86TH ANNUAL
Field Conference of Pennsylvania Geologists

DATING IN THE PLEISTOCENE

Establishing a Glacial Chronology in Northwestern Pennsylvania

October 6 — 8, 2022
Titusville, PA

HEADQUARTERS: Cross Creek Resort
3815 State Route 8, Titusville, PA 16354
814-827-9611

FEATURING • Erie Bluffs • Edinboro Lake • Conneaut Lake-Marsh system • Vincent Pit • McConnells Mill • Slippery Rock Gorge **HIGHLIGHTING** • OSL & thermoluminescence dating • kames & eskers • sand & gravel pits • paleoshorelines & ancient deltas • buried bedrock valleys • moraines & more

TRIP LEADERS & GUIDEBOOK CONTRIBUTORS

Gary Fleeger • Pennsylvania Geological Survey *(retired)*

Frank Pazzaglia • Lehigh University

Eric Straffin • PennWest University Edinboro Campus

Fred Zelt • Earth Science Excursions LLC

Aaron Bierly • Pennsylvania Geological Survey

Duane Braun • Prof Emeritus Bloomsburg University

Jocelyn Spencer • Glacial Sand & Gravel Co.

Gary D'Urso

Todd Grote • Indiana University of Pennsylvania

Brian Zimmerman • PennWest University Edinboro Campus

Katie Tamulonis • Allegheny College

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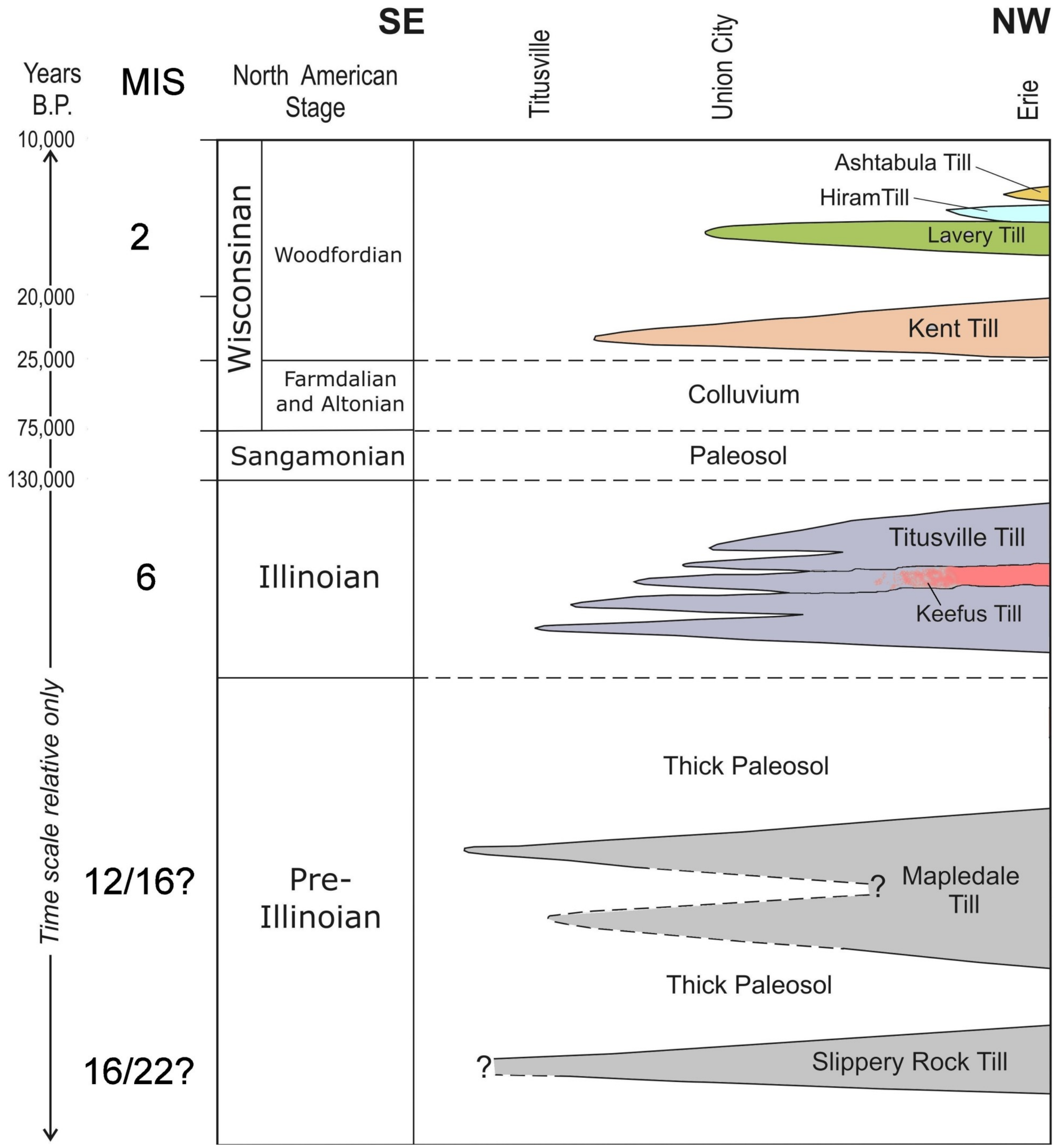


PLEISTOCENE STRATIGRAPHY

ROADLOG & STOP DESCRIPTIONS

DATING IN THE PLEISTOCENE

ESTABLISHING A GLACIAL CHRONOLOGY IN NORWESTERN PENNSYLVANIA

86TH FIELD CONFERENCE OF PENNSYLVANIA GEOLOGISTS – 2022

Figure 1. *Map of Day 1 and Day 2 Stops.*

ACKNOWLEDGEMENTS

When I agreed to organize this Field Conference, I realized that I would have to rely heavily on others to contribute to it. They have come through spectacularly. So many thanks to leaders Aaron Bierly, Gary D'Urso, Todd Grote, Frank Pazzaglia, Mike Simoneau, Jocelyn Spencer, Eric Straffin, Katie Tamulonis, and Brian Zimmerman. Duane Braun also contributed significantly to stop descriptions and articles, but could not attend the Field Conference.

I also thank stop owners/managers/superintendents for granting permission to use their facilities for stops - Don May (ACA), Mathew D. Greene, manager Erie Bluffs SP, Boroughs of Edinboro and Conneaut Lake, John Vincent, Mike Mortimer (McClymonds), Dustin Drew, manager of McConnells Mill State Park, Vic and Daniel Cheeseman, Jocelyn Spencer (Glacial Sand and Gravel).

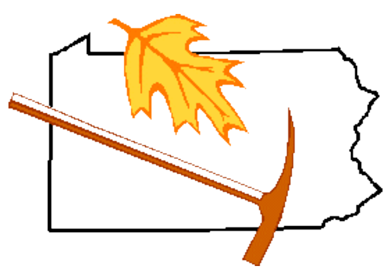
Robin Anthony, guidebook editor, put up with numerous late submissions, making her job more difficult. After having been the guidebook editor for many years, I can relate working with people who don't understand the concept of deadlines. I am now one of them.

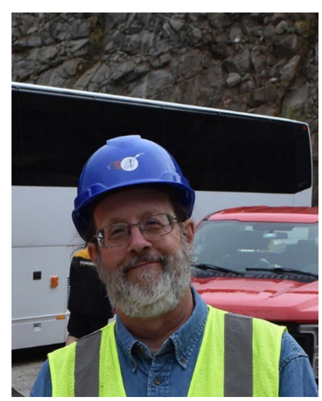
The Field Conference officers thank supervisors of Worth, Muddy Creek and Brady Townships, Kaylin Hudson from West Liberty Borough; Jason Bishop from Plain Grove Township; Joe Sporer, manager of Sugarcreek Borough; Road Foreman of Slippery Rock Township for giving us permission to travel the roads for one-time passing.

In addition to the field trip stop leaders and other guidebook contributors, we wish to thank the following for their assistance in the preparation of this year's Filed Conference:

- PennDOT - Anthony P. Pioli, P.E. and Mike Mattis of Engineering District 10-0 in Indiana for clarifying questions about local roads and bridges
- Natalie Simon, Environmental Education Specialist at McConnell's Mill
- Karissa from Cross Creek Resort, who has helped us with the reservations and food
- Clarks Donuts for providing Donuts and Coffee orders
- Stewart's Catering for boxed lunches
- Janet Polka for permission access to her private land for the Bills pre-conference trip
- Pre-Conference Leaders

  Bill Bragonier
  Fred Zelt
  Bill Kochanov
  Gary Fleeger
  Ivy Kuberry
  Katie Schmid





There are undoubtedly others who have been omitted, and we apologize for these omissions.

Gary M Fleeger

INTRODUCTION AND TRIP GOALS

GARY M FLEEGER

Welcome to Titusville, best known as the location where the modern oil industry began. Less well known is that it was the home of the Heisman Trophy namesake, John Heisman, and muckraker author, Ida Tarbell, who helped bring down Rockefeller's Standard Oil with her books, The Rise of the Standard Oil Company, in 1902, and The History of The Standard Oil Company: the Oil War of 1872, in 1908.

This is the third Field Conference headquartered at Cross Creek Resort. We were here previously in 1976 and 2009. Titusville, before Cross Creek, also hosted the 1959 Field Conference for the Drake Well centennial. All four Titusville Field Conferences looked at glacial geology, but this is the first that is exclusively concerned with glacial geology.

The Grand River sublobe of the Erie Lobe of the Laurentide ice sheet invaded northwestern Pennsylvania a number of times. An article in the 2005 Field Conference guidebook provides a summary of the various glaciations. The time-distance diagram on the inside of the front cover of this guidebook shows the known glacial advances into northwestern Pennsylvania, and their probable ages. Deposits from the Slippery Rock glaciation have infrequently been found, and some additional old tills have been found, but not enough to identify, name, and place in the glacial sequence. The Keefus Till, as defined (red, high carbonate), has been found only within 20 miles of Lake Erie on the Lake Plain in Ohio. The representation of the Keefus being within the Titusville on the time-distance diagram is based on my interpretation of Stop 5 of the 2005 Field Conference. To my knowledge, no additional work has been done on this problem to verify, refine, or refute that interpretation. The approximate distribution of the various tills at the surface is shown in Figure 2 of this year's guidebook article on previous published dates. Some modifications have been made since that map was published in 1969 (PaGS General Geology Report 55).

Over the next 2 days, we will look at the glacial geology of northwestern Pennsylvania, concentrating on attempting to establish a chronology. We have had a paucity of published absolute dates established in northwestern Pennsylvania, and not much more in northeastern Ohio and western New York. Most have been radiocarbon dates, but in recent years, other methods, specifically OSL (Optically Stimulated Luminescence) and TCN (Terrestrial Cosmogenic Nuclides) have been used. These methods have the benefit of being able to determine ages much older than can be done with radiocarbon, which can be used only for Wisconsinan dates. They also do not require the preservation of organic material.

This Field Conference will introduce a number of OSL dates in our attempt to develop a chronology. In recent years, Eric Straffin and Todd Grote have been using OSL and 14C and detailed lidar imagery to refine the glacial margins and date the glaciation in northwestern Pennsylvania in Erie and Crawford Counties. Likewise, after his work in the Ohiopyle area, visited during last year's Field Conference, Frank Pazzaglia with Mike Simoneau investigated the Slippery Rock Gorge and West Liberty areas, obtaining additional OSL and IRSL (Infrared Stimulated Luminescence) dates. Gary D'Urso and I (as well as Frank Preston in the 1940s and 50s) have also studied the origin of the Slippery Rock Gorge. Gary and I will discuss our interpretations at Stops 7 (McConnells Mill) and 8 (Cheeseman delta).

Several of the stops have been visited by the Field Conference in previous meetings. Stop 5 parallels a stop from 1976, in that it is in the same kame deposit, but a different quarry. We took a couple of samples for OSL dating, but unfortunately, did not receive the results in time for inclusion in the guidebook. Perhaps we will have them before the Field Conference so we can discuss them at the stop. Our interpretation is that the deposits are related to the Mapledale Till. If so, we will have our first absolute date of the Mapledale glaciation. Stop 8 was visited way back in 1950. Frank Preston, the driving force behind the creation of nearby Moraine State Park in the 1960s, discussed this site in relation to the origin of the Slippery Rock Gorge. We will do likewise, but we also have our first absolute date for the Titusville glaciation in Pennsylvania from this site. Stop 9 was a stop in 2009, when we looked at the sedimentology of the kame delta. This year, we will look at more detailed quantitative analysis of the deposits, by Katie Tamulonis and students, as well as discuss some new OSL dates obtained here.

SPEAKERS

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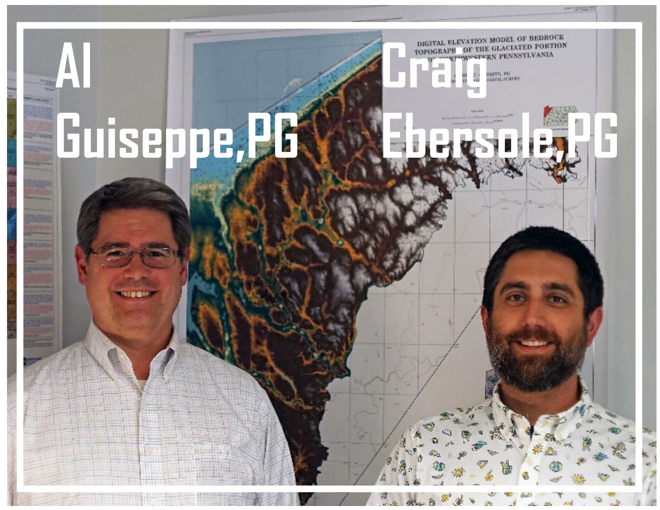

The Pennsylvania Geological Survey is embarking on a new endeavor to create a 3D geologic model of Pennsylvania as part of the US GeoFramework Initiative. Spearheading the effort is Al Guiseppe, the newly hired Geoscience Manager of the Geologic and Geographic Information Services Division at the Survey. With over 20 years of professional experience working at the intersection of geologic sciences and GIS technology, Al aims to bring a computer-aided 3D modeling perspective to traditional geologic mapping projects. Craig Ebersole, a professional geologist of 5 years, is a core member of the GIS team to bring about the 3D revolution at the Survey. In addition to wrestling with raster math to generate geologic surfacing in GIS software, Craig captures 3D point cloud data of geologically significant field locations using an unmanned aerial vehicle, or drone.

As a first step towards this ambitious goal of creating a 3D geologic model of Pennsylvania, the Survey has set out to create digital elevation models of major bounding surfaces. Towards this end, the Survey has developed a surface that represents the bedrock elevation beneath the unconsolidated sediments of the northwest glaciated portion of the state. Over the years, geologists have used subsurface data found in water wells, geotechnical borings, and seismic surveys to map the bedrock elevation in this area. Contouring the data by hand, the process of generating a bedrock elevation contour map is a laborious process and subject to radical changes in interpretation whenever new data is collected. Using digital mapping techniques, geostatistical analysis, and GIS workflow models, the Survey is striving to create a method to generate the bedrock elevation surface that relies more on automated computer processing than time-consuming manual efforts to allow for rapidly updating surfaces as new data is collected.

Roadlog & Stop Descriptions for the
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Editor
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Eric Straffin, PennWest University – Edinboro Campus

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Hosts
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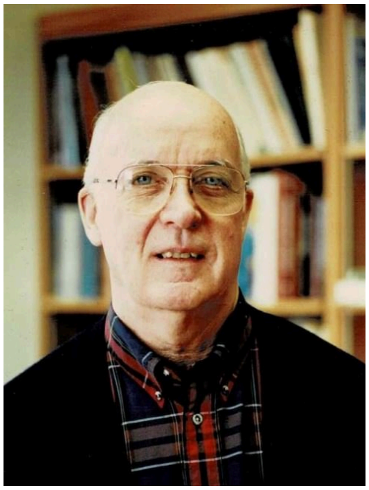
Headquarters: Cross Creek Resort, 3815 State Route 8, Titusville, PA 16354

MEMORIAL TO EDWARD COTTER



On May 13, 2022, Ed Cotter, professor emeritus at Bucknell University, passed away at age 85 in Shrewsbury, Massachusetts. Ed was a past attendee and leader of the Field Conference. He was also my first geology professor, when I took his Physical Geology class at Bucknell in 1974. It was after that class that I decided to switch my major to Geology, so it's all his fault. He was the last survivor of the "big three" professors from my years at Bucknell- Ed, Dick Nickelsen, and Jack Allen. I last saw him in 2014 at Nick's memorial service.

Ed did sedimentological research in Montana, Utah, Mexico, Ireland, Australia, and South Africa. But with the wealth of geological exposures available, he spent years studying the rocks in his own backyard in central Pennsylvania.

As with the other professors at Bucknell, Ed was very field oriented. Our classes always included almost weekly field trips, learning methods of field observation. Ed was known for his hand signals out the car window at 65 mph to indicate geologic features. Ed also organized and ran student field trips to the western US during Bucknell's January Program, that was a month-long, between semester program that existed at that time.

Ed Cotter reading a map on a Jan Plan trip about 1975. Roger Kerr, Robin Glaspey, and 2 unidentified students.

That field emphasis and central Pennsylvania research certainly translated well into Ed's participation in the Field Conference. He and Nickelsen organized and ran the 1983 Field Conference, Silurian Depositional History and Alleghanian Deformation in the Pennsylvania Valley and Ridge. This remains the largest Field Conference trip with 235 registrants, a 5-bus trip, if I recall correctly, at a time when undergraduate student participation was discouraged and was prior to the need for education credits now needed for geologist licensing. At the 1983 Field Conference, Ed presented years of research on the sedimentology of the Devonian and Silurian succession in central PA. At each of the 8 stops, Ed and Nick provided a thorough sedimentological and structural analysis of the rocks we were seeing.

Ed also was a co-leader of the 1986 Field Conference, in commemoration of the 150th anniversary of the Pennsylvania Geological Survey. He co-authored (with Jon Inners) an article on Silurian stratigraphy and sedimentology, and co-led (again with Jon) a stop at Allenport.

Ed, Nick and Jack are largely responsible for the high-quality geological education at Bucknell that continues today. Their reputation and department-building are responsible for Bucknell seeming to be one of the few separate Geology departments remaining at liberal arts schools. When I attended in the mid-1970s, Geology was combined with Geography. As opposed to the current trend of combining Geology with other departments, at Bucknell, Geology separated as a separate department in the early 1980s, and remains a separate department, now Geology and Environmental Geosciences.

Gary M Fleeger

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Sponsors & 2021 Group Photo at Laurel Caverns .... inside back cover
2021 FCOPG Group Photos at Laurel Caverns .... back cover

DAY 1 ROADLOG

Miles	Cum	Description
0.0	0.0	**START, 7:30 AM, Cross Creek Resort, Titusville, PA (41.56619, -79.69807)**
0.3	0.3	Turn left on PA-8 North. After we turn onto PA 8 (William Flinn Highway), the site of the type section of Titusville till is visible in about 2.7 miles.
2.7	3.0	The vegetated road cut on the east (right) side of PA 8 is the type section of the Titusville Till. As with most type sections for unconsolidated units, its exposure is no longer good. The 1976 FCOPG stopped at a gravel pit, just 100 yards north as a substitute for the type section. That pit also no longer exists.
1.4	4.4	Drake well
0.2	4.6	Titusville is the birthplace of the modern petroleum industry, with the drilling of Drake's well in 1859. It was also the home of Ida Tarbell, biographer of Abraham Lincoln. Her most well-known work is probably The History of the Standard Oil Company, which contributed to its breakup. Titusville was also the boyhood home of John Heisman, for whom the Heisman Trophy is named. See page 24 for details.
4.4	4.8	Continue straight on PA-89 North.
20.8	25.6	Turn left to arrive at **STOP 1**.

STOP 1: ACA SAND AND GRAVEL

LEADERS: ERIC STRAFFIN – PENNWEST UNIVERSITY, EDINBORO CAMPUS
TODD GROTE – INDIANA UNIVERSITY OF PENNSYLVANIA

1 hr. ***8:15 – 9:15 PM 41.898848 / -79.7035226***

Introduction

Very little is known about the age of glacial ice advance and retreat in northwestern Pennsylvania, with most of our knowledge about the timing of events coming from outside the state (e.g. Dalton et al., 2020). Recent advances in imaging landforms (LiDAR) and dating techniques (in particular OSL, or Optically Stimulated Luminescence) permit a better understanding of the region. However, these techniques also make clear that we have much to learn regarding the geologic details of the late Quaternary Epoch in northwestern Pennsylvania, and how multiple glaciations of the elevated Appalachian Plateau correlate with adjacent areas in Ohio and New York. Details regarding ice margin position are much more complicated than previously understood, and the data presented here provide some preliminary results.

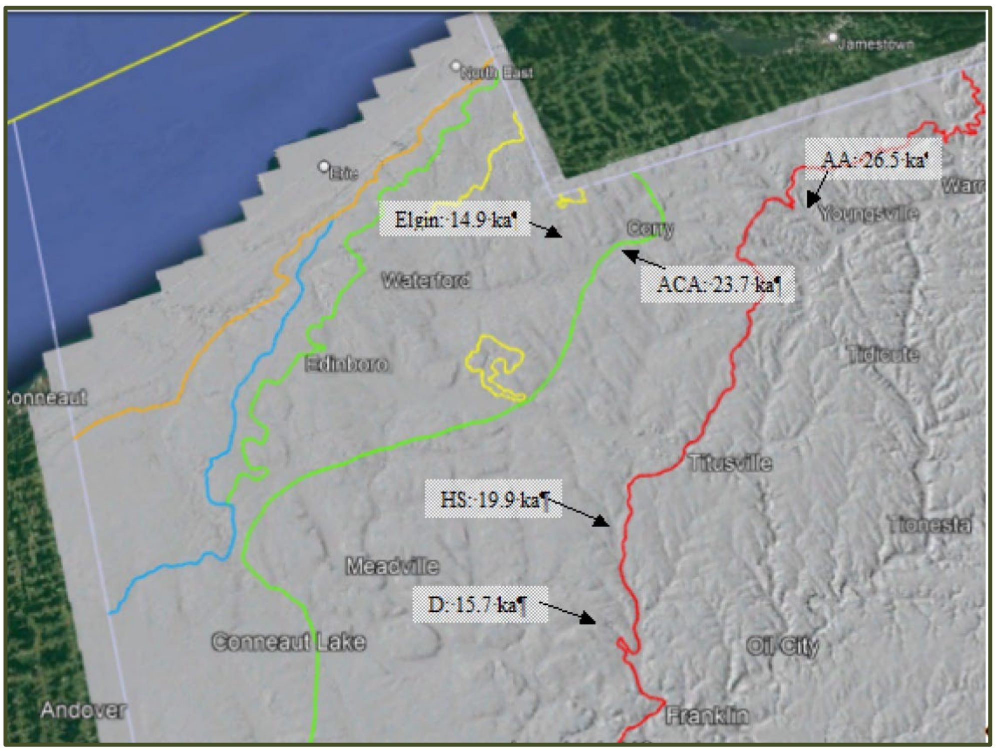


Figure 1.1. *Oblique view of northwestern Pennsylvania with overlain DTM model showing location of OSL ages discussed in this article. Moraine fronts and glacial borders (Shepps et al, 1969) are Ashtabula (orange), Hiram (Defiance Moraine-blue), Lavery Moraine and extended Lavery of White et al (1969) (green), Kent (red), Clymer and Findley Lake recessional moraines (yellow). From Google Earth and PASDA.*

Mapping across the region by Shepps et al (1959) and others (e.g. White et al, 1969) provides an excellent foundation upon which to build more detailed surficial geologic maps, using geomorphic mapping on LiDAR hillshade digital terrain models (DTM's; **Figure 1.1**). Landforms and associated sediments can then be used to guide site selection for potential dating (Straffin and Grote, 2010; Grote and Straffin, 2019). In particular, subtle moraines marking past ice margins can be traced across uplands that were previously unmapped and/or uncorrelated across the region. These same subtle, upland terminal moraines can also be traced and correlated to adjacent valleys with distinctive hummocky topography, forming valley blocking moraines

(VBM). VBM's were previously mapped in many valleys as kames (**Figure 1.2**) and are analogous to the valley choker moraines of MacClintock and Apfel (1944). Meltwater from glaciers produced outwash surfaces that dip away from many of the VBM's (**Figure 1.3**). Sand in outwash is potentially dateable with OSL (Fuchs and Owen, 2008; Huot et al., 2018) which can provide ages on the timing of ice advance and retreat.

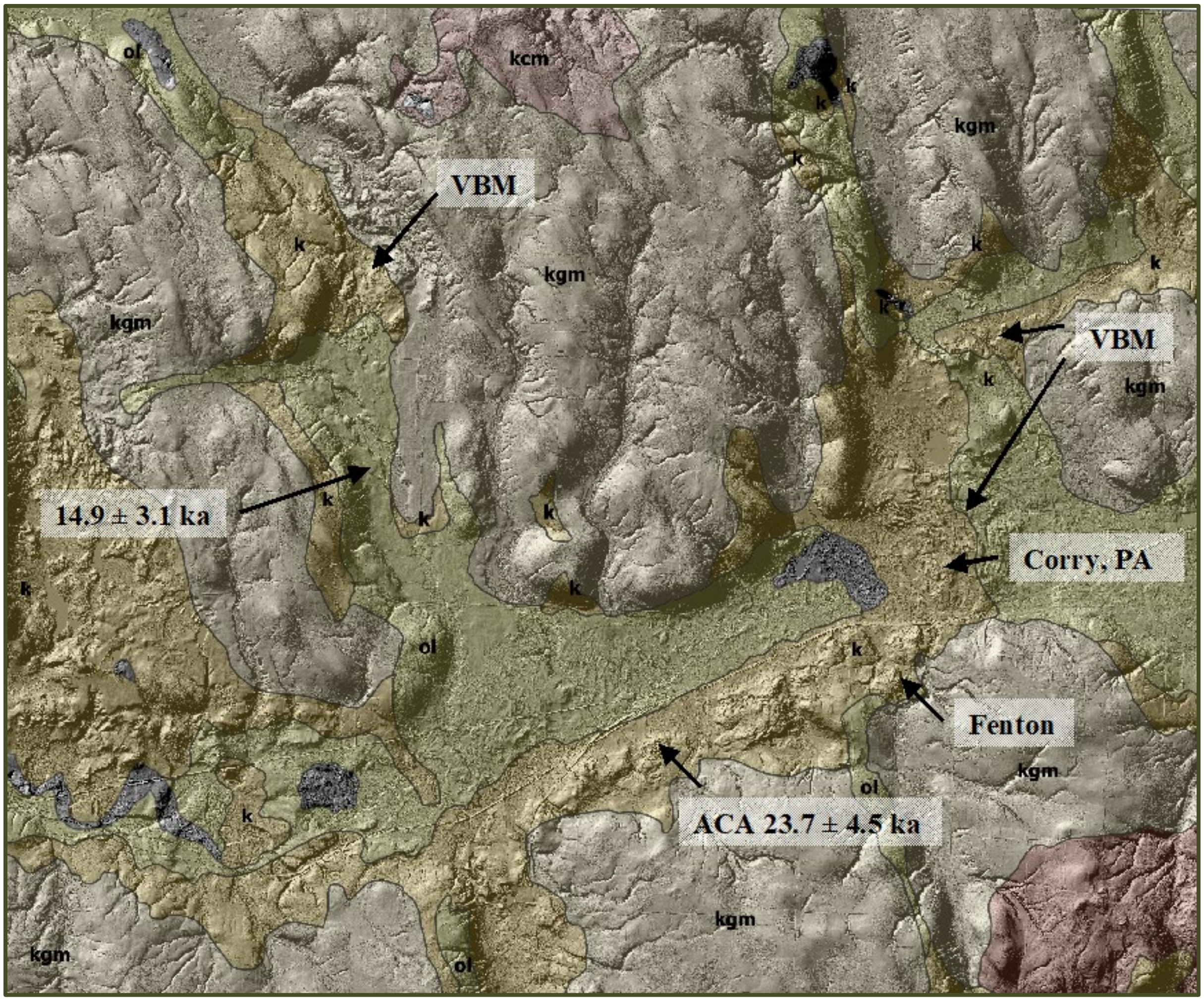


Figure 1.2. *Hillshade model (10x) showing location of ACA Sand and Gravel (ACA) and Fenton pits, situated within hummocky, ice marginal deposits (kames and valley blocking moraines; VBM). Smooth uplands are covered by silty ground moraine (kgm). Clip of surficial geologic map by Shepps et al. (1959). Kent ground moraine on uplands (kgm), kames (k), outwash (ol), and end moraine (kcm). PASDA.*

Stop #1: ACA Sand and Gravel

The ACA Sand and Gravel company is situated within hummocky topography associated with a lobe of ice that extended to the city of Corry, Pennsylvania (Figures 1.1, 1.2, and 1.3). The pit exposed several distinct, stacked packages of cross bedded sand and gravel, interpreted to be aggrading braided channel deposits (outwash). Wide, shallow channel fills fine upward from dark coarse sand to lighter, finer sands and silt. An OSL sample was recovered from cross bedded sand with an age of 23.7 ± 4.5 ka which roughly corresponds with the regional late Wisconsinan ice maximum position. Cross beds indicate eastward transport, which is opposite of the post glacial drainage direction. Deposition of a subsequent VBM (situated at the town of Corry) resulted in drainage diversion (Figure 1.3). Sediments overlying outwash were not well exposed at the ACA pit, having been removed as overburden. However, correlable sediments exposed in a nearby quarry (C.B. Fenton Gravel) were well exposed, but too coarse for OSL dating. The overlying sediments were poorly sorted kame deposits (gravelly till and silty kettle fills) associated with the hummocky topography of the ice margin and valley blocking moraine. The OSL age thus marks a date prior to the advance of the ice lobe that advanced to what is now the town of Corry. An OSL date of 26.5 ka from very coarse outwash just beyond the mapped Kent moraine margin

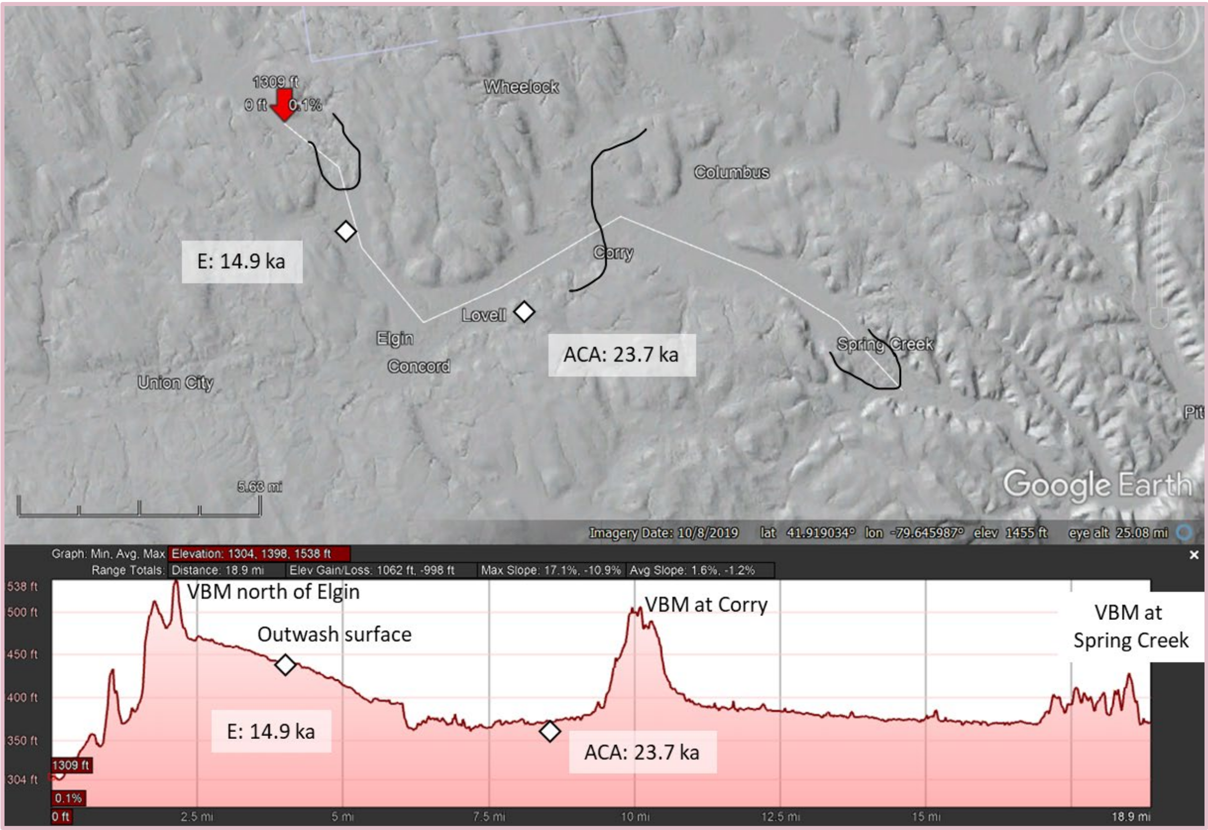


Figure 1.3. *Top: DTM with a section line down the valley axis through the study area, with terminus of valley blocking moraines (VBM) marked by black lines. Below: Topographic profile of section line illustrating geometry of valley profile.*

to the east of Corry (AA, Figure 1.1) falls within the error range of the ACA date, further defining the timing of ice advance in the region. s

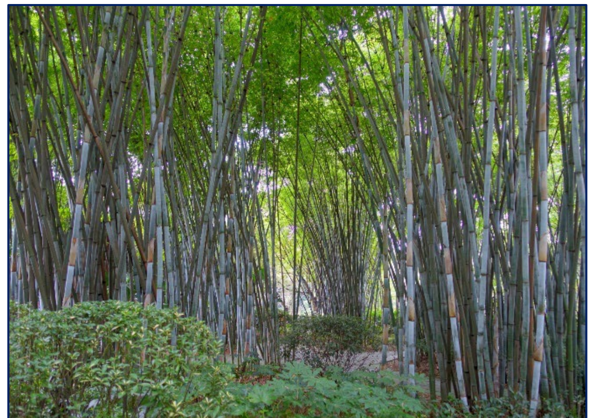
Up-valley from ACA Sand and Gravel is a younger outwash surface that can be mapped to a younger valley blocking moraine (Figure 1.1), which can be correlated with what Shepps et al (1959) mapped as the Clymer recessional moraine. A small quarry north of Elgin exposed weakly imbricated, very poorly sorted, cross bedded gravels typical of braided stream channels. Cross bedded coarse to fine sand lenses were interbedded with the gravel, and sampled for OSL. An age of 14.9 +/- 3.1 ka was obtained, which provides a minimum age on the "Clymer" moraine. This date may be significantly younger than the moraine itself, as braided stream deposition may have continued for some time after ice retreat. This age is similar to an OSL age on braided stream deposits associated with a VBM near Deckard, PA (Figure 1.1). Figure 1.3 illustrates the cross sectional topography of the VBM and outwash surfaces within the valley, and helps to demonstrate that more northerly VBM's are related to more recent advances of ice than southerly VBM's. Another OSL age of 19.9 ka from outwash traceable to the Kent end moraine (Figure 1.1) constrains the timing of the end of deposition of that distinctive landform.

Point of Interest: The 1859 Drake Well in Titusville is not the world's first oil well! As early as 347 C.E., the Chinese used bamboo poles to construct oil wells that went as deep as 800 feet (PBS, 2004). That means the Chinese constructed oil wells over 1,500 years before the Drake Well and that their wells went over 700 feet deeper (Drake Oil Well Museum, 1979).

(Source: PBS, Thirteen/WNET Net York, 2004, Extreme Oil

https://www.thirteen.org/wnet/extremeoil/history/prehistory.html).

(Source: Pees, S. T., 2004, Oil History: Drake's Well http://www.petroleumhistory.org/OilHistory/pages/drake/drakewell.html).



(Figure Source: Daderot, 2015, Wangjianglou Park – Chengdu, Sichuan, China, https://commons.wikimedia.org/wiki/File:Bamboo_-_Wangjianglou_Park_-_Chengdu,_China_-_DSC05737.jpg).

Miles	Cum	Description
	25.6	Turn left onto PA-89 North to exit Stop 1.
1.5	27.1	Turn left onto US-6 West/PA-89 North.
1.6	28.7	Turn right onto PA 89 North
1.1	29.8	We are traveling along an outwash terrace emanating from a valley-blocking moraine to the north. We will pass through the valley-blocking moraine in about a mile. The Elgin location discussed at Stop 1 is in this outwash deposit.
1.9	31.7	The hummocky topography to the left is the valley-blocking moraine from which the outwash terrace emanates. Titus Bog is a kettle in that moraine. The center of the bog contains a floating peat mat surrounded by a moat swamp (Ireland and Booth-Ecology, 92(1), 2011, pp. 11–18).
3.9	35.6	Turn right onto PA-8 North.
14.6	50.2	Turn left onto ramp to I-90 West.
13.6	63.8	Exit right to PA-98.
0.1	63.9	Turn right at end of ramp to PA-98 North.
3.2	67.1	Turn left onto PA-5 West.
5.7	72.8	Turn right into the Elk Creek Access at Erie Bluffs State Park to arrive at **STOP 2**.

STOP 2: GEOLOGY OF ERIE BLUFFS STATE PARK

ERIC STRAFFIN – PENNWEST UNIVERSITY, EDINBORO CAMPUS
TAMARA MISNER – ALLEGHENY COLLEGE

2 hrs **10:25 – 12:25 AM** **42.020968599 / -80.374706**

Introduction

This stop presents a description of landforms and sediments exposed along Erie Bluffs State Park, in Erie County, Pennsylvania (**Figure 2.1**). These observations add to the known geologic history of the region, and have implications for a range of important issues, including bluff erosion, sediment production and down-drift sediment supply to the beaches of Presque Isle.

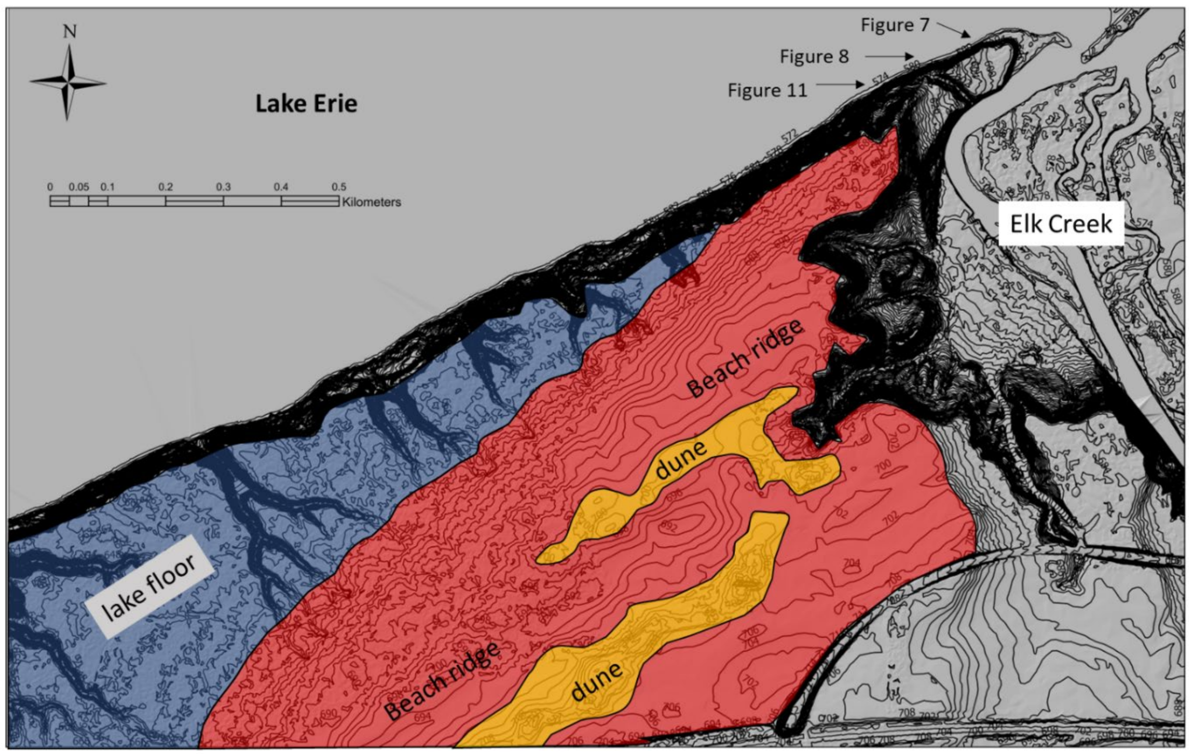


Figure 2.1. Map of a portion of Erie Bluffs State Park. Gullies and erosional bluffs not mapped. Lake floor = blue, beach ridges and associated shoreline = red, dunes =yellow, gray = not mapped. Contour interval 1 foot plotted on DTM. Figures indicated on the map can be found in the full stop description.

Depositional environment, landforms and sediments

Paleo-shorelines of ancestral Lake Erie are clearly visible on hillshade models of Erie County. At Erie Bluffs State Park, the most prominent paleo-shoreline feature has been previously mapped as the Warren I shoreline (Schooler, 1974; Totten, 1985) with a crest elevation of ~212 m (694 ft) a.s.l. The prominent northwest facing slope along the beach ridge dips down to 206 m (675 ft) where it transitions to a less steep lake bottom. Eolian sand dunes can be found as two ridges that cap the beach deposits, oriented roughly parallel to one another, in a northeast-southwest direction (Figure 2.1). These landforms developed along the margin of Lake Warren, a proglacial lake that formed as a result of major drainage reorganization during Late Wisconsinan glacial fluctuations.

Exposures of the bluffs occur as waves erode the base, oversteepening the bluffs, leading to slumping and removal of slumped sediment by ongoing wave action. Bluff exposures permit intermittent but detailed examination of exposed sediments. Near the mouth of Elk Creek, Devonian bedrock was observed at lake level, overlain by till (12 ft), overlain by convoluted, laminated lacustrine silt/sand (8 ft), capped by alluvium (2 ft) from Elk Creek. Further to the southwest, bluff height increases as it transitions from an intersection of the Elk Creek valley to paleo-shoreline sediments. The general profile is similar at the base, with the exception of increasing thicknesses of deposits, and a cap of shoreline sand and gravel from ancestral Lake Erie (Warren shoreline). Of note are laterally continuous lacustrine sand/silt couplets. In places these rhythmically laminated sediments are contorted, features consistent with rapid sediment deposition and loading of underlying soft sediment. Asymmetrical climbing ripples in lacustrine sediments clearly show paleocurrents to the northeast throughout the section, and further support episodic, rapid sedimentation. Occasionally, rounded cobbles and gravel can be found as isolated dropstones, indicating ice rafted debris. There are also very large convoluted sands that occur near the top of the section. These features are consistent along the length of the bluffs where the lower sandy shoreline sediments intersect the bluffs. Convoluted sand units often have ball and pillow structures at the base of the bed, where heavier sand was deposited on soft lake silts, permitting the sand to sag. Flame structures at the contact between silt and overlying sand demonstrate en-masse movement of sand to the northeast.

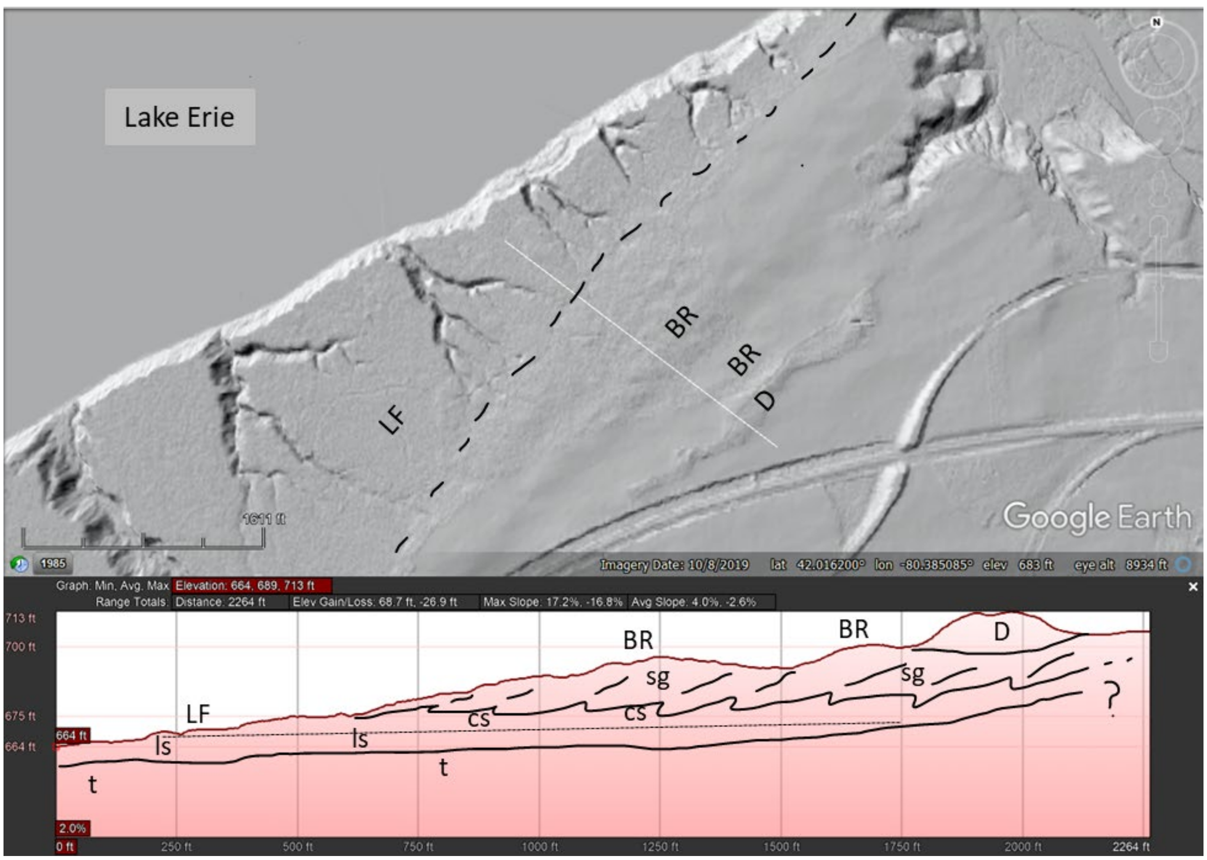


Figure 2.2. *Hillshade model, topographic profile, and interpreted cross section of paleo shoreline features at Erie Bluffs State Park. Landforms: LF = lake floor, BR = beach ridge, D = dune. Sediments: t=till, ls = lake silt/sand, cs= convoluted silt/sand, sg = sand/gravel. Dune sand is well sorted fine sand. Dashed line on hillshade marks boundary of lake floor-beach ridge transition, white line marks section line. Sinuous curves at southeast corner of image are roads and railways. Elk Creek valley wall visible in northeast corner of image.*

The relatively coarse sand grain size, and abundance of sedimentary structures common in the nearshore environment, suggest that the cause of the widespread convoluted sands is likely related to bank or bar collapse, and rapid, local sedimentation into proglacial ancestral Lake Erie. The broad beach profile preserved at Erie Bluffs State Park is interpreted to be a regressive shoreline, related to strong longshore currents (features of rapid sedimentation) and dropping lake level (broad slope of shoreface deposits and progressively lower beach crest) at the time of deposition (**Figure 2.2**, opposite). Large gravel pit exposures of the correlative Warren shoreline in northeastern Erie County clearly depict lake-ward dipping gravel/sand shoreline facies illustrating a lake-ward progradation of the shoreline. At Erie Bluffs State Park, this relationship is not well exposed, but coarse shoreline facies clearly grade to and overlie sandy/silty lake bottom facies.

Geology, water, erosion and environment at Erie Bluffs State Park

There are many interesting features to see throughout the park, that are controlled by the underlying geology. For example, if one walks along Timber Trail out to the bluffs, they will note that the gullies have flowing springs and interesting riparian vegetation that is very different from the surrounding relatively dry forest floor. The springs/gullies begin abruptly at a small but distinct break in slope (Figure 2.2) which is the contact of sandier nearshore/beach ridge sediments that overlie finer lacustrine silt and fine sand of the lake floor. Infiltrating water percolates rapidly through coarse shore-zone sand and gravel, then slows to create a perched water table atop the less permeable, silty lake bottom facies. Groundwater then migrates down-dip (lakeward) where springs emerge at the base of the shore-zone sediments in sufficient quantity to cause surface erosion and gully formation. The head of gullies leading uphill from the Lake Erie shoreline thus terminate near this boundary at approximately 206 m (675 ft) a.s.l.

Landslides and bluff erosion are both a hazard and a benefit to people utilizing the modern Lake Erie shoreline. Bluff erosion rates along Erie Bluffs State Park are relatively high, ranging between ~ 0.2 m/yr and 0.8 m/yr (0.656 ft/yr and 2.64 ft/yr) but with local rates as high as 1 m/yr (3.28 ft/yr) (Hapke et al., 2009). Bluff retreat occurs as waves erode and steepen the base of the bluffs, which over-steepens slopes leading to landslides that then deliver material downslope into the surf zone. Waves then remove that material, which is carried with the prevailing longshore current to the east. Water that infiltrates the upper portion of the bluffs also facilitates slope failures, especially at the contact between sandy lacustrine sediments that overlie silty lake bottom or till sediments.

While bluff retreat threatens bluff-top homes around Lake Erie, it also provides sediment necessary for the development of beaches along Presque Isle State Park, down-current. Landslides contribute significant sediment to the long shore current system. In fact, the bluffs are not primarily composed of silty till, but rather are predominantly sandy near-shore sediments of ancestral Lake Erie. Diminished bluff erosion will reduce the amount of sand that makes it into the longshore current resulting in less available sand for beaches on the most visited state park in Pennsylvania, Presque Isle.

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Point of Interest: In 1913, the Battle of Lake Erie (sometimes called the Battle of Put-in-Bay) was fought during the War of 1812. The US Navy coordinated the capture of six British Royal Navy vessels, which resulted in American control of Lake Erie for the remainder of the war.

(Figure Source: Powell, W. H., 1865, Battle of Lake Erie, U.S. Senate Art Collection, U.S. Capitol, Washington, D.C., https://commons.wikimedia.org/w/index.php?curid=251007).

Miles	Cum	Description
	72.8	Turn left onto PA-5 East to exit Stop 2.
5.7	78.5	Turn right onto PA-98 South.
12.2	90.7	Turn left onto US-6N East.
	90.7	Lavery Saloon (41.87951693019923, -80.22557704486105). The concrete pad to the right after the turn onto US 6N is the remains of the Lavery Saloon. The rumor is that Shepps named the Lavery Till for the Lavery Saloon, where Shepps was partaking of some late afternoon libations at the end of a long day in the field. This rumor has not been substantiated, and its origin is unknown.
4.8	95.5	Turn left into Edinboro Mall/Lakeside Commons to arrive at **STOP 3** and have lunch.

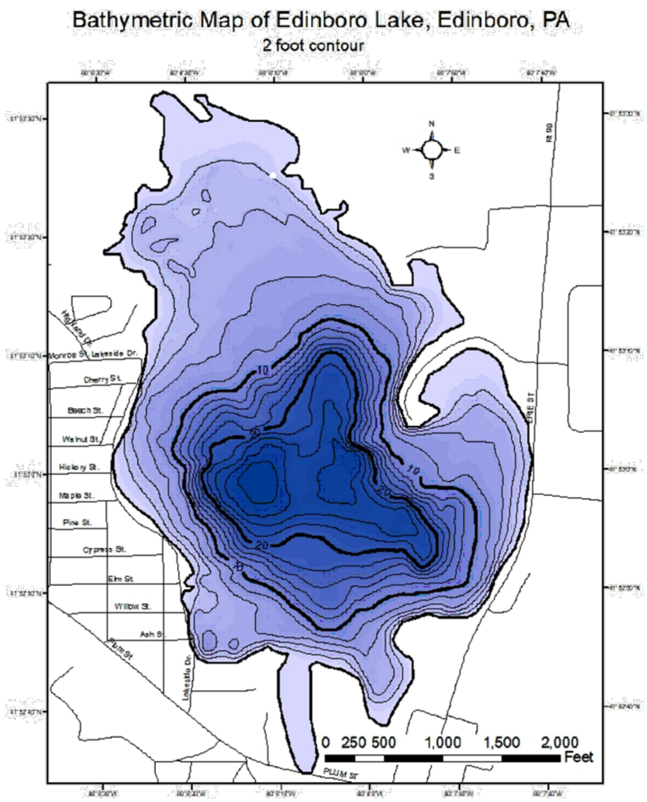
STOP 3: LUNCH – EDINBORO LAKE

BRIAN ZIMMERMAN AND ERIC STRAFFIN – PENN WESTERN UNIVERSITY, EDINBORO

1 hr ***12:55 – 1:55 PM*** ***41.8778739 / -80.133665979***

Introduction

Edinboro Lake is a kettle lake, one of 8 small glacial lakes in northwestern Pennsylvania (**Figure 3.1**) (Grund and Bissell, 2004). A dam on the lake's outlet raises the lake level approximately 9 feet (2.7 m) above the level of the original kettle lake. The maximum lake depth is 29.3 feet (8.9 m) with an average depth of 9.4 feet (2.9 m) (**Figure 3.2**).



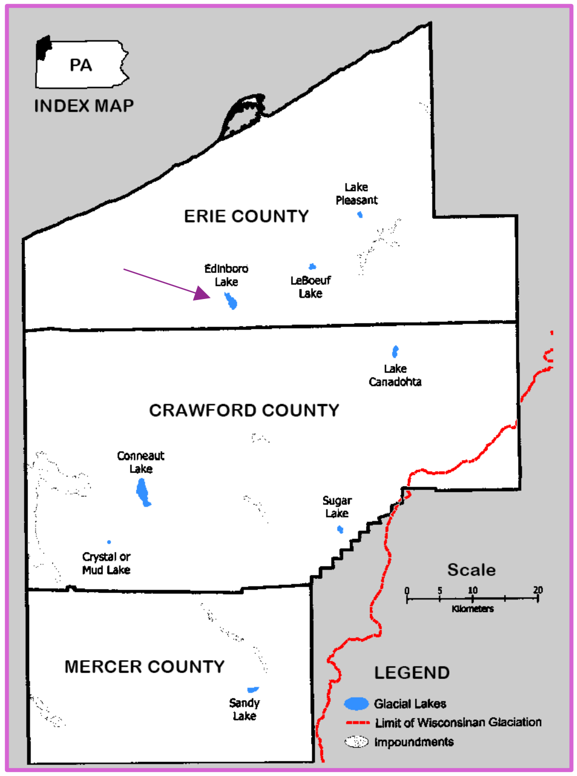


Figure 3.1. *(above) Location of glacial lakes in northwest Pennsylvania. Arrow points to Edinboro Lake. Other glacial lakes are Lake Pleasant, LeBoeuf Lake, Lake Canadohta, Conneaut Lake, Sugar Lake, Crystal/Mud Lake, and Sandy Lake. (Grund and Bissell, 2004).*

Figure 3.2. *(Left) Bathymetric map of Edinboro Lake (Byars and Zimmerman, 2000).*

The Edinboro Lake Fen (an alkaline wetland) is located along the northern shore of the lake and is a natural wetland community of global significance (WPC, 2000; Grund and Bissell, 2004). The shrub fen bordering Edinboro Lake is unique due the abundance of calcite in the glacial deposits surrounding the lake which maintains a high pH in the local groundwater. This provides habitat for a variety of rare and endangered plants which require alkaline conditions. Twenty-three plant species of special concern, eleven of which are listed as endangered in Pennsylvania occur within the watershed (WPC, 2000; Grund and Bissell, 2004).

Lake Formation

Edinboro Lake formed after the time of a Lavery advance, when two lobes of ice approached Edinboro from the north. One lobe of ice moved south down the Shenango Creek valley and a larger lobe moved from McLane into the Conneauttee Creek valley (Shepps et al., 1959). At the southern end of these ice lobes a morainal kame was deposited. The morainal kame forms the low gravel hills that surround Edinboro Lake to the southeast including the locations of the Edinboro Cemetery and Edinboro Mall. **Figure 3.3** illustrates several moraines in the Edinboro area.

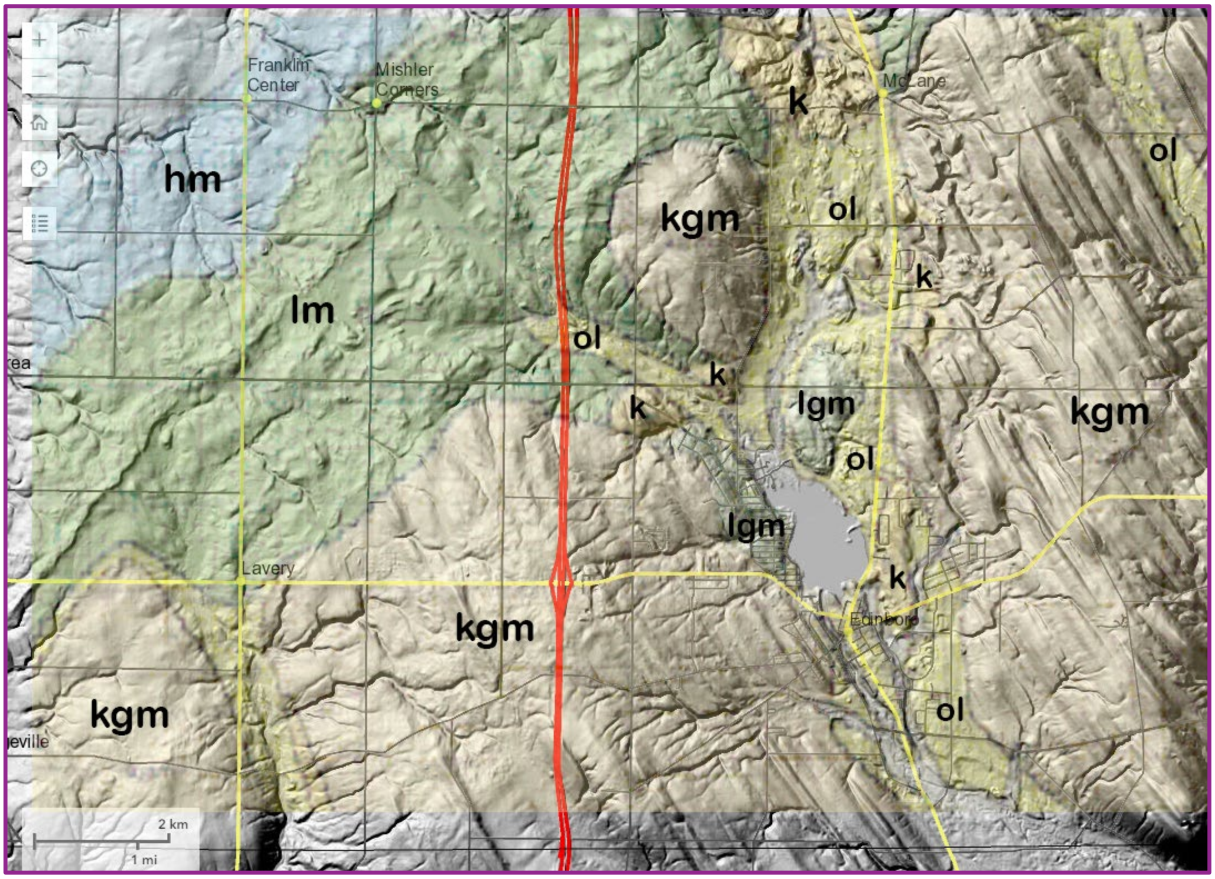


Figure 3.3. *Lidar hillshade model of area around Edinboro Lake overlain by glacial geologic map by Shepps et. al. (1959). Morainal topography is clearly visible. Drumlins occur on hilltops and are composed of thin Kent ground moraine over Devonian bedrock.*

Core Studies

The ecologically important habitats around Edinboro Lake, as well as a wide range of environmental issues related to sedimentation rates and water quality, have spurred many studies in and around the lake. For example, rapid sedimentation in the shallow margins of the lake have been an ongoing issue and led to two major dredging operations within the lake basin.

In order to more precisely measure the rate of sedimentation in the deepest part of Edinboro Lake a 1.4 meter sediment core was collected in 2007 by Edinboro University students (Szall et al., 2016). The sediment core was divided into 4 cm sections which were dated using 210-lead (210-Pb) radiometric dating techniques. The results of this study are shown in a graph of mass sedimentation rate versus depth in the sediment core (**Figure 3.4**). These data indicate that 96 cm (3.1 ft) of sediment has accumulated in the deepest part of Edinboro Lake since 1772. The data indicate a gradual increase in sedimentation rate from 14.8 mg/cm2/yr in 1772, prior to construction of the first dam and land-clearing in the watershed, to 286 mg/cm2/yr today. This is most likely caused by the gradual increase in population and accompanying development within the watershed. The rate of increase in sedimentation is less today than it was in the period prior to 1972. Significant short term increases in the sedimentation rate ca. 1953-1955 and 1987-1992 correlate with periods of intensive dredging within the lake. Disturbance during dredging caused redistribution of sediment from the shallower to deeper parts of the lake.

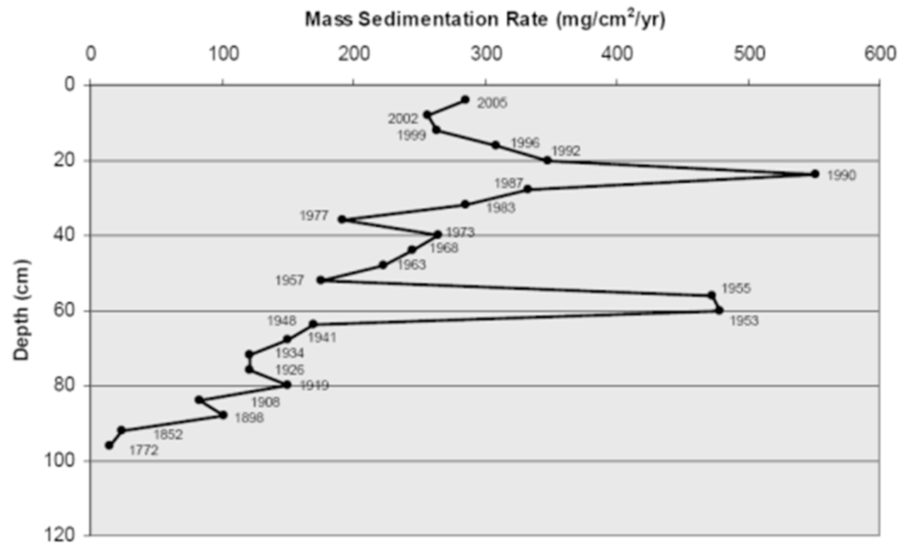


Figure 3.3 Sedimentation rate in Edinboro Lake (Szall et al., 2016)..

As is typical of lakes in the region, Edinboro Lake is dimictic and currently eutrophic to hypereutrophic. Diatom analysis of sediment samples from the 2007 core (Bradley, 2009) show that the lake was mesotrophic prior to European settlement and very rapidly transitioned to eutrophic conditions following construction of the dam and land-clearing within the watershed. Eutrophic conditions due to high Nitrogen and Phosphorous levels in the lake promote algal growth, and diminish water quality for activities such as swimming and boating.

In 2003 a 5.52 m sediment core was extracted from the deepest part of the lake by students and faculty of Edinboro University. Radiocarbon dates of 3,315, 6,430, and 9,575 years BP (calibrated) were obtained at depths of 1.90, 4.00 and 5.52 meters, respectively yielding an average sedimentation rate of only 0.56 mm/yr (Winger et al., 2004; Zimmerman and Straffin, 2006). The sample dated at 9,575 years BP was taken from just above the contact between deposits of underlying varved/inorganic silt and overlying non-varved organic rich lacustrine sediments, indicating that this transition occurred well after the Lavery ice advance. The authigenic phosphorous mineral vivianite occurs in the core below 220 cm indicating that a significant change in the trophic state of the lake occurred at approximately 4,000 years B.P. Prior to this time there was sufficient oxygen in the hypolimnion to allow phosphorous to be retained in the sediments as vivianite. After this time, the lake bottom become more anoxic, which decreased biological activity at the bottom of the lake, and also promoted the accumulation of organic mud.

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Point of Interest: Because Lake Erie is the shallowest of the Great Lakes, it has the warmest temperatures. In 1999 this became problematic for two nuclear power plants that relied on the Erie waters to maintain safe reactor temperatures. That year Lake Erie's temperature rose dangerously close to the upper limit set by the Nuclear Regulatory Commission. The company that owned both power plants responded by asking that the NRC raise the upper temperature limit for nuclear reactors.

(Source: Los Angeles Times, 1999, Lake Erie Heat Wave Threatens Nuclear Plants' Cooling Systems, https://www.latimes.com/archives/la-xpm-1999-aug-10-mn-64303-story.html).

(Figure Source: Davis Bess Power Plant, n.d., https://commons.wikimedia.org/wiki/File:Davis_besse_power_plant-CN.jpg)

Miles	**Cum**	**Description**
	95.5	Turn right onto US-6N West to exit Stop 3.
2.3	97.8	Turn left onto ramp to I-79 South.
18.3	116.1	Exit right to US-322 West.
2.7	118.8	We are descending Gable Hill. We don't know for sure who this hill was named after, but Clark Gable and his family had strong ties to this area. Even though Gable was born in Ohio, he lived in Vernon Township until he was about five years old.
3.8	122.6	Turn right onto N 2nd Street.
0.1	122.7	Turn right into parking lot for Fireman's Beach and arrive at **STOP 4**.

STOP 4: CONNEAUT LAKE-MARSH SYSTEM

ICE TONGUES, KAME MORAINES AND PALEOENVIRONMENTAL RECONSTRUCTION

TODD GROTE – INDIANA UNIVERSITY SOUTHEAST
ERIC STRAFFIN –PENNWEST UNIVERSITY, EDINBORO CAMPUS
LARA HOMSEY-MESSER – INDIANA UNIVERSITY OF PENNSYLVANIA
ANDY MYERS – ALLEGHENY ARCHAEOLOGY RESEARCH, LLC

1 hr

Fireman's Beach, Conneaut Lake

2:30 – 3:30 PM 41.605662 / -80.30263946

Introduction

The purpose of this stop is to provide a preliminary paleoenvironmental reconstruction of the Conneaut Lake-Marsh system using LiDAR-and field-based surficial geologic mapping, water well data, radiocarbon assays, regional paleoecological information and time-diagnostic artifacts. This stop also demonstrates the valuable synergy between the geoscience and archaeology communities.

With the widespread availability and use of light detection and ranging (LiDAR) digital terrain models (DTMs) our understanding of the glaciation of northwestern Pennsylvania and adjacent regions has been greatly advanced. Analyses of high-resolution (1 m) LiDAR DTMs provides an opportunity for re-examination, and in some cases revision, of the currently accepted glacial history of the region as it reveals topographic detail not available to earlier workers. The recognition of previously unmapped landscape elements (e.g. ice tongues) using LiDAR DTMs and the continued development of a sound Late Quaternary chronostratigraphic framework are of great importance for understanding landscape evolution, paleoenvironmental changes, and cultural resource (archaeological) potential throughout NWPA. This combination of methods were recently used to reconstruct Glacial Lake Conneaut as part of an undergraduate senior project by Jeremy Barnett at Indiana University Southeast (Barnett, 2019), and recently updated by Grote et al. (2022) with additional geochronological and archaeological information, forms the basis of this stop.

Preliminary reconstruction of the Conneaut Lake-Marsh system

The "Harmonsburg Moraine" lies just to the north of modern Conneaut Lake and creates the local drainage divide between the Ohio River Basin and Lake Erie. During the late Pleistocene, the "Harmonsburg Moraine" was the marginal position of an ice-tongue within the valley and the source of meltwater and sediment flowing into the moraine-dammed Glacial Lake Conneaut, which is dammed on the southern end by another kame moraine. Abutting the "Harmonsburg Moraine" to the south is a delta/fan-delta that would have fed into Glacial Lake Conneaut (**Figures 4.1 & 4.2a**). The kame moraine at the south end of Conneaut Lake can be physically traced to equivalent landforms within both arms of Pymatuning Reservoir, the former Shenango River and Crooked Creek valleys, and to minor moraines on the intervening uplands (Figures 4.1 & 4.2a). These cross-valley kame moraines in each of the valleys allowed for ice-dammed glacial lakes to exist and can be confirmed by the presence of glaciolacustrine sediments within the valleys (Shepps, 1959; Shepps et al., 1959; Fleeger et al., 2011).

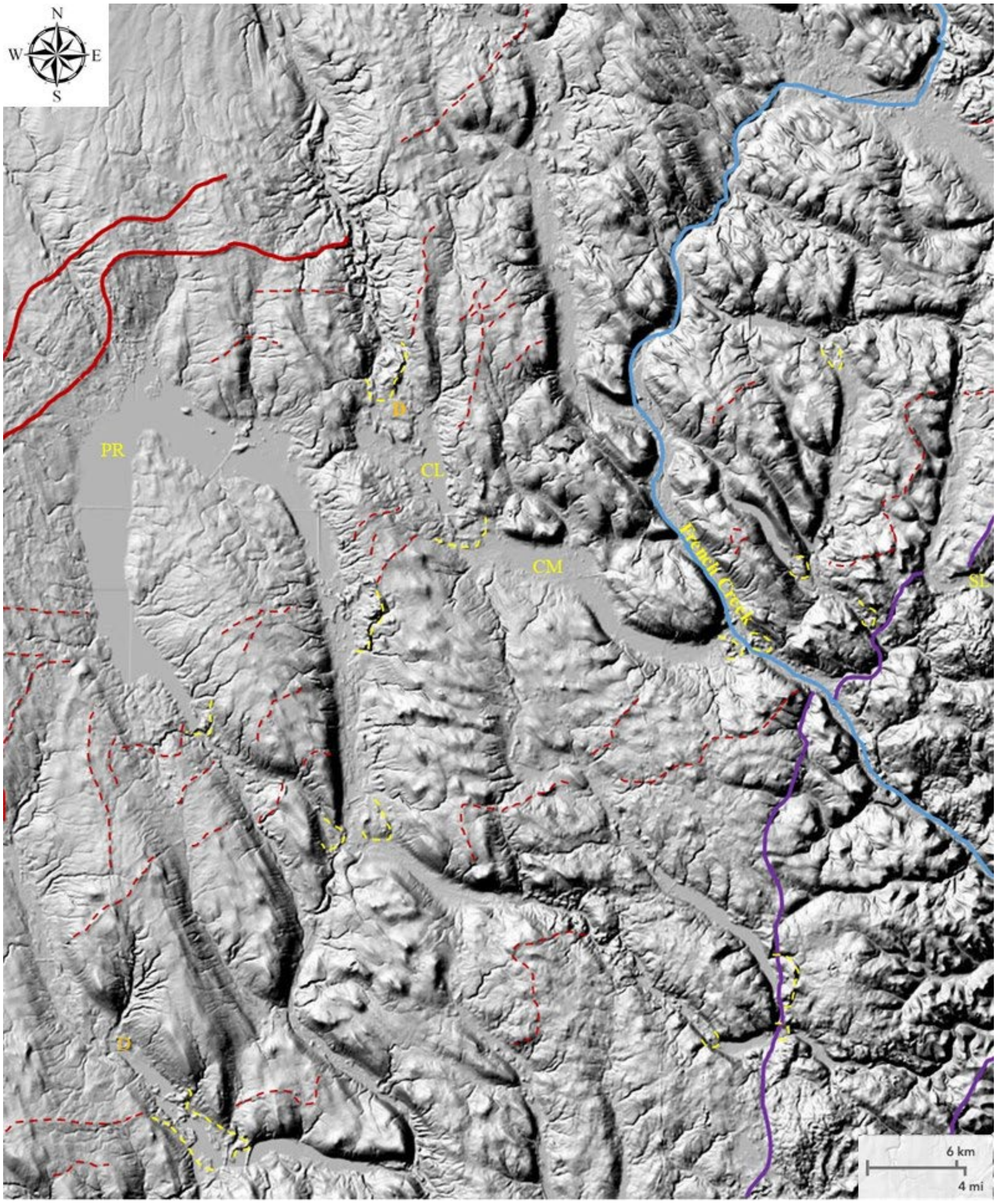

Figure 4.1. *LiDAR digital terrain model showing Conneaut Lake (CM), Conneaut Marsh (CM) and surrounding landscape. Maroon solid line is the mapped "Hiram" margin, Purple solid lines are the Kent End Moraine complex. Light Blue lines represent French Creek. Dashed maroon lines show previously unmapped ice-marginal positions on uplands. Dashed yellow lines denote valley-blocking kame moraines/heads-of-outwash. Note how the upland margins can be linked to valley kame moraines. SL – Sugar Lake. PR – Pymatuning Reservoir. D – glaciolacustrine delta. The Harmonsburg Moraine is located just to the north of the delta (D).*

In terms of paleolake reconstructions, at an elevation of 342 m (1122 ft), nearly all of the valley-blocking kame moraine at the south end of the lake would have been submerged and is considered an unlikely high-water level. Therefore, it was decided to base the reconstructions on an estimated a high-water level that approached the highest elevations of the kame moraine, but did not breach the top, and presence of a delta/fan-delta (almost entirely submerged at 340 m; 1116 ft) immediately in front of the "Harmonsburg Moraine" (**Figure 4.2b**). A question to ask is

– was the delta subaqueous or subaerial? All Paleoindian archaeological sites near the lake would have been submerged at the 340 m water level suggesting that this reconstructed time-slice predates the late Bolling-Allerod and Younger Dryas. At a lower water level of approximately 335 m (1101 ft), what appears to be a steep erosional scarp, or possibly ice-contact scarp, at the front of the delta/fan-delta emerges (335 m; 1101 ft). The fact that this contour line largely aligns with the base of the kettle, and sediments and soils appear to suggest a stable lake level for some period of time (**Figure 4.2c**). At the 335 m water level elevation, portions of the delta are now sub-aerially exposed. Two Paleoindian sites occur along the eastern margin of the delta suggesting that this landform was possibly habitable by the late Bolling-Allerod or Younger Dryas, but neither of the sites contain time-diagnostic artifacts to help constrain the timing of paleolake reconstruction (**Table 4.1; Figure 4.3**). Another reduction in water level to 328 m (1077 ft), roughly 2 m above the modern lake level, exposes most of the area where peat occurs within the kettle, the entire proglacial delta and all of the Paleoindian sites surrounding the reconstructed lake footprint (**Figure 4.2d**). Let us now attempt to place these lake level reconstructions into chronological and paleoenvironmental context.

Regional geochronological evidence suggest that ice retreated from NWPA, and surrounding area, by ~16,000 cal yrs BP (**Figure 4.4**). Within the Conneaut Lake-Marsh valley, deglaciation of the lower valley is recorded by charcoal-bearing sediments recovered from a sediment core on a kame terrace, and adjacent from the multicomponent Smock-Biguziak archaeological site (36CW248), overlooking Conneaut Marsh by ~ 20,246 cal yrs BP (16,740 +/- 70 14C yrs BP), indicating an ice-free, and habitable, landscape just prior to or during the very early Erie Interstade (Figure 4.4). The age of an ice-free and vegetated lower Conneaut Valley during the Erie Interstade however maybe questionable but plausible given other paleoenvironmental records for the region. Re-advance and retreat of Lavery (older) and/or Hiram (younger) ice into the Conneaut Lake-Marsh valley led to the formation of valley-crossing kame moraines which ponded water within the valley, thus forming Glacial Lake Conneaut (Figures 4.1 & 4.2). The topography within the Conneaut Creek valley north of the Harmonsburg Moraine (Figure 4.1 & 4.2) suggest collapse of the ice-tongue during deglaciation, and an assortment of what are interpreted as ice-contact sediments, including glaciolacustrine varves, suggests impounded water behind the Harmonsburg Moraine as the ice-tongue disintegrated (Shepps, 1959; Shepps et al., 1959; Fleeger et al.,2011; Grote et al., 2022).

Little is known about the lake level history of Glacial Lake Conneaut from the time of Lavery and/or Hiram ice stagnation and collapse within the valley, and the formation of Glacial Lake Conneaut until megafauna are known to be present in the area during the Bolling-Allerod (e.g. Vento et al., 2020). A radiocarbon assay from a woolly mammoth vertebra recovered from within Conneaut Lake (Figure 4.2a) yielded a median age of 13,857 cal yrs BP (11,960 +/- 70 14C yrs BP; mid Bolling-Allerod), consistent with other regional findings (e.g. Lothrop et al., 2016; Lothrop et al., 2017; Carr and Adovasio, 2020; Vento et al., 2020). Regional paleoenvironmental reconstructions for the Bolling-Allerod suggest a warming climate at that time and a habitable landscape likely dominated by spruce-pine-tamarack-oak forest (Table 4.1; Webb III et al., 2003; Lothrop et al., 2016; Swisher and Peck, 2020; Vento et al., 2020; Griggs et al., 2022). No Pre-Clovis archaeological sites are known to exist within the glaciated portion of NWPA (Burkett, 1981; Carr and Adovasio, 2020). The few time-diagnostic artifacts found in the vicinity of the Conneaut Lake-Marsh system reported in Burkett (1981) and the PASS files indicate Early and Middle Paleoindian Period occupations during the late Bolling-Allerod and Younger Dryas, and Late Paleoindian Period occupations during the Early Holocene, possibly co-eval with Early Archaic

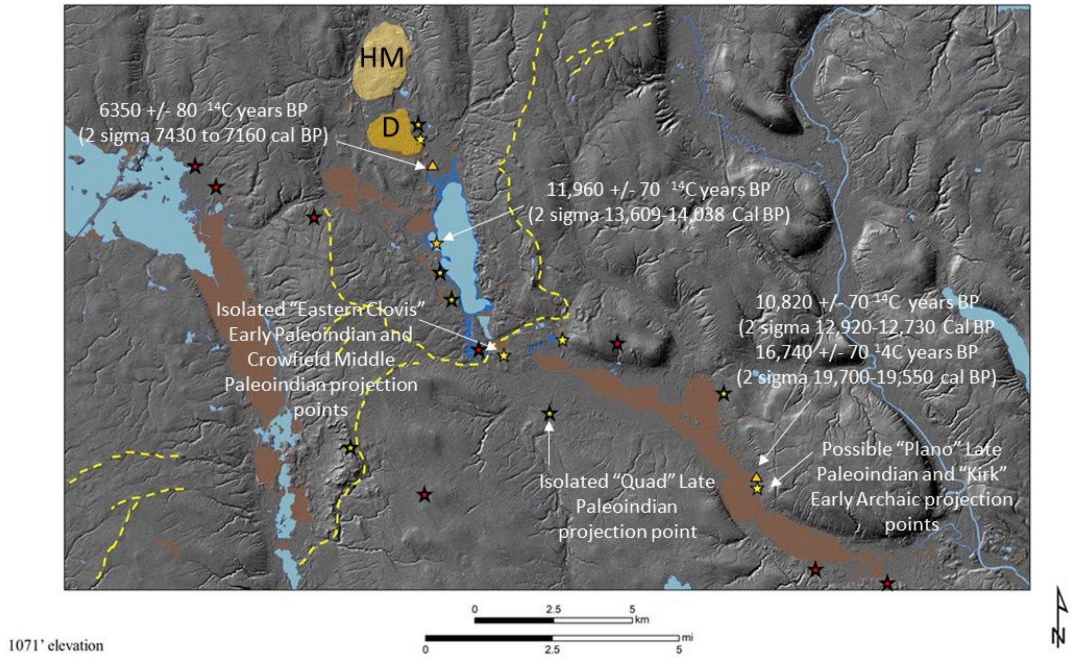

Figure 4.2 (a). *Modern level of Conneaut Lake (326-327 m; 1071-1073 ft) and the down-valley Conneaut Marsh. Brown solid shading denotes peat, light blue shading denotes water. Dashed yellow lines are reconstructed ice marginal positions. Medium orange shading denotes the location of a delta/fan-delta associated with the Harmonsburg Moraine (light orange). Yellow stars denote Paleoindian sites, red stars denote Early Archaic sites and the orange star is the approximate location of the 14C-dated mammoth bone discovery by divers. Orange triangles denote locations of 14C assays. Modified from Barnett (2019).*

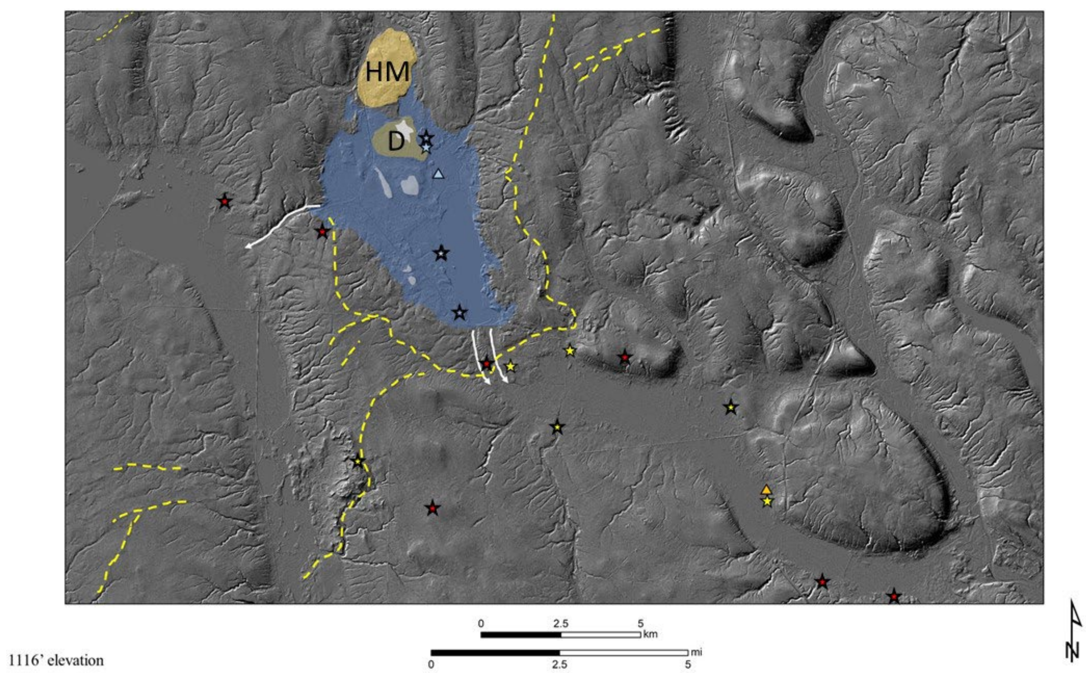

Figure 4.2 (b). *The 340 m (1116 ft) elevation contour is the highest water level considered likely based on topographic features within the valley . Ice-marginal features shown in dashed yellow. Possible spillways shown in solid white. Modified from Barnett (2019).*

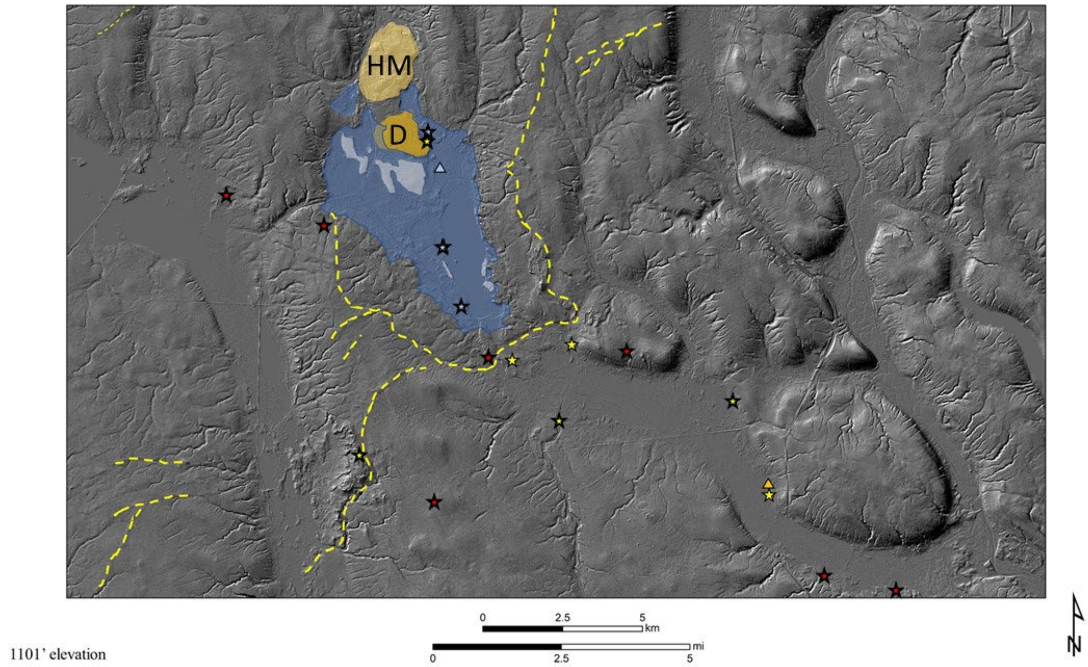

Figure 4.2 (c). *The 335 m (1101 ft) in elevation contour lies at and near the base of delta/fan-delta. At this elevation, the reconstructed lake level appears to align with several erosional features within the valley. Drainage through the northern outlet would have ceased near this lake level. Dashed yellow lines show ice-marginal features. Modified from Barnett (2019).*

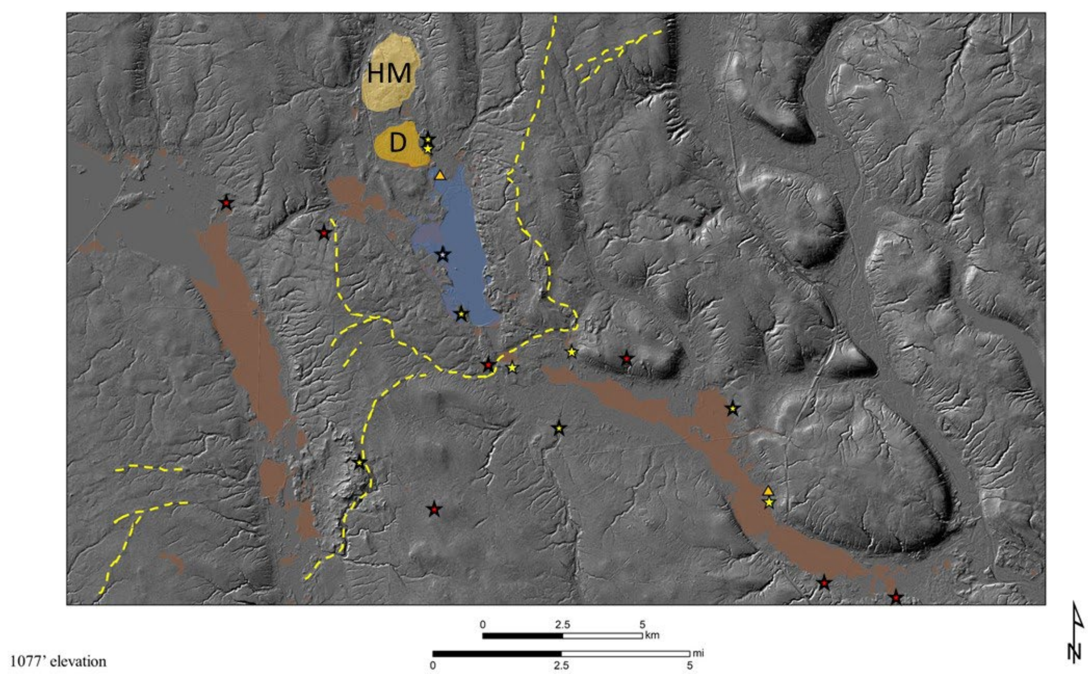

Figure 4.2 (d). *The 328 m (1077 ft) elevation contour is approaching the modern lake level of 326-327 m (1071-1073 ft). At this elevation, much of the former kettle hole is water-free and peat has developed in numerous poorly drained depressions and in areas of high groundwater. Dashed yellow lines show ice-marginal features.*

Table 4.1. **Summary of late Pleistocene and Early Holocene climate events, regional paleoenvironmental conditions, and eastern Great Lakes archaeology.**

Data compiled from Lothrop et al. (2016).

Climate Event	Middle Ohio Valley Paleoenvironments	Mid-Atlantic Paleoenvironments	Eastern Great Lakes Paleoenvironments	Cultural Period	Time-Diagnostic Paleoindian Point Types	Time-Diagnostic Early Archaic Point Types
Early Holocene 11.7-8.2 cal yrs BP (10.1-9.0 ^{14}C yrs BP) Warm-Dry	Pine-oak forest	Oak deciduous forest	Pine-Oak forest	Late Paleoindian 11.7-10.0 cal yrs BP / Early Archaic 11.7-8.2 cal yrs BP	Agate Basin/Hell Gap Quad/Beaver Lake/Dalton/Carson Lanceolate? Hi-Lo Eden-like	Charleston Palmer Kirk Corner- and Side-Notched St. Charles Kanawha
Younger Dryas 12.9-11.7 cal yrs BP (11.0-10.1 ^{14}C yrs BP) Cool-Wet/Dry	Spruce-pine-oak forest	Mixed boreal and deciduous forest	Spruce parkland to pine forest	Middle Paleoindian 12.2-11.6 cal yrs BP Early Paleoindian 12.9-12.2 cal yrs BP	Holcombe Crowfield Barnes/Cumberland Eastern Clovis Gainey	
Bolling-Allerod 14.6-12.9 cal yrs BP (14.0-10.9 ^{14}C yrs BP) Warming-moist	Deciduous woodland	Mixed boreal and deciduous forest	Spruce-tamarack-pine-oak forest	Pre-Clovis?	Non-diagnostic	

bands following the chronological terminology as discussed in Lothrop et al. (2016) and shown in Table 1. These sites nearly exclusively occur on kames or outwash terraces overlooking the lake-marsh system (Figure 4.2), consistent with the model of Paleoindian settlement patterns in NWPA suggested by Lantz (1984) and elsewhere in the formerly glaciated eastern Great Lakes region and northeastern North America (Ellis et al., 2011; Lothrop et al., 2016; Lothrop et al., 2017). This means that early Native Americans were living close to perceived resources near water bodies, often not on higher elevation uplands during the Pleistocene-Holocene Transition. We can discuss what this strategy means for the long-held idea that Paleoindian bands were "big game" hunters if we have time. However, caution is warranted with making cultural interpretations of settlement and subsistence in NWPA because none of these sites have undergone formal, intensive excavations, and also due to the sometimes sketchy nature of information in the PASS files entered into PA-SHARE.

Water levels in the lake-marsh system apparently fell ~12,768 cal yrs BP (10,820 +/- 70 14C years BP) based on the presence of an oxidized, charcoal-bearing buried soil on the adjacent kame terrace (see Figure 4.2a for location). The presumed drop in water level occurs during early Younger Dryas, and when paleoenvironmental conditions were rapidly changing from warming to cooling, and initial Early and early Middle Paleoindian bands were populating formerly glaciated portions of the region (Table 1; Newby et al., 2005; Ellis et al., 2011; Lothrop et al., 2016; Lothrop et al., 2017; Carr and Adovasio, 2020; Vento et al., 2020; Grote et al., 2022). At Silver Lake, located ~ 120 km (75 mi) southwest of Conneaut Lake in Summit County, Ohio, the Younger Dryas is also well expressed sedimentologically and within the pollen spectrum (Swisher and Peck, 2020). The Silver Lake pollen spectrum indicates that during the early YD (~12,910 cal yrs BP) spruce, fir and oak dominate the pollen spectra, which is consisted with numerous other regional paleobotanical studies in the Midwest and northeastern North America. At about 12,130 cal yrs BP, during the middle Younger Dryas, organic matter dramatically increases accompanied by a rapid increase in pine pollen, and decreasing concentrations of spruce and oak, and to a lesser extent fir, at Silver Lake, and other nearly sites on the Appalachian Plateau in Ohio (Swisher and Peck, 2020). They suggest that in the middle Younger Dryas there is a hydroclimate change from cool-wet to cool-dry in eastern Ohio. Several lakes and bogs located ~ 200-250 km (~124-155 mi) northeast of Conneaut Lake in western New York paint a similar picture as Silver Lake, Ohio (e.g. Miller and Futyma, 2003; Webb III et al., 2003) and are in general agreement with the reconstructions of Shuman et al. (2002) for the eastern United States (Table 4.1). Although the pollen record at Hartstown Bog (see green triangle on Figure 4.2a for location) is poorly constrained (only a single accepted radiocarbon assay), five changes in reconstructed vegetation have been identified and when compared to the "nearby" Ohio and New York pollen diagrams they appear reasonably similar.

Rapid warming at the end of the Younger Dryas signals the end of the Pleistocene glacial period and the ushering in of the Holocene Interglacial (Figures 4.4; Table 4.1). The end of the Younger Dryas also witnessed the abandonment of fluted technology and a shift in land utilization practices such as the abandonment of less productive land in favor of lake shores and the periphery of wetlands (Figure 4.3; Table 4.1; Newby et al., 2005; Munoz et al., 2010; Ellis et al., 2011; Lothrop et al., 2016). It is assumed that water levels in the Conneaut lake-marsh system (Figure 4.2a & d) were near modern levels at that point and Early Archaic archaeological sites in the vicinity likely suggest a continued use of the lake and marsh. The Early Holocene climate is interpreted to have been cool, but warming, and dry which allowed for the rise of closed forests of pine, oak and birch (Table 4.1; Watts, 1979; Webb III et al., 2003; Shuman et al., 2004; Munoz et al., 2010; Vento et al., 2020). The dominance of pine ends during the late Early Holocene (10,900-8200 cal yrs BP) in many regional pollen spectra and is replaced by oak and hickory (Shuman et al., 2004; Munoz et al., 2010; Lothrop et al., 2016). Regionally, 8200 cal yrs BP marks another major climate-ecosystem-human transition with a shift from cool and dry to warm and wet, and the end of the Early Holocene and Early Archaic cultural period (Table 4.1; Munoz et al., 2010). The shift in climate at 8200 cal yrs BP is related to the final collapse of the LIS. During the Middle Archaic cultural period the regional climate remained warm and wet with forests consisting of hemlock, beech and hickory (Shuman et al., 2004; Munoz et al., 2010). Marshland was present within the northern portions of the kettle around the lake inlet by ~ 7273 cal yrs BP (6350 +/- 80 14C yrs BP) as water levels stabilized at or very near (maybe 1 m or so from modern) the modern elevation of ~327 m (~1071-1073 ft) above mean sea level (Figures 4.2a & d). Sometime afterwards, overbank sedimentation produced a clastic-dominated floodplain in the lowest portions of the Conneaut Lake inlet valley while marshland persisted within the outlet valley and at higher elevations within the kettle.

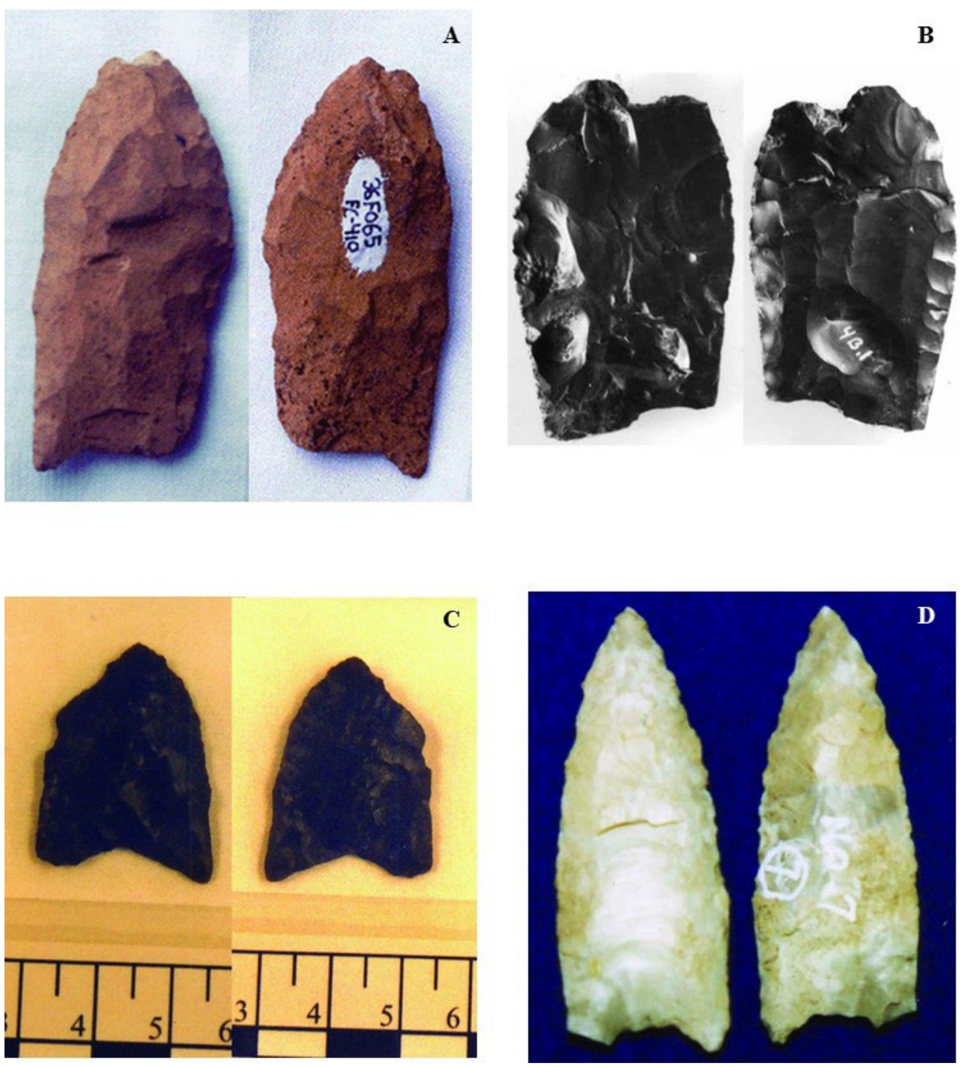

Figure 4.3. *Examples of Paleoindian projectile points recovered from northwestern Pennsylvania. A – Barnes point (Middle Paleoindian) made from Onondaga Chert, Andy Myers photo; B – half of a Crowfield point made from Upper Mercer Chert, Gary Fogelman photo; C – Eastern Clovis point made from chalcedony, Gary Fogelman photo; D – Eastern Clovis point made from Onondaga Chert, Carl Burkett (?) photo.*

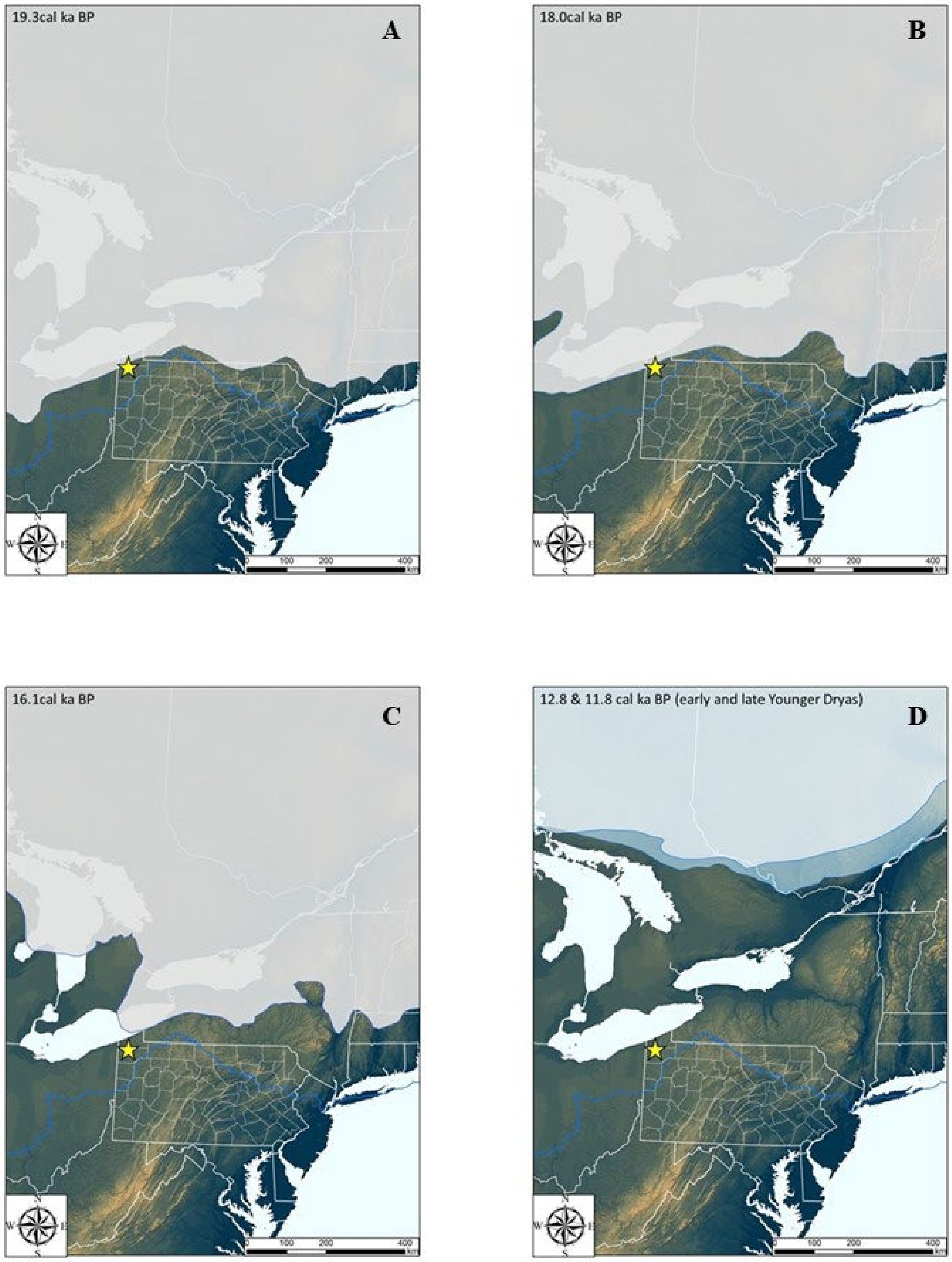

Figure 4.4. *Reconstructed post-glacial maximum ice marginal positions. A – 19.3 cal ka BP during the Erie Interstade; B – 18.0 cal ka BP; C – 16.1 cal yrs BP when northwestern Pennsylvania was ice-free; and D – the 12.8 cal yrs BP (medium blue, early Younger Dryas) and 11.8 cal yrs BP (light blue, late Younger Dryas). Yellow star is approximate location of this study. Blue line is the position of the last glacial maximum, locally the Kent End Moraine. Ice margins from Dalton et al., 2020.*

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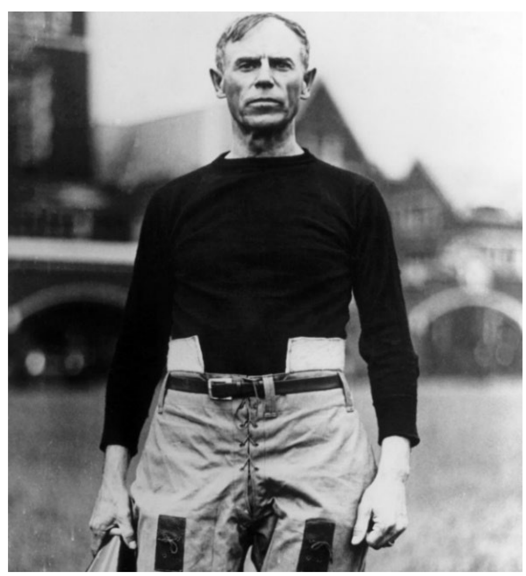
Miles	Cum	Description
	122.7	Turn left onto N 2nd Street to exit Stop 4.
0.1	122.8	Turn left onto US-322 East/US-6 East.
8.2	131	Meadville (41.6293, -80.15493). In addition to Clark Gable, Meadville was the childhood home of actress Sharon Stone.
8.3	131.1	Bear right (straight) onto Park Ave.
0.1	131.2	Turn right onto Linden Ave (US-322).
0.1	131.3	Stay straight on Linden Ave (US-322).
0.1	131.4	Turn left onto Liberty Street.
0.8	132.2	Turn right onto PA-27 East (North Street).
0.1	132.3	Bear left onto State Street, staying on PA-27 East.

0.2	132.5	Turn right onto Washington Street, staying on PA-27 East.
15.8	148.3	Turn right onto PA-427 South.
0.1	148.4	Entrance to Hillside Stone. This pit is briefly discussed with Stop 1. We are along Sugar Creek, which contains Kent-age outwash in an ice-marginal channel.
1.9	150.3	Turn left onto Ridgeview Road (SR-4022).
0.4	150.7	Turn right to stay on Ridgeview Road.
6.3	157	Continue straight through crossroad (cutting across Dempseytown Greshem Road) onto Buxton Road
3.0	160	Turn right onto PA-8 South.
0.4	160.4	Turn right to arrive at Cross Creek Resort.

Point of Interest: Titusville was the home of Ida Tarbell, one of the most influential muckrakers of the Gilded Age. In 1900, she wrote a series of investigative articles (later compiled into the book *The History of the Standard Oil Company*) that highlighted the illegal practices being used by J. D. Rockefeller to stamp out smaller competing oil companies. She was able to prove that Standard Oil had a history of strong-arm tactics, espionage, and collusion going back over thirty years. Her exposé is generally thought to be the inciting incident for the U.S. Supreme Court case in 1911, in which Standard Oil was found guilty of violating the Sherman Antitrust Act. As a result, Standard Oil was fractured into a series of smaller companies, the descendants of which include ExxonMobil and Chevron.

(Source: King, G., 2012, The Woman Who Took on the Tycoon, Smithsonian Magazine, https://www.smithsonianmag.com/history/the-woman-who-took-on-the-tycoon-651396/?no-ist).

(Figure Source: Purdy, J. E., Public Domain, 1904, "Ida M. Tarbell (1857-1944), head-and-shoulders portrait, facing front," http://www.commons.wikimedia.org/w/index.php?curid=9091982).



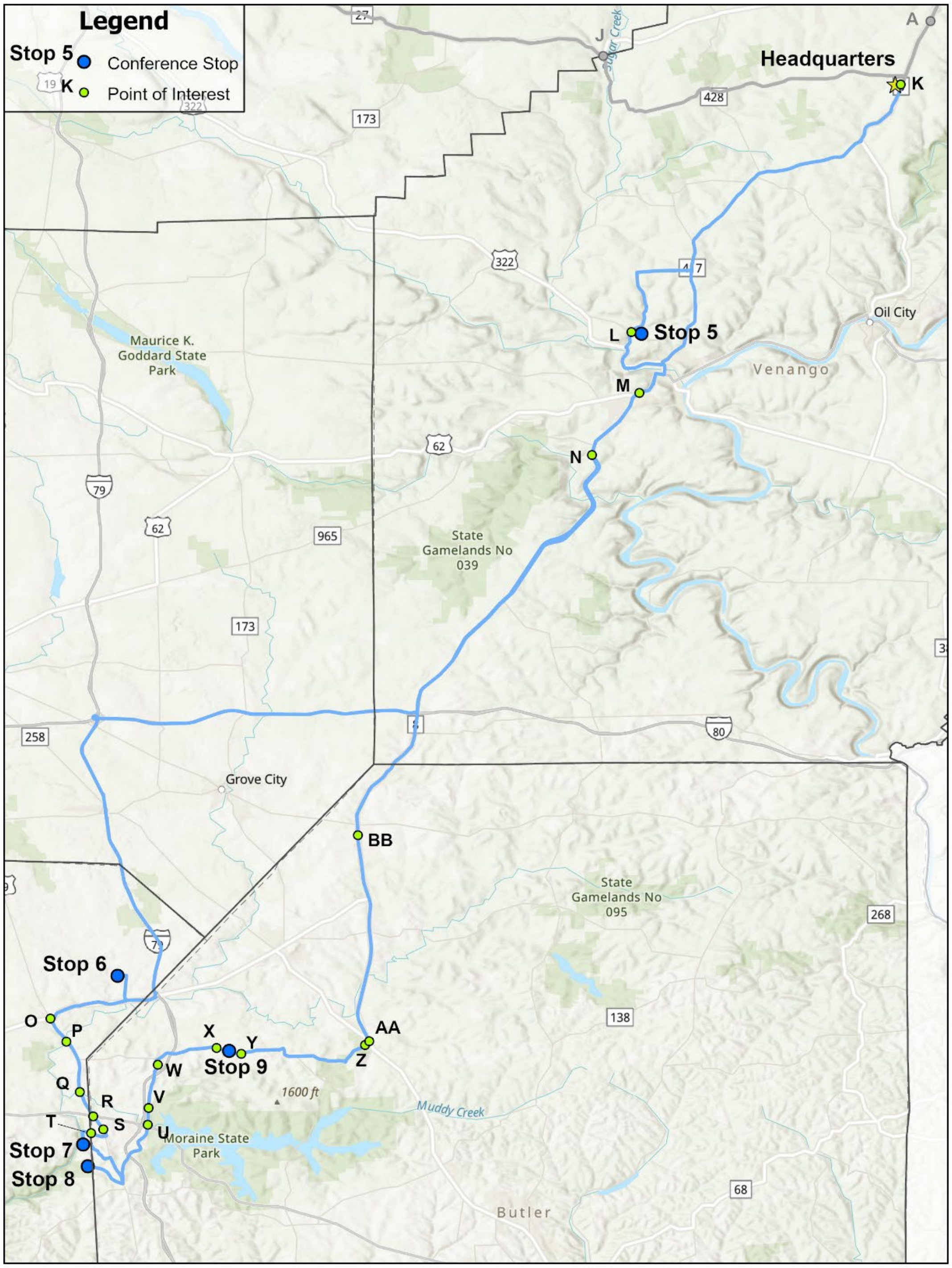
Point of Interest: Titusville was also the birthplace of John Heisman, for whom the Heisman Trophy is named. Among other things, Heisman's impact on football includes:

- Legalizing the forward pass
- Inventing the hidden ball play
- Originating the "hike" or "hep" shouted by the quarterback to start each play
- Leading the effort to cut the game from halves to quarters
- Listing downs and yardage on the scoreboard

(Source: National Football Foundation & College Hall of Fame, Inc., 2022, Hall of Fame: John Heisman, https://footballfoundation.org/hof_search.aspx?hof=1297).

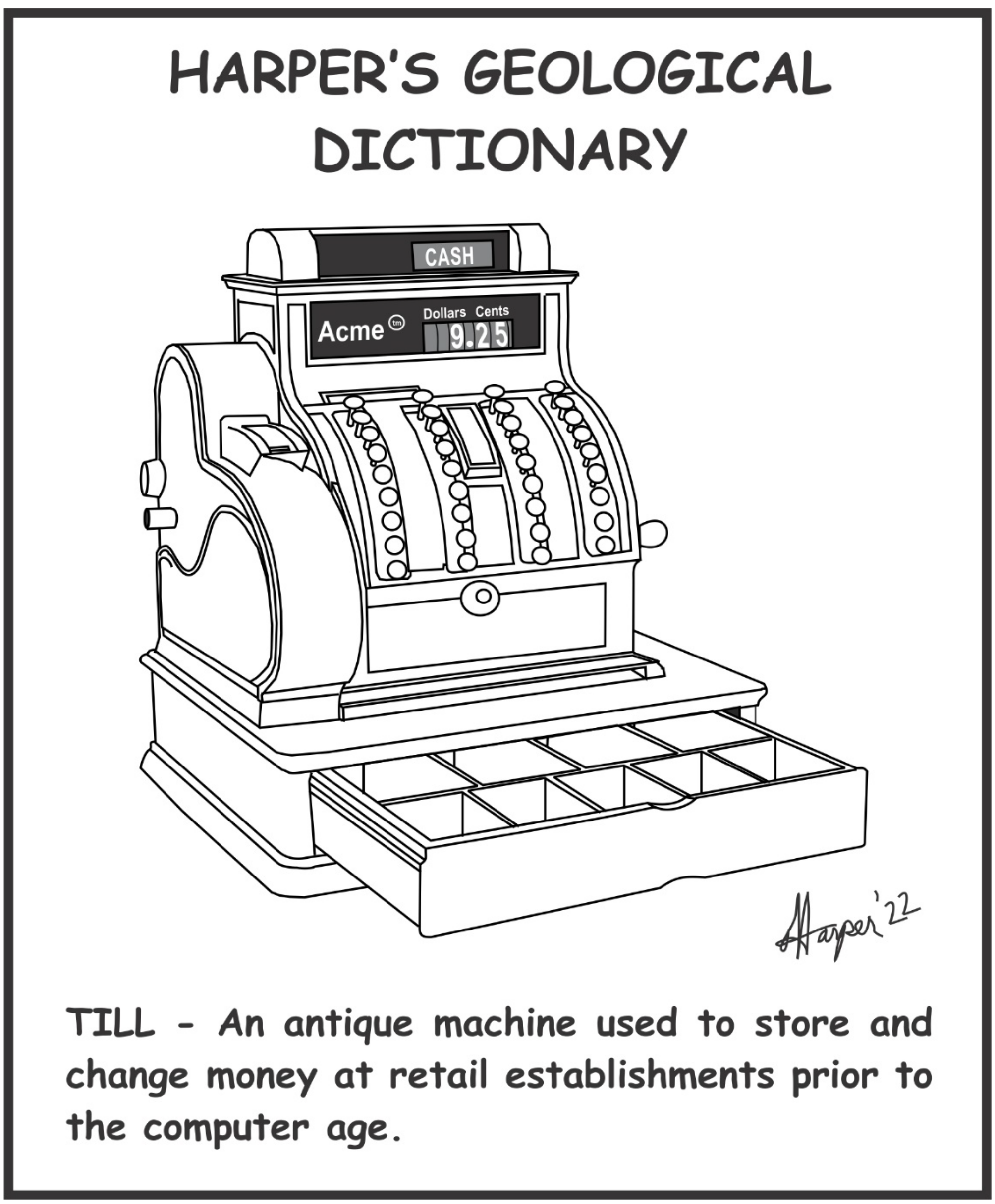
(Figure Source: Georgia Tech Archives & Records Management, 1917, John Heisman standing on Bowman Field, in front of Tillman Hall, on the Clemson University Campus, https://commons.wikimedia.org/wiki/File:John_Heisman.jpg).

DAY 2 ROADLOG



Miles	Cum	Description
0.0	0.00	**START, 7:30 AM, Cross Creek Resort, Titusville, PA (41.56619, -79.69807)**

Miles	Cum	Description (25 min)
0.3	0.3	Turn right on PA-8 North
2.7	3.0	Bear right onto PA-417 South.
8.1	11.1	Turn right onto Keely Road.
1.5	12.6	The pit at the intersection is the Cooperstown Pit discussed at Stop 5. This pit was Stop 11 of the 1976 FCOPG.
0.1	12.7	Turn left onto Patchel Run Road.
2.6	15.3	Turn left onto Meadville Pike.
0.3	15.6	Turn left to enter Vincent Excavating and Gravel / **STOP 5**.



STOP 5: VINCENT SAND AND GRAVEL PIT

ERIC STRAFFIN – PENNWEST UNIVERSITY, EDINBORO CAMPUS
GARY M. FLEEGER – PENNSYLVANIA GEOLOGICAL SURVEY *(RETIRED)*

1 hr.
Rt 417 N, Franklin, PA 16323
7:55 – 8:55 AM ***41.421266 / -79.845179***

Location

The Vincent Excavating and Gravel pit has been in operation since 1953 by the Vincent family. It is located along Patchel Run, a tributary to French Creek downstream from the confluence of Sugar and French Creeks, and northwest of Franklin, Pennsylvania (**Figure 5.1**).

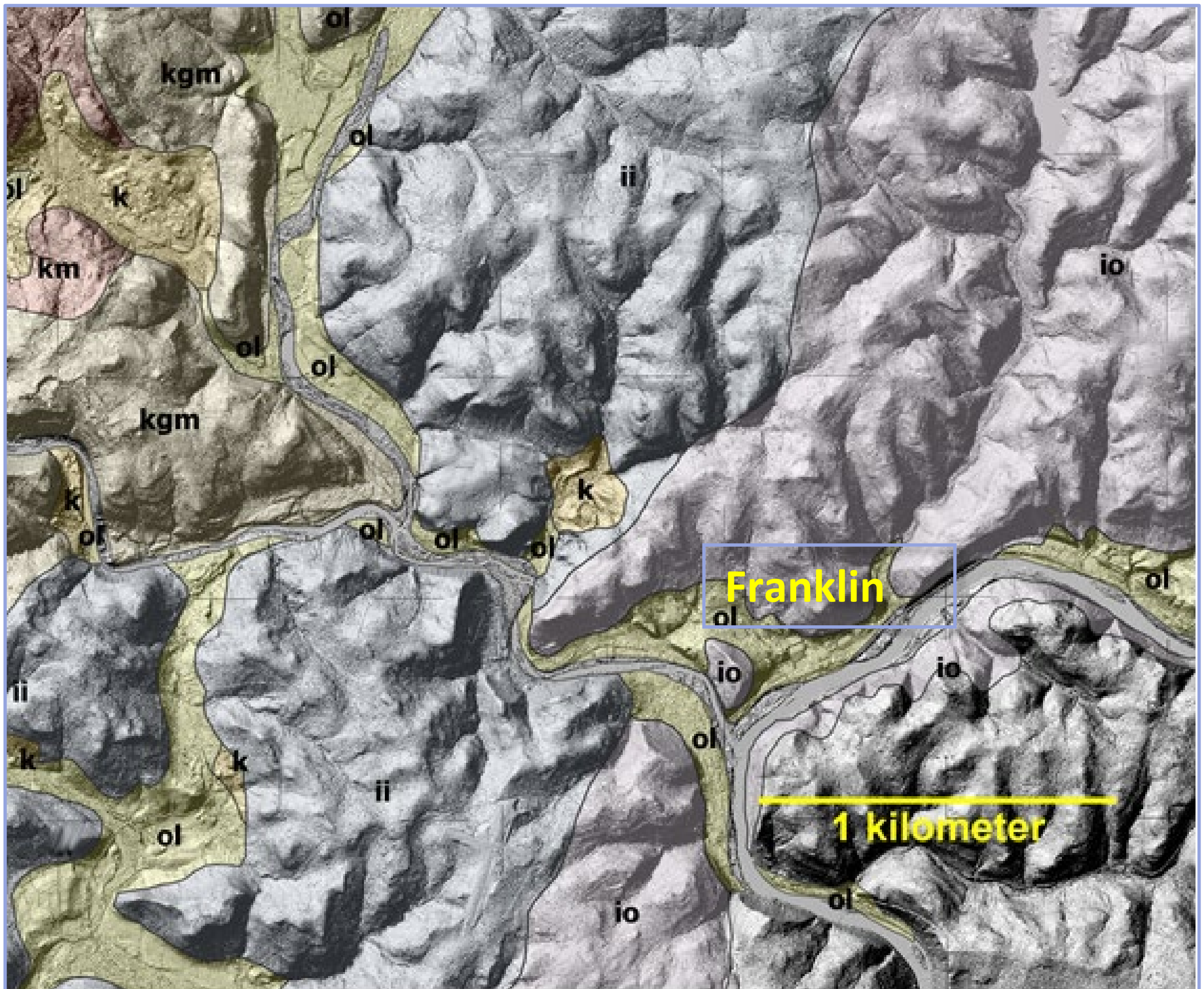


Figure 5.1. *The Vincent and Cooperstown pits are located in the kame deposit (k) in the center of the map. The ii is the mapped extent of Titusville Till. io is Mapledale Till. km and kgm are Kent Moraine and ground moraine, respectively. Outwash is labeled ol. Geology from Shepps et al (1959), Plate 1 overlain on 10x lidar hillshade.*

Geology

White et al (1969) interpreted this deposit, exposed in the Vincent pit and nearby Cooperstown S&G pit, ¼ mile to the west across Patchel Run (**Figure 5.2**), as a Mapledale kame deposit (Figure 5. 1). It is right at the mapped Titusville till border, just beyond the well-defined Kent end moraine (Figure 5. 1; Shepps et al, 1959). White et al (1969) interpreted less weathered Titusville till and gravel over Mapledale gravel in the Cooperstown pit. These kame deposits are along the Patchel Run valley walls. Previous work (White et al, 1969) suggests that pre-Illinoian tills could be present at depth.

We chose this stop because we sampled it for OSL dating, to confirm or revise the White et al (1969) age interpretation. However, we did not receive the dates from the lab in time to include them in the guidebook.

The Vincent pit exposes deposits from several different depositional environments, including glacial, fluvial, lacustrine, and colluvial settings. The southeastern edge of the pit (**Figure 5.3** and 5.4) bisects the westward sloping original hillslope (**Figure 5.4**), and from the top down (Figure 5.4 and **Figure 5.5**): a) colluviated till, with numerous horizontal platy sandstone clasts, b) weathered till, tentatively identified at the Mapledale(?) Till, with an eluvial horizon at the top (**Figure 5.6**), c) weathered coarse sand and gravel, with some imbrication, cemented with iron and manganese, d) unweathered, light, cross bedded, rippled sand and fine gravel. The stratified sand and gravel below the iron cemented unit were sampled for OSL (Sample 11-19-21-1; Figure 5.5) and provide a maximum age on the timing of that deposit.

The white clay eluvial horizon (Figure 5.6) is intensely weathered, and has had most of the iron and manganese removed, which has leached into the underlying weathered coarse sand and gravel. Much of the contact at the top of the coarse sand and gravel has an accumulation of manganese (Figure 5.5), and the pattern of iron and manganese accumulation suggest preferred groundwater flow paths.

The southwestern edge and western wall of the Vincent pit exposed till overlain by cross bedded sandy fluvial and silty, horizontally laminated sediments, likely of lacustrine origin. Cross bedded sands from fluvial units were sampled for OSL (Sample 11-19-21-2, **Figure 5. 7**) in order to provide age estimates of outwash, and a minimum age for the underlying till.

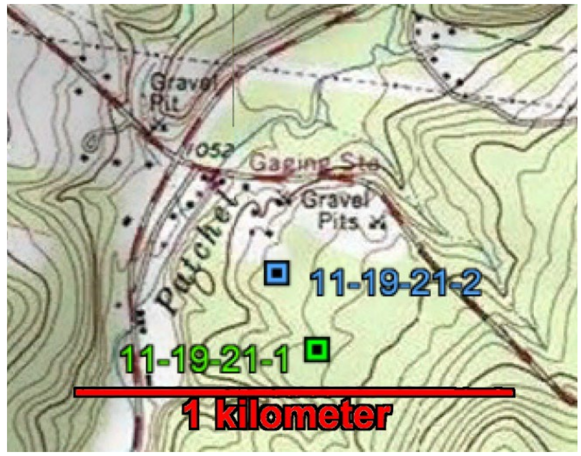


Figure 5.2. *Location of the Vincent (southeast of Patchel Run) and Cooperstown (northwest of Patchel Run) pits. Cooperstown appears to be a flat-topped terrace. Vincent deposit is partly covered to the east by hillslope (colluvial) deposits. Locations of the 2 OSL samples (Figures 3 and 4) are noted. From the USGS Franklin 7.5' quadrangle map.*

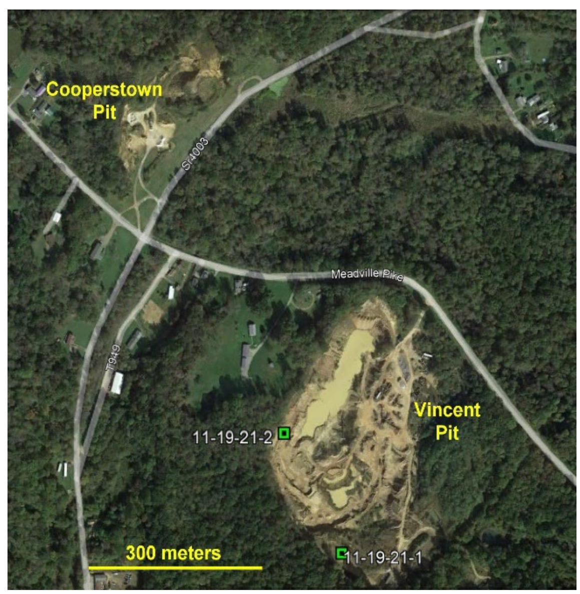


Figure 5.3. *Aerial view of the Vincent and Cooperstown pits, and locations of the OSL samples. Aerial photo from Google Earth, dated 10/9/2019. The pit had expanded in the 2 years between the photo and the sampling date.*

Figure 5.4. *South (distant) and west (right side) walls of Vincent Pit. OSL samples taken in the unweathered sand below dark weathered sand and gravel (maximum age of overlying till) in the southeast corner, and in sand above till (minimum age) in the west wall. Photo by Gary Fleeger.*

Considerable complexity in geometry and thickness of units were observed in the different walls of the pit. Cross bedded sand with coal coarsened upward to weathered coarse sand and gravel in the southeastern end of the pit, overlain by till, while a boulder to cobble rich till was present at the base of the west wall of the pit, overlain by laminated silt and sand (Figure 5. 4). It was difficult to trace the till from the south to west wall through a covered interval (Figure 5. 4), to determine if the same till is exposed above sand and gravel in the SW corner, and below sand and silt in the west wall.

A. Colluviated Till
B. Mapledale (?) Till
C. Weathered coarse sand and gravel.
D. Unweathered fine sand and gravel (OSL sample)

Figure 5.5. *Southeastern pit wall, Vincent Pit. Cross bedded sand and gravel lenses at base of pit (D), overlain by dark, cemented sand and gravel (C), and till (B). Colluviated till at top (A). Manganese accumulation in coarse, weathered sand and gravel at the contact with the overlying weathered Mapledale(?) Till. OSL sample 11-29-21 taken in basal unweathered sand.*

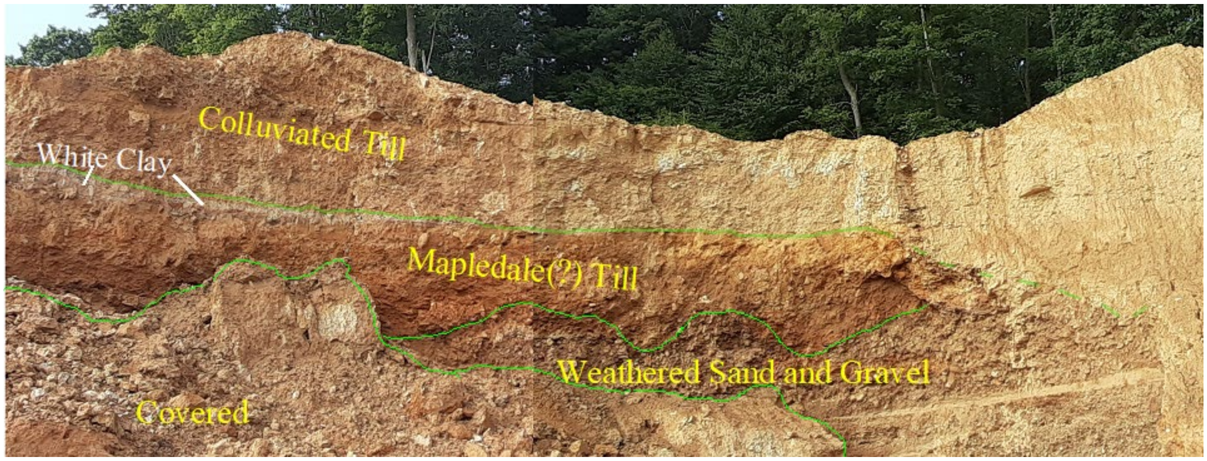


Figure 5.6. *Detail of the southeastern wall of the Vincent Pit. The white clay of the eluvial horizon is shown in this view. The horizontal platy sandstone pieces are obvious in the colluviated till.*

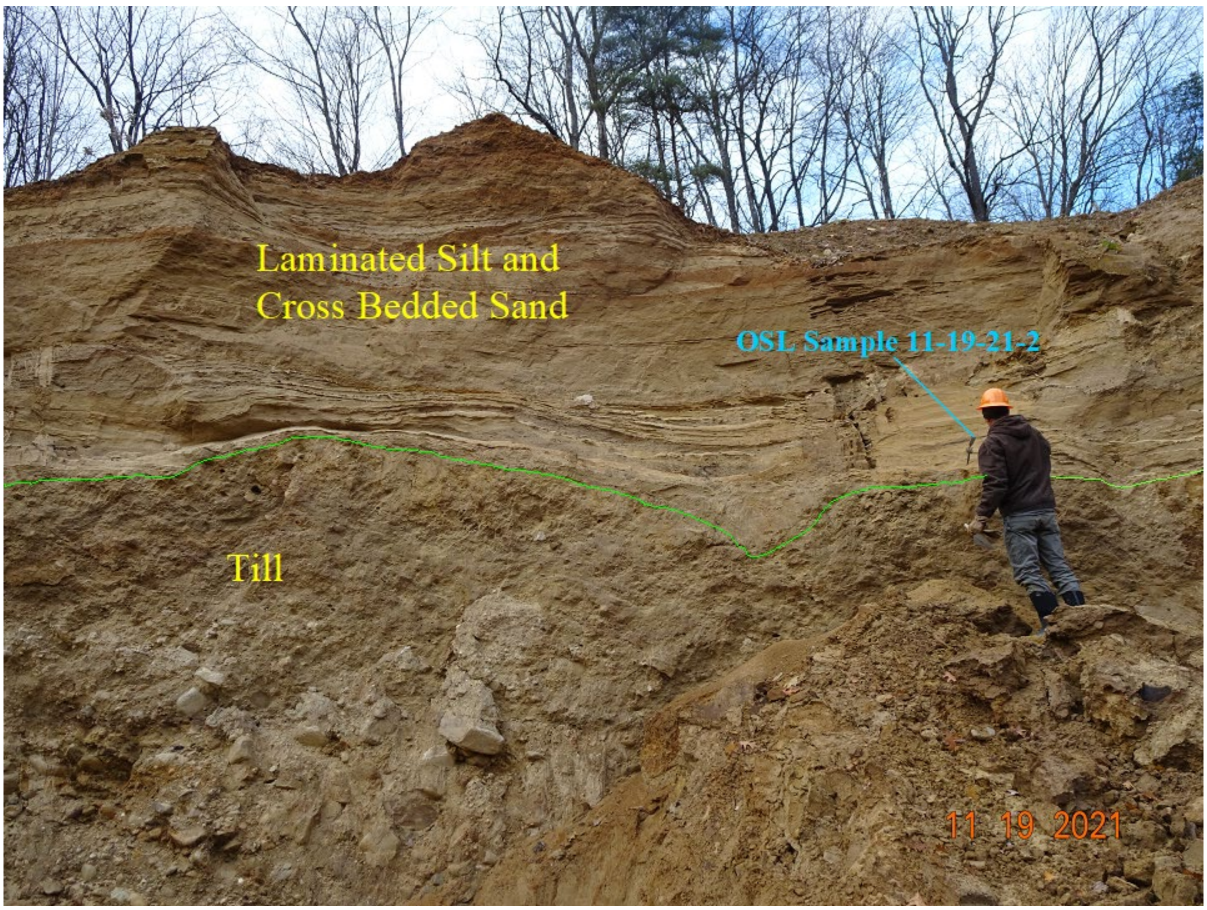


Figure 5.7. *Vincent Pit, west wall illustrating till at base, overlain by cross bedded sand and topped by silty laminated sediment. OSL sample 11-19-21-2 was taken just above till within sand. Photo by Gary Fleeger.*

References

Shepps, V.C, G.W. White, J.B. Droste, and R.F. Sitler (1959) Glacial geology of northwestern Pennsylvania, Pennsylvania Geological Survey, 4th series, General Geology Report 32, 59 p.

White, G.W., S.M. Totten, and D.L. Gross (1969) Pleistocene stratigraphy of northwestern Pennsylvania, Pennsylvania Geological Survey, 4th series, General Geology Report 32, 85 p.

Miles	Cum	Description (50 min)
	15.6	Turn left onto Meadville Pike to exit Stop 5.
0.3	15.9	Turn left onto Patchel Run Road.
0.7	16.6	Turn left onto US-322 East.
2.0	18.6	Turn right to stay on US-322 East.
0.5	19.1	Turn right onto PA-8 South.
1.3	20.4	To the west (right), behind the large white building with the arched roof is the type section of the Mapledale Till. The excavation was made during site preparation for that building. This was Stop 7 of the 1976 Field Conference.
2.8	23.2	The now heavily vegetated cut on the east (left) side of the road is the Sandy Creek Section. It was Stop 8 of the 1976 Field Conference. The section extended from complex glacial sediments at the top, into the Pennsylvanian Mercer shale through the Lower Member of the Mississippian Shenango Formation, for a distance of about 2 miles to Sandy Creek.
12.4	35.6	Turn right onto ramp for I-80 West.
9.9	45.5	Exist right onto I-79 South.
11.9	57.4	Exit right to PA-108.
0.2	57.6	Turn right at the end of the ramp onto PA 108 West
0.9	58.5	Turn right onto Plain Grove Road
1.0	59.5	Turn left onto Reese Road
0.2	59.7	Turn left to arrive at the McClymonds pit / **STOP 6**.

(Figure Source: Azovtsev, D., 2005, North American River Otters, *Lontra canadensis*, https://commons.wikimedia.org/wiki/File:LutraCanadensis_fullres.jpg).

Point of Interest: Venango County got its name from a variation on the Native American word for the region: *onenge*. English settlers butchered the pronunciation of this word into the present-day equivalent. So, what does *onenge* mean in the original Iroquois? It is the Iroquois word for "otter!"

(Source: Donehoo, G. P., 1928, Indian Villages and Place Names in Pennsylvania, https://www.crawfordcopa.com/history/FrenchCk.html

Point of Interest: There is significant disagreement on the origins of Lawrence County's name. Even the county government and their board of tourism disagree! The main consensus is that Lawrence County was either named for Captain James Lawrence, a hero in the war of 1812, or the *USS Lawrence*, a 493-ton ship named for the captain. Captain Lawrence is well-known for his last words, "Don't give up the ship!" This saying is still a popular battle cry in the US navy and was the motto and flag inscription of the *USS Lawrence.*

(Source: Lawrence County, 2022, The History of Lawrence County, Pennsylvania, https://lawrencecountypa.gov/history-lawrence_county/).

(Source: Visit Lawrence County, n.d., Visit Lawrence County, Pennsylvania – Simply Beautiful!, https://www.visitlawrencecounty.com/about-lawrence-county/history-of-lawrence-county/).

(Source: Gannett, H., 1905, The Origin of Certain Place Names in the United States, U.S. Government Printing Office, https://books.google.com/books?id=9V1IAAAAMAAJ&pg=PA182#v=onepage&q&f=false).

(Figure Source: Stuart, G., 1812, Oil on wood, 28.5 x 23.5, Painting in the U.S. Naval Academy Museum Collection, https://commons.wikimedia.org/w/index.php?curid=110019164).

STOP 6: McCLYMONDS SAND & GRAVEL PIT

3 RIVERS AGGREGATE COMPANY QUARRY, PLAIN GROVE, PA

Aaron D. Bierly & Gary M. Fleeger *(retired)* – Pennsylvania Geological Survey
Contributors: Allan C. Ashworth [1], Dorothy M. Peteet [2], Margaret A. Davis[3] and Brendan J. Culleton[3]

1 hr.
773 Reese Road, Slippery Rock, PA 16057
9:45 – 10:45 AM ***41.049 / -80.1485***

Regional Setting

The buried bedrock valley is very obvious on the geologic and bedrock topographic map of the Mercer 15' quadrangle (**Figure 6.1**).

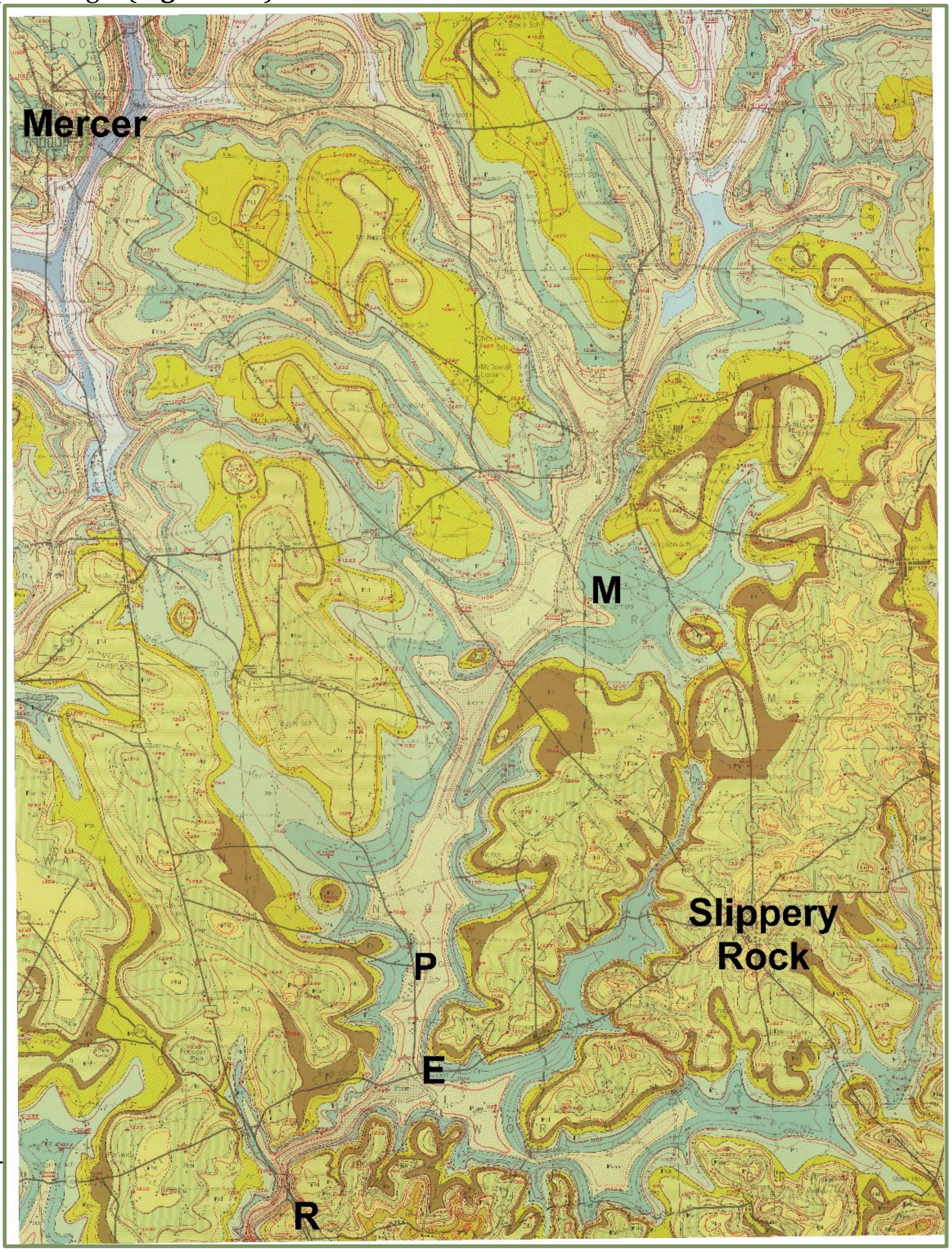


Figure 6.1. *Geologic and bedrock topographic map of the Mercer 15' quad. Modified from Plate 2 from Poth (1963). M = McCoys Corners, E = Elliotts Mill, R = Rockville, P = Plain Grove.*

[1] North Dakota State U
[2] Columbia University
[3] Penn State University

The buried valley is unusual for several reasons:

1. Much of it is very linear (Figures 6.1 and 6.2).
2. The gradient in the bedrock valley is south-southwest, approximately perpendicular to general northwest direction of pre-glacial drainage.
3. There are 4 well-developed partially-buried bedrock valleys extending northwest from the buried valley (Figures 6.1 and 6.2).
4. There are only a few, short tributary valleys on the east side of the buried valley.

The southernmost of the 4 partially-buried NW valleys, which today contains Schollard and Taylor Runs, is likely the pre-glacial course of Slippery Rock Creek (**Figure 6.3**). It flowed north in the buried valley from Elliotts Mill and northwest, probably to Lackawannock Creek and the Erie basin.

Each of the northwest-trending buried bedrock valleys has a bedrock divide in it (**Figure 6.2**). Each valley is currently occupied by a pair of streams flowing from a divide in the valley that does not coincide with the divide in the bedrock valley (**Figure 6.4**).

The linear southwest-trending buried valley was the original course of Wolf Creek (Figure 6.2), flowing to its confluence with the NW-flowing pre-glacial Slippery Rock Creek (Figures 6.2 and 6.3). The SW orientation of the buried Wolf Creek valley was likely structurally controlled, because it is so linear and heads at the Henderson Dome, a diapiric intrusion of Reedsville Shale (Fettke, 1950, 1954, Kuminecz and Gorham, 1993) or a magmatic intrusion (Pees and Palmquist, 1985).

Proposed Sequence of Events

1. The original pre-glacial drainage was to the NW through the 4 valleys. The southern one was Slippery Rock Creek (Figure 6.3).
2. An advancing glacier dammed Slippery Rock Creek. Lake overflow at the Rockville col (Valley Constriction on Figure 2) diverted Slippery Rock Creek through the col into the Muddy Creek valley and west to New Castle (Figure 6.2).
3. Slippery Rock Creek continued to erode deeper. Stream piracy of the headwaters of the other 3 NW streams by headward migration along lineament formed the original Wolf Creek bedrock valley (Figure 6.2). Erosion of the Wolf Creek bedrock valley along the lineament could have occurred partly or completely pre-glacially, but likely after the Rockville col eroded and Slippery Rock Creek was diverted through it.
4. As the combined Slippery Rock-Wolf Creeks downcut, the 4 west side tributaries eroded along the pre-glacial bedrock valleys by headward migration, capturing part of the flow of the 4 NW streams, and creating cols in those bedrock valleys (Figure 6.2). Some of the headward migration could have occurred by glacial damming of the 4 NW streams, and lake overflow into the Wolf Creek valley, which now had an outlet to Slippery Rock Creek through the Rockville col.
5. Glaciation partly filled Wolf Creek and the 4 NW valleys, terminating the erosion in those bedrock valleys. Modern post-glacial streams developed in those valleys at higher levels (Figure 6.4). Each of the 4 valleys today has 2 streams, one flowing NW and the other SE from a col that does not necessarily coincide with the bedrock col formed in #4 above (Figure 6.4).

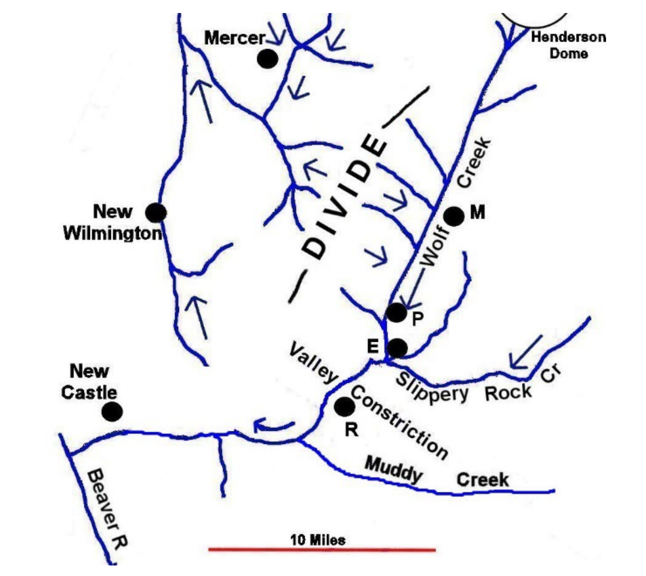


Figure 6.2. *Map of original Wolf Creek, Slippery Rock Creek, and 4 northwest-southeast bedrock valleys, as they are configured today. Most of these valley are now partly or mostly buried with glacial sediment.*

M = McCoys Corners

E = Elliotts Mill

R = Rockville

P = Plain Grove

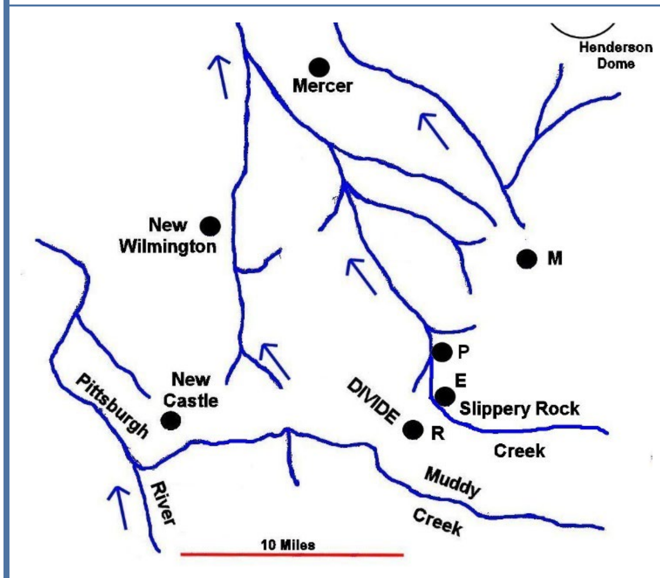


Figure 6.3. *Map of interpreted pre-Wolf Creek drainage to northwest through the 4 northwest-southeast valleys.*

M = McCoys Corners

E = Elliotts Mill

R = Rockville

P = Plain Grove

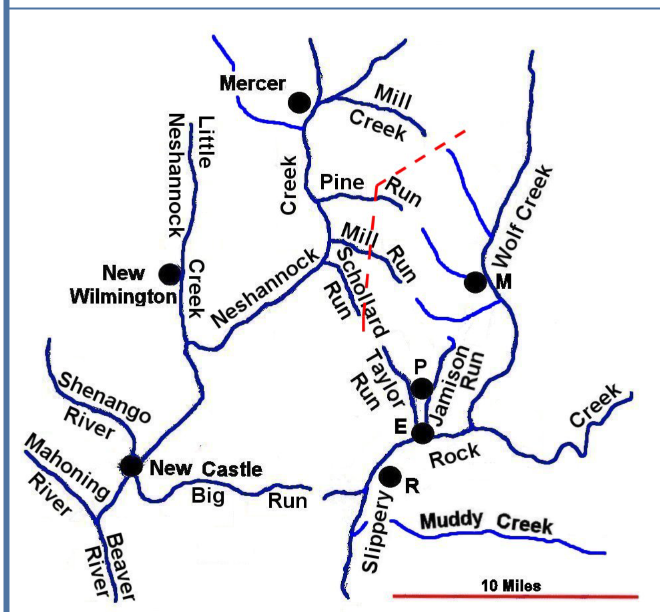


Figure 6.4. *Map of modern stream configuration. All drainage today is ultimately to the south. Red dashed line indicates current location of the bedrock divide in the four NW valleys.*

M = McCoys Corners

E = Elliotts Mill

R = Rockville

P = Plain Grove

While the relative sequence of events can be interpreted, we have insufficient data to determine when these events occurred. Radiocarbon dates of about 40,000 years from organic material in the upper 40 feet this core hole in the buried valley suggest that the valley was largely filled prior to the late Wisconsin glacial episode. But when the earlier events took place is unknown. The diversion through the Rockville col was likely during one of the earliest Pleistocene glaciations (MIS 22+, Braun, this volume).

Core Hole and Quarry

Key Points

- The quarry is located within a buried valley with glacial sourced sediments between 100 and 170 feet thick in the immediate area
- Sediment at 32 feet below ground surface at the quarry date between 41,000 BC and 46,000 BC
- The insect and pollen samples from 32 feet below land surface (bls) indicates a wetland environment in a spruce-dominant forest similar to those found currently in central Canada.
- The insect and pollen samples from 39 feet bls indicates a tundra environment similar to that of the North Slope of Alaska and the Canadian Arctic.
- The faunal and floral changes indicate climatic warming from the lower ft bls to 32 feet bls. The mean July temperature at 39.2 feet bls is estimated to be 11-12°C and at 32.0 ft bls 15-17°C compared to 21°C at Slippery Rock today. Representing deposition during a warming period (interstade)

The quarry at Reese Road is excavating Wisconsinan-aged, sand and gravel from till and glaciofluvial deposits. Drilling records from water wells indicate the sand and gravel operation is located on the western side of a buried valley (**Figure 6.5**). Northeast of the quarry the valley locally deepens preserving up to 170 feet of glacial drift.

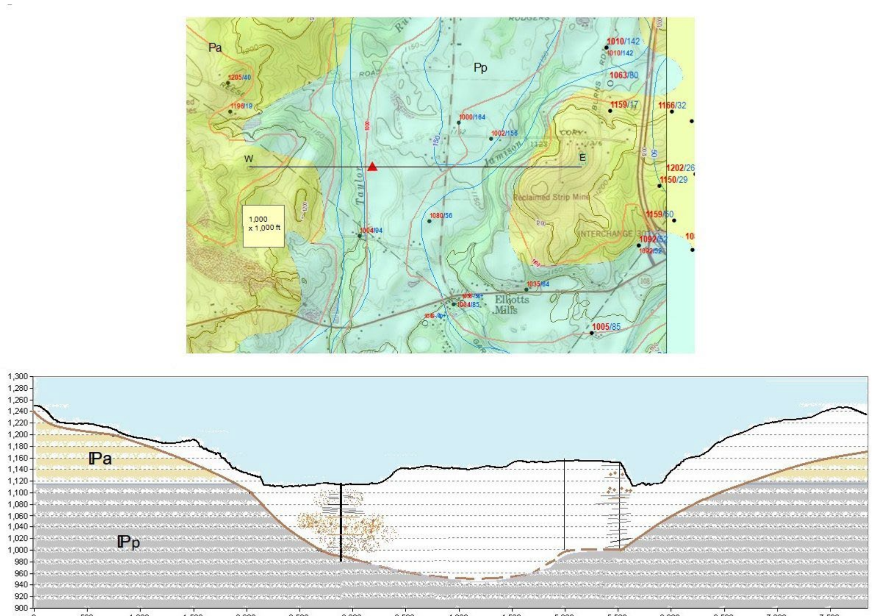
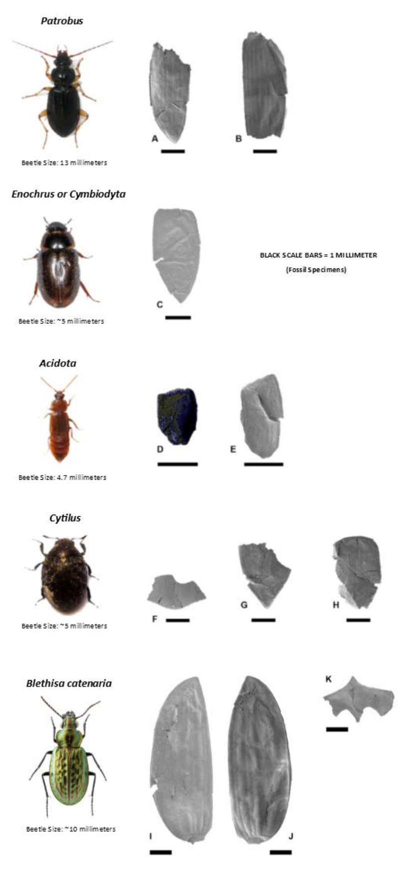


Figure 6.5. Top - Geologic, bedrock topography, and drift-thickness map of the area of the core hole, LAW073_2360, Blue drift-thickness and red bedrock elevation contours from Reese et al (2022). Wells in the area noted with the bedrock elevation labeled in red and the drift thickness labeled in blue. Bedrock geology from Berg et al (1980). Pa = Allegheny Formation. Pp = Pottsville Formation. Bottom - Cross section showing location of core hole within the buried valley.

In July 2020, the Pennsylvania Geological survey drilled a single sonic core that captured the entire glacial profile with depth of bedrock 118.5 feet bls (**Figure 6.6**). The core showed four intervals of sand, gravel, and till separated by three packages of silt and clay. At 32 feet below land surface the quarry intersected a thin peat horizon. The peat contained sparse and disarticulated insect fragments including Patrobus, Cytilus, Acidota, and either Enochrus or Cymbiodyta (Figure 6.6). Along with the beetle remains, wood, moss, charcoal, fungal sclerotia, Picea (spruce) needles, Salix (willow) buds, Carex (sedge) achenes, and a Viola (violet) seed were recovered (**Table 6.1**). Pollen (n=664) and spores (n=14) compiled from two samples showed additional flora (**Table 6.2**). Comparing the pollen to modern day assemblages (Farley-Gill, 1980 and Lichti-Federovich, 1968), the biota from this peat indicates a wetland environment (bog, fen, or lake shore) in a spruce-dominant forest similar to those found currently in central Canada. Two radiocarbon samples from this horizon have ages of 42,110±1280 BP (41,006 cal BC to 45,833 cal BC) and 42,190±1290 BP (41,029 cal BC to 45,938 cal BC) (Bierly et al, 2022).

At 39.2 ft bls, a ground beetle, Blethisa catenaria, was discovered in the core (Figure 6.6). Pollen from the interval was similar to that of the pollen assemblages at 32 feet. This biota assemblage suggests the sediment was deposited in a tundra-spruce environment similar to that today on the North Slope of Alaska and the Canadian Arctic (**Figure 6.7**). The only other record of this beetle was also found approximately 45 miles northeast of this quarry near Titusville, Pennsylvania (Cong et al, 1996). Radiocarbon dates from this site show similar ages to those found here at the quarry.

The faunal and floral changes indicate climatic warming from the lower to the upper organic horizons. The mean July temperature at 39.2 ft bls is estimated to be 11-12°C and at 32.0 ft bls 15-17°C compared to 21°C at Slippery Rock today. These sediments represent deposition during the MIS 3 interstade.



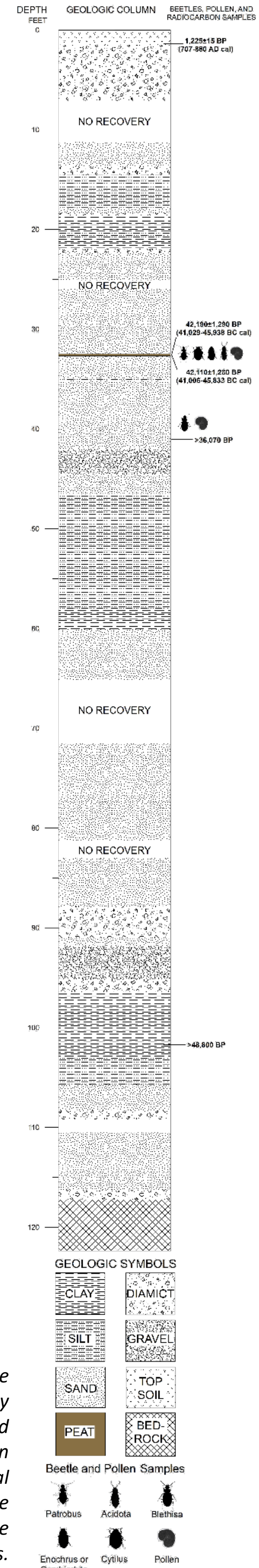


Figure 6.6. *Geologic Column (Right) of entire glacial section displaying beetle fossils, palynology analysis, and radiocarbon sampling. Calibrated radiocarbon dates used IntCal20:Northern Hemisphere (Reimer et al. 2020) with the OxCal 4.4 program. Beetles (Left) Modern day example each genus (color) and SEM photos (B&W) of the fossil beetle specimens.*

Table 6.1. Macrofossils from Core LAW073_2360.

Sample Depth (feet below ground surface)	*Picea* needle (Spruce)	*Salix* bud (Willow)	*Carex* achene (Sedge)	*Viola* seed (Violet)	Bud Genera Unknown	Wood	Moss	Charcoal	Fungal Sclerotia	Beetle remains
31.85-31.89	1	3	3	-	1	many pieces	several	several	10	-
32.03	1	1	-	1	-	many pieces	2	many pieces	17	1
32.4	-	1	-	-	-	many pieces	-	-	2	1

Macrofossils observed in and near the peat horizon. Note the addition of 2 plant species not observed in the palynology as well as fungi. Also, evidence of fire occurring during deposition of peat based on the abundance of charcoal fragments.

Table 6.2. Pollen and Spore Count from LAW073_2360.

Sample Depth (feet below ground surface)	*Picea* (Spruces)	*Pinus* (Pines)	Poaceae (Grasses)	Cyperaceae (Sedges)	Asteroideae (Flowering Plants)	Cichoroideae (Flowering Plants)	*Huperzia selago* (Northern Firmoss)	*Selaginella selaginoides* (Northern Spikemoss)	Polypodiaceae (Ferns)
31.85-31.89	156	142	-	-	1	-	-	-	13
32.03	205	118	2	12	3	1	-	1	-
39.2	182	102	-	22	-	1	3	5	-

Pollen and spore counts taken at the peat horizon (31.85-31.89 feet), directly below the peat horizon (32.03 feet), and at the interval where Blethisa catenaria was discovered (39.2 feet). Unlike the modern-day eastern temperate forest of today, the peat horizon has a diversity of plant species common of that of a boreal wetland such as a treed fen. The 39.2 ft interval suggests a similar environment but the presence of Blethisa catenaria constrains the horizon's environment/climate to tundra or the tree line edge of the Taiga.

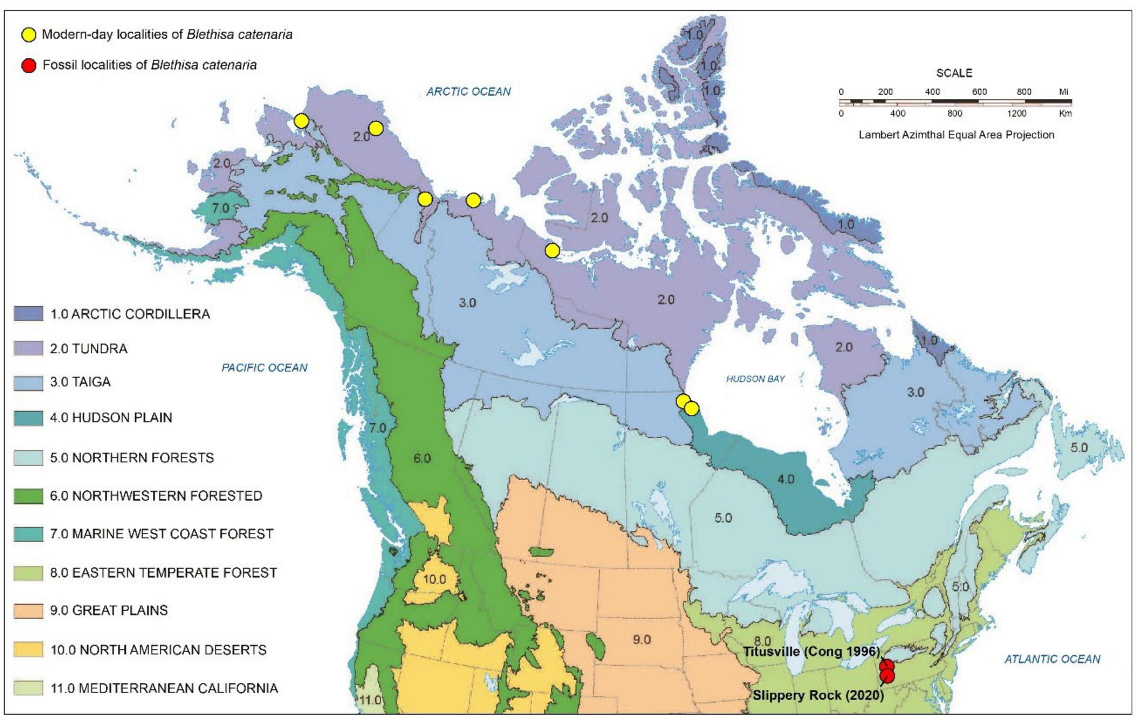


Figure 6.7. *Blethsia Range Map. Modified map of the ecological regions of North America (CEC 2007) displaying recorded observations of Blethisa catenaria with modern-day observations in yellow and fossil observations in red. Interestingly, the only other fossil locality this species is known from in North America is Titusville, PA (Cong et al, 1996). This makes the observation of Blethisa catenaria at the Three Rivers Aggregate Quarry near Slippery Rock currently the most southerly reported fossil observation of the species.*

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Miles	Cum	Description (20 min)
	59.7	Turn right onto Reese Road to exit Stop 6.
0.2	59.9	Turn right onto Plain Grove Road.
1.0	60.9	Turn right onto PA-108 West.
2.6	63.5	Turn left onto US-19 South.
	63.5	Harlansburg Cave (41.02443977253635, -80.18751083597361) Just up the hill across this intersection is the entrance to Harlansburg Cave, the longest cave in Pennsylvania. It was discovered during construction of PA 108 when the roadcut was being excavated. When they encountered the cave, much water gushed out of the opening.
1.0	64.5	US 19 passes here through the gap between pre-glacial Slippery Rock and Muddy Creeks. Slippery Rock Creek was diverted through and eroded this gap, as discussed at Stop 6.
2.1	66.6	Muddy Creek: This was the final drainage path draining glacial Lake Watts. It was named Gamma Pass by Preston (1950, 1977).
1.1	67.7	Beta Pass: As the glacier retreated, successively lower passes in the divide surrounding Muddy Creek were uncovered, partially draining glacial Lake Watts. This was the second of 3 such drainage passes.
0.6	68.3	Alpha Pass: This was the first of the 3 drainage passes opened by glacier retreat, and partially draining glacial Lake Watts.
0.3	68.6	Turn right onto Johnson Road.
	68.6	This area was extensively quarried for Vanport Limestone. These ponds are part of the reclamation. This valley paralleling Johnson Road was the course of glacial Lake Watts drainage from Alpha Pass to the McConnell Run/Slippery Rock Creek valley.
0.8	69.4	Turn left onto McConnells Mill Road.
0.5	69.9	Turn right to arrive at Kildoo Picnic Area parking lot / **STOP 7** and lunch.

Point of Interest: There is disagreement on how Slippery Rock Creek was named, but most stories agree that this name was taken from the Seneca Native Americans. Slippery Rock, or *Wechachapohka* in Iroquoian, was likely named for a natural oil seep that resulted in particularly slippery rocks (see article, this guidebook)

(Source: Slippery Rock Heritage Association, Inc., 2016, The Story Behind the Name, https://srheritage.org/the-story-behind-the-name/).
(Source: Pennsylvania Department of Conservation and Natural Resources, n.d., History of McConnells Mill State Park, https://www.dcnr.pa.gov/StateParks/FindAPark/McConnellsMillStatePark/Pages/History.aspx).
(Figure Source: Merrilove, 2016, McConnel’s Mills covered bridge over Slippery Rock Creek, https://commons.wikimedia.org/wiki/File:McConnel%27s_Mills_covered_bridge_over_Slippery_Rock_Creek.jpg).

STOP 7: MCCONNELLS MILL
AND THE SLIPPERY ROCK GORGE

GARY M FLEEGER[1], DUANE D. BRAUN[2], MICHAEL SIMONEAU[3,4], FRANK J. PAZZAGLIA[4], AND GARY J. D'URSO

2 hrs **11:05 AM – 1:05 PM** **40.95167 / -80.168279**

Slippery Rock Gorge – the topographic setting

The Slippery Rock Gorge is about 12 miles long, extending from Kennedy Mill to Wurtemburg, where it enters Connoquenessing Creek (**Figure 7.1**). Slippery Rock Creek at Kennedy Mill turns its course southward into the gorge (**Figures 7.2**) from its broad northeast- southwest valley. The upstream part of the bedrock gorge, the Kennedy gorge, is bracketed by non-bedrock reaches and is broken into two parts by a 1000 ft. long non-bedrock reach at the Muddy Creek confluence (Figure 7.2). A 1500-ft long non-bedrock reach at Rose Point separates the lower Kennedy gorge from the rest of the Slippery Rock Gorge that continues past McConnells Mill.

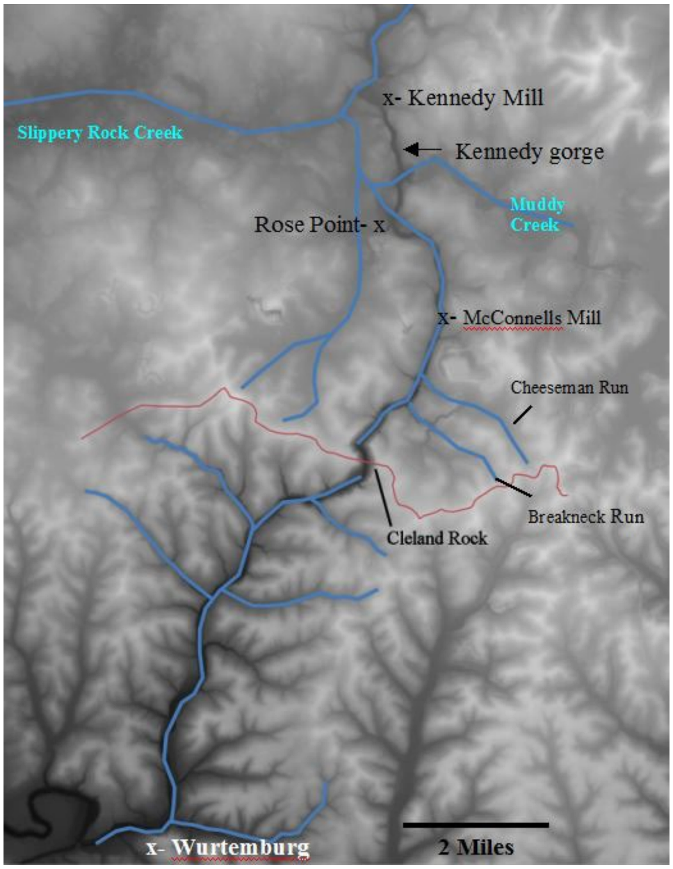

Figure 7.1. *Lidar DEM of Slippery Rock Gorge area. The red line indicates the pre-diversion divide at Cleland Rock. The Blue lines show the preglacial stream pattern with the course of McConnell Run flowing north past McConnells Mill, and Wurtemburg Run flowing south past Wurtemburg from the divide. McConnell Run diverged from the current course of Slippery Rock Creek at Rose Point to join Muddy Creek. Kennedy gorge, between Kennedy Mill and Rose Point, crosses the now-buried Muddy Creek valley.*

The main continuous part of Slippery Rock Gorge deepens from Rose Point, past McConnells Mill, to a maximum depth of 400 ft at Cleland Rock (**Figure 7.3**). What is deepening is an inner narrow very steep sided gorge with a wider less steeply sloping valley form rising above the inner gorge. At Cleland Rock there is only a narrow steep-sided gorge. South or downstream from Cleland Rock the inner gorge becomes progressively less deep towards Wurtemburg. Tributary valleys to either side of the main gorge themselves have inner gorges that abruptly shallow upstream above knickpoints that are often waterfalls. The last few miles to Wurtemburg, the less steeply sloped

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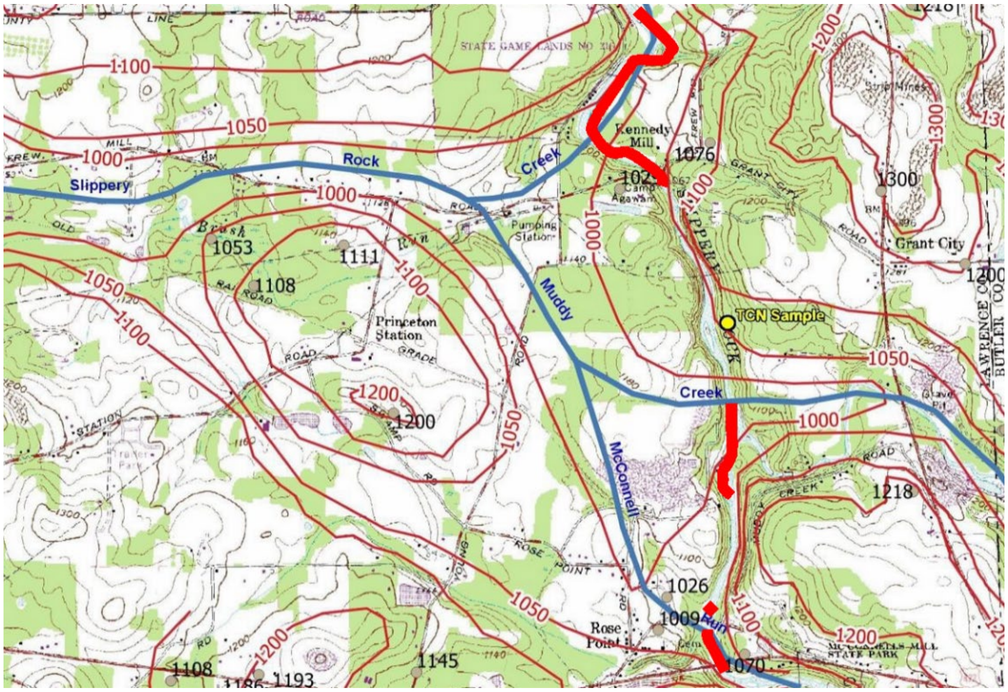
valley sides above the inner gorge widen markedly with broad strath terraces on one or both sides of the inner gorge. The average stream gradient through the gorge is about 20 ft/mile, with the steepest section from McConnells Mill to Cheeseman Run, having a 40 ft/mile gradient.



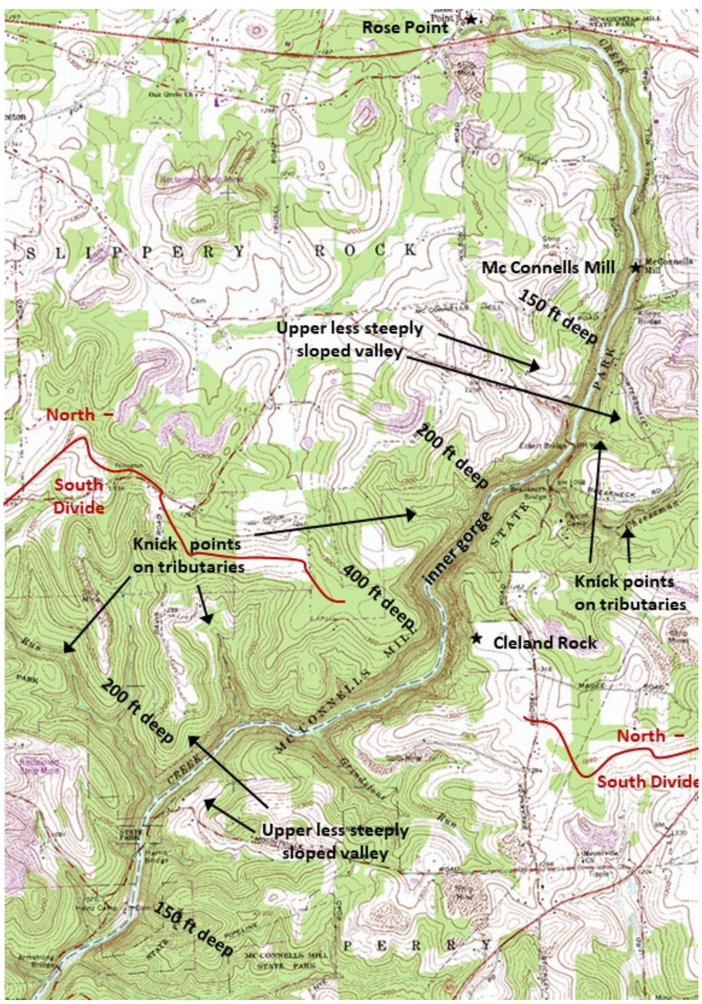


Figure 7.2. (Above) *Bedrock topographic map of Kennedy gorge, buried Muddy Creek, McConnell Run, and early Pleistocene Slippery Rock Creek. Location of the TCN sample (27,142 ± 1055 years) noted. Segments with no bedrock in red., each of which is where a bedrock valley crosses current Slippery Rock Creek.*

Figure 7.3. (Left) *Slippery Rock Gorge, a narrow steep sided inner gorge with a wider less steeply sloped valley above. Deepest at Cleland Rock and becoming less so to either side of that.*

Evidence of Glacial Drainage Diversion – The landform of the Slippery Rock Gorge

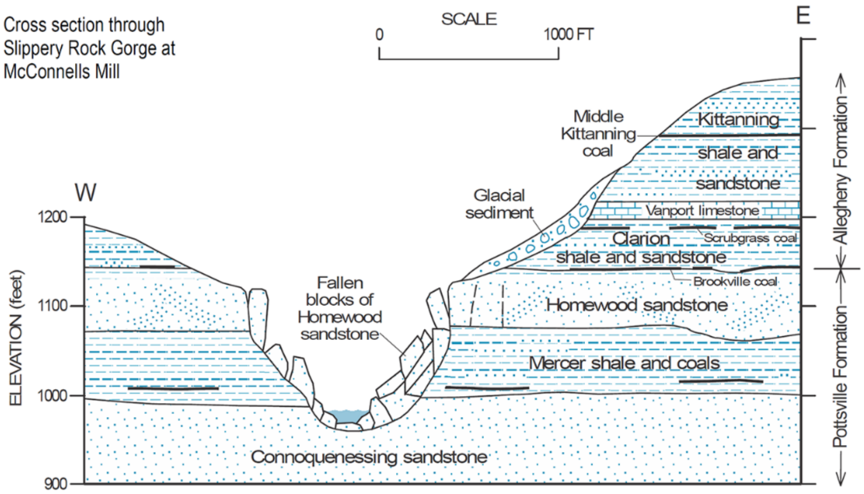


Figure 7.4. *Cross section of the Slippery Rock Gorge at McConnell's Mill showing major rock units. The steep inner gorge at the mill is in the Homewood Sandstone, the Mercer Shale, and the Connoquenessing Sandstone. The outer gorge here is in the Allegheny Formation. From Fleeger et al (2003).*

As noted in Figure 7.3, the Slippery Rock Gorge has an inner narrow steep gorge with upper less steeply sloped sides (**Figure 7.4**). The inner gorge deepens downstream to a point that is a regional north-south divide on streams adjacent to Slippery Rock Creek. Then the inner gorge declines in deepness continuing downstream to its confluence with Connoquenessing Creek. This maximum deepness at a regional divide is the topographic signature of a breached divide. It is the same topographic form that is seen at the other major divide breaches on Oil Creek, upper Allegheny River, Pine Creek, and other such sites in Pennsylvania. At all these sites, a northwest or northeast drainage system is blocked by an advancing glacier. First proglacial lake drainage starts notching a preexisting col in a divide, then the glacier approaches and sends sediment laden meltwater over the col, and then on retreat a final proglacial lake drains across the col to finish that glacial advance's cutting. The four glacial advances (Braun, 2011) we have record of have collectively cut down the divide to where it is today.

Valleys Cut Below the Level of the Upper Segmented Slippery Rock Gorge (Kennedy Gorge)

The key to identifying the Slippery Rock Gorge being a glacial diversion centers on the northern segmented part of the gorge, the Kennedy Gorge. The three non-bedrock reaches of the gorge (Figure 7.2) mark where the drainage was cut below the level of the present gorge. Well data (Fleeger, ongoing work) shows that those three reaches form a west draining system of buried channels that are eroded below the gorge level (Figure 7.2). Those channels must predate the cutting of the shallower present bedrock Slippery Rock Gorge and confirm Mc Connell Run drained north from the Cleland Rock divide.

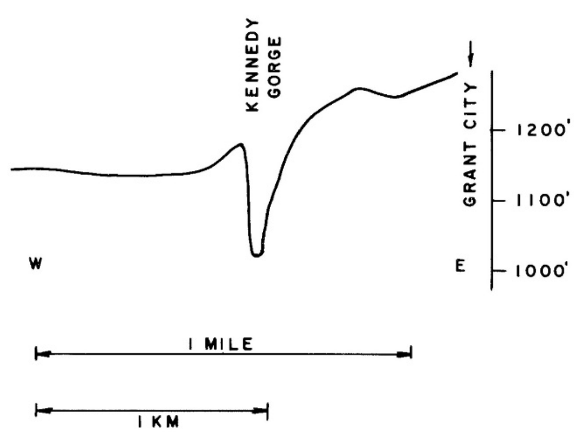


Figure 7.5. *Topographic section of the Kennedy gorge, looking north. From (Preston, 1977).*

The segment of the gorge from the sharp bend near Rose Point upstream to Kennedy Mill (Kennedy gorge; Preston, 1977) does not follow the course of pre-glacial McConnell Run (Figure 7.2). Rather, it is an ice-marginal channel eroded between the glacier to the west and the bedrock hill to the east (Figure 7.5), probably during the outburst flood draining of Lake Edmund during glacier retreat. The Kennedy gorge joins the preglacial course of McConnell Run at Rose Point. In the middle of the Kennedy gorge, Muddy Creek enters the gorge from the east over a waterfall in a hanging valley. This was the location of the final drainage of glacial Lake Watts (Preston, 1977). The final drainage of Lake Edmund also passed through this gorge, eroding the Kennedy gorge and leaving Muddy Creek hanging.

Pre-glacial Muddy Creek crossed this location at the middle non-bedrock reach (Figure 7.2) of Kennedy gorge, and continued west, being joined by McConnell Run, and then by the early Pleistocene course of Slippery Rock Creek to form the Muddy – Slippery Rock Creek (Figure 7.3 of Braun, this guidebook). That westward course is now partially buried and occupied by Brush and Big Runs. Sandstone ledges exist north and south of the confluence of modern Muddy and Slippery Rock Creeks. TCN sample GN was taken from the ledge north of Muddy Creek (Figure 7.2). Kennedy gorge bisects the buried, pre-glacial Muddy Creek valley, so Muddy Creek was eroded and buried prior to the erosion of the Kennedy gorge. Where the buried Muddy Creek valley crosses the gorge today, the bedrock ledges end, the gorge widens, and glacial sand and gravel exist to about 1010 feet elevation, about 20 feet below the bottom of the present gorge (Figure 7.2).

Because the Kennedy gorge does not follow the course of McConnell Run, it did not form by the upstream migration of the Cleland Rock col (whether by lake overflow or by stream piracy). The col currently exists near Rose Point from which the buried lower McConnell Run valley descends to the northwest from the southern non-bedrock reach (Figure 7.2) of the gorge, and the current Slippery Rock Creek flows south through the former upper McConnell Run valley (Figure 7.3). Kennedy gorge need not have been eroded at the same time as the rest of the Slippery Rock Gorge. But it had to be the last part of the Slippery Rock Gorge to form, because there had to be an outlet to the south. The Muddy - Slippery Rock Creek outlet to the northwest was filled prior to the Kennedy gorge erosion. It could have occurred during different glaciations, or during the same glaciation (filling the Muddy Creek valley during the advance, and eroding the Kennedy gorge during the retreat). The 10Be-derived date from the top of the Kennedy gorge (27,142 ± 1055) is older than the Kent glaciation terminus (about 20 - 25 ka at the West Liberty delta, Stop 9). So this gorge was initiated either upon the retreat of the Illinoian glacier or was initiated as Kent ice advanced toward its terminus. The Kennedy gorge is similar in appearance to the rest of the inner Slippery Rock Gorge through the Cleland Rock divide, suggesting that they both have their near final form carved during late Illinoian (Titusville) to late Wisconsinan (Kent) time.

The overall preglacial – early Pleistocene drainage pattern in the area of the present Slippery Rock Gorge is marked in blue on Figure 7.1. The LiDAR image vividly shows the preglacial dendritic pattern to either side of the Cleland Rock divide. The col or saddle at Cleland Rock must have been slightly lower than other adjacent cols along the divide and that permitted the proglacial lake in the Muddy Creek valley to first spill over there and initiate the Slippery Rock Gorge.

Terrestrial Cosmogenic Nuclide (TCN) dating in the gorge

We attempted to use TCN to better constrain the age of the Slippery Rock Gorge. Simoneau et al (2022) discuss the TCN dating technique used in the gorge. Five TCN samples were collected from the walls of SRG to generate an age and erosion rate model of the gorge. When collecting the TCN samples, areas were chosen to represent the top, middle and bottom of the gorge at different locations along the long profile (**Figure 7.6**). Four of these samples, MM1-MM4 were collected in October, 2018. The first two samples, MM1 and MM2 were taken very near McConnell's Mill near the top lip of the inner gorge on Homewood sandstone, while MM2 was taken about 10 – 15 feet above the present streambed at the right abutment of the mill dam on a bed of the Connoquenessing sandstone. The third sample, MM3 was collected from the proposed Lake Prouty outlet slot canyon beneath Breakneck Bridge, whereas the fourth sample, MM4 was taken at a mid-canyon level along the west bank, near Armstrong Bridge, in the downstream part of the gorge. A fifth sample, GN, was taken at a mid-canyon level in the Homewood sandstone in the Kennedy gorge in Nov, 2018.

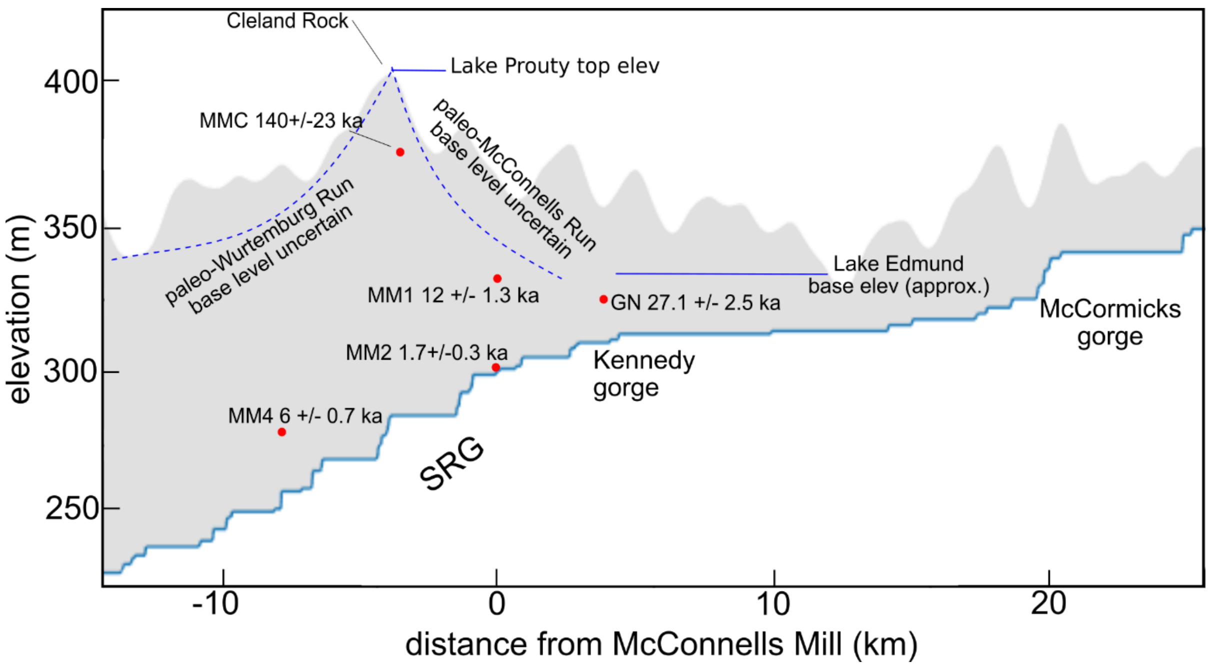


Figure 7.6. *Projection of numerically dated exposure age (MM1,MM2, MM4, and GN) and burial age (MMC) on the long profile and hillslope swath profile of the Slippery Rock Gorge reach.*

Using surface erosion rates of zero, the maximum TCN exposure ages in SRG range from ~1.7±0.3 ka for sample MM2 collected at river level at McConnells Mill to 27±2.5 ka collected for sample GN in a mid-gorge position in the Kennedy gorge. In general, the exposure ages are all LGM in age, young towards the river and young downstream (Figure 7.6). The steady-state erosion rates for the four TCN samples is highest at 500±90 m/Myr for sample MM2 and 30±3 m/Myr for sample GN. All of the calculated steady-state erosion rates for these exposed bedrock samples are unrealistically high in comparison to others measured in western PA (Pazzaglia et al., 2021) and in the Appalachians (Hancock and Kirwan, 2007; Portenga et al., 2013), which typically report steady-state erosion rates < 5 m/Myr. The young exposure ages and corresponding high steady state erosion rates may have resulted from a sample collection strategy to find and sample fresh, rather than obviously weathered surfaces. Insofar that the fresh surfaces sampled represent a recent process to remove more weathered material, such as rockfalls or slumps, then the TCN ages and erosion rates indicate where these processes are active in the SRG.

Taken at face value, the TCN exposure ages would argue that SRG is a very young feature, having been carved in the late Pleistocene-Holocene perhaps in response to the LGM glaciation. Alternatively, the TCN data can be interpreted as late Pleistocene-Holocene re-freshening of older existing gorge walls and valley bottom. There are other, plausible explanations for the TCN exposure ages that may have origins in multiple generations of SRG formation, the transient laying back of the SRG knickzone, or complicated exposure histories that include times of SRG burial and re-exhumation. SRG could be much older than the LGM or Illinoian glaciation, with the TCN exposure ages simple reflecting these complicated exposure histories, further modified by active, but unsteady hillslope and fluvial processes that periodically refresh rock surfaces. The TCN data also do not help in determining the scale of the Pleistocene glacial and/or interglacial discharges that have cut SRG.

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Portenga, E.W., Bierman, P.R., Rizzo, D.M., and Rood, D.H., 2013. Low rates of bedrock outcrop erosion in the central Appalachian Mountains inferred from in situ 10Be. Geological Society of America Bulletin 125. p. 201–215. DOI:10.1130/B30559.1.

Preston, Frank W., 1977, Drainage changes in the late Pleistocene in central western Pennsylvania, Carnegie Museum of Natural History, Pittsburgh, PA, 56 p.

Miles	Cum	Description (10 min)
	69.9	Leave Kildoo Picnic area Stop 7 by turning right onto McConnells Mill Road.
0.1	70.0	Turn left onto Kildoo Road.
1.1	71.1	Turn right onto US-19 South.
1.1	72.2	Turn right onto Cheeseman Road.
1.4	73.6	Turn right onto Kennedy Road.
0.1	73.7	**Stop 8**

STOP 8: CHEESEMAN SAND & GRAVEL PIT

GARY M FLEEGER[1], MICHAEL SIMONEAU[2,3], FRANK J. PAZZAGLIA[3], AND GARY J. D'URSO.

1 hr | **1:15 – 2:15 PM** | **40.938534/ -80.167146**

Introduction

This sand and gravel pit has been studied for many decades. Richardson (1936) mapped this deposit as terminal moraine. Dr. Frank W. Preston identified it as terminal moraine (1950) and as a delta (1977). Preston led a stop in the 1950 Field Conference of Pennsylvania Geologists at this pit. This deposit is part of a larger complex of features that are critical to the interpretation of the glacial and drainage history (**Figure 8.1**).

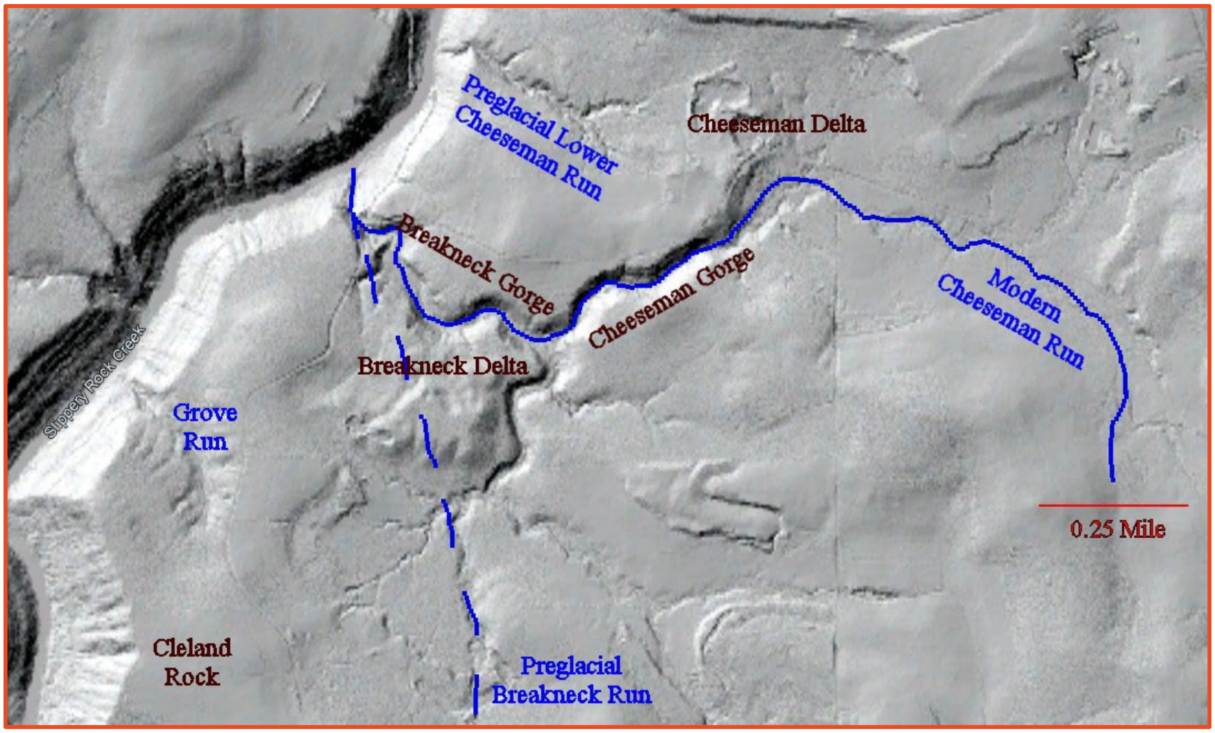

Figure 8.1 *Site location for Stop 8, with names used in text. Base map is the hillshade image derived from LiDAR*

Description

This pit is in what I (Fleeger) am calling the Cheeseman delta. The top of the delta is at about elevation 1250 feet. Based on projecting the gradient of preglacial Cheeseman Run, I estimate the thickness of the deposit to be up to 80 feet.

A half mile to the southwest is another sand and gravel deposit that I refer to as Breakneck delta. The top of Breakneck delta is 1260 feet, 10 feet higher than that of Cheeseman delta. It has a couple of long-abandoned sand and gravel pits (one appeared to be active in the 1939 aerial

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photography) that are now completely overgrown with a mature forest. Based on projecting the gradient of preglacial Breakneck Run, this deposit is estimated to be up to 100 feet thick.

Fleeger interprets the Cheeseman and Breakneck deltas as having prograded from the Titusville glacier front just to the north into a proglacial lake, designated by Preston (1977) as Lake Prouty.

Lake Prouty is one of the pro-glacial lakes that Preston (1977) identified in this area (**Figure 8.2**). Lake Edmund occupied the upper Slippery Rock basin, Lake Watts the Muddy Creek basin, and Lake Prouty, the Cheeseman and Breakneck Runs basins.

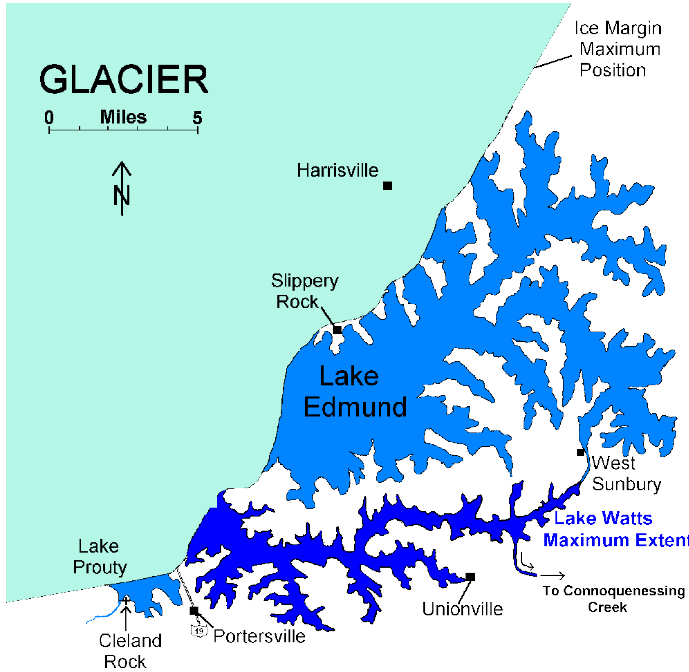

Figure 8.2. *Distribution of glacial Lakes Watts and Edmund at the maximum advance of the damming glacier. Modified from Preston (1977)*

Sitler (1957) mapped the glacial border adjacent to this site, and Shepps et al (1959) identified that border as Inner Illinoian, now named Titusville (White et al, 1969). It is a Gilbert-type delta with well developed foreset (**Figure 8.3**) and topset beds. The topset bed here is till-like, very coarse, poorly sorted, and contains numerous cobbles (**Figure 8.4**), suggesting that we are likely within the glacier margin, and the Titusville glacier overrode the Cheeseman delta.

Figure 8.3. *Foreset sand and gravel beds in the Cheeseman delta. View is to the west. Hammer for scale. A sample for OSL dating was taken in 2018 to the left of this view.*

Figure 8.4. *Coarse, unsorted topset beds in Cheeseman delta on the north side of the Cheeseman pit, appear to be Titusville Till deposited after overriding the delta.*

The pits in the Breakneck Delta are totally overgrown. The park manager has recently agreed to bring in their backhoe to expose a section for description and sampling for OSL age determination, but we were unable to get that information in time for inclusion in the guidebook. As best as could be determined in the 1980s, it is mostly sand and fine gravel, although cobbles, many erratic, litter the ground in the abandoned pits. The deposit has several depressions in the surface that have been described as kettles (Preston, 1977). By the 1950 aerial photography, both pits in the Breakneck delta were abandoned, and the Cheeseman pit was active. The owners of the Cheeseman pit have used it periodically since.

Conclusions regarding the origin of these deposits, and their significance to the origin of the Slippery Rock Gorge are preliminary, since we have not yet been able to study the Breakneck delta.

Preston (1977) considered the 2 sand and gravel deposits to have been originally parts of the same delta, with the intervening area eroded by modern Cheeseman Run. However, some characteristics of the 2 sand bodies suggest that they may not be the same deposit.

- The elevation of the surface of the 2 deposits is different, suggesting different lake levels when the 2 deltas were deposited, and therefore, they formed at different times- either different glaciations or different phases of the same glaciation. Alternatively, because the top sediment in the Cheeseman delta appears to be till (Figure 3), perhaps here has been erosion of 10 feet of the deltaic sediments by overriding ice, and the 2 deltas were originally the same elevation.
- The Cheeseman and Breakneck deltas are in adjacent valleys, with a divide between them. The divide between them ranges today between 1256 and 1238, partly lower than the top of Cheeseman delta and completely lower than the top of Breakneck delta. The divide was breached when Cheeseman Run was diverted into the Breakneck Run valley by the Cheeseman delta, creating the Cheeseman gorge, so it is post Cheeseman delta. Its age relative to Breakneck delta is unknown.
- There appears to maybe be a difference in dissection of the 2 deposits. A significant portion of the Cheeseman deposit has been eroded by Cheeseman Run (at the diversion into Cheeseman gorge) and a small tributary. The Breakneck deposit shows less apparent dissection.
- Breakneck delta blocks the pre-glacial Breakneck Run, diverting it into Breakneck gorge around the east and north sides of the Breakneck delta

Age of Deltas

Because of its association with the mapped Titusville Till border, Fleeger (1984) interpreted the age of the Cheeseman delta as Titusville in age. The Titusville age had been estimated as 145,000 ± 25,000 years (late Illinoian), based on thermoluminescene dates of the correlative Millbrook Till in the Scioto sublobe at a site in north-central Ohio (Totten and Szabo, 1987, Fleeger, 2022). However, Preston (1977), D'Urso (2000), and D'Urso et al (2004) interpreted this deposit as Late Wisconsinan in age, Preston because of the youthful appearance of the Slippery Rock Gorge, and D'Urso based on depth of oxidation and leaching in the deposit, and the degree of weathering of the granitic clasts. In 2018, we took a sand sample from this pit for IRSL (infra-red stimulated luminescence) dating (**Figure 8.5;** see **Table 1**, Simoneau, Pazzaglia and Fleeger, Pleistocene Drainage Reversals article, this guidebook). The IRSL date is 140,000 ± 23,000

Figure 8.5. *IRSL sample location on the west wall of the Cheeseman pit*

years (Simoneau, 2022), confirming the 1987 thermoluminescence date. So Lake Prouty existed as an ice marginal lake during the maximum advance of the Illinoian Titusville glacier.

Breakneck gorge

The Breakneck gorge between the 2 deltas is unique for tributaries to the Slippery Rock Gorge. Within the Breakneck gorge, modern Cheeseman Run and a tributary have three characteristics that are different from other similar-sized streams flowing into the Slippery Rock Gorge.

1. While most streams essentially fill a narrow valley bottom, lower Cheeseman Run and tributary in Breakneck gorge meander across a valley bottom up to five times the stream width.

2. Most streams have a series of small waterfalls where they cross resistant beds and many boulders in the bottom of the valleys. Breakneck gorge has one, very small waterfall, just upstream from the mouth of the Cheeseman gorge, which may be a knickpoint migrating upstream from the mouth of Cheeseman gorge. There are no others until it reaches the top of the Homewood Sandstone several hundred yards above Breakneck Falls.

3. The bottom of the Breakneck gorge is eroded below the delta deposits into bedrock, and is largely free of large boulders and has a cobble bedload in most places. In contrast, most tributaries to the Slippery Rock Gorge are boulder-choked.

4. Other streams flowing into the Slippery Rock Gorge enter the gorge over waterfalls at or near the top of the Homewood Sandstone (e.g. Alpha Falls, Kildoo Falls. Modern Cheeseman Run has eroded 30+ ft of the Homewood Sandstone before entering the Slippery Rock Gorge at Breakneck Falls at elevation 1,048 ft.

These characteristic suggest that the valley once had a much larger flow than the other tributaries to the Slippery Rock Gorge and/or maintained large flows for a longer period of time than other tributaries (Alpha Pass, Beta Pass, Muddy Creek). Such a flow would be consistent with an ice marginal channel that had a clear outlet to the south down the Slippery Rock Gorge (**Figure 8.6**).

Significance of Lake Prouty

Preston (1977) hypothesized that Lake Prouty formed by glacier damming of McConnell Run, and that the lake level was controlled by lake overflow through the col at Cleland Rock (Figure 8.6). He interpreted that the lake overflow eroded the col downward and headward, creating the incipient Slippery Rock Gorge. The gorge was further extended northward and deepened by glacial lake breakout floods from Lakes Watts and Edmund as successively lower drainage passes were uncovered during glacier retreat.

We have not been able to determine if the dam creating Lake Prouty was as described by Preston (1977), or if the gorge had been eroded earlier (earlier glaciation or pre-glacial). We would expect the Cleland Rock col to have eroded to lower than 1250 feet during 2 or more earlier glaciations, which would also have created lakes in the McConnells Run valley and drained through the col. Lake Prouty could also have formed by the damming of Cheeseman and Breakneck Runs by a small lobe of the Titusville glacier extending down the Slippery Rock valley. The interpretation of Breakneck gorge as an ice-marginal channel requires only that when the lake drained, that there was an open outlet to the south in the Slippery Rock valley. Perhaps future study of the Breakneck delta will provide additional evidence to help resolve this issue.

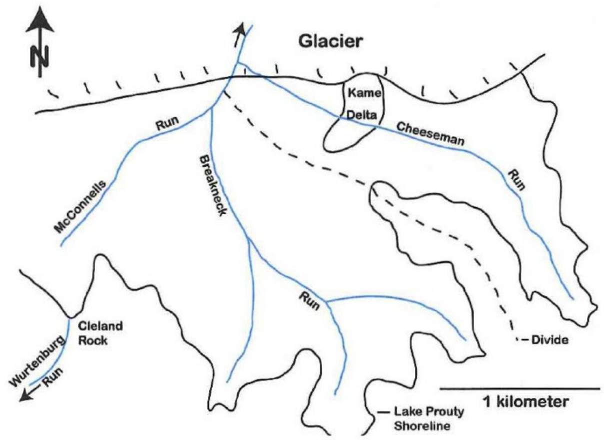

Figure 8.6 a). Pre-glacial drainage. Lake Prouty is formed ahead of the advancing glacier. Lake Prouty's spillway is at the Cleland Rock col into Wurtemburg Run. Alternatively, the Cleland Rock col may have already migrated north during prior glaciations, and Cheeseman and Breakneck Runs were dammed directly by a lobe of Titusville ice extending down the Slippery Rock valley. Cheeseman delta builds into Lake Prouty. Divide is that between Cheeseman and Breakneck Runs.

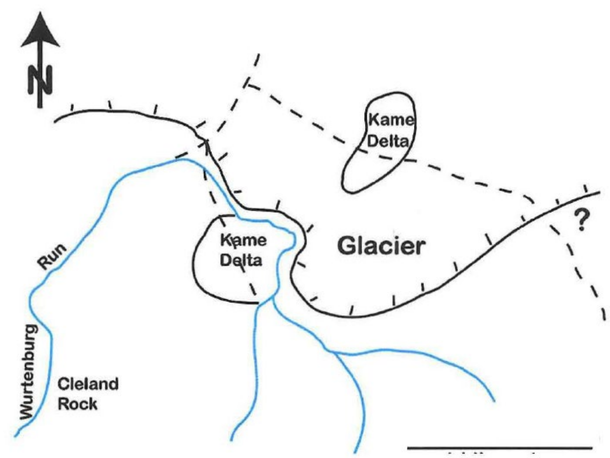

Figure 8.6 b). Maximum advance of glacier. Overridden Cheeseman delta depositing the till at the top. Breakneck delta builds into Lake Prouty. Ice marginal channel forms after Lake Prouty drains, either by migration of the Cleland Rock col or by retreat of the ice lobe in the Slippery Rock kvalley. Dashed lines = former course of pre-glacial Cheeseman and Breakneck Runs.

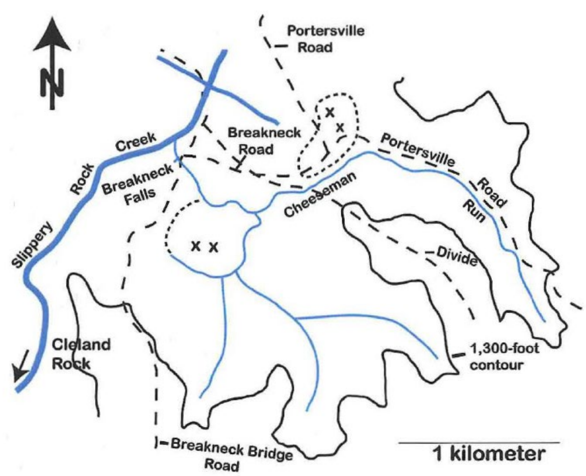

Figure 8.6 c). Present drainage. After retreat of the glacier, Cheeseman Run is diverted into the Breakneck Run valley because it's old course is blocked by the Cheeseman delta. The old course of Breakneck Run is also blocked by the Breakneck delta. The ice marginal channel is maintained. X= gravel pit.

Does this tell us anything about the origin of the Slippery Rock Gorge?

Scenario 1

The Slippery Rock Gorge is pre-Titusville (or pre-glacial), and Breakneck and Cheeseman Runs were dammed by a lobe of ice extending down the Slippery Rock Gorge. Lake Prouty overflow is through the Grove Run valley, and into Slippery Rock Creek.

- The elevation of the Grove Run col is about 18 feet higher than the top of the Cheeseman delta, suggesting that it did not control the level of the lake in which Cheeseman delta was deposited. It is only 8 feet higher than Breakneck delta, and might have been able to control the elevation of the lake that deposited Breakneck delta,
- When the glacier lobe retreats enough to drain Lake Prouty, the ice-marginal Breakneck Gorge can be eroded.
- If the ice is retreating, the ice margin would likely not be stable long enough to remain in that position for very long, and an ice-marginal Breakneck gorge is less likely to be eroded.

Scenario 2

The Slippery Rock Gorge does not yet exist, and the col is at 1250 or 1260 feet. Lake Prouty forms by a glacier dam across the McConnell Run valley to the north. Lake Prouty overflow is through the Cleland Rock col into Wurtemburg Run.

- Overflow through the Cleland Rock col erodes the col downward and headward (north), extending Wurtemburg Run and reducing McConnell Run, creating the incipient Slippery Rock Gorge.
- Once the col migration is far enough to reach the mouth of Breakneck Run, Lake Prouty drains into the south-flowing Wurtemburg Run.
- No glacial retreat is required to drain Lake Prouty, and a stable ice front can erode the ice-marginal Breakneck gorge.

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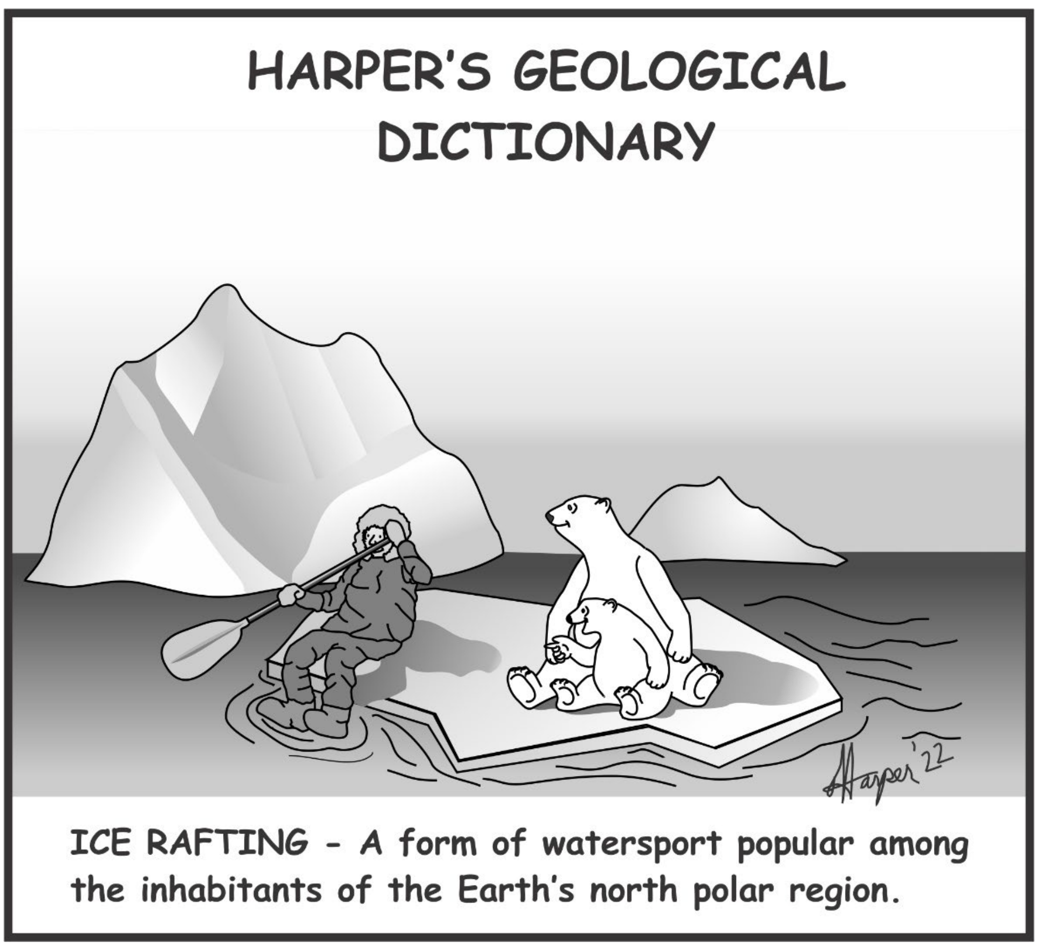
Miles	Cum	Description (20 min)
	73.7	Exit Stop 8 by turning south onto Kennedy Road (the direction we came from).
0.1	73.8	Turn left onto Cheeseman Road.
1.4	75.2	Turn right onto US-19 North.
150 ft		Bear right onto West Park Road.
2.7	77.9	Portersville Station Gorge (40.96285649819526, -80.13091015766838) We are passing over Muddy Creek, the outlet from Lake Arthur, where it flows through Portersville Station gorge. When the final drainage pass (Gamma Pass) opened upon retreat of the glacier, a remnant of glacial Lake Watts remained, dammed by the glacial fill in preglacial Muddy Creek. Lake drainage was through a col on the bedrock ridge upon which West Park Road is located. The drainage eventually eroded the gorge and drained Lake Watts.
0.7	78.6	Boy Scout Jamborees (40.9726982080767, -80.13058440776126) Two Boy Scout Jamborees took place in Moraine State Park: one in 1973 and one in 1977. A surface water treatment system was built to service the tens of thousands of people who attended these events. This system was retired in March, 2021 and was replaced by a supply well that had been drilled in 2017. It can produce up to 2 million gallons per day. Previous wells drilled in the park often had water quality problems, because they penetrated the marine lower half of the Allegheny Formation. The 2017 well was drilled in the buried preglacial valley of Muddy Creek, which we are currently crossing, entering bedrock at a depth of 150 feet in the Pottsville Formation, avoiding the lower Allegheny. The well water requires minimal treatment.
1.8	80.4	Billsburg Hill: We are on the divide between Muddy and Slippery Rock Creeks. To the east (right) of the road is the valley of upper Slippery Rock and Wolf Creeks (above the diversion into the Muddy Creek valley to the south). Much of the area seen from here was covered by glacial Lake Edmund. To the right of some grain silos, the Jacksville Esker can be seen, although it appears quite small from this distance. We will pass alongside the esker in a few minutes en route to Stop 9. This was Stop 3A of the 1950 Field Conference.
0.8	81.2	Continue straight onto West Liberty Road.

1.3 82.5 To the north (left) is the Jacksville Esker. It is probably the best-preserved esker in PA. It is over 3 miles long, with additional segments further northwest along the same trend. These segments would make the esker 7 miles long. The esker terminates at the kame delta that will be Stop 9.

0.4 82.9 Turn right to arrive at Glacial Sand and Gravel Rodgers pit / **STOP 9**.

Point of Interest: Over 2,000 feet of the Jacksville Esker, also known as the Miller Esker or the West Liberty Hogback, are protected by the Western Pennsylvania Conservancy. In late August the conservancy has the area mowed in order to provide habitat for migrating/wintering birds like the American pipit, the snow bunting, and the Lapland longspur.

(Source: Western Pennsylvania Conservancy, n.d., Miller Esker Natural Area, https://waterlandlife.org/properties/miller-esker-natural-area/).



STOP 9: SEDIMENTOLOGY OF THE JACKSVILLE ESKER – DELTA COMPLEX IN WESTERN PENNSYLVANIA

KATHRYN TAMULONIS[1], JOCELYN SPENCER[2], AND FRANK PAZZAGLIA[3]
CONTRIBUTORS: NOELLE KID[1], ZACHARY COLE[1], AND GARY FLEEGER[4]

1 hr | 2:35 – 3:35 PM | 41.004702319/ -80.0840258624

Introduction

The Jacksville esker-delta complex is located south of Slippery Rock, Pennsylvania and is composed of the 14.5-km-long Wisconsinan Jacksville Esker (also called the Miller or West Liberty Esker) that enters a kame delta. These delta deposits extend across Black Run Valley, and lacustrine sediments are located south of the delta. The complex was deposited approximately 23,000 years ago during the Kent glaciation (**Figure 9.1**; Fleeger and Lewis-Miller, 2011).

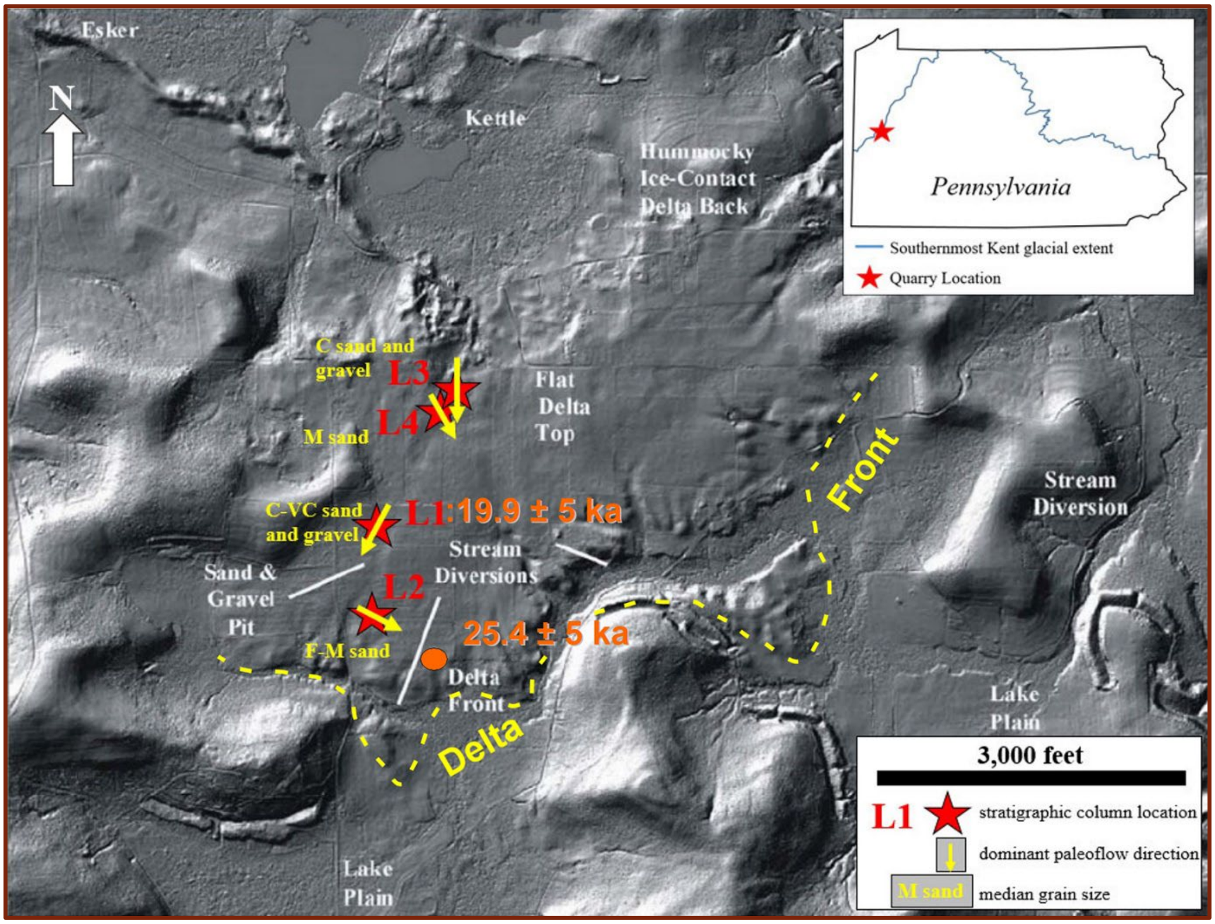


Figure 9.1. *Locations of the Glacial Sand and Gravel Quarry and sample locations (L1-L4) within the quarry pit. The dominant paleoflow direction and mean grain size for each stratigraphic column are represented by yellow arrows and yellow text, respectively. OSL dates in orange , WL-1 at L1 and WL-3 near L2. F = fine sand, M = medium sand, C = coarse sand, VC = very coarse sand.*

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[1] Allegheny College, currently at Vault 44.01
[2] Snyder Brothers, Inc.
[3] Lehigh University
[4] Pennsylvania Geological Survey, *retired*

The objectives of this on-going study include:

1) determining the esker/delta complex sediment distribution at proximal and distal locations (relative to the retreating glacier),

2) identifying the sedimentary environments that composed the complex,

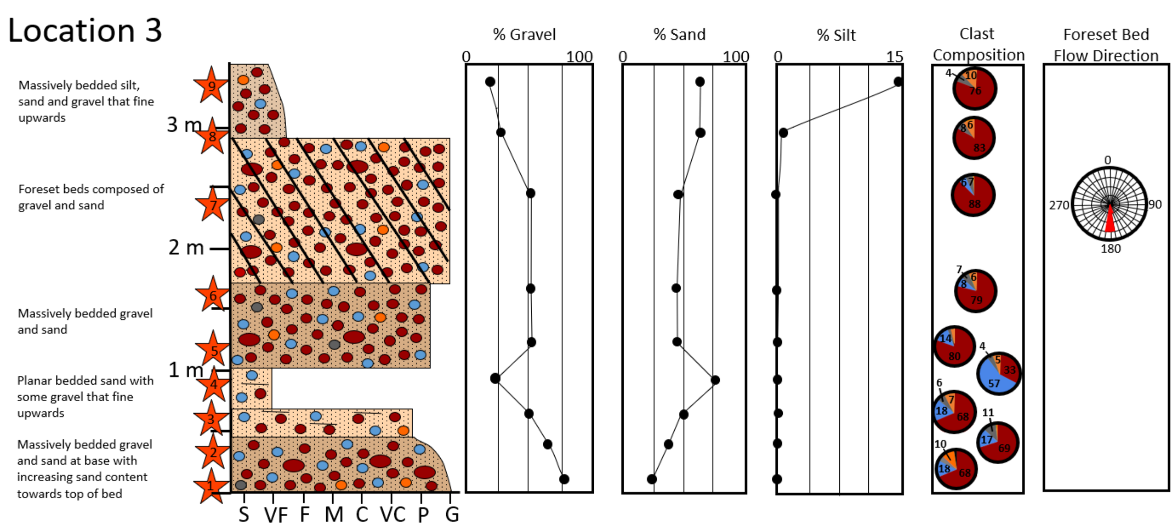
3) interpreting sediment provenance, and

4) understanding glacial dynamics and drainage patterns in the study area.

This site was visited by the 2011 NE-NC section of GSA (Fleeger and Lewis-Miller, 2011), and the reader is referred to that guidebook for additional details on the geology of the site.

Lithology

The internal composition and structure of the Jacksville esker-kame delta complex is exposed at the Glacial Sand and Gravel Company quarry, which opened in 2009, and due to the nature of quarry operations, new portions of the complex are continuously exposed as well as removed. Between 2019 and 2021, four separate locations (L1, L2, L3, and L4; **Figure 9.1**) within the exposed kame delta sediments in the quarry were described, sampled, and analyzed. At each location, samples within individual beds were collected and sieved for sediment size distribution, and the lithology of the gravel fraction was identified. Delta foreset bed orientations were measured to determine paleoflow direction, and stratigrahic columns were generated (**Figures 9.2, 9.3, 9.4, and 9.5**). **Table 9.1** summarizes the sampling frequency, median grain size, foreset bed orientation, and dominant gravel lithology for each of the sample locations. For this stop, the stratigraphic columns are described from the most proximal sample location (L3) to the most distal location (L2).



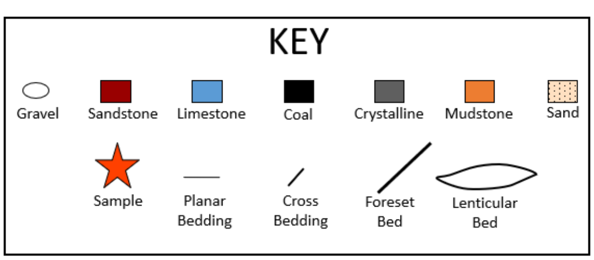
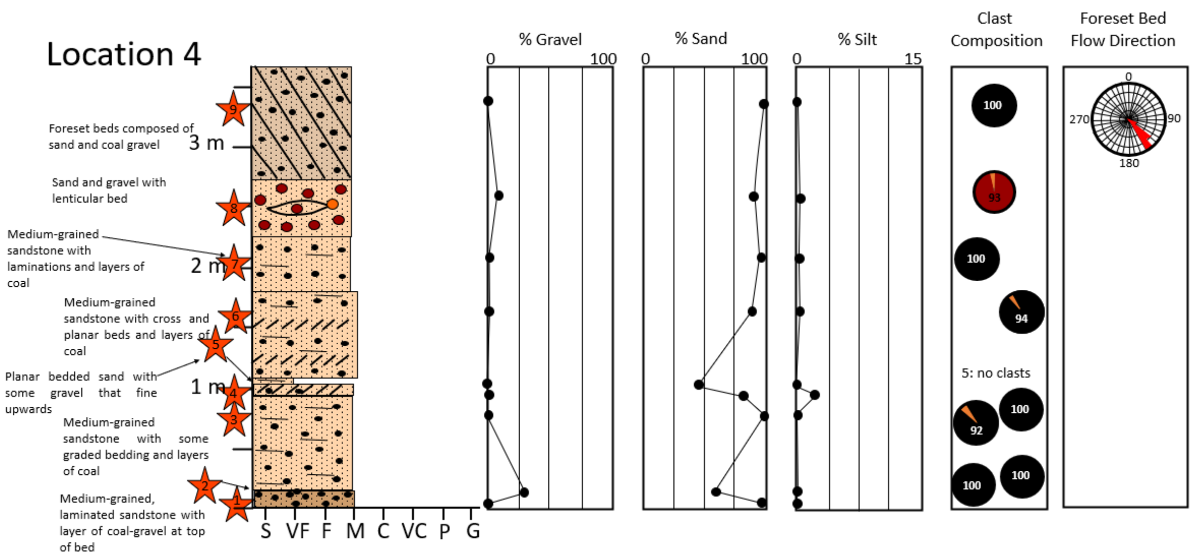


Figure 9.2. *L3 stratigraphic column and sediment description, sample location within the stratigraphic column (red stars), gravel/sand/silt percentages per sediment sample, gravel clast lithology for each sample, and a stereonet representing the paleoflow direction as measured by the foreset bed orientation. With respect to the stratigraphic column: S = silt, VF = very fine sand, F = fine sand, M = medium sand, C = coarse sand, VC = very coarse sand, p = pebble, g = gravel.*

L3 is primarily composed of medium to course-grained sand with some gravel dominated beds, and the gravel fraction lithology is dominated by sandstone. Sedimentary structures include foreset beds, fining upward sequences, massive bedding, and planar bedding. The paleoflow directions at L3, as recorded by the foreset bed orientation, is due south (Figures 9.1 and 9.2; Table 1). Crystalline (igneous and metamorphic) clasts do not exceed 11% and generally decrease up-section.



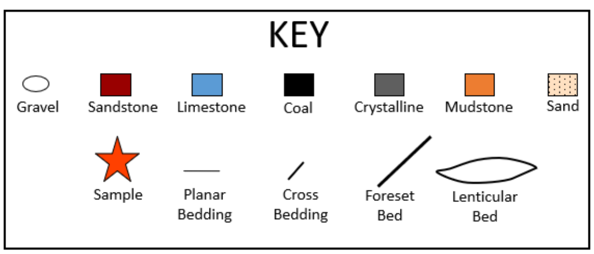
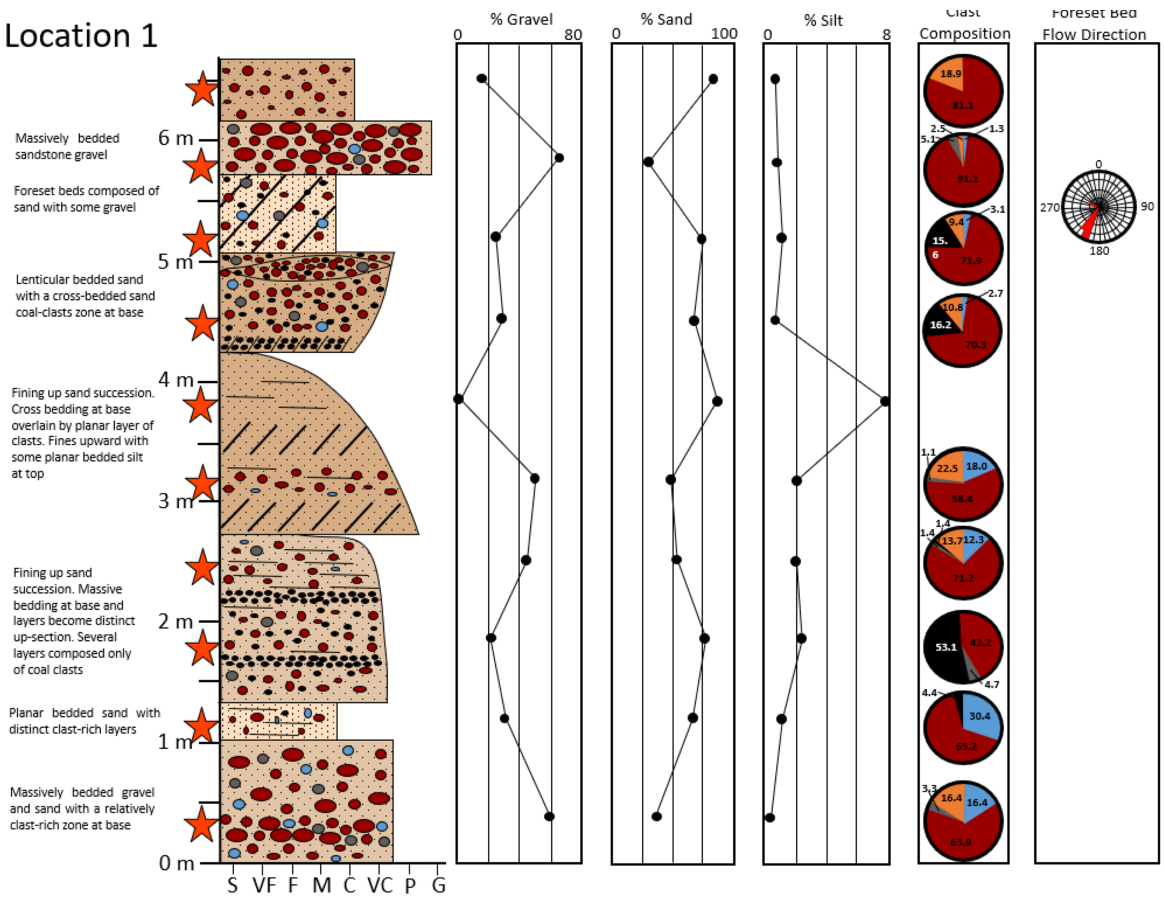


Figure 9.3. *L4 stratigraphic column and sediment description, sample location within the stratigraphic column (red stars), gravel/sand/silt percentages per sediment sample, gravel clast lithology for each sample, and a stereonet representing the paleoflow direction as measured by the foreset bed orientation. With respect to the stratigraphic column: S = silt, VF = very fine sand, F = fine sand, M = medium sand, C = coarse sand, VC = very coarse sand, p = pebble, g = gravel.*

L4 is the second most-proximal location and is composed of very fine to medium-grained sand and gravel. Sedimentary structures observed at this location include laminations, cross beds, a lenticular bed, planar beds, and foreset beds. The gravel fraction lithology is nearly all coal except for the lenticular bed near the top of the outcrop that is primarily composed of sandstone gravel. The paleoflow direction is to the southeast (Figures 9.1 and 9.3; Table 1).



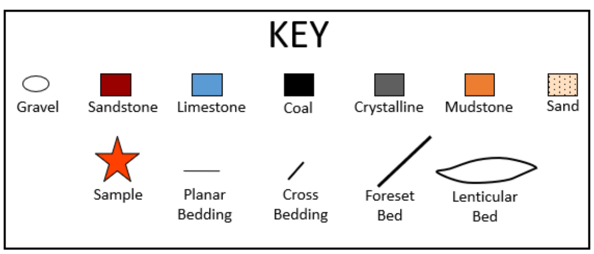
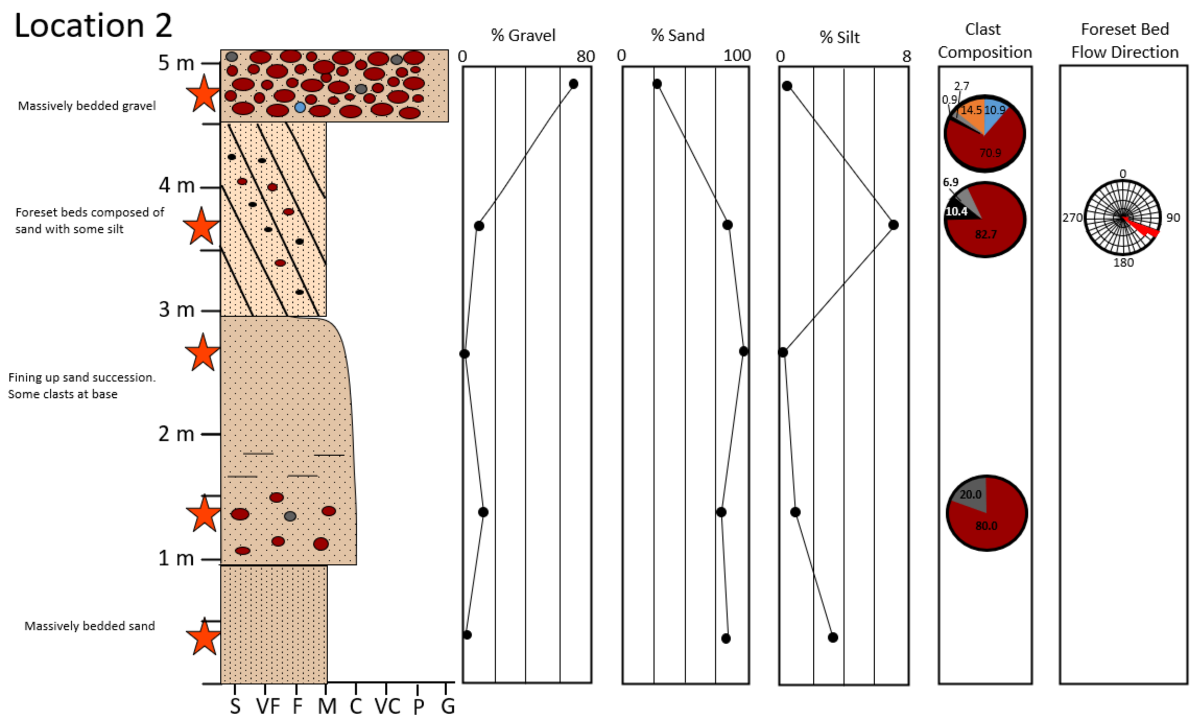


Figure 9.4. *L1 stratigraphic column and sediment description, sample location within the stratigraphic column (red stars), gravel/sand/silt percentages per sediment sample, gravel clast lithology for each sample, and a stereonet representing the paleoflow direction as measured by the foreset bed orientation. With respect to the stratigraphic column: S = silt, VF = very fine sand, F = fine sand, M = medium sand, C = coarse sand, VC = very coarse sand, p = pebble, g = gravel.*

L1 is a relatively distal sample location and resembles L3, as it is primarily composed of medium to coarse-grained sand with some gravel dominated beds (Figures 9.1 and 9.4; Table 1), and the gravel lithology throughout the entire stratigraphic column is primarily sandstone. L1 has three beds with distinct layers composed solely of pebble-sized coal clasts, some of which are imbricated. Crystalline clasts do not exceed 5%. This stratigraphic column has the highest limestone gravel lithology occurrence at 30% and distinct layers within beds that are composed solely of coal gravel. The paleoflow direction at L1 is to the southwest (Figures 9.1 and 9.4; Table 1).



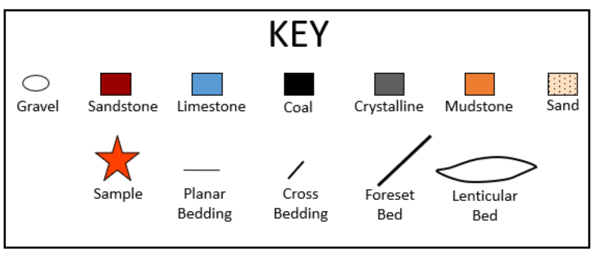


Figure 9.5. *L2 stratigraphic column and sediment description, sample location within the stratigraphic column (red stars), gravel/sand/silt percentages per sediment sample, gravel clast lithology for each sample, and a stereonet representing the paleoflow direction as measured by the foreset bed orientation. With respect to the stratigraphic column: S = silt, VF = very fine sand, F = fine sand, M = medium sand, C = coarse sand, VC = very coarse sand, p = pebble, g = gravel.*

L2 is the most distal sample location and is primarily composed of medium-grained sand with a gravel bed at the top of the outcrop. Gravel lithology is primarily sandstone, though crystalline clasts compose 20% of the gravel fraction near the base of the outcrop. The paleoflow directions at L2 is southeast (Figures 9.1 and 9.5; **Table 1**).

Table 1. Summary of sample locations L1-L4 (see Figure 1 for locations). F = fine sand, M = medium sand, C = coarse sand, VC = very coarse sand.

Location	Outcrop height (m)	Number of Samples	Median Grain Size	Dominant Gravel Lithology	Dominant Foreset Bed Flow direction
L1	~6.5	9	C-VC sand and gravel	sandstone	SW
L2	~5.0	5	F-M sand	sandstone	SE
L3	~3.5	9	C sand and gravel	sandstone	S
L4	~3.5	9	M sand	coal	SE

Deposition

Due to the varying orientations of the foreset beds, it likely that numerous outwash sources entered the kame-delta complex and/or the delta lobes changed orientation over time. Due to the dynamic nature of the quarry, the temporal relation among the stratigraphic columns has not yet been determined. Despite the proximity of L3 and L4, the contact between the respective foreset beds was not visible during field work. The differences between grain size, gravel lithology, and foreset bed orientation at L3 and L4 suggest that two separate lobes sourced the sediment despite the sample locations proximity.

The presence of coal pebble layers, abundant sandstone clasts, and general lack of crystalline clasts indicate that glacial drainage was locally organized around the ice margin, and erratics did not significantly contribute to the sediment load deposited during glacial retreat. Crystalline gravel lithologies do not exceed 11% and generally decrease up-section at L1, L2, and L3, suggesting that glacial erractic deposition decreased throughout the duration of the kame-delta complex deposition. Gross (1967) concludes that 50% of till material in northwest Pennsylvania is derived within 25 miles of the site of deposition, which is supported by the stratigraphic columns described in this study. The presence of coal pebble layers implies that coal gravel and sand are hydraulically equivalent, and the dominance of coal gravel and lack of crystalline gravel at L4 indicate that lobe of the kame-delta complex was locally sourced. The sediment size distribution trends do not follow the coarse to fine trend expected in a simple, single prograding delta scenario, though the most distal sediment at L2 is composed of relatively finer grained sediment. The varying foreset bed orientations support either or a combination of the following hypotheses: 1) a numerous outwash sources entered the delta complex, 2) these sources likely changed with time, and 3) several lobes composed the delta complex.

OSL Dating

In 2019, this site was sampled for OSL dating. Three samples were taken, 2 of which were dated (Figure 9.1), near L1 and L2.

The OSL ages obtained here are stratigraphically reversed (Figure 9.1, **Table 2**), caused by one or more of several possible reasons.

- incomplete bleaching and the grains carrying inheritance.
- WL-1 might have been from a higher delta lobe. Exposures in 2009 showed 2 superimposed sets of topsets-foresets. So WL-3 may have been deposited first in a lower set, and WL-1 later at a higher level over the older delta lobes. The sedimentological analysis has demonstrated no trend in grain size from proximal to distal, and varying foreset orientations, some of which do not come from the direction of the esker mouth, possibly because different delta lobes were being analyzed.
- Because of the OSL date uncertainties, it is possible that they are not actually reversed. Because of the uncertainties, WL-1 could be as old as 24.78 ka, and WL-3 could be as young as 20.8 ka.

The uncertainties are overlapping, so essentially OSL is here giving us the same age – LGM.

Table 2a. Luminescence Age Information

Sample	USU number	Lat	Long	Elev (m)	Method[1]	Number of aliquots[1]	Dose rate (Gy/kyr)	Fading Rate g_{2days} (%/decade)	Equivalent Dose[2] ±2σ (Gy)	Age[3]±2σ(kyr)
MMC	USU-2981	40.93933	-80.16634	375	IRSL	16(18)	2.85±0.13	2.4±0.3	316.1±44.0	140 ± 23
WL-1	USU-3550	40.99696	-80.08162	382	OSL	20(35)	0.9±0.04	N/A	17.89±7.78	19.94 ± 4.84
WL-3	USU-3551	40.99261	-80.07931	388	OSL	35(53)	0.91±0.04	N/A	23.0±5.66	25.41 ± 4.61

1 = Age analysis using the single-aliquot regenerative-dose procedure of Murray and Wintle (2000) on 1-2 mm small-aliquots of quartz sand. Number of aliquots used in age calculation and number of aliquots analyzed in parentheses.

2 = Equivalent dose (De) calculated using the minimum age model (MAM) of Galbraith and Roberts (2012).

3 = IRSL age on each aliquot corrected for fading following the method by Auclair et al., (2003) and correction model of Huntley and Lamothe (2001).

Table 2b. Dose Rate Information

Sample	USU number	Depth (m)	In-situ H_2O (%)[1]	Grain size (μm)	K(%)[2]	Rb (ppm)[2]	Th (ppm)[2]	U(ppm)[2]	Cosmic (Gy/ka)
MMC	USU-2981	5	3.6	125-212	0.87±0.02	37.5±1.5	6.3±0.6	1.6±0.1	0.12±0.01
WL-1	USU-3550	15	3.6	150-250	0.5±0.01	22.1±0.9	3.1±0.3	0.87±0.02	0.047±0.005
WL-3	USU-3551	15	3.4	150-250	0.52±0.01	20.9±0.8	3.0±0.3	0.87±0.02	0.047±0.005

1 = Assumed 5.0±2.0% for samples as moisture content over burial history.

2 = Radioelemental concentrations determined using ICP-MS and ICP-AES techniques; dose rate is derived from concentrations by conversion factors from Guerin et al. (2011).

References

Fleeger, G.M., and Lewis-Miller, J. 2011. Stop 1: Jacksville Esker, Delta, Lake Plain and Drainage Diversion Complex. in Szabo, J. Supplement to Geological Society of America Field Guide 20: Quaternary Geology of Northwestern Pennsylvania, p. 1-8.

Gross, D.L. and S.M. Moran (1971) Grain-size and mineralogical gradations within tills of the Allegheny Plateau, in Till/A Symposium, Ohio State University Press, pp. 251 - 274.

Miles	**Cum**	**Description (75 min)**
	82.9	Exit Stop 9 by turning right onto West Liberty Road.
0.4	83.3	To the right side is a good view of the proximal slope of the delta at Stop 9. This is the back side of the delta that was deposited in contact with the glacier. The hummocky topography of this proximal slope resulted from sediment collapse after the retreat of the supporting glacier ice.
1.4	84.7	Turn right at crossroads to stay on West Liberty Road.
0.2	84.9	Bear left, staying on West Liberty Road.
0.4	85.3	Bear right, staying on West Liberty Road.
1.6	86.9	Turn left onto PA-528 North.
2.0	86.9	Jennings Blazing Star Prairie. To the left is one of the few remaining prairies left in It is a remnant of the prairie peninsula that extended to the east from the prairies of the Midwest after the last glacier retreated. This prairie is today maintained as a prairie by the PA Bureau of State Parks, Jennings Environmental Education Center. Without maintenance, the surrounding forest would eventually encroach upon and replace the prairie. Because it remains as a prairie, it supports a unique (for Pennsylvania) ecosystem with several plants and animals more common to the Midwest, and rarely found elsewhere in PA.
240 ft		Old Stone House (right) is a reconstructed wayside inn, originally built in 1822. It was restored by the Western PA Conservancy in 1965, transferred to the PA Historical and Museum Commission, and eventually to Slippery Rock University, who currently operates it as a museum.
8.5	97.5	Harrisville: The borough is built upon a delta built into Lake Edmund from the Kent (LGM) border, as mapped by Sitler (1957). The flat surface of the delta is apparent to the east (right).
21.9	119.4	Turn left onto PA-322 West.
0.5	119.9	Turn right onto PA-417 (not onto 2nd St).
12.3	132.2	Turn left onto PA-8 North.
8.0	140.2	Turn left to arrive at **Cross Creek Resort**. **(4:50 PM)**

Point of Interest: This image shows Carnegie Museum botanist Otto Emery Jennings (1877-1964), for whom the Jennings Environmental Education Center is named. He is shown here with his wife, Grace Kinzer Jennings (d. 1957). Grace worked as a botany assistant at the Carnegie Museum. After they were wed, Otto and Grace accompanied one another on nearly every field excursion.

(Source: Smithsonian Libraries and Archives, n.d., Otto Emery Jennings (1877-1964) and Grace Emma Kinzer (d. 1957), https://www.si.edu/object/siris_arc_297448).

(Figure Source: Smithsonian Libraries and Archives, n.d., Otto Emery Jennings (1877-1964) and Grace Emma Kinzer (d. 1957), https://www.si.edu/object/siris_arc_297448).

We would like to acknowledge our generous donors

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