Trip A-2

PLEISTOCENE GLACIATION OF THE TIOUGHNIOGA RIVER AND FALL CREEK VALLEYS

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INTRODUCTION

The Pleistocene Epoch in eastern North America was characterized by a series of glaciations, the most recent of which was the Wisconsinan (from about 117 to 11.9 ka B.P.). Advance and retreat of glacial ice resulted in erosion of the landscape and the formation of landforms and deposition of glacial and related deposits. At the peak of the Wisconsinan glacial period, the Laurentide Ice Sheet extended from Canada and covered most of eastern North America, with its margin located in Ohio, northern Pennsylvania, northern New Jersey, and extending through Long Island into the Atlantic off the southern coasts of Connecticut, Rhode Island, and Massachusetts. Deposits of the previous Illinoian glaciation can be found to the south of the Laurentide margin, but are mostly lacking to the north of the margin as a result of erosion and reworking of sediments and deposition during the Wisconsinan glaciation (Randall 2001).

In New York State, glacial ice flowed south/southeast from Canada, as indicated by glacial striations deposits/landforms. Valleys parallel to ice flow were typically eroded into U-shaped glacial valleys, whereas valleys perpendicular to flow were infilled with glacial deposits and, upon ice retreat, eroded by meltwater and rivers. Over successive glaciations, through valleys such as the valleys of the Finger Lakes were carved out, and glacial landforms and deposits, including the drumlin fields of the Ontario Lowlands in western New York and several moraine systems were deposited / formed.

In the Late Wisconsinan Last Glacial Maximum (LGM), following ice advance to the position of the terminal moraine around 20,000 (radiocarbon) years ago, ice began to retreat back to the north. The retreat phase in the Appalachian Plateau of New York State was characterized by a relatively rapid retreat of ice in the uplands, while ice tongues remained longer in glacially eroded U-shaped valleys. Valley ice tongues retreated through the processes of back- and downwasting (Fleisher 1993). Backwasting involved active ice retreat and typically occurred in through valleys. Downwasting was characterized by stagnant ice retreat and took place in smaller valleys (Fleisher 1991).

Ice retreat from the LGM was accompanied by formation of lakes in front of the retreating ice margin, especially where previously deposited glacially derived sediment blocked southward drainage. At least one period of stagnation and readvance of ice resulted in the deposition of the Valley Heads Moraine (Stops 1, 3, and 4) within several valleys of Central and Western New York (Fig.. 1) (Miller et al. 1998). The Valley Heads Moraine is a characteristic ablation or dead ice moraine that formed as a result of ice stagnation, as shown by the large kettle ponds and lakes in the Tully region (Stop 1) confined between the moraine to the north and the valley train to the south (Fleisher 1991). Deposition of the Valley Heads moraine resulted in the formation of large proglacial valley train sequences confined to valleys south and east of the moraine (such as the Otisco, Factory Brook, West and East Branch Tioughnioga, Otter/Dry Creek, Trout Brook, and Main Stem Tioughnioga valleys, which are the subject of this field trip). Retreat of ice north from the Valley Heads position also led to development of large proglacial lakes.

Ice re-advance and the resulting deposition of the Valley Heads Moraine reorganized pre-LGM drainage divides in several of the through valleys in central New York. Two segments of the Valley Heads Moraine provide drainage divides and boundaries for the Tioughnioga and its associated drainage. The Tully Moraine (Stop 1) forms the drainage divide at the northern end of the West Branch Tioughnioga Valley. Drainage to the north of the moraine, in the Onondaga Trough, flows north towards the Seneca River and Lake Ontario, while drainage to the south of the moraine flows south through the West Branch and Main Stem Tioughnioga River to the Chenango River and eventually the Susquehanna. To the southeast of Cortland, the South Cortland Moraine (Stops 3 and 4) forms another drainage divide. Flow to the west of the moraine is west-southwest through the Fall Creek Valley to Cayuga Lake. To the east of this moraine, Dry Creek and Otter Creek flow east-northeast into the West Branch Tioughnioga River, which then turns southwest down the Main Stem Tioughnioga.

This trip focuses principally on the deglaciation of the Tioughnioga Valley between Tully and Whitney Point, NY, with additional examination of the Fall Creek Valley between Cortland and Ithaca, NY. The goal is to illustrate most of the key morphologic and sedimentologic features that characterize active and dead-ice retreat of the LGM ice through this area of central New York. In addition, exposures in Fall Creek Valley allow us to examine some pre-LGM deposits.

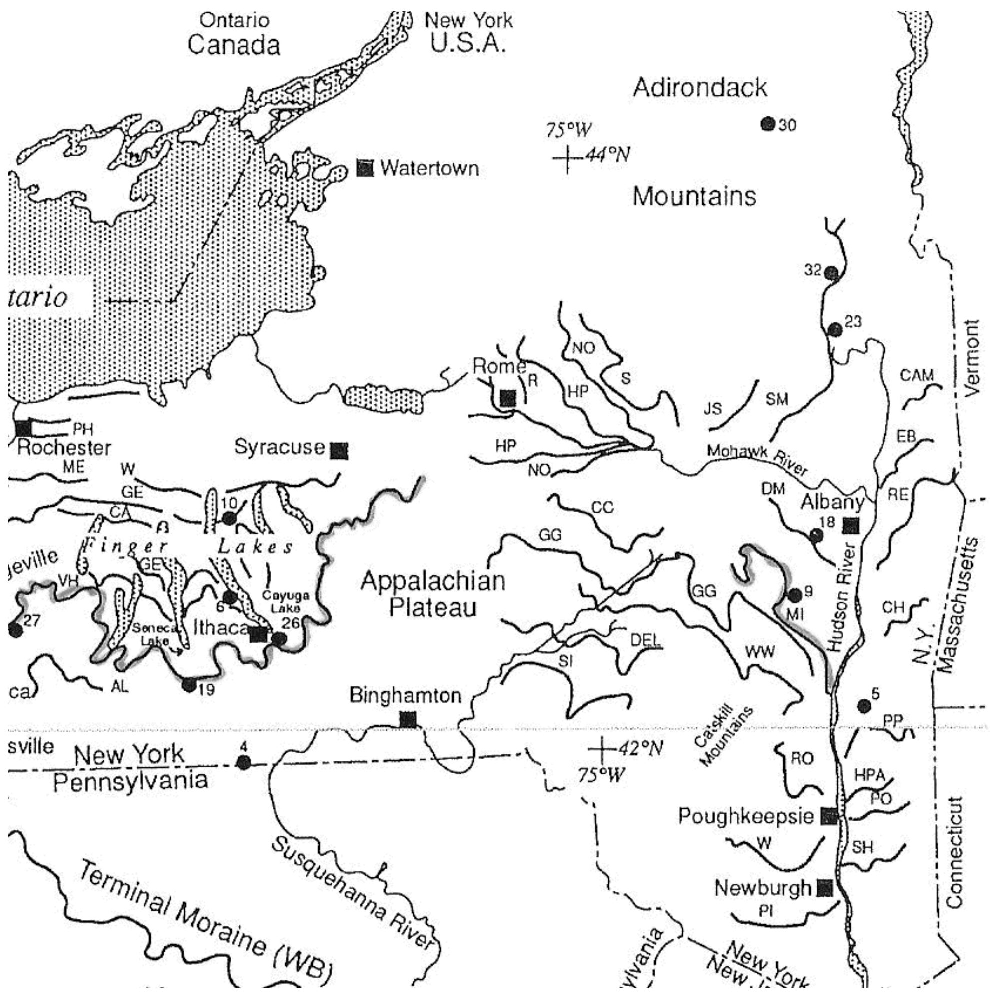

FIGURE 1—Valley Heads Moraine in Central New York (Muller and Calkin 1993).

Glacial Deposition

The advance and retreat of glacial ice both in the uplands and within valleys resulted in the deposition of till over most of Central New York. Glacial till, also known as hardpan or fragipan, consists of a poorly sorted mix of sediments ranging in size from clay to boulders. Erratics, sediment clasts that have origins far from the region of deposition, are often found within tills, as well as other glacial deposits. In the field-trip area, these erratics are commonly metamorphic rocks, igneous rocks (granite), and red sandstones.

Ice-contact sediment (till) was deposited as lodgement, meltout or ablation, flow, or deformation till. Lodgement tills consist of debris deposited at the base of active glacial ice, and are characterized by compacted, unsorted, unstratified sediment with faceted and striated clasts. Meltout or ablation tills can be deposited subglacially as basal ice melts and deposits sediment, or supraglacially as the ice surface melts and sediments within the ice are released. Both sub- and supraglacial meltout tills are less compact than lodgement tills, but may be interbedded with meltwater deposits and may show some stratification. Supraglacial meltout tills, deposited from the retreating glacial terminus are more common than subglacial meltout tills. Flow tills result from supraglacial sediment flowing off the surface of glacial ice and depositing in front of the terminus. Clasts in these tills are usually more rounded, sorted, and the deposits are more stratified than meltout tills.

As glacial ice retreated from Central New York, sediment-laden braided rivers of glacial meltwater flowed down valleys that were previously filled with ice, resulting in the deposition of outwash sediments as valley train sequences (outwash confined to valleys). Sands and gravels were deposited on top of previously deposited sediments, including lacustrine deposits, tills, and previously deposited outwash, as well as along, above, or within/below stagnant ice remaining in the valley. The formation of several glacial valley landforms resulted from the interaction of meltwater with stagnant and/or active ice. Sources of this meltwater could have originated from up valley where active ice was retreating or stagnant ice was melting, or from upland meltwater sources flowing into the valley onto or up-valley from active or stagnant ice.

Stagnant ice blocks that were buried by sands and gravels produced kettle holes, lakes, and ponds when the ice melted and outwash sediments collapsed downward. Meltwater that flowed within or below stagnant ice deposited sands and gravels within a tunnel that was later exposed, after ice melted, as a ridge of outwash or an esker. Kame deposits, including isolated kames, kame terraces, and kame deltas, form from glacial meltwater flowing over the surface of glacial ice or between the ice margin and a valley wall. In instances when the ice surface contained depressions or holes, outwash sediments can infill these regions as meltwater enters them, slows, and deposits its sediment load. When the ice melts, these outwash deposits would be lowered to the land surface as isolated mounds or kames. Due to the curved surface of valley ice tongues, meltwater often flows over the surface of active and/or stagnant ice in the region along the valley wall, where the ice elevation is at its lowest. Outwash would be deposited in the region between the glacial ice and the valley wall. Upon melting of the ice, this outwash would lose its ice-side support and thus collapse downward in the direction of the valley. The upper surface of this kame terrace deposit would remain nearly flat and at a higher elevation than the valley floor, while the side facing the valley typically would contain collapse features and faults oriented in the direction of the ice support. Kame deltas result from ice-contact meltwater flowing from the front edge of the ice into a proglacial lake. As the meltwater slows, it deposits sediment as a deltaic deposit.

Proglacial lakes formed in glacial valleys throughout central New York and are identified by their associated silt and clay lacustrine deposits, which are often varved, and/or by preserved tributary deltas that now “hang” topographically above valley bottoms. Proglacial lake formation results when drainage within the valley is blocked, either by active or stagnant ice, by glacial deposits including moraines and valley plugs, or by higher elevations and bedrock knolls down-valley that result from erosion and over-deepening of the valley upstream by glacial erosion. These lakes may drain catastrophically as the ice blocking their drainage retreats or as the down-valley outlet is eroded, producing hanging shorelines and terraces. The lakes may also be infilled with coarser-grained outwash sediments.

FIELD TRIP AREA

The field trip area is located in Cortland, Broome, and Tompkins Counties, New York, within the valleys of the West Branch Tioughnioga River from Tully to Cortland, Fall Creek from Cortland to Ithaca, and the Main Stem Tioughnioga River from Cortland to Whitney Point (Fig. 2). This area is located in the Eastern

Appalachian Plateau region of Central New York, also known as the Allegheny Plateau. The Appalachian Plateau is an upland region with elevations ranging between 450 and 670 m. Valleys within the plateau have been deepened an average of about 325 m, and widened, with major valleys ranging from 300 up to 2500 m wide, through multiple glacial episodes. Quaternary sediments within these plateau valleys are the result of past glaciations and consist of outwash sands and gravels or valley train landforms. Upland tributary valleys contain deposits of alluvium that overlie till and bedrock (Randall 2001).

The northern rim of the Appalachian Plateau and the Erie-Ontario Plain, with its associated northward drainage, is located just north of the field trip region. The Finger Lakes and associated drainage are located to the west, and although they are part of the Appalachian Plateau, their present-day drainage is also to the north. The southward draining Chenango Valley is located to the east of the Tioughnioga Valley. Confluence between the Chenango and Tioughnioga valleys occurs at Chenango Forks, and the Chenango Valley continues southward (Coates 1963).

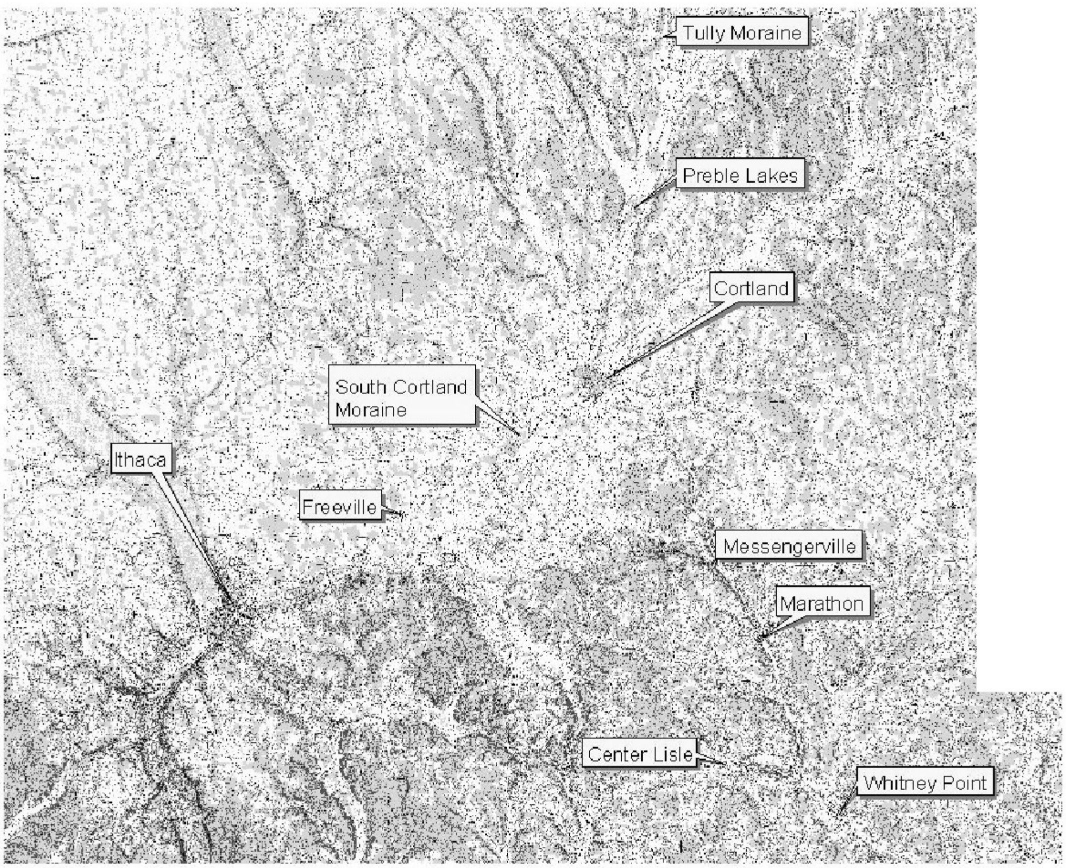

FIGURE 2—Map of field trip area; West Branch, Main Stem, and Fall Creek Valley locations in Cortland, Broome, and Tompkins County, Central New York.

West Branch and Main Stem Tioughnioga Valleys

The West Branch Tioughnioga Valley, located between Tully and Cortland NY, is a through valley that extends southward from the Tully Lakes region. This valley extends northward beyond the Tully Lakes (Stop 1) to the Tully (Valley Heads) moraine and is known as the Tully Trough. To the north of the moraine, the through valley continues northward towards Syracuse as the Onondaga Trough and contains the northward flowing Onondaga Creek. The West Branch Tioughnioga drains Tully Lake and flows south through the Preble area (Stop 2; Preble Swamp and Preble Lakes Goodale, Upper Little York, and Lower Little York), to Homer and Cortland. Major tributaries to the West Branch Tioughnioga include the Otisco Valley, from which there is no present-day drainage, Cold Brook, and Factory Brook. To the north of the city of Cortland, the West Branch turns to the east and is joined by Otter and Dry Creeks before confluence with the East Branch Tioughnioga.

Upon confluence of the East and West Banches, the Main Stem Tioughnioga resumes a south-southeast course. To the southeast of Cortland (east of Polkville), the Trout Brook Valley and its west-flowing drainage merges with the Main Stem Tioughnioga. Tributaries to the Main Stem between Trout Brook and the next major confluence at Whitney Point, where the Tioughnioga and Otselic rivers join, include Hoxie Gorge Creek, Gridley Creek, Hunts Creek, Jennings Creek, and Dudley Creek, as well as some small unnamed tributaries. To the south of the Otselic-Tioughnioga confluence, tributaries to the Tioughnioga include Bull Creek, Halfway Brook, and several smaller unnamed tributaries. At Chenango Forks, the Tioughnioga converges with the Chenango River, flowing south to the Susquehanna.

The Main Stem Tioughnioga Valley retains a glacial U-shape, with steep valley walls and a broad, flat valley bottom, although the width of the valley decreases greatly south of the East and West Branch confluence. In the Cortland region, a juncture of four valleys occurs (West Branch Tioughnioga, East Branch Tioughnioga, Main Stem Tioughnioga, and Otter/Dry Creek valleys), producing an extremely large overall valley width of around 4500 m at the widest point. At the Trout Brook – Main Stem confluence, the Tioughnioga Valley is around 1100 m across. The valley width averages around 500 m at Blodgett Mills, and width continues to decrease southward, reaching around 200 m at Messengerville. From Messengerville onward, valley width fluctuates, with wider areas of around 400 to 600 m (1000 m at Whitney Point) and narrower areas of around 200 and 300 m (Fig. 2). According to Coates (1981), this fluctuation of valley width south of Cortland resulted from the Tioughnioga Valley having been a meltwater conduit or sluiceway during glacial retreat.

Bedrock in the Tully, NY, region consists of the Middle Devonian Hamilton Group (Kappel and Miller 2003). Bedrock in the valley near Marathon is of the Ithaca Formation, whereas bedrock in the uplands consists of Enfield Formation siltstone (HydroSource Associates Inc. 1999). In the region of Whitney Point, bedrock consists of Late Devonian Genessee Formation and Sonyea Group sandstones and shales (Rickard and Fisher 1970). Sandstone and shale of the Genesee Formation is found in the valleys at Cortland and within the Fall Creek Basin (Karig and Elkins 1986). Bedrock within the West Branch and Main Stem Tioughnioga valleys is buried by thick surficial deposits of glacial and alluvial origin. Deposits include glacial outwash sands and gravels, deltaic deposits of medium and fine sand, glaciolacustrine silts and clays, till, and alluvial silt, sand, and gravel (Muller and Cadwell 1986).

Fall Creek Valley

The Fall Creek Valley is located in the Finger Lakes Region of Central New York west of Cortland and extends from the western side of the South Cortland / Fish Hatchery (Valley Heads) Moraine (Stops 3 and 4) to Cayuga Lake at Ithaca. Tributaries to the valley include Lake Como Outlet, Webster Brook, Mud Creek, Mill Creek, Virgil Creek, and several smaller tributaries. The creek flows in an east–southeast direction. The valley turns northward at Ithaca, and Fall Creek flows into Cayuga Lake. Due to its east-west orientation, the valley was perpendicular to glacial ice flow and thus filled with glacial deposits during both glacial advance and retreat (Stop 5). Following glacial retreat, Fall Creek excavated its valley, with incision to bedrock in the lower reaches beyond the Cornell Arboretum. Upstream of this region, surface deposits consist of alluvium, and terraces record the incision of Fall Creek into its channel.

GLACIAL HISTORY OF THE WEST BRANCH AND MAIN STEM TIOUGHNIOGA VALLEY

The West Branch and Main Stem Tioughnioga valleys (Fig. 3) are oriented parallel to the direction of ice flow, and as a result, were widened and deepened, forming U-shaped glacial valleys. Retreat methods were defined using Fleisher's (1991, 1993) through and non-through valley glacial assemblage model. Fleisher proposes that kame moraines with associated valley train, deltaic gravel terraces, lacustrine plains, kame fields, and dead-ice sinks are associated with backwasting (active retreat) in through valleys, whereas kames, kame fields, and discontinuous gravel plain remnants with dead-ice sinks and eskers are characteristic of downwasting in non-through valleys. In the case of downwasting, dead-ice sinks are bounded up- and down-valley by landforms such as terraces, kame moraines and kame fields, and valley trains (Fleisher 1991). Both the West Branch and Main Stem Tioughnioga valleys are identified as through valleys, in which retreat occurred through backwasting with some episodes of detached margins and downwasting.

A glacial plug deposit of sand and gravel is found in the Tioghnioga Valley at Chenango Valley State Park just upstream of Chenango Forks, where the Tioughnioga River flows into the Chenango River. This deposit formed as a block of ice detached from the actively retreating ice margin and meltwater deposition increased (Cadwell 1972). As the Tioughnioga Valley was deglaciated, flow eroded through the valley plug deposits (Cadwell 1972). Between Chenango Forks and Whitney Point ice was actively retreating at this time. Outwash was deposited on the floor of the valley, and kame terraces and deltas were deposited along the valley walls. A kame terrace/delta is found where Halfway Brook enters the valley from the east, and a kame terrace is found along the western valley wall at Istaka. Well logs collected from the NY State Department of Environmental Conservation, Department of Transportation, county health departments, and the U.S. Geological Survey show a buried deposit of clay and silt, which we interpret as a glaciolacustrine deposit, beneath outwash sediments at and south of Whitney Point. The southward extent of this lake is not known, due to a lack of subsurface information in that region. The lake may have formed by impoundment of meltwater between the retreating ice margin and valley plug deposits downvalley. A large kame terrace and delta deposit is found along the eastern valley wall to the north of Whitney Point, within the Town of Lisle. Sediments of this deposit are recorded in well logs within the terrace and exposed at the Taylor Ready Mix sand and gravel pit. Kame delta structure is preserved in a deposit along Watts Road.

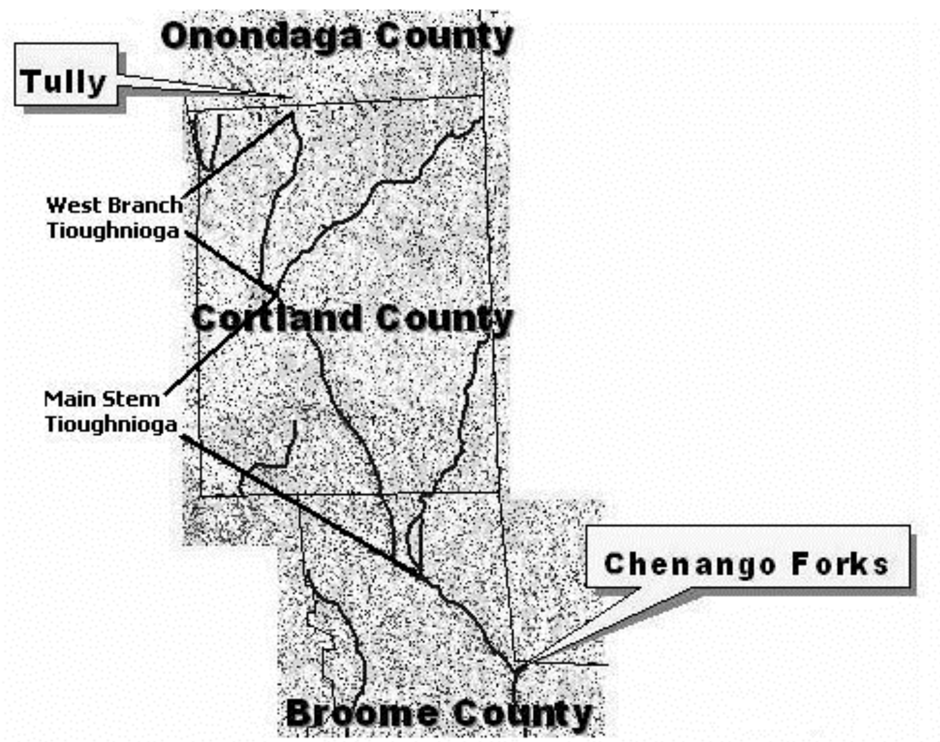

FIGURE 3—West Branch and Main Stem Tioughnioga valleys oriented parallel to ice flow direction.

Stagnant ice within Dudley Creek Valley west of Lisle led to the deposition of associated non-through valley deposits (Fig. 4). Kame terraces are found along both sides of the valley wall along Dudley Creek near the Dudley Creek–Tioughnioga junction. The terrace deposits on the north side of the valley are exposed along Dudley Creek behind the Town of Lisle firehouse (Stop 7) and above the valley in a road cut along Owen Hill Road (Stop 8). On the southern side of the valley, kame terrace deposits are exposed in the valley across the road from the firehouse and above the valley in gravel pits along Smith Hill Road. A large subglacial channel deposit known as the Lisle Esker (Stop 6) is found between Richford and Lisle. In some areas, the esker is attached to the valley wall, whereas it is detached in other locations. It is thought to have formed when a distributary tongue of ice extended through a gap in the Owego Creek Valley to the west and stagnated during deglaciation, when it was cut off from the main ice tongue to the west (von Engeln 1961).

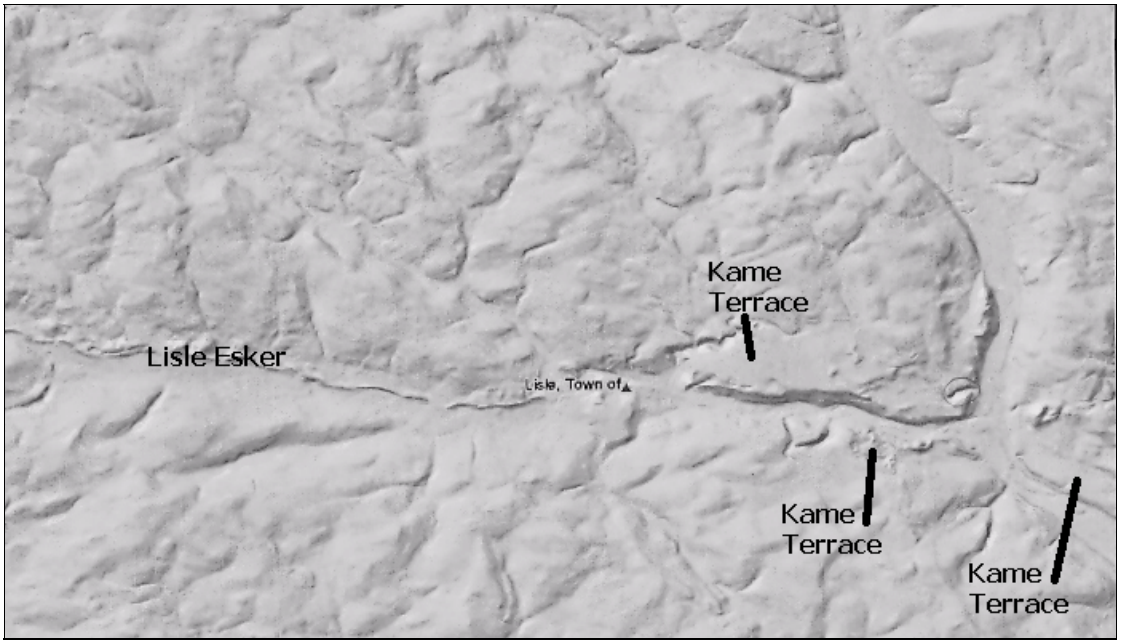

FIGURE 4—Dudley Creek Valley stagnant ice landforms.

Ice retreat from Whitney Point to Marathon was characterized by active ice retreat. Stratigraphy in the Tioughnioga Valley north of Lisle, as interpreted from well logs, includes glacial till overlying outwash and/or bedrock that is overlain by outwash. Surface deposits in the valley are composed of alluvium. Kame terraces are present along the valley walls east of Killawog and both east and west of Marathon (Optional Stop). The lack of glaciolacustrine deposits in this area shows that drainage to the south was not blocked by glacial deposits downvalley.

A preglacial drainage divide probably was located north of Marathon, in the region of Messengerville, based on the orientation of tributary valleys. Flow to the south of this divide was south toward Marathon, while flow to the north was toward Cortland, and down the Otter-Dry Creek valley southwest toward the Fall Creek Valley (Fig. 5) (Miller 2000). The dendritic pattern formed by valleys in the region of Cortland shows that flow from the Main Stem Tioughnioga and Trout Brook north of Blodgett Mills was toward Cortland. Bedrock in the Main Stem Tioughnioga Valley from Messengerville to Cortland slopes northward, providing additional support for preglacial flow in this direction (Fig. 6). As a result of glacial processes, drainage at Cortland was diverted southward, down the Main Stem Tioughnioga Valley and across the former drainage divide, forming the present-day drainage patterns. The narrowing of the through valley southeast of Cortland is a result of drainage diversion from a large valley system at Cortland, where valleys and their associated drainage converged, to the smaller Main Stem Tioughnioga Valley, where preglacial drainage was to the north via a small stream valley. The present day Otter Creek Valley is underfit, in which a small stream occupies a much larger valley (Miller et al. 1998).

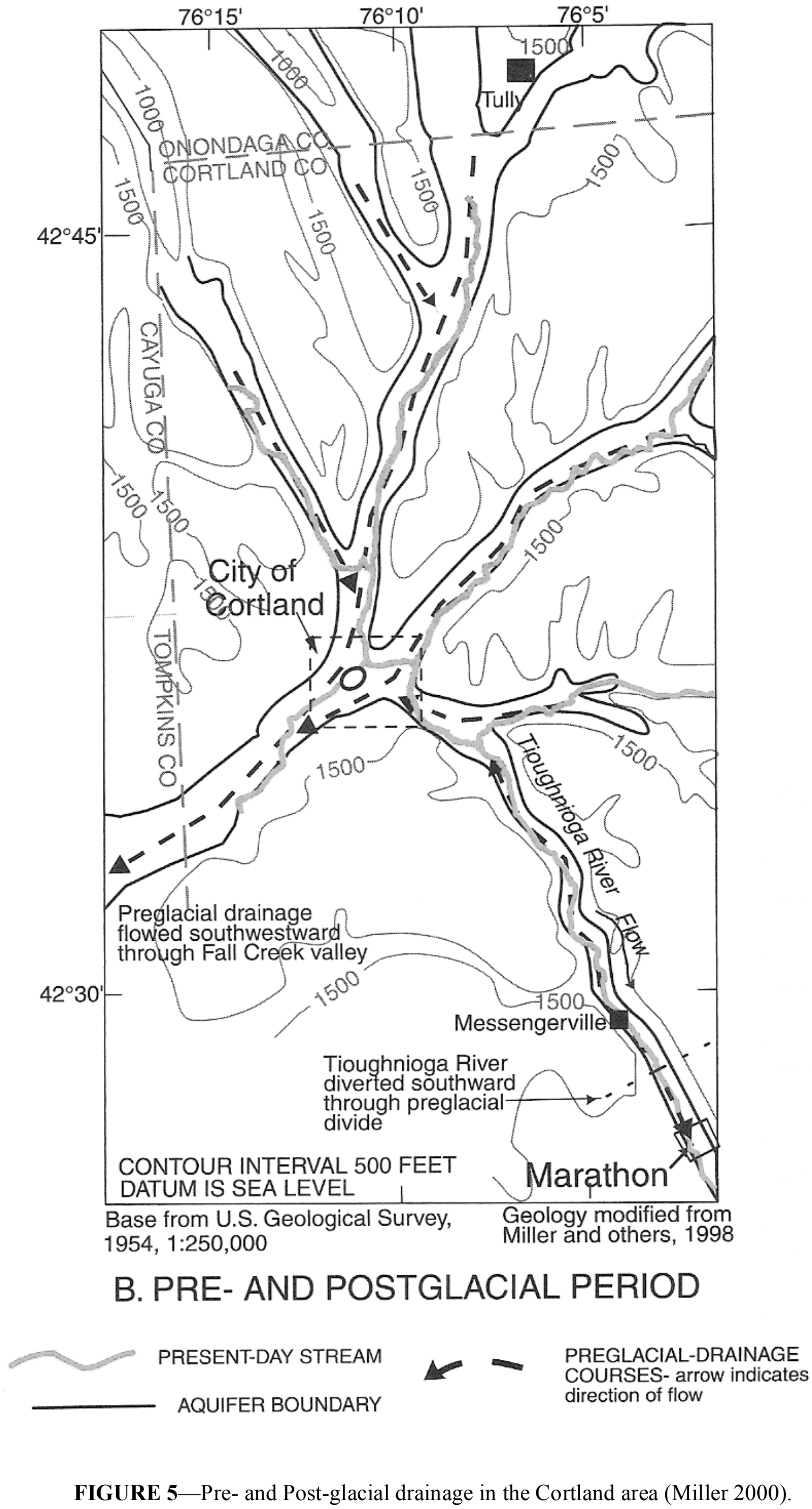

FIGURE 5—Pre- and Post-glacial drainage in the Cortland area (Miller 2000).

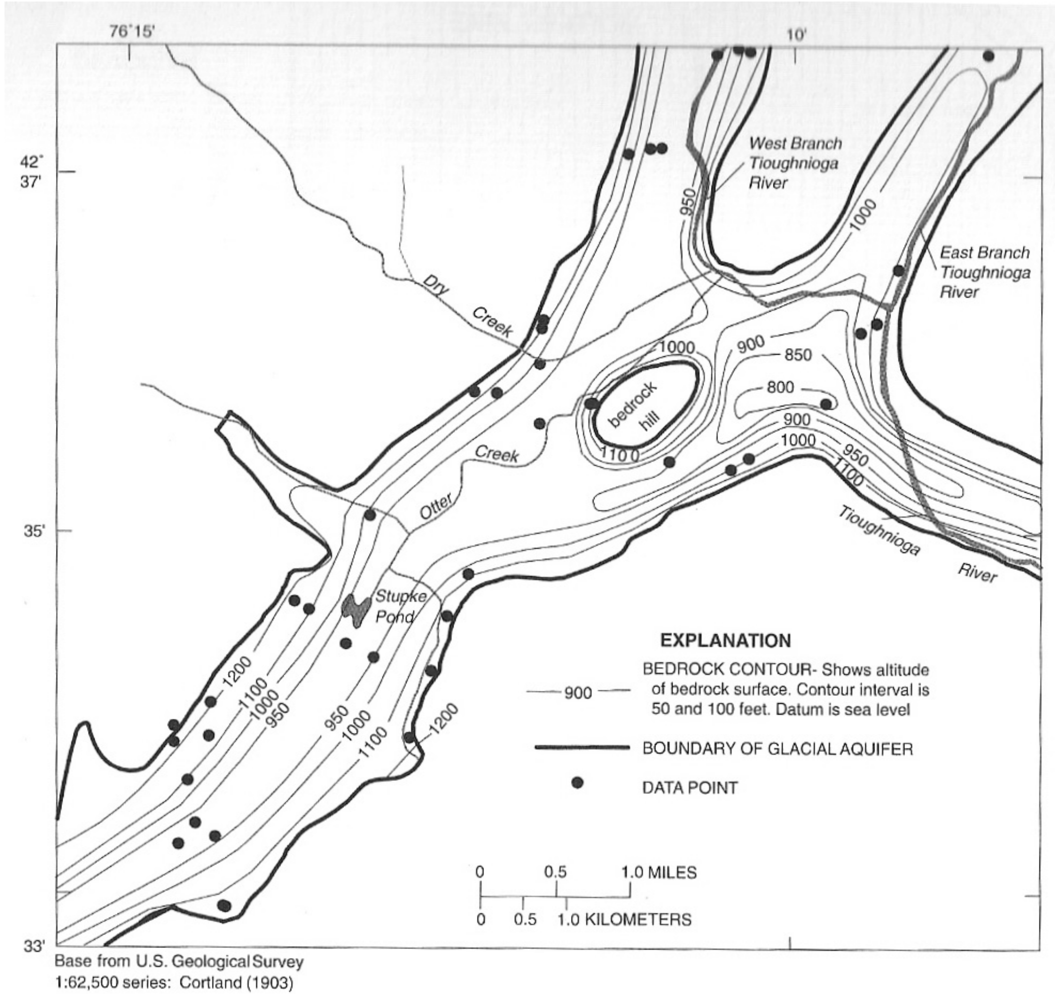

FIGURE 6—Map of depth to bedrock, Cortland area (Miller et al. 1998).

Glacial retreat and ice in the Cortland region led to the deposition of large kame deposits that formed as meltwater from upland regions flowed into the valley. A large kame terrace is found on the southern valley wall at Cortland, with elevations reaching up to 385 m. Terrace deposits are also found along the northwest valley wall, between the West Branch and Dry/Otter Creek valleys. Mapping of glacial deposits based on soil parent materials suggests that the terraces might have been deposited as a moraine (Fig. 7). Glacial stratigraphy as interpreted from well logs and subsurface information shows that outwash and possible buried kame deposits overlie bedrock. These outwash deposits are overlain by a thick layer of glaciolacustrine silts, clays, and very fine sands that were deposited in a proglacial lake. Surficial outwash deposits overlie the glaciolacustrine deposits. Uplands and the uppermost reaches of the valleys contain deposits of till over bedrock. The South Cortland moraine is found to the southwest, in the Dry/Otter Creek Valley. In this region, bedrock is overlain by till, outwash (kame) deposits, and kame moraine (Miller et al. 1998). A kame deposit is found in the Otter/Dry Creek valley along Route 28 just north of Webb Road. Glaciolacustrine deposits in the valley extend south of Cortland to Blodgett Mills. Ice retreat is interpreted as having been active, following Fleisher's (1991) through valley assemblages.

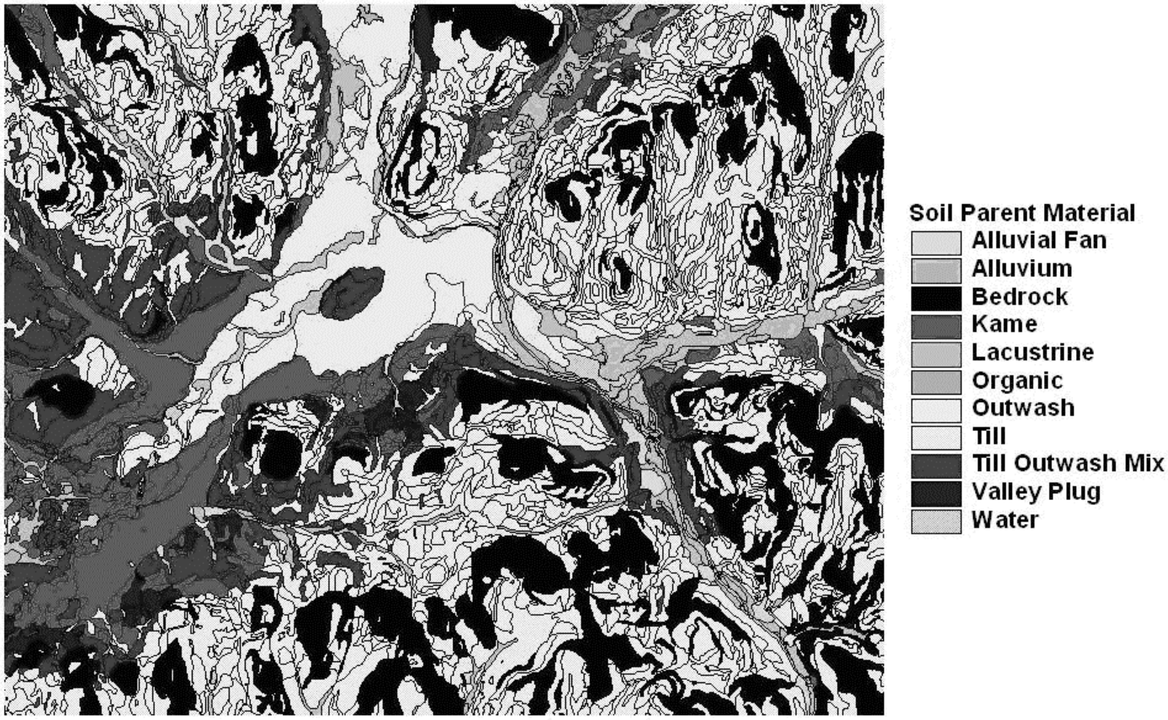

FIGURE 7—Surface deposits based on soil parent materials (base map from USDA, NRCS, SSURGO for Cortland County).

The West Branch Tioughnioga flows southward through the Homer-Preble Valley, north of Cortland. Glacial retreat through this valley led to a stratigraphy consisting of till and/or outwash overlying bedrock and overlain by glaciolacustrine deposits, with some silt and clay units over 30 m thick. In some areas, glaciolacustrine deposits directly overlie bedrock. Glaciolacustrine deposits are buried beneath deltaic sands and outwash composed of sand and gravel. At the Factory Brook junction in Homer, glacial till at the surface may be an indication that a glacial readvance down the Factory Brook Valley reached as far as the West Branch Tioughnioga–Factory Brook valley confluence. Large kame terraces are found within the Factory Brook region north through Cortland and the West Branch Tioughnioga River Valley south of the Skaneateles Valley Heads Moraine (Fig. 8). These most likely were produced as upland meltwaters flowed into the valley, depositing outwash between the ice and the valley walls. Glaciolacustrine deposits extend northward through the Preble Lakes area to the Tully Lakes and Tully (Valley Heads) Moraine (Buller 1978; Kappel and Miller 2003).

Bedrock in the region slopes northward toward the moraine, and an actively retreating ice tongue was present within this valley (Buller 1978). The Preble Lakes just south of the Otisco Valley confluence, and the Preble swamp just north of the confluence, are large kettles that may be interpreted as dead ice sinks (Fig. 9). Valley train deposits are found both up and down valley from the lakes and swamp. We interpret that the Preble Lakes and swamp formed as part of the retreating ice margin detached, resulting in large, stagnant ice blocks within the valley that were buried beneath outwash deposits. Upon melting of the ice, overlying sediments collapsed downward, forming depressions in the valley floor that filled with water and resulted in kettle lakes. The Preble swamp may have been a shallow lake that was gradually infilled, eventually producing a swamp. A kame terrace is found along the eastern valley wall just north of the Preble swamp.

FIGURE 8—Factory Brook Kame Terrace Deposits

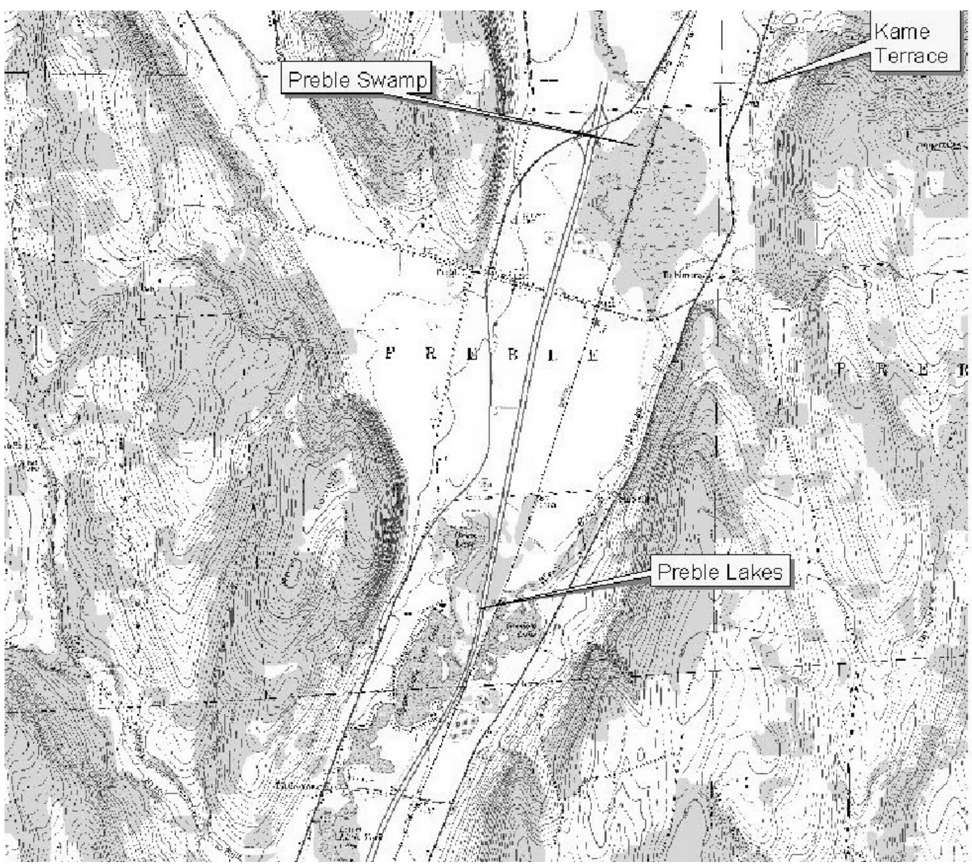

FIGURE 9—Preble Lakes and Swamp

The Tully Lakes and Tully Moraine (Stop 1) are found north of the Preble Swamp (Fig. 10). The Tully Moraine formed during the Valley Heads episode as a result of ice stagnation. The uppermost surface of the moraine is at around 365 m, around 200 m above the valley floor. The northernmost edge of the moraine in the Onondaga Trough has an elevation of around 210 m. From this region north, the elevation of the valley floor continues to decrease, reaching around 170 m in Lafayette and around 90 m at Onondaga Lake in Syracuse. To the south of the moraine, elevations remain at around 365 m, with the Tully Lakes occupying lower elevation basins. Kames are found in association with the kettles, and valley train deposits extend downvalley from the lakes. Valley-floor elevations are higher to the south of the moraine than those to the north due to glacial readvance, due to the scouring and deepening of the Onondaga Trough and the deposition of the Tully Moraine (Kappel and Miller 2003). As ice stagnated at the Valley Heads moraine within the Tioughnioga and associated Otisco, Skaneateles, and Fall Creek valleys, drainage to the south dammed between the moraine and the drainage divide in the Main Stem Tioughnioga Valley. An outlet to the lake was located at Blodgett Mills, and drainage diversion occurred at Cortland, with flow to the southeast down the Main Stem Tioughnioga, rather than down the Otter Creek Valley (Miller et al. 1998). As the Tioughnioga River established its channel, glacial and alluvial deposits and drainage into the valley controlled the location of the river. This is evident at the confluence of the Otisco Valley at Preble and the Factory Brook Valley at Homer, where large glaciofluvial fan deposits were produced as meltwater from the retreating ice margins in the Otisco and Skaneateles Lakes troughs flowed into the West Branch Tioughnioga Valley. In these areas, flow in the West Branch Tioughnioga River is confined along the eastern valley wall.

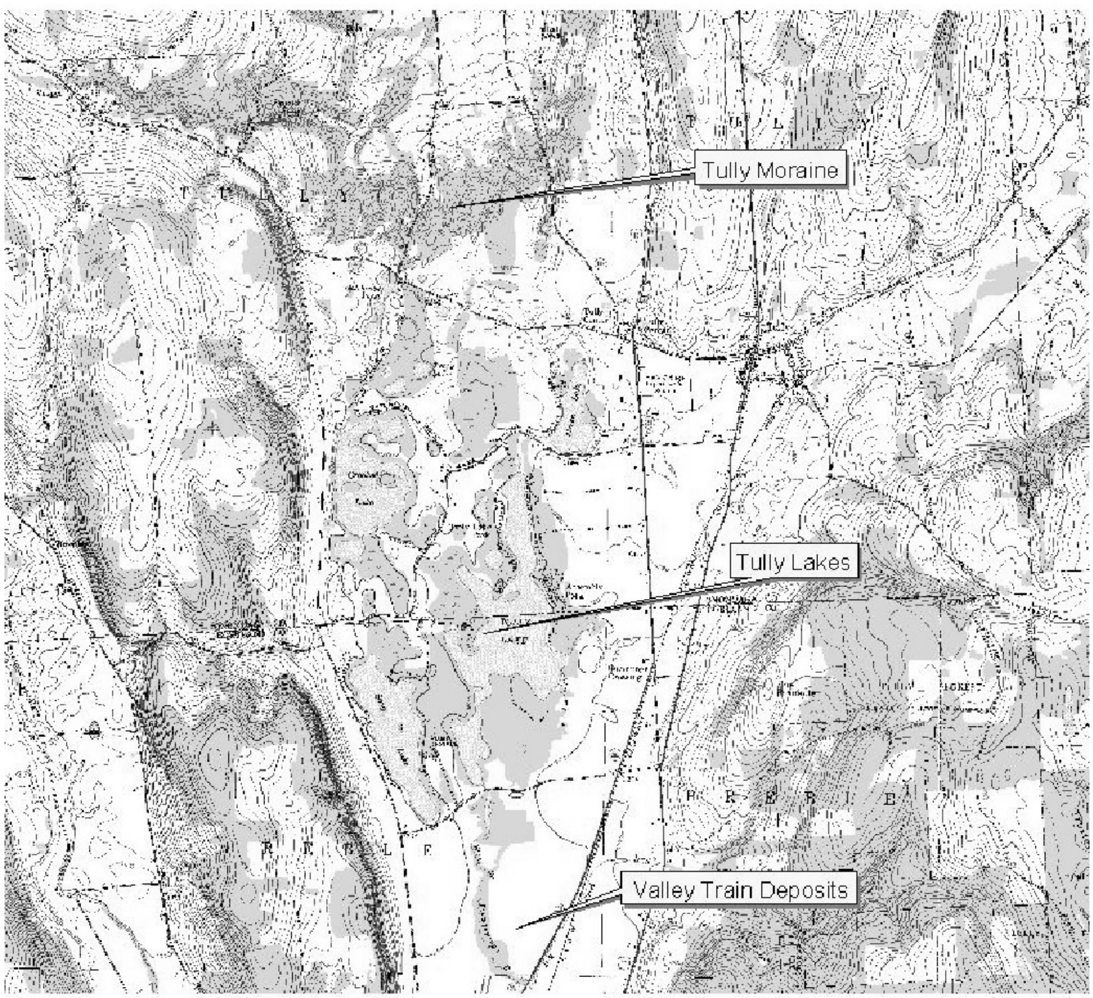

FIGURE 10—Tully Lakes and Moraine Region.

GLACIAL HISTORY OF THE FALL CREEK VALLEY

Drumlins located in northwestern central New York to the north of the Finger Lakes indicate that ice, possibly laden with subglacial meltwater, flowed fast across that region during late stages of the LGM (Ridky and Bindschadler 1990; Shaw and Gilbert 1990). Erosion resulted in the low elevation of the Ontario Lowlands region. The Finger Lakes were produced over successive glacial episodes as ice flowed into river valleys oriented parallel to the direction of ice flow. Subglacial erosion widened and deepened these valleys, producing overdeepening of the Finger Lakes troughs (Bloom 1986), with erosion in Seneca and Cayuga Lakes below sea level (Mullins and Hinchey 1989). The Finger Lakes gorges and hanging valleys were produced as glacial troughs were widened and deepened (Bloom 1986). Much of the overdeepening was associated with the readvance to the Valley Heads Moraine position (Mullins and Hinchey 1989), and the modern gorges and hanging valleys were rapidly incised as ice retreated back to the north and pro-glacial lakes dropped to near their modern level, in as little as 500 years (Knuepfer and Lowenstein 1998; Knuepfer and Hensler 2000).

Successive periods of glaciation in the region resulted in expansion of the Cayuga Trough far enough to intersect with the lower reaches of the Fall Creek Valley. A change in the valley floor material from alluvium to bedrock in the region of the Cornell Arboretum reflects the southward expansion of the trough and glacial erosion of the lower Fall Creek Valley. During the LGM, Fall Creek Valley, oriented perpendicular to ice flow direction, was infilled with glacial debris, burying earlier Wisconsinan glaciolacustrine sediment and till (Bloom 1986). Glacial ice from the Cayuga Trough flowed up the Fall Creek Valley, resulting in the erosion of unconsolidated deposits and bedrock and the deposition of lodgement till in the valley (Cline and Bloom 1965). As ice retreated from the valley, the retreating ice tongue and glacial deposits blocked drainage flowing from the Willseyville area, resulting in the formation of Freeville-Dryden Lake. A well sorted, stratified layer of glaciolacustrine sediments composed of sand and silt was deposited within this lake and overlies Fall Creek Valley lodgement till (Cline and Bloom 1965). A period of ice readvance in the Fall Creek basin is recorded by a deposit of glacial lodgement till and supraglacial meltout till that overlies moraine, outwash, and glaciolacustrine deposits. These deposits are overlain by fill (Miller et al. 1998). Glacial Lake Ithaca formed as Freeville-Dryden and other proglacial lakes in the region drained to a lower elevation and merged together. Glaciolacustrine silts and clays were deposited within this lake (Cline and Bloom 1965). As ice retreated and Freeville-Dryden Lake drained from the Fall Creek Valley, Fall Creek began to re-excavate its channel, and a fan-delta formed where Fall Creek flowed into Glacial Lake Ithaca. Following ice retreat and drainage of Glacial Lake Ithaca, hanging valleys, terraces, and deltas formed as Fall Creek re-excavated its valley in response to base-level lowering of the Cayuga trough (Bloom 1986).

The Varna high banks exposures (Stop 5; Fig. 11) provide a record of glaciation within the Fall Creek Valley. Basal deposits consist of laminated glaciolacustrine silts and clays, sometimes exposed at the base of the bluff. Elsewhere in the valley these varved sediments, which overlie strongly weathered till (Bloom 1986), have yielded radiocarbon ages in excess of 35,000 ^{14}C yr B.P. (Muller and Cadwell 1986). The high banks expose 30 m of poorly sorted till, composed of sand and gravel of local origin with larger crystalline clasts, above these lacustrine sediments. The till contains interbeds of stratified sand and gravel that were deposited as water from the ice-free headwaters of Fall Creek flowed south and was blocked by the ice tongue and its associated deposits (Bloom 1986). This till is overlain by a blue-gray matrix-dominated lodgement till. The majority of clasts are local shales and sandstones, but a greater number of crystalline rocks are present in this upper till than in the lower till. The lowermost part of the upper till contains clasts of limestone and dolostone, while the uppermost 3-6 m lacks carbonate clasts and shows evidence of oxidation and water reworking. The blue-gray lodgement till is overlain by a 3-m-thick, well-sorted, stratified glaciolacustrine deposit composed of silts, sands, and some clays deposited within Freeville-Dryden Lake (Cline and Bloom 1965).

The South Cortland moraine (Fig. 12) is an ablation moraine with hummocky topography and ice-contact meltwater deposits. Kames, kettles and eskers are found at the Malloryville esker, bog, and wetland complex (Stop 4; Fig. 13) and the Lime Hollow Nature Center (Stop 3), with kettle holes occupied by ponds and wetlands. Gravel pits contain subrounded to rounded clasts, some of which are faceted. The majority of clasts are composed of local rocks, but exotics, including granite, gneiss, and red sandstone, are also found. The deposits are massive and matrix dominated, with the majority of clasts ranging between sand and gravel size.

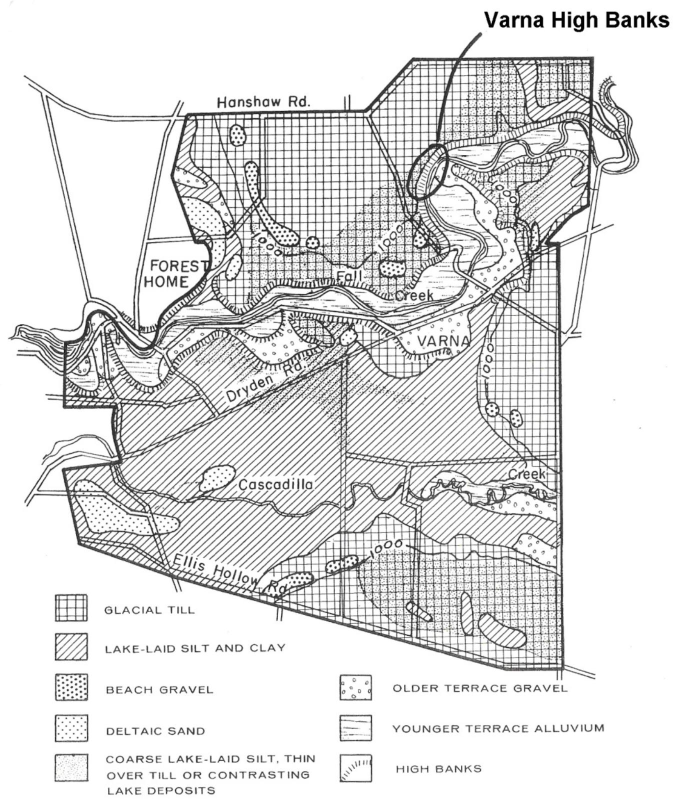

FIGURE 11—Fall Creek glacial deposits and Varna High Banks area (Cline and Bloom 1965).

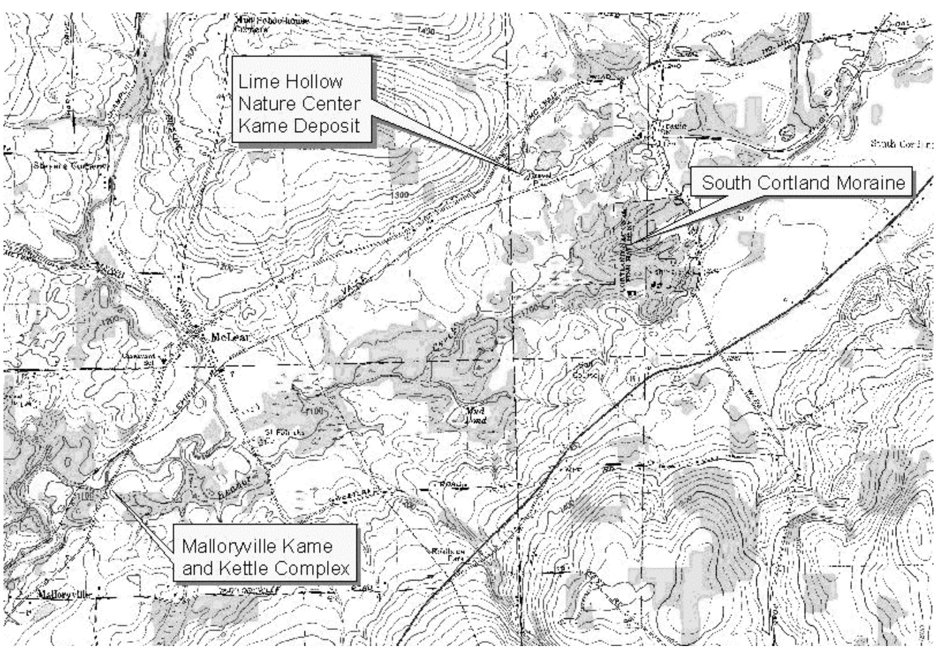

FIGURE 12—South Cortland Moraine and kame, kettle, and esker locations.

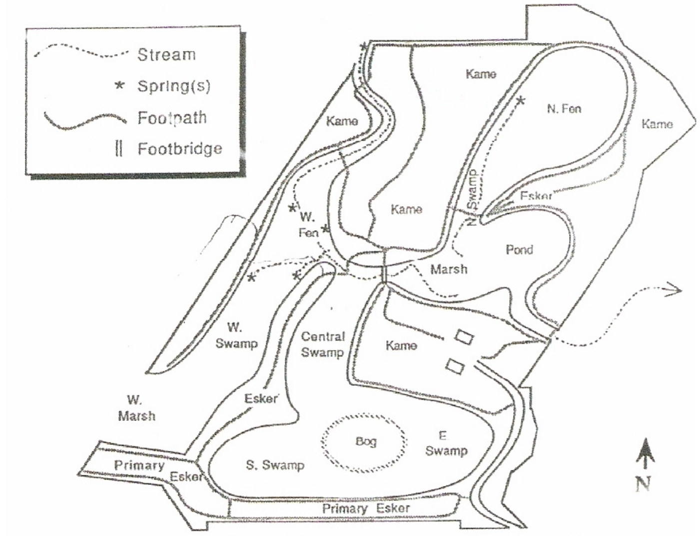

FIGURE 13—Malloryville Kame and Kettle Complex: Glacial landform locations (McNamara et al. 1992).

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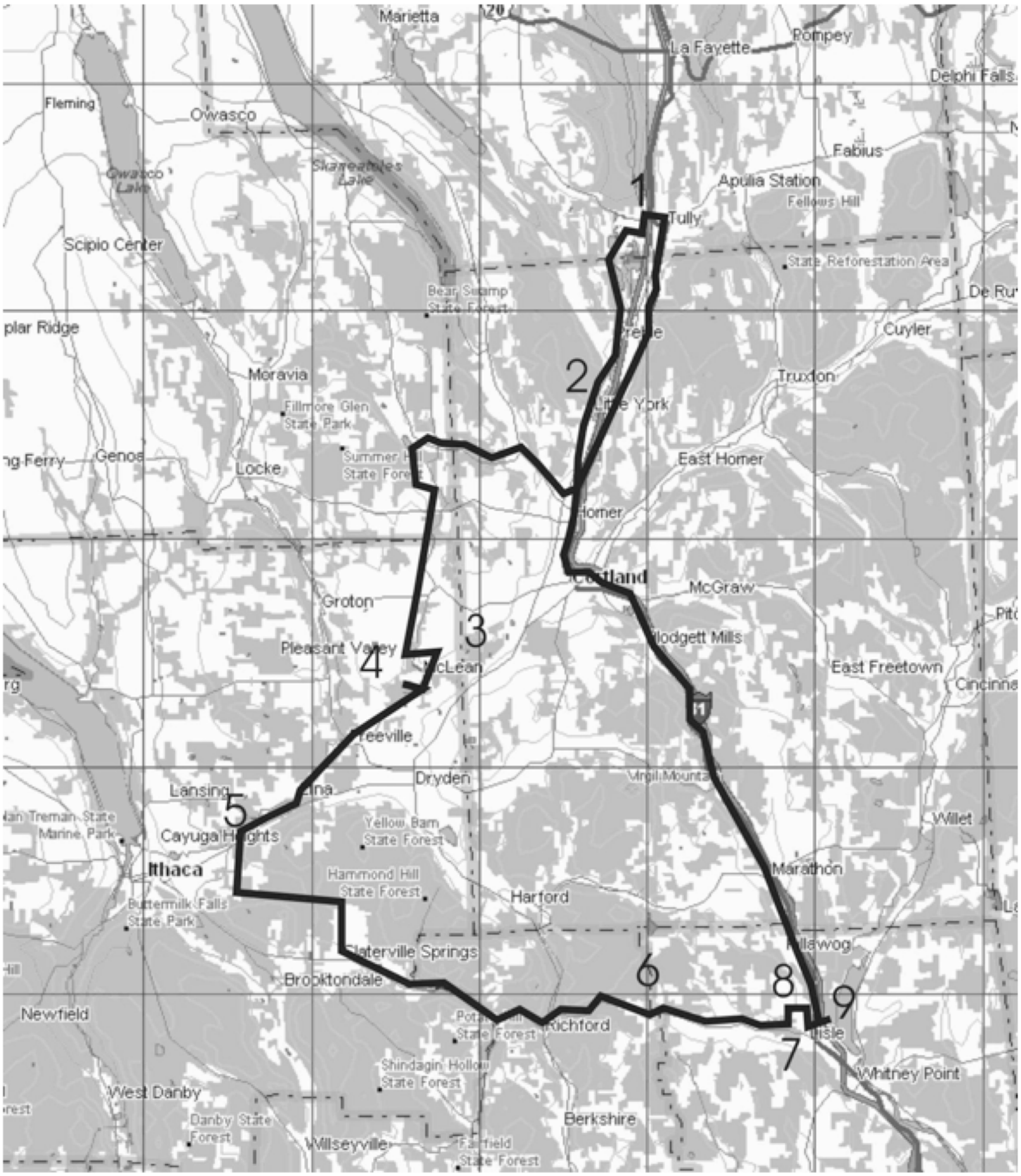

FIGURE 14—Map of field trip stops

ROAD LOG FOR TRIP A-2

PLEISTOCENE GLACIATION OF THE TIOUGHNIOGA RIVER AND FALL CREEK VALLEYS

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0	0.0	SUNY Cortland Gerhart Drive Parking Lot, Bowers Hall. Departure
0.1	0.1	Exit SUNY Cortland Parking Lot: Turn Left onto Graham Avenue, proceed to Groton Ave
0.2	0.1	Turn Right onto Groton Ave (route 222), proceed on Groton Ave to North Main Street.
0.6	0.4	Turn left onto North Main Street (route 11)
1.2	0.6	Bear right onto Homer Ave, route 11. Continue on route 11 through Homer to Preble Lakes region. Note the gravel pits in outwash deposits along route 11 in Homer.
12.0	10.8	At the Preble Swamp area, note the gravel exposure in the kame terrace to the east. The Preble swamp is a kettle, possibly a dead ice sink, formed as an ice block broke off from the actively retreating ice margin and was buried beneath glacial outwash. As the ice melted, outwash deposits collapsed downward, forming a kettle at the surface. To the east of the kettle, a kame terrace formed as glacial meltwater deposited sediment between the ice block and the valley wall. As the ice melted, the sediments collapsed and a kame terrace resulted. An exposure in this terrace is located just north of the swamp. Continue North on route 11 to Tully Lakes region.
15.3	3.3	Turn left onto route 80/11 at Tully
15.9	0.6	Continue straight on route 80 and go under I-81 bridge.
17.4	0.1	Turn left onto Lake Road
18.2	0.8	STOP 1 at Green Lake, parking area on left side of road.

STOP 1. TULLY LAKES KETTLES AND KAMES

Green Lakes and the rest of the Tully Lakes, ponds, and depressions, are kettles. These lakes formed as ice stagnated and blocks of ice were buried beneath outwash deposits. As ice melted, outwash deposits collapsed downward, forming depressions and kettles. Some of these depressions were below the water table and thus filled with water, forming kettle ponds and lakes. In areas where depressions were found on the ice surface, sand and gravel was deposited by glacial meltwater flowing over the ice surface. As the ice melted, these deposits were lowered to the valley floor, forming mounds known as kames. The gravel pit to the south of Green Lakes is excavated into such a kame deposit. Overall, the deposit is poorly sorted, with larger clasts of gravel in a sand matrix. Clasts are mostly of local origin, with some exotics, including granites, metamorphics, red sandstones, and limestones transported to the region from areas to the north. Gravels commonly contain calcium carbonate rims, and large post-Pleistocene conglomerates composed of sands, gravels, and cobbles, cemented with calcium carbonate, are found at the site. This Tully Lakes moraine complex commonly is considered part of the Valley Heads Moraines, although the cross-section of Kappel and Miller (2003) implies that this Valley Heads morphology may be developed on a relatively shallow till deposit that in turn overlies laminated silt and clay over a buried till deposit. Thus, whether this area represents the “true” Valley Heads Moraine—or a slightly younger recessional moraine formed during retreat from the Valley Heads position—is unclear.

Return to vehicles, turn left onto Lake Road.

18.9	0.7	Bear left, staying on Lake Road. Continue south and southeast to Song Lake Road.
20.2	1.3	At intersection of Lake Road and Song Lake Road, turn left, traveling south toward Homer. Note Song Lake, another kettle lake, to the left.
22.8	2.6	Song Lake Road merges onto route 281.
23.5	0.7	Cross through the Otsico-West Branch Tioughnioga Valley confluence. Glacial and alluvial fan deposits from the Otisco Valley control the location of the West Branch Tioughnioga River at this junction, with the river confined along the eastern valley wall. Valley Heads Moraine deposits and Otisco Lake (one of the Finger Lakes) are found up the Otisco Valley to the northwest. Continue south on route 281 to the Preble Lakes region.
25.2	1.7	Turn left onto Little York Lake road, toward Dwyer Memorial Park
25.3	0.1	Turn left onto New Road.
26.1	0.8	Proceed to end of New Road, pull over along Little York Lake. STOP 2 is here at Preble Lakes

STOP 2. PREBLE LAKES

These lakes are large kettles that occupy most of the valley width, and are possible dead-ice sink deposits. They were formed in association with the Preble Swamp to the north, as ice blocks detached from the retreating ice margin and were buried beneath glacial outwash deposits. As ice melted, outwash at the surface collapsed, forming depressions that intersect the water table. Kettle lakes and ponds of the Preble area resulted.

Return to vehicles, turn around and proceed back to route 281.

26.9	0.8	Turn left on route 281, continue south to Homer.
31.9	5.0	At Clinton Street (route 41) in Homer, turn right.
33.6	1.7	Proceed up the Factory Brook Valley along route 41. Note large active EZ Acres gravel pit to the left. This pit is in a kame terrace, deposited as glacial meltwater flowed between the ice surface and the valley wall. Although this is an excellent exposure through the entire kame terrace deposit, the height of the quarry wall at the time of this writing presupposes a safe visit. Continue north along route 41.
34.5	0.9	Turn left onto route 41A. Note exposure of bedrock as you enter Homer Gulf; this would be the equivalent of the valley-wall side of the kame terrace.
37.8	3.3	Turn left onto Cutler School Road. Note that road isn’t marked, but cross-road to the north (right) is Atwood Road.
38.2	1.4	Turn right onto Creech Road.
38.9	0.7	Turn left onto Champlin Road.
46.1	7.2	Hamlet of McLean. Turn left at stop sign onto McLean Road.
47.8	1.7	Pull into parking area of Lime Hollow Trail Head for STOP 3.

STOP 3. LIME HOLLOW NATURE CENTER TRAILS

This area contains a pitted, hummocky kame and kettle landscape, with wetlands located in low lying depressions and kettles. Walk along the trail, heading southeast. Pass the trail sign, continuing straight. Cross the field, heading towards a mostly reclaimed gravel exposure. This is an exposure in a kame deposit. The unit overall is poorly sorted and matrix dominated, with grain sizes ranging from sand and silt to cobbles. Clasts include local sandstones and shales, as well as limestones, granites, red sandstones, and other exotics transported to the region from the north.

Return to vehicles, exit Lime Hollow trailhead, turning right (northeast) onto McLean Road.

48.5	0.7	Drive to Lime Hollow Visitor Center for LUNCH STOP. After lunch, reverse course back to McLean
50.0	1.5	McLean Road becomes Fall Creek road. Continue southwest.
51.5	1.5	Turn right onto W. Malloryville Road.
52.0	0.5	Turn right at sign on right into parking area for O.D. von Engeln Malloryville Preserve of the Nature Conservancy.

STOP 4. O.D.VON ENGELN PRESERVE AT MALLORYVILLE

This preserve is named for Otto D. von Engeln, late Professor of Geology at Cornell, who bequeathed much of the site in order to preserve the glacial geology and wetlands ecosystem; von Engeln was keenly interested in the glacial history of New York. The preserve is located within glacial deposits associated with deposition of the South Cortland (Valley Heads) Moraine. The area contained stagnant ice that resulted in the production of kame and kettle topography, as well as an esker. The site also contains abundant wetland types, including marshes, bogs, fens, and swamps, within depressions and low, poorly drained areas. Wetlands are in low-lying areas and depressions that formed as kettles at as buried ice blocks melted and overlying deposits collapsed downward. The esker was deposited as a subglacial meltwater channel beneath stagnant ice.

Return to vehicles, exit the Malloryville Reserve, and proceed northeast along Fall Creek Road.

52.5	0.5	Return to Fall Creek Road and turn right.
55.2	2.7	Freeville: Continue southwest on route 366. Fall Creek Road becomes Main Street.
58.7	3.5	Bear right onto route 13 / route 366 (Dryden Road).
60.0	1.3	Route 13 and route 366 split. Turn left onto route 366 (Dryden Road) toward Varna.
61.1	1.1	Turn right onto Monkey Run Road Proceed to end of road, parking where possible. Walk down to Fall Creek.

STOP 5. VARNA HIGH BANKS.

In this section of Fall Creek Valley, a large meander loop of Fall Creek cuts into blue-gray till and associated deposits. Basal deposits, exposed occasionally along the base of the exposures on either side of the creek, consist of laminated glaciolacustrine silts and clays. Elsewhere in the valley these varved sediments, which overlie strongly weathered till (Bloom 1986), have yielded radiocarbon ages in excess of 35,000 14C yr B.P. (Muller and Cadwell 1986). Lodgement till is typically exposed at the base of the southeastern bank of Fall Creek. This unit is highly compact, poorly sorted and matrix dominated, with clasts ranging from angular to rounded in shape. Some clasts contain glacial striations. Grain size ranges from clay to cobble, with an assortment of clast lithologies, including sandstone, granite, limestone, quartzite, and others. The lower layer of this till are contains a higher percentage of gravel and is better sorted, with some stratification. Till in this bank has been eroded by Fall Creek and is overlain by alluvial deposits.

Along the northwestern side of Fall Creek, the Varna High Banks are exposed. The lower section of this deposit is poorly sorted and matrix dominated, with grain size ranging from clay to cobbles. Clasts are predominantly of local origin, with some exotics. Precipitation of calcium carbonate has led to the cementation of the lower unit. Some layering and stratification is present in the unit, with interbeds of unsorted material and sorted, layered sands and gravels. The lower unit of the Varna High Banks is overlain by a blue-gray glacial lodgement till. This is the same till as that exposed in the eastern bank. The uppermost section of the till shows evidence of being reworked by flowing water. Glaciolacustrine deposits from Freeville-Dryden Lake overlie the till. This unit has been eroded from the eastern bank. Grains consist primarily of silt and fine sand.

Return to vehicles. Return to route 366, turn right toward Varna and Ithaca.

61.7	0.6	Turn left onto Mt. Pleasant Road.
62.1	0.4	Turn right onto Turkey Hill Road.
63.7	1.6	Turn left onto Ellis Hollow Road.
68.6	4.9	Turn left onto route 79, head toward Lisle.
71.8	3.2	Caroline area. Note truncated spur ridges ahead that dominate the narrowing valley through which route 79 passes. The morphology of the valley-facing slopes is typical of east-west valleys in this part of New York: a steep north-facing slope on the south side of the valley, a gentler south-facing slope on the north side. Coates (1966) attributed this morphology to till shadows, formed because south-flowing ice dropped its basal load at the stress reduction caused by the north valley wall and had increased erosional capacity with increased basal stress at the south valley wall.
78.1	6.3	Richford. This is the through valley that connects Owego Creek with Dryden and, ultimately, the Fall Creek Valley.
81.2	3.1	Michigan Hill Road. This is the approximate location of the west end of the Lisle / Dudley Creek esker, which continues east for approximately 5 miles (8 km). The esker is intermittent at this west end, but becomes more continuous to the east (except where it has been quarried away).
83.4	2.2	Turn left into Broome-Tioga Sport Center (motocross) for STOP 6

STOP 6. LISLE ESKER.

Most of the deposit has been removed at this location during construction of the speedway parking area, but part of the esker is exposed to the west of the parking area. This esker was deposited within a fluvial channel beneath (likely) stagnant ice. Clasts range from sand to cobble in size, and are rounded. The unit is stratified and contains well-sorted lenses of sand and gravel. Clast lithologies are predominantly of local origin, with a small percentage of exotics.

Return to vehicles, turn left onto route 79, continue toward Lisle.

85.8	2.4	Center Lisle; east end of Lisle Esker. Continuing to the east, the valley margins are marked by a series of kame terrace deposits.
88.8	3.0	Turn left into Lisle Fire Station parking lot. Walk down to Dudley Creek for STOP 7.

STOP 7. KAME TERRACE WITHIN NORTHERN CUTBANK OF DUDLEY CREEK.

Dudley Creek has been undercutting its north bank at a number of locations through this narrow valley. This has produced a number of large slumps, the best exposed of which is here. Most of the slumps expose stratified sands and gravels. The deposits at this location also are stratified, with a massive, well-sorted sand unit in the lower section overlain by a unit of interbedded sand and gravel. The lower sand unit contains cross beds and collapse structures. Layers within the interbedded unit dip upstream and contain large scale cross beds.

Return to vehicles, turn right onto route 79 to retrace your steps to the west end of the narrower part of Dudley Creek Valley.

91.6	2.8	Turn right onto Tony Road.
91.7	0.1	Turn right onto Owen Hill Road. Owen Hill Road climbs onto broad kame terrace surface. This is the same kame that is exposed in the bank of Dudley Creek (Stop 7).
93.2	1.5	Crest of Owen Hill Road onto kame terrace surface.
94.5	1.3	Descend onto lower kame terrace surface.
95.0	0.5	Begin descent from lower kame surface.
95.1	0.1	Pull over to left at exposure on north side of Owen Hill Road for STOP 8.

STOP 8. KAME TERRACE

This terrace is a continuation of the deposit along the northern wall of the Dudley Creek Valley. Clasts within this deposit are rounded and range from fine sand to boulders. The lithologies are mostly of local origin, but exotics, including red sandstone and metamorphics are also found. Clasts are oriented into the deposit, indicating meltwater flowing south toward Owen Hill Road and parallel to the Tioughnioga Valley. The sand and gravel near the top of this deposit is cemented by calcium carbonate.

Return to vehicles, turn left onto Owen Hill Road continuing downhill.

95.8	0.7	Turn right onto Walker Road.
96.3	0.5	Turn left onto route 79.
96.7	0.4	Turn left onto route 11 and take an immediate right onto Johnson Hill Road
97.0	0.3	Turn left onto Watts Road.
97.3	0.3	Turn left along dirt road into exposure for STOP 9.

STOP 9. KAME DELTA

This deposit is above the Tioughnioga Valley on the eastern valley wall. A large kame terrace with a working sand and gravel operation is found below this deposit. Here, the kame deposits are deltaic. The delta deposit is stratified, with topsets and forsets exposed. A channel deposit is present in the upper left section of the deposit, with a channel bar to the right. A fault offsets channel sand beds, and gravels along the fault have slumped and rotated. Overall, the deposit is poorly sorted, but individual well-sorted layers with imbricated pebbles are present.

Return to vehicles, turn right onto Watts Road.

97.6	0.3	Turn right onto Johnson Hill Road.
97.9	0.3	Turn right onto route 11.
98.3	0.4	Note the working gravel pit and kame terrace exposure to the right, along the east valley wall. This is the gravel pit and kame surface west of and below Stop 9. Continue north up the Tioughnioga Valley.
104.8	6.5	In Marathon, optional side trip to an overview of the valley. For side trip, turn right onto East Main Street / route 221. Proceed 0.1 mile (under I-81), and turn left onto Galatia Street . Continue 0.3 miles to Alboro Road and turn left. Proceed 0.8 miles to Appleby School (Marathon Elementary) for Marathon Glacial Landscape Overview

OPTIONAL STOP. MARATHON GLACIAL LANDSCAPE OVERVIEW

The valley walls at Marathon contain large kame terrace deposits, including a deposit at the location of the graveyard just north of the Interstate 81 onramp. A terrace is present to the southwest, across the valley from the high school. Note the relatively flat topography of the terrace surface. Kame terraces are also found to the south of Marathon, just north of the Cortland – Broome County boundary.

Return to vehicles, leave the Marathon school, and retrace route to route 11 in Marathon. Turn north.

104.8	0.0	Continue on route 11 from Marathon. Head north along the east valley wall. Note the narrowing of the Tioughnioga Valley and the bedrock outcrops along the east valley wall.
109.0	4.2	Just north of Messengerville is the likely location of a pre-glacial upland and valley drainage divide. Drainage north was toward Cortland and drainage south was toward Marathon. As a result of glaciation, this drainage divide was eroded and the Tioughnioga River now flows south from Cortland toward Marathon and Whitney Point.
111.3	2.3	Abandoned gravel pit just east of road. Pit exposes more than 30 m of stratified sand and gravel; most is cemented by calcium carbonate. This deposit may be part of a recessional moraine that was a valley plug deposit, impounding a lake that deposited thick glaciolacustrine sediments now buried beneath the Tioughnioga Valley to the north.
113.1	1.8	Hoxie Gorge Road. Spectacular bridges take I-81 across this deep gorge, which is incised into glacial deposits and (mostly) bedrock.
116.9	3.8	Continue north to Polkville. This area is within the valley of the Main Stem Tioughnioga. The Trout Brook Valley merges with the Main Stem Valley from the east in this area. Pre-glacial drainage in this area was to the northwest, as shown by the orientation of the Trout Brook and Tioughnioga valleys, the change in valley width from northwest (wide valley) to southeast (narrow), and the northwestward sloping longitudinal bedrock profile within the Tioughnioga Valley. A sand and gravel mining operation in glacial outwash deposits is located within the valley, just southwest of the highway. Beneath the outwash deposits, a thick layer of glaciolacustrine silt and clay is present. This silt and clay was deposited in a large glacial lake that extended to the Valley Heads Moraine deposits. The lake outlet was located south of Blodgett Mills, quite possibly impounded by the valley plug deposit described above at mile 111.3. Continue north on route 11.

118.2	1.3	Bear left onto Port Watson Street, the continuation of route 11.
119.0	0.8	Pendleton Street. A kame surface is located to the left (south) along the southern valley wall here at Cortland. The terrace deposits, as shown by soil parent materials, extend southwest along the Otter Creek Valley. Additional kame terraces are found along the northern valley wall of Otter Creek. These kame terraces may be part of a moraine that was deposited as ice retreated northward from the region, possibly pinned against the high topography south of Cortland. Within the valley itself, outwash deposits overlie glaciolacustrine deposits, buried outwash, and till.
119.4	0.4	Turn left at Tompkins Street (Route 13).
119.5	0.1	Turn right at Prospect Ave.
119.6	0.1	Bear left on Prospect Ave.
119.8	0.2	Turn right at Graham Ave.
120.0	0.2	Turn left onto Gerhart Ave into SUNY Cortland.
120.1	0.1	Return to Bowers building. END OF TRIP.

END OF FIELD TRIP