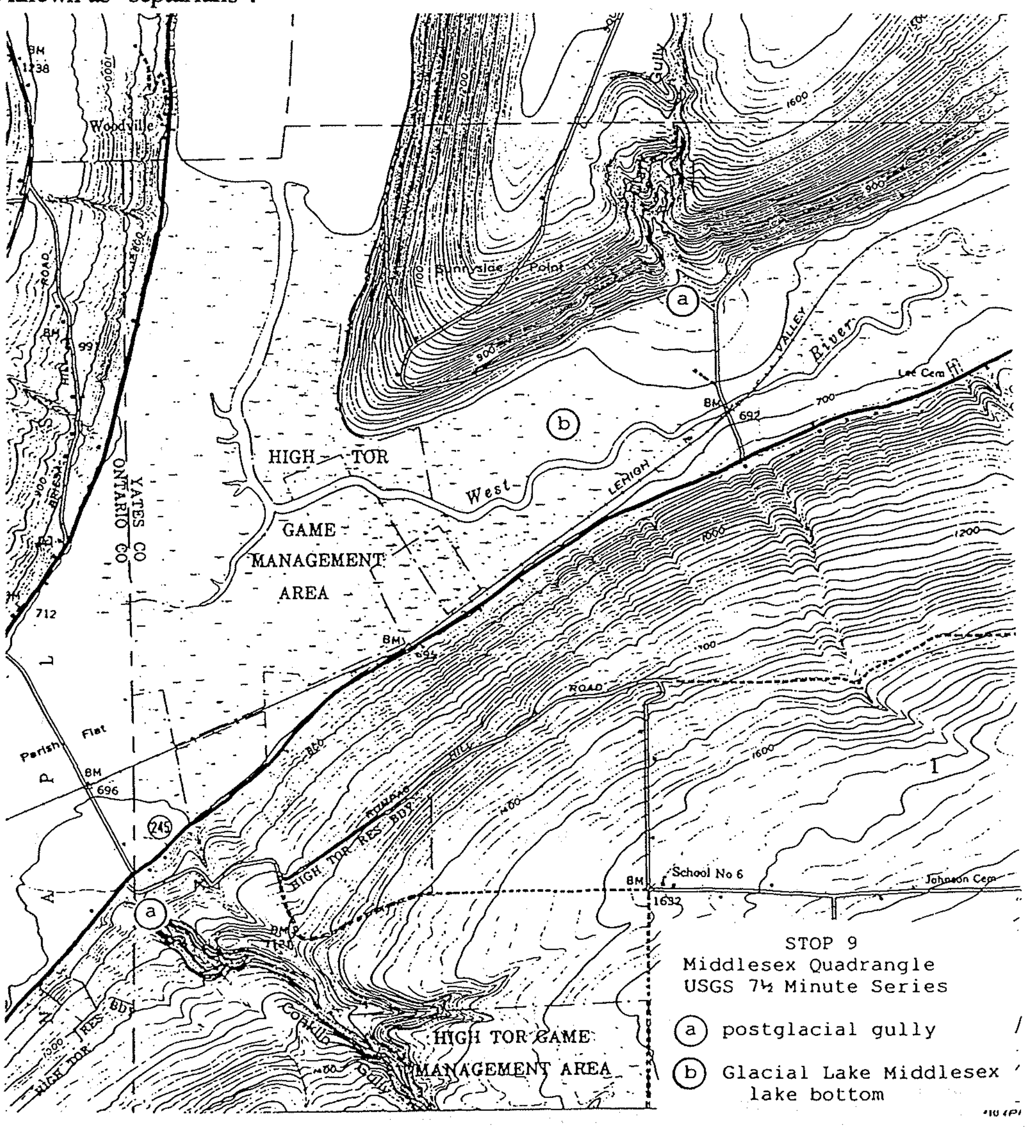


CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
141.1	4.0	Leave roadside parking lot, return north on Rte. 371to intersection with Rte. 21 in village of North Cohocton
147.0	5.9	Intersection of Rte. 21 and Rte. 245, turn north on Rte. 245
151.1	4.1	Intersection of Rte. 245 and Sunnyside Road, turn west on Sunnyside Road
151.7	0.6	Travel along Sunnyside Road, just past intersection with West Avenue to small gravel drive on the right, STOP 9

STOP 9. POST-GLACIAL GULLY EROSION, A TRIP INTO CLARK'S GULLY ON STATE OWNED-LANDS OFF WEST AVENUE.

Steep, narrow V-shaped gullies are common wherever hanging tributaries retrace their course into over deepened glacial troughs. Each Finger Lake has excellent examples, including the popular Watkins Glen, Enfield Glen and Taughannock Falls. North of Naples along Route 245, Conklin Gorge may be seen along the east at the barbed trough junction. Despite being post-glacial, and therefore geologically young, it has built a considerable alluvial fan on the valley floor locally known as Parish Flats.

Just ahead on the west side of the Middlesex trough is a magnificent post-glacial gorge called Clark's Gully. All the land here is part of the state-owned High Tor Wildlife Management Area. Walk the lower section of the gully. Watch for exposed shale and limestone in the gorge walls. Notice glacial erratics in the stream and peculiar concretions known as "septarians".

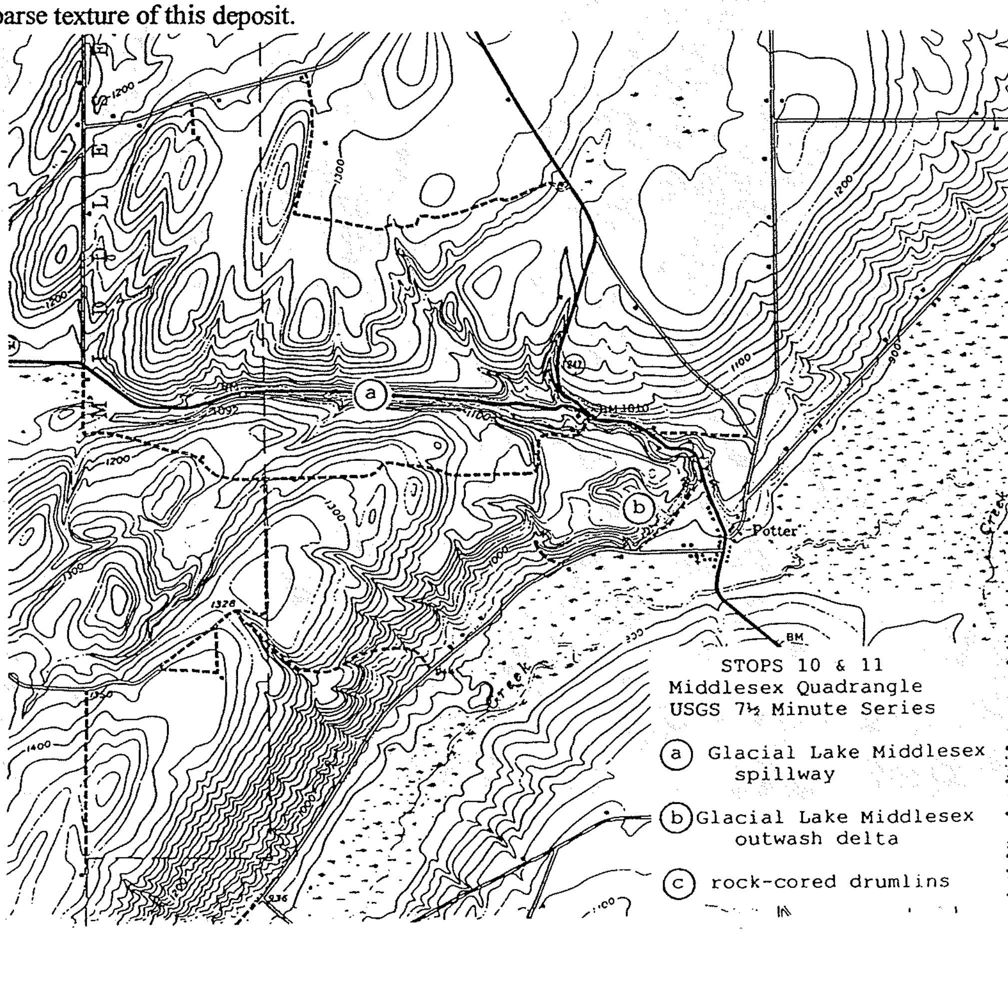


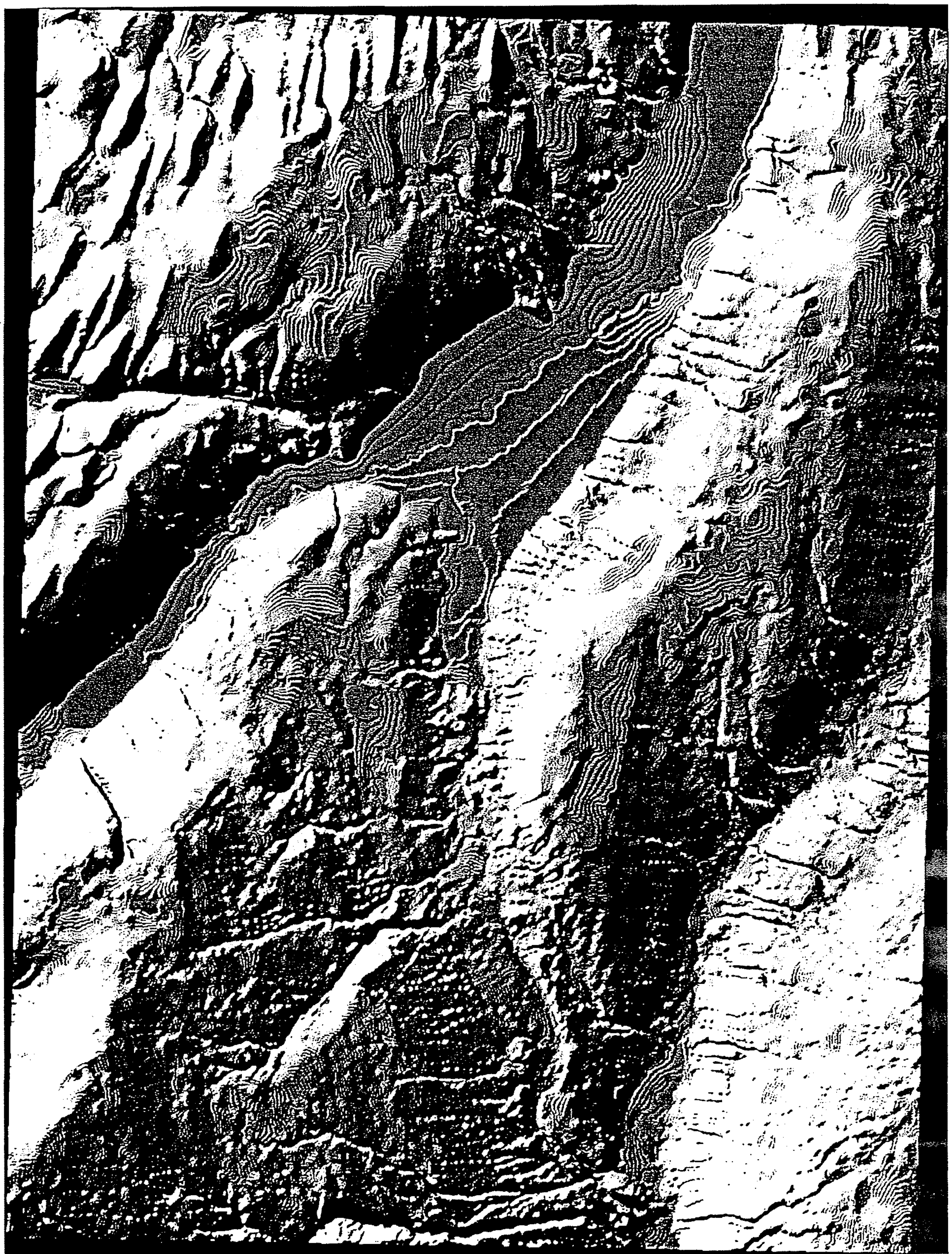
CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
156.1	4.4	Leave Clark's Gully, travel north on West Avenue to intersection with Rte. 364, turn east on Rte. 364 passing through the village of Middlesex then heading strongly uphill
159.0	2.9	Watch for small waterfall along south side of Rte. 364, spillway portion of STOP 10
159.6	0.6	Continue east on Rte. 364 to intersection with Rte. 247, stay on Rte. 364
160.3	0.7	Intersection of Rte. 364 and Phelps Road in hamlet of Potter, turn south on Phelps Road
161.0	0.7	Gravel pit, delta deposit portion of STOP 10

STOP 10. GLACIAL LAKE MIDDLESEX SPILLWAY ALONG ROUTE 364 EAST OF MIDDLESEX.

Some 11,000 years ago, the Middlesex and Canandaigua troughs were jointly occupied by the same body of water. Then, ice sheet retreat uncovered a hilltop notch east of Middlesex that was 220 feet lower than the Cohocton spillway used by Lake Naples. Suddenly and catastrophically, the surface elevation of Lake Naples fell and a new lake came into existence...Glacial Lake Middlesex! South Hill emerged as a large island in this 600 feet deep lake.

The conspicuous spillway is traversed by Route 364 between Middlesex and Potter. Notice the depth, width and unusually straight form of this spillway. The small stream now found in the hilltop notch could not have had the erosive power to produce a channel of these dimensions. We will stop briefly by a small waterfall eroded by this same stream and let you make the visual comparison. One can also notice the forest damage caused by a localized tornado (microburst?) in 1996. Continuing down the spillway, we arrive at the next glacial trough, the broad expanse of the Potter Swamp (now largely converted to muck farming). A large, gravelly delta deposit is located here where waters draining from Lake Middlesex entered this valley. Cross-bedding of the layers is very evident due to the coarse texture of this deposit.





For return trip to Geneva

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
161.7	0.7	Travel north on Phelps Road to intersection the Rte. 364, turn west on Rte. 364
162.4	0.7	Intersection of Rte. 364 and Rte. 247, turn north on Rte. 247
166.1	3.7	Intersection of Rte. 247 and Rte. 245 in village of Rushville (flashing light), stay on Rte. 245and Rte. 247 as they travel together to the east of Rushville, then stay on Rte. 245
177.6	11.5	Pass through villages of Gorham and Stanley to intersection of Rte. 245 and Rte. 14A, turn north on Rte. 14A
180.8	3.2	Intersection of Rte. 14A and Routes 5 and 20, turn east on Routes 5 and 20
182.4	1.6	Intersection of Routes 5 and 20 with Rte. 14 in city of Geneva

ROAD LOG FOR GLACIAL FEATURES OF THE WESTERN FINGER LAKES LANDSCAPE HALF DAY EXCURSION

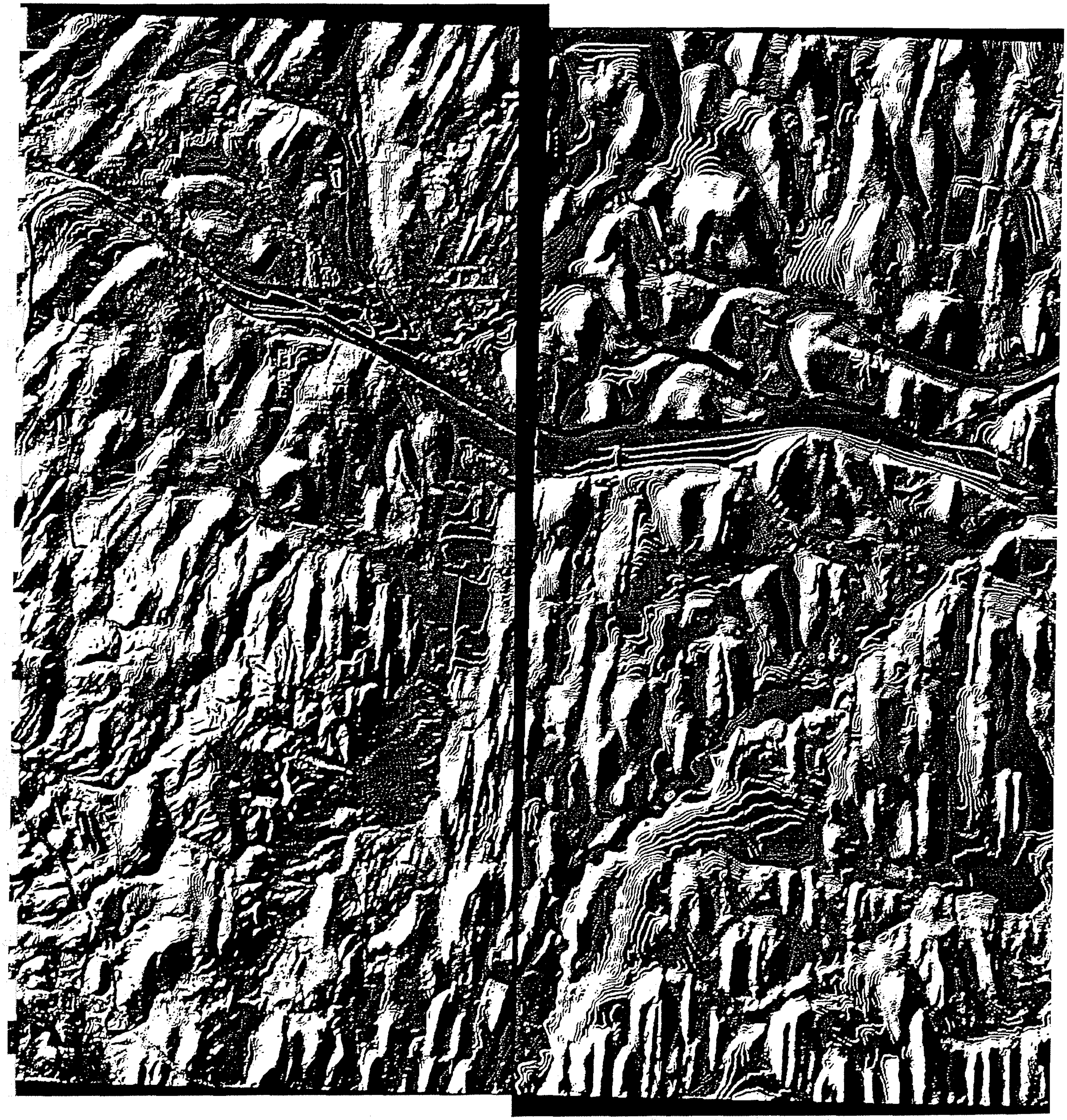
CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0	0.0	Intersection of Routes 5 and 20 with Rte. 14 in the city of Geneva, turn west of Routes 5 and 20
15.2	15.2	Intersection of Routes 5 and 20 with Rte. 332 (Main Street) in the city of Canandaigua, turn north on Rte. 332
23.1	7.9	Intersection of Rte. 332 and Rte. 96, turn west on Rte. 96
24.4	1.3	Intersection of Rte. 96 and McMahon Road, turn north on McMahon Road
25.0	0.6	Intersection of McMahon Road and Plaster Mill Road, turn west on Plaster Mill Road
25.1	0.1	Intersection of Plaster Mill Road and Brownville Road, turn north on Brownville Road
27.2	2.1	Intersection of Brownville Road and Gillis Road, turn west on Gillis Road
27.3	0.1	Around curve in Gillis Road, bear left at intersection with Cline Road, STOP 1

STOP 1. NEW YORK'S WORLD FAMOUS DRUMLIN FIELD AS VIEWED FROM GILLIS ROAD NEAR THE HAMLET OF BROWNVILLE.

While the best known local drumlin is likely to be Hill Cumorah, this stop at an unnamed drumlin was selected because most of the hill is unforested, readily revealing its streamlined shape. For more information on drumlins, turn to STOP 2 in the full day excursion.

STOP 1
Fairport Quadrangle
USGS 7½ Minute Series

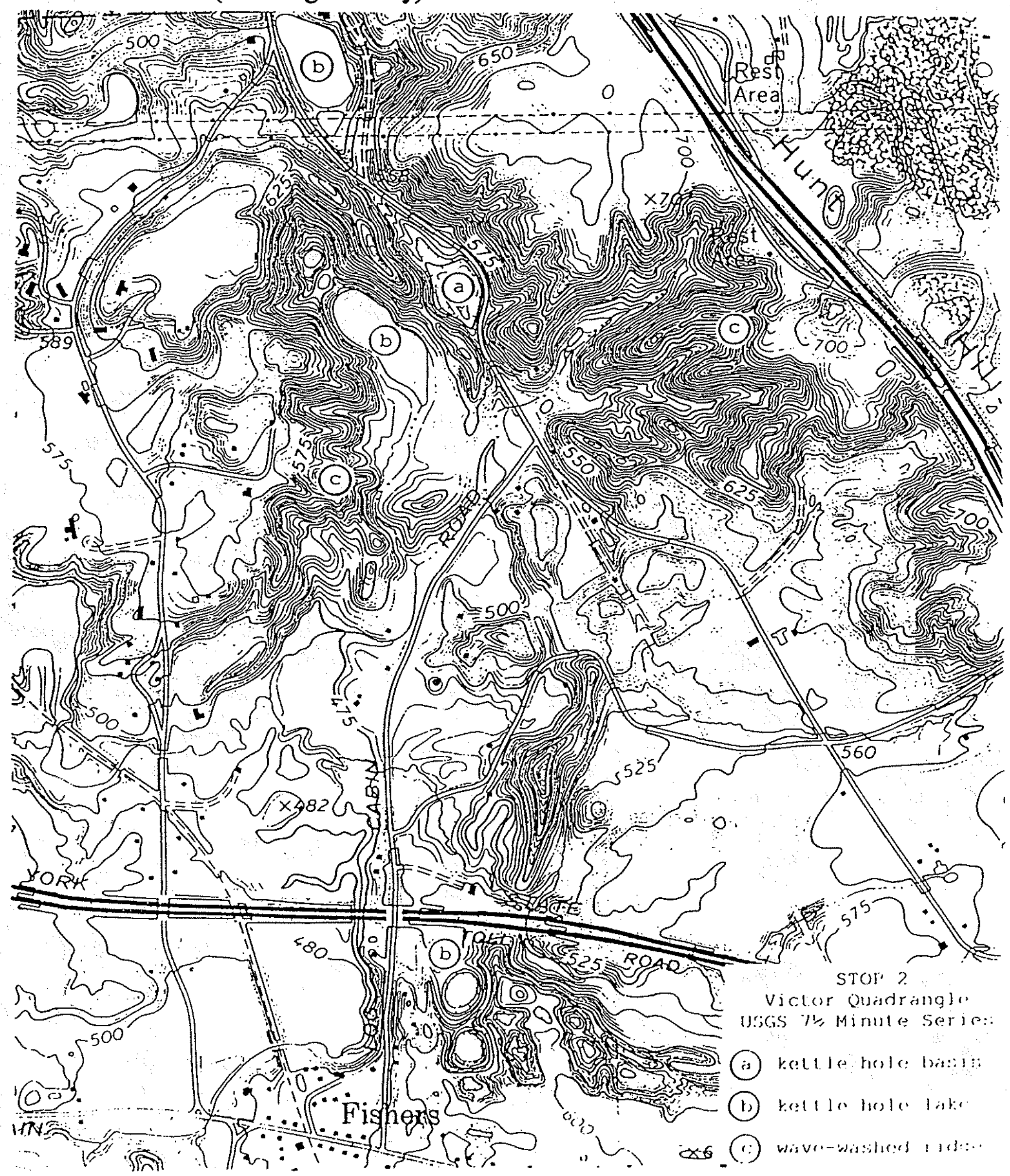
(a) drumlin

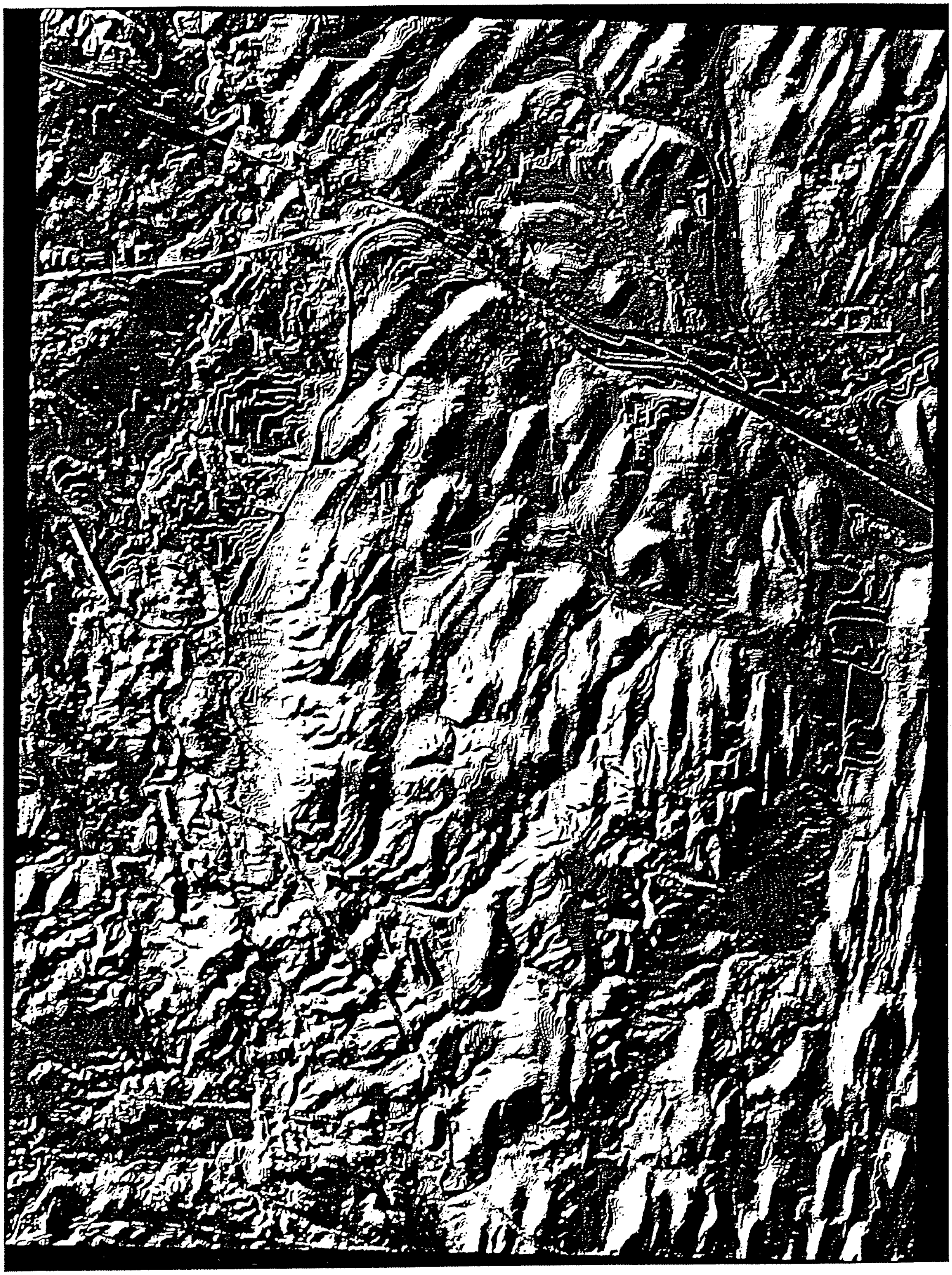


CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
30.2	3.0	Continue west on Gillis Road to end, intersection with High Street, turn north on High Street
31.4	1.2	Intersection of High Street and Rte. 96 (near East View mall), turn north on Rte. 96
33.3	1.9	Intersection of Rte. 96 and Fishers Road, turn south on Fishers Road
34.1	0.8	Intersection of Fishers Road and Benson Road, STOP 2

STOP 2. KETTLE HOLE LAKES NORTH OF FISHERS ALONG BENSON ROAD.

This disintegration landscape of stagnant ice features contains kettle hole basins, kettle hole lakes, wave washed ridges and hummocky kames. Large chunks of ice (actually crumb-like in size when compared to the massive continental ice sheet) were buried here. Subsequently they were covered by outwash and, as melting occurred, they formed nearly circular depressions. Today, several of them are spring- fed ponds. Other well known kettle hole lake complexes in the Finger Lakes region include Mendon Ponds (Monroe County), Junius Ponds (Seneca County) and Labrador Hollow (Onondaga County).





CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
36.0	1.9	Continue south on Fishers Road to Main Street, turn east on Main Street
36.1	0.1	Intersection of Main Street and CR 42
36.9	0.8	Intersection of CR 42 and Rte. 251, turn west on Rte. 251
37.2	0.3	Intersection of Rte. 251 and Strong Road, turn south on Strong Road
42.4	5.2	Intersection of Strong Road and Rte. 64, STOP 3

STOP 3. KAME MORAINE, LOCALLY KNOWN AS THE HOPPER HILLS, VIEWED FROM STRONG ROAD NEAR THE HAMLET OF IONIA.

(For stops 3 through 6, the half day excursion now overlaps with the description and maps provided for the full day field excursion)

STOP 7. GLACIAL LAKE MIDDLESEX SPILLWAY ALONG ROUTE 364 EAST OF MIDDLESEX.

(After viewing the barbed trough junction, continue traveling south on Rte. 21 to intersection with Rte. 245 just north of the village of Naples. Turn east on Rte. 245. The description for stop 7 on the half day excursion is the same as the description for stop 10 in the full day excursion)

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The Late Devonian Clastic Wedge in Central New York and Northern Pennsylvania
Donald L. Woodrow, Hobart and William Smith Colleges, Geneva, NY 14456

This field trip has been designed as a study trip in which the rock sections are discussed and problems for further study are suggested. We will be concerned with what we see in individual exposures, selected to illustrate facies and their origin. Temporal relationships, though well-constrained in the lower part of the section (House and Kirchgasser, 1993), become less so toward the top. Details of temporal relationships in the Fammenian sections are problematic. As a result, concepts of sequence stratigraphy have yet to be applied over much of this section.

We will start with the Tully Limestone and move upsection through black shales, turbidites, fossiliferous sandstone and shales, interbedded red/green and gray strata, and end in coarse sandstones at or just above the Devonian/Carboniferous boundary. Broadly interpreted, the facies represent deeper water marine environments which give way upsection to shallower marine environments, the shore and lowland alluvial plain. Facies sequences seen upsection express Walther's Law within the time intervals that have been sufficiently well deciphered to permit such analyses. That is, deeper water facies are replaced toward shore by shallower water facies. Our predecessors working on these and related sections in Pennsylvania and New York established the patterns over the past century or so.

Insights about the Late Devonian sequences garnered over the past 30 years or so include: elucidation of the physical and chemical processes responsible for these rocks, placement of rock sequences in a plausible time framework and explanations of their regional relationships, facies development in relation to tectonics and paleoclimate, and interpretation of faunas and floras based present-day biology and ecology. Among the next steps will be development of quantitative models of deposition and stratigraphy, more complete outline of temporal relationships, better understanding of paleoclimates, fauna and flora and their relationships to facies development, and development of models of fluid/gas movements.

Stop #1 Kashong Creek, Bellona, New York.

After parking on the west side of the road, we will come into the stream bed from the north, through the woods.

The section in the stream is

Geneseo Shale (above the falls)
Tully Limestone
Windom Shale (below the falls)

This location was the site of a mid-19th century grist mill with its mill-dam. A flood in the 1950's took out the dam and the lip of the falls has retreated somewhat since then. Some of the large blocks downstream of the plunge pool are remnants of the dam. The mill was reroofed about 25 years ago, otherwise the building is mostly a shell. When the mill was active, the low building just south of the bridge over the creek served as the mill office, town store, post office, and a lively dance hall.

The section is typical of those seen at falls on streams tributary to any of the Finger Lakes. The resistant unit, whether it be limestone as seen here or sandstone as seen further east, is surrounded upsection and down by less resistant shale or siltstone. Post-glacial erosion has proceeded at rates controlled by rock-unit resistance and the falls result.

The Tully at this location is gray, fine-grained biomicrite with crinoid fragments as a prominent component. The unit is about 2.5 m thick. Upper and lower subdivisions are recognized within it (Heckel, 1973). The Tully thickens to the east and south of Bellona but it does not extend much further west. West of the Genesee River, the comparable stratigraphic position is marked by the Leicester pyrite. Erosion surfaces bound the Tully top and bottom and mark its internal subdivision.

Below the Tully is the Windom Shale of the Moscow Formation (Brett and Baird, 1994). Gray and fossiliferous at the base, it grades upsection into poorly fossiliferous, black, fissile shale. A prominent erosion surface separates the Windom from the overlying Tully. Above the Tully is the Geneseo Shale, a poorly fossiliferous, black, fissile shale which on freshly broken surfaces, yields a strong petroliferous odor. The Tully/Geneseo is not exposed here but elsewhere is seen to be sharp or gradational over a few cm.

How are we explain the abrupt change from black shale to clean, fossiliferous carbonate followed by a return to black shale? Deposition in relatively deep water seems to be required for the Geneseo given its very fine grain size, laminations, dark color, petroliferous materials, and lack of benthonic or infauna. Its very great areal extent (New York to Alabama and west into the midcontinent as part of the Chattanooga Shale sequence) suggests deepening in response to eustatism (Johnson, Klapper and Sandberg, 1985). Acadian tectonism to the east provided the siliciclastics found in the Geneseo and probably contributed to the deepening.

The Tully at this location, on the other hand, represents a time of reduced siliciclastic influx and increased deposition of primarily biologic carbonates. Heckel (1973) explained the reduced clastic influx to the Tully deposites in New York by postulating a fault-bounded uplift further east. Alternatively, Brett and VerStraeten suggested that the uplift might be a foreland bulge (reported in Heckel, 1997, p.80). Whatever the explanation for the lack of clastics in the Tully, a rapidly subsiding basin existed to east in New York. The easterly basin trapped enormous volumes of sandstone and shale represented, for example, in southeastern NY and northeastern Pennsylvania by the Sparrow Bush Sandstone (Woodrow and Fletcher, 1972). The basin filled rapidly and the boundary uplift was overwhelmed, spilling finer sediments to the west and flooding the Tully depositional surface and forming the Geneseo Shale as sea level rose.

Stop #2 Watkins Glen State Park.

THIS IS A HARDHAT LOCATION.

Vertical cliffs about 50 m high bound the stream draining from the narrow mouth of Watkins Glenlls. In the cliff are exposed medium gray, fine-grained sandstones and dark gray, silty shales of the Penn Yan (and West River?) Shales of the Genesee Group. With the Geneseo below, these rocks and the younger Devonian rocks above form a basin-fill about 2000 m thick in this region, of which all but a tiny percentage is siliciclastic

Exposures of the Group are available at many other locations around the south end of Seneca Lake. These rocks represent extend, at approximately the same elevation, from north of Watkins Glen south to Montour Falls village where they are exposed in a falls. The Fir Tree Point anticline crests about 4 km north of Watkins Glen and this fold disrupts the regional southerly dip of a degree or less and renders the sequence nearly horizontal for a north/south distance of at least 10 km.

Watkins Glen village has long been the site of salt production and tourism and, occasionally, disastrous flooding. Two companies are presently extracting salt by solution from the Salina Group about 700 m below ground. Tourists come to WGSP and its campground, the Glen auto-racing track on the hill above, the nearby wineries, and Seneca Lake. Few people, however, are aware of the flooding potential posed by the creek which flows through WGSP, Watkins Glen village and into the adjoining marsh. The stream flows out of the Glen on to the alluvial fan on which the village is built. This means that much of the village is subject to the sedimentary processes associated with fan development. An example: on a summer evening in July, 1938, 7-8" of rain in a few hours time resulted in a mass of water, mud, boulders, tree trunks, pieces of railroad bridge and other flotsam plugging the Glen mouth and then bursting out on to the town. In the resulting flood, one person died, several houses were destroyed, and much of the village suffered damage. Major flooding events look to have about a high recurrence at intervals of about 30-50 yrs and are little thought about in the interim.

The sandstones and shales in this exposure are arrayed in cm-scale fining-upward sequences. Body fossils are extremely rare but there is scattered plant debris and some bioturbation. The sandstone beds are sharp-based with their basal surfaces marked by groove casts and rare, flutes. The sandstones are fine- to medium-grained at the base, some contain shale chips, and they fine upwards to siltstone and shale. Well defined small-scale and steep cross-strata, some arrayed as climbing ripples, are found at the base of individual beds with larger-scale, low angled cross-strata at the top. Sandstones grade into shales at the top of each couplet.

The sequence looks to be a stack of turbidites made by dilute, relatively slow-moving and lightly erosive density currents. No complete turbidite sequences are found in these exposures. Most are based on Bouma subdivision "c" and a few are based on subdivision "b." (Bouma, 1962; Isley, 1981; Woodrow and Isley, 1984). As differentiated by color in the cliff face, it is apparent that there are 3-5 m thick, repetitive sequences, probably fifth-order sequences or cyclothems.

It should be noted that the sequences in and near WGSP are typical of those seen in this facies in the Late Devonian of New York and Pennsylvania which strongly suggests that the Late Devonian sea floor in this region was of low, steady gradient. Abrupt changes in gradient were the exception, not the rule. This interpretation is based on the absence of channeling, slump scars, slumped masses and thick "slope muds," all typical of modern-day continental slopes. That channels are rare in this sequence is demonstrated by their being only a single channel-fill in rocks of this facies known to this writer and that is exposed along I390 south of Danville, NY (Kirchgasser, Over, and Woodrow, 1997). Further, sediment transport and deposition on a low-gradient ramp would explain the weakly erosive turbidity currents responsible for the turbidites seen here.

Stop #3 Cowanesque Dam Spillway.

THIS IS A HARD-HAT LOCATION.

PERMISSION TO VISIT THIS AND THE TIOGA/HAMMOND DAMS MUST BE OBTAINED FROM THE US ARMY CORPS OF ENGINEERS AT 570-835-5281 OR 570-827-3143.

Completed in 1980, the Cowanesque dam, like the Tioga/Hammond dams to the south, is mainly a flood-control structure. Construction of the three dams was impelled by devastating hurricane-related flooding in 1972. Exposures resulting from the construction of the three dams plus those along US 15, a rerouted railroad and local streams provide the most complete and extensive late Frasnian sections in this region. The exposures presently available will be added to by new exposures along US15 in NY and PA as it is upgraded to interstate specifications. The Tioga gas-storage field underlies the hills between the Cowanesque and Tioga/Hammond dams and data from the wells drilled in it will provide further insights into the local stratigraphy. A well in the Tioga gas field provided samples which constitute the type section of the Middle Devonian Tioga Bentonite.

At Cowanesque, the stratigraphic position of the rocks is latest Frasnian (pre-Dunkirk Shale) equivalent to the Wiscoy Sandstone of New York. The Pennsylvania Geologic Survey places these rocks in the Lock Haven Formation. Without more detailed mapping and work on the fossils, more confident temporal placement of these beds is not possible.

At the spillway is a 60+ meter section made up of medium-grained sandstones and gray, silty mudstones and shales. A stratigraphic section will be provided on the trip. Thickness of individual sandstone beds varies from a few cm to a meter. Cross-strata occur at many scales in the sandstones and some are hummocky. Mudstones are heavily bioturbated. The finer grained rocks contain many fossils, mostly brachiopods. Bone fragments and plant debris are found scattered through the section.

These strata represent shallow-water marine environments. Waves effects are apparent in the sandstones and the diverse epifauna and infauna indicate shallow water as well. Red strata are about 100 m upsection and to the southeast, toward the ancient shoreline, red strata are developed in this interval within 50 km of this location.

In the cliff above PA 49 (and inaccessible to us) are several, 5-8 m thick bodies of medium gray, medium- to coarse-grained sandstone. They rest on strata like those seen in the spillway and are taken to be distributaries or distributary-mouth bars built on to a muddy sea floor.

Alternative to Stop #4. PA rte 287, about 2 km west of Tioga village.

THIS IS A HARDHAT LOCATION.

This is one in a group of a closely-spaced exposures found along the RR track below rte. 287, on both sides of rte. 287 and on both sides of the access road from rte. 287 to the Hammond Dam Overlook on the hillside above. About 75 m of section are available here. If the trip visits this location, sections on the north side of rte. 287 and the Overlook access road will be examined.

These are highly fossiliferous sandstones and shales. A bed of rugose corals is found at the base of the section. A meter-thick sandstone, granule-bearing sandstone about 15 m above the base of the section has in it well preserved bivales and spiriferid brachiopods. Brachiopods and bivalves are common in the higher strata and are the predominant feature in some beds. Ball-and-pillow structures occur in reddish-gray sandstones toward the top of the section.

By projection, these strata look to underlie those seen in the Connecting Channel (and those at stop #5) by about 100 meters. The relationship oft these strata to those exposed at the Cowanesque Spillway is uncertain but if both sections are pre-Dunkirk then their stratigraphic positions may be comparable.

Stop #4 Tioga Dam and connecting channel.

THIS IS A HARD HAT LOCATION.

PERMISSION TO VISIT THIS SITE MUST BE OBTAINED FROM THE US ARMY CORPS OF ENGINEERS AT 570-835-5281 OR 570-824-3143.

We will look first at the section as it is exposed on the south side of the Connecting Channel and, depending on time, proceed down the access road to examine the "white bed" and the rocks immediately above and below it. A stratigraphic sequence will be provided at the trip. We will then walk through channel to look at very large burrows in red strata thought to be estivation tubes of lung-fish and to see what is thought to be the Center Hill ash bed.

This section, and the one like it on US 15 overlooking the dam and about 2 km east of it, spans the Frasnian/Fammenian boundary. (A column will be provided at the trip.) It also documents the marine to nonmarine transition. Starting at the base is a sequence of fossiliferous, darkgray shales and sandstones. In the dark gray shales near the base of the section is what appears to be a bed of ash, perhaps the equivalent of the Center Hill Ash Bed (Wahler, 1984). Between the dark gray shales at the base and thinner gray shale and sandstone sequence above is a thin red sequence exhibiting mudcracks and what appear to be lungfish aestivation burrows. A light-gray sandstone referred to informally as the "white bed" is just above the second gray unit, about 10m above the red bed. Above that, gray, fossiliferous strata return and those give way upsection to red beds many tens of meters thick. Fish material is common in the uppermost red beds.

This is clearly the record of a shoreline without a beach. Instead, the sequence appears to represent a low- relief, muddy shore protected from wave attack by sand bars (white bed) just offshore.

Alternate stop #4. Roadcut, PA rte 287, west of Tioga village.

Three separate, but closely spaced exposures: along a railroad, on both sides of rte 287 and along road to the Hammond Dam Overlook, provide access to about 75 m of section. A stratigraphic section of the road exposures will be provided on the trip.

The section is made up of medium grained sandstones and gray silty shales with many fossils throughout. Notable strata include: a bed of rugose-corals near the base, two quartz granule-bearing sandstones about 15 m higher, profusely fossiliferous strata about 15 m above that and ball-and-pillow structures in dusky red, fine-grained sandstones near the top. Brachiopods, bivalves, and crinoids are the most common fossils.

Knowing the stratigraphic position of these strata is difficult. Projecting them across the valley to the Connecting Channel suggests that they are 100 m lower than the rocks seen there. That would make them Late Frasnian, a position in accord with finding rugose corals. Those corals are a well-known feature in Frasnian strata in New York.

Stop #5 (optional). Roadcut, US 15 overlooking the Tioga Dam.

THIS IS A HARDHAT LOCATION.

This section duplicates most of what is seen at Stop #4 except that the section is less well exposed over much of its extent and the din and danger of heavy traffic is constantly in evidence. However, the section is available for study at any time with no permission needed.

Stop #6 (optional). Roadcut (new), US 15 at Blossburg, PA.

THIS IS A HARDHAT LOCATION.

This section has been recently opened as part of the upgrading of US 15. A stratigraphic section will be provided at the field trip. The main feature of the base of this 100+ m section is medium- to coarse-grained sandstones arrayed in 10 m thick, cross-stratified, fining-upward sequences. A 5m thick, very fine-grained gray shale occurs mid-way up the section with red strata and light-gray sandstones at the top. The shale may mark the base of the Carboniferous. Results from a study of miospores study may be available at the time of the trip as a test of this this hypothesis.

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ROAD LOG

Distances are approximate

0.0	Parking lot, Scandling Center, Hobart and William Smith Colleges, Turn left (s) to Pulteney St.
0.3	St.Clair St. Turn right (w).
0.8	White Springs Road. Turn left (s).
2.1	Snell Road. Turn right (w).
3.2	Snell Road veers to the right.
3.7	Preemption Road (Ontario County Rd. 6)
8.0	**Stop #1, Kashong Creek, Bellona, NY**. Park where convenient. Be certain not to block the Fire Department driveway. Leaving Bellona, proceed right (s) on Preemption Road.
8.3	Earl's Hill Road. Turn left (e) toward Seneca Lake.
10.3	NY rte 14. Turn right (s).
38.1	**Stop #2, Watkins Glen State Park (WGSP), Watkins Glen, NY**. Park in the parking lot along the creek bank. Do not enter stairway to Glen. Leaving WGSP, proceed right (s) on NY 14.
38.8	Junction of NY 414 and NY 14. Veer right (s) on NY 414 toward Corning.
57.8	Junction with NY 17 (I86). Turn right (w). Road Cut on right is of the Frasnian West Falls Group. Sequences with shale at the base grading upsection through 5-10 meters to lighter gray sandstones, some containing corals. Leslie (1999) has described the lower part of this poorly accessible exposure.
60.7	Junction with US 15. Turn left (s).
73.8	Lawrenceville, PA. Turn right on PA 49. Cowanesque Dam is visible straight ahead.
76.1	**Stop #3. Cowanesque Dam, Lawrenceville, PA**. Pull off the road and walk downhill on the dirt access road. Exposures in spillway, cliffs below and above road. Leaving Cowanesque, proceed left (e) on PA 49.
78.9	Lawrenceville, PA. Turn right (s) on US 15.
83.3	Junction of US 15 with PA 287. Go straight ahead on PA278.
85.6	Tioga, PA. Junction of PA 278 with South Main St. Continue straight ahead (s) on South Main St.
86.0	Turn right (w) on Channel Overlook Access Road.
87.3	**Stop #4. Tioga/Hammond Dams connecting channel**. Sections are available here along the various access road and in the channel proper. **Be very careful as we walk on the paved ledges beside the channel.** These rocks appear to span the Frasnian/Fammenian boundary. Gray, marine rocks are at the base of the section and

red beds are found at the top. Leaving the Channel Overlook, return via access road and S. Main St. to junction with PA 278.
[Note: If the weather is bad, we will forego the Tioga/Hammond Dams Connecting Channel and go, instead, to a major exposure on PA 287, about 2 km west of Tioga Village. This exposure is the first one west of the village the right (n) side of rret 287.]

88.9 Junction with PA 287. Continue straight ahead on 287.

90.6 Junction with US 15. Turn right (s) on 15 for two optional stops.
Optional stop #5. Roadcuts on US 15 east of Tioga Dam. This section duplicates much of what is seen at stop #4, however, much of the section is not well exposed along the highway. The red beds at the top of the section are more readily accessible here as is the sandstone/shale section at the base.
Leaving Stop #5, proceed south on US 15 to see optional exposure #6.

112.6 **Optional stop #6. Roadcuts on US 15 at Blossburg, PA.** This section is new and has not been examined in detail. The lowermost strata are thought to be latest Devonian with the Devonian/Carboniferous boundary higher in the section. The coarse grain size of the sandstones, presence of non-persistent sandstone bodies as much as 10 m thick, rarity of gray strata, presence of channel-fill cross-strata and lack of body fossils and bioturbation all suggest that these rocks are non-marine.
Leaving Blossburg,, turn left (N) on US 15. Return to Geneva via US 15 to Corning, NY 17 east to NY 414, NY414 to Watkins Glen and NY 14 to Geneva.

195.8 Scandling Center parking lot, Geneva, NY.

MASTODON ROAD LOG

John Chiment, Cornell University

Actual directions are in boldface, points of interest in regular typeface. These are **not** stops!

Geneva to Demonstration site via P.R.I.

0.0 Hobart and William Smith Colleges. The corner of Pulteney and Rts. 5 and 20. **Turn right on Rts. 5/20.**

0.5 Ramada Inn. **Follow Rts. 5/20 east.**

0.8 Lakeshore Park. "The Geneva" lake tour boat on the right. To the left, the Fingerlakes Railroad (a privately owned railroad with 100 miles of track).

2.5 **Take Rt. 96a right to Ovid/Ithaca. Proceed south on Rt. 96a.**

3.3 Crows Nest Restaurant

3.8 Rose Hill Mansion. Greek revival style mansion. Built in the early 1800s. Site of many early agricultural experimental plantings.

4.1 Historical Marker commemorating the Clinton-Sullivan Campaign of the Revolutionary War. In August 1779 four thousand soldiers of the Continental Army marched out of Pennsylvania against the Iroquois. The Drain Tile Museum, just behind the marker, commemorates the introduction of drain tiles to the western hemisphere.

7.6 New Land Winery

9.1 The white plastic tanks are connected to natural gas wells.

9.9 Seneca Army Depot. Decommissioned, former home of nuclear warhead missiles. Now the home of Kids Peace organization and N.Y. State Correctional Facility. Home to a herd of albino deer.

13.8 Sampson State Park. Former Navy and Air Force training area.

14.2 Old Seneca Army Airbase. Reported to have the longest runway on the East Coast.

15.2.1 Kendai-i, site of an Iroquois village destroyed by the Clinton-Sullivan Campaign.

17.5 Willard. Originally a hospital during the Civil War (War of Northern Aggression). In 1864 it became the first N.Y. State Land Grant University. Later it was a psychiatric hospital and is now a prison for drug offenders (don't pick up hitchhikers).

19.9 **Ovid. Turn right at the flashing red light/stop sign. IGNORE the Ithaca sign. Go straight ahead to Ovid. Stay on Rt. 96a to Watkins Glen.**

20.2 Look at the cute County Buildings on the left. The courthouse, Sheriff's office and library are known as "the three bears".

20.5 **Continue south on Rts. 96a/414.** Keep an eye out for horse-drawn Amish conveyances.

24.5 **Lodi. Turn left on Rt. 96a at the Eagle Hotel.**

26.1 Drainage divide between Seneca and Cayuga Lakes. Notice the flat horizon of the Devonian seabeds.

29.1 Interlaken. Summer home of the Westinghouse family and Rod Serling. Site of the infamous sponge fossil find at Mike Potts' service station (see exhibit at PRI).

29.5 **Turn right on Rt. 96 south.**

31.1 Interlaken. Across the lake is Milliken Power Plant. Coal-fired plant supplied by a train from Pennsylvania.

33.3 Hamlet of Covert. Covert Bed & Breakfast.

35.5 Trumansburg. Tompkins County Line.

37.5 Smith Woods. Large trees in an old-growth forest.

37.7 **Turn left at Taughannock Falls State Park onto Taughannock Park Road.** See Taughannock creek on the right.

38.3 Former home of Ithaca College Professor Moog. Father of the Moog Synthesizer, used by the Beatles on the Abbey Road album.

38.5 Kimberlite dikes intersect the creek bedrock. These were discovered following the flood of 1935. Diamond mine opened in 1935-36. Sorry folks, no diamonds.

38.8 Follow the road to the right noting how the creek's path is joint-controlled.

38.9 **Turn left into Taughannock State Park.**

39.5 Taughannock Falls overlook on the right (restrooms, water fountain). The bumper-stops are concretions from the Tully Limestone. **Continue downhill.**

40.3 **Turn right on Rt. 89 south.**

40.4 Taughannock Creek Delta.

Quick! Look right to see

40.5 Lower Taughannock Falls, spilling over the Tully Limestone.

SHARP RIGHT, NOW!

40.6 **Turn right on Gorge Road.** As you climb, be sure to notice the precipitous drop into the gorge on your right.

42.3 **Turn left onto Jacksonville Road at the stop sign.** This area was settled by Quakers in the 1820s.

43.7 **Turn left onto Rt. 96S.** The houses on your left were temporarily abandoned because of well contamination.

45.6 Spikes BBQ. Best BBQ in the area. Pick up a bumper sticker that says, "You Can't Beat Spike's Meat".

46.0 Bellwether Hard Cider (you can stop for a sample…)

46.7 ISA Babcock Chicken Hatcheries. Currently owned by a French company, this small hatchery produces a large portion of the world's laying hens.

STOP #1 PRI

48.6 **Turn Left onto road IMMEDIATELY after the traffic light at the hospital.** Park at the first brick and stone building. This is the Paleontological Research Institution, a former International Order of Odd Fellows orphanage, where you will meet such odd fellows as Cornell's Big Red Mastodon (aka the Chemung Gilbert Mastodon), PRI's Hyde Park Mastodon, and the skeleton of a Right Whale.
Continue south on Rt. 96.

49.2 View of Cornell University on Ithaca's East Hill.

49.9 View of Ithaca College on Ithaca's South Hill.

50.7 Welcome to the Octopus! **Proceed to the junction of Rt. 13 (Fulton St.) and Rt. 96. Turn right onto Rt. 13.**

51.0 **Follow Rt. 13 south- bear right.** During the flood of '94 the Tops/Wegman's parking lot to your right was a fishing and water-skiing paradise for about a day and a half.

52.5 To the right it the proposed site of a "big box" store.

52.7 To the left is the entrance to Buttermilk Falls State Park

53.2 To the right is the site of a Tutelo Indian village. The Tutelo were subject to the Iroquois, and were granted a sort of "reservation" here. The Clinton-Sullivan Campaign wiped out the village in 1779.

54.1 The entrance to R.A. Treman State Park. **Stay in the right lane; follow Rt. 13 south toward Elmira.**

54.4 On the left, the building with the amazing color and architecture is the Gables Inn. It was originally called "Sunny Sides" and was the home of the founder of The Agway and P&C stores. It has survived several reincarnations as a restaurant.

57.4 Town of Newfield. Devonian shale exposed in road cuts.

58.7 On the right Arnot Forest, Cornell research facility.

60.2 On the right, Connecticut Hill, highest point in Tompkins County. In the 1780s the subject of a land dispute between New York, Pennsylvania and Connecticut.

63.9 On the left- almost anything you can imagine in plaster or concrete for your lawn!

65.7 On the right is old-growth forest that has never been logged.

66.7 **Continue south on Rt. 13 at the traffic light, BUT BE PREPARED TO TURN RIGHT SOON!** New Harley-Davidson dealership on your left.

66.8 **Turn right on Schuyler County Road 14.** This is the old Hinman Turnpike. Don't worry- they don't charge anymore.

70.2 This 3-WAY intersection is known as "The Corners". It marks the boundary of the Watkins-Flint purchases of 1795. **Continue south on C.R. 14.**

73.9 **Go left at the stop sign onto Rt. 14.**

74.4 On the right is Catherine Creek, a world famous trout stream. It used to be the Chemung Canal, the only canal in this area to cross the Susquehanna/St. Lawrence drainage divide.

STOP #2 DEMONSTRATION SITE

Look for sign and Cornell Van (dark blue van)

76.4 **Turn left and park at the Demonstration Site for GPR, GPS, and Coring Demonstrations.** This is an open grassy area on the left.

This is the official southern end of the field trip. If you continue south on Rt. 14, you will reach Elmira/Horseheads. If you go north on Rt. 14, you will reach Watkins Glen and eventually, Geneva.

To go back to Watkins Glen and Geneva (Hobart-William Smith)

7.64 **Proceed north on Rt. 14**

78.9 Montour Falls. **Do not turn right. Continue on Rt. 14.**

79.1 To the right is Havana Glen.

79.2 Crossing Catherine Creek.

79.4 The Fire Academy. Formerly Cook's Academy, one of Cornell's competitors for land grant university in 1864.

79.9 **Turn left at the traffic light and follow the business district signs.** Straight ahead is She-Qua-Ga falls.

80.2 On the right are two unusual all-brick Greek Revival buildings. **Turn left (south on Genesee st.), park and visit She-Qua-Ga Tumbling Waters. Go north on Genesee St. to Catherine St. Follow Catherine and turn left at the intersection with Rt. 14.**

80.7 On the left, Devonian shale in the road cuts and waterfalls. On the right, Queen Catherine Marsh.

81.2 Chef's Restaurant.

82.1 Watkins Glen. **Stay on Rt. 14 north.**

82.3 Pizza Hut.

82.6 Entrance to Watkins Glen State Park.

82.7 The original finish line for the Watkins Glen Grand Prix.

83.0 On the right, Glen Mountain Market and the Watkins

Hotel. Start the Seneca Lake Wine Trail.

85.4 Cascada Winery. **Stay on Rt. 14 north to Geneva.**

86.6 Lakewood Vineyards.

87.2 Arcadian Winery.

89.0 Yates/Schuyler County line. Earliest European settlement in the Seneca Lake Area. Jemima Wilkins religious sect settled in the late 1700s.

91.2 Fulkerson Winery.

91.8 Glenora Winery.

92.9 Freedom Village.

93.3 Barrel People Winery

96.9 Weimar Winery

98.3 Meadery (F. Y. I. if you've never attended a Renaissance Fair: mead is a drink made from fermented honey).

101.0 Torrey Ridge Winery

101.5 Prejean Winery.

101.6 River cobble house

102.5 Longpoint. Salvation Army camp.

103.0 Look out in the lake. The U.S. Navy's Underwater Sonar Testing Research Facility.

104.5 Dresden Power Plant. Coal-fired plant supplied by Pennsylvania Coal.

106.8 Anthony Road Winery

107.6 Seneca Shore Wine Cellar

108.6 Fox Run Winery

108.9 Cobblestone house

111.1 Historical Marker. Clinton-Sullivan Campaign.

104.7 Spinnakers (Seafood- good food, good view).

106.1 Bellhurst Castle (hotel & restaurant).

106.8 Geneva on the Lake (hotel & 4 star restaurant).

107.5 Hobart and William Smith Colleges.

FACIES AND FOSSILS OF THE LOWER HAMILTON GROUP (MIDDLE DEVONIAN) IN THE LIVINGSTON COUNTY-ONONDAGA COUNTY REGION.

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INTRODUCTION

The stratigraphic interval between the top of the Late Eifelian Onondaga Limestone and the base of the Givetian Ludlowville Formation (Union Springs, Oatka Creek, Skaneateles formations) has traditionally received less attention from stratigraphers and paleontologists than overlying Hamilton Group formations. This is due partly to poor exposure of these units in the western New York region, but also to the general impression (largely correct) that this overall succession consists of sparsely fossiliferous and unfossiliferous dark gray to black shale facies. Discovery of widespread fossil-rich condensed limestone beds within the Union Springs and Oatka Creek formations and associated corrosional discontinuities in these same formations (Baird and Brett, 1986, 1991; Griffing and Ver Straeten, 1991; Ver Straeten et al., 1994) has served to enhance our understanding of foreland basin dynamics during a key pulse of the Acadian Orogeny. Study of fossil-rich levels in the Skaneateles Formation in central New York induced the present authors to trace known key beds westward across New York into the undivided shale succession of the Levanna Member (Baird et al., 1999).

The present paper continues from the theme of last year's NYSGA paper and field log (Baird et al., 1999) which reviewed lower Hamilton facies and key beds between Buffalo and the Genesee Valley. This paper and excursion examines the same divisions in the region from the Genesee Valley eastward to the Cazenovia meridian in central New York. Because the stratigraphy and issues surrounding units in the Union Springs and Oatka Creek formations have been covered extensively in the Baird et al. (1999) field trip and comprehensively in Griffing and Ver Straeten, (1991); Ver Straeten et al., (1994), these units are treated more synoptically in this paper. However, a brief review of key issues pertaining to these formations is provided below and in the stop description for the Seneca Stone Quarry (STOP 1). The present paper focuses on correlational connections within the Skaneateles Formation, most notably the relationships of key Levanna Member markers (top-Cole Hill discontinuity, Papermill Bed, Roanoke Bed, Pole Bridge Bed, Wadsworth Bed, Slate Rock beds), described in Baird et al. (1999), to recognized member-capping divisions in the central New York Skaneateles section.

UNION SPRINGS FORMATION

Across central and western New York the Union Springs Formation is a thin, significantly truncated division composed of two very widespread units (Figs. 1, 2). The lower unit, called the Bakoven Shale, is a basinal bituminous shale that typically overlies a corrosional discontinuity and associated bone bed developed on the topmost carbonate unit (Seneca Member) of the Onondaga Limestone (STOP 1). The Bakoven records combined eustatic and tectonic deepening probably associated with thrust loading during the second tectophase of the Acadian Orogeny (see Ettensohn, 1987). Above the Bakoven a thin, fossiliferous limestone unit, the Chestnut Street submember of the Hurley Member is observed. In western New York the Chestnut Street submember, yields a moderate diversity of fossils including the brachiopod *Variatrypa*, small rugosans, numerous exuviae of the proetid *Dechenella* and a small crinoid *Haplocrinites*. It records oxic conditions and a significant shallowing from the basinal setting of the Bakoven. The Bakoven correlates eastward to the vastly thicker siltstone and calcareous siltstone succession of the Stony Hollow Member in the Hudson Valley (Griffing and Ver Straeten, 1991).

OATKA CREEK FORMATION

In western New York, the Oatka Creek Formation consists, in ascending order, of the Cherry Valley Member, Berne Member, Halihan Hill Bed, and the Chittenango Member (Ver Straeten et al., 1994). The Cherry Valley

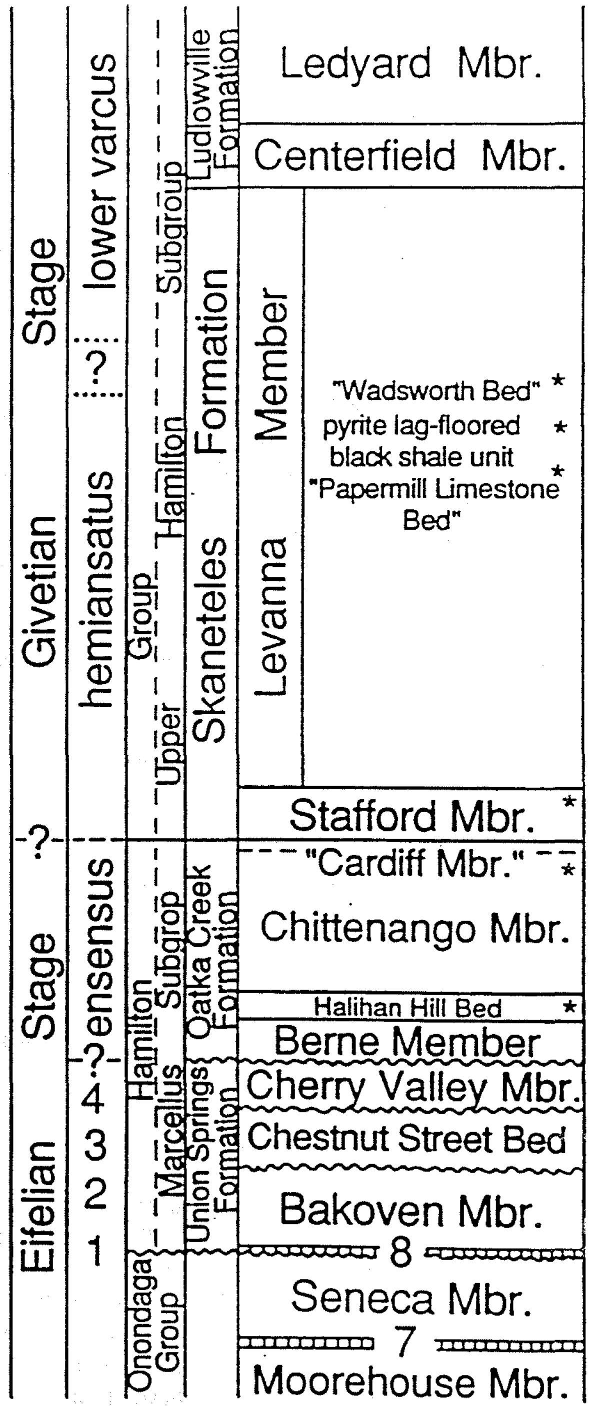

Figure 1. Generalized succession of lithologic and zonal units in the uppermost Onondaga Formation-through-basal Ludlowville Formation interval in western New York. Numbers denote: 1, base-Bakoven Member discontinuity; 2, *Cabrieroceras plebieforme* zone; *Haplocrinites* zone; 4, *Agoniatites vanuxemi* zone; 7, Onondaga Indian Nation (OIN) K-bentonite; 8, Tioga "F" K-bentonite (from Baird et al., 1999).

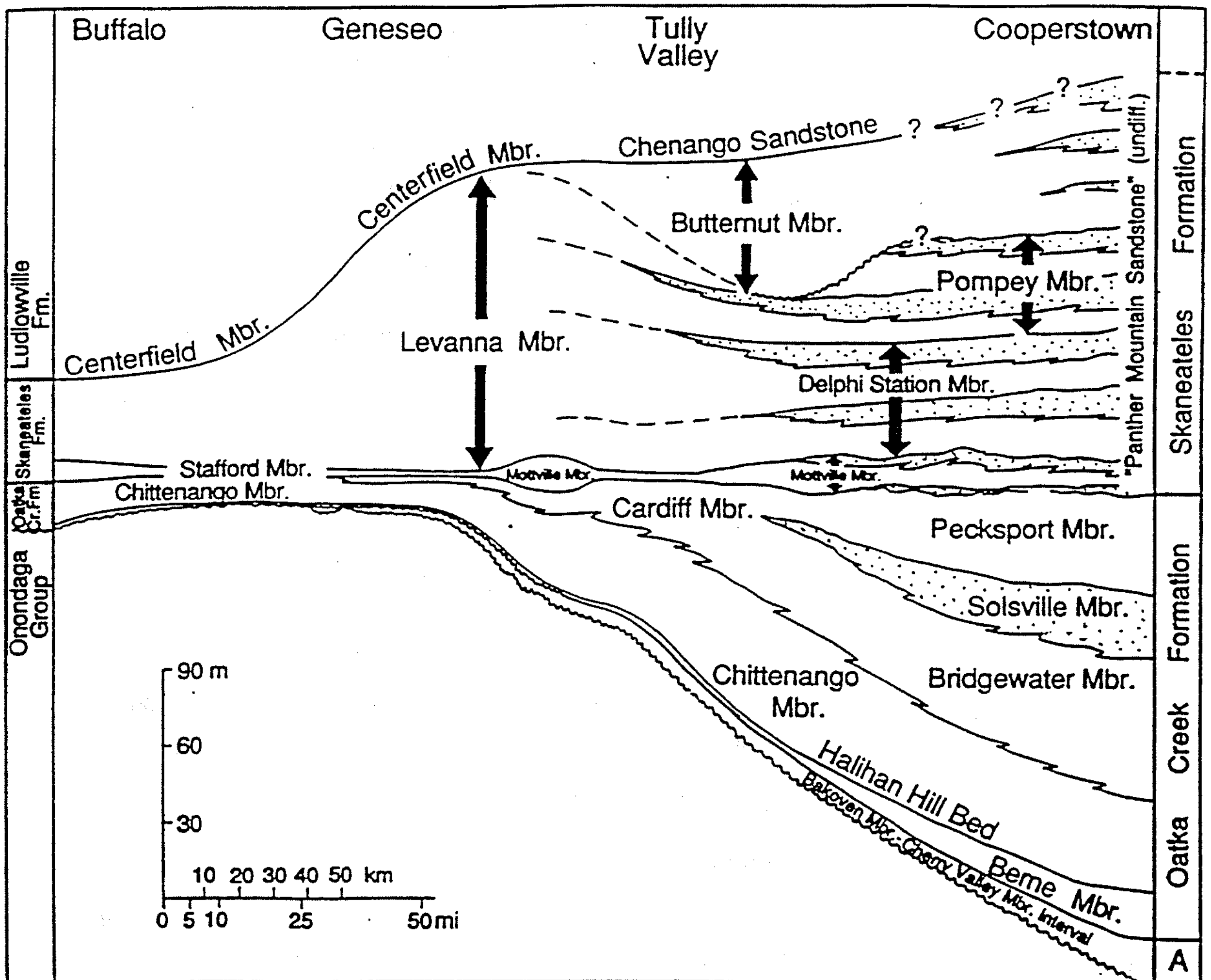

Figure 2. Generalized stratigraphy and unit relationships in the lower part of the Hamilton Group along the east-west outcrop belt across New York State. Conspicuous eastward thickening of units reflects clastic influxes associated with the second tectophase of the Acadian Orogeny and coincident deepening of the Devonian foreland basin (from Baird et al., 1999).

Limestone is a distinctive brown petroliferous and nodular, thin carbonate layer that is extremely widespread (Fig. 2). At STOP 1 it shows its typical condensed character and distinctive fauna. Key fossils in this unit include styliolines, thickets of auloporid corals, and large cephalopod conchs. Orthoconic cephalopods and the zonally important goniatite *Agoniatites vanuxemi* are particularly abundant in the upper part of the unit; these were exposed by the hundreds, until recently, on the top-Cherry Valley discontinuity surface at the Seneca Stone Quarry (STOP 1). The Cherry Valley truncates the upper part of the Union Springs Formation across western New York and it is overlain, in turn, by a corrosional discontinuity beneath the Berne Member from Cayuga Lake westward. West of the Genesee Valley both the Cherry Valley and the underlying Union Springs Formation appear to be absent due, in part, to erosional (corrosional) beveling beneath the Berne Member (Baird and Brett, 1986, 1991; Baird et al., 1999; Fig. 2). The fauna of the Cherry Valley and that of the underlying Chestnut Street Bed-Stony Hollow interval differs significantly from that of the Onondaga fauna and that of the overlying Hamilton fauna. This reflects the global Kacak-otomari evolutionary-ecological biotic succession and faunal disturbance that is recognized by many workers (Chlupac and Kukal, 1986; Trylos-Massoni et al., 1990).

The Cherry Valley Limestone is succeeded by a black, fissile highstand shale unit known as the Berne Member (Griffing and Ver Straeten, 1991; Ver Straeten et al., 1994; Fig. 1). From Syracuse westward to LeRoy the Berne is represented, at best, by only a meter or less of section in outcrop, although this unit is vastly thicker in the Hudson Valley. Above the Berne Member is 0.3 - 1.0 meter-thick interval of profusely fossiliferous gray shale that is designated the Halihan Hill Bed (see Griffing and Ver Straeten, 1991; Baird et al., 1999). This unit is unusual both for the fact that it remains thin from the mid-Hudson Valley region all the way to LeRoy in western New York and for the first appearance of the Hamilton fauna, an evolutionary-ecological biota that would persist almost to the end of the Givetian (Brett and Baird, 1995). Key fossils in this bed include the brachiopods *Tropidoleptus*, *Pseudoatrypa*, *Athyris*, *Mediospirifer* chonetids, and ambocoeliids. Small corals, bryozoans, diverse bivalves and the trilobite *Phacops* are also present. The widespread, thin and condensed nature of this unit is problematic considering that it records a major regression at this time. Typically, Hamilton regressive units (Mottville Member, Chenango Member, Ivy Point and Owasco sandstones) record significant influxes of coarse sediment into the study area (Baird et al., 1999).

The Halihan Hill Bed is succeeded by an interval of black, organic-rich shale (Chittenango Member) that marks resumption of anoxic highstand conditions comparable to those recorded by the Berne Member. From Cayuga Lake westward this unit is less than 17 meters-thick, but to the east, it thickens to greater than 33 meters in the vicinity of Syracuse (Fig. 2). Moreover, the upper part of the Chittenango Member grades eastward into gray shale facies beginning at the Skaneateles Valley meridian. This gray shale interval, known as the Cardiff Member, thickens significantly to the east across Onondaga County (Fig. 2).

SKANEATELES FORMATION

STAFFORD MEMBER-MOTTVILLE MEMBER INTERVAL

The Stafford Member and stratigraphically correlative Mottville Member comprise the basal divisions of the Skaneateles Formation (Fig. 1). In sections west of Auburn, New York the Stafford Member consists of a 0.5 to 4 meter-thick interval of impure limestone beds yielding a low to moderate diversity biota. In Erie County the Stafford is 3 to 4 meters-thick and is characterized by a lower limestone bed yielding abundant *Devonochonetes* and *Emanuella* (Stafford "A" Bed) followed by an interval of thin bedded impure limestone which is succeeded, in turn, by a massive, nodular, cherty limestone unit yielding auloporid corals and a few other fossils (Stafford "B" Bed). From Stafford east to the meridian of Waterloo, the Stafford Member is a 0.3 - 1.0 meter-thick interval marked by a thin shell-rich shale unit at the base yielding *Emanuella*, auloporids rare *Dipleura* exuviae as well as flattened gastropods and orthocones (Meyer, 1985; Baird et al., 1999). Above the fossiliferous shale is a 0.25 - 0.7 meter-thick limestone ledge, or double ledge displaying a wackestone texture. Key fossils in the limestone include: *Bembexia* and orthoconic nautiloid conchs displaying black calcite preservation, the brachiopod *Cupulrostrum sappho*, *Phacops* exuviae and auloporid corals. At Great Gully south of Union Springs and at the roadcut and farm section (STOP 3) south of Half Acre, the Stafford again thickens to 3 - 3.5 meters and takes on the lithologic appearance of the Stafford in eastern Erie County, though with fewer fossils (Baird et al., 1999; see STOP 3). The basal *Emanuella*-rich limestone bed at STOP 3 probably corresponds to the "A" bed in Como Park at Lancaster. The

0.7 meter-thick nodular, and slightly cherty bed at the top of the STOP 3 section corresponds to the "B" bed in Erie County and to the Case Hill Coral Bed of the upper part of the Mottville in Onondaga County sections (Meyer, 1985; Baird et al., 1999). Fossil-rich calcareous shale deposits below the *Emanuella*-rich limestone layer at STOP 3 appears to correspond to a *Mediospirifer* and *Dipleura*-bearing calcareous mudstone unit at the base of the Mottville sections in Onondaga County that we herein name the Mason Hill Bed (see discussion below).

East of STOP 3, the middle and upper parts of the Stafford abruptly balloon in thickness as one crosses the Auburn meridian (Fig. 2). At Smiths Falls and at the type Mottville section north of Skaneateles, this interval exceeds 7 meters in thickness and is expressed as monotonous hard calcareous mudstone yielding *Zoophycos* and rare body fossils. The term Mottville applies to sections from Smiths Falls eastward, although sections east of Mottville are much thinner and are different in character. We believe, however, that lower Mottville units remain condensed and distinctive through the region. East of the Skaneateles meridian the Mottville thins and is quite condensed in sections south and west of Marcellus. However, only a short distance further east in the Marcellus quadrangle, the Mottville thickens slightly and develops the well known "two-limestone" motif of central New York sections (Grasso, 1986).

The Central New York Mottville Member is characterized by five mappable internal divisions; these are, in ascending order: a, a basal shell-rich calcareous mudstone or impure limestone layer yielding small brachiopods and mollusks as well as abundant *Mediospirifer*, large *Aulocystis* and the trilobite *Dipleura dekayi*; b, a calcareous siltstone interval (present mainly at and east of STOP 7); c, a hard, falls-capping crinoidal unit; d, a calcareous mudstone unit rich in *Mediospirifer*, *Tropidoleptus*, *Rhipidomella* and diverse associated fossils; d, a hard muddy limestone unit (Case Hill Coral Bed) yielding abundant rugose and tabulate corals; e, an interval of soft, gray shale yielding abundant *Ambocoelia* and small bivalves. Units b and d are the two limestone markers that make for easy identification of the Mottville Member across Onondaga County.

The lowest Mottville division is a 0.4 - 0.8 meter-thick shell-rich calcareous mudstone unit that caps the long mudstone succession of the Cardiff Member. We herein name this unit the Mason Hill Bed for exposures on an unnamed ravine paralleling Eager Road southwest of Mason Hill in the Jamesville 7.5' quadrangle. This layer typically yields large *Aulocystis*, *Mediospirifer audaculus*, *Emanuella*, as well as numerous bivalves and orthoconic cephalopods. *Mediospirifer* is rare in this bed west of the Otisco Valley meridian and the bivalve fraction is increasingly dominated by nuculoids in the same direction. This unit is confidently recognized in sections from Pompey Hollow (STOP 7) west to Smiths' Falls near Auburn.

Above the Mason Hill Bed at Pompey Hollow (STOP 7) is a 3.7 meter-thick interval of calcareous siltstone that is characteristically *Zoophycos*-churned. This unit is missing further to the west where the Mottville crinoidal limestone is juxtaposed onto the Mason Hill Bed. We believe that this siltstone unit thickens eastward and becomes a major regressive marker unit in the lower Mottville in the Chenango-Sangerfield valley region.

Above the unnamed calcareous siltstone interval is a 0.3 - 0.45 meter-thick calcarenitic limestone bed that typically caps waterfalls across the Onondaga County region. Herein, we name this ledge the Cedarvale Bed for waterfalls-capping exposures in three small gullies located 2.0 - 4.2 kilometers southwest of Cedarvale near the east edge of the Marcellus 7.5' quadrangle. The Cedarvale Bed is a crinoidal packstone to grainstone that unit occasionally yields large corals. At its base are minor channels and hydraulically enlarged burrows. This basal contact appears to mark a discontinuity; westward pinchout of the underlying calcareous siltstone unit is believed to reflect westward erosional overstep of this unit by the Cedarvale Bed. The Cedarvale Bed is an analog of the Stone Mill and Tichenor limestones, both of which are encrinite beds resting on sequence boundary unconformities (Brett and Baird, 1996). We believe that the sub-Cedarvale contact marks a eustatic lowstand and is a sequence boundary as well. At Pompey Hollow (STOP 7) the Cedarvale Bed is absent and its position is marked by a reentrant (Fig. 6). Moreover, the eastward appearance of the unnamed calcareous siltstone between the Mason Hill and the Cedarvale reentrant level at STOP 7 is consistent with our belief that the Mason Hill is a precursor bed followed by a regressive progradational clastic unit associated with a major lower Mottville lowstand event (Brett and Baird, 1996).

Above the Cedarvale Bed is a 0.7 - 2.0 meter-thick interval of calcareous mudstone yielding a diverse fauna. This unit, as yet unnamed, yields abundant *Tropidoleptus*, *Mediospirifer*, *Nucleospira* and *Rhipidomella*. Other fossils

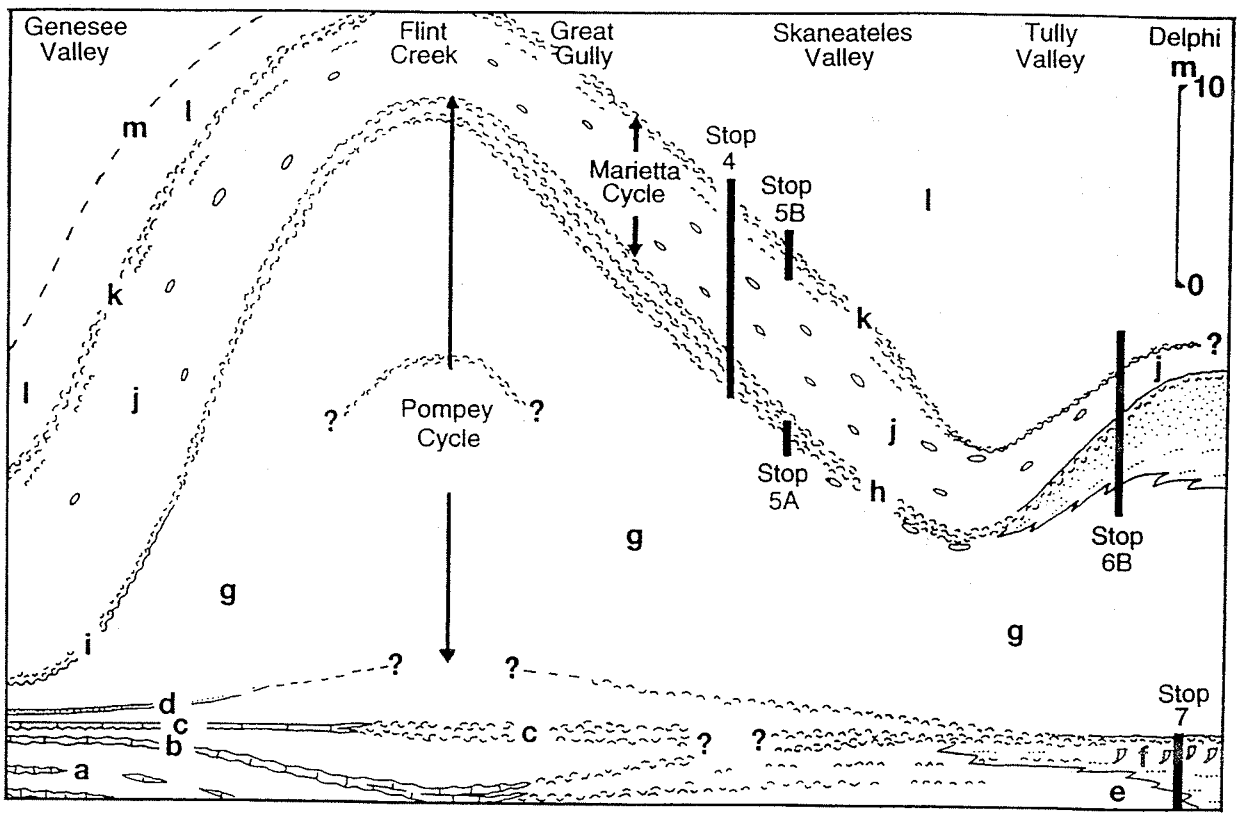

Figure 3. Medial Skaneateles Formation correlations across the Finger Lakes region. Divisions shown include: the upper Delphi Station cycle, Pompey-Marietta cycle interval and the Butternut Shale interval. Lettered units include; a, calcareous shale and limestone facies comprising the upper part of the upper Delphi Station cycle in western New York; b, Papermill Limestone Bed; c, Pole Bridge Limestone Bed and equivalent *Crurispina nana*-rich shell bed; d, *Tasmanites*-rich bed flooring Pompey cycle; e, silty shale of Delphi Station Member; f, siltstone-fine sandstone facies of uppermost Delphi Station Member; g, Pompey cycle shale succession; h, top-Pompey *Nyassa-arguata*-rich shell bed bundle; i, Wadsworth Bed; j, Marietta cycle shale succession; k, Slate Rock bundle of shell beds; l, dark gray to black highstand shale facies of Butternut succession, m, Centerfield Member.

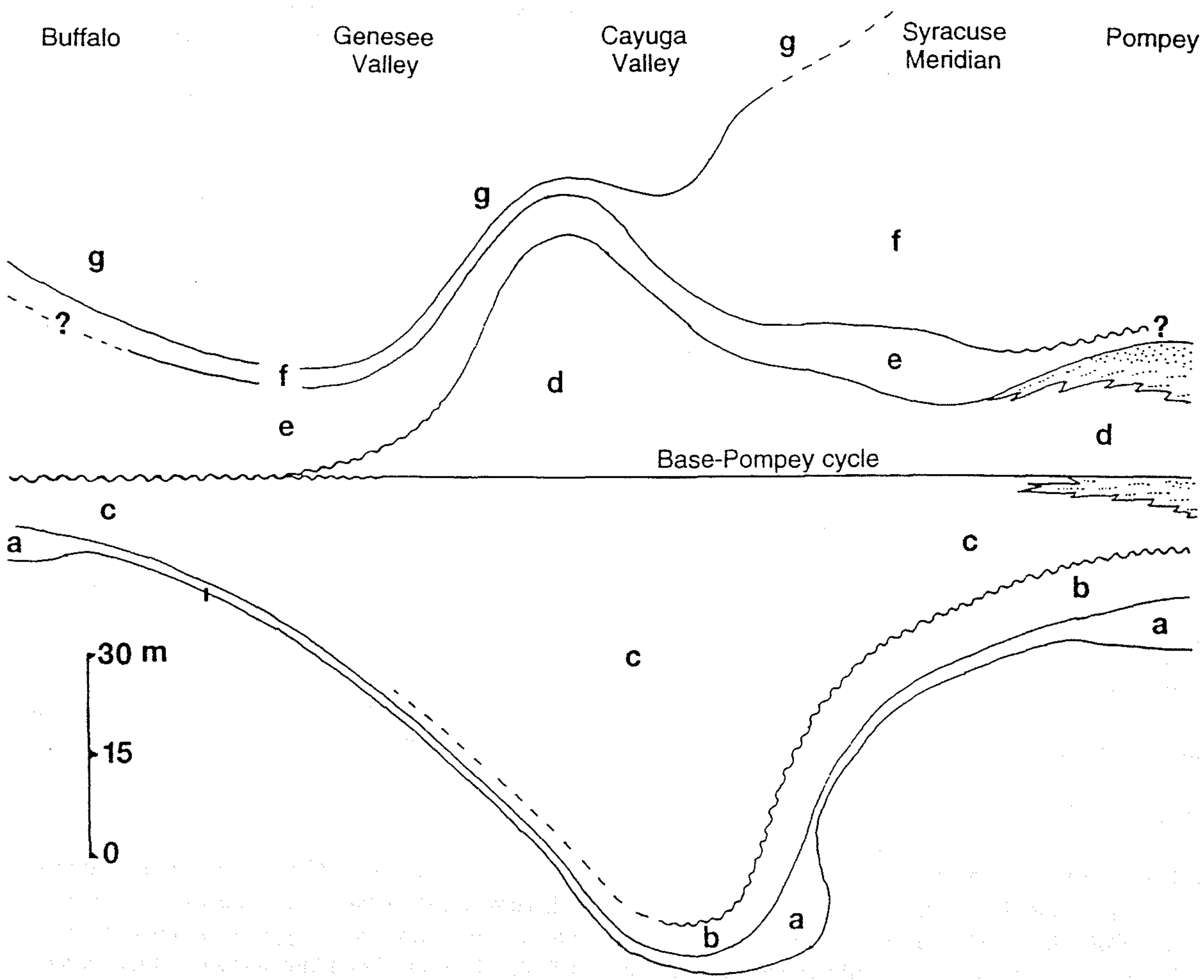

Figure 4. Dynamic pattern of shifting depocenters observed in the Skaneateles Formation. Divisions shown include: a, Stafford-Mottville interval; b, Cole Hill cycle; c, upper Delphi Station cycle; d, Pompey cycle; e, Marietta cycle; f, Butternut Member and Butternut Member-equivalent Levanna Member strata; g, Centerfield Member.

include abundant bryozoans and diverse bivalves. At STOP 7, this division is represented by two meters of fossil-rich strata between the Cedarvale reentrant and the overlying Case Hill Coral Bed (Fig. 6). The Case Hill Bed is the second regional carbonate marker of the central New York Mottville section (Grasso, 1996). This layer is typically 0.3 - 0.6 meters-thick and is typically represented by a muddy limestone ledge that holds up a secondary higher falls lip in Mottville sections. Key fossils include large corals such as *Heliophyllum*, *Heterophrentis* and *Favosites* which are often abundant and distinctive to this level. Other fossils include *Mediospirifer*, *Rhipidomella*, bryozoans and large bivalves. Above the Case Hill Coral Bed is a thin calcareous shale unit rich in the small rugose coral *Stereolasma* and the trilobite *Phacops rana*. Other fossils include the brachiopods *Rhipidomella* and *Pholidostrophia*. This unit is overlain by a 2 - 3.3 meter-thick softer gray shale interval rich in *Ambocoelia* and small bivalves. At the top of the soft shale unit, one typically observes a pavement of *Ambocoelia* in association with numerous gastropods and cephalopods displaying black calcite preservation. This horizon underlies somewhat more silty, monotonous gray to dark gray shale deposits of the basal Delphi Station Member.

We believe that the overall facies trend from the Chittenango Member up to the base of the Cedarvale Bed is a regressive systems tract culminating in a sequence boundary unconformity at the base of the Cedarvale ledge. From the Cedarvale ledge up to the shell pavement at the base of the Delphi Station the section has the overall aspect of a transgressive systems tract culminating in a maximum flooding surface. Within this transgressive interval, the Case Hill Coral Bed can be viewed as a regressive culmination of a second, more minor, Mottville cycle.

LEVANNA MEMBER AND COEVAL DELPHI STATION, POMPEY, "MARIETTA" AND BUTTERNUT MEMBERS

OVERVIEW.

The balance of the Skaneateles Formation above the Stafford-Mottville interval is represented by the shale-dominated Levanna Member west of Skaneateles Lake and coeval siltstone-sandstone capped cyclic units (Delphi Station, Pompey, "Marietta" and Butternut members) to the east of there (Figs. 2 – 4). This picture is complicated by the fact that the Delphi Station Member actually includes two sedimentary cycles (Cole Hill and upper Delphi Station cycles) and the "Marietta Member" is, as yet, an unofficial unit. As such, the post-Mottville succession encompasses five significant cyclic divisions capped by siltstone or sandstones; these are, in ascending order: the Cole Hill, upper Delphi Station, Pompey, Marietta, and Butternut-Centerfield cycles (Figs. 3 – 5). Notice that the last cycle includes the lowest division of the Ludlowville Formation. In the ensuing description we use cycles rather than member names as headers for ease of visualization of the correlation scheme.

LOWER DELPHI STATION CYCLE (COLE HILL CYCLE).

This lowest of the post-Mottville cycles develops a sandstone cap largely east of the Cazenovia meridian, hence it has been lumped into the Delphi Station Member to the west of there where the Delphi Station is essentially all shale. The Cole Hill Siltstone is named for Cole Hill Road east of Sangerfield where its type section is heavily worked by collectors for trilobites and large bivalves (Grasso, 1986). The upper bounding surface of this division can be traced westward from Delphi Falls, the type section of the Delphi Station Member, to the Genesee Valley. In the Genesee Valley and at Flint Creek near Phelps it is a thin shell bed 3.3 meters above the Stafford Member (Figs. 4, 6). At Great Gully, near Union Springs, it is expressed as a bed of reworked concretions encrusted by auloporid corals that occurs 7 meters above the top of the Stafford. From the vicinity of Marcellus east to Lord's Corners the layer of reworked concretions is well developed and typically associated with thickets of auloporid corals. Southeast of Lord's Corners reworked concretions become scarcer at this level but are replaced by small phosphatic pebbles and a greater abundance of associated shells. At the Pompey Hollow cut on US Route 20, this bed occurs 7 meters above the top of the Mottville and it yields phosphatic pebbles in association with small bivalves and numerous valves of *Athyris cora* (Fig. 6). At Delphi Falls the siltstone bed below this shell bed yields numerous *Dipleura dekayi*. This is particularly significant because the type Cole Hill Siltstone is famous for these fossils.

UPPER DELPHI STATION CYCLE.

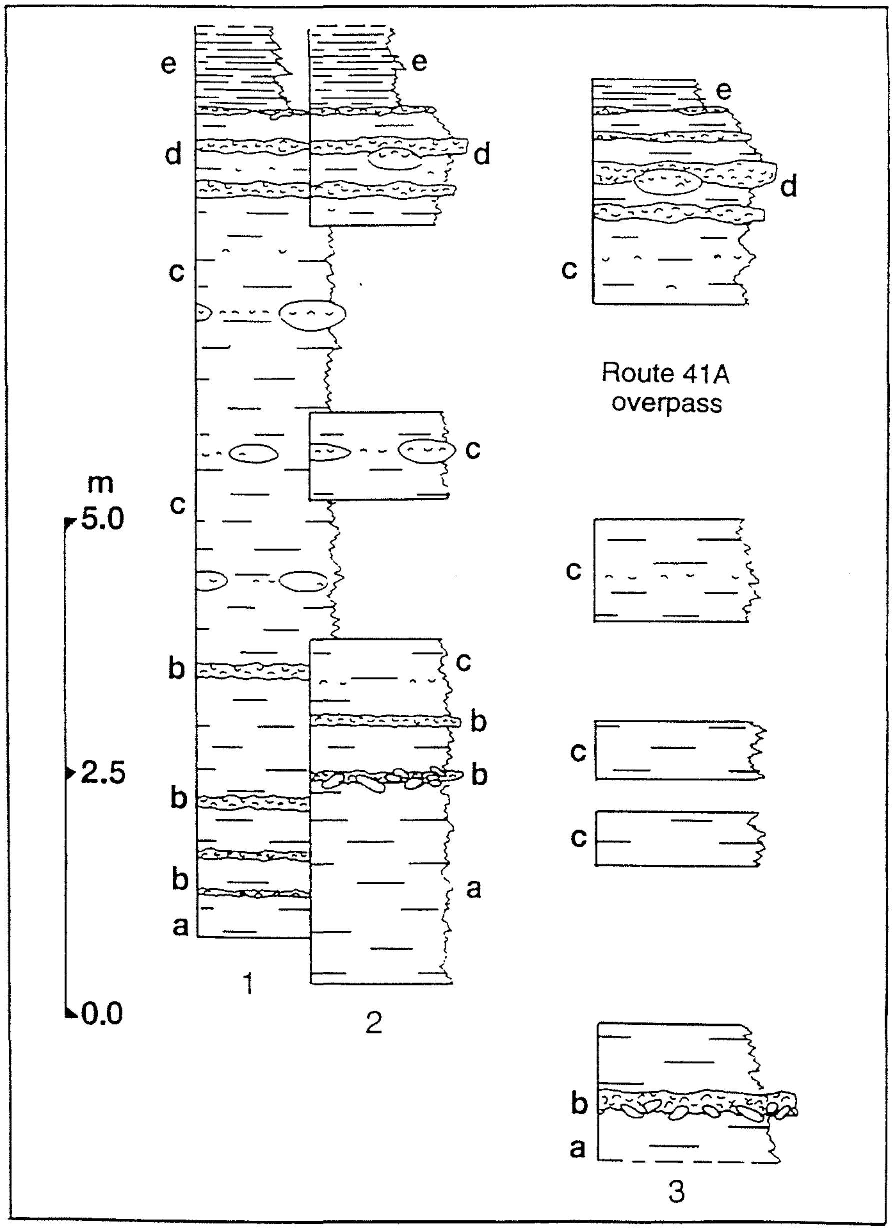

Figure 5. Marietta cycle succession and adjacent divisions exposed near Auburn and Skaneateles. Sections shown include: 1, roadcut exposed on Rockefeller Road east of Koenig Point on the east side of Owasco Lake (STOP 4); 2, Section in ravine east of Long Point on the east side of Owasco Lake; 3, section in ravine between Skaneateles Lake west shore and Skaneateles Aerodrome (STOP 5A, 5B). Lettered units include: a, shale of Pompey cycle; b, top-Pompey cycle shell bed bundle yielding *Nyassa arguata* and locally yielding reworked concretions; c, fossiliferous shale of Marietta cycle; d, top-Marietta cycle shell bed bundle (Slate Rock beds interval); e, Butternut Member-equivalent dark shale facies of upper Levanna Member succession.

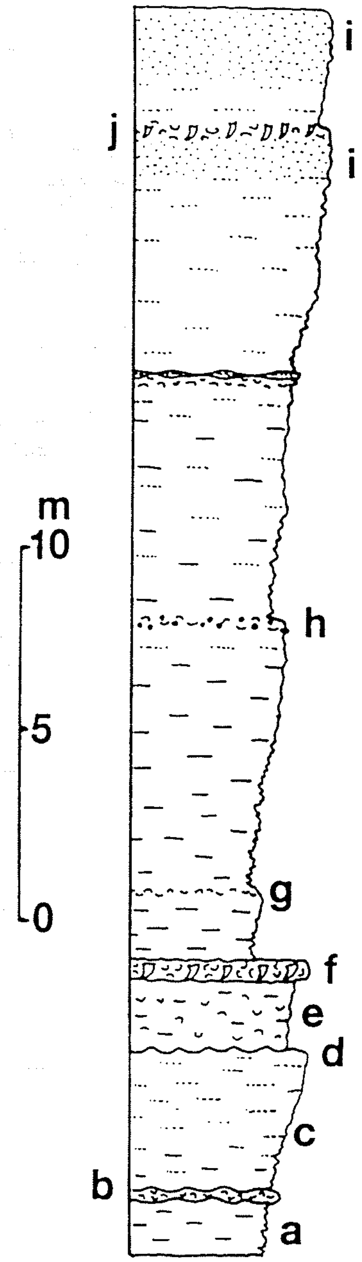

Figure 6. Roadcut section on US Route 20 west of Pompey Hollow (STOP 7). Lettered units include: a, uppermost part of Cardiff Member; b, Mason Hill Bed; c, calcareous muddy siltstone interval marking prominent regression in lower Mottville Member; d, reentrant marking probable position of the Cedarvale Bed which is missing here; e, *Tropidoleptus* and *Mediospirifer*-rich shale interval; f, Case Hill Coral Bed of upper Mottville Member; g, Mottville-Delphi Station Member-contact (maximum flooding surface shell pavement-level); h, top-Cole Hill cycle discontinuity bed yielding phosphatic pebbles; i, siltstone-fine sandstone facies of upper part of Delphi Station Member; j, bed of large corals and *Spinocyrtia* that is probably correlative to Papermill Bed-Roanoke Bed interval in Genesee Valley region sections.

Between the top of the Cole Hill cycle and the base of the Pompey Member is 20 - 50 meters of section that includes numerous concretionary limestone beds west of the Rochester meridian, a thick monotonous shale succession in the central Finger Lakes region, and a regressive, upward-coarsening facies succession east of the Syracuse meridian (Figs. 3, 4). In western New York, the top of the upper Delphi Station cycle is marked by distinctive beds (Papermill Limestone Bed, Roanoke Bed, Pole Bridge Bed) listed in ascending order (Baird et al., 1999). The resistant Papermill Bed can be traced from Oatka Creek eastward to the east side of Seneca Lake (Fig. 3). The Pole Bridge Bed, characterized by abundant *Ambocoelia* is believed to be traceable as far east as Great Gully near Union Springs (Fig. 3). Although the top-Delphi Station markers lose their calcareous character as they are traced eastward to the Cayuga Valley, the top of the upper Delphi Station cycle remains characterized by several closely-spaced shell beds indicative of sediment slow-down within the transgressive uppermost part of the Delphi Station cycle. This bundle of shell beds is again seen at Clintonville Ravine near Otisco Lake where it overlies silty regressive shales. At Rattlesnake Ravine in the Tully Valley, the upper part of the upper Delphi Station cycle has changed to a hard, silty, falls-forming succession and the shell beds are reduced in number (Fig. 3). Larger brachiopods such as *Tropidoleptus* and *Spinocyrtia* have replaced the mix of *Eumetabolotoechia* and nuculoids that characterize these shell beds in the central Finger Lakes region. At STOP 7 the culminating lithofacies of the cycle is siltstone and fine sandstone (Grasso, 1986; Linsley, 1991). *Spinocyrtia* occurs in this interval as do numerous medium to large bivalves including *Nyassa arguata*. A band of large corals observed at STOP 7 and adjacent sections marks a regression maximum within the uppermost part of this cycle; this level may be equivalent to the Papermill Bed-Roanoke Bed interval in western New York sections (Figs. 3, 6).

POMPEY CYCLE.

The type Pompey Member section at Pratts Falls (STOP 6B) includes 12 meters of silty shale followed by 5 meters of regressive siltstone and fine sandstone (Cooper, 1930). This unit grades westward to a 11 - 12 meter-thick shale succession bracketed by the top-Delphi Station shell-bed bundle at the base and by a shell-bed bundle (*Nyassa arguata*-rich shell bed interval) at its top in sections between the Tully and Otisco valleys. West of Skaneateles Lake where Pompey-equivalent strata occur in the Levanna Member, the top and bottom of this unit is delimited by these shell-bed bundles (Figs. 3, 5). The Pompey Member-equivalent shale interval reaches a maximum thickness of 33+ meters at Flint Creek near Phelps before thinning to about 3 meters in the Genesee Valley (Figs. 3, 4). At Conesus Outlet near Avon, this interval includes 3 meters of black shale underlain by a 25 centimeter-thick bed containing dense concentrations of *Tasmanites*. The spore-rich zone appears to mark a maximum flooding surface at the base of a near-anoxic early highstand Pompey interval (Baird et al., 1999). West of the Genesee Valley the Pompey Member-equivalent shale is believed to be absent due to erosive beveling (Figs. 3, 4).

In the Tully Valley-Skaneateles Valley region, the *Nyassa arguata*-rich zone at the top of the Pompey typically consists of two to three closely spaced shell beds typically yielding *Nyassa* and other mollusks that are three-dimensionally preserved and retaining shells of black calcite (see STOP 5A). The lowest of the shell beds is observed to locally exhume concretions (see STOP 5A). In the Levanna Member these shell beds persist as key markers, at least, as far west as Seneca Lake. We believe that the shell-bed bundle at the top of the Pompey Member-equivalent shale interval connects to a clearly erosive layer designated the Wadsworth Bed in Genesee Valley sections (Baird et al., 1999; Figs. 1, 3). This bed, occurring above a thin Pompey Member-equivalent black shale interval near Avon, is believed to truncate successively lower marker beds towards the west (Figs. 3, 4). At Oatka Creek the Wadsworth Bed is juxtaposed onto upper Delphi Station strata with the uppermost Delphi Station interval and overlying Pompey-equivalent *Tasmanites*-rich interval removed by erosion at this meridian. At Buffalo Creek, the undulatory disconformity contact observed at Union Road (see Baird et al., 1999) may correlate to this erosional bed.

MARIETTA CYCLE.

Above the type Pompey section on the west tributary at Pratts Falls (STOP 6B) and below the Butternut Member succession upstream is a 2.3 meter-thick sequence of soft fossil-rich gray shale capped by siltstone that appears to be a stand-alone sedimentary cycle. Traced westward this division thickens to 4 meters in the Tully Valley and 8 - 10 meters in the Otisco and Skaneateles valleys (Figs. 3 - 5). This interval typically consists of soft gray shale with minor shell beds and several levels of discoidal concretions in the lower and middle parts. The upper 0.8 - 1.7 meters is characterized by a bundle of closely spaced shell beds in association with discoidal concretions (Fig. 5). This succession, referred to as the "Slate Rock beds" interval (Baird et al., 1999) is traceable from the Tully Valley west to the Batavia meridian (Fig. 3). We herein informally name this unit the "Marietta Member" for excellent exposures of this interval at Willow Dale Glen on the west side of Otisco Lake south of Marietta, New York.

Fossils in the gray shale part of the "Marietta Member" include abundant ambocoeliids including the newly described form *Microclypeus* (Goldman and Mitchell, 1990) and occasional *Mucrospirifer*. Auloporid corals occur in the shell beds and dispersed nuculoid bivalves and orthoconic cephalopods are common in the shale. An interval of pyrite nodules and pyritic fossil steinkerns is present near the middle of the shale interval within the Tully Valley-Skaneateles Valley area. Nuculoid bivalves, orthoconic cephalopods and the goniatite *Tornoceras* are key steinkern elements. The Slate Rock beds yield abundant ambocoeliids as well as numerous *Devonochonetes* and *Mucrospirifer*. Auloporids are common and *Stereolasma* is also present. Small bivalves and pelmatozoan hash round out the mix of fossils. As with the underlying *Nyassa arguata*-rich shell beds below the Marietta, black calcite preservation is typical for many bivalves and orthocones in the Tully Valley-Skaneateles Valley region (see STOP 5B). West of the Skaneateles Valley, these fossils are preserved as flattened composite molds (see STOP 4).

In the Owasco-Seneca Valley region the Marietta cycle is 4 - 8 meter-thick. However, this interval thickens to 9 meters in the Genesee Valley and approximately 15 meters on Oatka Creek (Fig. 4). West of the Genesee Valley Marietta Shale facies begins to darken as the interval thickens (Baird et al., 1999). Although the Slate Rock beds interval is concealed west of the Batavia meridian, rendering correlations uncertain in this part of the section, we believe that the Marietta Member includes at least 23 meters of black and near-black shale on Buffalo Creek in Erie County (Fig. 4). This black shale caps the spectacular undulatory disconformity exposed below Union Road on that creek (Baird et al., 1999). Eastward thinning of the Marietta cycle from the Tully Valley eastward to Pratts Falls probably reflects combined internal condensation and erosive beveling.

BUTTERNUT-CENTERFIELD CYCLE.

The Slate Rock beds interval is abruptly overlain by black and dark gray, fissile to platy shale from the Batavia area east to the Cazenovia meridian (Figs. 4, 5). From the Batavia meridian to the west edge of the South Onondaga 7.5' Quadrangle, the top of the Butternut is marked by a discontinuity lag bed (Peppermill Gulf Bed) associated with the base of the Centerfield. From the Tully Valley eastward the Butternut spectrally grades upward from basinal shale facies into proximal cross-bedded sandstone facies of the Chenango Member without a discernible break (Gray, 1984, 1991). Hence, the interval between the top of the Slate Rock beds and the sequence boundary between the Chenango Sandstone and the Stone Mill Limestone appears to be part of one and the same upward-coarsening aggradational event (see below).

Across much of western New York, the Butternut Member is only 2.5 - 5 meter-thick (Fig. 4). However, this unit balloons from 2.5 meters of thickness at STOP 2 west of Cayuga Lake to 23 meters on the east side of Cayuga Lake (Fig. 4). At the Cazenovia meridian the Butternut is about 75 meters-thick and is characterized by interbedded dark shale and tabular siltstone beds. In this region the Butternut actually resembles parts of the Penn Yan-Sherburne succession of the highest Givetian. Of all the Skaneateles divisions, the Butternut clearly records the greatest transgression event.

SKANEATELES FORMATION DEPOSITIONAL PATTERNS

The upper part of the Oatka Creek Formation, Skaneateles Formation and lower Ludlowville Formation-interval encompasses seven transgressive-regressive cycles; these include in ascending order: a cycle commencing below the Cardiff Member and culminating at the base of the Cedarvale Limestone Bed, an upper Mottville cycle centered on the Case Hill Coral Bed; the Cole Hill cycle; the upper Delphi Station cycle; the Marietta cycle and the Butternut-Centerfield cycle centered on the Chenango Member-Stone Mill Bed contact (Figs. 3, 4). As such, the first and last cycles are of the greatest magnitude. In fact, it is a moot question as to whether the Butternut and Centerfield members should be combined as a distinct new formation owing to their internal genetic continuity. We view the shell-bed bundles within the Levanna and coeval members to be the expressions of transgressive systems tract intervals above variably monotonous regressive aggradational shale-siltstone successions.

As with the higher Ludlowville and Moscow formations, the Skaneateles interval shows a pattern of laterally shifting depocenters (Fig. 4). The depocenter for the Cardiff-lower Mottville cycle is located east of the Cazenovia meridian. The depocenter for the upper Mottville cycle is localized in the region north and west of Skaneateles. The Cole Hill cycle has no well defined depocenter as yet, but it may exist somewhere east of the Cazenovia meridian. The upper Delphi Station cycle interval appears to be thickest in the Cayuga Valley and the Pompey cycle is thickest at Flint Creek near Phelps. The Marietta cycle is clearly thickest and most basinal in aspect in Erie County. However, the Butternut Member interval is thickest and most basinal in aspect in central New York. Some of this thickness variation may be influenced by erosional processes associated with discontinuity development but some of it clearly reflects flexural crustal processes presumably linked to the Acadian Orogeny. The abrupt change from westward depocenter migration to eastward (retrograde) depocenter migration during Butternut Member deposition may signal a pulse of renewed thrust loading.

ACKNOWLEDGEMENTS

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ROAD LOG FOR FACIES AND FOSSILS OF THE LOWER HAMILTON GROUP

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0	0.0	Junction of Route 14 with US Route 5 & 20 in Geneva; proceed east on US Route 5 & 20.
2.5	2.5	Junction of US Route 96A; proceed straight (east) on US Route 5 & 20

8.6	6.1	Junction of US Route 5 & 20 with Route 414 west of Seneca Falls; turn right (south) onto Waterfalls Bridge Road crossing the NYS Barge Canal in order to bypass downtown Seneca Falls.
8.7	0.1	Junction of Waterfalls Bridge Road with River Road. Turn left (east) onto River Road.
10.55	1.85	Intersection with red light. River Road becomes West Bayard Road; proceed straight (east) on West Bayard Road.
10.7	0.15	Intersection of West Bayard Road with Route 414. Turn right (south) onto Route 414.
14.6	3.9	Junction of Route 414 with Yellow Tavern Road; turn left (east) onto Yellow Tavern Road.
16.7	2.1	Turn left (north) into entrance of Seneca Stone Quarry. Stop to sign release forms and continue into quarry.
16.9	0.2	Turn left onto dirt road south of main pit and park vehicles.

STOP 1. ONONDAGA LIMESTONE-BASAL OATKA CREEK FORMATION-SUCCESSION IN SENECA STONE QUARRY

Seneca Stone Quarry has been written up in many previous reports (see Ver Straeten et al., 1994) particularly with respect to the stratigraphy of the Oriskany sandstone and overlying Onondaga Limestone. On this trip we focus on the post-Onondaga succession exposed on the top-riser at the south end of the quarry.

The Seneca Member of the Onondaga Limestone, forming the highest wall below the riser, is bracketed by the Onondaga Indian Nation K-bentonite at its base and dark post-Onondaga shales at its top. Units belonging to the Union Springs Formation are represented by the Bakoven Member, represented here by black, bituminous shale and ribbon limestone facies and by the thin overlying Chestnut Street Limestone submember which is gray in color and rich in fossils. The Bakoven records lower dysoxic to near-anoxic highstand conditions and is marked by a maximum flooding surface at its base. A prominent bone bed rich in *Onychodus* teeth is present at the base as are several K-bentonites which are developed in the vicinity of the bone bed. Higher Bakoven strata yield *Camarotoechia*, styiolinids and the large bivalve *Panenka*. Bitumen ("dead oil") is conspicuous along fractures and bounding surfaces associated with the limestones. The Chestnut Street submember occurs amalgamated to the base of the overlying Cherry Valley Limestone and is partly overstepped by the unit at this locality. Key fossils in the unit include the proetid trilobite *Dechenella* and a very small inadunate crinoid *Haplocrinites*. The Chestnut Street submember displays an erosional disjunct contact with the underlying Bakoven Member.

The Oatka Creek Formation overlying the Union Springs Formation is represented in the quarry by the Cherry Valley Member, Berne Member and Halihan Hill Bed, all of which are highly condensed and/or erosionally truncated. The Cherry Valley is represented by 0.7 meters of friable brown limestone which is distinctly nodular and petroliferous. It is rich in styliolinids, auloporid corals and distinctive for large cephalopod conchs. Orthoconic cephalopods and the early goniatite *Agoniatites vanuxemi* occur in the uppermost bed of the unit; these were spectacularly exposed along the top-Cherry Valley discontinuity surface in this quarry for a number of years. The Cherry Valley is part of the transgressive systems tract succession above the Stony Hollow-Chestnut Street submember regression maximum; it is highly condensed, contains internal discontinuities and yields a largely pelagic fauna.

Post-Cherry Valley strata at this locality are represented by the 0.7 meter-thick black shale interval of the Berne Member and by the fossil-rich Halihan Hill Bed which is occasionally seen in the quarry scrapings. The Berne represents basinal early highstand deposits over a wide region and it overlies a regional corrosional discontinuity surface on the Cherry Valley in western New York. The somewhat enigmatic Halihan Hill Bed, by contrast, yields the greatest diversity of fossils observed in the lower Hamilton Group.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPION
17.1	0.2	Return to vehicles and retrace route to quarry entrance. Turn right (west) onto Canoga Springs-Yellow Tavern Road.
19.2	2.1	Junction of Canoga Springs-Yellow Tavern Road with Route 414; turn left (south) onto Route 414.
21.6	2.4	Junction of Route 414 with Poormon Road in Village of Fayette;

		turn right (west) onto Poormon. Road.
21.9	0.3	Fayette Town Quarry on south side of Poormon Road; turn left (south) into quarry and park vehicles

STOP 2. UPPER SKANEATELES-THROUGH-BASAL LUDLOWVILLE FORMATION SUCCESSION IN FAYETTE TOWN QUARRY

The Fayette Town Quarry exposes the uppermost part of the Skaneateles Formation and the overlying Centerfield Member of the basal Ludlowville Formation. Skaneateles Formation deposits comprise gray and dark gray shale of the Levanna Member which are exposed in the lower 7.5 meters of the quarry section. Two prominent shell beds rich in *Ambocoelia*, *Devonochonetes*, *Mucrospirifer*, nuculoid bivalves and orthoconic cephalopods cap a bench in this quarry. These layers, designated the Slate Rock beds (Baird et al., 1999), mark the uppermost part of a shale-dominated interval that we believe correlates to a unit that we designate the Marietta Cycle in central New York localities (see text; Fig. 3). Shale deposits below the Slate Rock beds yield several levels rich in the distinctive ambocoeliid brachiopod *Microclypeus* (Goldman and Mitchell, 1990) and auloporid corals often in association with discoidal concretions.

The top 2.5 meters of the Levanna Member below the Centerfield is a dark gray to near –black shale unit yielding *Eumetabolotoechia* ("*Leiorhynchus*"), *Styliolina* and few other fossils. We believe that this is a major highstand unit that is correlative with the Butternut Member in central New York sections. The top of the dark shale interval is abruptly overlain by richly fossiliferous, calcareous shale deposits of the Centerfield Member.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTIOM
		Return to vehicles. Exit Fayette Town Quarry turning right (east onto Poormon Road.
22.2	0.3	Junction of Poormon Road with Route 414; turn left (north) onto Route 414.
28.5	6.3	Junction Route 414 with US Route 5 & 20 in downtown Seneca Falls. Proceed straight (north) onto US Route 5 & 20.
33.35	4.85	US Route 5 & 20 bridge over Cayuga Outlet near entrance to Montezuma Wildlife Refuge. Continue east on US Route 5& 20.
33.55	0.2	Junction of US Route 5 & 20 with Route 90 just east of Cayuga Outlet overpass. Continue east on US Route 5 & 20.
39.9	6.35	Junction of US Route 5 & 20 with Half Acre Road; turn right (south) onto Half Acre Road. Small Onondaga Limestone exposure to right south of the intersection.
40.55	0.65	Junction of Half Acre Road with Route 326 at intersection in Half Acre. Proceed straight (south) on Route 326.
41.8	1.25.	Outcrop of Mottville Member of Skaneateles Formation to left on the southeast side of Route 326
42.0	0.2	Turn right from Route 326 onto driveway of Dairy Farm. Park vehicles.

STOP 3. STAFFORD MEMBER, CAYUGA VALLEY MERIDIAN

This newly discovered shale pit on the Ray Lockwood Dairy Farm and the nearby roadcut section on Route 326 display essentially a complete section of the Stafford Member as well as 2 - 3 meters of the underlying Oatka Creek Formation. The Stafford at this locality, though expressed as a ridge-forming impure carbonate unit, is surprisingly depauperate in fossils at most levels. Most fossils, including the brachiopods *Cupulorastrum*, *Emanuella*, and *Devonochonetes*, auloporid corals, the gastropod *Bembexia* and orthoconic cephalopods, are found near the base of the unit. We believe that this fossiliferous condensed interval correlates to the Mason Hill and Cedarvale beds in the equivalent Mottville Member. Above the *Emanuella*-rich "A" limestone at this locality is a 1.7 meter-thick interval of thin-bedded lenticular limestone layers yielding sparse fossils. At the top of the section is a 0.7 meter-thick massive limestone bed yielding hard, dolomitic? nodules and occasional chert. This unit, yielding *Zoophycos* and sparse body fossils, is designated the "B" limestone bed of the Stafford (Meyer, 1985; Baird et al., 1999). It is well developed between Erie County and Cayuga Lake. This bed dramatically thickens eastward to approximately 8 meters at Smiths Falls on the other side of Auburn (Figs. 2, 4) before rapidly thinning again to form the fossil-rich

Case Hill Coral Bed in Onondaga County sections. The low fossil diversity of limestone beds at this locality is believed to reflect the "double whammy" of low oxygen conditions coupled with soft, turbid substrate conditions.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
		Exit farm and retrace route to US Route 5 & 20.
44.1	2.1	Junction of Half Acre Road and US Route 5 & 20; turn right (east) onto US Route 5 & 20.
46.1	2.0	Enter city of Auburn.
47.5	1.4	Intersection in downtown Auburn where US Route 5 splits off from US Route 20; turn right (south) on US Route 20.
47.65	0.15	Intersection where US Route 20 turns left (east); proceed straight (southeast) on Route 38A.
49.8	2.15	Northern end of Owasco Lake; continue straight (southeast) on Route 38A.
53.6	3.8	Junction of Route 38A with Rockefeller Road; turn right (south) onto Rockefeller Road.
54.9	1.3	Small shale exposure on east side of Rockefeller Road; park vehicles on wide shoulder area opposite outcrop.

STOP 4. MEDIAL-UPPER DIVISIONS OF LEVANNA MEMBER, OWASCO VALLEY MERIDIAN.

Visible in this roadcut are two shell bed bundles respectively capping Pompey Member-equivalent Levanna strata and "Marietta Member"-equivalent Levanna beds (Fig. 5). The lower shell bed bundle; visible in the lower end of this cut is represented by two main shell beds which are 1.2 meters apart and minor lower beds which are now concealed. These correlate eastward to the *Nyassa arguata* shell-rich zone which we will see at STOP 5A. In this cut the shell layers yield *Devonochonetes*, occasional *Protoleptostrophia* and *Mucrospirifer*, pelmatozoan debris, *Phacops*, auloporid corals and nuculoid bivalves. The small rugosan *Stereolasma* occurs in both shell beds. Reworked concretions are observed at the level of the lower shell bed in the nearby gully above Long Point signifying localized erosion below this layer (Fig. 5). Above the lower shell bed bundle is a 4.6 meter-thick fissile shale interval yielding minor shell-rich layers, dispersed ambocoeliid brachiopods and discoidal concretions. We believe that this unit is equivalent to the lower and middle parts of the "Marietta Member" in the Otisco Valley-Cazenovia region (Fig. 3).

The upper bundle of shell beds includes three subequal fossil-rich layers in a 0.8 meter-thick interval near the upper end of this roadcut. This bundle corresponds to the "Slate Rock beds" interval that caps the Marietta cycle across western and central New York. Key Slate Rock fossils include ambocoeliids, *Mucrosirifer*, pelmatozoan debris, auloporid corals, occasional *Stereolasma* and nuculoid bivalves. As with the lower shell bed bundle mollusks are typically preserved as flattened composite molds. This condition changes to the east of this locality where Levanna shell beds begin to yield mollusk fossils preserved as shells of black calcite (see text; STOP 5).

Above the Slate Rock beds shell bundle is an abrupt change into dark gray, highly fissile shale yielding few fossils. This part of the Levanna corresponds to the Butternut Member at localities east of here. The Butternut records a major transgression with development of near-anoxia during late Skaneateles time. Less than a meter of the dark shale can be seen here.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
		Return to vehicles and retrace route back to Route 38A via Rockefeller Road.
56.2	1.3	Junction of Rockefeller Road and Route 38A; turn right (southeast) onto Route 38A.
60.35	4.15	Junction of Route 38A with Route 359, turn left (north) onto Route 359.
62.0	1.65	Junction of Route 359 with Route 41A in Mandana. Turn left (north) onto Route 41A.
65.2	3.2	Turn right (east) onto private lane immediately south of New York State boat launch entrance. Lane parallels small creek southeast of the

		Skaneateles Aerodrome.
65.55	0.25	Turn vehicles around at driveway loop of David Robinson residence at end of lane and park along lane part way back from loop.

STOP 5A *NYASSA ARGUATA*-RICH LAG BED AT TOP OF POMPEY CYCLE.

Although the section of this creek is generally discontinuous and sloughy, the top of the Pompey Member-equivalent part of the Levanna Member, marked by *Nyassa arguata*-rich shell beds is fortuitously well exposed near the private lane. Similarly, the Slate Rock beds interval is well exposed 10 meters higher along this creek above the Route 41A overpass (see STOP 5B; Fig. 5).

At this locality the base of the *Nyassa arguata*-rich shell bed interval is a 14 - 18 centimeter-thick shell layer which is profusely fossiliferous. Brachiopods including *Devonochonetes*, *Protoleptostrophia*, ambocoeliids and occasional *Mucrospirifer* are present. *Stereolasma* and auloporid corals, *Phacops*, nuculoid bivalves and orthoconic cephalopods are also common. Both at and east of the Skaneateles Valley meridian, molluscan fossils are preserved as shells of black calcite, a condition that we will also see in the lower Delphi Station Member at STOP 7. The bivalve *Nyassa arguata*, a rare component of this interval west of the Skaneateles Valley is present and conspicuous at this level from Skaneateles Lake eastward. Typically the anterior of this clam is beautifully reinforced by thick black calcite while the posterior displays only a thin, often corroded, veneer of the carbonate. Reworked concretions are abundant in this bed at this locality; these are heavily bored and may yield a variety of encrustors (see Baird, 1981; Baird and Brett, 1981 for detailed study of this phenomenon). Exhumation of nodules below this bed in the Owasco and Skaneateles Valley region is consistent with our belief that this layer is correlative with the erosive Wadsworth Bed in western New York (see text; Baird et al., 1999; Fig. 3).

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
		Return to vehicles and return along private lane to Route 41A.
65.8	0.3	Junction of private lane and Route 41A; proceed straight (west) across Route 41A into private driveway of James Garrison residence on the west side of Route 41A. Park vehicles near barn and proceed on foot to outcrop upstream from previous stop.

STOP 5B "SLATE ROCK BEDS'-INTERVAL. TOP OF MARIETTA CYCLE.

The creek bed just above the Route 41A overpass exposes the upper part of the "Marietta Member"-equivalent part of the Levanna, including the Slate Rock beds, as well as the base of the Butternut Member-equivalent part of the Levanna (Fig. 5). The Slate Rock beds interval is represented by a bundle of closely-spaced shell beds in association with discoidal concretions. The shell beds contain abundant ambocoeliid brachiopods, numerous *Mucrospirifer* and occasional *Protoleptostrophia* and *Rhipidomella*. Other fossils include auloporids and occasional *Stereolasma*, nuculoid bivalves and orthoconic cephalopods. As with the *Nyassa arguata* bed downstream, mollusks in the Slate Rock interval display black calcite preservation.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
		Return to vehicles.
65.8	0.0	Driveway entrance on Route 41A. Turn left (north) onto Route 41A.
68.2	2.4	Junction of Route 41A and US Route 20 in Skaneateles; turn right (east) onto US Route 20.
68.65	0.45	Center of Skaneateles. View of Skaneateles Lake to the right. Continue east on US Route 20.
69.4	0.75	Leave village of Skaneateles. Continue east on US Route 20.
73.55	4.15	Junction of US Route 20 with Route 174 in axis of Otisco Valley. Continue east on US Route 20.
79.55	6.0	Junction of US Route 20 and Route 80 at Lords' Corners; continue east on US Route 20.
82.95	3.4	Junction of US Route 20 and Tully Farms Road in axis of the

		deep glacially scoured Tully Valley. The recent Tully Valley landslide (see Fakundiny and Brett, 1997; Negussy et al., 1997) occurred south of this road junction.
85.25	2.3	McDonalds' Restaurant to the left (rest stop for trip participants). Butternut Member of Skaneateles Formation visible on I-81 entrance ramp across US Route 20 from restaurant.
85.35	0.1	Junction of US Route 20 and Interstate 81; continue straight (east) on US Route 20.
87.55	2.2	Junction of US Route 20 with Apulia Road in Butternut Creek Valley.
91.35	3.8	Enter village of Pompey Hill.
91.55	0.2	Junction of Hennaberry Road and US Route 20. Turn left (north) onto Hennaberry Road.
93.55	2.0	Junction of Hennaberry Road and Pratts Falls Road; turn right (east) onto Pratts Falls Road.
94.05	0.5	Entrance to Pratts Falls County Park from Pratts Falls Road; turn left (north) into Pratts Falls Park.
94.4	0.35	Continue to large parking area by Pratts Falls. Park vehicles and proceed on foot to falls overlook.

STOP 6A MEDIAL SKANEATELES FORMATION SUCCESSION EXPOSED AT PRATTS FALLS

The east and west forks of this creek display almost a complete view of the Skaneateles Formation. Pratts Falls itself provides a view of the upper part of the Delphi Station Member which is exposed in the lower part of the falls and the Pompey Member which makes up the upper part of the falls face and falls cap. Although strata are inaccessible from the overlook, one can clearly see that the upper part of the Pompey succession has coarsened to resistant siltstone and fine sandstone. This part of the succession is best viewed on the west fork of this creek (see STOP 6B).

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
		Return to vehicles and proceed west in park to pull off just past the smaller west fork of the creek.
94.8	0.4	Park vehicles at parking area by small bridge over the creek west fork within the park.

STOP 6B DELPHI STATION, POMPEY, "MARIETTA" AND BUTTERNUT MEMBERS OF SKANEATELLES FORMATION

Strata on the west branch include the Delphi Station, Pompey, "Marietta" and Butternut members. However, the Delphi Station and lower part of the Pompey members are difficult to observe here; we will focus on the capping sandstone beds of the Pompey Member between the road and the footbridge, the "Marietta Member" upstream from the road and the basal Butternut Member in the upstream waterfall.

Fossil-rich sandstone and siltstone beds yielding abundant moldic *Nyassa arguata* and spirifers can be viewed below the park road overpass; these most likely correspond, in part, to the *Nyassa arguata*-rich shell bed observed at STOP 5A and the lower shell bed bundle at STOP 4 (Fig. 3). This coarse facies represents the regressive capping part of the Pompey Member (and Pompey coarsening-up cycle). At Delphi Falls, south of this locality, the corresponding sandstone is 6.5 meter-thick attesting to coarse sediment progradation from the east or southeast. The underlying regressive top-Delphi Station interval at this locality, by contrast, is mainly a muddy siltstone suggesting that the Pompey cycle contains more proximal facies in this area.

Above the road is a short covered interval where the Pompey Member-"Marietta Member" contact is concealed. However, above this gap is a three and 1.3 meter-thick interval of soft gray fossiliferous shale succeeded by a 0.7 meter-thick falls-capping siltstone bed; this is the visible part of the 2.3 meter-thick "Marietta Member" succession at this locality. The soft shale below the siltstone bed is rich in ambocoeliids and an alate form of *Mucrosirifer* resembling *M. arkonensis* as well as many other taxa. The soft shale is much finer than corresponding shales in the basal part of the Pompey Member, suggesting that the Marietta cycle is part of a backstepping transgressive systems tract succession. Eastward thinning of the "Marietta Member" across this area, noted earlier, may reflect erosion and/or section condensation.

Above the small falls held up by the top-Marietta siltstone bed is a large falls displaying fissile dark gray shale and thin siltstone beds of the Butternut Member. In this region the Butternut has thickened to 75 meters and numerous tabular, flaggy siltstone beds are present in the middle and upper parts of the succession (Figs. 2, 4). The base of the Butternut is sharp and possibly erosional upon the top-Marietta siltstone; this contact is a classical maximum flooding surface associated with a major transgressive event.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
		Return to vehicles and retrace route back to park entrance.
95.3	0.5	Turn left (east) onto Pratts Falls Road.
96.2	0.9	Junction of Pratts Falls Road with Waterville Road; turn right (south) onto Waterville Road.
96.75	0.55	Junction of Waterville Road with US Route 20; turn left (east) onto US Route 20.
98.05	1.3	Intersection in Pompey Center; continue straight (east) on US Route 20.
99.05	1.0	Large roadcut on US Route 20 that begins at upper end of long descending grade into the Limestone Creek Valley. Vehicles will park on level ground on west (upper) end of this roadcut. Participants will exit vehicles and proceed on foot to lower end of exposure.

STOP 7 MOTTVILLE AND DELPHI STATION MEMBERS, POMPEY HOLLOW SECTION

This is a roadcut that has served as an important section for viewing lower Hamilton Group facies and collecting fossils. Recent widening of the road has both enlarged and lengthen the section (Fig. 6). Moreover, a year of exposure of the fresh rock face to the elements has served to loosen and release an enormous number of fossils.

The Mottville Member is now exposed in its entirety as well as 1.0 meter of underlying rock assignable to the Cardiff Member of the Oatka Creek Formation (Fig. 6). Above the 8 meter-thick Mottville succession is a 23 meter section including almost the entire succession of the Delphi Station Member. This latter interval includes 7 meters assignable to the Cole Hill cycle within the lower part of the Delphi Station Member and 10 meters comprising most of the main Delphi Station cycle succession within the middle and upper parts of the Delphi Station Member (Fig. 6).

The Mottville Member, at this locality, is marked by two prominent fossil-rich layers, the Mason Hill and Case Hill beds (see text). Between these markers is a 7.5 meter succession of calcareous silty mudstone marked by a prominent parting about 3.7 meters above the Mason Hill Bed(Fig. 6). Between the parting and the Case Hill Bed is mudstone rich in *Tropidoleptus*, *Nucleospira* and *Mediospirifer*. Above the Case Hill Bed is 2 more meters of softer mudstone rich in *Ambocoelia* and small mollusks.

The Mason Hill Bed yields abundant brachiopods including *Mediospirifer* as well as associated bryozoan debris and exuviae of *Dipleura*. The 0.3 meter-thick shell-coral-rich bed in the upper Mottville is clearly the Case Hill Coral Bed of Grasso (1986) and it corresponds to the Mottville "B" bed of Meyer (1985). We believe that a third key marker, the Cedarvale Bed is poorly developed in this section and corresponds to the bank reentrant below the *Tropidoleptus*-rich interval (Fig. 6). In sections within the Marcellus, South Onondaga and Jamesville 7.5' quadrangles, the Cedarvale Bed is a packstone-grainstone encrinite layer comparable to the higher Stone Mill and Tichenor limestones. It probably overlies a sequence boundary regionally; at this section the sequence boundary unconformity is probably represented by the reentrant below the *Tropidoleptus* interval.

The Case Hill Coral Bed yields large rugose and tabulate corals as well as diverse brachiopods. The upward change from the unit into soft, *Ambocoelia*-rich shale marks a significant deepening event within a larger transgressive systems tract succession above the sequence boundary reentrant. The top of the Mottville is typically marked by a bedding plane covered by small brachiopods as well as gastropods and orthoconic cephalopods displaying black calcite preservation. This maximum flooding surface, unfortunately, is poorly exposed in this section.

Above the Mottville interval is a 7 meter-thick interval of gray shale and gray silty shale that is bounded at the top by a shell bed yielding abundant phosphatic nodules associated with numerous *Athyris cora* and other fossils (Fig. 6). This shell bed marks a discontinuity that can be traced westward into the Levanna Member as far as Cayuga Lake (Fig. 4). Between Cayuga Lake and the Tully Valley, this layer is typically characterized by reworked concretions encrusted by auloporid corals in association with molluscan debris. East of the Tully Valley the reworked concretions are replaced by small phosphatic pebbles and a somewhat more diverse associated biota. We believe that this shell-phosphate layer projects to the top of the Cole Hill Sandstone bed near Sangerfield.

Between the top of the Mottville and the top-Cole Hill cycle shell-phosphate bed is an interval of shale yielding abundant clams, snails and cephalopods displaying black calcite preservation. Gastropods, including *Bembexia* and *Palaeozygopleura,* as well as nuculoid bivalves and cephalopods, are typically preserved three-dimensionally.

Above the shell-phosphate bed is a 16 meter-thick interval of silty shale grading upward to fine sandstone at the upper (west) end of the outcrop. This part of the section corresponds to the upper Delphi Station upward-coarsening cycle. The uppermost beds in this interval are considerably coarser than equivalent strata at Pratts Falls suggesting a trend to greater facies proximality towards the southeast. The coarse beds at the top of the section contain abundant bivalves and occasional large brachiopods such as *Spinocyrtia*. Three meters below the top of this section is a band of medium-size corals that is also observed at Pratts Falls and at a section near Delphi Station; this bed may correlate to the Papermill Bed-Roanoke Bed interval in western New York (Fig. 3).

End of Road Log.

JAVA SOFTWARE FOR EARTH SCIENCE EDUCATION

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INTRODUCTION

The Earth Science Educational Resource Center (ESERC), which is based at SUNY Stony Brook, conducts four programs through which students have created software designed for Earth Science education and research. This workshop is designed to introduce high school teachers and college-level faculty to these programs, which are: 1) Project Java, 2) GEO 327: Computerized Modeling of Geological Phenomena, 3) GEO 511: Computer Programming for the Geosciences, and 4) Summer Educational Interns. Software produced under these programs is used in high school educational enrichment programs and undergraduate and graduate courses conducted at SUNY Stony Brook. In addition, it is disseminated on the World Wide Web and in teacher enrichment programs and courses. During the present workshop, participants will have an opportunity to use some of the software developed through these programs, and will be given an opportunity to create some simple Java programs called applets.

Participants in the workshop are invited to form a network of people who are interested in fostering the development of additional interactive educational material that will be created and posted on the Web. High school teachers and college faculty would be especially valuable in this network as sources of ideas for new applets that can be used for education in their area of interest. Selected ideas put forth by the group will be implemented as software by SUNY Stony Brook Project Java students, with periodic evaluations from the network members. Some of the attending college faculty or high school teachers may wish either to learn to program themselves, or to assemble a group of students who can create applets at their own institutions. Means of accomplishing this will be discussed.

ESERC EDUCATIONAL PROGRAMS THAT CREATE SOFTWARE

ESERC, which is funded by the National Science Foundation, offers several programs that generate software designed for use in Earth Science education and research. These programs, the types of software they have created, and selected examples of this software are listed in table 1.

	Model natural phenomena	Model analytical techniques	Present hypothetical scenarios for analysis by students	Access data to present it graphically	Present data formatted for processing
Project Java	Lake Applet (figure 1), Chemical Charge Applet (figure 5)	Bragg's Law Applet (figure 2)	Plume Finder (figure 3)	Tr660 Applet	Future work
GEO 327: Computerized Modeling of Geological Phenomena	Geyser Applets				
GEO 511: Computer Programming for the Geosciences	Littoral Drift Applet	Impedance Applet		MgO Analyzer Application	Future work
Summer Educational Interns	Future work	Future work	Future work	Earthquake Distance Applet (figure 4)	Future work

Table 1. Summary of ESERC programs that create software for use as educational and research tools

password. and is assigned a scenario chosen by the server from among a set of possibilities. During the spring. 2000 semester. the Plume Finder applet was used as the basis of an extra credit project for GEO 101: Environmental Geology.

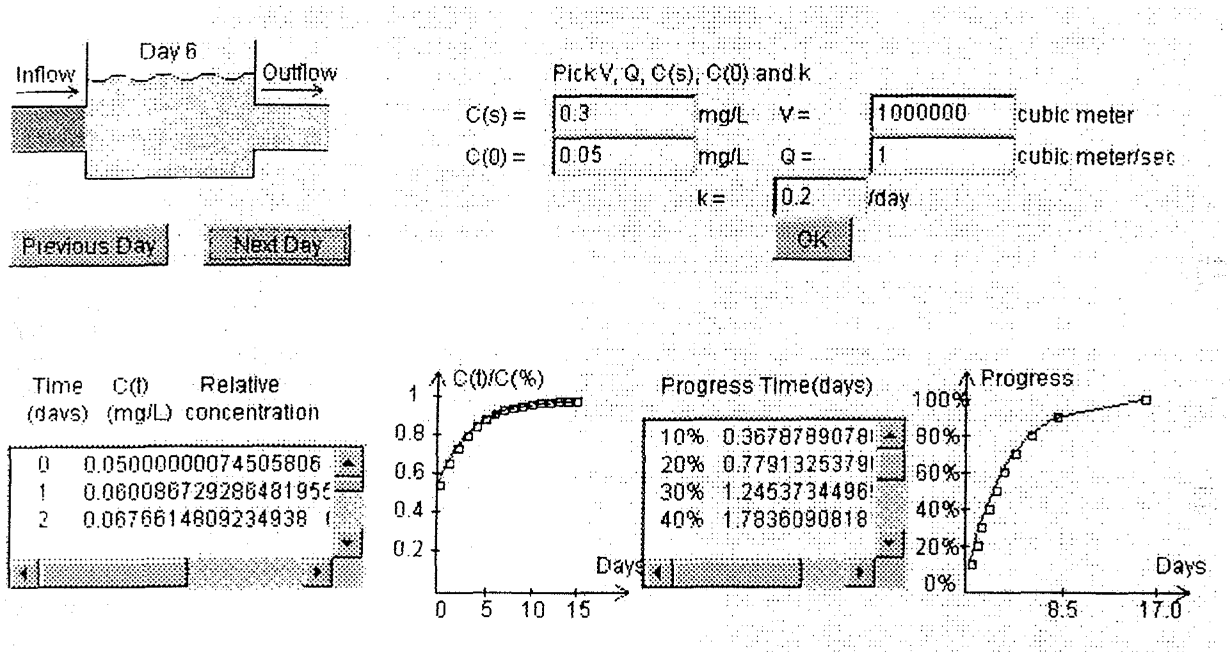

Figure 1. The Lake Applet

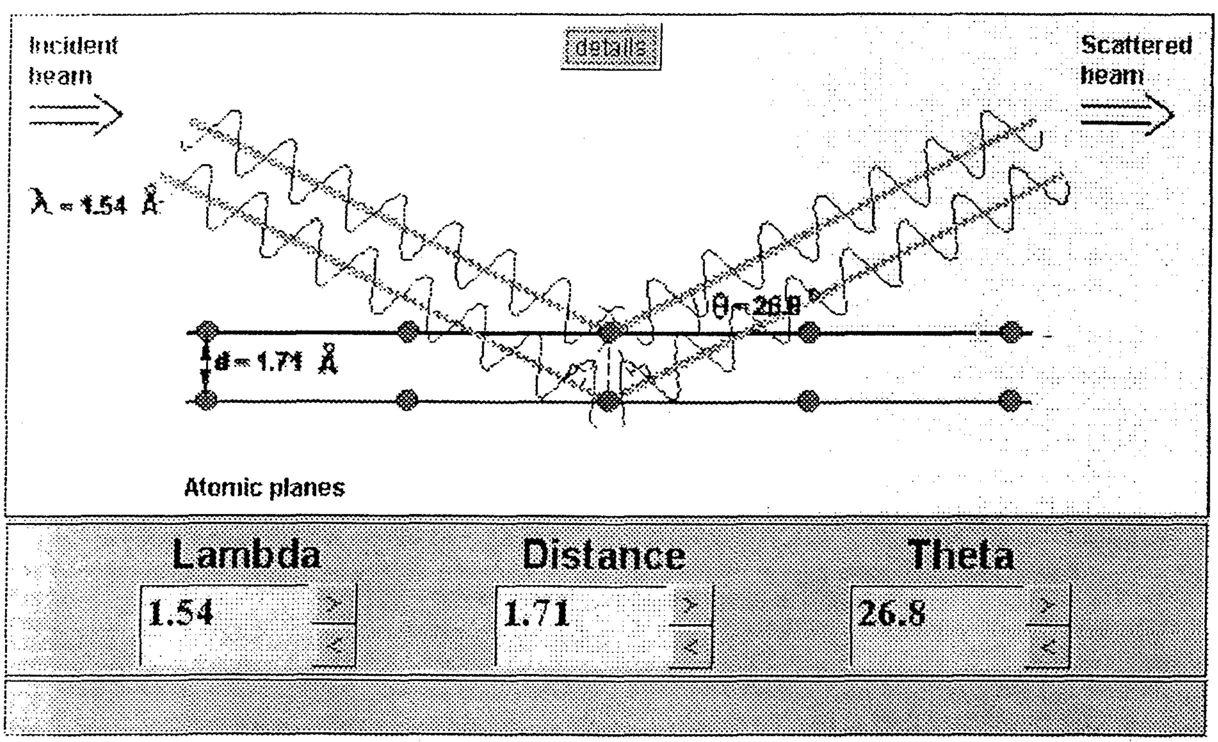

Figure 2. The Bragg's Law Applet

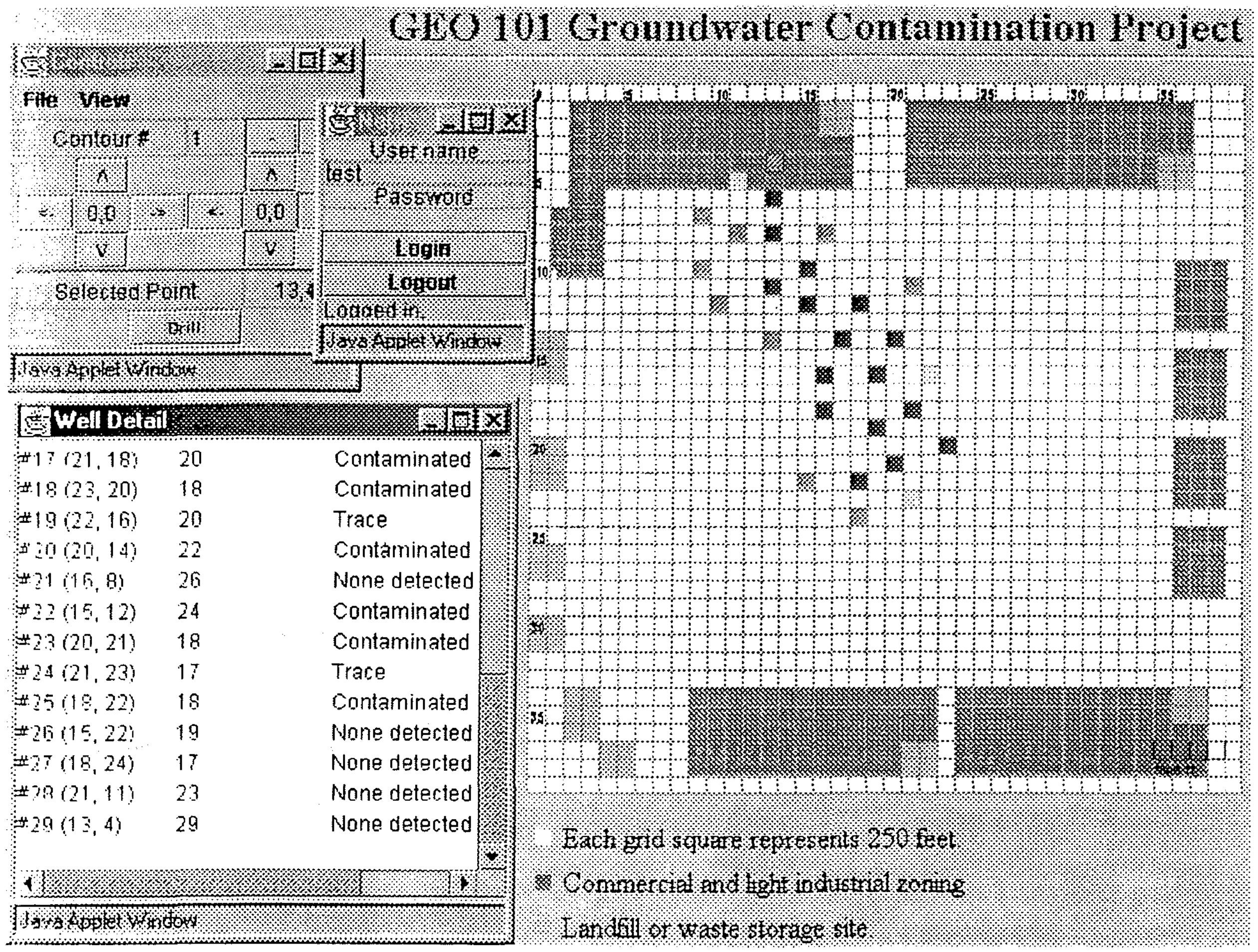

Figure 3. The Plume Finder Applet

Access data to present it graphically

This software collects data and presents it in a form that can be easily interpreted by humans. The software may perform numerical analysis prior to graphical presentation. The Earthquake Distance Applet (figure 4) was developed by Vincent Ugenti, a former Project Java student, while he was participating in the Summer Educational Interns program. It enables users to pick P and S wave arrival times in order to view earthquake event distances represented on a map. Possible epicenter locations are represented by a circle that expands or contracts with the time interval between the P and S wave arrivals. This applet is currently being refined for use in education programs.

Li Li, a student in GEO 511, developed a program designed to analyze images of materials under pressure in order to calculate strain rates. The first set of images she used represented magnesium oxide, which contained thin sheets of gold foil as reference features. The gold foil appears as diffuse vertical dark lines in the images. The mouse is used to select areas for the software to compare within the images. After the areas are chosen, the software uses various mathematical strategies to compute the locations of the lines and their displacements within a series of images. An inner difference method, which computes the displacement that results in the minimum sum for the differences in gray scale values for corresponding pixels when the two images are compared, was one of the numerical analysis techniques used. Least squares and other schemes were subsequently employed, ultimately resulting in resolution on the scale of a fraction of a pixel.

Present data formatted for processing

A fifth category of software will be designed that retrieves data from digital libraries and presents it to students in a format that is convenient for saving and opening later as a file or copying into software for analysis. For example, seismic data can be copied and pasted into spreadsheets. ESERC is beginning to explore strategies for implementing this type of software. and programming of these modules will be performed by Project Java students during the 2000 to 2001 academic year.

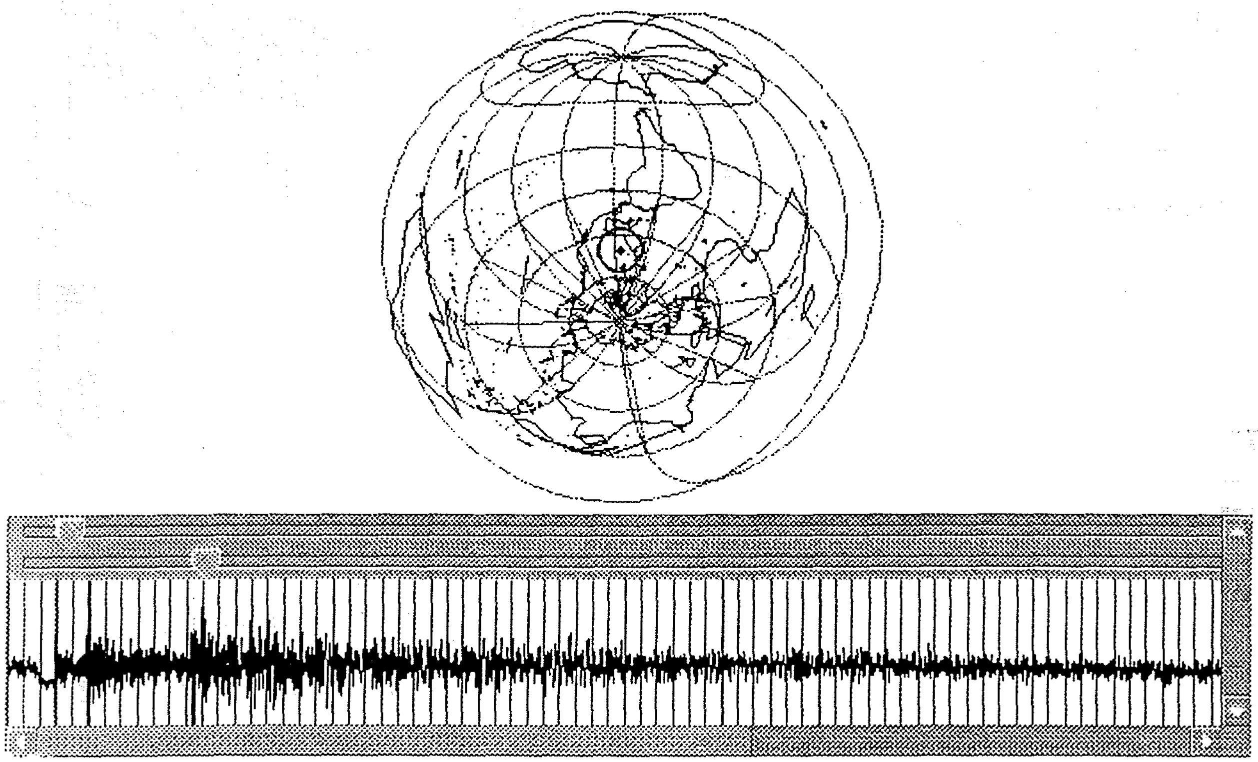

Figure 4. The Earthquake Distance Applet

SOFTWARE DEVELOPMENT BY EARTH SCIENCE EDUCATORS

Educators who learn Java can develop their own software. with the advantage that they can efficiently design and create it according to their own specifications. Janet Kaczmarek, Educational Specialist at ESERC, joined Project Java and learned how to program during the summer of 2000. Subsequently, she was able to create the Chemical Charge Applet (Figure 5). and post it with background information and instructions for educational activities. The applet enables students to either choose cations and anions at random or select them from pull-down lists. The user can then use buttons to vary the quantity of each ion in order to generate a compound with a neutral charge and a proper empirical formula. Although this applet is aimed primarily at chemistry students, the interdisciplinary nature of Earth Science dictates that a knowledge of all the sciences contributes to its understanding.

INITIATING SOFTWARE DEVELOPMENT PROJECTS SIMILAR TO PROJECT JAVA

A software development project similar to Project Java can be initiated at institutions of higher learning, provided that at least one person who is knowledgeable about Java is prepared to conduct the program. that there is a source of student programmers available for participation, and that a group of scientists is prepared to offer content, develop specifications. and assess the resulting software. The software also needs to be evaluated by representatives of its intended audience.

It is extremely important to build a system for student accountability into this type of project. Students have many competing academic demands. and a program such as this one. which is less structured than a formal course. suffers the danger of being viewed as a low priority responsibility. A system of accountability can be implemented by requiring participants to deliver periodic presentations of their work in progress. to carefully comment their source code. and to document the revision process. The students should be offered pay or academic credit for their work.

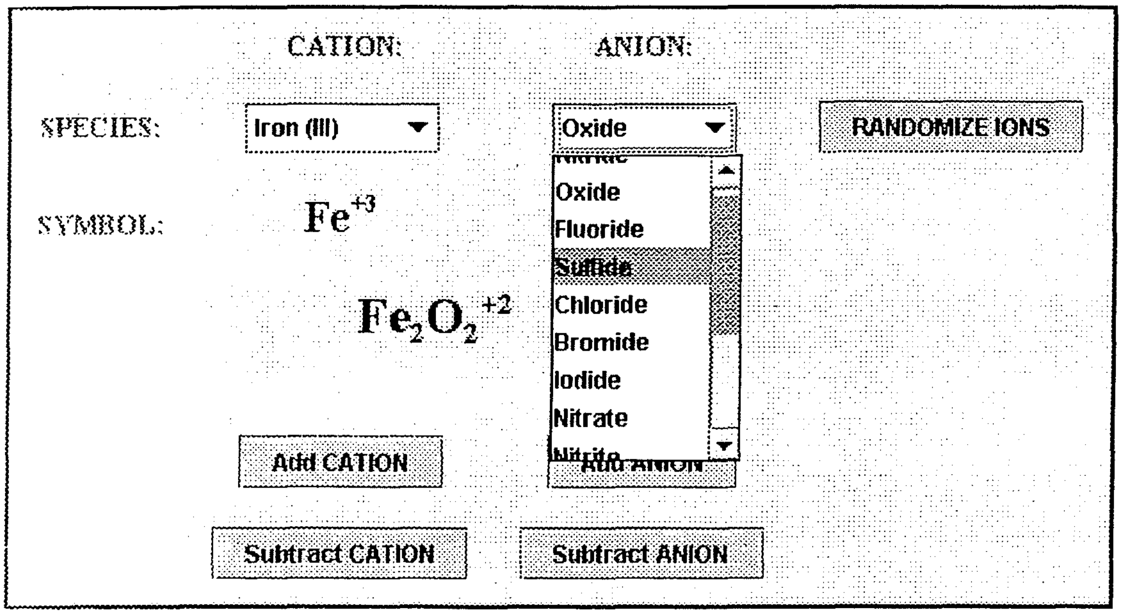

Figure 5. The Chemical Charge Applet with an open pull-down list of anions.

The Java 2 SDK version 1.3.0 is free as a download (Sun Microsystems) and easy to install on systems running Solaris, Linux, or Windows. Macintosh systems can be used as well, but as of this writing, version 1.1 is the most recent release available for that platform. However Apple plans to integrate Java 2 into Mac OS X (Mac OS X). The first step in establishing a mentored software development program is to speak at length with a person with experience in conducting this type of project. This type of activity has tremendous potential for creating software for education and research, and for providing students with a working knowledge of programming and an opportunity for analytical creativity of a very intricate nature (Richard and Kaczmarek, 2000).

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Stratigraphic Logs to Accompany NYSGA 2000 Field Trip Guidebook, Trip B1: The Late Devonian Clastic Wedge in Central New York and Pennsylvania by D.L. Woodrow.

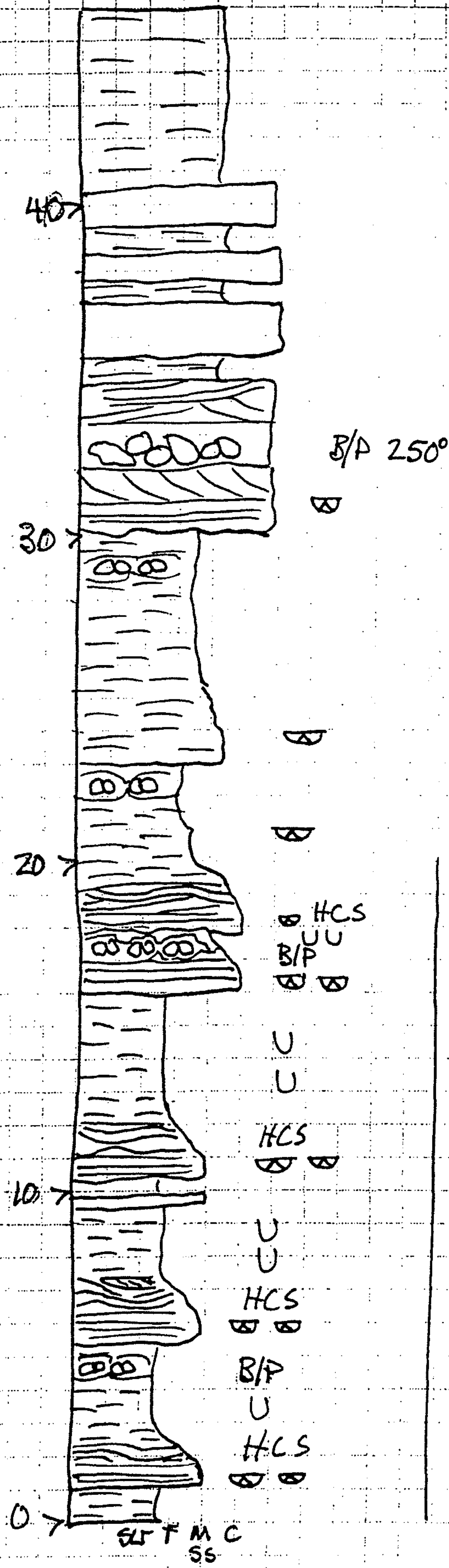
Log I. Cowanesque Dam spillway and roadcut on PA Rte. 49 south of the spillway and west of the village of Lawrenceville, PA.

Log II. Roadcut on PA Rte. 287, west of the village of Tioga, PA.

Log III. Strata in and around the channel connecting the Tioga-Hammond Dams at Tioga, PA and in the roadcut on US Rte 15 overlooking Tioga, PA. From: Brett, C.E. and Ver Straeten, C.A., eds, 1997, Devonian Cyclicity and Sequence Stratigraphy in New York State, Field Trip guidebook for meeting of International Commission on Devonian Stratigraphy, University of Rochester, 369 p.

Log IV. Roadcut on realigned US Rte 15 at Blossburg, PA. Section starts at the most northerly point of the road cut and proceeds uphill along the ramp to old US Rte 15.

LOG I



RTE 49 CLIFF

TEICHICHNUS
B/P: 16 AXES MEASURED. MEAN ≅ 270°/280°

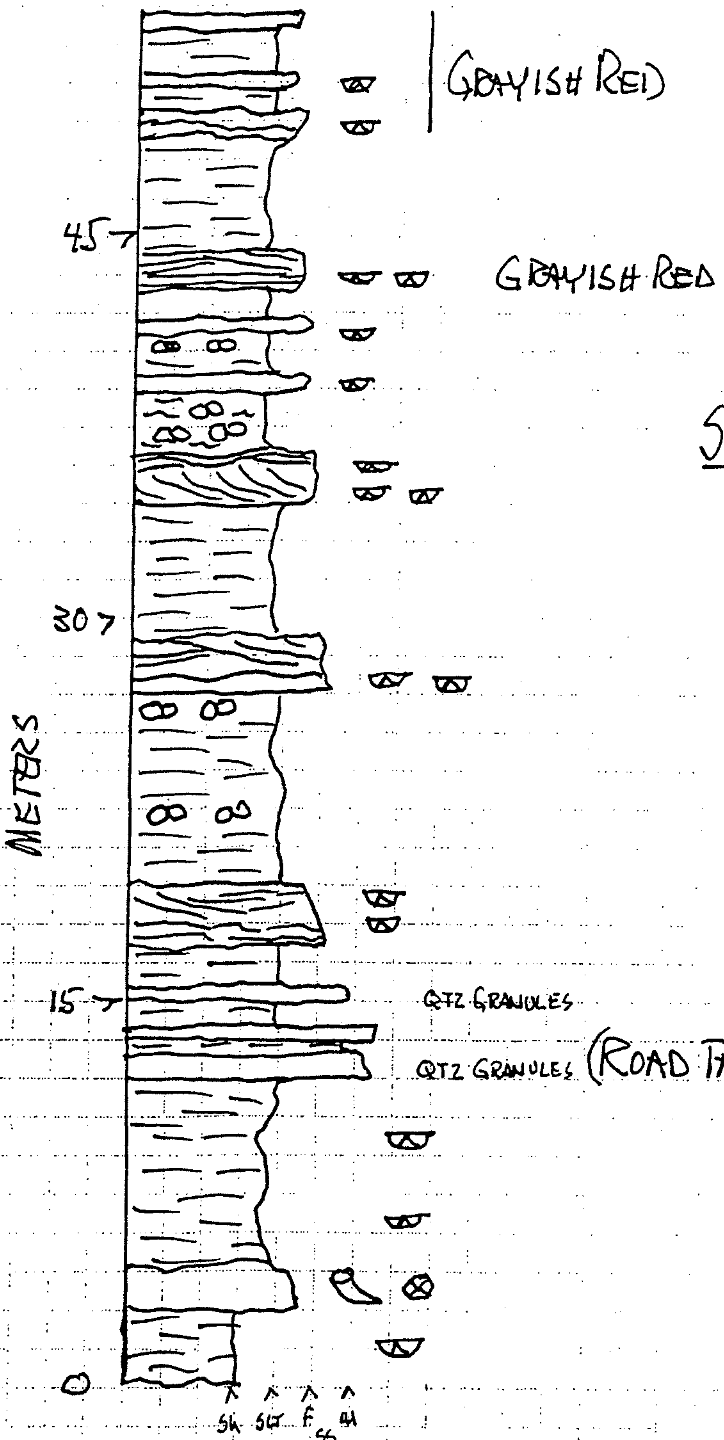
SPILLWAY, SOUTH END OF COWANESQUE DAM
RIPPLES: 232°, 238° CHAN. 265°
CHAN. 260°, 265°, 225°

RIPPLES: 242°, 243° CHAN - 253°, 217°
B/P: 255°, 310°, 318° CHAN - 278°, 281°
CHAN 280°, 240°, 230°
TEICHICHNUS, CHONDRITES

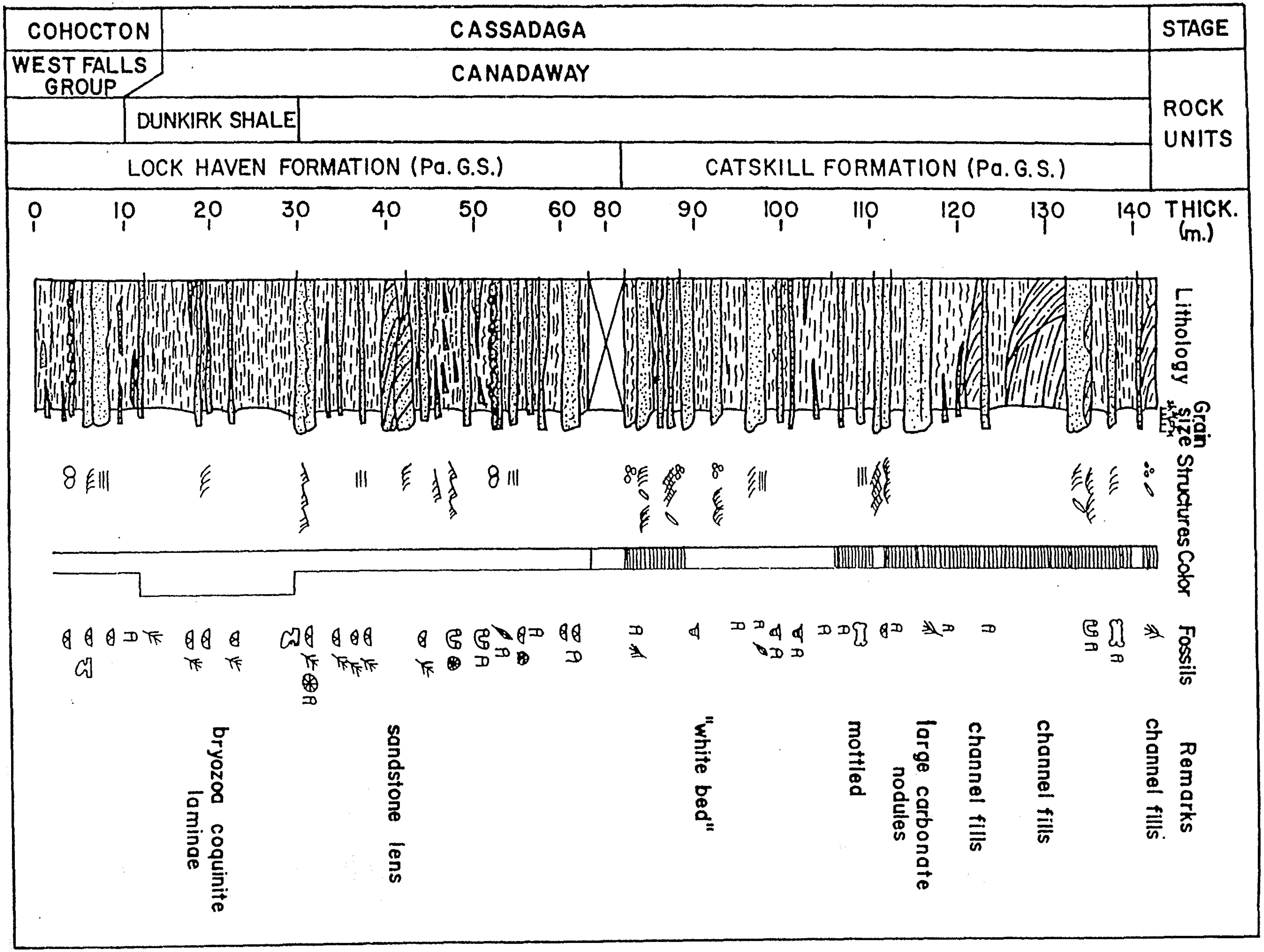
LOG II.

MOST EXPOSED ON OVERLOOK ACCESS ROAD

SECTION ALONG PA RTE. 287
WEST OF TIOGA, PA.

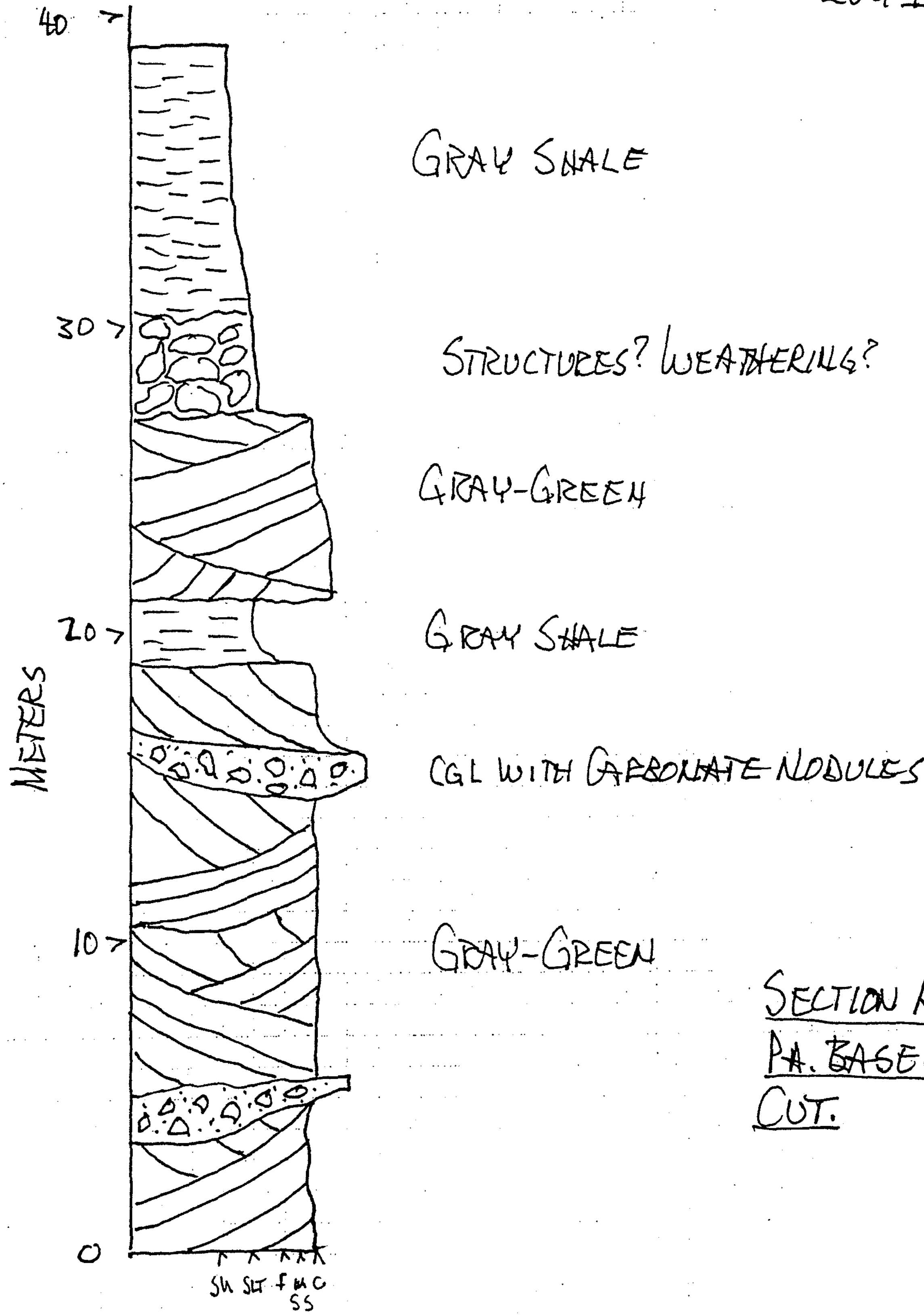


(ROAD TALUS, SOUTH SIDE OF ROAD)


COHOCTON
CASSADAGA
STAGE
WEST FALLS GROUP
CANADAWAY
DUNKIRK SHALE
ROCK UNITS
LOCK HAVEN FORMATION (Pa. G.S.)
CATSKILL FORMATION (Pa. G.S.)
0 10 20 30 40 50 60 80 90 100 110 120 130 140
THICK. (m.)
Lithology
Grain size
Structures
Color
Fossils
Remarks
bryozoa coquinite laminae
sandstone lens
"white bed"
mottled
large carbonate nodules
channel fills
channel fills
channel fills

LOG III.

LOG IV.



SECTION AT BLOSSBURG. PA. BASE OF NEW ROAD. CUT.