A FRESH LOOK AT THE SEDIMENTS WITHIN THE TERRACES AND CLIFFS THAT PARALLEL THE LAKE ERIE SHORE IN ERIE COUNTY, PENNSYLVANIA

DAVID THOMAS and RAYMOND BUYCE
(Mercyhurst College)

INTRODUCTION

The lake plain adjoining the coastal bluffs of Lake Erie in Pennsylvania is comprised of two to three major southwest-northeast trending terrace systems. They form a stair-step arrangement of very gently sloping terraces each bounded on the north by slightly to precipitously steeper escarpments or cliffs. The edges of these terraces have been referred to as "beach ridges" by several early workers (e.g. Leverett, 1892). Extensions of the terrace margins in Ohio and elsewhere are actually ridge-like although their beach origin has been questioned. Each relatively flat terrace level is reliably attributed to deposition associated with a corresponding lake level of a Pleistocene precursor to Lake Erie. It is still an open question whether the environment of deposition for any particular terrace or part thereof can be justifiably ascribed to beach deposition or whether a braid-plain (sandar), delta, or some other setting might have been responsible. Some of the early work relied heavily upon topographic expression to seek answers to the questions of origin but on this trip we will have the opportunity to look at two fine exposures within the terraces to see if the sedimentological evidence is more definitive.

Exposed in the gravel pit at the first stop is the uppermost of the two terraces present along the southeastern part of the Harborcreek 7 1/2 minute quadrangle. The upper terrace is attributed to sediment deposition associated with Lake Whittlesey (elevation: 740 feet, age: 13,000 yr B.P.).

Our second stop is on the shore of the modern Lake Erie where the upper approximately 70 feet of the bluff exposes the sands and gravels which underlie the lowermost of the two terraces. These sediments are ascribed to deposition associated with Lake Warren which was both lower and later (elevation: 675. age: 12,000-13,000 yr B.P.) Also exposed underlying the sands and gravels in the bluff at this location is more than 100 feet of glacial till (periglacial? diamict).

To enable you to better orient yourself geologically a brief description of the geology of the field trip area is provided below.

PHYSIOGRAPHY

The major physiographic divisions within the field trip area are, from north to south, the Eastern Lake Section of the Central Lowland Province and the Glaciated Section of the Appalachian Plateaus Province (Figure 1).

The Eastern Lake Section of the Central Lowland Province occupies a band 2 to 5 miles wide extending from Lake Erie to the base of an escarpment that rises southward onto the Glaciated Section of the Appalachian Plateau. It consists of three major east-west trending Pleistocene lake terraces delimited by gentle escarpments and the northernmost precipitous Lake Erie bluff. The terraces are dissected by streams that flow northward off the plateau to the lake. Abandoned stream channels with less than 3 m (10 ft) of relief also cut the terraces.

The Glaciated Section of the Appalachian Plateaus Province consists of relatively flat-lying beds of sedimentary rock that have been erosionally truncated to form a north-facing escarpment with up to 60 m (200 ft) of local relief at the northwest margin. The plateau and escarpment are covered by glacigenic deposits of irregular thickness and distribution.

The courses of most major streams draining the Plateau in the area begin by flowing westward, then flow northward for a short distance and then westward again until they reach the escarpment. They then flow northward off the escarpment, through the lake terraces and into Lake Erie.

BEDROCK GEOLOGY

The oldest rocks exposed at the surface in northwestern Pennsylvania are those along the Lake Erie shore. The westernmost 2 miles of the shoreline are underlain by the Girard Shale. The Northeast Shale underlies the remainder of the shoreline up to the New York State line (Berg and others, 1980). Both are Upper Devonian in age and correlate with portions of the Chagrin Shale to the west and the Brallier Formation, Bradford Group, and Catskill Formation elsewhere in Pennsylvania (Berg and others, 1986). The regional dip is gentle and to the south.

The Northeast Shale is a series of alternating gray shales and thin layers of gray siltstone and fine-grained sandstone. Fossils are uncommon in this unit in Pennsylvania, but fucoids have been noted (Tomikel and Shepps, 1967). Cone-in-cone structures have also been documented in these rocks. The maximum thickness of the Northeast Shale in eastern Erie County, PA is about 475 feet. The overlying Girard Shale is an

FIGURES

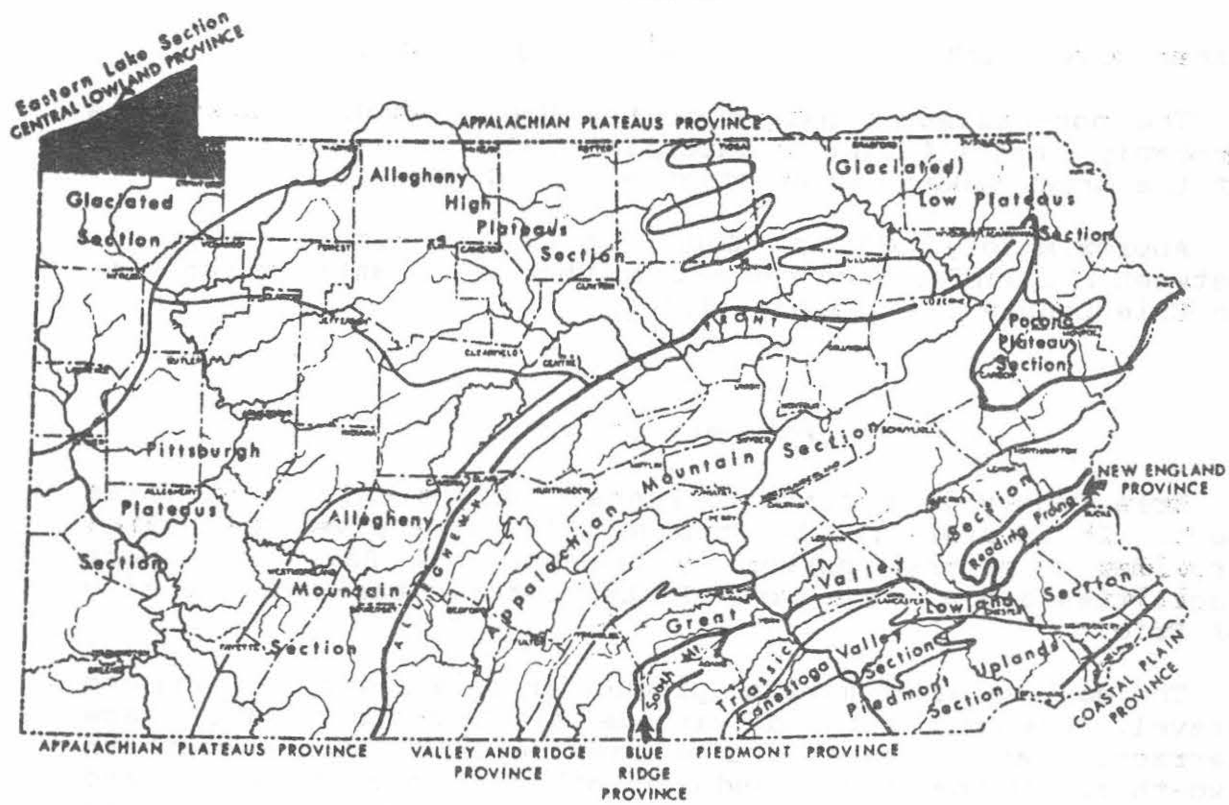
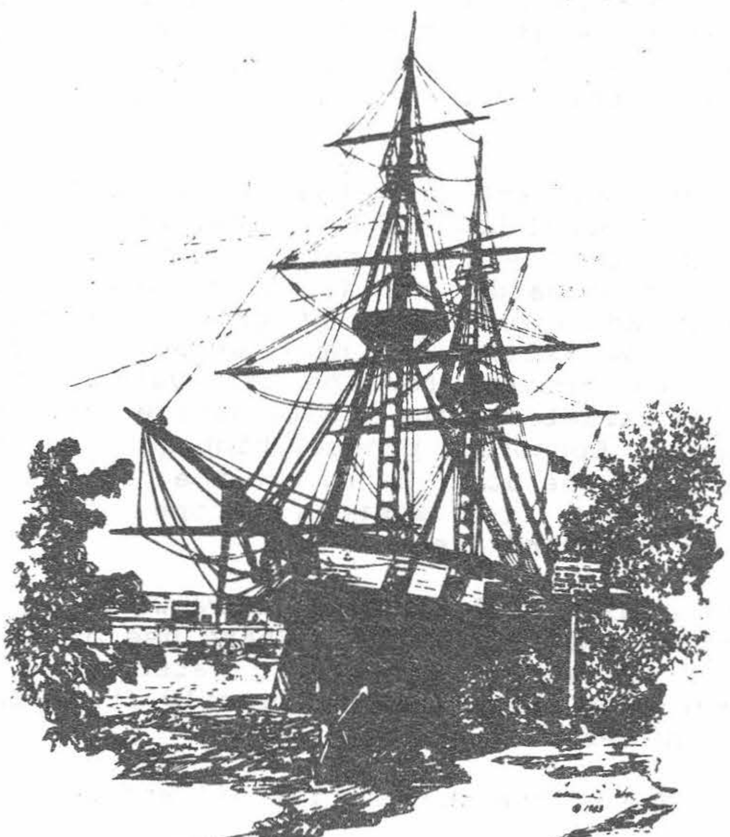


Figure 1. Physiographic provinces of Pennsylvania and location of field trip area (Erie County with diagonal pattern).



ashen gray, flaky shale with rare marine fossils.

The non-resistant nature of the Upper Devonian shales is probably a major factor in determining the locations and extent of the Great Lakes basins (Figures 2 and 3).

Approximately 1830 m (6,000 ft) of Paleozoic rocks lie between the surface and the metamorphosed Precambrian basement in Erie County, PA (Lapham, 1975).

ECONOMIC GEOLOGY

Erie County lays claim to Pennsylvania's only Great Lakes port. It is protected by Presque Isle, a recurved spit which provides a natural harbor in Presque Isle Bay. The port facilities are a large part of the economic base for the city of Erie.

The most valuable mineral product in Erie County is sand and gravel. Numerous pits of various sizes exploit kame, kame terrace, glaciodeltaic, and outwash deposits in the southern two-thirds of the county, and glaciofluvial, glaciodeltaic, and glaciolacustrine sediments at Lake Wittlesey, Arkona, and Warren I and II levels in the northern third. These materials are used for road and building construction, concrete block manufacture, and as nourishment material for the beaches of Presque Isle. In addition, sand is dredged from Lake Erie for concrete and masonry sand. The total production in Erie County, PA exceeds 500,000 tons/year (Tomikel and Shepps, 1967). The field trip will visit one pit at the Lake Whittlesey level.

The well-drained sand and gravel soils along the eastern Lake Section of the Central Lowland Province, which is commonly referred to as the Lake Plain, provide excellent soil for nursery stock, fruit orchards, and fruit and vegetable farms. This soil, plus 15 additional days of growing season in the fall due to the slow release of heat energy by the lake, provides an ideal environment for the cultivation of grapes. There are two major varieties. The fruity native North American grapes, most commonly Concords, produce high quality jelly and juice. Most wines, on the other hand, are the product of vines that have been brought from western Europe. We will be travelling through vineyard areas.

Lake Erie has a plentiful, high quality water supply for adjacent communities and industries. Where use of lake water is not practical, industries and public water supplies must derive their water from subsurface, primarily from glacigenic sand and gravel aquifers.

Erie County is one of the most active oil and gas producing

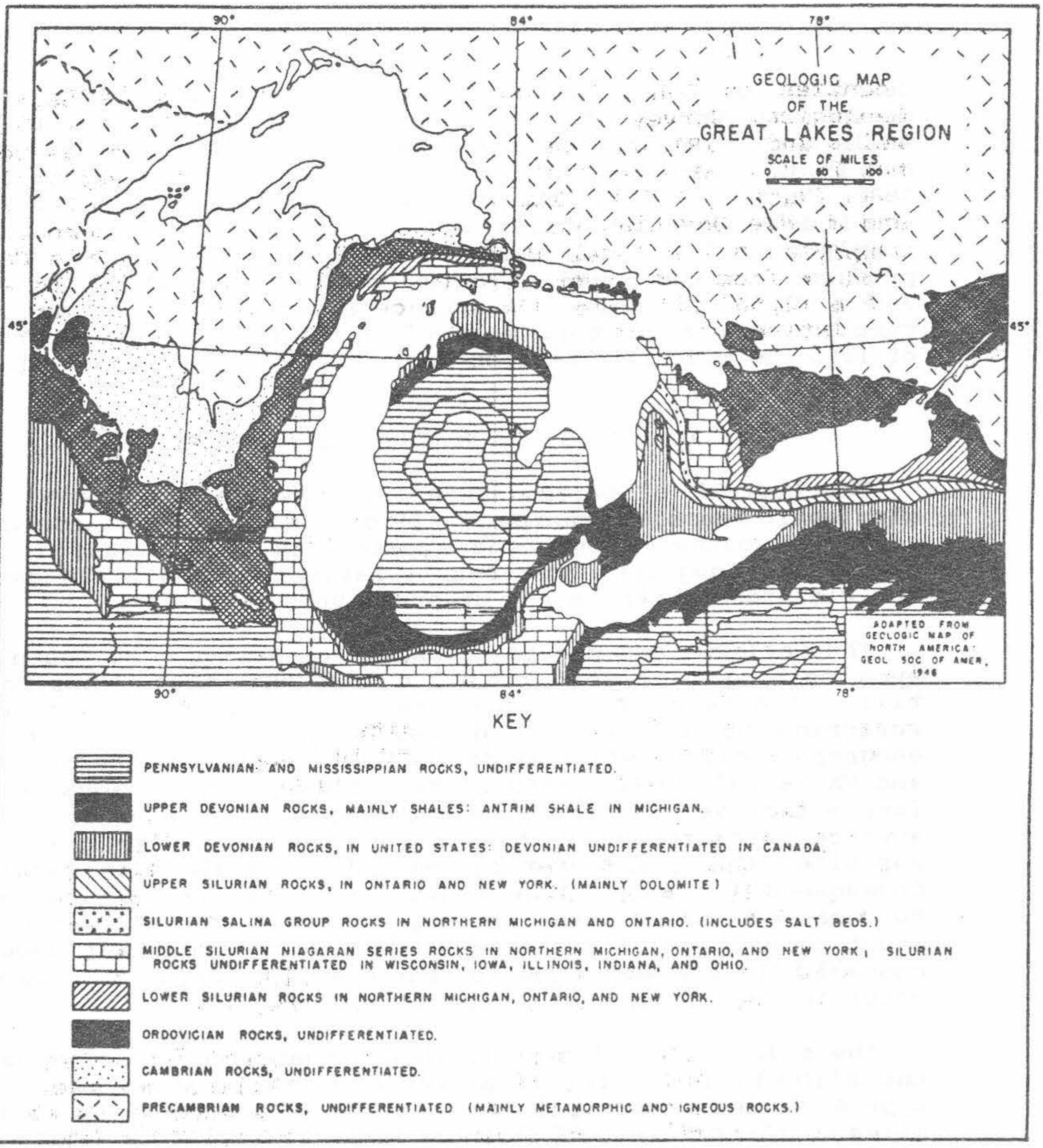


Figure 2. Geologic map of the Great Lakes Region (from Hough, 1958).

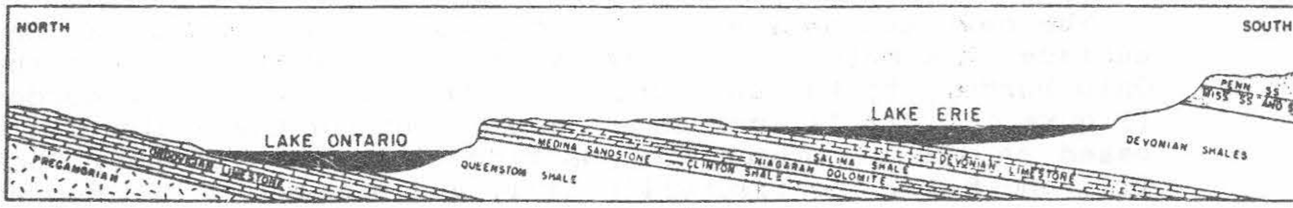


Figure 3. Cross section through the western end of the Ontario basin and the eastern end of the Erie basin, showing relations of the basins to weak shales (from Hough, 1958).

counties in Pennsylvania. In June 1987, the Pennsylvania Geological Survey had well records on file for 406 shallow wells and 2,191 deep wells in the county. Most are gas wells, but 15,825 barrels of oil were produced from 121 deep wells in 1986 (Harper, 1987). The shallow wells produce from the Upper and Middle Devonian shales and are typically non-commercial, supplying a few local users. Most deep wells in Erie County produce from the Lower Silurian Medina Group, which is about 760 m (2,500 ft) below the surface along the lake shore. The cumulative total deep gas production for Erie County at the end of 1985 was over 118 trillion cubic feet of gas (Harper, 1986).

GLACIAL GEOLOGY OF NORTHWESTERN PENNSYLVANIA

The bedrock of northwestern Pennsylvania is covered with glacigenic deposits transported by continental ice sheets which advanced southward onto the Appalachian Plateau and to the southwest along the Ontario-Erie Basin numerous times during the Pleistocene (White and others, 1969).

The earliest ice sheets advanced farthest to the south and upon melting back left behind the southernmost deposits of till. The term till is used here in a stratigraphic sense referring to all glacial deposits of a specified age and geographic distribution as defined in Shepps and others (1959) and White and others (1969). Each subsequent ice advance was less extensive than the immediately preceding advance. Each advance deposited till that only partially covers the older deposits, the whole overlapping in a shingle-like fashion. Consequently, each till sheet outcrops in an elongate northeast-southeast band roughly parallel to its former ice front or margin. The overlapping of each subsequent deposit conceals the preceding drifts, but the older deposits commonly occur in the subsurface (White and others, 1969).

The oldest glacial deposit in northwestern Pennsylvania is the Slippery Rock Till of probable pre-Illinoisan age. The type section is described from a subsurface occurrence about 3 miles north-northwest of Slippery Rock, Pennsylvania (White and others, 1969). The presumed age is based upon its stratigraphic position below the Mapledale Till.

The next youngest unit, the Mapledale Till, occurs at the surface in a belt 1 to 5 miles wide from Beaver County at the Ohio border, to Warren County near the New York State border (Figure 4). The Illinoisan age assignment for the Mapledale is based on its stratigraphic position above the Slippery Rock Till and below the Titusville Till, and because of the degree of weathering of a paleosol on its surface.

The Titusville Till is exposed at the surface along a belt 0 to 10 miles wide extending from northern and western Warren County at the New York border to the Ohio border in

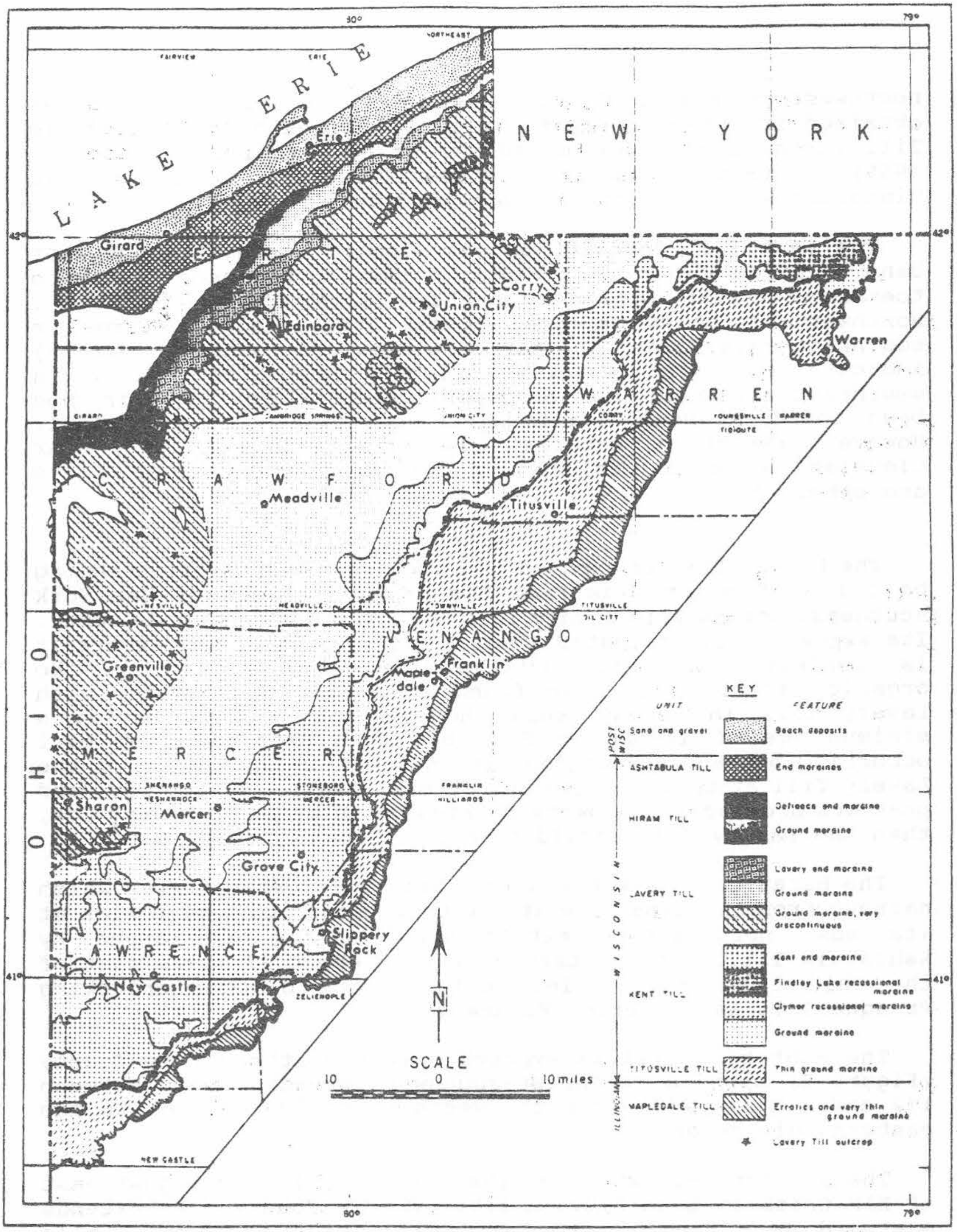


Figure 4. Glacial map of northwestern Pennsylvania showing distribution of Illinoian and Wisconsinan tills, ground moraine, recessional moraine, end moraine, and sand and gravel beach deposits. Neither the Slippery Rock Till nor the Girard moraine are shown on this map (from White and others, 1969).

northwestern Beaver County (Figure 4). Radiocarbon dates obtained from peat deposits in gravel beneath the Titusville Till range from 35,000 to 40,500 yr B.P. (White and others, 1969). This places the Titusville Till within middle Wisconsinan time (Dreimanis and Goldthwait, 1973).

The Kent Till deposits extend along a northeast-southwest band 30 miles wide from the Ohio border in Lawrence County to the New York State border in northern Warren County (Figure 4). Northwest-southeast oriented linear subglacial landforms in southeast Erie County and northern Crawford County (Figure 5) indicate that the movement of the Kent ice was in a southeasterly direction. No organic material for ^{14}C dating has been found in Pennsylvania in association with Kent Till. However, lacustrine material associated with Kent Till near Cleveland, Ohio has yielded a ^{14}C date of 24,000 yr B.P. (White and others 1969).

The Lavery Till is exposed in a northeast-southwest trending belt 1 to 5 miles wide from the western border of New York southeast across Erie County into northwestern Crawford County. Its exposure is terminated about 10 miles east of Ohio where it is completely overlapped by the Hiram Till (Figure 2). No organic material has been found in direct association with Lavery Till in Pennsylvania. However, a ^{14}C date having a minimum age of 14,000 yr B.P. has been obtained from marl occurring beneath a peat deposit in front of the margin of the Lavery Till at Corry (White and others, 1969). If the marl and peat are proglacial deposits related to ablation of Lavery ice, then the Lavery Till should be older than 14,000 yr B.P.

The Hiram Till is exposed in a triangular-shaped area which narrows from 14 miles wide at the Ohio border to 1 mile wide at its most northeastern extent where it is overlapped by Ashtabula Till. The eastern extent is about 23 miles east of the Ohio line and 5 miles south of the bluff overlooking Presque Isle Bay in Erie (Figure 2).

The Ashtabula Till is exposed across northern Erie County (Figure 2) along a northeast-southwest trending belt between 1/2 and 5 miles wide from the western New York border to the eastern Ohio border.

The westernmost extent of the Girard Till occurs just east of Elk Creek in Lake City, northwest Erie County. It extends eastward as a band 1/2 to 1-1/2 miles wide to about 1 mile south of the Borough of North East where it appears to coalesce with the Astabula Till.

Except for the Titusville, each of the Wisconsinan-age tills has an identified end moraine (Figure 2). The end moraine associated with the Hiram Till is named the Defiance end moraine. Each of the other end moraines takes the same name as

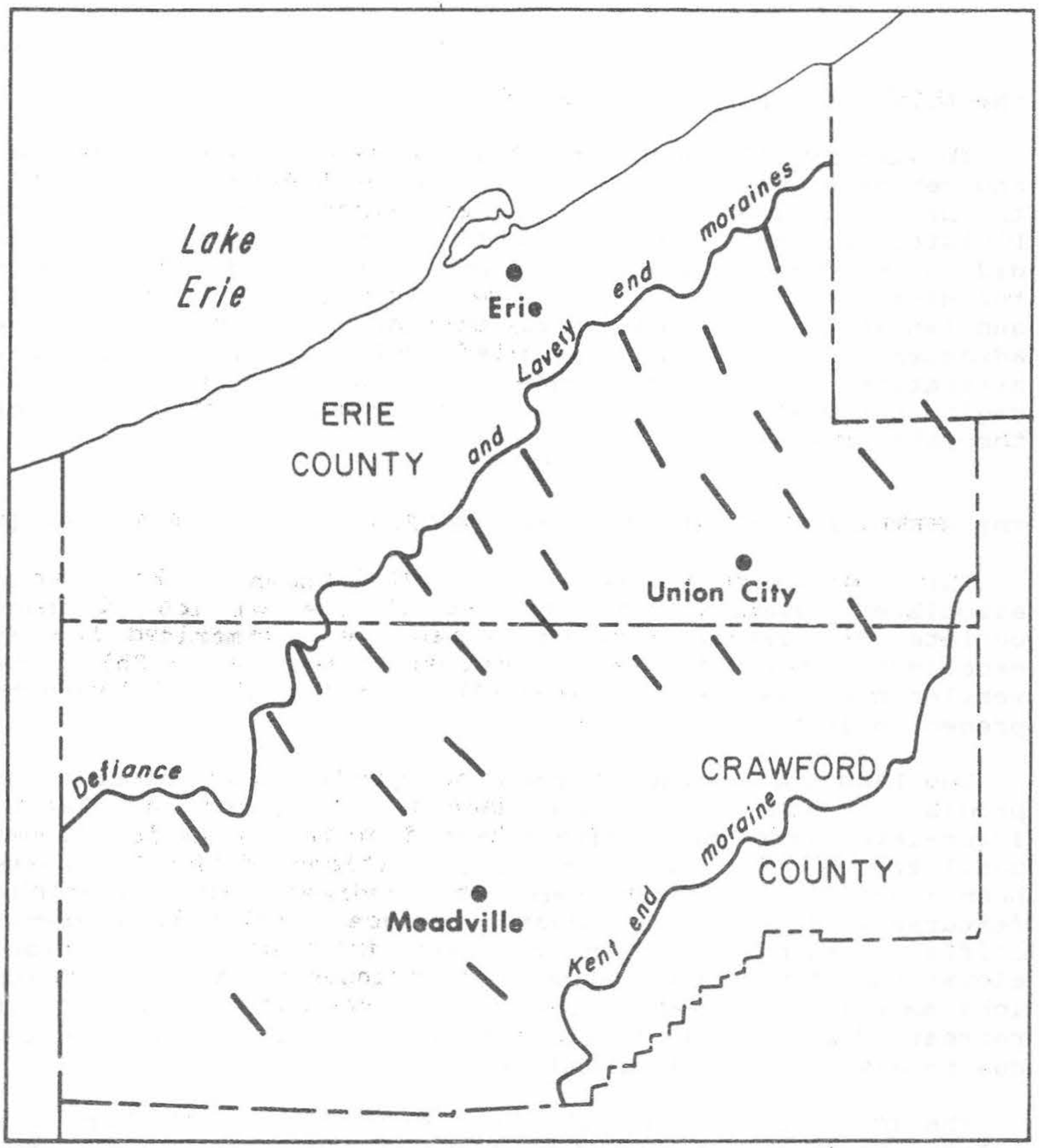


Figure 5. Orientation of linear landforms in northwestern Pennsylvania. Each linear-trend line represents an average of up to 40 orientation measurements. Orientation measured on 1:50,000 scale topographic maps of Erie and Crawford Counties. Only hilltop landforms were measured. Presumably the landforms represent both constructional and erosional features, but no field verification has been done. Note that the linear landforms occur only in a ground moraine area between the Kent and Defiance-Lavery end moraines. Figure prepared by W. D. Sevon, Pennsylvania Geological Survey, 1987.

the till with which it is associated.

In summary, it appears that there were at least 8 advances and retreats of glacial ice into northwest Pennsylvania within the pre-Illinoisan, Illinoisan, and Wisconsinan Stages of the Pleistocene. Each left behind till. Each succeeding advance did not encroach as far south as the previous advance although the Hiram ice did completely override part of the Lavery Till and Ashtabula ice moved across part of the Hiram Till. These advances and retreats resulted not only in large-scale alterations of the topography and surface drainage of the region but must have been the major excavators and shapers of the Lake Erie basin.

THE HISTORY OF PLEISTOCENE LAKE LEVELS IN THE LAKE ERIE BASIN

The following discussion of Pleistocene lake levels, associated advances and retreats of glacial ice, drainage outlets, and radiocarbon dates has been summarized from an excellent compilation by Calkin and Feenstra (1985). The version presented here is a simplification and is intended to present only the major points.

The Lake Erie basin has been occupied by a series of major proglacial ice or moraine-dammed lakes and non-glacial lower-level lake phases from the end of the Hiram ice advance until today. The positions and elevations of the lakes have been identified by their associated sediments and topographic features such as beach ridges, terraces, and relic wave-cut cliffs. Among the factors that influenced the various elevations of the lake stands were advances and retreats of ice lobe margins, opening of lower drainage channels during ice retreat, downcutting of outlet channels, and crustal warping due to glacial unloading and reloading.

The geologic history of the lakes of interest here are related to the advances and retreats of three ice lobes in two Great Lake basins. The earlier glacial ice that extended well south of Lake Erie excavated the Huron and Ontario-Erie basins. The basin topography largely controlled the movements of subsequent ice lobes that moved across the area during the time of the glacial and non-glacial lakes. The Huron ice lobe and the Saginaw ice lobe flowed within the Lake Huron basin and the Ontario-Erie lobe flowed within the Lake Ontario-Lake Erie basin. As the ice lobe margins retreated lakes occupied the vacated basins and as the margins readvanced the lakes moved in response.

The lakes have been named Lakes Maumee I (earliest), II, and III; Lake Arkona; Lake Ypsilanti; Lake Whittlesey; Lakes Warren I, II, and III; Early Lake Erie; and present Lake Erie (latest). The sediments and topographic features to be seen during the field conference are those related to Lakes

Whittlesey, Warren I, Arkona, and Lake Erie.

Lake Maumee I

The first of the proglacial Great Lakes in the Lake Erie basin developed in northwestern Ohio and northeastern Indiana following the culmination of the Hiram ice readvance and deposition of the Defiance end moraine during the Late Wisconsinan (Figure 6). Named Lake Maumee I, it stabilized at a present-day elevation of 800 feet and drained into the Wabash River through two outlets cutting the Fort Wayne Moraine. Maumee I beaches have been traced in northwestern Ohio and southeast Michigan. A ^{14}C date for the minimum age for Hiram ice recession from the Defiance Moraine is 14,500 ± 150 yr B.P. This should serve as a minimum age for Lake Maumee I.

Lakes Maumee II and III

As the ice of the Huron Lobe melted back to the north along the Lake Huron basin and the Ontario-Erie Lobe retreated northeast along the Lake Erie basin from the Defiance Moraine, a lower drainage channel was either uncovered or downcut by escaping water north of Imlay, Michigan causing abandonment of the Maumee I outlet (Figure 7). Consequently, the Maumee II and III phases were stabilized at 780 feet and 760 feet respectively. There is considerable confusion about the sequence of the two latter Maumee levels and as to the location of the drainage channel for Maumee II. Nevertheless, it appears that Maumee III stabilized, after a readvance or standstill of ice that formed the Tillsonburg Moraine in Ontario, the Ashtabula Moraine in Pennsylvania, and an as yet unlocated moraine below the present Lake Erie. A ^{14}C date for Maumee III is 13,700 ± 220 yr B.P.

Lake Arkona

Subsequent retreat of the Huron and Saginaw ice lobes northward along the Lake Huron basin and the northeast melt back of the Ontario-Erie Lobe in the Lake Erie basin to the Paris Moraine in Ontario and the Girard Moraine in Pennsylvania caused the waters in the Lake Huron and Lake Erie basins to subside and at the same time to join forming an early phase of Lake Arkona (Figure 8). This lake merged with early Lake Saginaw and drained westward via the Saginaw Bay outlet through the Grand River valley to Lake Chicago. Three different Arkona phases have been identified: Highest Lake Arkona, 710 feet; Middle Lake Arkona, 700 feet; and Lowest Lake Arkona, 695 feet. Beaches of the two higher lakes have been traced to 7.4 miles east of the Ohio-Pennsylvania border by Totten (1982; 1985). A ^{14}C date places Lake Arkona at 13,600 ± 500 yr B.P.

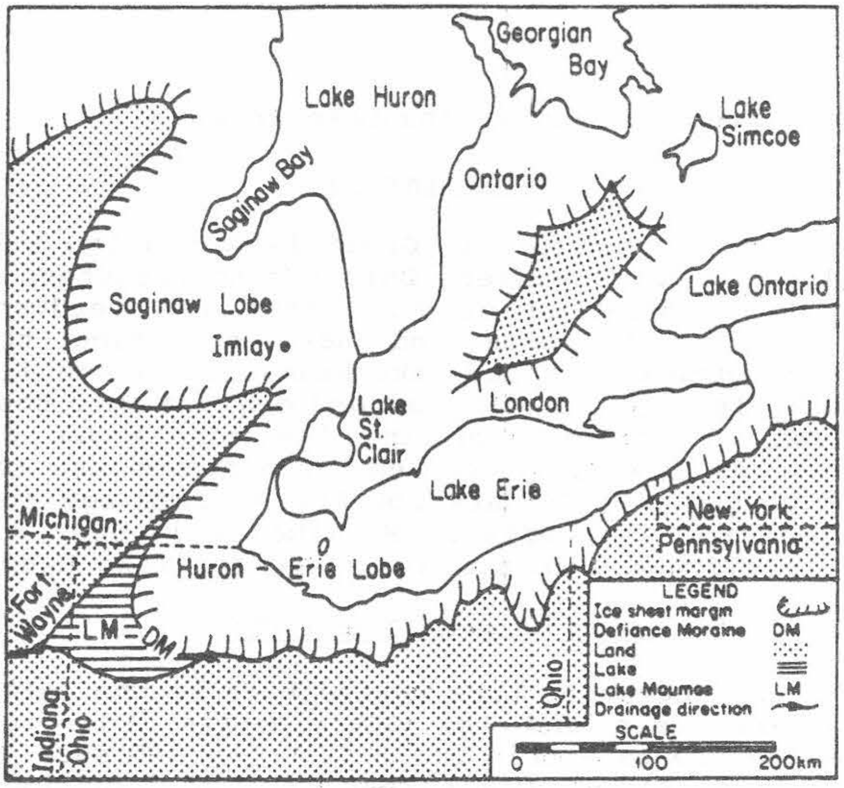


Figure 6. Locations of Maumee I, the western outlet at Fort Wayne, Indiana, and the Defiance End Moraine. Note the positions of Lakes Huron, Erie, and Ontario, and the Huron-Erie Lobes (from Calkin and Feenstra, 1985).

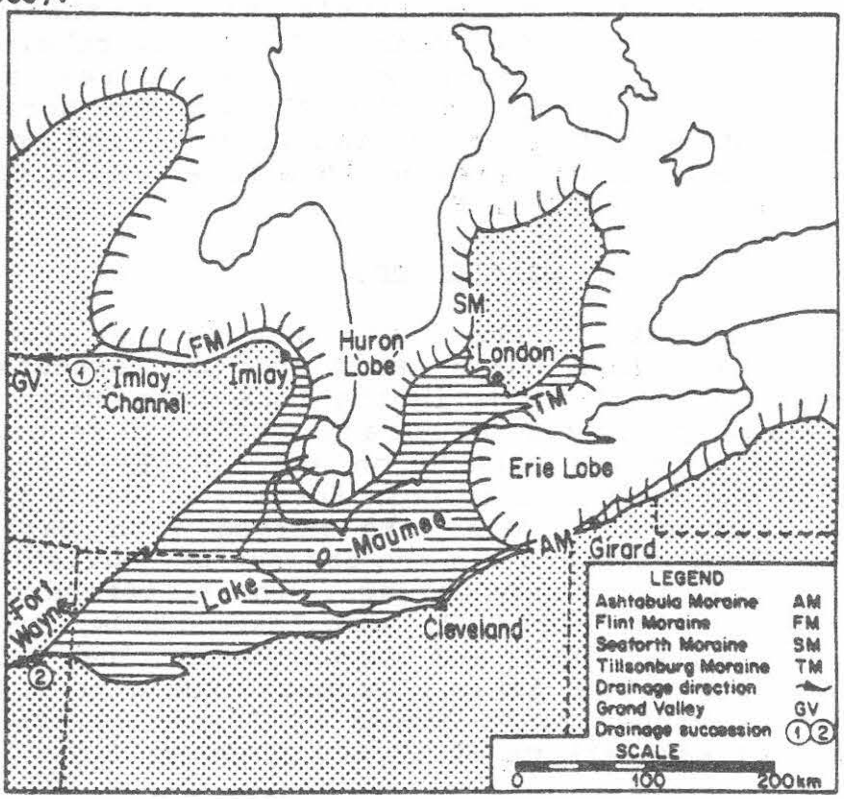


Figure 7. Locations of Lake Maumee III, the western outlet north of Imlay, Michigan, the Grand River valley crossing Michigan, and the Tilsonburg and Ashtabula end moraines. Note the positions of the Saginaw, Huron, and Erie Lobes (from Calkin and Feenstra, 1985).

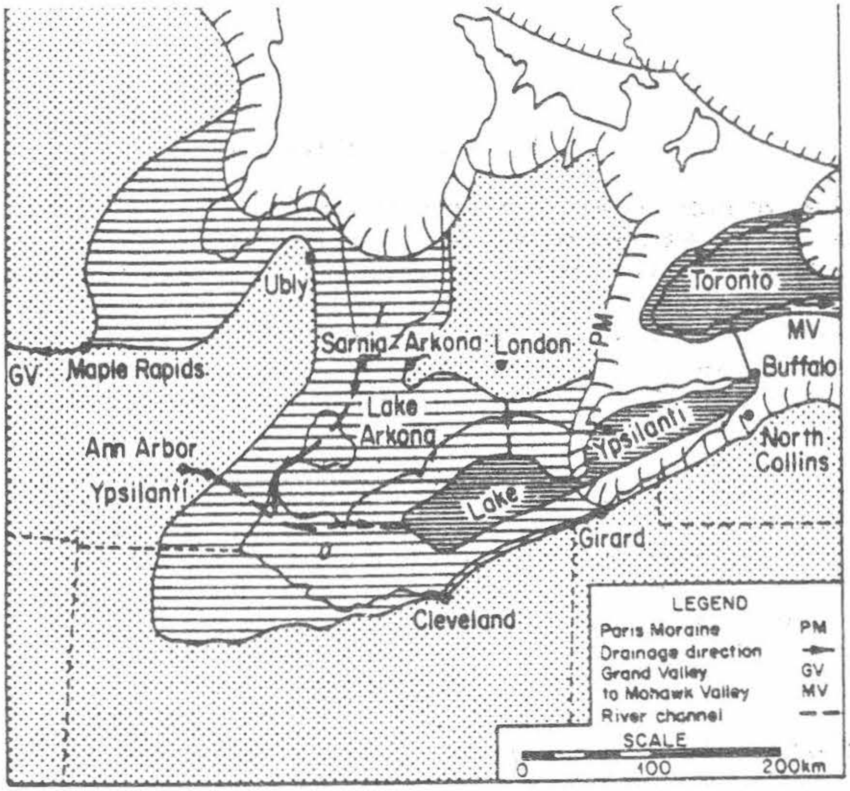


Figure 8. Locations of Lake Arkona, the western outlet through the Grand River valley in Michigan, and the Paris and Girard Moraines. Note the positions of the Saginaw, Huron, and Erie Lobes at the east end of Lake Arkona and the margin of the ice and the eastern outlet through the Mohawk River valley during the existence of Lake Arkona (from Calkin and Feenstra, 1985).

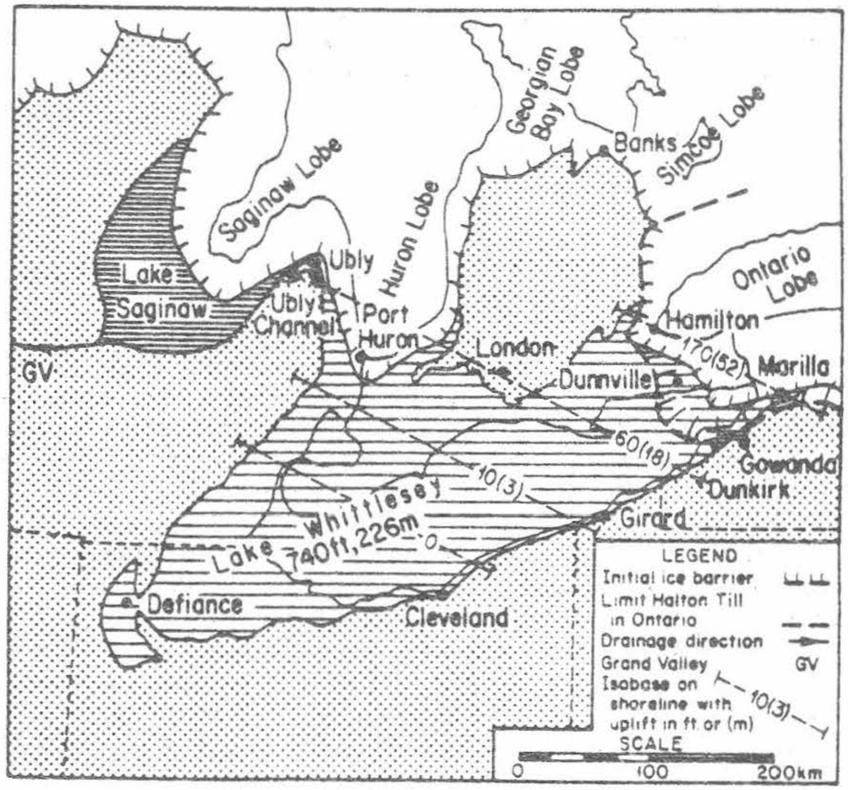


Figure 9. Locations of Lake Whittlesey, the western outlet north of Ubley, the Grand River valley in Michigan, and the Hamburg Moraine in western New York. Note the positions of the Saginaw, Huron, and Ontario Lobes (from Calkin and Feenstra, 1985).

Lake Ypsilanti

The Huron ice lobe continued to retreat to the present location of Georgian Bay while the Ontario-Erie ice lobe melted out of the Erie basin, across the Niagara Escarpment, beyond Toronto to the north, and into the northeast portion of the Lake Ontario basin. This opened an eastward drainage channel from the basins of Lakes Michigan, Huron, and Erie into a lower lake in the Ontario basin which, in turn, drained eastward through the Mohawk River valley and then through the Hudson River valley. The lower lake that developed in the Lake Erie basin was the nonglacial Lake Ypsilanti (Figure 8). Ypsilanti sediments have been found at elevations between 677 feet and 300 feet reflecting a fairly rapid lowering during this time. ^{14}C dates of organic material that relate to Lake Ypsilanti range between 12,600 ± 440 yr B.P. and 13,360 ± 440 yr B.P.

Lake Whittlesey

As the Saginaw and Huron Lobes readvanced south through the Lake Huron basin into Michigan and as the Ontario-Erie Lobe readvanced southwest within the Ontario basin across the Niagara Escarpment and into the northeastern-most part of the Lake Erie basin, waters in the Lake Erie basin rose to form Lake Whittlesey (Figure 9). Westward drainage was re-established through a spillway at Ubley, Michigan to Lake Saginaw which then drained through the Grand River valley to Lake Chicago in the Lake Michigan basin. The farthest extent of the readvance of the ice into the Erie basin is marked by the Hamburg Moraine near Buffalo, New York (Figure 10). Proglacial Lake Whittlesey stabilized against this moraine at the elevation of 740 feet. ^{14}C dates give a maximum age for Lake Whittlesey of 13,000 yr B.P.

Lake Warren

As the ice margin retreated from the Port Huron Moraine north of Ubley, Michigan (Figure 9) and from the Hamburg Moraine to the Alden Moraine south of Buffalo, New York (Figure 10), high discharges into Lake Saginaw and Lake Whittlesey produced downcutting of the western drainage channel through the Grand River valley and into Lake Chicago. This resulted in the lowering of Lake Whittlesey (740 feet) to the highest Lake Warren level (685 feet). As a result of either continued downcutting of the channel in Michigan or retreat of the ice margin in western New York State, three phases of Lake Warren were established: Warren I at 685 feet, Warren II at 675 feet, and Warren III at 670 feet. Warren II has been identified only locally. The various Warren phases were the last and most extensive of the major great glacial lakes to occupy the Erie basin (Figure 11). ^{14}C dates range from 13,050 yr B.P. on wood beneath Warren I deposits to 12,000 yr B.P. on organic material believed to be post-Warren.

Lakes Grassmere and Lundy

The northward retreat of the ice margin from the Alden Moraine (which had restricted Warren III) was interrupted by brief standstills that are reflected by the Fort Erie-Buffalo Moraine, Niagara Falls Moraine, and the Vinemount-Barre Moraine (Figure 10). The drainage at this time was eastward through the Mohawk Valley which resulted in lower-level lakes named Lake Grassmere at 640 feet and Lake Lundy at 620 feet. These lakes are represented by discontinuous and low relief (less than 2 to 6 feet) shore features.

Early Lake Erie

The final ice margin retreat that affected the Lake Erie basin caused the lake surface to fall below the elevation of the Niagara Escarpment. This initiated the first phase of modern Lake Erie known as Early Lake Erie (Figure 12). The final lowering occurred as a channel incised northward across the Fort Erie-Buffalo and Niagara Falls Moraines and down to the underlying Onondaga limestone at Buffalo, New York. This channel became the southern part of the Niagara River. The Onondaga limestone now serves as a threshold for present Lake Erie. Rather than continuing to flow north, the water spilled into the east-west trending Lake Tonawanda which subsequently spilled through drainage channels that opened across the Niagara Escarpment east of Buffalo as the ice retreated farther north into the Ontario Basin. Because of the loading of glacial ice, the Onondaga limestone threshold at that time was 120 feet below its present level and that of the present Lake Erie datum of 570 feet. This places the level of Early Lake Erie over 120 feet below present Lake Erie! ^{14}C dates from organic material found in sediments associated with Early Lake Erie places its age between 12,650 ± 170 yr B.P. and 12,080 ± 300 yr B.P.

Present Lake Erie

Glacio-isostatic uplift of the Onondaga threshold successively raised lake levels to about 12 feet below Lake Erie datum of 570 feet by 3,500 yr B.P. Continuous glacio-isostatic response of that threshold has resulted in the present datum of 570 feet (Figure 13).

Some Points of Controversy in Lake Erie Basin History

1. The eastern margin of Lake Maumee III may have been the Ashtabula Moraine (Fullerton, 1980; Totten, 1982) or the Girard Moraine (Schooler, 1974).
2. Lake Arkona may have occurred before Lake Whittlesey rather than after.
3. Lake Whittlesey and Lake Warren strands may have been

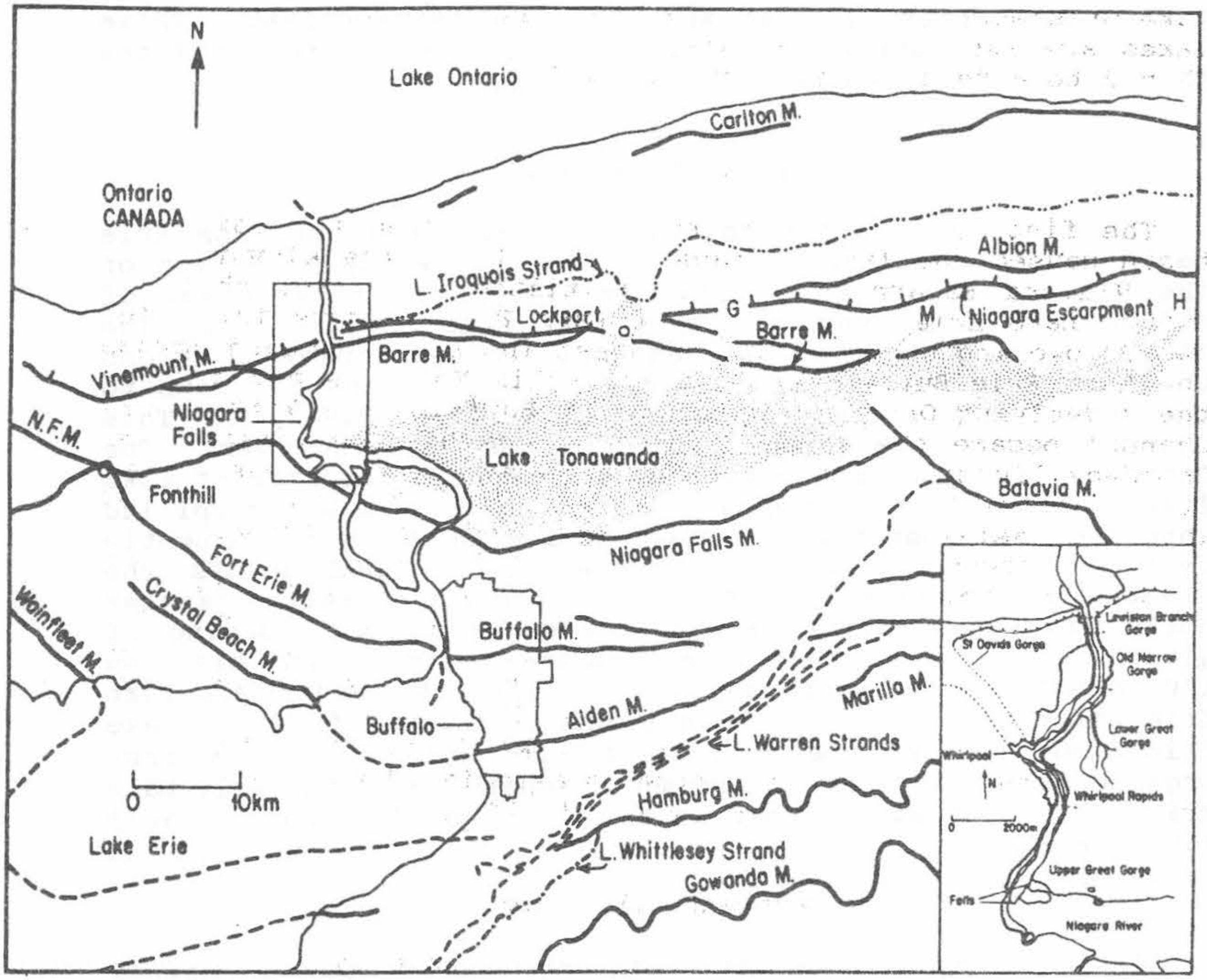


Figure 10. Locations of Lakes Whittlesey and Warren strands and the related Hamburg and Alden Moraines. Note the positions of the Buffalo-Fort Erie and Niagara Falls Moraines that were breached during the formation of Lakes Grassmere and Lundy, and of Lake Tonawanda that formed as a result of the breaching. Also note the northern outlet channels that drained Lake Tonawanda at H, M, O, and L into the Lake Ontario basin (from Calkin and Feenstra, 1985).

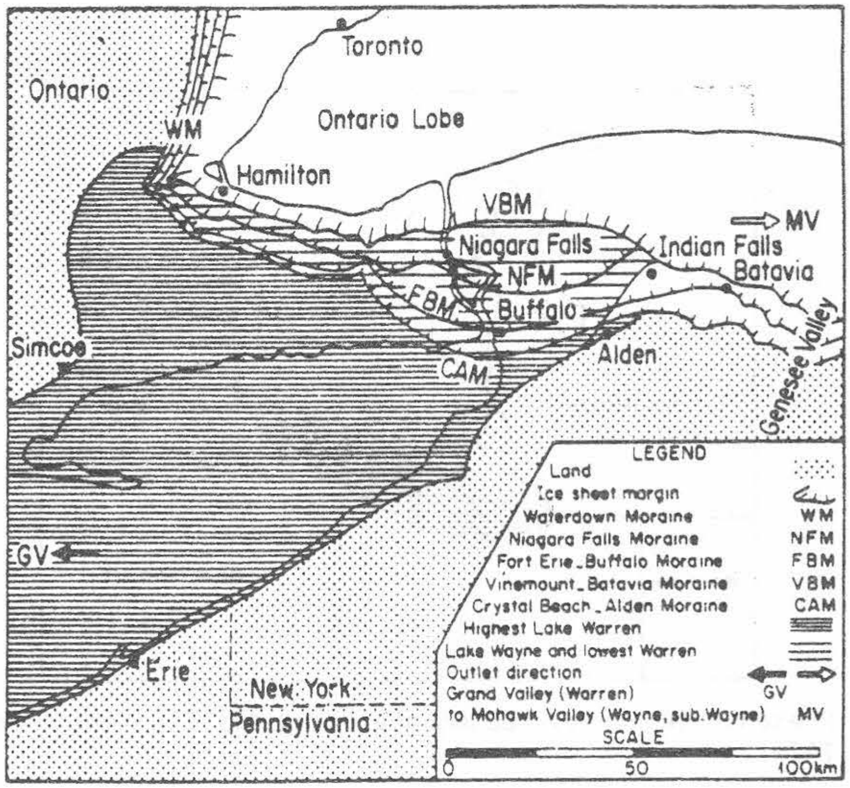


Figure 11. Location of Lake Warren and the position of the Alden Moraine (from Calkin and Feenstra, 1985).

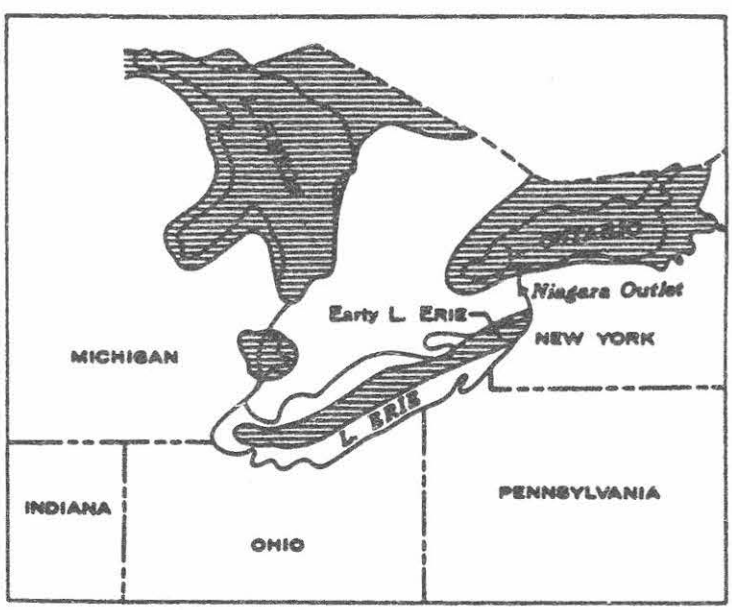


Figure 12. Location of Early Lake Erie. The Niagara River outlet was at least 120 feet lower than today. Note the possible position of the ice margin in Ontario, Canada (from Schooler, 1974).

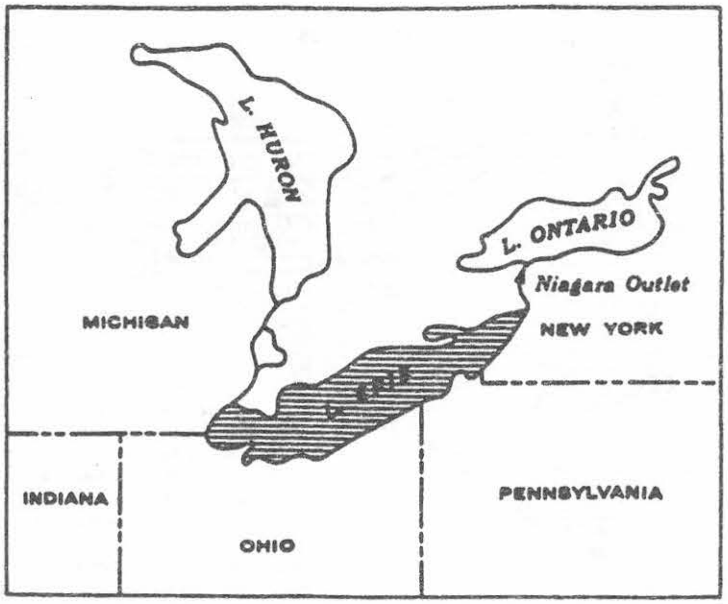


Figure 13. Present Lake Erie. Datum approximately 570 feet (from Schooler, 1974).

mapped upon sediments that are not beach deposits.
4. Lake Warren III (lowest) may have drained eastward along the Mohawk Valley rather than westward through the Grand River Valley in Michigan.
5. Some evidence suggests that Lake Erie may have been higher than its present level within the last few thousand years (Coakley and Lewis, 1985; Barnett, 1985; Larsen, 1985).

ROAD LOG AND STOP DESCRIPTIONS

The road log begins at Exit 10: Harborcreek-PA Rt. 531 of Interstate 90 in Pennsylvania.

Cumm. Miles	Miles from last point	Description
0.0	0.0	Stop sign at intersection of Harborcreek exit ramp and PA 531. Turn right (North) onto PA 531 and proceed for about .1 mile to intersection with Davison road.
0.1	0.1	Intersection of PA 531 and Davison Road. Bear right onto Davison Road. We will cross Seven-Mile creek, an essentially north-flowing creek that empties into Lake Erie. Seven-Mile refers to the distance of the creek and the city of Erie to the west, and not the length of the creek.
0.15	.05	Intersection of Davison Road and Dugan Road on the right. Continue North on Davison Road. You will be traveling across the Ashtabula Morainic System. The Girard and Ashtabula Moraines which are easily distinguished south of Erie, PA cannot be recognized at the two separate ridges east of Erie, Ashtabula till Halburn, PA.
0.6	.045	Overlook. Ahead is the steeply descending North-facing slope of the Ashtabula Moraine and the flatter lying terraces of lakes Whittlesey, Warren I-II and Warren III.
0.7	0.1	Intersection of Davison Road and McGill Road. Continue north on Davison Road. We are continuing to descend the north-facing slope of the Ashtabula ice marginal moraine.
1.4	0.7	Stop sign at intersection of Davison road and Belle road. Stop and turn right (east)

		onto Belle road. We will be traveling east on and parallel to the north facing slope of the Ashtabula Ice Marginal Moraine.
2.4	1.7	Intersection of Belle road and Rohl road to the right. Continue east on Belle road.
2.8	0.4	Intersection of Sidehill road (Belle road becomes Sidehill road at this point) and Mooreheadville road. Continue east on Sidehill road.
3.5	0.7	Intersection of Sidehill road and Brickyard road. Turn right (north). We will be descending a much gentler north slope of the Ashtabula Moraine.
4.4	0.9	Intersection of the Brickyard road and Law road. Continue north on Brickyard road. We'll remain on Ashtabula deposits.
4.9	0.5	We cross a west-flowing tributary of Twelve-mile creek. The stream has cut into stratified, subangular to subrounded cobbles with an occasional glacial erratic. The material has not been extensively worked.
5.1	0.6	Railroad tracks. There are two separate sets of tracks with two separate gates. Use extreme caution. Trains often move past here at very high speeds.
5.2	0.1	We will descend a relic "wave cut" cliff of Lake Whittlesey and proceed north across much flatter terrain. The terrain is underlain by gravel of a variety of sizes.
5.4	0.2	Intersection of Brickyard road and US Route 20. Stop sign. Turn left (west) and continue on US Route 20. To our right is the lake Warren I terrace.
5.7	0.3	The cemetery to our left illustrates the true topography. Large amounts of gravel have been quarried from both sides of the cemetery.
6.0	0.3	Entrance to Central Sand and Gravel Co. pit. Turn Left.

Stop 1. CENTRAL SAND AND GRAVEL PIT
(Stop description by: Charles Carter, Univ. of Akron
from Thomas and others, 1987)

Introduction

This pit is part of an extensive (several kilometers long and up to a few kilometers wide) sand and gravel deposit that trends southwest-northeast, roughly parallel to the present Lake Erie shore (Figure 14). The existing pit is nearly mined out as are adjacent pits to the west and south. The sand and gravel are used for road construction, the mining is done with front-end loaders, and the processing is accomplished by a hydraulic sorter. The deposit is at least 8 m (26 ft) thick and mining has been done to 5 or 6 m (16 or 20 ft) below the original, prestripped surface. Foreman Scott Wassink said that the deposit was coarser to the east so that although the sediments exposed along the western face are largely granule- and pebble-sized, the overall grain size for the pit was larger.

A small, about 4 m (13 ft) long, normal, nearly bedding-plane parallel fault occurs near the center of the face. The apparent fault plane is curved and has a strike of about east-west and an overall dip of about 23'N although siltstone cobbles are oriented nearly 90' from the horizontal at the north end. Whether the origin of the fault is tectonic or isostatic is unknown.

The elevation of the surface of this deposit (about 780 to 790 ft), and the correlation of this surface both to the east and the west, has led to the mapping of this feature and elevation as the Whittlesey strandline (Schooler, 1974, p. 11, 12). The deposits underlying this surface in this area of Pennsylvania have been interpreted as "beach deposits" (most recently by Schooler, 1974, p. 19) mainly on the basis of geomorphic evidence. However, she also recognized a "channel-like feature" at one location that included imbricated gravel that she interpreted as a "delta" (p.22). Schooler's work is typical of most of the work that has been done on the "beach ridges," in that the interpretations of these deposits have been made largely on topographic expression and texture with little consideration given to the internal characteristics and geometry of the deposits. Because of this, University of Akron students and faculty are doing sedimentologic studies of the ridges in order to improve our knowledge of their origin and evolution.

Sedimentology and Paleogeography

The pit lies near the western apex of a triangular-shaped terrace that opens to the east (Figure 15). A north-south face with a length of about 350 m (1148 ft) and a mean height of

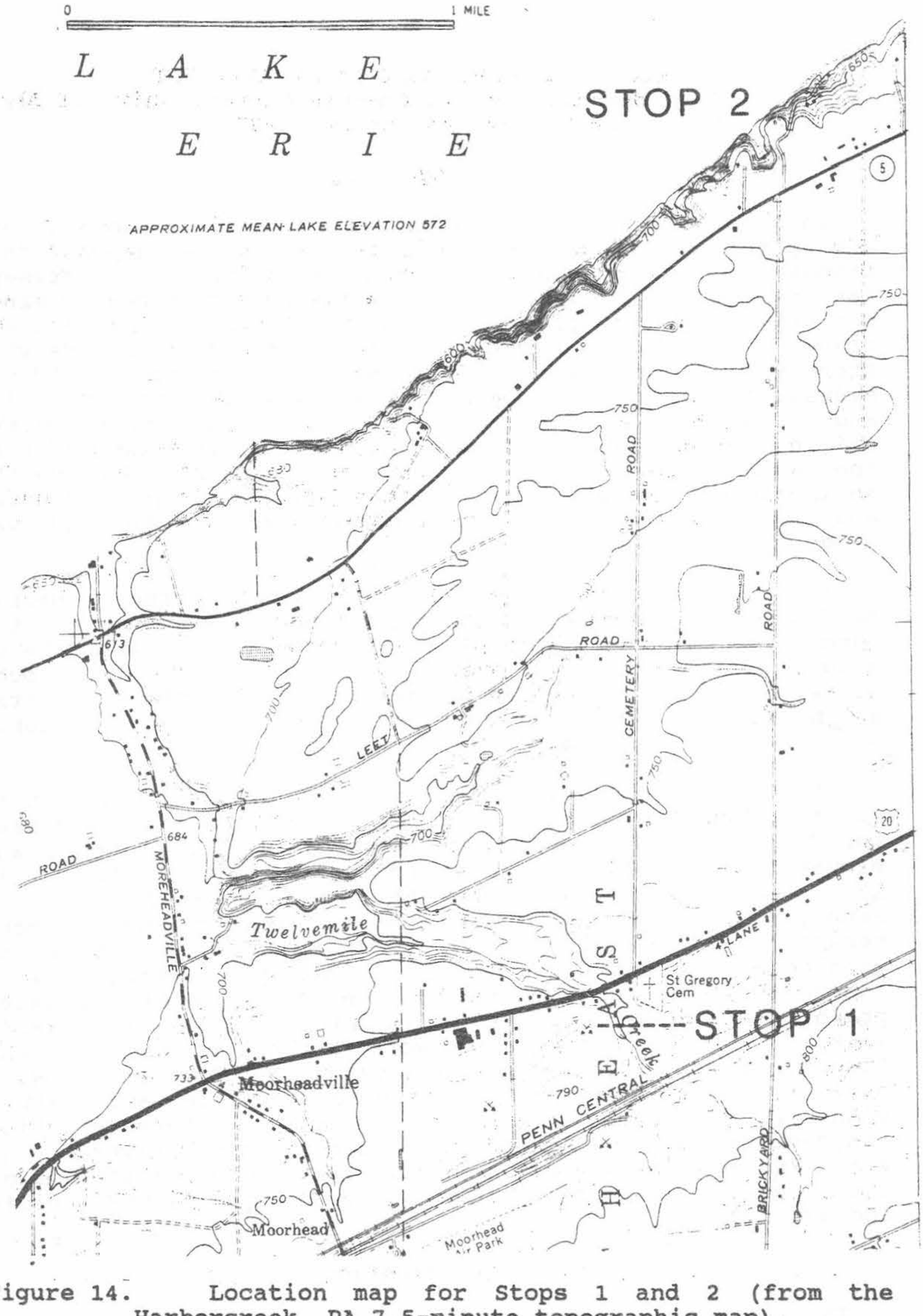


Figure 14. Location map for Stops 1 and 2 (from the Harborcreek, PA 7.5-minute topographic map).

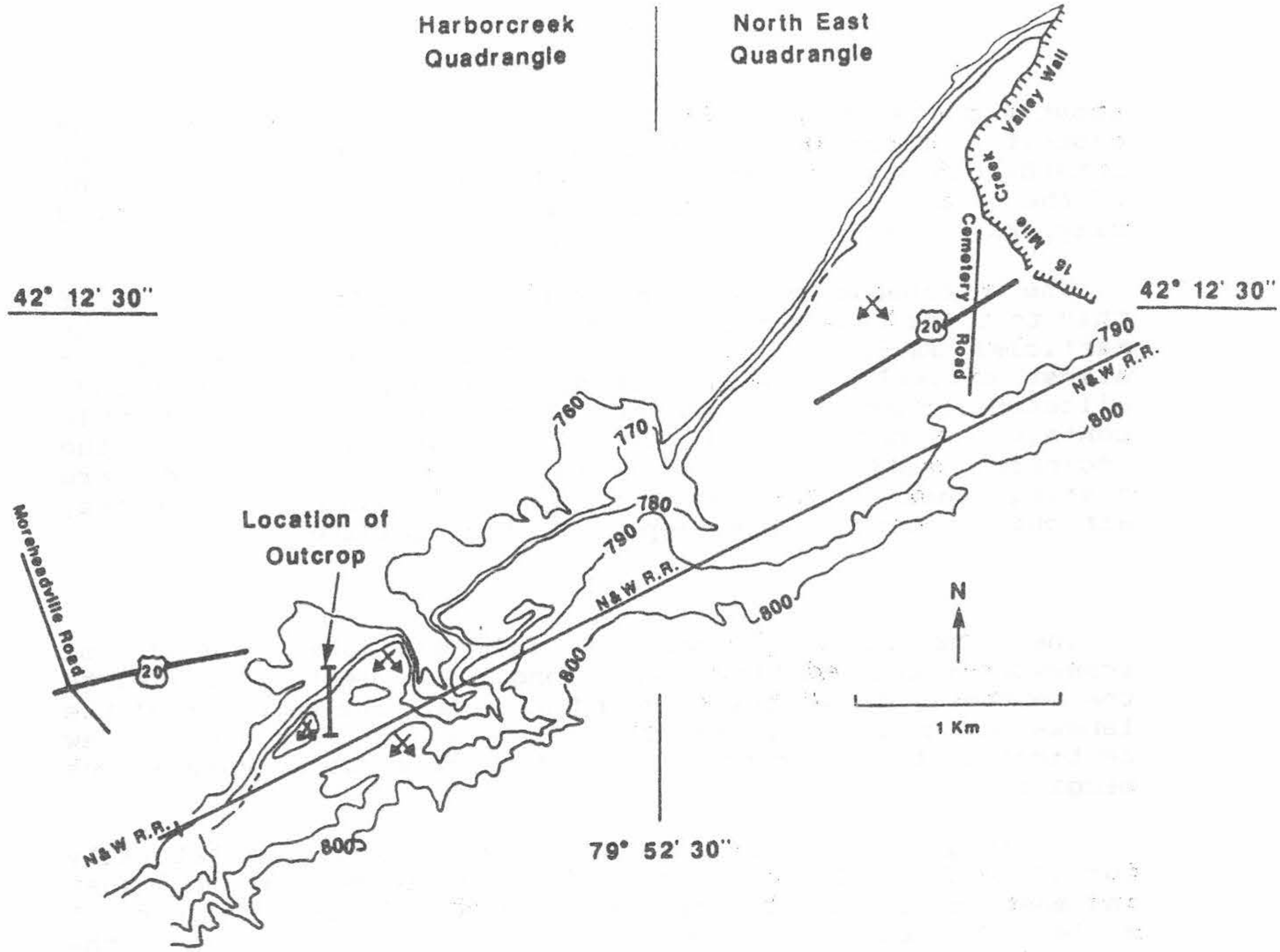


Figure 15. Location map of Central Sand and Gravel pit and plan view of deposit.

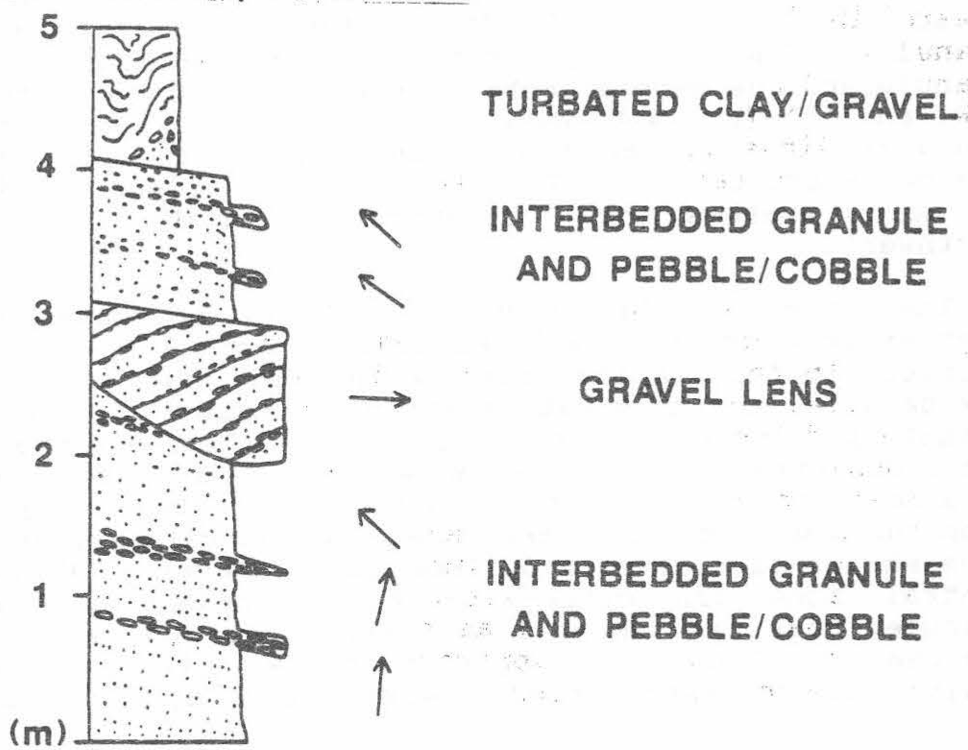


Figure 16. Generalized sequence with facies and paleoflow directions.

about 4 m (13 ft) provides an excellent cross section of the deposit. There are three facies exposed in the face: an interbedded granule and pebble/cobble facies (about 80 percent of the face), a gravel lens facies (5 percent), and a turbated clay/gravel facies (15 percent) (Figure 16).

The interbedded granule and pebble/cobble facies consists of thin to thick beds and lenses that dip gently to the north The particles making up the individual beds or lenses consist almost entirely of well sorted, well rounded, disc-shaped, siltstone clasts. The individual beds and lenses of granule contain laminations and very thin beds that parallel the enclosing bedding planes. The laminations and beds are distinguished on the basis of slight textural differences, although internally they appear to lack grading.

The individual lenses of pebble/cobble consist of framework-supported clasts with long axes oriented parallel to the northerly dip of the surrounding beds. The majority of the lenses are made up of siltstone pebbles no more than a few centimeters thick and thin to single pebble thicknesses at the margins.

In general, the beds and lenses can be traced laterally for 10 to 20 m (33 to 66 ft). The granule beds are thickest and most continuous, but the pebble/cobble lenses are up to 25 m (82 ft) and 20 cm (0.6 ft) thick. In places, the pebble/cobble lenses truncate the underlying granule at low angles. Overall, there is little if any lateral change in this facies from north to south, but vertically the facies fine upward in a 2-3 m (6-10 ft) section from fine pebbles to granules. The true dips of the sloping surfaces in both the granule and the pebble/cobble lenses are oriented between 305' (NW) and 15' (NE) with dips from 4' and 17' (the dips of 6 of the 7 readings lie between 4' and 7'). The dip orientations are not scattered. The 2 lowermost orientations are just east of north whereas the 5 uppermost orientations are to the northwest.

The gravel lens facies consists of flat to convex-up lenses that enclose cross-stratified beds of granules, pebbles, and cobbles In this facies, some of the long axes of the gravels lie parallel to the stratification and others do not. In two flat-topped lenses near the south end of the face, the shape of the cross-stratification resembles lateral accretion surfaces. In a major convex-up lens located about one-third the distance from the southern end of the face, the central part of the lens consists of tightly packed, imbricated gravels. Flanking the central zone are cross-stratified cobbles, pebbles, and granules that fine as well as steepen (11' to 27') away from the center. There is no apparent change in the texture of the individual cross-stratified layers. A second, much smaller but coarser (mostly cobbles), convex-up lens lies about 30 cm (1 ft) above the larger lens. This lens lacks the cross-stratification of the underlying lens. In both lenses the siltstone cobbles dip uniformly in a westerly direction whereas the stratification flanking the major lens dips to the south.

The gravel-size clasts, as in the interbedded facies, are framework supported, although in both facies there are numerous discrete cobble and even siltstone boulders that occur here and there in the section, parallel to the stratification of the enclosing granules, and commonly in the same planes. The pebbles and cobbles in the lenses are mostly siltstone. However, at three scattered places, well sorted and rounded, more spherically-shaped, gravel-sized clasts of mixed rock types are found. A pebble count of 69 clasts from one of these gravel lenses showed the following: 53 percent siltstone, 23 percent sandstone, 20 percent igneous and metamorphic, and 4 percent carbonate clasts.

The gravel lenses can be traced laterally for 10 m (33 ft) or more with the major convex-up lens having a lateral extent of at least 30 m (98 ft). The lenses dip gently to the north and although there are no vertical changes in the lenses, nearly all of the lenses show an updip (south) decrease in grain size. The true dip orientations of the "cross-stratification" in the lenses lie between 160° (SE) and 190° (SW) with dips from 11° to 27°. The true dip orientation of the cobbles in one imbricated zone is 275° (NW) with a dip of 10°, and the unmeasured orientation of other imbricated zones is also to the west.

The turbated clay/gravel facies consists of pods of clay separated by contorted zones of granule/gravel. Most of the facies has been removed, but before the surface was stripped there was about 15 cm (0.5 ft) of soil underlain by about 75 cm (2.5 ft) of clay (Scott Wassink, personal communication).

In terms of facies association and order, the interbedded granule and pebble/cobble facies is eroded by the gravel lens facies, with a relief as much as 1 m (3 ft). There are about 6 gravel lenses along the face with the lenses occurring throughout the section in a vertical sense, and along the southern two-thirds of the face. The turbated clay/gravel facies caps the two underlying facies.

Interpretation

The northward-dipping, interbedded granule and pebble/cobble facies is interpreted as proximal Gilbert-type deltaic foresets. The gently dipping lenses represent deposition from grain flow and avalanching on the delta foreset because of flow expansion and deceleration at the river mouth. The coarser gravel lenses may have been segregated during avalanching and/or may represent higher energy, episodic events. Rapid deposition took place during homopycnal flow mixing (Nemec and Steel, 1984). The incomplete foreset thickness of 3 to 4 m (10 to 13 ft) indicate minimum water depths of 3 to 4 m (10 to 13 ft) at the river mouth. The overall fining-upward sequence in these deposits may be due to decreased flow strengths caused by a gentler gradient.

The cross-cutting, cross-stratified sands are interpreted as channel deposits. Incisions of the delta slope by distributary channels during episodic drops in water level, and subsequent rises in water level, may have caused this scour and fill type of structure.

The northerly paleoflows are consistent with a delta/coastal alluvial fan origin. Northward flowing streams coming off the steep isostatically uplifted glaciated uplands debouched into glacial Lake Whittlesey with little modification by waves. The high rate of bedload coupled with low wave energy allowed the deltas to build directly to the north.

Alternate hypotheses could include sandbar or barrier systems. However, the geometry of the deposit and the thickness and lateral extent of the interbedded granule and pebble/cobble facies make these hypotheses unlikely.

ROAD LOG AND STOP DESCRIPTIONS

Cumm. Miles	Miles from last point	Description
6.0	0.0	Exit Central Sand and Gravel Co. pit. Intersection of Gravel pit entrance and US Route 20. Turn right (east) onto Route 20 and continue east.
6.5	0.5	Intersection of US Route 20 and Brickyard road. Turn left (north) and proceed north on brickyard road. We will descend a short, steep slope onto an area of relatively low relief. The elevation along Route 20 is about 780 feet. This is the edge of the Law-Whittlesey Terrace. The elevation at the bottom of the steep slope is 760 feet. This is the general elevation of the Lake Warren I-II level in the eastern section of Erie county. The slope is thought to be a relic wave cut cliff cut by the waves of Lake Warren I and can be seen running parallel to US Route 20 about 40 feet above it.

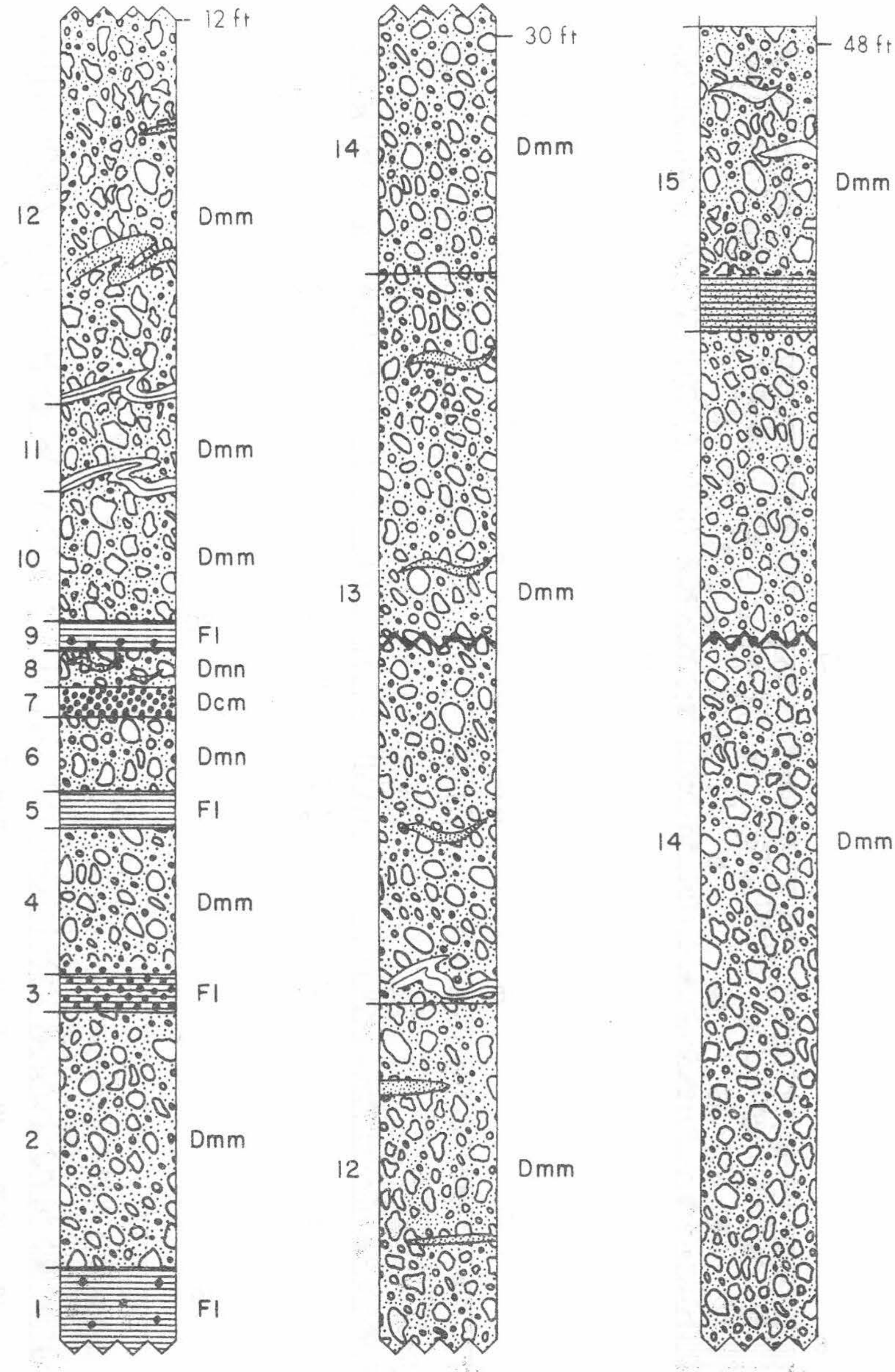
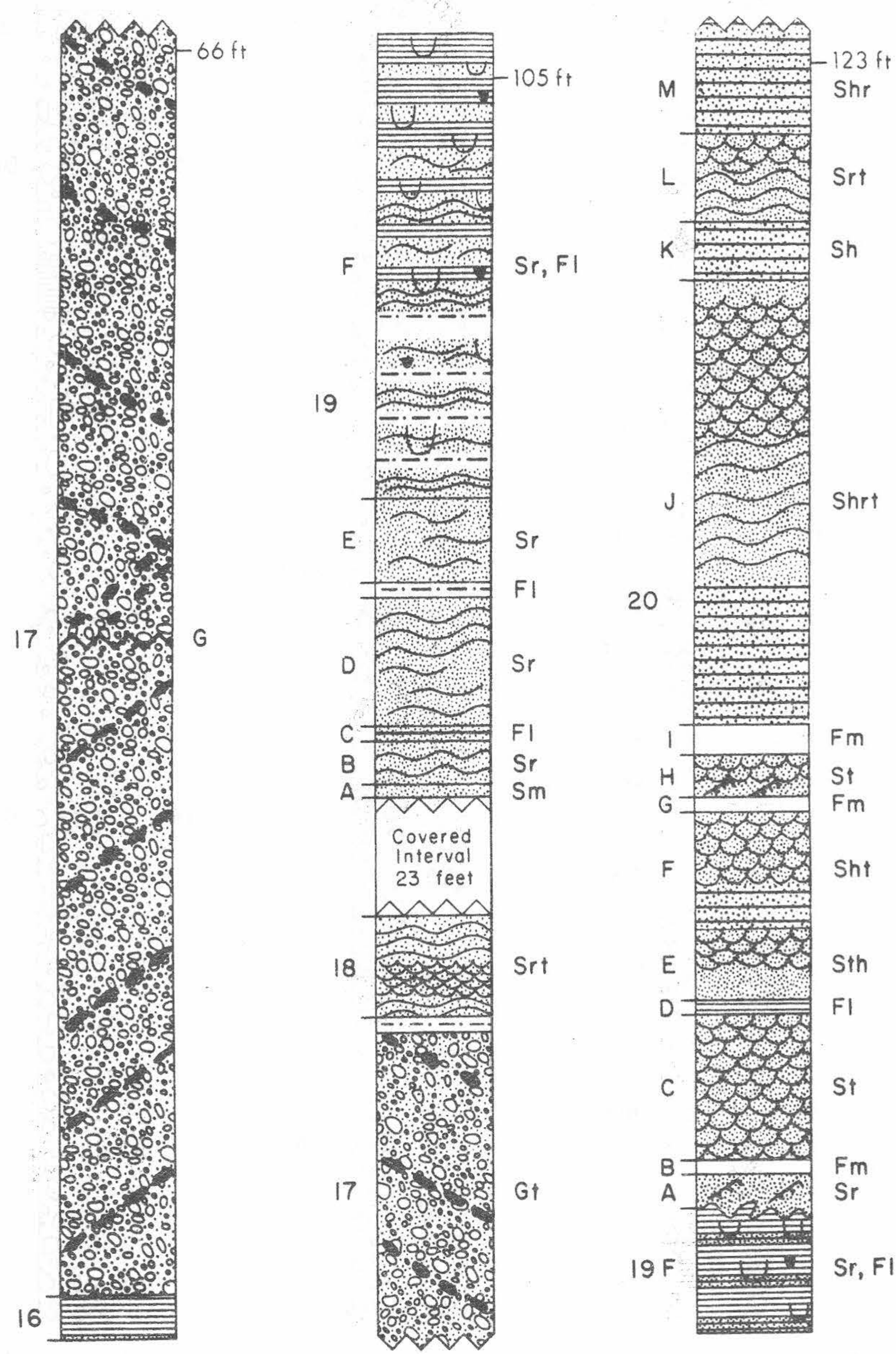
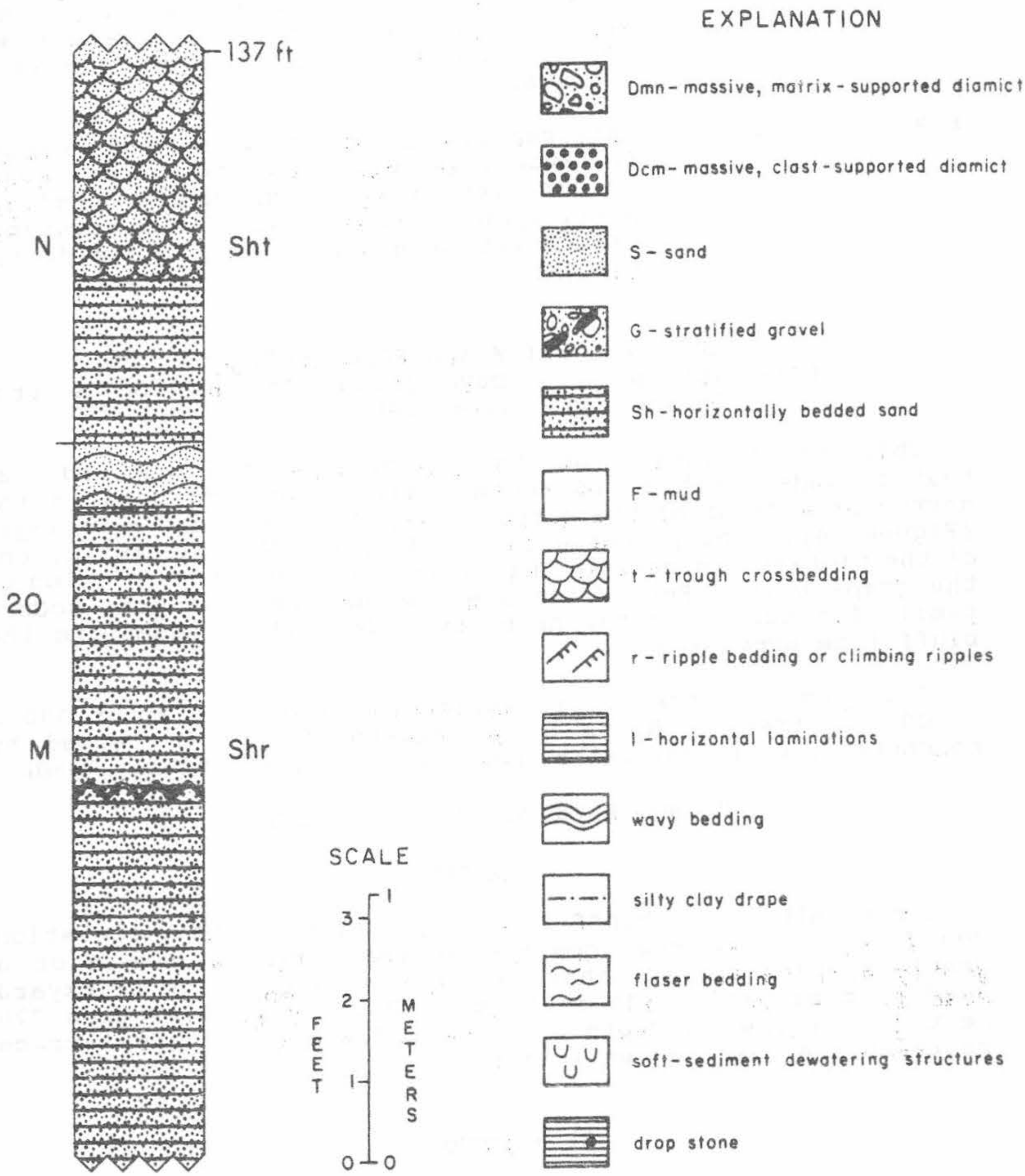


Figure 17. Graphic log of sediments occurring in the Brickyard Road bluff face. See Table 1 for measured section description


66 ft
17
G
16
105 ft
F
Sr, Fl
19
E
Sr
Fl
D
Sr
C
Fl
B
Sr
A
Sm
Covered
Interval
23 feet
18
Srt
17
Gt
123 ft
M
Shr
L
Srt
K
Sh
J
Shrt
20
I
Fm
H
St
G
Fm
F
Sht
E
Sth
D
Fl
C
St
B
Fm
A
Sr
19 F
Sr, Fl

Sun. F28


137 ft
N
Sht
20
M
Shr
SCALE
3
2
1
0
FEET
1
0
METERS
EXPLANATION
Dmn - massive, matrix - supported diamict
Dcm - massive, clast - supported diamict
S - sand
G - stratified gravel
Sh - horizontally bedded sand
F - mud
t - trough crossbedding
r - ripple bedding or climbing ripples
l - horizontal laminations
wavy bedding
silty clay drape
flaser bedding
soft - sediment dewatering structures
drop stone

Sun. F29

7.1	0.6	We are crossing a channeled west flowing tributary stream to Twelve-mile Creek.
7.8	0.7	Intersection of Brickyard road and West Middle road (Leet road on the topographic map). Continue north on Brickyard road. We continue to cross the lake Warren I Terrace.
8.9	1.1	Intersection of Brickyard road and US Route 20. Stop sign. Park vans and unload. Route 20 carries very high speed traffic; participants should cross with caution. Walk north on gravel road along side the vineyard.

STOP 2. BRICKYARD ROAD SECTION.

(Description by: Dave Thomas and Ray Buyce from Thomas and others, 1987)

This stop is located at the foot of a private, unpaved road that extends north of US Route 5 from Brickyard Road in the northeast section of the Harborcreek, PA 7.5-minute quadrangle (Figure 14). The property is owned by the McCord family, one of the pioneer vintners in the Pennsylvania-New York section of the grape belt. Permission must be obtained from the McCord family for access to the property. We will be examining the bluff-face exposures.

The summit of the bluff overlooking Lake Erie about 300 m (1000 ft) from US Route 5 is dangerous! It is capped by noncohesive sand that fails under very small additional loads.

DO NOT WALK TO THE BLUFF EDGE!

Landform

The summit of the bluff at this location is about elevation 700 feet. It is the location of the northern margin of a gently sloping terrace that can be traced south on Brickyard Road from elevation 730 feet at US Route 5 to elevation 770 feet just below US Route 20. We believe that this terrace represents a Lake Warren I level.

Stratigraphy

General. Wave erosion and a variety of mass wasting processes have exposed approximately 50 m (165 ft) of glacigenic deposits represented by 2 distinct facies. The lower part of the section is a diamict facies which comprises 17.4 m (57 ft) or 35 percent of the total bluff height. The upper 33 m (108 ft) or 65 percent of the total bluff height is composed of a gravel and sand facies. Figure 16 presents a graphic display and Table 1 the detailed stratigraphic description of the measured section.

Diamict Facies. This facies may be divided into 2 distinct lithologic types based upon thickness and grain size distribution. The lower segment consists of 11 units (1 through 11, Measured Section) ranging in thickness from 0.06 m (0.2 ft) to 0.6 m (1.75 ft). These 11 units occur as 2 different lithologies. Six of the units are massive, matrix-supported diamicts composed of olive gray, clayey silt to very fine sand supporting angular to subrounded pebbles and rarer gray and reddish gray soft clay clasts. Thicknesses range from 0.07 to 0.53 m (0.25 to 1.75 ft). The other 5 units are laminar-bedded, clayey silt, silt, or very fine sand supporting angular to subrounded pebbles and rarer gray and reddish gray soft pebble-size clay clasts. The thicknesses range from 0.06 to 0.07 m (0.20 to 0.25 ft). These 2 lithologies consistently alternate up through the entire 2.2 m (7.25 ft) of this segment of diamicts. At the lower contact of the uppermost unit (11) are alternating dark and light gray, clayey silt laminae with a roll-up structure and folds overturned westward.

The upper diamict segment is 12.75 m (41.85 ft) thick and consist of 4 units (12 through 15) ranging in thickness from 1.3 to 5.3 m (4.25 to 17.25 ft). These 4 units are composed of olive gray, massive, clayey silt or very fine sand matrixes supporting angular to subrounded pebbles, and fewer cobbles and rare boulders. The angular cobbles are hard siltstones or very fine sandstones whose origins may be found in the Upper Devonian bedrock to the immediate east. The subangular to subrounded cobbles are either Lower Paleozoic sedimentary rocks plucked from the Ontario-Erie basin farther to the east or Precambrian crystalline igneous and metamorphic rocks transported from the Canadian Shield. The lower 2 units (12 and 13) show, at their lower contacts, roll-up structures and folds in laminar clayey silt beds that are overturned toward the west. In addition, there is a normal fault with 6 mm (0.25 in.) displacement in the rolled-up laminar beds near the base of Unit 12.

Gravel/Sand Facies. The diamict and gravel/sand facies is separated by a 0.15 m (0.5 ft) thick laminar-bedded clay with a thin sand bed at the base and top. The contact between the clay and gravel facies appears erosional. The gravel segment of the gravel/sand facies (Unit 17) is 6.6 m (21.65 ft) thick. It consists of angular to subrounded pebbles and interstitial sand and clayey silt. The lower part of the unit has 2 cut and fill channels. The beds of the lowest channel dip northwest, while the beds of the upper channel truncate those of the lower and dip northeast. Bedding is not apparent in the remaining upper part of the gravelly unit; however, discontinuous fine-grain drapes occur throughout. A continuous 2.5 to 5 cm

(1 to 2 in.) drape separates the gravel from the sandy units above.

The sandy segment of the gravel/sand facies is about 20 m (66 ft) to the summit of the bluff. The upper 4.6 to 6 m (15 to 20 ft) were not measured because of steepness and instability of the slope. The sand units are composed of very fine, fine, and medium sand with relatively thin interlayers of clayey silt or very fine sand. The clayey silts or very fine sands occur as drapes.

The lowest unit (18) is composed of 0.46 m (1.5 ft) of very fine laminated sand displaying horizontal, trough, wavy, and flaser bedding and beds of horizontally laminated clayey silt.

The overlying unit (19) is 10.6 m (35 ft) thick. The lower 7 m (23 ft) is covered with sandy colluvium; however, exposures east and west of the Measured Section indicate lithologies consistent with the measured upper 3.7 m (12 ft) of the unit. The upper 3.7 m (12 ft) is composed of alternating beds of very fine sand and clayey silt beds. The laminar clayey silts are bedded horizontally while the very fine sand units display horizontal, trough, wavy, and flaser bedding. Pebble-size drop stones are sparsely scattered through the unit. The thicker sand beds in the lower part of the unit yield to clayey silt beds upward through the unit. This fining upward sequence is contorted by soft sediment deformation structures with amplitudes of 3 ft or more in its upper part. The remainder of the measured section (Unit 20) which is 20.1 m (66 ft) thick is composed of sand and clayey silt or very fine sand beds. The sand beds display laminar and thin horizontal, wavy, trough, and flaser bedding and climbing ripples. The clayey silt or very fine sand occurs as relatively thin drapes.

QUESTIONS

Questions to be asked at this stop are basically the same as those at Stop 2:

1. What process (es) formed the diamicts?
2. Is there evidence of sublacustrine deposition and if so what mechanisms were involved?
3. Is there more than one age of diamict here? What approach could be utilized to resolve the problem?
4. How many different environments of deposition may be represented by these sediments?

Table 1: Measured Section: Brickyard Road Bluff Face.

Stratigraphic section measured on bluff just east of valley which provides access to the beach. The upper 4.6 to 6 m (15 to 20 ft) were not described because of the steepness and instability of the slope.

Unit	Thickness Meters (feet)	Description
20-N	1.49 (4.9)	Sand, light brown, laminar, fine to medium. Trough and horizontal bedding.
20-M	3.0 (10)	Sand, light brown, laminar, fine to medium. Horizontal bedding. Ripple cross laminated unit near top.
20-L	0.36 (1.2)	Sand, light brown, laminar. Wavy and trough crossbedding.
20-K	0.24 (.8)	Sand, fine, light brown, very thinly bedded to thinly bedded. Horizontal bedding.
20-J	1.9 (6.2)	Sand, fine, light brown laminar coarsening upward to medium. Horizontal, wavy and trough crossbedding.
20-I	0.15 (.5)	Clay, gray
20-H	0.18 (.6)	Sand, fine, light brown, laminar. Trough crossbedding and climbing ripples. Slit bed at top.
20-G	0.03 (.1)	Clay, gray, massive
20-F	0.34 (1.6)	Sand, fine, light brown, laminar. Horizontal and trough crossbedding.
20-E	0.34 (1.13)	Sand, fine, and silt; light brown, laminated. Ripple crossbeds with wave lengths of about 6.5 cm (2.5 in.) and amplitudes of 2.5 cm (1 in.) Some flaser bedding.
20-D	0.048 (.16)	Clay, silt, gray, laminar.

20-C	0.6 (2.0)	Sand, light brown, laminar to very thin bedded. Trough bedding throughout.
20-B	0.045 (.15)	Clay, silt, gray, laminar.
20-A	0.09 (.3)	Sand, fine to medium, light brown, laminar. Horizontal and flaser bedding. Climbing ripples with lee and stoss sides preserved.
19	10.74 (35.25)	Sand, very fine, light to medium gray, alternating with silt or clay beds in upper 3.7 m (12 ft). Trough, wavy, flaser, and horizontal bedding in the sand units. Clay or silt laminations are horizontally bedded. Rare subangular to subrounded dropstones. Silt or clay beds become more apparent upward through the silt. Loading structures become more apparent upward with amplitudes greater than 1.5 m (5 ft) in the uppermost part. Lower 7 m (23 ft) is covered with sandy colluvium.
18	0.46 (1.5)	Sand, laminated, olive gray to light olive gray and yellowish brown, with clayey silt. Trough, wavy, and flaser bedding.
17	6.6 (21.65)	Gravel, light brown angular to subrounded pebble-size with silt and sand interstices. A 2.5 cm (1 in) clay drape extends across the top of the unit separating it from Unit 18. Middle bed truncates both the lower and middle beds about 0.6-0.9 (2-3 ft) above the contact with Unit 16. No bedding is evident in the upper 6 m (20 ft) of the unit, but several discontinuous clay drapes occur throughout. Lowest bed dips about 23' northwest.
16	0.1-0.15 (.33-.5)	Sand, fine to very fine, laminated, alternating with clay. Some lenses of pebbles. Sand is rippled at the top of the unit. 5 cm (2 in), laminar, medium gray and dark gray clay near center of unit. Bottom 2.5 cm (1 in) is fine to medium sand.
15	0.38-1.3	Diamict, massive, matrix supported.

	(1.25-4.25)	Olive gray, clayey silt supporting pebble-size angular, hard siltstone and subangular to subrounded sedimentary, igneous, and metamorphic rock fragments with maximum diameters of 2.5 cm (1 in). Large number of cobble-size, angular, hard siltstones and subangular to subrounded sedimentary, igneous, and metamorphic rocks. Cobbles become more abundant and smaller upward.
14	5.26 (17.25)	Diamict, massive, matrix supported. Olive gray, clayey silt supporting pebbles of angular, hard siltstone and subangular to subrounded sedimentary, igneous, and metamorphic rock fragments up to 2.5 cm (1 in) in diameter.
13	3.0 (10)	Diamict, massive, matrix supported. Silt and clay supporting angular to subrounded pebbles with 1.3-5.0 cm (.5-2.0 in) in diameter. Rarer angular siltstone and subrounded to rounded sedimentary, igneous, and metamorphic cobbles and one .6 m (2 ft) subrounded boulder. Cobbles increase in size and number eastward. 3 wavy sand layers, 2, 6, and 25 mm (.15, .25, and 1 in) thick, with horizontal laminations occur within the unit. Roll-up structure overturned toward the west occurs near the base. Lower contact is not distinct, but probably erosional. Undulating intercalated sand bodies along east end of contact. One .6 m (2 ft) cobble and angular, flat siltstone cobbles positioned on Unit 12 at western end.
12	2.97 (9.75)	Diamict, massive, matrix-supported. Olive gray, clayey silt supporting angular, subangular, and subrounded pebbles between 6mm and 5 cm (.5 and 2 in) in diameter with cobble-size angular siltstones showing striations; Subangular to subrounded sedimentary and crystalline igneous and metamorphic rocks with 7-13 cm (3-5 in) diameters in lesser amounts. One 25 cm (10 in) subrounded boulder. Sparsely occurring beds of very fine

		to fine sand between 6 and 25 mm (.25 and 1 in) thick and from .45 to 1 m (.18 to 45 in) long with light and dark laminae below and above a massive core. A roll-up structure and folds overturned to the west and normal faults with apparent dips of 75' west are displaced 6 mm (.25 in) along the fault plane within part of the roll-up structure 0.8 m (2.6 ft) above the lower contact.
11	.13-.4 (.42-1.44)	Diamict, massive, matrix supported. Silt with scattering of angular to subrounded pebbles with a maximum diameter of 2.5 cm (1 in). Lower part shows alternating dark and light laminae. Roll-up structures at bottom contact with Unit 10 are deformed from east to west.
10	.38 (1.25)	Diamict, massive, matrix-supported. Olive gray, clayey silt or very fine sand supporting a scattering of angular to subrounded pebbles with a maximum size of 2.5 cm (1 in) and a few cobbles 8 cm (3 in) or more in diameter.
9	0.06 (.21)	Sand, very fine to fine, occurring as 1-2 mm alternating light gray and light gray laminae. Rip-up clasts from Unit 8 in bottom 6 mm (.25 in) of unit. Dark gray layer of mud laminae in upper 1.4 cm (.5 in). Rippled very fine sand bodies with amplitudes and lengths of 3 mm (.1 in).
8	0.08 (.27)	Diamict, massive, matrix-supported. Silt with scattering of angular to subrounded pebbles. Wavy laminae 2 mm (.05 in) thick of very fine sand occur within one unit.
7	0.008 (.27)	Gravel, pebble size. Maximum diameter of 2.5 cm (1 in) with very fine interstatial sand, silt and clay. No bedding or imbrication observed.
6	0.15 (.5)	Diamict, massive, matrix-supported. Brownish gray silt or fine sand matrix supporting a scattering of angular to subrounded pebbles and

		rare grayish red and medium gray soft clay clasts.
5	0.08 (.25)	Sand, very fine, thin to medium laminae, light brownish gray alternating with dark gray silt or clay laminae.
4	.15 (.5)	Diamict, massive, matrix-supported. Olive gray to brownish gray silt or fine sand supporting a scattering of angular to subrounded pebbles and rare grayish red soft clay clasts with olive gray interstatial silt or very fine sand.
3	0.08 (.25)	Silt or fine sand, alternating in thin to medium laminae of pale red and grayish red with dense scattering of angular to subrounded pebbles of up to 2.5 cm (1 in) in diameter.
2	.53 (1.57)	Diamict, massive, matrix supported. Olive to brownish gray silt or very fine sand supporting a scattering of angular to subrounded pebbles up to 2.5 cm (1 in). Pebbles become more sparse upward. Slight evidence of bedding when dampened with water.
1	0.08 (1.75)	Silt and/or very fine sand in alternating bands of light and darker olive gray laminar bedded, supporting a sparse scattering of subrounded to rounded pebbles and rare clasts of grayish red clay. BASE OF SECTION

ROAD LOG

Cumm. Miles	Miles from last point	Description
8.9	0.0	Leave Stop 2. Proceed south on Brickyard road. We will be travelling across the Warren I-II Terrace from elevation 740 feet to elevation 760 feet over the next 1.8 miles, a gradient of about 11 feet per mile.
10.0	1.1	Intersection of Brickyard road and West

		Middle road to the right. Continue south on Brickyard road. US Route 20 is straight ahead (south) running along the edge of Lake Whittlesey Terrace, just above the Warren I scarp (Wave Cut?).
10.7	0.7	Stop sign at intersection of Brickyard road and US Route 20. Turn left (east) onto US Route 20 and continue east. We are now travelling on the Lake Whittlesey Terrace with the Warren I-II Terrace to our left.
11.1	0.4	Intersection of US Route 20 and Williams road to the right. Continue east on US Route 20.
12.2	1.1	Intersection of US Route 20 and Cemetery road. Continue east on US Route 20.
13.0	0.8	Traffic signal at intersection of US Route 20 and South Mill street. Continue east through the town on Northeast, Pennsylvania.
13.4	0.4	Traffic Signal at intersection of US Route 20 and PA Route 89. Continue east on US Route 20.
14.0	0.6	Yellow flasher intersection of US Route 20 and Orchard Beach road. Continue east on US Route 20.
14.1	0.1	Boundary sign of Northeast Township. Also beginning of divided highway. Continue east on US Route 20.
16.4	2.3	Intersection of US Route 20 and Eastbound entrance ramp of Interstate 90. Proceed onto entrance ramp and on to Fredonia, New York.

REFERENCES CITED

Barnett, P.J., 1985, Glacial retreat and lake levels, north central Lake Erie basin, Ontario, in Karrow, P.F. and Calkin, P.E., eds, Quaternary evolution of the Great Lakes: Geological Association of Canada Special Paper 30, p. 185-194.

Berg, T.M., and others, 1980, Geologic map of Pennsylvania: Pennsylvania Geologic Survey, 4th ser., Map no. 1.

Berg, T.M., and others, 1986, Stratigraphic correlation chart of Pennsylvania, revised edition: Pennsylvania Geologic Survey, 4th ser., General Geology Report 75.

Calkin, P.E., and Feenstra, B.H., 1985, Evolution of the Erie-Basin Great Lakes in Karrow, P.F., and Calkin, P.E., eds., quaternary Evolution of the Great Lakes: Geological Association of Canada Special Paper 30, p. 147-170.

Coakley, J.P. and Lewis, C.F.M., 1985, Postglacial lake levels in the Erie basin in Karrow, P.F. and Calkin, P.E., eds., Quaternary evolution of the Great Lakes: Geological Association of Canada Special Paper 30, p. 195-212.

Dreimanis, A., and Goldthwait, R.P., 1973, Wisconsin glaciation in the Huron, Erie, and Ontario lobes, in Black, R.F., Goldthwait, R.P., and Willman, H.B., eds., The Wisconsin Stage: Geological Society of America Memoir 136, p. 71-106.

Fullerton, D.S., 1980, Preliminary correlation of post-Erie Interstadial events (16,000-10,000 radiocarbon years before present), central and eastern Great Lakes region, and Hodsonm, Champlain, and St. Lawrence lowlands, United States and Canada: U.S. Geological Survey Professional Paper 1089, 52 p.

Harper, J.A., 1986, Oil and gas developments in Pennsylvania in 1985: Pennsylvania Geologic Survey, 4th ser., Progress Report 199, 112 p.

Harper, J.A., 1987, Oil and gas developments in Pennsylvania in 1986: Pennsylvania Geologic Survey, 4th ser., Progress Report 200.

Hough, J.L., 1958, Geology of the Great Lakes: University of Illinois Press, Urbana, 313 p.

Lapham, D.M., 1975, Interpretation of K-Ar and Rb-Sr isotopic dates from a precambrian basement core, Erie County: Pennsylvania Geological Survey, 4th ser., Information Circular 79, 26 p.

Larsen, C.E., 1985, A stratigraphic study of beach features on the southwestern shore of Lake Michigan: new evidence of Holocene lake level fluctuation: Illinois Geological Survey, Environmental Geology Notes 112, 31 p.

Leverett, F., 1892, On the correlation of moraines with raised beaches of Lake Erie: American Journal of Science, 3rd Series, 43, p. 281-301.

Nemec, W and Steel, R.J., 1984, Alluvial and coastal conglomerates: their significant features and some comments on gravelly mass-flow deposits, in Koster, E.H., and Steel, R.J., eds., Sedimentology of gravels and conglomerates: Canadian Society of Petroleum Geologists Memoir 10, p. 1-31.

Schooler, E.E., 1974, Pleistocene beach ridges of northwestern Pennsylvania: Pennsylvania Geologic Survey, 4th ser., General Geology Report 64, 38 p.

Shepps, V.C., White, G.W., Droste, J.B., and Stitler, R.F., 1959, Glacial geology of northwestern Pennsylvania: Pennsylvania Geologic Survey, 4th ser., Bulletin G 32, 54 p.

Thomas, D.J. and others, 1987, Pleistocene and Holocene geology of a dynamic coast. Guidebook for the 52nd annual field conference of Pennsylvania geologists.: Pennsylvania Geological Survey, 88 p.

Tomikel, J.C., and Shepps, V.C., 1967, The geography and geology of Erie County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Information Circular 56, 64 p.

Totten, S.M., 1982, Pleistocene beaches and strandlines bordering Lake Erie: in White, G.W., ed., Glacial geology of northeastern Ohio: Ohio Geological Survey Bulletin 68, p. 52-60.

White, G.W., Totten, S.M., and Gross, D.L., 1969, Pleistocene beaches and bars, Presque Isle, Erie, Pennsylvania (6/22/74-8/10/74): unpublished M.S. thesis, State University of New York College at Fredonia, 157 p.