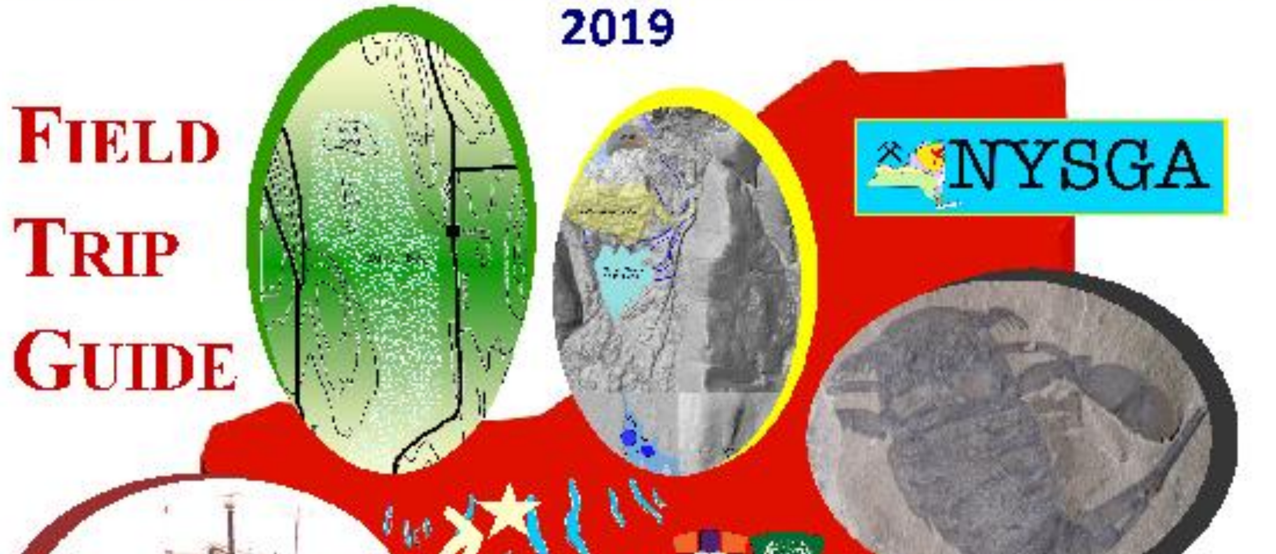
ISSN 1061-8724 (print)
ISSN 2689-0917 (online)

91st ANNUAL MEETING OF THE

New York State Geological Association

2019

FIELD TRIP GUIDE



HOSTED BY THE

NYS Council of Professional Geologists

AND

Hobart and William Smith Colleges

NYS GEOLOGICAL ASSOCIATION

91st ANNUAL MEETING

Guidebook for Fieldtrips

New York's Finger Lake Region

October 5-6, 2019

hosted by

NYS Council of Professional Geologists

and

Hobart and William Smith Colleges

All field trip guides are available for free download by following this link: www.nysga-online.net

The front cover photo credits are clockwise from top left:

- Zurich Bog Topographic sketch map of the Zurich Bog wetland complex. Redrawn from the USGS 7.5 minute quadrangle Sodus, NY (2016)
- LiDAR Hillshade of the Valley Heads area, US Dept. of the Interior, USGS
- Eurypetid Photo by Stephen M. Mayer
- Tully Valley Mudboil, US Dept. of the Interior, USGS
- Taughannock Falls, Photo by R.M. Ross, Annotations by Don Haas
- The *William Scandling*, courtesy of HWS

DISCLAIMER

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Welcome to HWS Colleges

David Kendrick,

Dept of Geoscience, Hobart & Wm Smith Colleges

The Hobart & William Smith Colleges Department of Geoscience welcomes the geoscientific community to the 91st Annual Meeting of the New York State Geological Association in 2019. We are proud to host NYSGA this year and look forward to sharing the spectacular landscapes of the Finger Lakes with you. The Geoscience Department at HWS traces its roots to a sedimentologist/stratigrapher and a meteorologist/oceanographer, who established our program with a strong interdisciplinary character; this interdisciplinary nature runs as strong as ever through our department today. Our faculty expertise includes sedimentology and stratigraphy, meteorology and climate science, paleontology, paleobotany, limnology, geochemistry, and more. The field trip offerings this year echo that broad, interdisciplinary approach to investigating this region and the world. Finally, we are also pleased to share the beautiful HWS campus with you; its location overlooking Seneca Lake is hard to beat. Welcome and we hope you enjoy the 91st NYSGA.

Welcome to the 91st Annual Meeting

Gene Florentino, NYSCPG President

This is New York State Council of Professional Geologist's (NYSCPG's) first time co-hosting this great NYSGA event. NYSCPG's main goal in co-hosting this event is to emphasize our Mission in serving the community, especially Geoscience students and academia~~.~~

As per our mission statement, NYSCPG is the principal organization of professional geologists responsible for the advancement of the competent and ethical practice of geology in New York State. NYSCPG's primary goals, on behalf of its members, are to strengthen and advance the application of geological sciences as a profession by providing leadership, advocacy, and education to promote the protection of public health, safety, and welfare, and the balanced protection of the environment.

From my personal experience, both being a former student in geology and now working in the profession, it is a very rewarding experience - I hope you enjoy your studies and the profession as much as I do. Enjoy this weekend's field trips. Hope to see you working in our profession upon your graduation!

Cheryl Neary, NYSGA President (2019)

NYSCPG, Immediate Past-President

I would like to take this opportunity to welcome you to the 91st Annual Meeting of the NYSGA held in another of New York State's geographical region. Per the Finger Lakes Regional Tourism Council:

"The Finger Lakes Region of New York State is a 9,000 square mile, four-season playground, set against a backdrop of Mother Nature's best work - from waterfalls and gorges to thick, cool woods to rolling hills to miles of spectacular shoreline on 11 glacial lakes and one Great Lake. No matter what you like to do, you'll find it in abundance in the Finger Lakes."

Hosting this years' NYSGA has brought back many fond memories of attending my first NYSGA at Vassar in 1976, followed by my involvement in 1977 in collating the 49th Annual Meeting guidebook, when my college – SUNY Oneonta -hosted the event! Over the years I have attended many more of the annual meetings – each time struggling to determine which of the field trips I should participate in, with each one chosen a rewarding experience. Each year that I have attended one of the annual meetings, I have gained more knowledge of the geological field, as well as the profession. Each annual meeting provides you with technical information and professional networking opportunities.

I hope you continue to support this annual event – as faculty and students - of all ages. acquiring knowledge and skills through your experience as a participant.

NYSCPG Mission

The New York State Council of Professional Geologists (NYSCPG) is the principal organization of professional geologists responsible for the advancement of the competent and ethical practice of geology in New York State. NYSCPG's primary missions, on behalf of its members, are to strengthen and advance the application of geological sciences as a profession by providing leadership, advocacy, and education to promote the protection of public health, safety, and welfare, and the balanced protection of the environment.

NYSCPG Services

The focus at NYSCPG is three fold: 1) Promote the competent practice of professional geology by adhering to sound ethical, scientific, and geologic principles; 2) Monitor and offer professional reviews and opinions regarding pending legislation and research New York State and local laws and regulations as they pertain to or may affect the practice of geology in New York State; 3) Monitor and offer professional reviews and opinions regarding current laws and regulations and pending legislation so that sensible and practical measures are incorporated to protect public health, safety, and welfare and promote the balanced protection of the environment; and, 4) Encourage stewardship for the profession of applied geology.

What do we do?

- Strengthen the role and importance of the professional practice of geology in the State of New York;
- Advocate and promote professional geologists across the many geologically-related sub-disciplines and practice areas;
- Facilitate continuing education, awareness, and training to our members; and,
- Provide career development, networking opportunities, and other benefits to professionals and students dedicated to the learning, application, and advancement of geological sciences.

How do we do it?

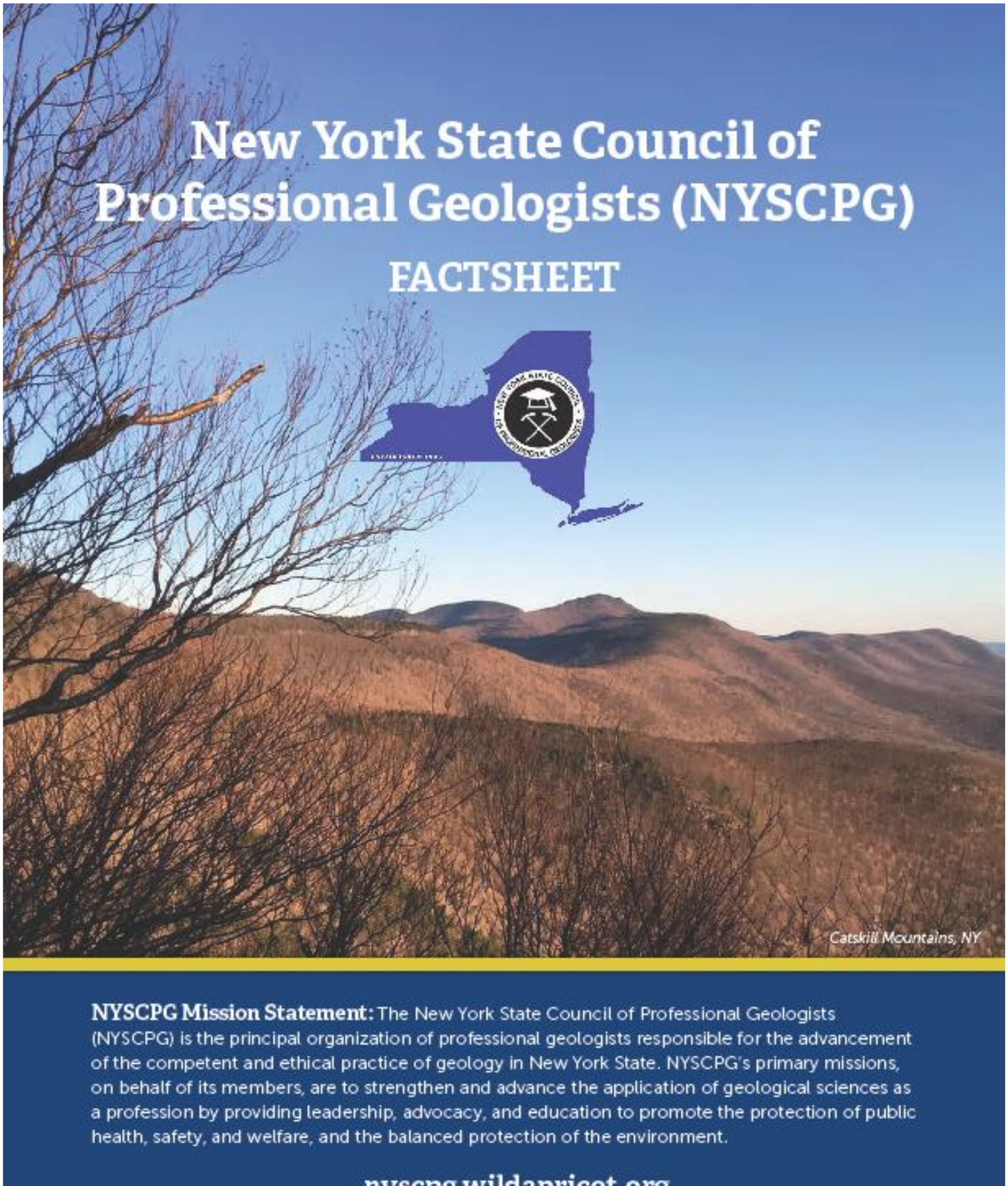
NYSCPG aims to represent the interests of professional geologists and students over a variety of practice disciplines. NYSCPG will advance the science of geology, and its related fields, by encouraging education, training, and awareness through meetings, exchange of information, and providing a common voice on behalf its members. The dues paid by its members allow NYSCPG to advance and promote the profession of geology through building public appreciation for how professional geologists contribute to protection of public health, safety, and welfare, and the balanced protection of the environment.

Who do we serve?

NYSCPG's leadership team represents not only its members, but also advocates for all NYS-licensed professional geologists, and individuals on the path to a NYS professional geologist license. NYSCPG will fulfill members' needs with a wide range of useful services (e.g. career development, education, networking opportunities) enabling them to be more effective in their career through advocacy, continuing education, training, and outreach.

New York State Council of Professional Geologists (NYSCPG)

FACTSHEET



Catskill Mountains, NY

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nyscpg.wildapricot.org

January 2019

§7204-a. Definition of the profession of geology

The practice of the profession of geology is defined as performing professional service such as researching, investigating, consulting and geological mapping, describing the natural processes that act upon the earth's materials, predicting the probable occurrence of natural resources, predicting and locating natural or human-induced phenomena which may be useful or hazardous to humankind and recognizing, determining and evaluating geological factors, and the inspection and performance of geological work and the responsible supervision thereof in furtherance of the health, safety and welfare of the public; provided, however, that geological mapping shall not include the practice of land surveying as defined in section seventy-two hundred three of this article.

§7204-b. Practice of geology and the use of title "professional geologist"

Only a person licensed or otherwise authorized under this article shall practice geology or use the title "professional geologist".

* *Effective March 1, 2019*

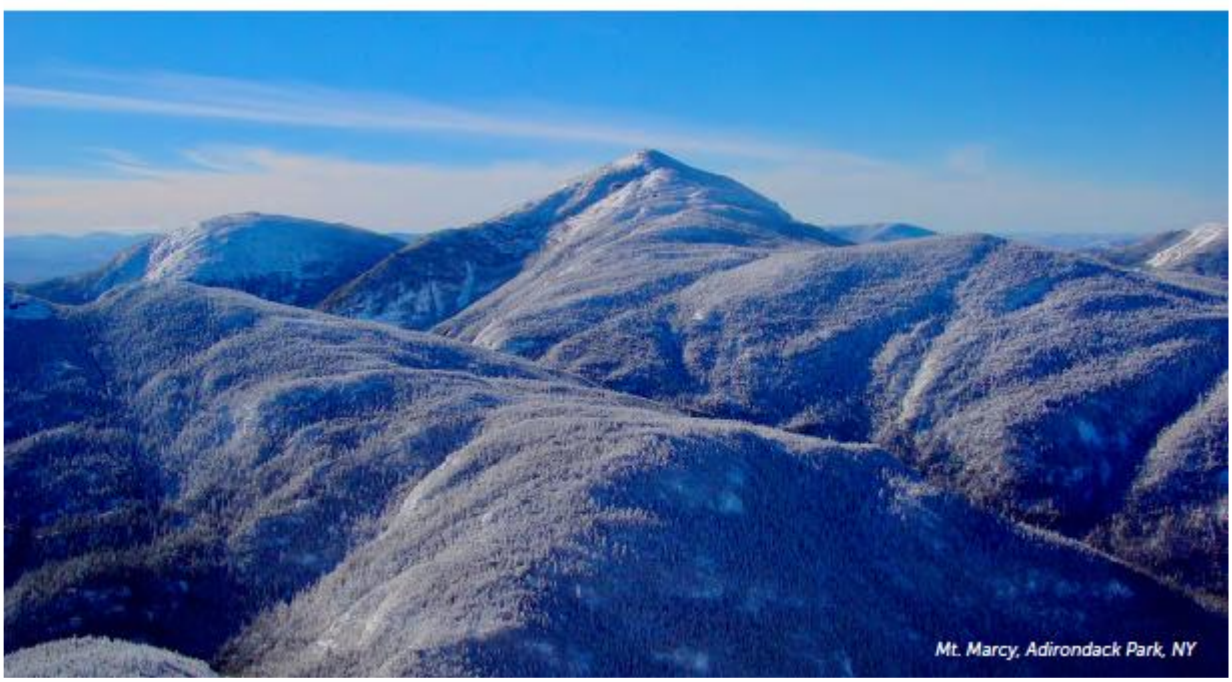
*§7210. Certificates of authorization

All business entities legally permitted to provide professional geology services in New York State are required to obtain a "Certificate of Authorization to Provide Professional Geology Services in New York State" from the State Education Department according to section 7210 of Education Law.

Individual licensees, who are legally permitted to practice geology in New York State, can obtain a "Certificate of Authorization" according to section 7210 of New York State Education Law, however, they are not required to do so.

§6509 Definitions of professional misconduct/§6512 Unauthorized practice a crime

The laws of the State are clear in regard to unauthorized practice. Section 6512.1 of the Education Law makes it a class E felony for anyone not authorized to practice who practices or offers to practice or holds themselves out as being able to practice professional geology. Section 6509 of the Education Law defines professional misconduct as, among other things, permitting, aiding or abetting



Mt. Marcy, Adirondack Park, NY

an unlicensed person to perform activities requiring a license; and, section 6512.2 of the Education Law makes it a class E felony for anyone, including a public official, to knowingly aid or abet three or more unlicensed persons to practice a profession requiring a license.

Pathway to Licensure

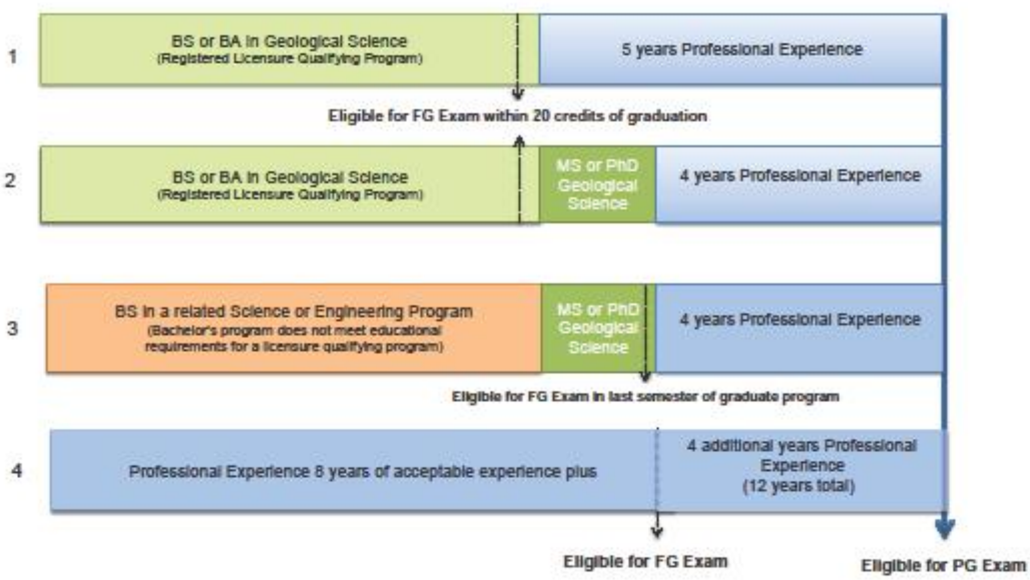
To be licensed as a professional geologist in New York State you must:

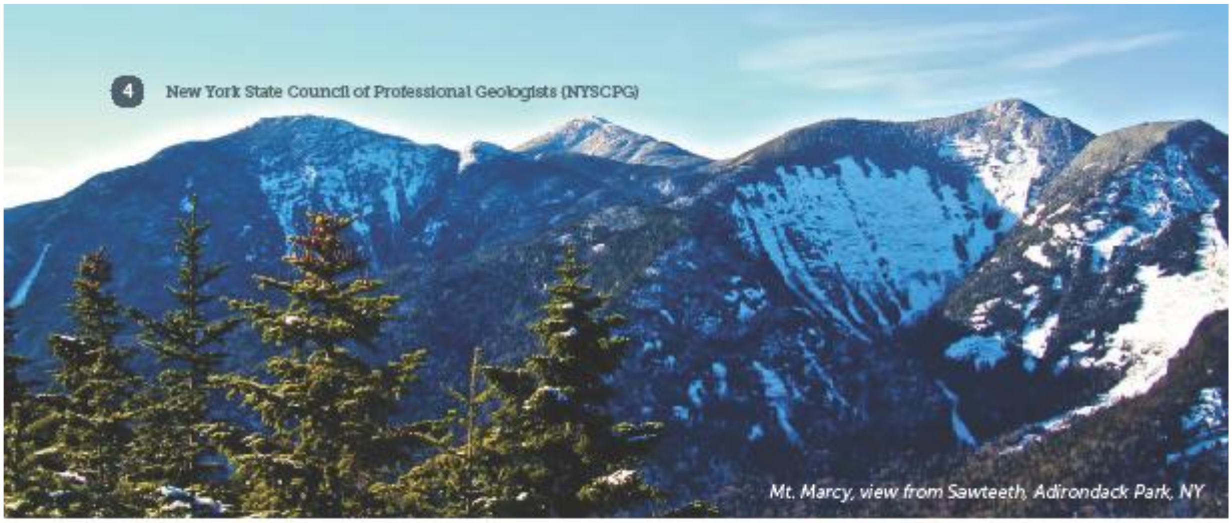
- Be of good moral character;
- Be at least 21 years of age; and
- Meet education, examination, and experience requirements.
- Submit an application for licensure and the other forms indicated, along with the appropriate fee, to the Office of the Professions at the address specified on each form.

The specific requirements for licensure are contained in Title 8, Article 145, section 7206(b) of New York's Education Law and Part 68 of the Commissioner's Regulations *(http://www.op.nysed.gov/prof/geo/geolic.htm)*.

Helderberg Escarpment, NY

Education and Experience Requirements for Professional Geology Licensure





Mt. Marcy, view from Sawteeth, Adirondack Park, NY

What is NYSCPG and how can I benefit as a member?

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BIOGRAPHIES

Gene Florentino, Speaker

Gene Florentino has a MS degree in Geology from the University of Akron, OH; and a BS degree in Geology from the State College of NY at Oneonta. He is also a licensed Professional Geologist in NY and PA. He is currently President of the New York State Council of Professional Geologists (NYSCPG) and has been on the Board of Directors for over 16 years. Mr. Florentino was also President of the Buffalo Association of Professional Geologists (BAPG) in 1999, and served on their Board for several years. After studying for several months is in 2017, Mr. Florentino earned a Project Management Professional (PMP) credential from the Project Management Institute. After achieving this recognition, he felt after 33 years it was time to sit for the National Association of State Boards of Geology (ASBOG) Fundamentals of Geology and Practice of Geology exams. Passing both of those exams was the major milestone of his career! In his spare time, Mr. Florentino was a Project Manager/Practicing Geologist at Ecology and Environment in Buffalo for over 30 years and now has a similar position with GHD Services in Niagara Falls.

David Kendrick | Dept of Geoscience | Hobart & Wm Smith Colleges

By geological standards of time, David Kendrick was born and grew up in Indiana, earned a B.S. in Geology and Geophysics from Yale and a Ph.D. in Geological Sciences from Harvard, studied rocks and fossils in places like Utah, Montana, Jamaica, the Bahamas, New York, Australia, Sweden, and the Netherlands, and became an Associate Professor of Geoscience at Hobart & Wm Smith Colleges, all in the blink of an eye.

Field Trip A1:

Dan Karig came to Cornell in 1973 and taught there for 25 years. His research interests began in structural geology and marine tectonics, mostly related to island arc systems. He then worked on the experimental deformation and mechanical behavior of soft sediments After retirement he became interested in the glacial geology of the local area, where field work has led him to a number of controversial conclusions.

Bryan Isacks, from 1954 to 1971 did his undergraduate - graduate study at Columbia University and a post-doc at the Lamont-Doherty Earth Institute. He then joined the newly re-constituted Department of Geological Science in 1971. His research interests changed over the years from earthquake seismology and tectonics of subduction zones in the SW Pacific to topographic expressions of tectonics and glaciation in the South American Andes. Retiring in 2008, he became fascinated with the topographic expressions of glaciation in central New York, particularly features revealed by the new LIDAR high resolution digital elevation models.

Field Trip A2:

Stephen Mayer. I received my BS in geology from SUNY Oneonta in 1985.and my MS in geology in 1989 with specialization in Stratigraphy and Paleontology. I studied the Jaycox Shale Member, uppermost Ludlowville Formation, Hamilton Group using key fossil beds to correlate the unit from about Lake Erie shoreline thru Finger Lakes to Skaneateles Lake. I studied the paleoecology of these fossil assemblages as well.

Since then I focused on the overlying Lowermost Moscow Formation, the transition from the Tichenor Member thru Deep Run Shale Member subdividing the latter and correlating these beds in a like wish fashion. Past 4 years I have concentrated on Eurypterid bearing horizons in NY studying taphonomy and paleoecology of these chelicerates.

Field Trip A3:

John D. Halfman

John D. Halfman, Professor of Limnology and Hydrogeochemistry, teaches in the Department of Geoscience and Environmental Studies Program at Hobart and William Smith Colleges. He is also intimately linked with creation and development of the Finger Lakes Institute at the Colleges, accumulating over $10 million dollars in funding from state, federal and private foundation sources since its inception in 2004. He has recently taught the following courses: GEO-186 Introductory Hydrogeology, GEO-210 Environmental Hydrology, GEO-330 Limnology, ENV-200 Environmental Science, and ENV-203 Fundamentals of GIS.

Building on Lake Superior and East African Rift Lake paleoclimatic research before coming to HWS, his current research interests focus on water quality issues in the Finger Lakes. The projects include: (1) water quality variability between the Finger Lakes and potential drivers for the observed variability; (2) nutrient sources and nutrient loads within selected Finger Lake watersheds; (3) nearshore nutrient dynamics and potential drivers for the recent nearshore blue green algae blooms, (4) spectral signatures of algal blooms and their surface concentrations, and especially blue green algae concentrations as observed by Unmanned Aerial Vehicles (UAVs – aka drones); and, (5) potential remediation efforts to mitigate blue green algae blooms in nearshore regions.

David Finkelstein

David Finkelstein earned his Ph.D. from the University of Illinois at Urbana-Champaign and M.S. and B.S. degrees from the UMass Amherst and works in variety of scholarly disciplines focused around geochemistry and limnology. Among his recent research interests are comparing modern ancient lacustrine systems, analyzing controls on the chemical evolution of till-derived waters, characterizing the intersection of organic and aqueous geochemistry in the evolution of ponds to lake systems, and exploring microbial life on the edge of hydration in lakes, seeps and hot spring. Professor Finkelstein joined the HWS faculty in 2013.

Field Trip A4:

Nan Crystal Arens is Professor of Geoscience at Hobart & William Smith Colleges. She earned a B.Sc. in Earth Science from Penn State University and an M.Sc. in Geology also from Penn State. Her Ph.D. is in Organismal Biology from Harvard with specialization in paleobotany and palynology. She served as a faculty member at the University of California, Berkeley and curator of fossil plants at the University of California Museum of Paleontology before coming to HWS in 2001. Her research focuses on the environmental factors that force macroevolutionary and ecological change. In the last several years she has also begun investigating the role education plays in student's understanding of contemporary climate change.

Field Trip A5:

William (Bill) Kappel earned both undergraduate and graduate degrees from Penn State. He has worked as a hydrologist for the U.S. Forest Service in Missouri and Wisconsin. For over 35 years he has studied the hydrogeology of upstate New York with the U.S. Geological Survey in the New York Water Science Center. At present he is a hydrogeologist emeritus with the New York Water Science Center at Ithaca, NY.

Past investigations include the Onondaga Trough, studying the movement of natural brine to Onondaga Lake at Syracuse, NY; study of mudboil (mud-volcano) activity in the Onondaga Creek Valley; study of landslides in upstate New York – in relation to glacial lake clays; aquifer studies in central and western New York, and carbonate and evaporite karst 'challenges' throughout New York. He has also coordinated USGS water-resource information and study efforts related to shale-gas development in New York and with other Water Science Centers across the Marcellus 'Play' - West Virginia to New York.

Field Trip B1:

Robert Ross is the Associate Director for Outreach at the Paleontological Research Institution (PRI) and is adjunct faculty in the Cornell Department of Earth and Atmospheric Sciences. He received his Bachelors degree in Geological Sciences from Case Western Reserve University (1984) and his Ph.D. in Earth and Planetary Sciences from Harvard University (1990). Ross took a post-doctoral fellowship in paleoclimatology at the University of Kiel (Germany) (1990-1992) and was on the Faculty of Sciences at Shizuoka University (Japan) (1992-1997). Ross's research has included the diversity and biography of tropical marine organisms, carbon cycling associated with coastal upwelling, and science education. He has been at PRI since 1997, where he has been involved in a wide variety of education and exhibits in Earth science, paleontology, evolution, and climate change.

NYSGA bios for Ross et al article

Warren Allmon is the Director of the Paleontological Research Institution (PRI) and the Hunter R. Rawlings III Professor of Paleontology in the Department of Earth and Atmospheric Sciences at Cornell University. He earned his bachelor's degree in Earth Sciences from Dartmouth College (1982) and his PhD in Earth and Planetary sciences from Harvard University (1988). For four years, Allmon was assistant professor of geology at the University of South Florida, Tampa, and in 1992 he became director of PRI, where he has been instrumental in rejuvenating the institution's internationally known fossil collections; starting its local, regional, and national programs in earth science education; and planning and fundraising for PRI and its Museum of the Earth and Cayuga Nature Center. Allmon's major research interest is macroevolution and paleoecology, particularly using Cenozoic marine gastropods.

Don Haas is Director of Teacher Programs at the Paleontological Research Institution (PRI). He received a BS in Physics from SUNY Geneseo (1985), an MS in Earth Science Education from SUNY Cortland (1990), and a PhD in Science Education from Michigan State University (2000). He has 10 years experience as an Earth science teacher, and has taught in education departments at Kalamazoo College, Cornell University, and Colgate University before joining PRI in 2008. Haas played an active role in the development of the Next Generation Science Standards (NGSS), served as Chair of the Geological Society of America's Geoscience Education Division, was President of the National Association of Geoscience Teachers, and was on the New York State Science Leadership Team for the NGSS. Don's work focuses on effective teaching of societally significant issues such as climate change and energy and on the use of technology-rich place-based approaches to teach Earth systems.

Jonathan Hendricks is Director of Science Communication at the Paleontological Research Institution (PRI) and is adjunct faculty in the Department of Earth and Atmospheric Sciences at Cornell University. Hendricks received his BS in Geology & Geophysics and Zoology from the University of Wisconsin-Madison (1999) and a PhD in Geological Sciences from Cornell University (2005). He was a post-doctoral researcher at the University of Kansas (2005-2008) and was on the faculty of the Department of Geology at San Jose State University (2008-2016). Besides managing PRI's publications, he is also active in paleobiological research on the evolutionary history of cone snails and in outreach activities associated with the National Science Foundation-supported Digital Atlas of Ancient Life project (www.digitalatlasofancientlife.org). His recent Digital Atlas projects include founding the Digital Encyclopedia of Ancient Life (an online, open access paleontology textbook), developing an online virtual teaching collection of 3D fossils, and creating an online field guide to fossils from the Cretaceous of the U.S. Western Interior region.

Trip A1 a

A REVISED HISTORY OF LATE QUATERNARY GLACIATION IN THE CAYUGA BASIN

DAN KARIG AND BRYAN ISACKS

Dept of Earth and Atmospheric Sciences, Cornell University

INTRODUCTION

The glacial history of the Cayuga Basin has yet to be completely understood and has recently become controversial. The current story is basically that of Tarr (Williams et al., 1909) and Fairchild (1934), with minor updates from von Engeln (1961), Muller (e.g. Muller and Cadwell, 1986), Bloom (2018) and Mullins (e.g. Mullins et al, 1996). For the last glacial stage, this is a story of ice retreating from the Last Glacial Maximum (LGM) into the Ontario basin, re-advancing to the Valley Heads moraine and then retreating again, leading to a series of proglacial lakes trapped between the ice front on the north and higher topography to the south. With the assumption that the ice sheet was an impermeable barrier to flow northward and the dearth of chronologic control, this model was logical, given that the simplest model that fits the available data is to be preferred.

Research over the past decade or so has generated data that requires the modification of this paradigm, in some cases significantly. The most radical modification is northward subglacial drainage during the Mackinaw Interstade, requiring the rejection of the existence of the large proglacial lakes Ithaca, Newberry and Hall in the Cayuga Trough (Karig and Miller, 2017; submitted). Other different interpretations are the nature of the Valley Heads re-advance and the extent of ice retreat during the Erie Interstade. These modifications were largely due to the availability of Lidar imagery, scientific drilling, and seismic profiling, but also to field studies that relied more on pitting and coring than had earlier studies. This paper reviews as much of the glacial history of the Cayuga basin as is available but is largely devoted to the history since the LGM because this advance overrode and largely destroyed the evidence of earlier glaciations.

General Quaternary Glaciation

Ice began to build up in North America about 2.7 ma ago (Haug, et al., 2004) but reached the Cayuga basin a significant time later. Although there is no explicit evidence for when this arrival occurred, there is indirect evidence that there were many ice advances to and through the area prior to the LGM. It is clear that such penetration occurred during Wisconsin and preceding Illinoisan stages and, because several advances of similar extents occurred in the mid-West, there were almost certainly several such major advances through central New York. Evidence for multiple advances includes the contrast in the shape of the topography along the north flank of the Appalachian Plateau, which lies near Ithaca, with that further south. The northern flank of the plateau is marked by linear or arrowhead shaped ridges (Karig, 2015) that have a dominantly N-S trend. The topography shows little of the presumed pre-Quaternary dendritic drainage patterns. Those dendritic patterns remain clearly evident in the topography farther south, where topographic evidence of massive glacial sculpting is not apparent. The video playing and available online at Ithaca's Museum of the Earth (Isacks, 2013) shows that the assembly of Valley Heads Moraines is the approximate boundary between the remarkably different topographies. This difference reflects multiple ice advances into the northern flank of the plateau but far fewer into its interior because ice sheets would have to have thickened markedly to generate the necessary southward surface slope to drive the ice far into or beyond the plateau.

It has been recognized since the work of Tarr (Williams et al., 1909) that glacial erosion in the Cayuga and other troughs has been much greater than that on the uplands. Modern concepts would lead to identification of the troughs as sites of small ice streams, where ice flow was far faster than over the interfluves. The relative lack of glacial erosion on the uplands (e.g. Williams et al., 1909, Muller, 1965) is probably due to thinner and slower moving ice and possibly even to cold based ice in those settings.

Not only was glaciation variable with respect to location within the basin but almost certainly also differed during the various glacial stages. Several lines of evidence suggest that erosion and trough deepening was greater during the Illinoisan Stage than during the Wisconsin. The most explicit evidence is the subsurface geometry of the Sixmile Trough, a major glacial trough tributary to the Cayuga Trough. Cross sections of this trough (Karig, 2015, Fig. 4 of field trip guide) show the Illinoisan glacial trough (the inner glacial trough of Karig (2015)) deeply incised into an older glacial trough (outer glacial trough) but there is no additional bedrock excavation during the Wisconsin Stage. A large amount of bedrock appears to have been eroded between the pre-glacial topography and the creation of the outer glacial trough but there is no evidence concerning the number of glacial advances that moved through the valley during this interval. The combination of surface, well and seismic data from Cayuga Inlet valley strongly indicate the existence of a thick section of pre-Late Wisconsin sediment there, which precludes any Late Wisconsin bedrock erosion there. Combined with the lack of pre-Late Wisconsin deposits beneath Lake Cayuga (Mullins et al, 1996) this suggests the removal of only that material in the deeper part of the Cayuga Trough. A possible reason for the lack of Late Wisconsin

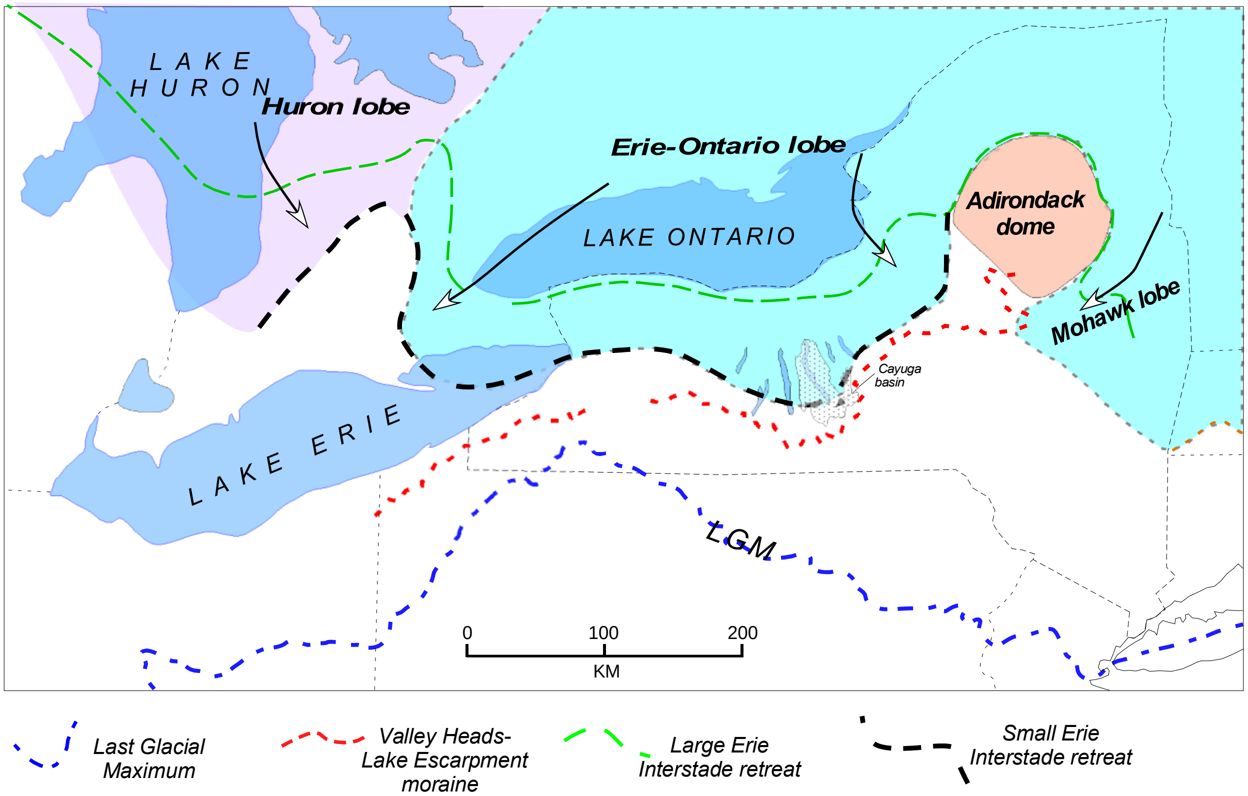


Figure 1. Regional setting of the Cayuga basin and major ice front positions since the LGM.

bedrock erosion is that glacial striae show that ice movement in the Cayuga basin during that advance was southwest to south-southwest (Williams et al, 1909; Denny and Lyford, 1963), strongly oblique to the trend of the Cayuga Trough. Although ice covered the entire area, this obliquity could have led to the reduction in speed of ice flow in the trough, restricting erosion.

Each glacial stage was complex, with secondary advances and retreats. There were several ice advances that reached the Appalachian Plateau margin during the Wisconsin Stage (Tarr, 1905; Kozlowski, 2014; Karig and Miller, 2013) and one can safely assume that the situation was similar for earlier stages. This line of reasoning leads to the conclusion that there were on the order of a dozen ice advances that reached the Cayuga basin, but only the history of those during the last, Wisconsin Stage, is sufficiently preserved to be described in any detail.

<u>LGM to Erie Interstade</u>

The LGM is dated as approximately 25 ka ago (this and all dates in this paper are in calibrated radiocarbon or calendar years) (e.g. Corbett et al., 2017; Stokes, 2017 and references therein), when the ice margin reached northeastern Pennsylvania and northern New Jersey (Fig 1). The ice thickness in the area of the Cayuga basin at that time has been estimated as about 1.5 km (Peltier, 2004), but with a relief of about 500m between the base of the Cayuga trough and the surrounding uplands, the ice thickness over the trough was probably 2 km or more.

The preserved evidence of the ice movement in the Cayuga basin to and from the LGM terminal moraine is dominantly the Olean Till. Over at least the central and southern sections of the Cayuga basin the Olean till is characterized by a blue-gray silty clay matrix, with a variable clast content. This suggests that the till consists largely of reworked older lacustrine sediment from the trough. Of the valleys of the Cayuga basin this till is best exposed in the Sixmile trough where post-glacial fluvial erosion has incised through the Quaternary section and along the edges of the Cayuga Inlet Valley, between Erie Interstade lacustrine deposits and bedrock. In those areas the clasts in this till have a high percentage of exotic lithologies and are often quite well-rounded. Along the Sixmile trough there are a number of rafts of highly deformed lacustrine silts and clays within the lower part of the till, which supports the interpretation that the till in this region was derived from a proglacial lake that lay in front of the advancing ice. This is consistent with the apparent lack of Olean till beneath Cayuga lake (Mullins et al, 1996) and under the northern section of Cayuga inlet Valley (Tarr, 1904). Decreasing southward glacial erosion led to an increase in Olean till thickness to the south where exposures in the Sixmile trough (Karig, 2015) and seismic profiles in Cayuga Inlet Valley (Figs. 11 and 12 of field trip guide) indicate thicknesses of several tens of meters along the valley axes.

In the uplands of the Appalachian Plateau portion of the Cayuga basin the Olean till is very thin, with only angular clasts of local lithologies. This contrast in clast character led originally to the idea that there were two tills (e.g. MacClintock and Apfel, 1944); Olean with local clasts and Binghamton with exotic clasts, representing advances of different ages, but Moss and Ritter (1962) later showed that the clast difference represented different ice flow trajectories during the same period. The more rounded exotic clasts were derived from clastic deposits moved south along the troughs by older glacial advances and by interglacial fluvial processes.

Except for the Olean till there is very little glacial record of the ice front retreat from the LGM, through the Nissouri Stade, to that of the peak of Erie Interstade, which was at least as far north as the vicinity of Ithaca, but it was apparently slow. If the beginning of the ice front re-advance, which marked the peak of the Erie Interstade occurred about 18,000 years ago (e.g. Dyke, 2004) this withdrawal took about 7000 years. Several lines of evidence indicate that the climate remained very cold during this period. ^{18}O and dust data from Greenland ice cores (Rasmussen et al, 2014) show a continuous, very slow warming over this interval. Radiocarbon ages from bog and kettle bottom cores in New York have not shown the expected northward decrease, but instead have an almost uniform grouping around 14ka (Fig. 2).

This result was interpreted to reflect permafrost conditions over the newly exposed region (Karig and Peteet, 2015), which kept buried ice masses from melting until after the sharp rise in temperature at 14.7 ka (Rasmussen et al, 2014), when melting of the permafrost and buried ice probably occurred over the entire area. Although recognized in neighboring regions, permafrost conditions have not yet been recognized in the Cayuga basin, but have been reported from the period following retreat from the LGM in Pennsylvania (Merritts et al., 2014), New Jersey (French, et. al., 2009) and Connecticut (Stone and Ashley, 1992). The only possible example of such conditions reported in the Cayuga basin are the cirque-like “coves” in the headwaters of streams south of the Valley Heads front, which were interpreted as the result of periglacial solifluction by Bloom (2018). It is quite possible that a more serious search would lead to more discoveries of permafrost conditions in the Cayuga basin.

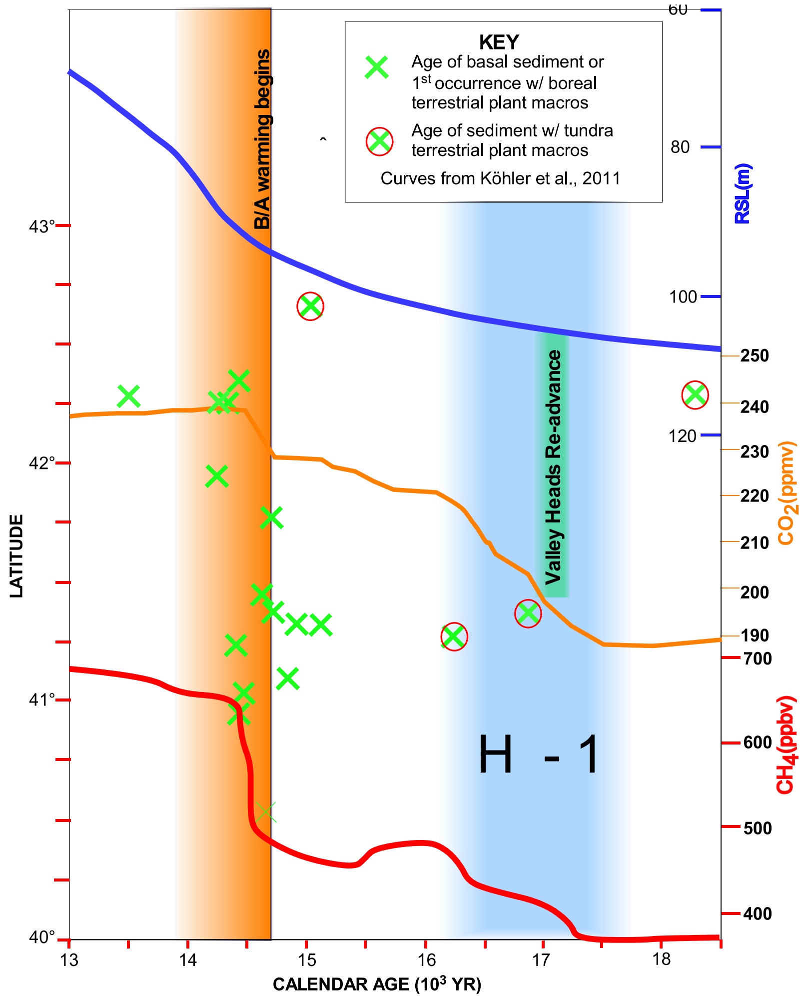


Fig. 2. Plot of basal sediment ages in bogs and kettles and in proglacial lakes in New York as a function of latitude (from Karig and Peteet, 2015).Most sites older than 14.7 ka reflect a tundra environment, whereas all younger sites reflect boreal conditions. There is a slight northward younging of this transition.

The first direct evidence of the ice retreat from the LGM in the Cayuga basin are lakes that were trapped between the retreating ice and local drainage divides. The largest of these was one in the Cayuga Trough, north of the drainage divide between Susquehanna and Ontario watersheds. Lacustrine clays, silts and fine sands are recognized from south of the present drainage divide northward, thickening to more than 100m near Ithaca, where they end against a bedrock sill (Fig. 11 of the field trip guide). Redeposited (slump) units within this sequence contain a tundra floral assemblage that has been dated as 18.4 ka, indicating its Erie Interstade age as well as reflecting a very cold climate at that time. Smaller Erie Interstade lakes existed in the Sixmile-Willseyville trough and in Fall Creek Valley.

This long slow ice front retreat was ended by the readvance to the Valley Heads ice front. (Fig. 1). Based on a beach deposit along the north shore of Lake Erie, which was at such a low elevation as to require drainage down the Mohawk Valley, it has generally been assumed that the ice front at the beginning of the re-advance had retreated into the Ontario basin (e.g. Dreimanis, 1958; Mörner and Dreimanis, 1973; Ridge,1991, 1997). However, the evidence from the Cayuga basin indicates that the ice front at the peak of the Erie Interstade retreated no further north than the vicinity of Ithaca. None of the Erie lacustrine deposits that occupy the three major tributaries to the south end of Cayuga Lake extends even to that lake (Karig and Ridge; 2015). Moreover, from that area northward, a single Late Wisconsin till represents the period from the Nissouri Stade to the Port Bruce Stade (Muller, 1957; Kozlowski, 2014; Karig, 2015).

Port Bruce Stade

The Port Bruce Stade is effectively defined in the Cayuga basin by the Valley Heads re-advance, which has generally been described as having resulted in a thick, valley choking deposit of glacial drift or kame moraine (Muller and Cadwell, 1986) in most glacial troughs of central New York. The Valley Heads re-advance in the Cayuga basin clearly does not fit that description. Instead, it is a thin carapace of a till overlain by a kame and kettle unit, both of which overlie older Quaternary deposits, the age and character of which are largely unknown (Fig. 11 of the field trip guide). The Valley Heads front is usually marked by an outwash head rather than by a moraine, although a kame end moraine does occur in the Cayuga Inlet Valley. The predominant components of the Valley Heads system are the outwash plains, which can reach 30 m in thickness, and the valley trains into which the outwash plains trend. These coarse fluvial clastics are dominated by exotic lithologies, especially near the base of those units. To the north of the outwash heads or end moraines are extensive valley floor hummocky terranes, termed kame moraine by Muller and Cadwell,1986). The character of these in the different troughs of the Cayuga basin varies in details such as drainage direction and clast character, but all appear to be quite thin.

The Valley Heads front in Cayuga Inlet Valley is relatively unusual in being marked by an end moraine instead of an outwash head. Moreover, the hummocky terrane to the north has two easily distinguishable sections, representing two very different environments. Immediately behind the end moraine is a section characterized by extensive, irregular wetlands and intermediary uplands composed of silt and fine sand. This regime drained south as shown by proglacial channels and by a kame terrace along the east side of valley (Fig. 10 of the field trip guide). Coring in one of these wetlands recovered a tundra flora, which is yet to be dated, but indicates a colder and most probably older environment than that of the rest of the hummocky terrane. A working hypothesis is that the wetlands here occupy small proglacial lakes that succeeded supraglacial lakes, the fills of which are the fine-grained uplands, which developed after meltout and topographic inversion. The larger portion of the hummocky terrane in Cayuga Inlet Valley, to the north, slopes and drains north and is occupied by a more classic kame and kettle terrane.

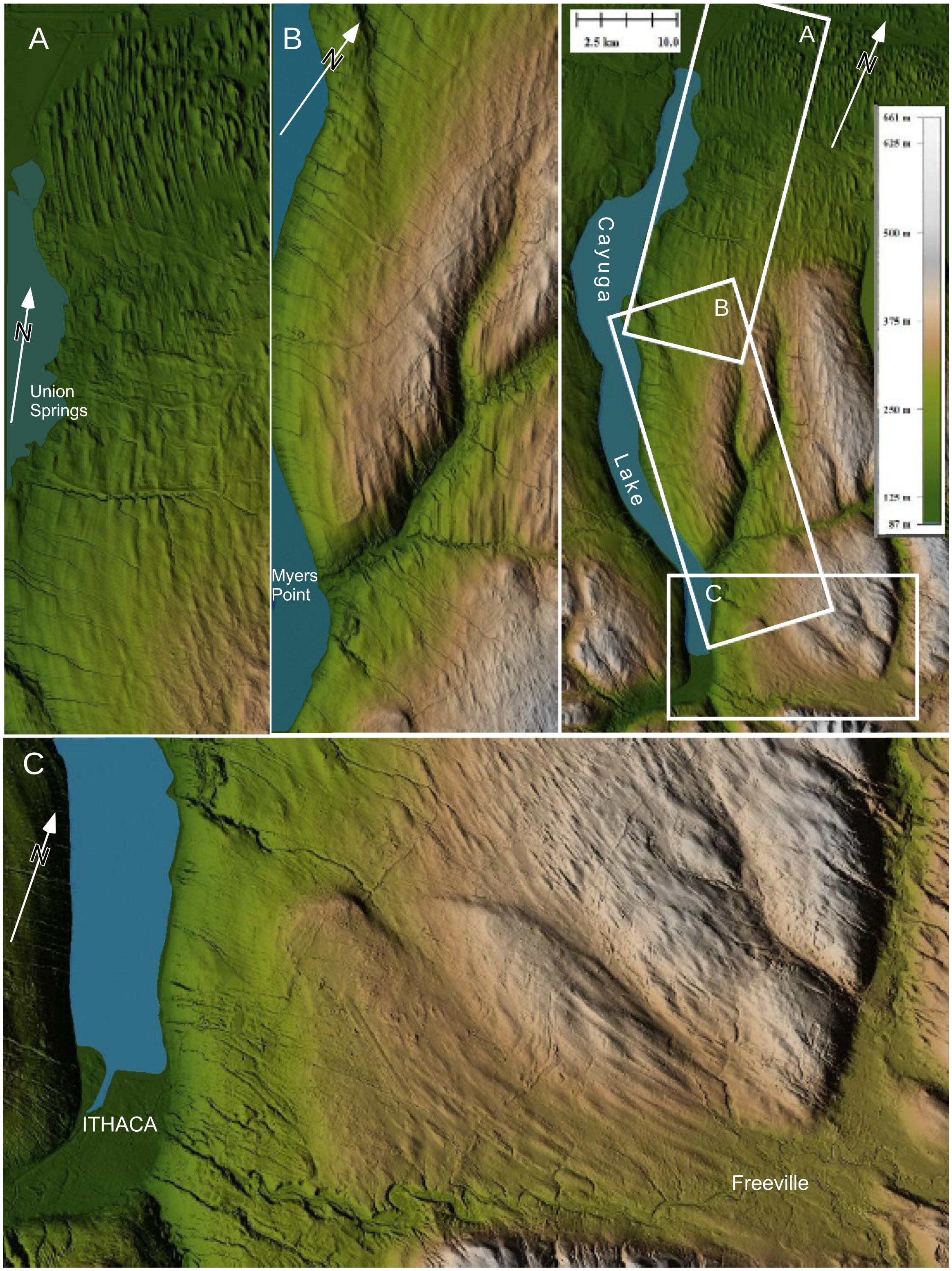


Fig. 3. Lidar hillshade montage from north of Cayuga Lake to the Fall Creek valley, showing the transition from drumlins in the north to MSG's in the south. These lineations are thought to mark the flow directions of ice during the Port Bruce Stade.

The chronology of the Valley Heads readvance is not well constrained and will undoubtedly prove complex because it involves a number of ice front oscillations. In the Cayuga basin and elsewhere in central New York the event began with an “advanced Valley Heads” phase (Muller,1964) during which the ice front advanced several km south of the location of the outwash fronts and moraines that marked a later, more stable Valley Heads front. There are no age constraints for the Valley Heads readvance in the Cayuga basin but extrapolations from western New York (Muller and Calkin,1993) and from the Mohawk Valley (Ridge, 2003) indicate that it peaked about 17ka ago.

The Valley Heads readvance is recorded by a till that lies on the surface in the uplands and in the Sixmile trough and below a kame and kettle unit in the northern section of the Cayuga Inlet valley. Closer to the Valley Heads front there are multiple tills and interbedded glacial deposits reflecting the ice front oscillation. Where this till is exposed it has a silty clay matrix, with very few clasts, and shows almost no internal deformational structure. In the uplands the surface of this till is patterned by drumlins in the north and by megaflutes further south (Fig. 3). These lineations generally parallel the Cayuga trough but swing eastward into the Fall Creek Valley, where the Valley Heads front has a more N-S orientation. These lineations seem to have been initiated during the Valley Heads readvance and show not only the direction of the ice movement but also indicate a high ice velocity during that advance (e.g. Briner, 2007). This suggests that the Valley Heads was basically a large-scale surge rather than representing a period of cooling, for which there is no climatic cooling signal at that time in the Greenland ice cores (Rasmussen et al., 2014).

If the Erie Interstade ice retreat was no further than the south end of Cayuga Lake, the readvance to the Valley Heads position in the Cayuga basin was only 20-30km (Fig. 1), rather than the generally assumed distance of 100 km or more (e.g. Ridge, 1997). However, the ice front oscillations mean that total southward movement of ice to the north of these oscillations was much greater than 20-30 km. The general Valley Heads readvance was followed by a phase of ice stagnation, which is manifested by the kame and kettle terrane in the Willseyville trough, by the proglacial lakes in the Cayuga Inlet Valley and by an area of kame and kettle terrane and eskers at the eastern prolongation of the Fall Creek Valley.

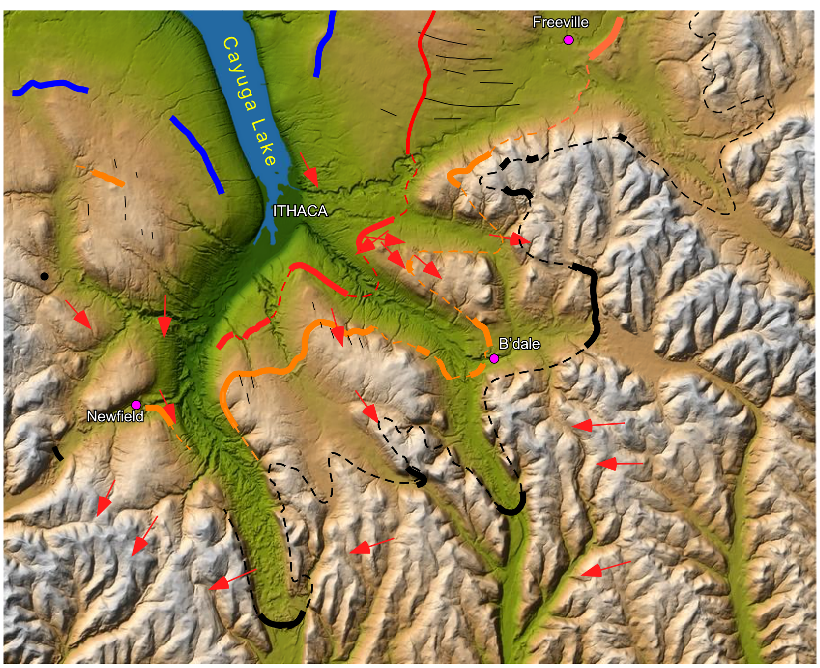
Brooktondale Readvance and Northward Subglacial Drainage

This period of general ice stagnation that followed the Valley Heads re-advance was punctuated by very minor re-advances, some marked by push moraines. One of the larger of these re-advances was of at least several km and was marked by a moraine that can be traced semi-continuously from the Sixmile-Willseyville trough into the Cayuga trough (Fig.4). This event has been termed the Brooktondale re-advance (Karig, 2015) and was interpreted to be correlative with the Hatfield event in the Connecticut Valley (Ridge et al, 2012) and the Little Falls advance in the Mohawk Valley (Ridge, 1992), which occurred about 16.3 ka, during the transition from the Port Bruce Stade to the Mackinaw Interstade. This would indicate that the period of general stagnation following the Valley Heads readvance was of the order of 700 years.

The Brooktondale re-advance marks a radical change in mode of deglaciation in the Cayuga basin. During the period between the Valley Heads and Brooktondale re-advances, drainage was southward. Following the Brooktondale re-advance drainage became northward, into the ice front (Karig,2015; Karig and Miller, 2018). Although this surprising and very controversial conclusion was first reached in the Harford-Dryden area (Miller,1993), and later in the Sixmile-Willseyville trough (Karig,2015), it was even more conclusively documented in the Cayuga Inlet Valley.

Evidence of drainage into the ice in the Sixmile trough after the Brooktondale readvance came first from recognition of an ice marginal channel that lies inside and parallel to the Brooktondale moraine but then turns clockwise (NW) and dissects the Brooktondale delta (Fig. 7 of field trip guide). This geometry demands that the channel would have fed surface water into the ice. Subsequently another channel, north of and erosionally truncated by the post-glacial Sixmile Creek was recognized as paralleling the Brooktondale moraine in that area and also feeding water from the upper Sixmile Creek drainage into the ice (Karig, 2015). Finally, a well-defined ice marginal channel along the southwest side of the Sixmile trough can been seen to have broken through the lateral moraine and fed water into and below the ice as a sub-glacial chute (Karig, 2015).

Transport of sediment in the Sixmile trough would have been under the ice and is probably the reason why there are no kames or kettles along this section of Sixmile Valley. It is also possible that erosion along this subglacial stream created the bedrock gorges in sections of the valley where degradation through the underlying till didn't follow the older, interglacial channels.



Moraines
(Solid,heavy where observed;
thin and dashed where interpolated)

Valley Heads (black)
Brooktondale (orange)
Un-named (red and blue)

Striations *(red arrows)*
(from Williams et al, 1909)

Megaflutes *(black lines)*
(from Lidar hillshade)

Fig. 4. Moraines around the south end of Cayuga Lake. Striae south of the Valley Heads readvance show that Nissouri ice advanced southwesterly whereas striae and megaflutes show that the Valley Heads ice moved generally along the valleys.

Northward subglacial drainage in the Cayuga Inlet Valley during the Mackinaw Interstade is strongly supported by field evidence, but with different characteristics than in the Sixmile trough. The southern section of the valley drained south, but the northern section, which is a more normal kame and kettle terrane, drains north (Fig.11 of field trip guide). This terrane is characterized by scattered ovoid kettles and flat-topped kames consisting of coarse clastics. The kames are largely constructed of cobble-sized clasts with a largely exotic provenance at the south but northward the clasts become finer, to gravel and sand sized and the composition becomes dominated by local lithologies. Because this section of the valley slopes northward, and because the kames reflect a surficial fluvial drainage, it must be concluded that this drainage was into the ice here as well as in the Sixmile trough. The boundary between the two sections in Cayuga Inlet valley seems to be coincident with the extension of the Brooktondale moraine into that valley, which supports the initiation of sub-glacial drainage here, as well as in the Sixmile trough just after the Brooktondale re-advance.

Further support for northward sub-glacial drainage came from recent multichannel seismic reflection profiles at the southern end of Cayuga Lake (Scholz, 2006; Commercial profile released to the first author, 2016) and from re-interpretation of data from water wells in the Ithaca area (Tarr, 1904). Earlier single channel seismic profiles in Cayuga Lake (Mullins et al, 1996) clearly elucidated the shallow sub-bottom Quaternary sediment section beneath the lake but these were much less successful in outlining the deeper section. Where Mullins et al. (1996) interpreted a southward thickening wedge of Valley Heads till at the south end of the lake, the multichannel profiles identify a sub-aqueous fan, sourced from the south (Fig. 5). Because this fan was the earliest post-Valley Heads deposit in the lake, at a time when the ice front was still to the south, this fan must have been a grounding line feature at the contact between the ice and a subglacial lake in the Cayuga trough. Karig and Miller (2018) have correlated this fan with the near-basal thick clastic unit in the deep water wells, described by Tarr (1904) as morainal till, but which does not resemble the kame sediments that are exposed not far to the south. It is most likely that this fan consists of sediment carried down the sub-glacial channel in the Sixmile trough and deposited at the grounding line, where the water velocity dropped after exiting the channel.

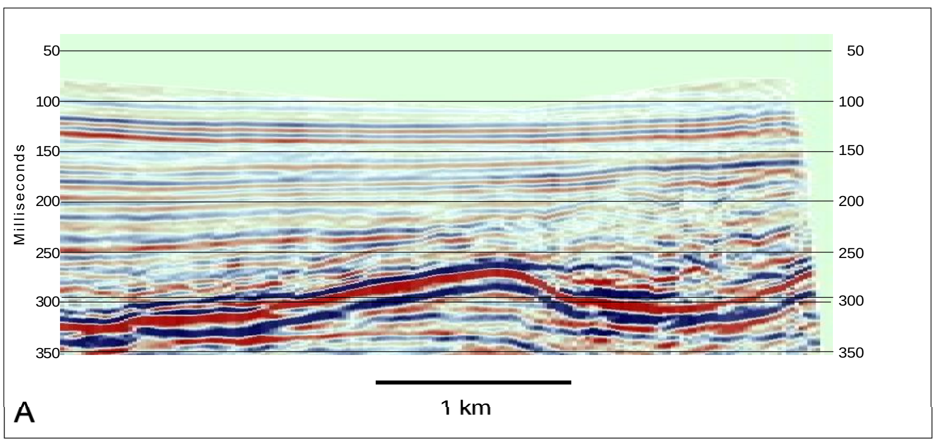
The obvious question arises as to where the water that drained into the ice front in the Cayuga trough went. The simplest answer is that it was a form of marginal drainage that penetrated deep

into the ice sheet but exited in the Mohawk Valley (Fig. 6), where the ice front at that time was at a lower elevation than at the entry points (Ridge, 1992). This solution is defended in greater

detail by Karig and Miller (2019, submitted) but it should be noted here that the maximum elevation along the drainage path up the Cayuga trough and eastward along the east branch of the Montezuma channels would have been less than 100m, after removal of post-glacial rebound. When the northward drainage changed from subglacial to proglacial as the ice front retreated, the proglacial lake level couldn’t have been any higher than the maximum along the drainage path, which would have precluded the existence of the high-level proglacial lakes Ithaca, Newberry and Hall in the Cayuga trough, as postulated by the Fairchild (1934) model.

Integration of Local and Regional Observations

Another question is how the ice front advances and retreats, as determined by regional information, fits the deglaciation scenario in the Cayuga basin. The retreat that defines the Mackinaw Interstade is thought to have peaked about 16.0 ka ago (Barnett, 1992; Mickelson and Colgan, 2003) with the ice front in the Ontario basin lowlands (Eyles, et al, 2011; Lewis and Todd, 2019). Such an ice front retreat would have led to drainage of the Cayuga trough through the Mohawk Valley, quite likely through the Syracuse channels, as suggested by Fairchild (1934). This retreat should or could have led to Fairchild's (1934) Cayuga 1, between his falling and rising Vanuxem Waters. The end of northward subglacial drainage would thus have had to end before the peak of the Mackinaw retreat. The elevation of the lake surface in the Cayuga Trough could well have stayed about constant, controlled by the bedrock high near Weedsport, during the Mackinaw Interstade retreat, rising slowly and slightly due to glacial rebound associated with the ice retreat. The northward ice retreat during the Mackinaw Interstade was halted and reversed by an ice re-advance of at least several 10's of km during the Port Huron Stade, which been described as a double advance with ages between 15.25 and 14.6 ka cal (Mickelson and Socha, 2017). The Port Huron re-advance in the



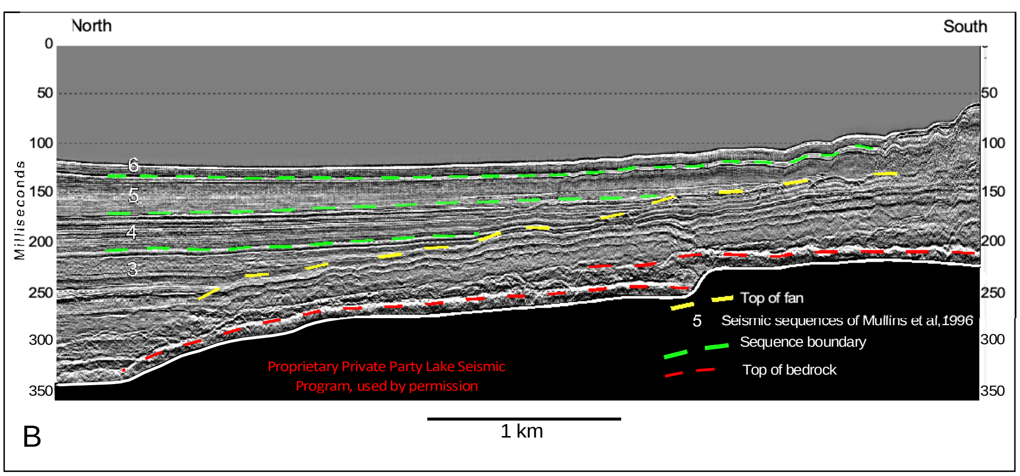


Fig. 5. Multichannel seismic reflection profiles along the axis of Cayuga Lake near its south end, showing a subaqueous fan sourced from the south. Profile A from Scholz (2006) and Profile B from a proprietary source, released to the first author. Seismic sequences from Mullins et al (1996) superimposed on Profile B.

Cayuga trough is suggested to have been back to the Mapleton moraine, just north of Aurora (Kozlowski et al., 2018). This moraine has an age of 15.1 ka, which places it well within the Port Huron age range. The rapid warmup at MWP 1 at 14.7 ka (Rasmussen et al, 2014) followed the advance associated with the Port Huron Stade and led to the Two Creeks Interstade which peaked between 13.8 and 13.5 ka. (Rech et al., 2012 and references cited therein). Proglacial Lake Iroquois formed during this time as ice retreated across the Ontario basin. Recent estimates indicate that Lake Iroquois, as defined by drainage down the Mohawk Valley, existed from 14.5 to 13 ka years ago (Anderson and Lewis, 2012; Lewis and Anderson, in press).

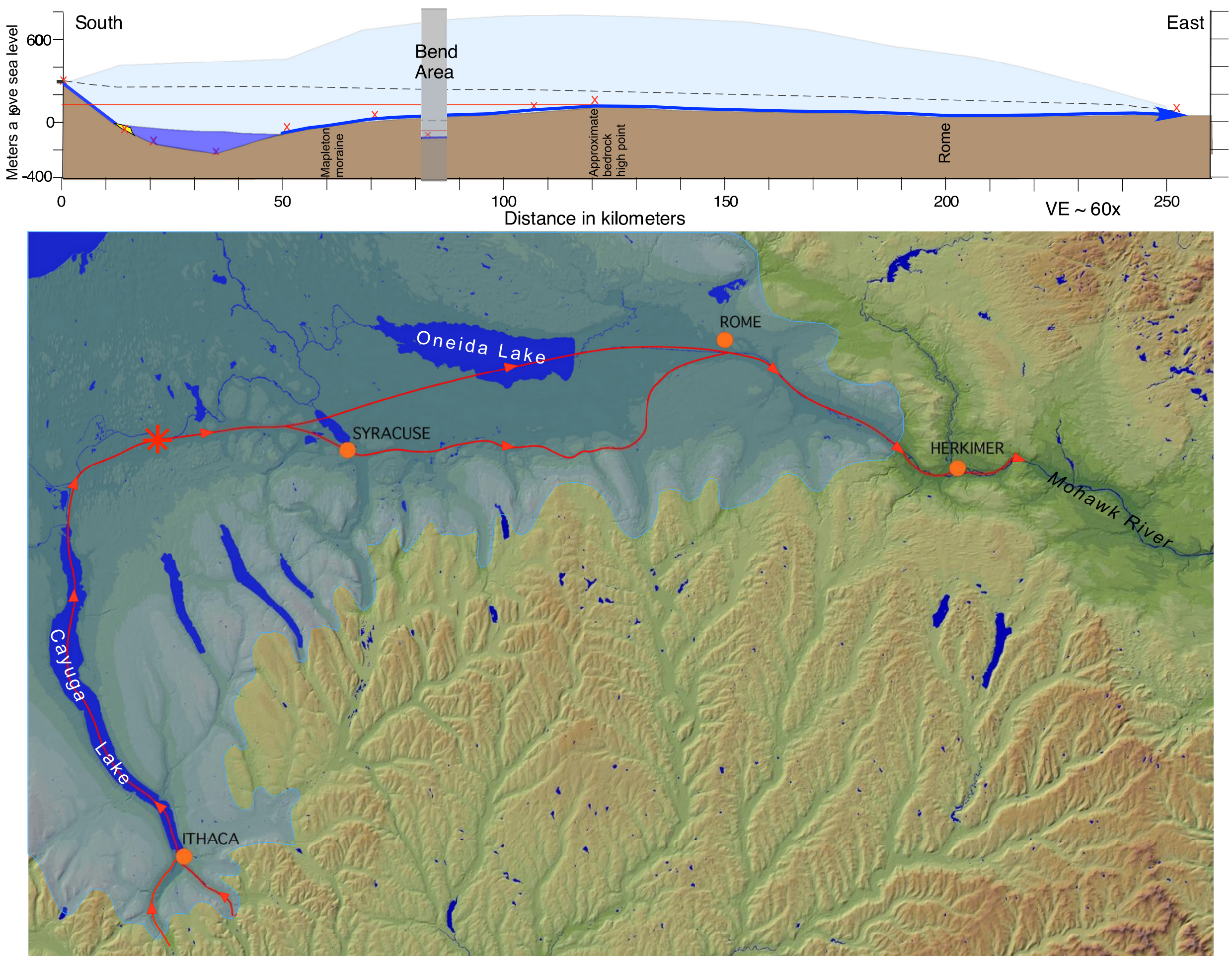


Fig. 6. Possible subglacial drainage paths during the Mackinaw Interstade (from Karig and Miller, submitted) and semi-quantitative profile along that path. Dashed line is the hydraulic surface along that path and red line is the level of proglacial lakes following ice retreat from subglacial lake stage. Drainage through a subglacial Lake Ontario is also possible.

This regional ice front history could well explain a number of features observed in the Cayuga basin. The Port Huron re-advance should have led to the flooding of the Cayuga trough to an elevation around Ithaca of almost 250m. This would explain the coarsening upward, post-till sequence in the lower Sixmile Trough (Karig, 2015) that occurs to about that elevation. In this area are several flat-topped erosional remnants of a sequence that begins with “finely laminated lake clays” (Rich and Filmer (1915) or fine sand (Karig, 2015) that coarsens upward to gravel and cobbles. The surface slopes of most individual erosional remnants of this sequence, as well as its overall slope, are 0.04 to 0.05, much steeper than that of the present Sixmile Creek (±0.01). This coarsening upward sequence is most likely the result of an advancal proglacial lake and the steeply sloping surface records a subsequent rapid lake level decrease. Both correlate nicely with a Port Huron readvance into the Cayuga trough followed by a rapid ice front retreat after the 14.7 ka warmup that led to the Two Creeks Interstade and to the formation of Lake Iroquois.

Flooding in the Cayuga trough to an elevation of about 250m correlates fairly well with Fairchild’s (1934) Lake Warren elevation at Ithaca of 242m, although Kozlowski et al. (2014) associate Lake Warren with the Waterloo moraine, which is north of the Mapleton moraine. Nevertheless, a proglacial lake blocked by an ice front along the Mapleton moraine would have had a suitable elevation to account for the lacustrine/deltaic sequence in Sixmile Creek. The deltas in Coy Glen (e.g. von Engeln, 1961), along Taughannock Creek (Kneupfer and Hensler,2000), and at the mouth of Buttermilk Creek in Inlet Valley (Williams et. al, 1909) very likely also formed during and following his period. Deltaic foresets are documented below elevations of about 240m, but sand and gravel deposits occur to elevations of at least 310m. These higher occurrences, which could well represent inwash and supraglacial fans, need further study.

The assumption of an approximate age of 15 ka for the peak of the Port Huron readvance in the Cayuga trough and the establishment of the Lake Iroquois water level at 14.5 ka leads to an rapid fall in lake level from that of Lake Warren to that of Lake Iroquois, which extended down the Cayuga trough almost to Ithaca where its surface elevation is now about 100m (extrapolated from Pair and Rodrigues, 1993). Such a rapid fall in lake level would explain the steeply sloping surface of the lacustrine/deltaic sequence in the Sixmile Valley and would have caused a large-scale drop in the local erosional base level, which should have been recorded in the deglaciation history. This record may be the coarse clastic unit that overlies the lacustrine section in the Cayuga Inlet Valley (Tarr, 1904; Lawson, 1977), which was associated by Tarr (1904) and Mullins et al., (1996) with some period of base level lowering. Tarr (1904) describes this unit as having a large number of logs and small mollusks and interpreted it as a stream or beach deposit. His well sections also show that the base of the unit varies in elevation among the wells by up to 25m. A similar variation in basal elevation of that contact was noted in recent boreholes just west of the junction of Sixmile valley with Cayuga Inlet Valley (Karig, 2015). Such a variable contact geometry suggests stream channel incision, resulting in an erosional disconformity between the coarse clastic unit and the underlying lacustrine sequence.

This coarse clastic unit was correlated by Mullins et al. (1996) with their seismic sequence 5, which would be a finer grained offshore facies, lying conformably on seismic sequence 4. Mullins et al. (1996) interpreted seismic sequence 5 as a "response to a drop in lake level" resulting from drainage reversal when the ice front retreated to the north end of Cayuga Valley, opening lake outlets to the north. They inferred that this drop in lake level was associated with the Syracuse channels (e.g. Hand, 1978), although these channels were probably used during several periods (Sissons, 1960).

The question is whether this coarse clastic unit was deposited during the base level drop between the Port Huron re-advance and the establishment of Lake Iroquois or following the base level drop when the Lake Iroquois surface fell during the shift in outlet from the Mohawk Valley to glacial Lake Vermont (e.g. Pair and Rodrigues, 1993; Donnelly et al., 2004; Rayburn et al., 2005). The Port Huron/Iroquois drop was of the order of 250m and should certainly have resulted in enhanced sediment transport. On the other hand, the post Lake Iroquois drop of more than 100m (e.g. Anderson and Lewis, 2012) did not extend to the Cayuga trough because of sills along the Seneca River, which isolated that trough from the Ontario basin. Clearly identified sills at Jack's Reef and Howland Island had elevations prior to canal engineering 5 to 6m higher than at present (William Kappel, USGS, Ithaca, NY, 2018, pers. comm.) and were less than 10m lower than the Lake Iroquois strand line elevation in that area (Bird and Kozlowski, 2014). Possible additional upstream sills would further reduce this difference, but, in any case, the base level drop in the Cayuga Trough following the outlet shift in Lake Iroquois was minor and would favor the association of the coarse clastics to the drop prior to the establishment of Lake Iroquois.

Differential isostatic uplift of the northern end of the Cayuga trough led to progressive southward transgression of the Cayuga Lake shoreline and to deposition of paludal and lacustrine organic silt and clay, which Mullins et al. (1996) correlated with their seismic sequence 6. Decreasing isostatic tilting and continuing sedimentation into Cayuga Lake from the south has caused southerly migration of the south shore to cease and even to reverse. This period, representing modern Cayuga Lake, spans most or all of the Holocene (e.g. Mullins, 1998).

A serious question remains concerning the chronology of the post Valley Heads deglaciation in the Cayuga basin. The demise of Lake Iroquois, the last of the proglacial lakes in the Cayuga trough, is dated at about 13 ka (Lewis and Anderson, in press). Mullins et al. (1996) concluded from radiocarbon ages of bulk samples of organic sediments at the south ends of several Finger Lakes, which were assumed to postdate the proglacial lakes, that the end of those lakes occurred at or before 15.6 ka. This is a great discrepancy with the 13 ka date of Lewis and Anderson (in press). Evidence detailed by Karig and Miller (submitted) demonstrates that bulk sample ages obtained by Mullins (1998) are about 2000 years older than wood ages from almost exactly the same location and the same depths. As has been clearly reported in the literature (e.g. Peteet et al., 2013, and references therein), radiocarbon ages from bulk sediment samples, as well as from aquatic plant samples are too old, often much too old. There is a desperate need for well-chosen and carefully dated material from all units within the Cayuga basin.

Conclusions

There are as yet no conclusions concerning the deglaciation of the Cayuga basin. The iconoclastic views presented above must be tested, not only in this basin but in other Finger Lakes basins of central New York. We would point out that recent studies in the Cayuga basin, using techniques not employed during the former studies and recognizing the behavior of modern ice sheets, resulted in no end of surprises-and that is continuing. We predict that studies similar to ours will produce equally surprising results in the other basins.

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Trip A1 b

FIELD GUIDE AND ROAD LOG

The objectives of this field trip are to visit some of the critical sites that led to the conclusion that there was northward subglacial drainage in the Cayuga basin during the Mackinaw Interstade as well as to show some sites that have not been on previous field trips. The trip officially begins at the Judd Falls (East Hill) shopping center parking lot in Ithaca.

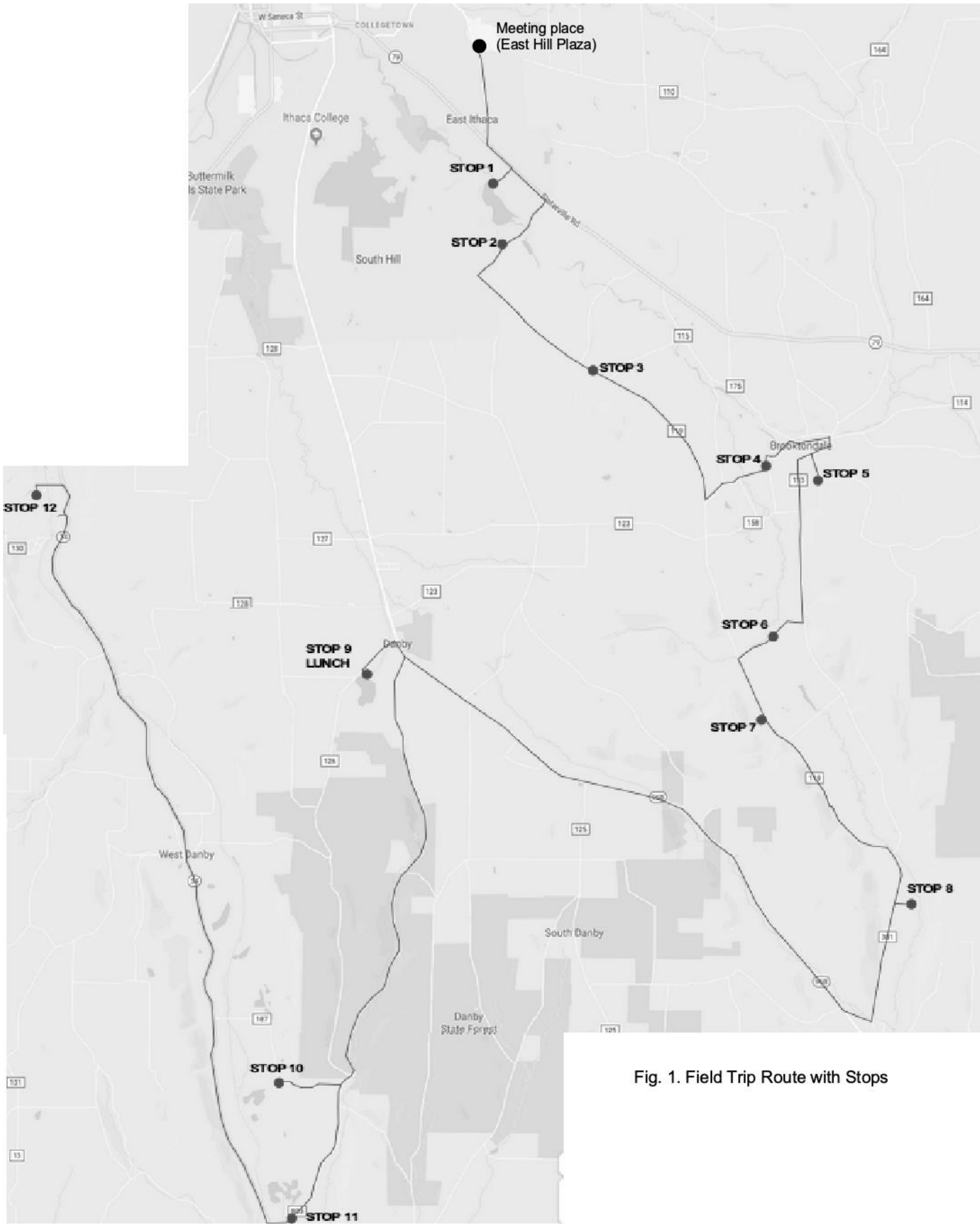

Fig. 1. Field Trip Route with Stops

The route to East Hill Plaza finishes along the Cayuga Trough, which follows a pre-glacial river valley that was oriented close to an ice flow line from the Laurentide ice sheet center. This trough was excavated by numerous ice advances-at least 4-but undoubtedly many more over the past 2 my. The Illinosian advance(s) seem(s) to have caused major glacial erosion in the trough, whereas the Wisconsin stage glaciation probably caused very little. Instead, it mostly cleaned out older Quaternary trough fill and deposited clay-rich till to the south.

Miles from last point	Cumulative mileage	Route description
0.00	0.00	Board bus at SW corner of the Judd Falls shopping center
1.34	1.34	Turn left through gate to Ithaca water supply dam (needs to be unlocked; with permission only)
0.26	1.60	STOP 1. 60' Dam, post glacial gorge,Interglacial gorge; Inner glacial trough

From the Judd Falls starting point we will go SE on Slaterville Rd (Rte 79) to the gate to the City reservoir and (with permission) go down the reservoir road to the 60' dam

(STOP 1). The dam was constructed in a post-glacial gorge of Sixmile Creek. The very narrow width at base of the gorge supports its creation during a single erosional cycle, but the present rate of erosion in the gorge wouldn't be sufficient for that creation. There must have been a period of much higher flow earlier, but how and why? I'm hoping for some ideas from the group, but I have an iconoclastic one.

The reservoir is in a very wide section of the valley, part of the large, probably Sangamon interglacial gorge, called the 600' gorge (Fig. 2). Its location at the dam site is just beyond the "rock island" that forms the south abutment to the dam. This interglacial gorge has been re-excavated downstream by the post-glacial Sixmile Creek except opposite the 30' dam (in another post-glacial gorge). Even further downstream another gorge (the interstadial 200' gorge) has been incised into the base of the 600' gorge and Van Natta's dam was built in a site where another post-glacial gorge formed outside this 200' gorge. The 600' gorge can be followed upstream in the subsurface using well and seismic data at least as far as Brooktondale. The entire gorge has a gradient much lower than the present stream gradient (Fig. 3).

A few feet above the 60' dam is a flattish bedrock surface. This is the base of the inner glacial trough, which was probably eroded by an Illinoian ice advance or advances. This bedrock surface has a U-shaped cross-section, the steep upper edge of which will be seen at stop 2 (Fig. 4). The gradient of this glacial trough is very similar to that of the interglacial gorge. This trough is filled by late Wisconsin till, and very locally by mid-Wisconsin deposits.

Miles from last point	Cumulative mileage	Route description
0.26	1.86	Return to St. Hwy 79, lock gate and turn right.
0.55	2.41	Turn right onto Burns Rd
0.91	3.32	STOP 2. East Hill Rec Way. Park along right side of road. Walk about 1/4 mile to RR fill over a trib to Sixmile Creek. Lip of inner glacial trough, Mid Wisconsinseds.

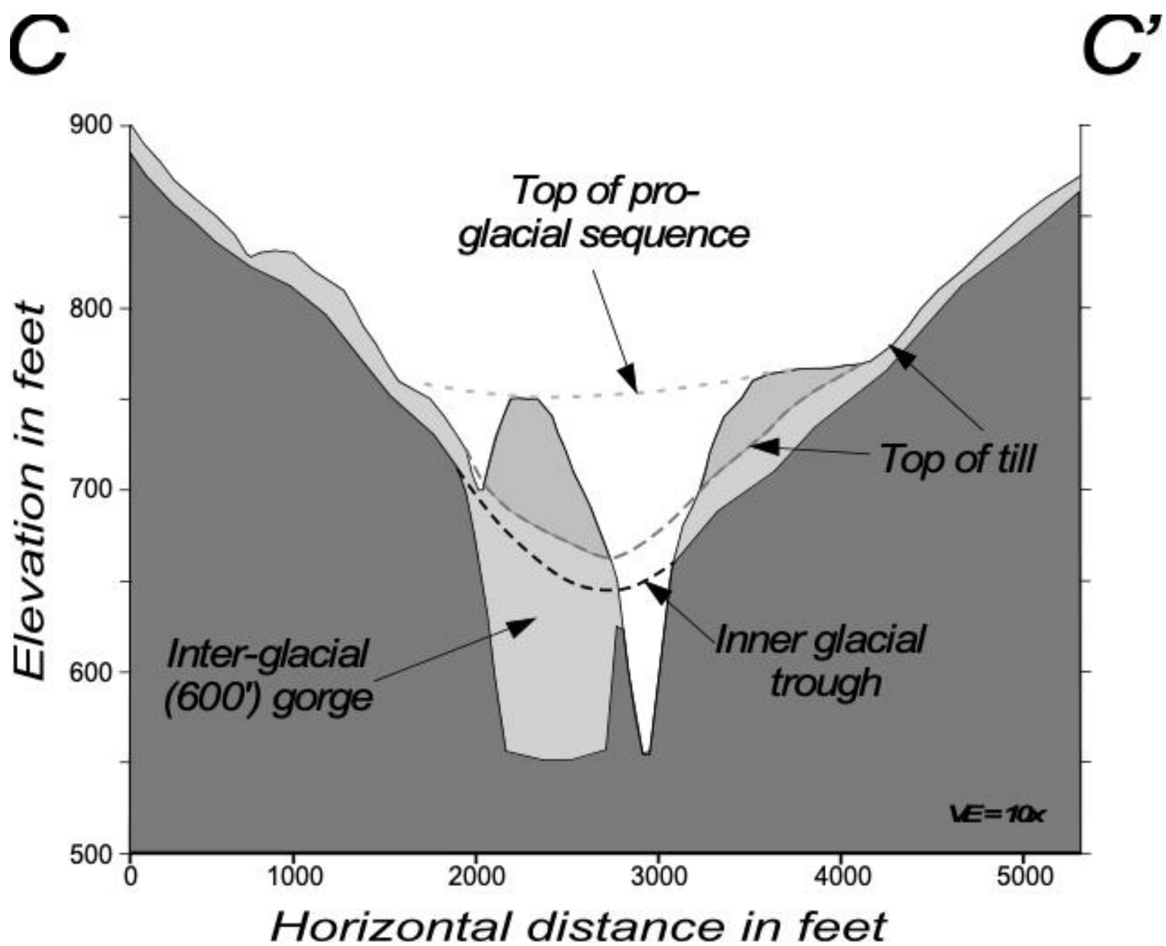

Fig. 2. Geologic section at 30' dam, but similar to that at 60' dam

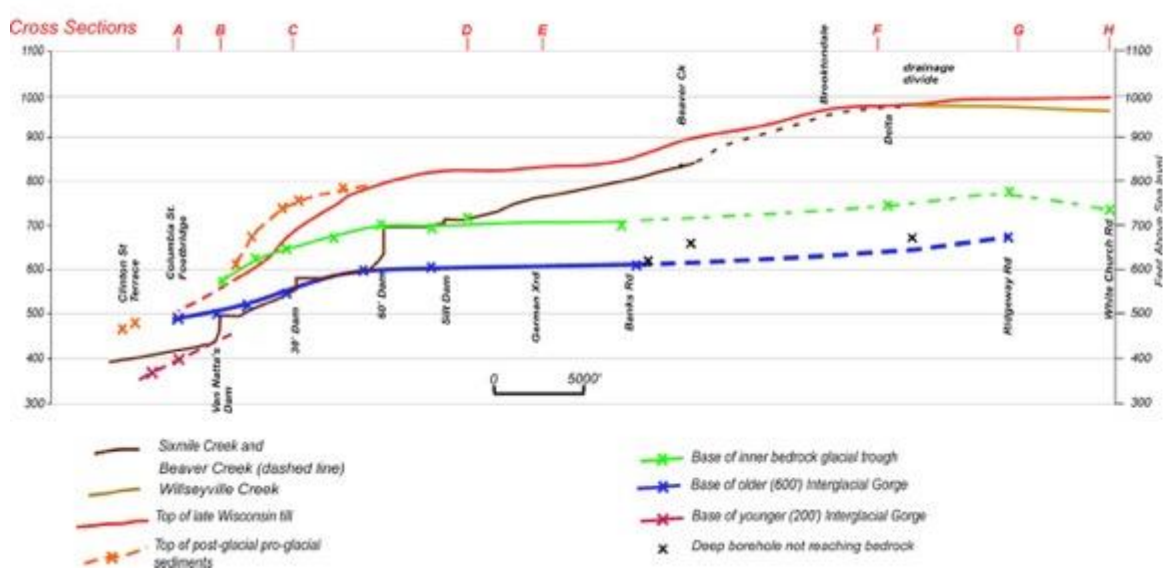

Fig. 3. Longitudinal section along the Sixmile-Willseyville Trough

Go back out the access road to Rte 76 (Slaterville Rd), turn right and and turn right again onto Burns Rd. Drive up the hill a parking spot along the right side of the road **(STOP 3).** An old RR grade, which is now the South Hill Recreation Way, meets Burns Rd at this point. Disembark and walk several hundred yards down the Rec Way to the large fill across a tributary to Sixmile Creek. Here we are on the bedrock lip marking the boundary between the inner and outer glacial troughs. The inner glacial trough is covered with mid-Wisconsin sediments just downstream of the gully crossing. Only a thin till covers a gently sloping bedrock above the lip.

Miles from last point	Cumulative mileage	Route description
0.21	3.53	Continue on Burns Rd to Coddington Rd and turn left
1.12	4.65	**Stop 3**(brief). View of Outer glacial trough and nature of Sixmile trough

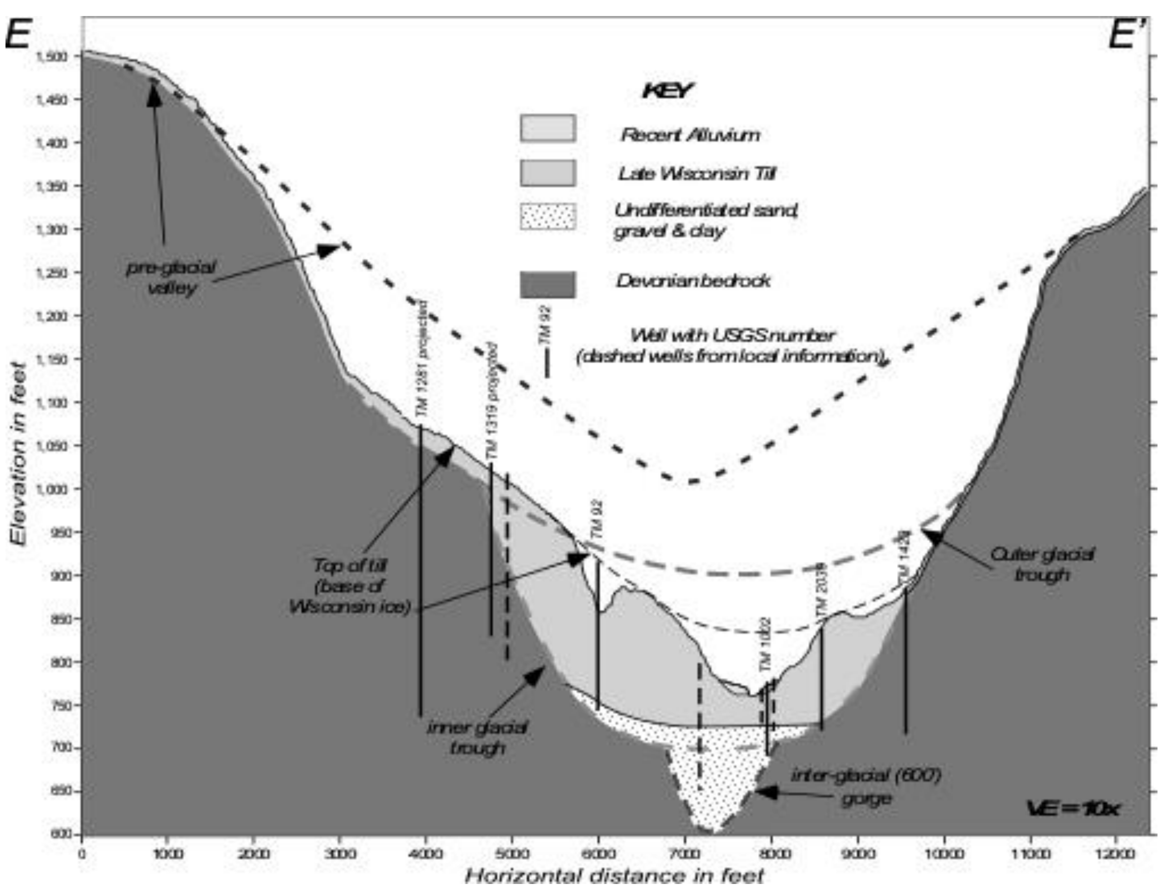

Fig. 4. Geologic Section across the Sixmile Trough at German Crossroad

Return to the vehicles and continue up Burns Rd and turn left (southeast) along Coddington Rd to point where there are open fields on both right and left and before reaching the large farmhouse on left. **STOP 3**.

Here we can look up upper Sixmile Valley to the left. Upper Sixmile is a subsidiary glacial valley that "hangs" above the main Sixmile-Willseyvile trough, which lies straight ahead and curves to the right (south). We are parked on the outer glacial trough (Fig. 4) and the smooth concave upward shape can clearly be seen. Bedrock is basically parallel to the surface with a thin cover of Late Wisconsin till. There are no kettles or kames along the Sixmile trough, in sharp contrast to what we will see along the Willseyville trough. Above the steep upper slope of the outer glacial trough the topography is much flatter and more subdued and has been interpreted as pre-glacial with only very mild modification by glacial erosion even though late Wisconsin ice was quite thick even there. Several reasons for this lack of erosion can be suggested, including a thinner ice cover, slower ice movement and cold-based ice.

Miles from last point	Cumulative mileage	Route description
1.49	6.14	Continue on Coddington Rd and turn left on Middaugh Rd
0.27	6.41	Continue straight onto (dirt) Beaver Brook Rd. No sign here
0.56	6.97	Continue on Beaver Brook Rd and stop in front of Gravel pit office (**Stop 4**) Discussion of Brooktondale delta

Continue east on Coddington Road to Middaugh Rd and turn left (north). Go down Middaugh to where it turns 90° left-and go straight. This is Beaver Creek Road, although there is no sign. Continue down Beaver Creek Rd, across Beaver Creek and up to the dirt road junction in front of the University Sand and Gravel Co office (a trailer). **STOP 4.** In front of us is the Brooktondale delta, where foreset beds could formerly be seen on the west-facing quarry headwall (Fig. 5).

Fig. 5. Foresets in the Brooktondale Delta

Before gravel extraction removed most of this delta it had a surface elevation ranging from about 1020 at its eastern head to about 1010' at its outer, western margin. The delta was interpreted by Tarr and von Engeln to have formed in an early proglacial Lake Brookton and continued to develop into the larger Lake Ithaca, with an outlet through the Willseyville channel at 980'. This interpretation cannot be correct because one or more tills occur within the deltaic sequence (Fig. 6) and the delta is overlain by yet another till, which marks a post Valley Heads re-advance. The delta fed sediment into an ephemeral lake that formed at the junction of the two arms of the glacier, which still occupied the Sixmile trough. This re-advance is marked by a very well-preserved moraine, which I've named the Brooktondale re-advance, the moraine for which can be easily traced into Cayuga Inlet Valley (Fig. 4 of preceding article).

Miles from last point	Cumulative mileage	Route description
0.38	7.35	Drive east from pit office on Valley Rd to Brooktondale Rd and turn right
0.43	7.78	Drive east on Brooktondale Rd and turn right onto White Church Rd.
0.27	8.05	Drive south and west along White Church Rd to Bald Hill Rd and turn left
0.22	8.27	Drive along Bald Hill Rd to **STOP 5.** We will discuss the ice margin channel here and then walk to the Brooktondale moraine and look at the head of the channel that led into the ice front at that time

Fig. 6. Till within foresets of the Brooktondale delta

Follow the directions above to the first hard left turn along Bald Hill Rd This is where a large and long known “ice margin” channel swings around the nose of Bald Hill. It isn’t truly an ice margin channel because the outer side is a till moraine, which appears to mark a segment of the Brooktondale readvance moraine. The channel here is a linear pond because the downstream end is blocked by an alluvial fan that emanates from a small drainage, but the channel continues southward and can be followed into the kame and kettle terrane south of the delta. We’ll walk a short distance south along this moraine, crossing the present outlet to the pond where bedrock is often exposed. We’ll stop where we can overlook the head of the enigmatic channels that start “inside“ the moraine and swing almost 180” clockwise and cut through the delta. Gravel removal has destroyed the evidence of some of this path but aerial photographs taken before gravel mining began clearly show that the channel crosses the delta (Fig. 7)

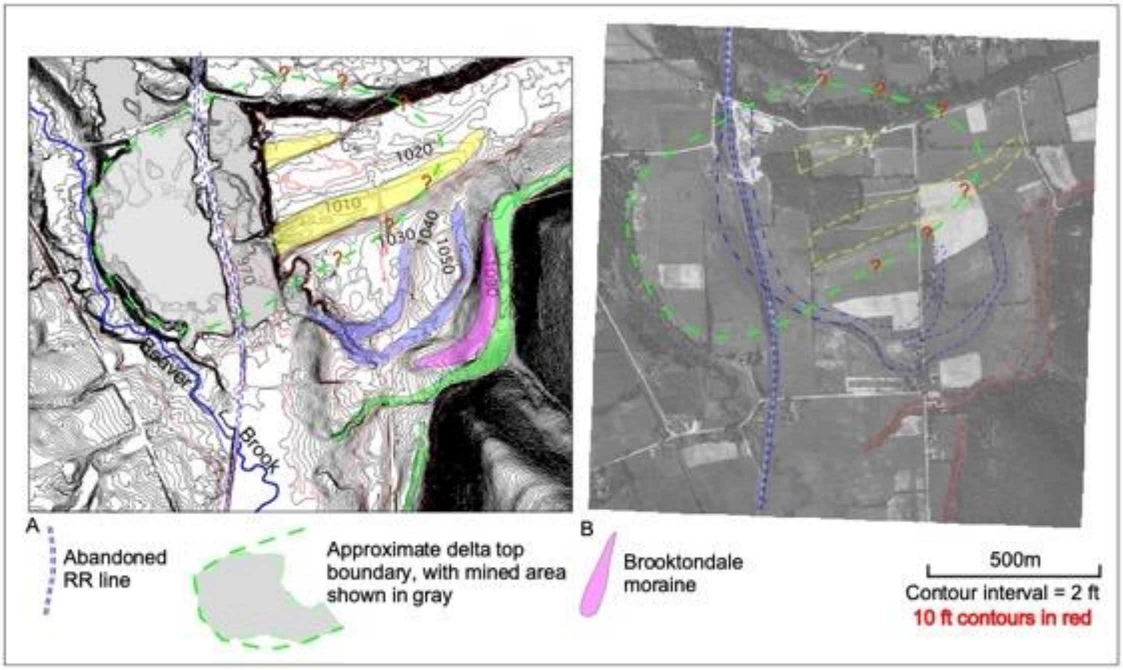

Fig. 7. A. Lidar 2' contour topographic map of the area around the Brooktondale delta. The Lidar topography shows an ice margin channel (red) that debouches into the kettle kame terrane, two fluvial channels (yellow) that fed the delta and the enigmatic channel pair (blue) that begins on the till slope and swings clockwise more than 90° as it approaches the excavated area of the delta. B. 1936 aerial photograph, taken immediately after the railroad line was abandoned and before gravel mining, showing that the enigmatic channel continued across the delta and into the ice front. This channel is more clearly defined on a stereographic pair of photographs but can be observed by the cut along the railroad line as it crosses the southwestern side of the channel.

Miles from last point	Cumulative mileage	Route description
0.22	8.49	Return down Bald Hill Rd to White Church Rd and turn left
1.78	10.27	Drive west along White Church Rd and turn right onto Belle School Rd..
0.26	10.53	Drive north on Belle School Rd to **STOP 6** (brief). Discuss the 980' Lake Ithaca spillway and the Willseyville channel.

Go back to White Church Rd. and turn left (south), noticing the irregular surface of the trough. This reflects the many kettles and kames along this section of the trough. The road is built on a degraded kame terrace. Turn right (west) on Belle School Rd and briefly **STOP 6** at the bottom, where the old RR line crosses. We are in the Willseyville channel, an outlet from the lake into which the delta was built. Tarr and von Engeln identified it as the outflow to a proglacial Lake Ithaca at 980'. However, the 980' elevation is that of a recent alluvial fan that enters the trough from the west here and also created the present drainage divide. A series of hand driven cores along the channel showed that its high point is well to the south and at an elevation of about 965' or less.The typical aspect of the channel cannot be seen from roads crossing the valley because all these were built on alluvial fans-for obvious reasons. Access to the channel is very difficult except where sections of the RR line have been cleared as trails (e.g. Fig. 8). The channel was more likely the result of one or more glacial lake outburst floods (GLOFs) from Lake Brookton.

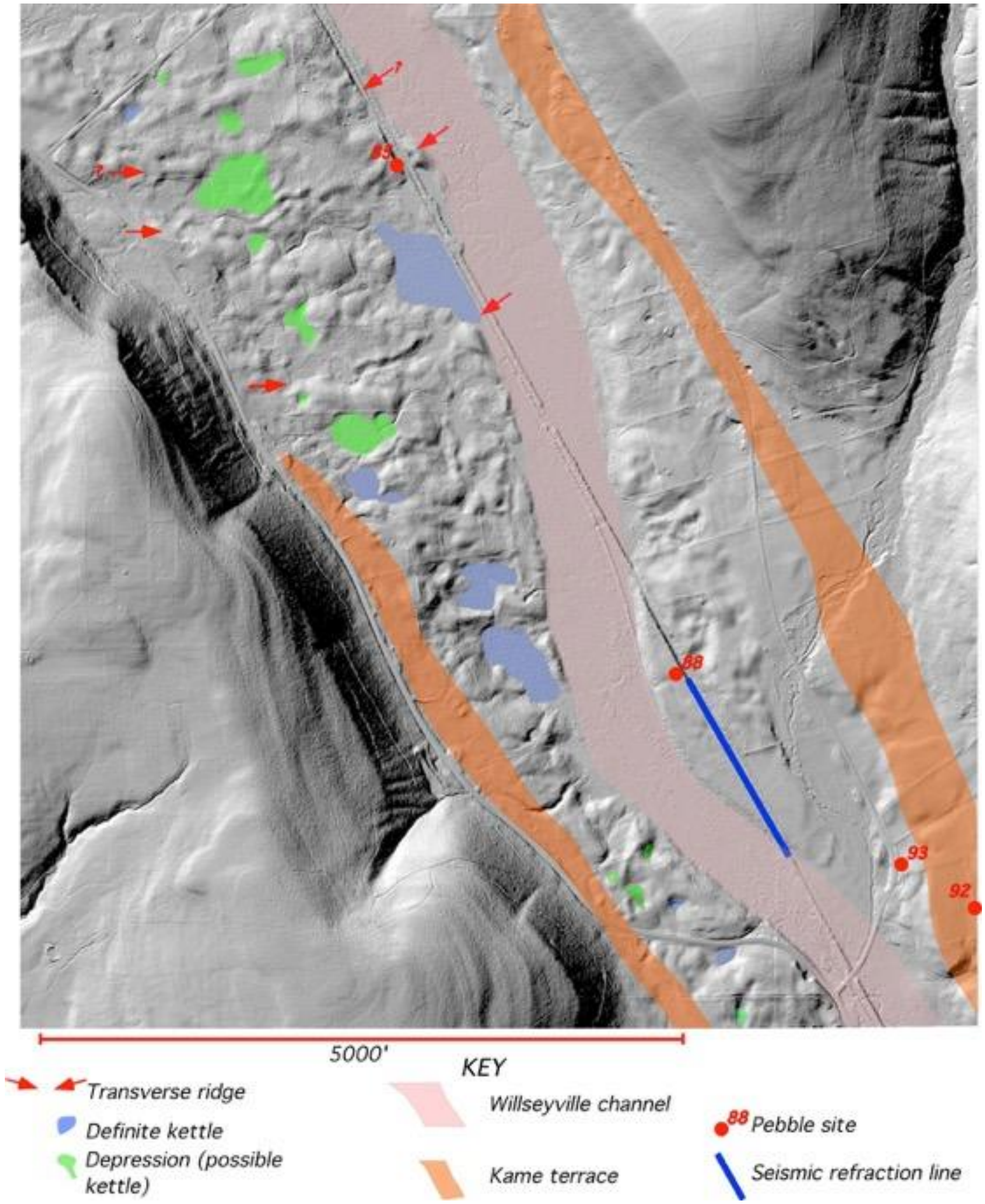

Fig. 8. Willseyville channel and kettle kame terrane

Miles from last point	Cumulative mileage	Route description
0.60	11.13	Continue north on Belle School Rd to Coddington Rd and turn left
0.39	11.52	Drive south along Coddington Rd to **STOP 7** for a brief look at truncated spurs that mark the original drainage divide of this through valley

Continue along Belle School Rd to Coddington Rd and turn left (south). **Stop 7** is just north of Ridgeway Rd. This section of the Willseyville Trough is flanked by two very well-developed truncated spurs, which mark the pre-glacial drainage divide, Repeated ice flow over the drainage divide cleaved the ends of ridges forming the divide and eroded it from an elevation about 1600’ to about 700’, which is the bedrock elevation established by a seismic refraction line along the railway line in the center of the valley (Fig. 8). This one of the best developed “through valleys” in the region.

Miles from last point	Cumulative mileage	Route description
2.44	13.96	Continue south along Coddington Rd to the junction with White Church Rd and continue on Coddington Rd
0.82	14.78	Continue south along Coddington Rd to **STOP 8**, the entrance to the Sultana gravel pit. Distances within the pit complex are not calculated. Here we will look into the pit to see it’s internal framework.We’ll then walk aross the outwash plain and look into the Willseyville channel

Two large kettles just past the junction of Coddington and White Church roads are located just behind (north) of the Valley Heads head of outwash. No end moraine is seen here but one may be buried in the thick outwash to the south. Continue on Coddington Rd past the intersection with White Church Rd to the entrance to the Sultana gravel pit. Note the remarkable flatness of the outwash plain. Enter - with permission.

STOP 8. The gravel pit exposes about 80’ of outwash (sand to cobble size) and also a till, which is seen on the north face of the quarry (Fig. 9). This till represents an ice front oscillation before its longer pause at the head of outwash location. The Willseyville channel here is near the east side of the valley floor and is deeply incised into the outwash. Incision decreases southward until the channel merges with the outwash valley train.

Fig. 9. North wall of the Sultana Gravel Pit showing till within outwash

Miles from last point	Cumulative mileage	Route description
1.08	15.86	Continue south along Coddington Rd to junction with Willseyville Rd and turn right.
0.31	16.17	Continue the short distance to St. Hwy 96 and turn right
6.57	22.74	Drive north along Hwy 96 to Bald Hill Rd in the Village of Danby
0.50	23.24	Go southwest on Bald Hill Rd to Jennings Pond (Buttermilk State Park). We'll have lunch there. Also rest rooms.

Continue south on Coddington Rd. This section can be termed a valley train-an extension of outwash. Go to the T junction with Willseyville Rd and turn right (north). At the junction with 96B bear right (north). Follow 96B north into Danby and turn left on Bald Hill Rd, and left again into Jennings Pond S.P. We will have lunch there (also toilet facilities).

After lunch we will return to Danby (96B), turn right (south) and go to Michigan Hollow Rd. (next road) and follow it south, down Michigan Hollow to Hillview Rd, where we enter the Cayuga Trough, one of the largest and the lowest of the Finger Lakes glacial Troughs. Michigan Hollow was a glacial overflow route but also contained a short-lived pro-glacial lake.

Miles from last point	Cumulative mileage	Route description
0.50	23.74	Go back on Bald Hill Rd to Danby (Rte 96) and turn right
0.21	23.95	Drive south on Rte 96 to Michigan Hollow Rd and turn right.
5.10	29.05	Follow Michigan Hollow Rd (mostly dirt) to Hillview Rd and turn right
0.68	29.73	Go west on Hillview Rd to the 90° turn to the north (right) **STOP 10.** Here we'll discuss the local wetlands and nature of the end moraine

STOP 10. A short detour to the right on Hillview road will show us a very-well preserved kame terrace that is shown with Lidar topography to slope southward and documents glacial outflow in that direction, at least initially (Fig. 10). The topography in this area is grossly flat with a very large percentage of depressions, largely water filled. This southern section of the Cayuga Inlet Valley differs from the more northerly kame and kettle terrane in having these larger and irregular shaped wetlands as well has having uplands that consist mostly of clay and silt rather than cobbles. Coring in the wetland just to our south recovered a tundra flora dominated by Dryas integrifolia, very different from the boreal flora in kettles to the north. We don't yet have reliable ages on the Dryas leaves but it appears that the wetlands represent small proglacial lakes that succeeded supraglacial lakes that left the silt/clay deposits after meltout and topographic inversion. At least one recessional moraine crosses this area, just north of our stop, and there may be more further north.

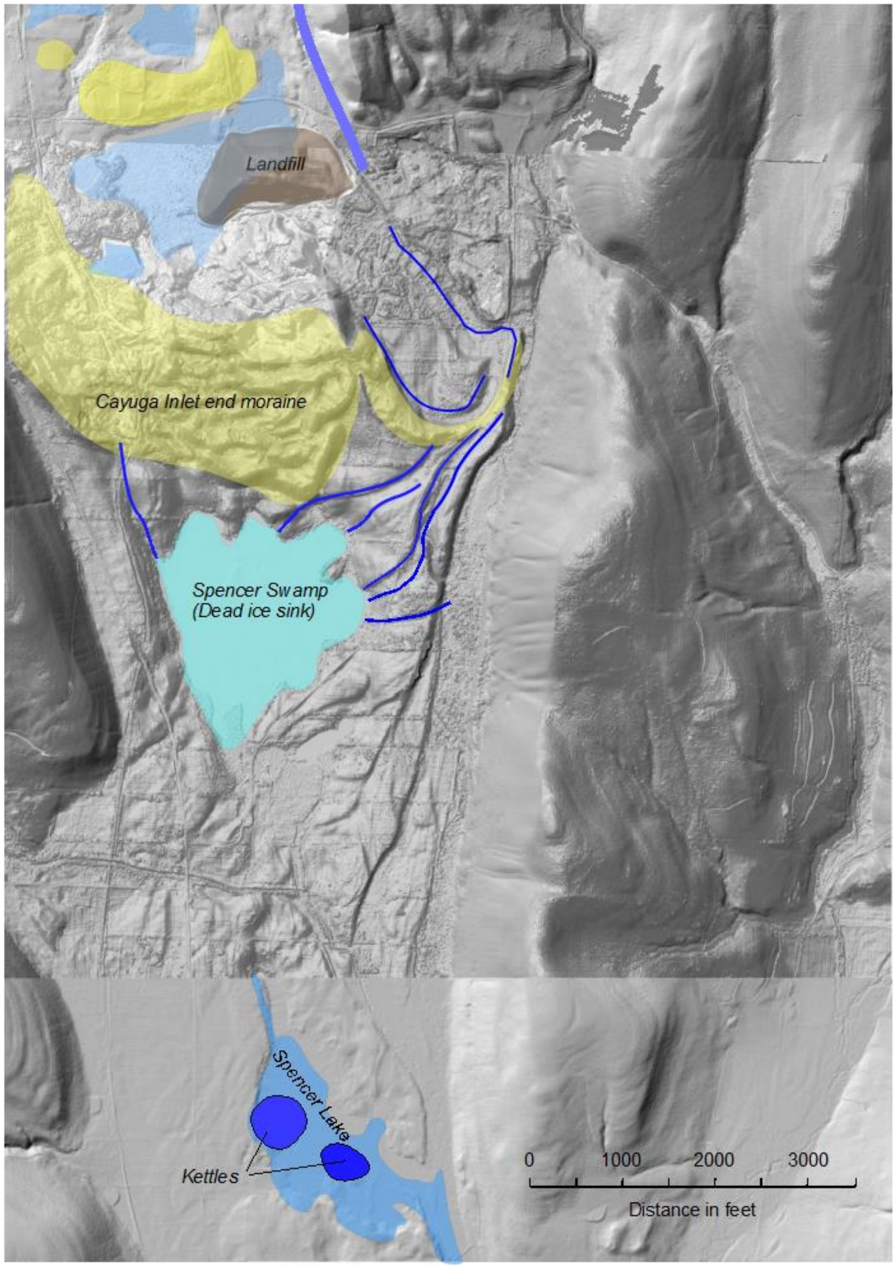

Fig. 10 Lidar hillshade of the Valley Heads area

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Driving back south on Michigan Hollow Rd we cross a number of glacial outflow channels that empty into Spencer Swamp, a nearly valley-wide depression, termed by Jay Fleischer a dead-ice sink (Fig. 10). This represents a large tract of ice that stagnated when the active ice front jumped north to the location of the end moraine Coring in the Spencer Swamp recovered a section of tan marl beneath peat, with a basal ^{14}C age of 12.35ka, which was initially surprisingly young. It is now realized that almost all bog bottom ages in central New York are about this old and (I think) represent a melt out following the marked warmup associated with MWP-1.

Stop 11 at the southern edge of Spencer Swamp. Here we will discuss the Advanced Valley Heads phase, which in Inlet Valley extended at least to Spencer Lake, a dammed group of at least 2 kettles. The Valley heads re-advance in general correlates in time with Heinrich Event H-1 and may represent a "purge" in a binge-purge sequence thought by some to be responsible for H events.

In the distance, north of Spencer Swamp, is the main end moraine of the Valley Heads re-advance. The outwash plain is not as smooth at that in the Willseyville Trough, with a number of low hills. These are kames from the Advanced Valley Heads phase.

Miles from last point	Cumulative mileage	Route description
0.68	30.41	Go back (east) on Hillview Rd to Michigan Hollow Rd and turn right
2.09	32.50	Follow Michigan Hollow Rd to Rtes 34/ 96. Few pauses along way to point out things
8.70	41.20	Follow Rtes 34/96 north to Shelter Valley Rd and turn left. Few things pointed out on the way.
0.87	42.07	Go to end of Shelter Valley Rd and turn left on South Rd. Go to end and park. With permission we'll walk several hundred yards to a huge exposure of Erie lacustrine sediments ,which overlie till over bedrock (a nice waterfall) **STOP 11**

Continue on Michigan Hollow Rd to Hwy 34/96 and turn north. The road passes the end moraine (ridge behind the trees) through an outwash channel (sort of a kame terrace) and skirts a section of Inlet Valley full of kettles and kames. Several kettles are seen in the vicinity of the Lindsay-Parsons Preserve of the Finger lakes Land Trust, but there are many more off the road.

Somewhat past the wide spot in the road called West Danby the road crosses Inlet Creek several times. Along the creek here a terrace has developed which increases in width downstream (northward). By the time the road reaches Shelter Valley Rd, where we turn left, this terrace occupies nearly the entire valley floor. I speculate that this terrace started to develop when the local erosional base level fell, which would have occurred when there was a significant drop is the level of proglacial lakes in the Cayuga trough. The largest such drop, in my scheme of things, would have been from that of Lake Warren to that of Lake Iroquois (>800'). The earlier association of this drop with the drainage of Lake Iroquois cannot be valid because Cayuga Lake formed at this time behind several sills, which resulted in a base level drop of 30' or less.

The base level drop caused not only stream degradation but construction of a delta/flood plain assemblage at the south end of proto Cayuga Lake manifested in the seismic data as seismic sequences 5 and 6 of Mullins et al (1996) and in Cayuga Inlet Valley as the organic silt and clay and underlying gravel in wells.

Stop 12. Park at the end of Shelter Valley Rd and walk several 100's of ft to the base of the falls at the bedrock edge of the glacial trough. Bedrock is covered by a thin till most probable of Nissouri (Late Wisconsin max) age. This till lies below a very thick lacustrine section of an Erie Interstade pro-glacial lake that had not been recognized as such until my fieldwork.

The lacustrine sediments here are strongly deformed, especially in the lower part of the section because of slumping down the steep Erie proglacial lake slope (effectively the bedrock trough flank). Higher in the section thin slump units are interbedded with thinly, and well bedded strata. Although pro-glacial lake sediments are notoriously free of plant material, the thin slump units have plant macro "fossils", which denote an herbaceous tundra environment. We are having problems with dating these plants, but one Dryas integrifolia sample gave a ^{14}C age of 15.2 ka, documenting the Erie Interstade age of the proglacial lake. This lacustrine section is overlain by a thin Valley Heads till, which is covered by kame and kettle deposits.

These lacustrine clays and fine sands are observed in many places below the terrace gravels in the valley floor and in a number of large exposures at the edge of the valley. They were also penetrated in water wells and are shown on the seismic section run along Shelter valley Rd (Figs. 11 and 12). This seismic section shows that there is a thick till and probably even older lacustrine strata beneath that till. The subsurface data now available in Cayuga Inlet Valley shows that the Valley Heads deposits are only very small fraction of the total Quaternary section in the valley (Fig. 11). These data also show that there is a bedrock sill just south of Ithaca which separates very different Quaternary stratigraphic sections. To the south there is a thick pre-Valley Heads section, whereas to the north the entire Quaternary section is post Valley Heads.

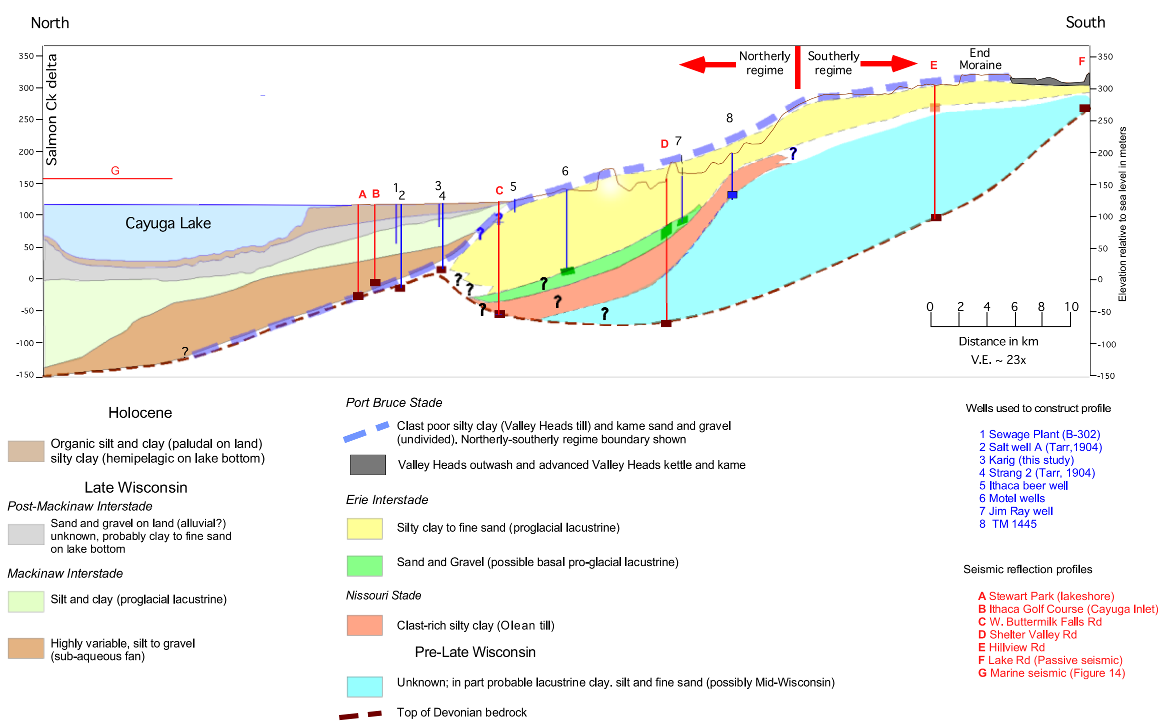

Fig. 11. Composite geological section along Cayuga Inlet Valley

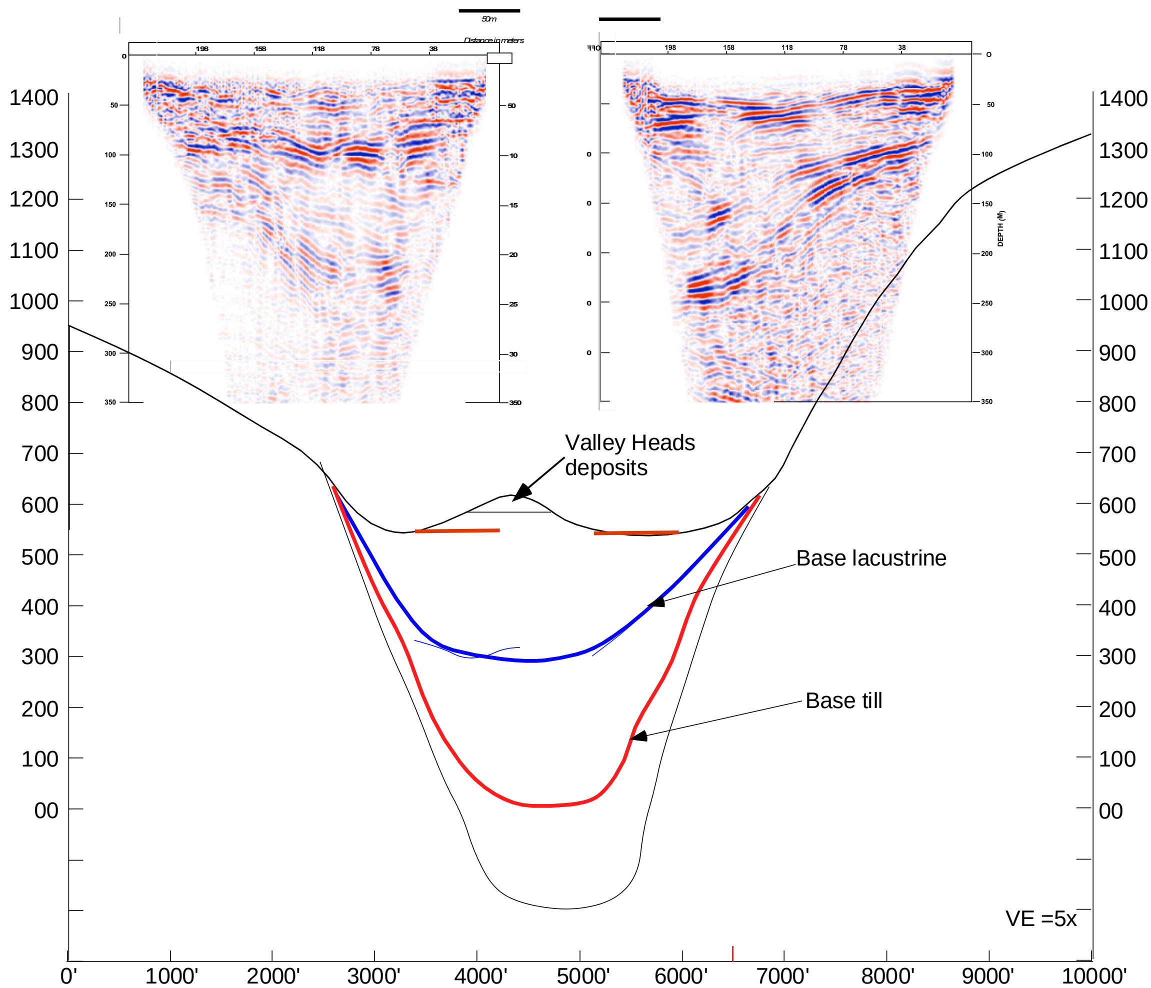

Fig. 12. 64 channel seismic reflection depth section along Shelter valley Rd

Miles from last point	Cumulative mileage	Route description
0.87	42.94	Go back (east) on Shelter Valley Rd to Rtes 34/96 and turn left (north)
0.70	43.64	Drive north on Rte 34/96 to Blakeslee Hill Rd and turn right
2.10	45.74	Follow Blakeslee Hill Rd, past Townline Rd, where the road name becomes W. Jersey Hill Rd, to West King Rd and turn left.
0.51	46.25	Drive north on W. King Rd to Yaple Rd and turn right
0.65	46.90	Follow Yaple Rd to Comfort Rd and turn left
0.73	47.63	Follow Comfort Rd to Rte 96B and turn right
0.30	47.63	Follow Rte 96B south and turn left on Nelson Rd
0.65	48.28	Drive east on Nelson Rd to Ridgecrest Rd and turn left
0.95	49.23	Drive north on Ridgecrest Rd and turn right on E. King Rd.
0.96	50.19	Drive east on E. King Rd and turn right on Coddington Rd
0.15	50.34	Drive east on Coddington Rd and turn left on Burns Rd.
1.11	51.45	Drive north on Burns Rd. to Rte 79 and turn left
0.86	52.31	Drive northwest on Rte 79 and turn slightly right on Pine Tree Rd
0.98	53.29	Drive north on Pine Tree Rd to the Traffic light-and the parking lot is just to the north