PROGLACIAL LAKES, SOUTHERN CAYUGA AND SENECA VALLEYS

PETER L.K. KNUEPFER
Dept. of Geological Sciences and Environmental Studies, Binghamton University, Binghamton, NY 13902-6000
email: knuepfr@binghamton.edu
STEPHEN M. HENSLER
Dept. of Geological Sciences and Environmental Studies, Binghamton University, Binghamton, NY 13902-6000

INTRODUCTION

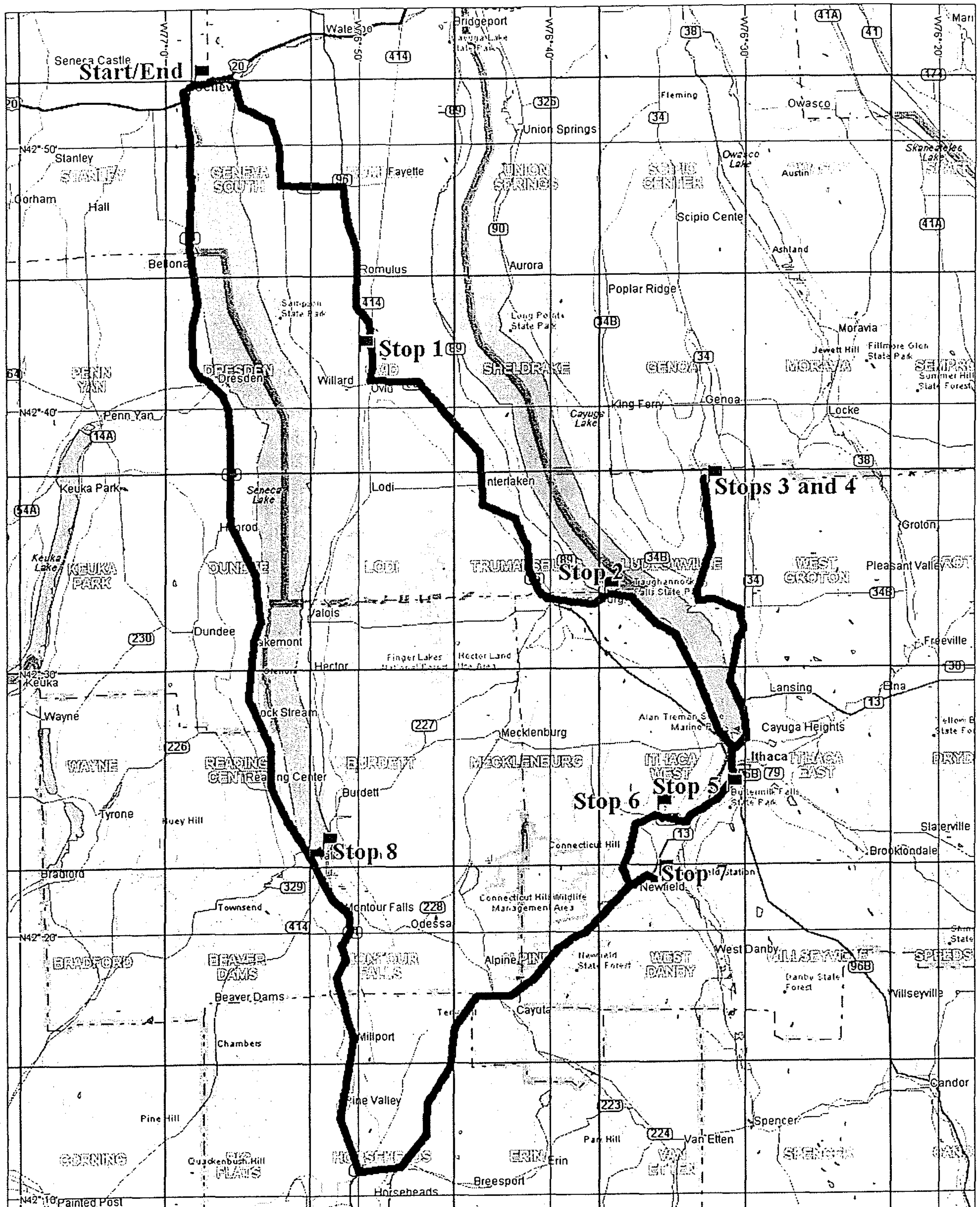
The modern Finger Lakes troughs of central New York developed by a combination of glacial scouring and the action of high-pressure sub-glacial meltwater (Mullins and Eyles, 1996). Seismic stratigraphic relationships suggest that the stratigraphic and morphologic record left behind by this event–including 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).

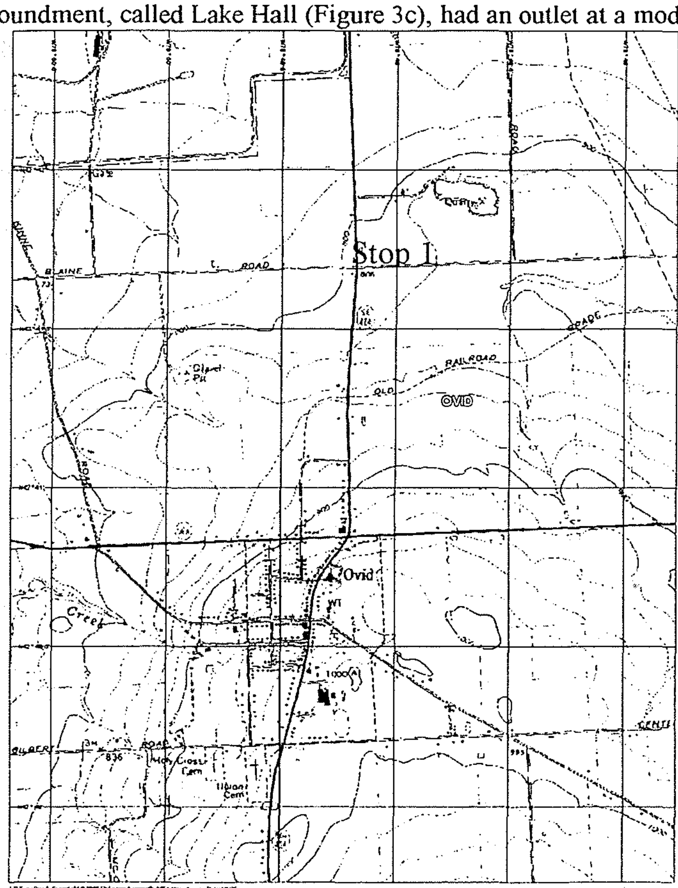


Figure 2. Topographic map of Ovid area and location of Stop 1. USGS Topographic map produced from DeLorme 3D TopoQuads program. Note flat surface at Ovid at elevation of approximately 1000 ft (305 m), which we interpret as scour surface and/or shoreline from overflow of Lake Ithaca into Lake Watkins (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).

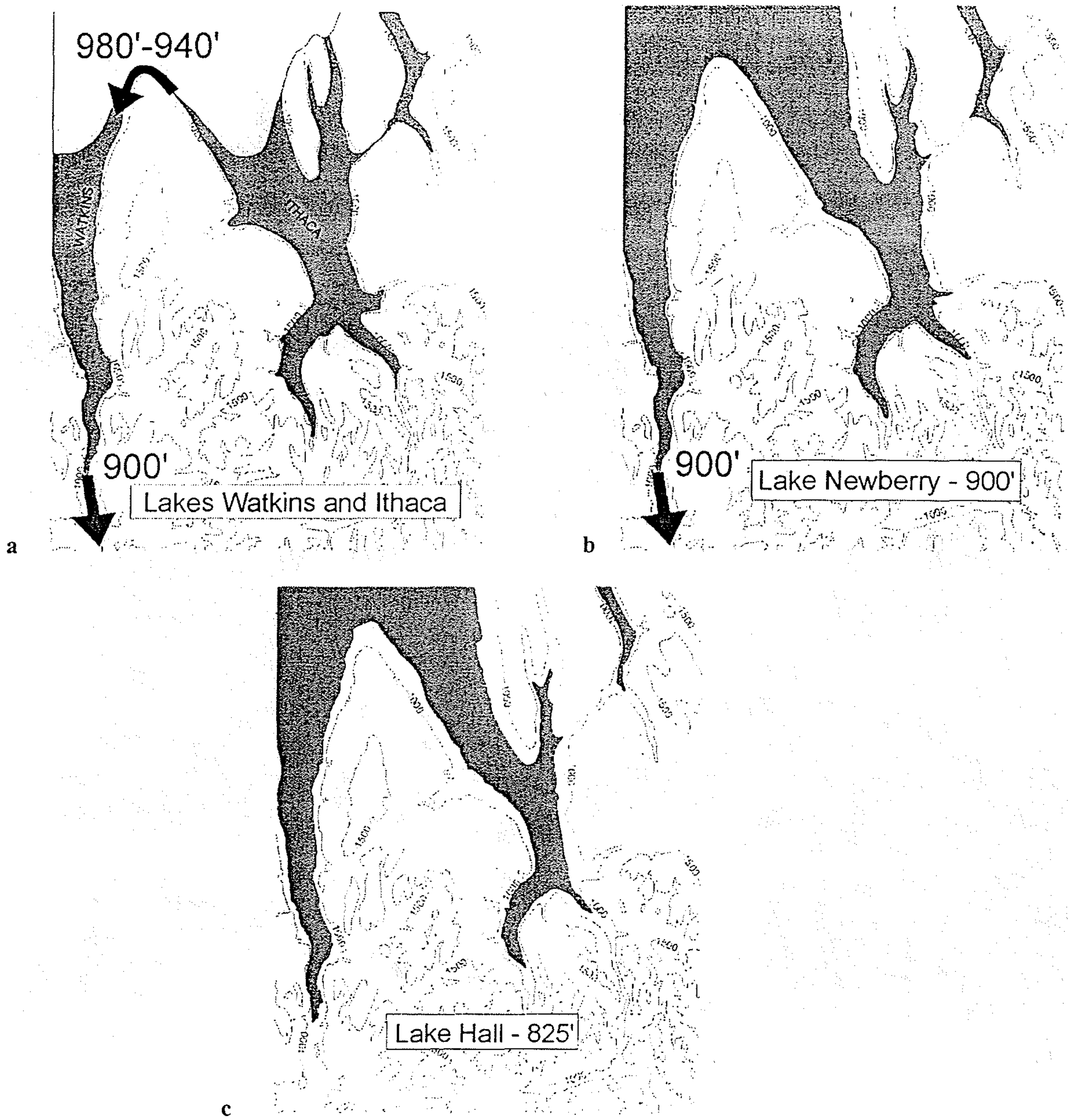


Figure 3. Evolution of pro-glacial lakes in the Cayuga and Seneca troughs. **a**. Initial overflow of Lake Ithaca into Lake Watkins at Ovid when spillway opened due to ice retreat. **b**. Amalgamation of Lake Newberry at common elevation between Cayuga and Seneca troughs after spillover complete. Outlet 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.

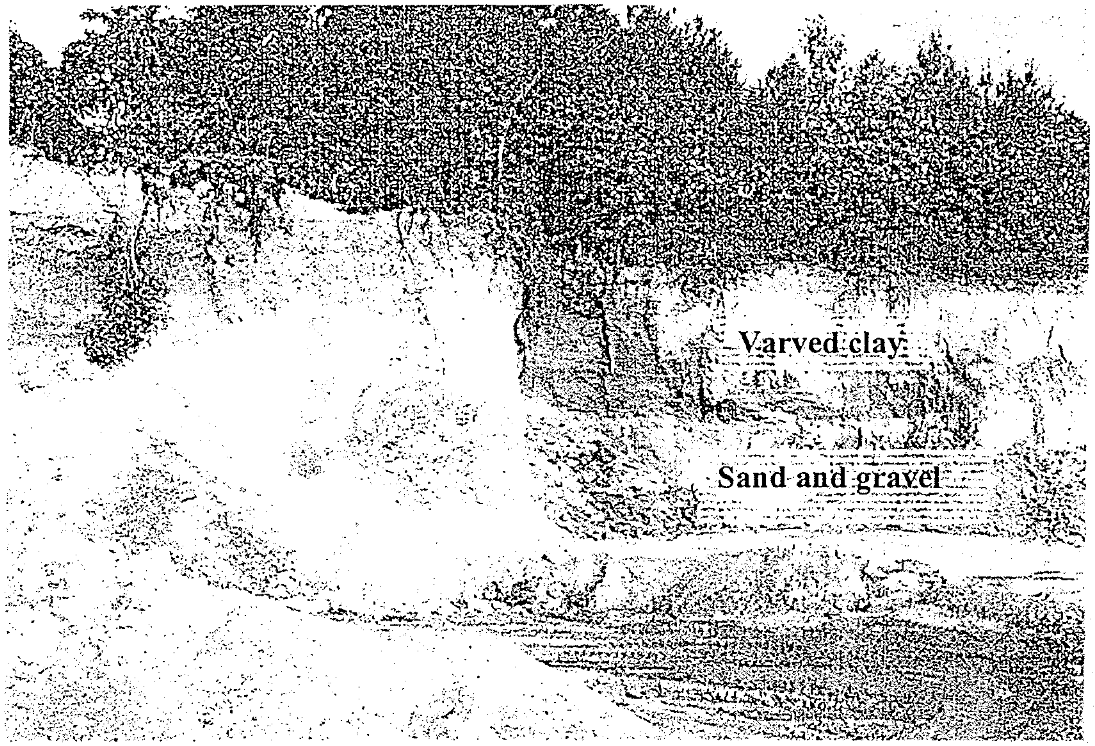


Figure 5. Exposures of stratified sand and gravel at Thompson and Genoa Sand and Gravel pits. Top: Exposure of stratified outwash(?) overlain by varved lacustrine clay (and locally diamict). View looking east at north end of pit wall. Photo taken 10 August 2000. Bottom: Exposure of faulted outwash(?) 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.

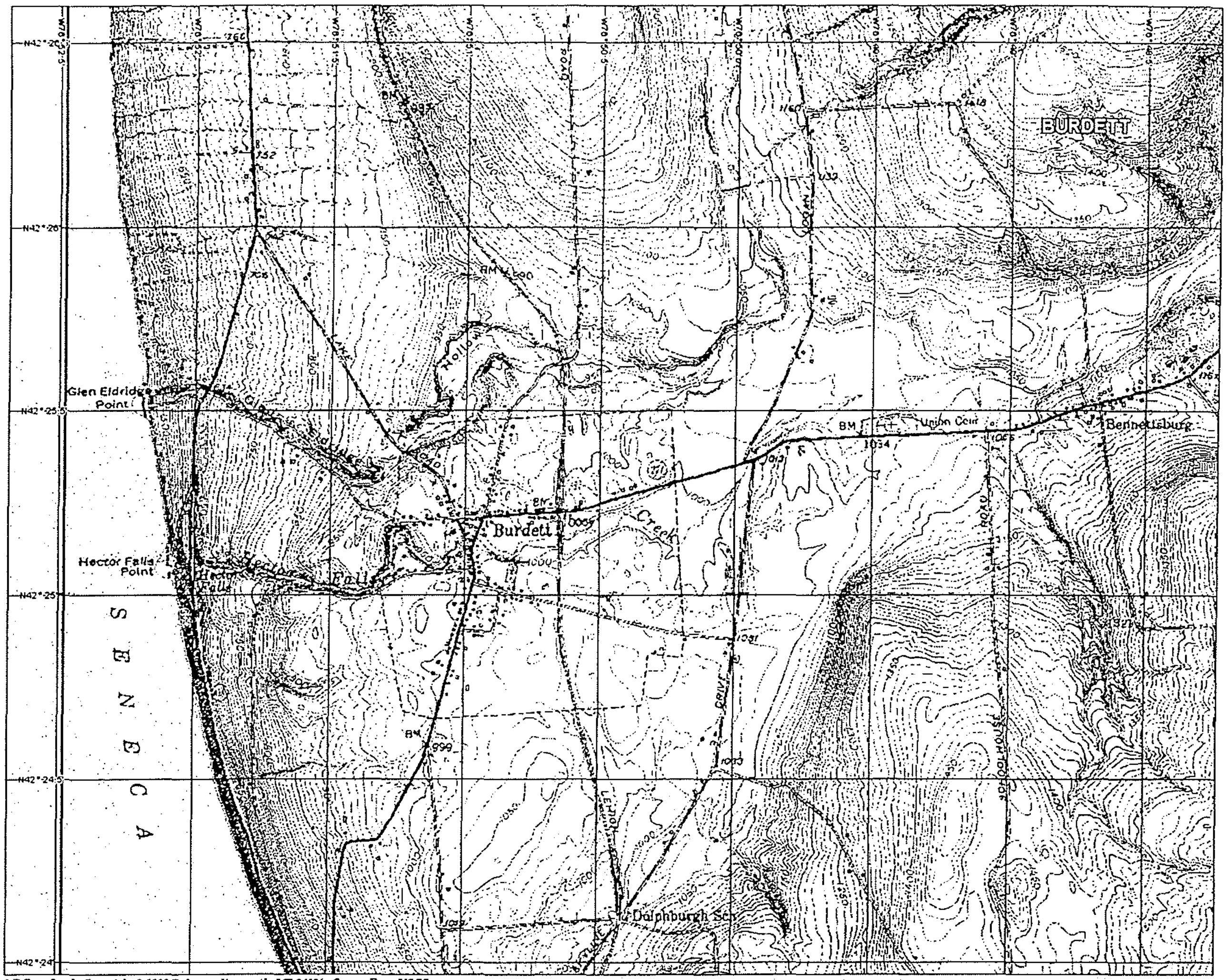


Figure 6. High delta surface at Hector Falls Creek, Burdett. Delta front 950-970 feet (290-295 m) at Burdett above Hector Falls Creek. This delta complex, representative of many at the southern end of Seneca Lake, graded to the stable Lake Watkins level controlled by the Horseheads outlet. Topographic 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.

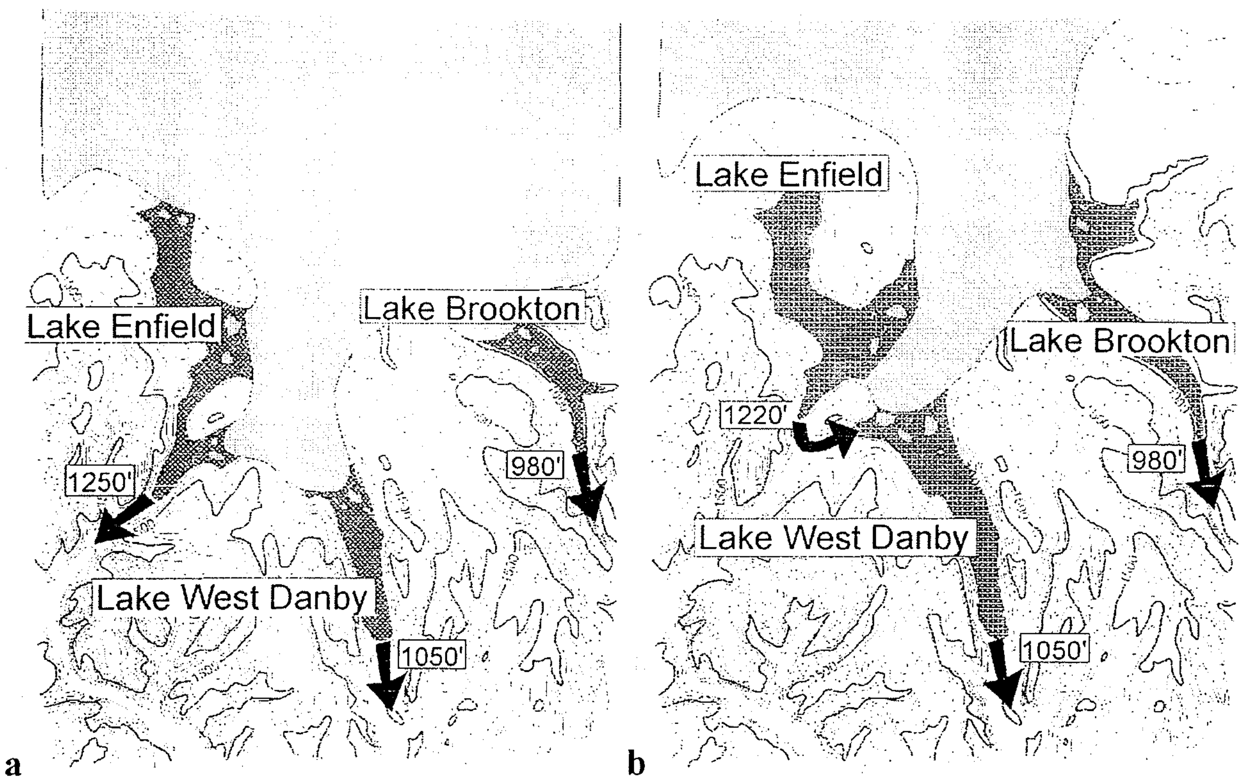


Figure 7. High-level lakes of the southern Cayuga trough during early stages of glacial retreat from the West Danby Valley Heads moraine position. a. Lake Enfield controlled by ice margin and Pony Hollow spillway. b. Lake Enfield drains to Lake West Danby through Fish Kill outlet, which is incised during 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.

REFERENCES CITED

Bloom, Arthur L., 1972, Schedule and Guidebook, Friends of the Pleistocene 35th Annual Reunion: Cornell University, 20 p.

Bloom, Arthur L., 1986, Geomorphology of the Cayuga Lake basin: Field Trip Guidebook, 58th Annual Meeting, New York State Geological Association, p. 261-279.

Braun, Duane D., 1994, Lack of evidence in the Susquehanna Valley for hypothesized late Wisconsinan catastrophic discharges, *in* Braun, Duane D.; Ciolkosz, Edward J.; Inners, Jon D.; Epstein, Jack B.; Clark, G. Michael; Sasowsky, Ira D.; and Koberle, Robin, eds., Late Wisconsinan to pre-Illinoian(G?) glacial and periglacial events in eastern Pennsylvania (guidebook for the 57th field conference, Friends of the Pleistocene Northeastern Section): U.S. Geological Survey Open-File Report OF 94-0434, p. 30-33.

Fairchild, Herman L., 1899a, Glacial waters in the Finger Lakes region of New York: Geological Society of America Bulletin, v. 10, p. 27-68.

Fairchild, Herman L., 1899b, Glacial Lakes Newberry, Warren and Dana, in central New York: American Journal of Science, Fourth Series, v. 7, p. 249-263.

Fairchild, Herman L., 1909, Glacial Waters In Central New York: New York State Museum Bulletin 127, 66 p.

Fairchild, Herman L., 1916, Pleistocene uplift of New York and adjacent territory: Geological Society of America Bulletin, v. 27, p. 235-262.

Fairchild, Herman L., 1934, Cayuga Valley lake history: Geological Society of America Bulletin, v. 45, p. 233-280.

Grasso, Thomas X., 1970, Proglacial lake sequence in the Tully Valley, Onondaga County: Guidebook, 42nd Annual Meeting, New York State Geological Association, p. J-1 - J-23.

Hand, Brice M., 1978, Syracuse meltwater channels: Fieldtrip Guidebook, 50th Annual Meeting, New York State Geological Association, p. 286-314.

Karrow, P.F., Warner, B.G., Miller, B.B., and McCoy, W.D., 1990, Reexamination of an interglacial section on the west shore of Cayuga Lake, New York [abs.]: CANQUA-AMQUA Joing Meeting, Programme and Abstracts, p. 22.

Knuepfer, P.L.K., and Lowenstein, T.K., 1998, Finger Lakes gorges revisited, *in* Naslund, H.R., ed., Field Trip Guide for the 70th Annual Meeting of the New York State Geological Association: New York State Geological Association, p. 23-42.

Maury, Carlotta Joaquina, 1908, An interglacial fauna found in Cayuga Valley and its relation to the Pleistocene of Toronto: Journal of Geology, v. 16, p. 565-567.

Muller, Ernest H., and Cadwell, Donald, 1986, Surficial geologic map of New York; Finger Lakes Sheet: New York Geological Survey Map and Chart Series #40, scale 1:250,000.

Muller, Ernest H., and Calkin, Parker E., 1993, Timing of Pleistocene glacial events in New York State: Canadian Journal of Earth Sciences, v. 30, p. 1829-1845.
Mullins, Henry T., 1998, Environmental change controls of lacustrine carbonate, Cayuga Lake, New York: Geology, v. 26, p. 443-446.
Mullins, Henry T., and Eyles, Nicholas, eds., 1996, Subsurface Geologic Investigations of New York Finger Lakes: Implications for Late Quaternary Deglaciation and Environmental Change: Geological Society of America Special Paper 311, 89 p.
Mullins, Henry T., and Hinchey, Edward J., 1989, Erosion and infill of New York Finger Lakes: implications for Laurentide ice sheet deglaciation: Geology, v. 17, p. 622-625.
Mullins, Henry T., Hinchey, Edward J., and Muller, Ernest H., 1989, Origin of New York Finger Lakes: a historical perspective on the ice erosion debate: Northeastern Geology, v. 11, p. 166-181.
Mullins, Henry T., Hinchey, Edward J., Wellner, Robert W., Stephens, David B., Anderson, William T., Jr., Dwyer, Thomas R., and Hine, Albert C., 1996, Seismic stratigraphy of the Finger Lakes: a continental record of Heinrich Event H-1 and Laurentide ice sheet instability, *in* Mullins, Henry T., and Eyles, Nicholas, eds., 1996, Subsurface Geologic Investigations of New York Finger Lakes: Implications for Late Quaternary Deglaciation and Environmental Change: Geological Society of America Special Paper 311, p. 1-35.
Shaw, John, 1996, A meltwater model for Laurentide subglacial landscapes, *in* McCann, S.Brian, and Ford, Derek C., eds., Geomorphology Sans Frontières: John Wiley & Sons Ltd., London, p. 181-236.
Shaw, J., and Gilbert, R., 1990, Evidence for large scale subglacial meltwater flood events in southern Ontario and northern New York State: Geology, v. 18, p. 1169-1172.
von Engeln, O.D., 1961, The Finger Lake Region; Its Origin and Nature: Cornell University Press, Ithaca, 156 p.
Wellner, Robert W., Petruccione, John L., and Sheridan, Robert E., 1996, Correlation of drillcore and geophysical results from Canandaigua Lake valley, New York: Evidence for rapid late-glacial sediment infill, *in* Mullins, Henry T., and Eyles, Nicholas, eds., 1996, Subsurface Geologic Investigations of New York Finger Lakes: Implications for Late Quaternary Deglaciation and Environmental Change: Geological Society of America Special Paper 311, p. 37-49.

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

		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
38.0	0.7	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