Subsurface Geology of the Great Gully Buried Valley System
Cayuga County, New York

by
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Supported in part by the U.S. Geological Survey's National Cooperative Geologic Mapping Program
Great Lakes Mapping Coalition Award Number G17AC00312

Holocene Group

Hca **Cayuga Member Alluvium (Hca)**
This member represents stratified, silt, sand gravels and cobbles deposited in rivers, streams and lakes. Principally inferred as post-glacial alluvium, it includes modern channel, over-bank and fan/deltaic deposits. Although these deposits principally are Holocene in age, at the latitude of the Union Springs 7.5-minute Quadrangle isostatic rebound had recovered to a linear stage during the Late Wisconsin (Bird and Kozlowski, 2016). As a result, in the area constrained by the quadrangle modern lake levels closely coincide with lake levels present during the main phase of glacial Lake Iroquois that inundated and occupied the southern Ontario Basin including Cayuga Lake, thus some deltaic deposits in his member may be of Late Pleistocene age.

Hcw **Cayuga Member Wetland (Hcw)**
This member comprises of peat, muck, marl, silt clay or sand deposited in association with wetlands environments. Various sediments can be present as transitional from one facies to another.

Pleistocene Group

Psp **Springport Member (Psp)**
The Springport Member consists of isolated and discontinuous pockets of well-sorted and stratified sand and gravel, 2-15 meters thick deposited as glacial outwash or in association with meltwater streams that were adjacent to former glaciers prior to the Port Huron Phase advance and hence this member is overlain by the Mapleton Formation. In some localities the cemented gravels and sands convey groundwater and form localized springs and may serve as a framework for water resources. Spring Road south of the Village Union Springs probably derived its name from seeps originating from the Springport member.

Pf **Farleys Member (Pf)**
The Farley Member consists of bedded sand and gravel with a maximum observed thickness of approximately nine meters deposited as deltas entering a proglacial lake at an approximate elevation of 558 feet amsl within the Cayuga Basin. This delta deposit represents glacial Lake Dana, the second youngest Late Wisconsinan proglacial lake level after glacial Lake Iroquois.

Pcc **Cooney Corners Member (Pcc)**
The Cooney Corners Member consists of bedded sand and gravel of unknown thickness deposited as deltaic facies into glacial Lake Warren (of the Cayuga Basin, See Fairchild, 1934), a proglacial lake at an elevation of 692 feet amsl (212 meters amsl) that was building into the Cayuga Basin. The exact age of this stabilized lake level is uknown, but it coincides with a well-developed shoreline and represents the second highest lake level after the Port Huron readvance to the Mapleton Moraine.

Pno1 **Number One Member (Pno1)**
The Number One Member consists of a bedded and stratified sand and gravel deposited as a deltaic landform into glacial Lake Hall, a high elevation proglacial lake stage occupying the Cayuga Basin at an elevation of 905 feet amsl (275 meters amsl). This member represents the first and highest in elevation of the deltaic deposits observed along the course of Great Gully. Meltwater channels flowing westward along the margin of the Ontario Lobe delivered sediment into the elevated lake stage associated with the Port Huron readvance to the Mapleton Moraine. Similar to the Cooney Corners Member, coincident shorelines are traceable on the lidar terrain models to this member that initiates on the western edge of Scipio Township near the head of Great Gully.

Pmpl **Mapleton Formation (Pmpl)**
The Mapleton Formation comprises the uppermost stratigraphic unit north of Great Gully. Principally, it consists of a matrix supported, clast rich diamicton (till) approximately 2-15 meters thick deposited during the Port Huron Phase readvance approximately 15,000 years before present (Kozlowski et. al., 2018). Till is a generic term used to describe poorly sorted admixture ranging from silt sized particles to boulders deposited directly by glacial ice, diamicton is the non-genetic scientific terminology to describe poorly sorted deposits. In some locations the Mapleton Formation has a silt rich semi-stratified appearance that resulted from subaqueous deposition within high-elevation proglacial lakes within the Cayuga Basin. The formation is in direct association with the east to west trending Mapleton Moraine on the north rim of Great Gully that demarks the furthest southern extent of the Port Huron Ice Advance. This glacial till is correlative with the Summerset Till described by Calkin and Muller (1992) along Lake Ontario Shoreline and the Sterling, New York area. We believe this till unit to correlative with the Halton Till in southern Ontario.

Plyd **Ledyard Formation (Plyd)**
First identified on the Swayze Farm located near the intersection of Kings Corners Road and Redmond Road where it was first observed, the Ledyard Formation is the name applied to the matrix supported, clast-rich, calcareous diamicton (till) brown to gray in color that blankets the upland surface south of Great Gully. Often observed as 1-2-meter-thick deposit directly overlying Devonian bedrock; however, exploratory wireline coring indicates thicknesses of at least 12 meters are present and extend across the map area. Good examples of shallow till/rock relationships may be observed in roadside ditches along Cooney Corners Road, Dills Road and Kings Corners Road in the central Union Springs map area. Within Great Gully and adjacent tributaries, an underlying bedded fine to medium grained sand and silt unit is traceable and comprises the sand member of the Ledyard Formation. Age assignment of the Ledyard Formation is ambiguous. Theoretically the till sheet should be associated with the Port Bruce Phase readvance hypothesized to have reached a terminal position of the Valley Heads Moraine south of the Finger Lakes Basins slightly prior to 17,000 years before present (Muller and Calkin, 1993; Ridge, 2003). Yet, our field mapping and stratigraphic investigations indicate only a single diamicton (till unit) at the surface of the map area. Multiple age dates from both AMS radiocarbon and optically stimulated luminescence (OSL) on the underlying sand member and organic materials contained within yield an age range of 30,000-40,000 years before present* equivalent with the Farmdale Phase interglacial of (Karrow et. al., 2000). Thus, the direct age relationship with the surface till of the Ledyard Formation may also represent the Nissouri Phase equivalent to Marine Isotope Stage (MIS) 2, associated with the late glacial maximum approximately 25,000 years before present*.

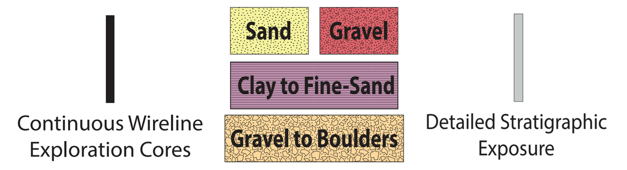
Pbnkr **Bunker Formation (Pbnkr)**
Exposed by erosion associated with incision of Great Gully, the Bunker Formation consists principally of a gray colored, matrix supported, clast rich, over consolidated and highly jointed diamicton (glacial till). This indurated unit is abundant in red and green clasts of the upper Ordovician Queenston Shale and black Ordovician Limestones. The till unit is occasionally interbedded with sporadic sand and silt lenses and generally appears thicker than two meters but has been observed in wireline cores and outcrops as thick as 14 meters. Underlying the principle till member unit are stratified, sometimes cross-laminated sand and silt beds that range in thickness from 1-4 meters. Associated with the sand and silt units is indurated peat member 0.25-0.5 m in thickness. This paleosol serves as important marker bed and has been encountered in several exploration boreholes. The sand, silt and peat are interpreted as lacustrine and near shore sediments deposited during an interval of high lake level during a phase we term as glacial Lake Nanette within the Cayuga Basin. The sand units often contain organic detritus and wood and the upper contact between the till unit often displays shearing and deformation. The age of the Bunker Formation is Middle Wisconsin (MIS 3) and the till member is bracketed in age by the overlying sand member of the Ledyard Formation (~40,000 years before present*) and multiple age dates from AMS radiocarbon, optical stimulated luminescence (OSL) and pollen spectra from the underlying sand and peat member that consistently yield and age between 50,000 and 55,000 years before present*. The till unit is consistent with a regionally recognized glacial episode known as the Brimley Phase observed in Southern Ontario and the organic sand dominant facies are consistent with Interstadial Port Talbot Phase recognized in buried deposits along the north shore of Lake Erie.

Paa **Aurora Formation (Paa)**
Exposed along the walls in the eastern end of Great Gully, the Aurora Formation consists of a cross-bedded and cross-rippled sand member 2-3 meters in thickness that contains an abundance of organic detritus within the sedimentary structures. These sand units often display alternating oxidized (orange) and reduced (gray) coloration. The organic detritus includes branches and wood fragments that are beyond the range of radiocarbon dating. Multiple optical stimulated luminescence dates on these sand beds yield an approximate age of 60,000-76,000 years before present* The diamicton (till) member of the formation consists of a gray, matrix supported, clast rich, highly jointed unit sometimes in excess of 10 meters thick, but more often less than 3 meters in thickness. An underlying 1-2-meter-thick gray colored, massive, fine-grained sand member brackets the diamicton. Optical stimulated ages on this fine-grained sand indicate burial occurred between 90,000 and 100,000 years before present*. Thus, our interpretation is that the diamicton represents an Early Wisconsin (MIS 4) glacial advance into the Finger Lakes Region and is possibly equivalent to the Guildwood or Greenwood Phases observed in the Ontario Provinces (Karrow et. al., 2000).

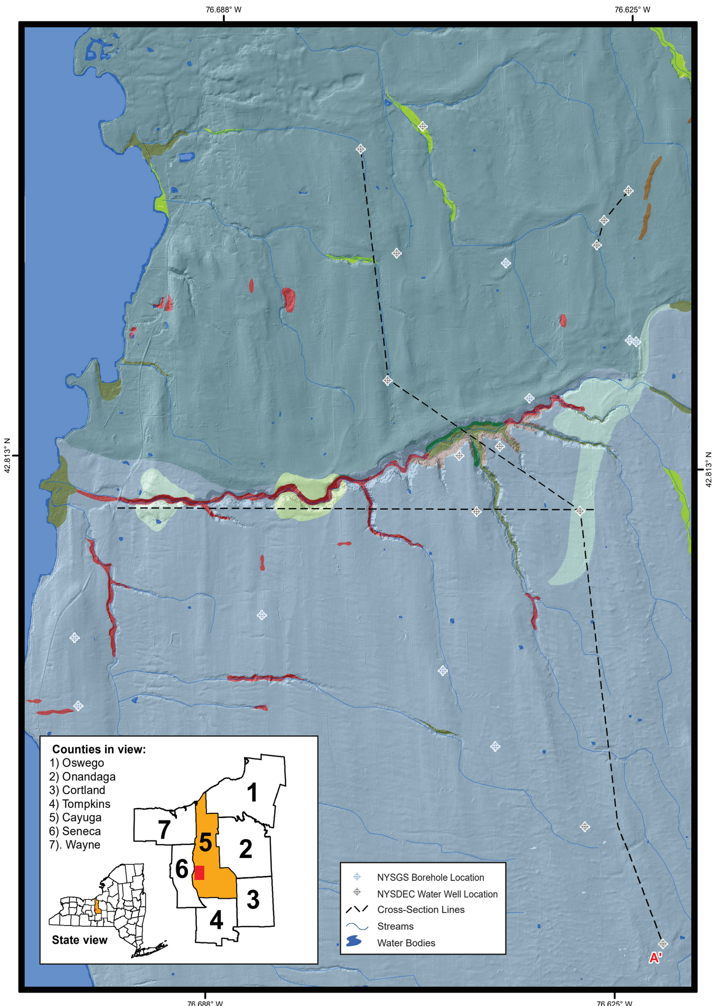
Pgg **Great Gully Formation (Pgg)**
The Great Gully Formation consists of a thin, discontinuous bedded, medium-coarse grained oxidized sand and gravel member often no more than one meter thick that overlies a dark gray, matrix supported, clast rich, jointed, dense and highly indurated diamicton (glacial till) member. This diamicton contains an abundance of black Ordovician Limestone boulders and clasts often faceted and striated in greater abundance than other tills observed within Great Gully. This member is only visible in the eastern end of Great Gully along the floor of the ravine and appears as the lowermost observed till that occupies a north-south buried valley that transects Great Gully. The thickness of the deposit is poorly constrained; however, exploration wireline cores indicate thicknesses of 12 meters are present. Optical stimulated luminescence ages between 90,000 and 100,000 years before present* from the lower member of the Aurora Formation indicate this till unit is likely of Illinoian Age (MIS 6). By association we surmise the discontinuous sand and gravels above the till may represent the Sangamon Interglacial period (MIS 5). The till member is quite likely equivalent to the York Till in Southern Ontario.

Pkc **Kings Corners Formation (Pkc)**
The Kings Corners Formation consists bedded silt, sand and gravel, with sand and silt facies that are overconsolidated, indurated and or semi-lithified. It also contains multiple diamicton units (till member). These deposits have only been observed in deep exploration boreholes directly beneath the Great Gully Formation. The age of the formation is unknown but as it underlies the Illinoian age till it is presumed to represent Pre-Illinoian alluvial, lacustrine and glacial environments.

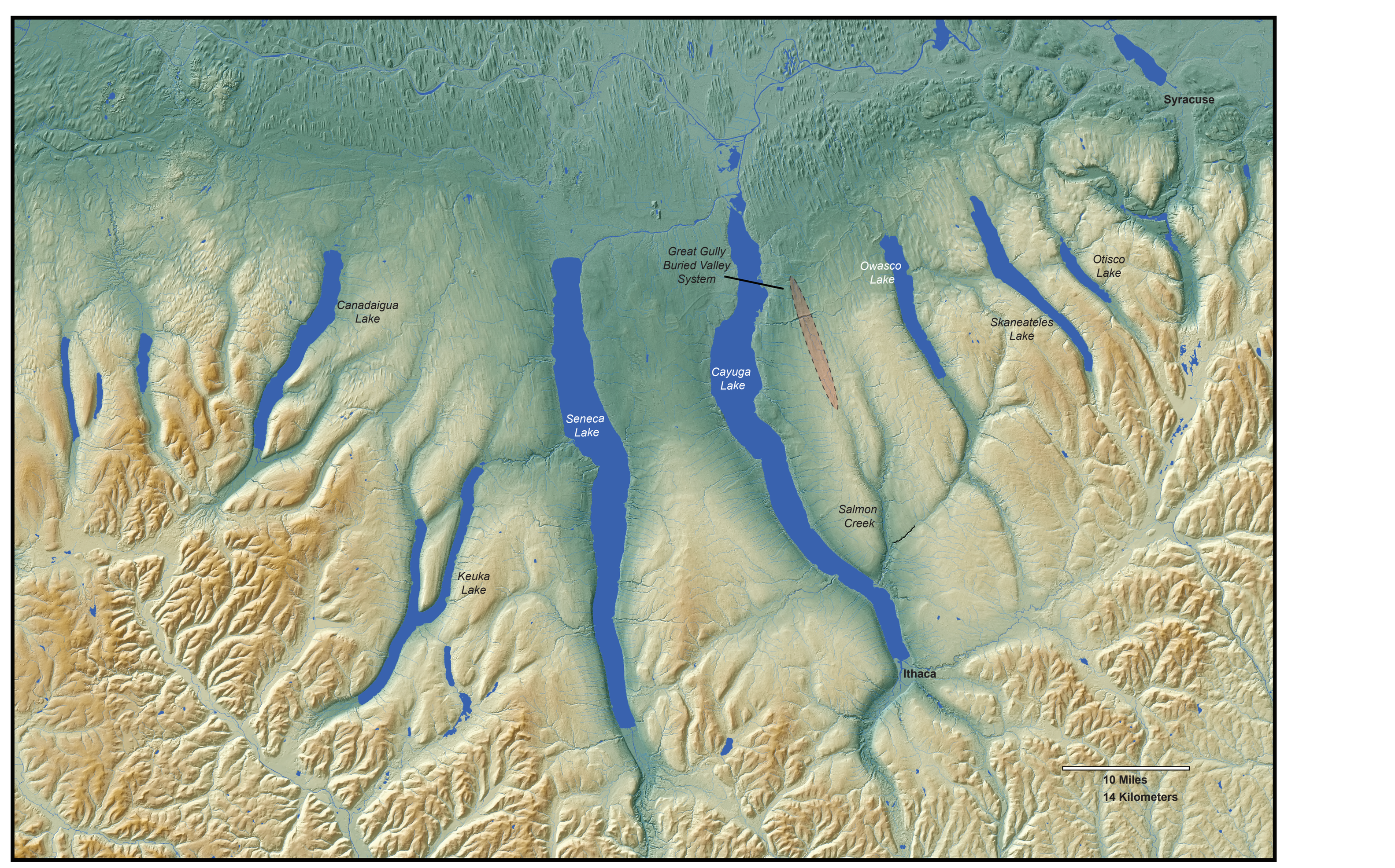
Miscellaneous Materials and Legend

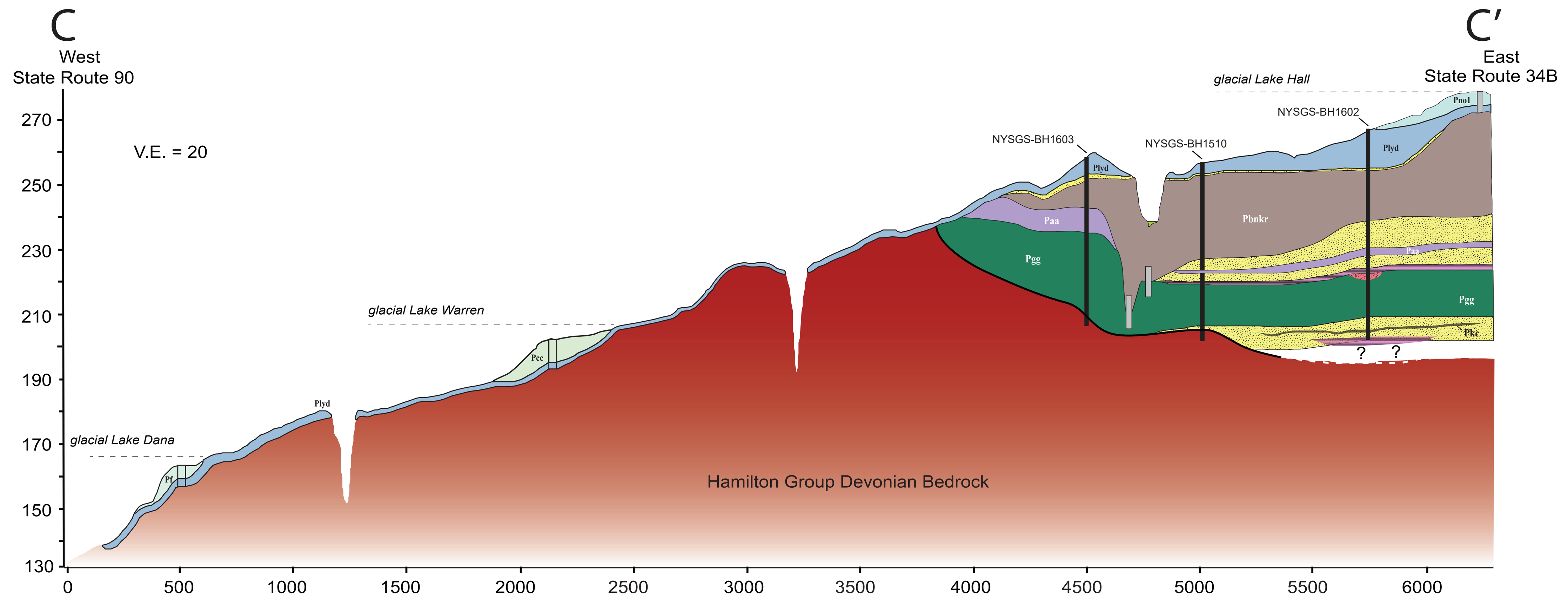


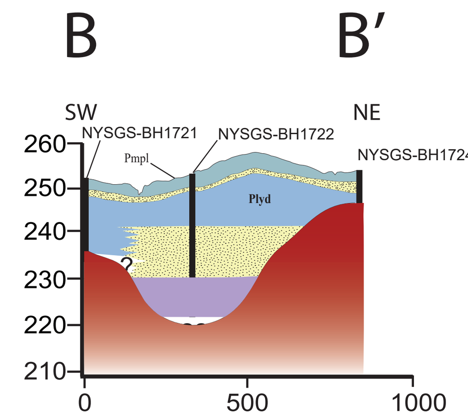
Cross-Section Location Map



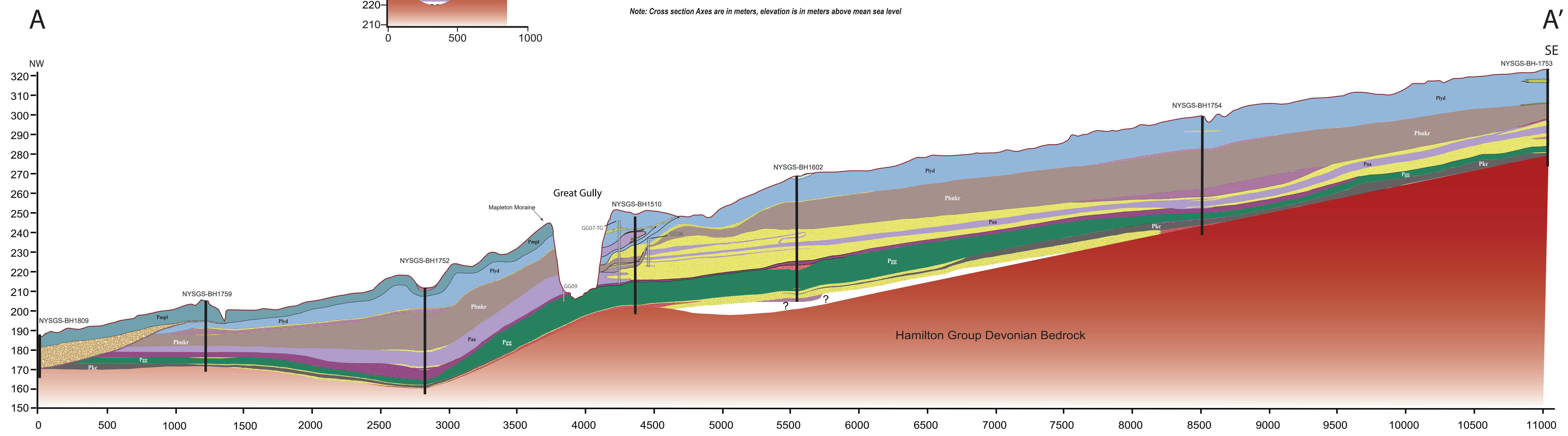
Finger Lakes Regional Terrain Model







Note: Cross section Axes are in meters, elevation is in meters above mean sea level



Introduction

This chart is the culmination of more than five years of stratigraphic investigation into the Late Pleistocene deposits in the vicinity of Great Gully, which is located four kilometers south of the Village of Union Springs in Cayuga County, New York. The gully is a prominent physiographic feature that extends six kilometers in length between State Route 90 and State Route 34B. Great Gully is the longest and most deeply incised (>50 meters) tributary on the east side of Cayuga Lake. The stratigraphic investigations are part of a larger mapping project for Cayuga County; the broader distribution of surficial materials and glacial landforms throughout the county is described in Kozlowski et al. (2018B).

Great Gully has been recognized as an important location described in summary publications detailing Pleistocene events in New York (Cadwell et al., 2003; Muller and Calkin, 1993: Muller and Cadwell, 1986) However, until the present investigation little detail or reporting beyond the pioneering work of Robert Shumaker (1957) has been available for this feature. In 1957 Shumaker completed his master's thesis on portions of the Union Springs and Scipio Center Quadrangles between Cayuga Lake and Owasco Lake. In completing surficial geologic maps to investigate till textures he explored Great Gully and reported the presence of multiple till units separated by sand deposits containing plant material including tree sticks and branches. Under the advice of his then advisor Ernest Muller, he collected samples and they were submitted to the United States Geological Survey for radiocarbon dating, a very new chronometric technique at the time. The resulting radiocarbon age was greater than 35,000 years, beyond the limit of radiocarbon dating at the time. In his thesis, Shumaker suggested the deposits were interstadial in age. However, in a letter written to James Broughton then State Geologist of New York in May of 1957, he speculated that the organic rich deposits bracketed by the two till deposits recorded an interglacial period.

Historical Perspective on Stratigraphic Investigations

Within the Cayuga Basin, the ages of interglacial deposits have been interpreted based on assemblages of mollusks and pollen (Maury, 1908; Karrow et al., 2009) at the Fernbank site, located near Taughannock Falls State Park. Bloom and McAndrews (1972) recovered three pieces of wood from interstratified deposits near the supposed Fernbank site that radiocarbon dated greater than 50,000 cal yr BP. More recently Karrow et al. (2009) tried to reexamine the site and find additional material to date but were only able to obtain a single thermoluminescence date on lake clays with a central age of approximately 81,000 years (full 2σ range 59,000-103,000 cal yr BP), which they suggested is inaccurate. Based on supporting evidence from pollen, molluscan fauna and other materials they assigned the lacustrine unit examined to the Sangamon Interglacial (110,000-130,000 cal yr BP), equivalent to Marine Isotope Stage (MIS) 5e. Thus, the broader stratigraphic context of the Fernbank site and its precise age remain poorly described and incompletely understood in the context of the Cayuga Lake Basin. Karig and Miller (2013), following up on the original work of Schmidt (1947) in Six-Mile Creek near Ithaca, interpreted a till unit overlying a thick sequence of varves as representing a Middle Wisconsin (30,000- 64,000 cal yr BP) ice advance into the Cayuga Basin, similar to suggestions of ice advance proposed in the Genesee Valley (Young and Burr, 2006). The presence of an ice sheet in central New York in the Middle Wisconsin has been viewed cautiously (Muller & Calkin, 1993) and conclusive evidence by well dated till units have not been established.

Throughout New York evidence of pre-Late Wisconsin glacial deposits remains very limited. The typical justification for the paucity of data and sites has been that subsequent Late Wisconsin glaciations have erased any record of older events (Cadwell et al. 2003, Mullins et al., 1996; Mullins and Hinchey, 1989) and/or that such deposits are likely to be preserved only in small isolated depressions-oriented transverse to southerly ice flow and thus protected from erosion (Coats,1966).

Ledyard Formation Till overlying Farmdale Age sands from top of GG06 exposure

Organic ripple sands (~65,000 cal yr BP) underlying Aurora Formation Till at base of GG06 Exposure

Bunker Formation Till and associated buried peat in Mid exposure of site GG07

Aurora Formation Till overlying Illinoian Great Gully Formation Till at exposure GG09

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Acknowledgments

The NYSM/NYSGS would like to thank the many landowners that provided access for mapping and investigation. John and Cheryl Roemmelt of Swayze Farms, James and Larraine Young of Fleming Homestead Farm: John Young, Dan and Tim Littlejohn, Brian Duggan, Dave Connally and Rick Saxton of Ledyard and Scipio Township. We also want to thank Deirdre DiBiagio and Katherine Charmicael, William Morgan and Kelly O'Hara of Springport Township. We also wish to thank the Nature Conservancy of Central New York, and many others who granted access for mapping and coring investigations. This mapping was funded by in part by the United States Geological Survey STATEMAP Grant, Award numbers G11AC20362-G17AC00265.

This study

The present investigation began while remapping the Union Springs Quadrangle for the county map compilation project and an attempt to relocate the Great Gully exposures described by Shumaker (1957). After several weeks of exploring the six-kilometer-long ravine and its tributaries two observations were evident. First, most of the length of Great Gully is cut into bedrock of the Hamilton Group, forming a very steep-walled, well jointed, rock floored gully, in some cases resembling a slot canyon. Second, the rock floor abruptly transitions to alluvial and glacial sediments in the upper third of the gully. The section of unconsolidated sediment extends eastward for a maximum distance of ~2 kilometers before abruptly terminating and resuming a bedrock floor with well-established rock canyons and waterfalls. Thus, the glacial deposits occupy only a portion of the east-west gorge system.

Stream-cut exposures of thick unconsolidated deposits were evident within tributaries on the south side of the gully, and after close inspection we were able to locate exposures containing multiple till units that bracket sand deposits containing organic materials. The sand units display ripple cross beds and contain plant material including twigs and sticks and in some instances log fragments like those described by Shumaker (1957). Twelve exposures allowed detailed recording of sedimentology, structural geology and stratigraphy. These exposures ranged in thickness from two meters to more than 40 meters and displayed multiple diamicton (till) units separated by sand and silt-clay units displaying sedimentologic indicators of fluvial and lacustrine deposition. Exposures were seldom greater than a few hundred meters apart ensuring that the lateral continuity of units could be observed. Sand and lacustrine fine sand-silt facies underlying till units often displayed shearing, folding and deformation consistent with compression and thrusting of overriding ice. More than 50 organic samples have been analyzed with accelerated mass spectrometry (AMS) radiocarbon dating from multiple stratigraphic levels. All age dates discussed in this study have been calibrated using Calib 7.1 software with Intcal 13 correlation (Reimer et al, 2013). In addition, more than 20 sand samples have been analyzed using optically stimulated luminescence (OSL) dating to estimate age of burial and constrain AMS ages.

Based on stratigraphic continuity and age dating, a basic geologic framework was developed for the thick deposits observed within outcrops in Great Gully. From the top edge of the gully to stream level the stratigraphy consists of multiple diamicton units separated by associated fluvial and or lacustrine facies. The surface till on the south side of the valley is designated the Ledyard Formation, whereas, the surface till on the north side of Great Gully coincides with the Mapleton Moraine, the maximum readvance position during the Port Huron Phase and is designated as the Mapleton Formation (Kozlowski et al. 2018A). The Ledyard Formation surface till to the south of Great Gully represents an earlier glacial advance most likely associated with the Port Bruce Phase or the Nissouri Phase (MIS 2) (Muller and Calkin, 1993). Precise age assignment is ambiguous because after careful study it appears that only one till unit comprises the surface formation south of Great Gully. Underlying the Ledyard Formation is an oxidized cross bedded sand unit with some lenses of laminated fine sand. Both OSL dating on sediments and AMS radiocarbon dating of plant macrofossils indicate the age of the sand unit to be ~31,000 calibrated years before present. This age is well established in the Midwest and southern Ontario as the Farmdale Phase (Karrow et. al, 2000) a well-established interstadial period. In the lower stratigraphic sequence, below the Farmdale Age sands a few key units serve as insightful key stratigraphic markers to organize the framework into additional formations (till units) and adjacent members. One such exposure is a 50-cm-thick, indurated and compressed buried peat horizon, first observed in exposure TG-GG07. This paleosol, a member of the Bunker Formation, had valuable pollen data, plant macrofossils and including a black spruce log fragment (NYSM-QLM-TG 0114). This unit is approximately 50,000 years old based on radiocarbon and OSL dating and has been determined to be Middle Wisconsin in age. Younger till units directly overlay this peat unit and multiple older till units underly it. Sand units observed in exposure GG06 near the Chase Road Rill are bracketed by till units underlying the peat member of the of the Bunker Formation. The climbing ripples and cross beds contain an abundance of organic materials within the sedimentary structures that indicate paleocurrent directions flowing to the north into the main gully. More than 20 AMS radiocarbon dates have been attempted on plant macrofossils from these lower sand units and all have yielded age estimates beyond the dateable range (>50,000 years). OSL of sand grains have yielded ages greater than 65,000 cal yr BP. Underlying these sand units are additional till layers that we have designated as the Aurora Formation of Early Wisconsin phase age. The best locality that displays the interstratified till organic ripple sands is outcrop GG06.

To the west in the main gully the tills of the Aurora Formation can be traced until they reveal a 1-2-meter layer consisting primarily of silt, with oxidized lens of sand and gravel underlying the till units. This unit is directly overlying an indurated dark gray clast rich till designated as the Great Gully Formation. OSL dates on sand grains from the silt unit indicate the age of burial between 80,000 to 140,0000 cal yr BP. These results indicate the underlying Great Gully Formation (till) was deposited by a glacier (>100,000 cal yr BP. Given the regional understanding of glacial events in the Ontario Basin (Karrow et al., 2000) the oxidized silt and sand unit represent the Sangamon interglacial (MIS 5e) and the Great Gully Till resulted from deposition during the Illinoian Glaciation (MIS 6).

With the zone of unconsolidated outcrops it is apparent that the deposits occupy an older bedrock depression transverse to the orientation of Great Gully. In the absence of water-well data, geophysical methods were employed to identify the dimensions and geometry of the bedrock depression containing the glacial deposits exposed by Great Gully. However, the thickness of glacial deposits, presence of multiple tills and underlying bedrock composition (weathered shale) proved too challenging for the seismic and electrical methods. As a result, starting in 2015 wireline coring was used to identify key stratigraphic markers, recover plant macrofossils for AMS dating, and correlate stratigraphic units. Coring began near Great Gully and expanded outward to define the dimensions and geometry of the bedrock depression. A total of 13 exploration boreholes were completed, 12 to bedrock and one that did not encounter bedrock at a depth of 65 meters. Results indicate that the glacial deposits exposed within Great Gully represent the infill of a large, complex buried valley system, with the longest segment extending > 11kilometers, crossing Great Gully, and oriented northwest to southeast, approaching the Village of Union Springs. The valley segment traced has an estimated average width of 1.5 to 2 kilometers, although multiple channels have been encountered (cross section B-B′), and the subsurface drainage pattern is likely complex and anabranching. The longest bedrock valley segment slopes northward with a steep gradient of 10 meters per kilometer.

The glacial deposits infilling the valley encountered in the exploration cores display similar stratigraphic sequence, sedimentary details and plant macrofossils as those observed in the Great Gully outcrops representing a continuation of the formations and members identified and studied within Great Gully and its tributaries. The combined observations from the outcrop level and the borehole stratigraphy indicate that some formations are inset into the partially eroded surfaces of earlier formations and is representative that the buried valley has been covered and re-excavated over several glacial cycles. Supporting evidence for this includes ripple sand units with preserved north draining paleocurrent, buried peat-paleosols and multiple laminated silt clay units indicating the valley periodically contained lakes probably dammed by either ice marginal deposits (moraines), advancing ice, or as an embayment of high-elevation proglacial lakes within the Cayuga Basin. The borehole stratigraphy also reveals deeper stratigraphy of the Kings Corner Formation underlying the Great Gully Formation. The units in this formation have not been observed in outcrops and include older till units, presumably pre-Illinoian (MIS 8 300-337 yr BP). Lacustrine silt-clay facies and alluvial sand and oxidized and weathered gravel units directly overlying bedrock.

The dimensions of the buried valley as presently mapped is larger in area or equal to the individual area of the five smallest present-day Finger Lakes. The burial of this large valley is so complete that no surface expression of its former existence is evident, even from high resolution LIDAR terrain data. Further, the location of the valley trend is parallel to and on the interfluve between Owasco Lake and Cayuga Lake. Lastly, the longest buried valley illustrated by cross section A-A′ directly aligns with the west fork of the south draining Salmon Creek Valley and traces to a very subtle, buried, bedrock drainage divide between the opposed north-south drainage systems, which we can only assume are pre-glacial and possibly date to the Pliocene (2.58-5.33Million Years)

Conclusions

The geologic details illustrated in this chart provide several lines of evidence to revisit and consider some long-held concepts regarding the glacial history and origins of the Finger Lakes region. First is that relict deposits of previous glacial and non-glacial periods have been effaced by erosion from more recent or the most recent glaciation to affect the region. Clearly the thickness, continuity and rather remarkable stratigraphic record spanning MIS2->MIS6 preserved within the Great Gully buried valley system demonstrates that preservation of older sediments is possible in New York. Obviously, not every locality will retain a record as complete as that observed in this study, rather, it is far more likely that only fragmentary records may be preserved. Second, the conceptual models of how and where deposits are likely to be preserved need to be reconsidered. Previous suggestions indicate preservation would be in locations transverse to ice flow, perhaps in the lee of a slope or hillside that protects deposits from erosive phases of geological activity. While such a concept is logical and probably accurate in many instances, the thick infilling of a large valley, parallel to ice flow, on an upland between two adjacent glacial troughs clearly indicates a transvers protection is not required for the preservation of such deposits. The results of this study further reinforce that deposition, burial, and subglacial erosive activity are complex phenomena and thereby may result in complex depositional models.

The stratigraphic and sedimentologic evidence associated with the Bunker Formation provide the requisite data to evaluate previously proposed suggestions for a Middle Wisconsin ice advance in central New York. The age of the till unit overlying the peat unit is bracketed by AMS radiocarbon dates and OSL dates on the underlying peat and sand deposits that are approximately ~50,000 years old. While the upper bracketing age is represented by the lower sand member of the Ledyard Formation that overlies the till unit and has an approximate age of ~31,000 cal yr BP (Farmdale Phase of Karrow et al., 2000) derived from both AMS and OSL dates (Kozlowski et al. n.d.). The chronologic and stratigraphic data confirm a Middle Wisconsin (MIS 3) ice advance into the northern Finger Lakes. The thickness and substantial deformation observed from deposits within the Bunker Formation further confirm this glacial advance.

Additionally, the stratigraphic position and chronologic data (>100,000 cal yr BP) associated with the Great Gully Formation in this chart provide the first known documentation of a credible Illinoian age till (MIS 6) in the Finger Lakes Region. This correlates to the York Till in southern Ontario, and the overlying oxidized sands and gravels support the Sangamon interpretations within the Cayuga Basin suggested by Karrow et al., (2009) for the Fernbank site. We suggest correlation of shallower Ledyard Formation till with the Kent Till units of Muller (1977), Lafleur (1979) and Miller and Calkin (1992) in western New York. The Mapleton Formation has a suggested minimum age of 15,000 cal yr BP and has been mapped as the southern extent of the Port Huron Phase ice advance (Kozlowski et al., 2018), perhaps correlating with the Halton Till in southern Ontario. The deposits retained within the Great Gully Buried Valley System retain a remarkable record of Late Pleistocene glacial events. Continued mapping and explorations will yield important new scientific data for reconstructing glacial history in New York.

NOTICE
This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program. A Great Lakes Geology Mapping Greant award number G17AC00312 in the year 2009.

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ISSN:0097-3793 ; ISBN: 978-1-55557-316-4