THE GEOLOGIC FRAMEWORK OF THE OHIO AREA OF LAKE ERIE

BY

J.A. FULLER[1], R.C. CIRCE[2], AND R.N. OLDALE[3]

U.S. GEOLOGICAL SURVEY OPEN-FILE REPORT 95-220

[1]Ohio Geological Survey, Sandusky, OH 44870
[2]U.S. Geological Survey, Reston, VA. 22092
[3]U.S. Geological Survey, Woods Hole, MA 02543

CONTENTS

LIST OF ILLUSTRATIONS

THE GEOLOGIC FRAMEWORK OF THE OHIO AREA OF LAKE ERIE

by

J.A. FULLER, R.C. CIRCE, AND R.N. OLDALE

INTRODUCTION

In September of 1991, the Ohio Department of Natural Resources-Division of Geological survey began field work as part of a cooperative with the U.S. Geological Survey Coastal Studies Program. This multifaceted effort was designed to evaluate the geologic framework under the Ohio waters of Lake Erie and in the adjacent nearshore areas, rates of coastal erosion, as well as the mechanisms and processes responsible for that erosion. The focus of this part of the study is on the geologic framework under the offshore waters and represents an effort to tie together and improve the resolution of previous seismic reflection and coring studies.

Lake Erie is the shallowest of the Great Lakes and the only one where the altitude of the bottom is entirely above sea level. Lake Erie is divided, morphologically, into three basins, the shallowest (average 7 m deep) in the west, and the deepest (average 25 m deep) in the east. The central and largest basin averages about 19 m deep. Ohio waters include parts of the western and central basins (Fig. 1).

The Ohio portion of Lake Erie lies on the gently east dipping flank of the Findlay Arch. The bedrock is composed of

Upper Silurian carbonates west of Sandusky and Devonian shale to the east.

At least two ice sheets scoured the area. Tills of probable Illinoian age and drift of possible pre-Illinoian age are found to the south of Lake Erie (Miller, and others, 1991: Szabo, 1992). Wall (1968) reports that deposits overlying bedrock are thickest (83 m) in central Lake Erie. Till and stratified drift of late Wisconsinan age form the surficial deposits in some areas of the Erie Basin (Szabo, 1992). The earliest late-Wisconsinan pro-glacial lake in the Erie Basin formed about 14,000 yr BP as the Erie and Huron lobes of the Laurentide ice sheet retreated northward and eastward out of the basin (Calkin and Feenstra, 1985). Pro-glacial lakes continued to occupy the Erie basin until about 12,400 yr BP. Each lake had a level directly tied to the elevation of the lowest outlet that was ice free at the time (Fig.2).

The postglacial lake stages began with Early Lake Erie which formed about 12,400 yr BP after the lake outlet that drained across the isostatically depressed Niagara Escarpment at Buffalo and into the Lake Ontario Basin had been opened by retreat of the glacial ice (Calkin and Feenstra, 1985). Several post-glacial lake-level recovery curves (Fig. 2) have been published for Lake Erie (Lewis, 1969; Coakley and Lewis, 1985; Barnett, 1985). The curve proposed by Barnett can be summarized by the following sequence of events: 1) The ice dam at Buffalo was breached and Early Lake Erie formed at a level about 35 m below present. 2)

Lake-level rise was rapid during the early part of the isostatic rebound of the Buffalo outlet, but tapered off to a more gradual rate of rise after about 10,000 yr BP. 3) About 4,000 yr BP there was an increase in the rate of rise which resulted in a rise to a level higher than the present lake. 4) A gradual drop to the present lake-level followed the peak at about 2,000 yr BP. Similarly, Coakley and Lewis (1985) show a rapid rise resulting in a higher than present lake level between 5,000 and 3,000 yr BP. The rapid rise and higher levels were presumably due to reestablishment of drainage of the upper lakes through the Erie Basin and the subsequent downcutting of the upper lake outlet, at the southern end of Lake Huron, to its present level.

Early maps of the bedrock surface beneath Lake Erie, based on seismic reflection and fathometer profiles, include Morgan (1964) who mapped the eastern basin and roughly the eastern half of the central basin, Lewis (1966) who mapped the whole lake, Wall (1968) who mapped the central basin, and Hobson and others (1969) who mapped the western basin. Lewis (1966) also mapped the thickness of the glacial and postglacial sediments in the lake. Nearshore seismic reflection surveys along the southern shore (Michigan to New York) were carried out by the U.S. Army Corps of Engineers and reported by Carter and others (1982) and Williams and Meisburger (1982).

METHODS

Approximately 1300 line kilometers of data were collected aboard the Ohio Geological Survey's 15 m research vessel, RV/GS-1, during five cruises conducted from 1991 to 1993. Base maps for this project were the NOAA 1/100,000 navigation sheets. In the field, horizontal position was determined with a LORAN-C navigation system; on the first cruise, September 1991, a PC-based GPS (Trimble)[1] navigation unit was also used. The research vessel averaged a speed of about 8.6 km/hr during profiling. Vertical control was tied to the NOAA water level gauges along the Ohio shore of Lake Erie. All elevations are related to the International Great Lakes Datum (IGLD, 1985).

High-resolution seismic-reflection data were collected using an ORE narrow-band pinger with 10 Kw of power at a frequency of 3.5 kHz (Fig. 3). For deeper penetration a lower frequency boomer system was used; the system included a HUNTEC boomer sled, Geopulse power supply, and an ITT 10-element hydrophone. Bathymetry data was collected with an Odem ECHOTRAC digital precision depth recorder. Depths below bottom were calculated assuming a speed of sound of 1500 m/sec (fig. 3). Depths were picked every 5 minutes along each trackline. These values were plotted on the base map to produce structure contour maps of the bedrock surface (Fig. 5) and the top of the late Wisconsinan

---

[1]Trade names in this publication are used for descriptive purposes only, and do not constitute endorsement by the U.S. Geological Survey.

deposits (Fig. 6) related to the glaciation of the Lake Erie basin. Derivative maps include isopach maps of the glacial deposits and the late Wisconsinan and Holocene lacustrine deposits (Figs. 7-8).

Interpretations as to the age and nature of the bottom and subbottom deposits were derived from existing sample data that were on file, in the form of vibratory and piston cores, bore holes, and jetted hole data. In addition bottom sediment descriptions that aided in map preparation were also used (Fig. 1). Figure 3 is a representative seismic line section with a line drawing interpretation showing the sediment units and the associated geologic data. An expanded-stylized sediment section is included in Figure 4 summarizing the units and their general relationships.

RESULTS

Two prominent subbottom seismic reflectors were mappable on the seismic records from the lake. The lowermost reflector is inferred to represent the top of the bedrock consisting of carbonates west of Sandusky and shale east of Sandusky. The upper subbottom reflector is inferred to be the top surface of deposits laid down by the glacial ice or in the various glacial lakes. The lake floor caps the seismic profiles and is a multicharacter surface underlain in various places by bedrock, glacial deposits, and postglacial lacustrine deposits. The reflector atop bedrock and the upper subbottom reflector define a seismic unit that represents glacial deposits of late Wisconsinan age.

These deposits consist of till and glaciolacustrine sediments. The glaciolacustrine sediments consist of proglacial laminated silt and clay, which were deposited in close proximity to the retreating glacial front, and a massive clay unit, which was deposited in the more distal reaches of the glacial lake. The lake floor and the upper subbottom reflector define a seismic unit composed of postglacial gravel, sand, and mud.

ELEVATION OF THE BEDROCK SURFACE

Figure 5 shows the elevation of the bedrock surface beneath the Ohio part of Lake Erie. In the western basin, with the exception of a high (170 m) ridge extending about 5 km offshore from Locust Point, and the bedrock high which is exposed on and around West Sister Island (about 20 km east northeast of Cedar Point near Toledo), the bedrock surface rises unevenly from a low of 140 m close to the Michigan-Ohio border to >174 m where it is exposed above the lake surface on the Bass Islands. Two bedrock highs, remnants of two bedrock cuestas, trend northeastward across the International Boundry into Canada. The western high is represented by Catawba Island and the Bass Islands chain and the eastern high is represented by Marblehead and Kelleys and Pelee Islands

East of the islands, in the central basin, the bedrock surface is much smoother, probably reflecting the change in bedrock from the carbonate to shale. The surface dips gradually to the north and east into a valley that extends first northward from Cleveland (about 120 m) and then trends eastward to a low of 80 m north of Fairport Harbor. North and west of Cleveland are several northeastward-trending narrow (2-4 km wide) troughs.

East of Cleveland, the bedrock surface slopes mostly north to northwest from about 160 m (174 m where bedrock is exposed at the shoreline) into the broad trough noted above. Further to the east, north of Conneaut, the bedrock surface does not drop off as rapidly but levels out to form a broad platform at about 100 m. This platform extends to more than 30 km offshore before the bedrock surface drops rapidly away to an elevation of about 70 m. The surface seems to rise again to the northeast indicating a 70 m deep channel but this is also the northeast edge of the study area where data are sparse.

ELEVATION OF THE TOP OF THE GLACIALLY RELATED SEDIMENTS

Figure 6 shows the elevation to the top of the glacially related deposits. In the western basin the uneven bedrock relief has been nearly smoothed by infilling with glacial till and proglacial lake deposits. Relief only ranges from 150 to 174 m above sea level, where the glacial deposits are exposed at the shoreline. The glacial deposits are absent where bedrock is exposed around West Sister Island and on the bedrock ridge north of Locust Point, where the rock is exposed in at least 7 small areas. Glacial deposits are also absent where bedrock is exposed at the surface around all of the Bass Islands and the smaller islands in that chain as well as around Kelleys Island and the islands associated with that cuesta.

Northeast of Kelleys Island there is a small, ridge-like glacial deposit (>160 m) that may be a moraine, as it somewhat resembles a larger, equally high ridge (Pelee-Lorain Moraine) 18 km to the east (south southeast of Pelee Point). Another glacial surface high just east of Cleveland is interpreted to be the southern end of the Erieau Moraine. A third high north of Conneaut is interpreted to be part of the Norfolk Moraine (Sly, 1976). Near the southern end of each of these moraines there seems to be a channel that cuts the ridge. Presumably, these channels were cut through their respective ridges by an eastward flowing river that drained the area to the west during the low stages of Early Lake Erie.

In the central basin, elevations of the glacial surface range from 160 m on the ridges noted above, or 174 m along the southern margin of the basin where it is exposed at the shoreline, to a low of <120 m north of Fairport Harbor. In this low the glacially related sediments appear to be partially infilling the low in the bedrock surface mentioned previously. A broad low valley, bordered on the east by the poorly defined Erieau Moraine (Calkin and Feenstra, 1985) extends north of Cleveland to beyond the International Boundary. This, and a similar feature off Toledo, may be broad channels associated with the present Cuyahoga and Maumee Rivers, which would have been cut during low lake levels prior to the final retreat of the Wisconsinan ice.

For much of the Ohio part of Lake Erie the subbottom reflector atop the glacial deposits is an unconformity. The unconformity represents wave erosion in the nearshore as the lake level rose in response to the isostatic rise of the outlet at Buffalo. Thus it is a time transgressive interface which continues to be cut along the present shore of the lake. In the deepest parts of Lake Erie the top of the glacial deposits represented by the upper subbottom reflector may be a conformable contact between the glacial and postglacial deposits.

THICKNESS OF THE GLACIALLY RELATED SEDIMENTS

Figure 7 is an isopach map that shows the thickness of the glacially related sediments. Generally speaking, the glacially related sediments range in thickness from zero around the islands and along much of Ohio's southern shore of Lake Erie to a maximum of about 60 m in the extreme northeastern part of the map area, north of Conneaut.

Where present in the center of the western basin and near the islands, the unit is relatively thin (<10 m). The thickest part of the unit (20 m) lies in a linear feature oriented northeast close to the Michigan-Ohio border. Although not recognized by previous workers (e.g. Calkin and Feenstra, 1985), this may be a submerged moraine. Its trend is roughly similar to on-land moraines to the west.

In the central basin east of Sandusky two thick (30 m) lobes of sediment extend north and east from the regions of the Huron River (about 16 km east of Cedar Point, Sandusky) and Sandusky River respectively, and are presumably glacial deposits filling old river channels. About 10 km offshore of Lorain there is a single north trending lobe associated with the positive topography of the Pelee-Lorain Moraine extending south from Point Pelee. To the east thickness varies little between 15-20 m until another lobe is encountered extending north from Cleveland. This lobe extends to the International Boundary and is 20-30 m thick. This also appears to be infilling of a broad river channel. This thickened section then extends eastward reaching 40 m in thickness north of Fairport Harbor. Another thick area of sediment extends like a platform northwestward from Conneaut, but it loses its identity about 20 km from shore. The thickest glacial deposits in the study area lie north of Conneaut and vary from 50-60 m in a series of small lobes with long axes oriented northwest. The Conneaut platform and lobes are the result of the till of the Norfolk Moraine infilling of the bedrock valley to the northeast.

THICKNESS OF THE POSTGLACIAL LAKE SEDIMENTS

Figure 8 is an isopach map showing the thickness of the postglacial lake sediments. Post-glacial sediments in most of the area west of Cleveland are thin (<10 m). The area of maximum thickness (30 m) lies north of Fairport Harbor. Recent sediments are sparse to absent on the Pelee-Lorain Moraine. East of Cleveland, the zero isopach extends as far as 10 km offshore before recent sediments begin to cover and thicken into an east-oriented lens culminating north of Fairport Harbor in a circular area with a diameter of about 20 km where the recent sediments reach their maximum thickness of 30 m. The area of thickest glacially related sediments at the northeast edge of the map area is not enhanced by a thick deposit of recent sediments. The thickness of the recent sediments only attain about 20 m north of Ashtabula and Conneaut.

DISCUSSION AND CONCLUSIONS

The bedrock map presented here adds considerable new detail to the previously published maps. The major trends mapped in this report are similar, although not identical, to those shown by Morgan (1964), Lewis (1966), and Wall (1968). The more detailed studies of bedrock in the nearshore such as those of Carter and others (1982), Carter, (1976), Benson (1978), Carter and Guy (1980,1983), Pincus (1960) and the compilation of lake samples by Herdendorf and others (1978) as well as input from B. Stone and G. Shideler (personal Communication) have been incorporated into our nearshore interpretation. This has allowed us to draw more detail in the nearshore area where tracklines were not extended. Buried bedrock valleys in the offshore area along the south shore of Lake Erie are occasionally associated with the location of modern streams entering the lake basin.

The lower seismic unit represents deposits of the late Wisconsinan glaciation in Lake Erie basin. These deposits include basal till and the proximal and distal glaciolacustrine sediments laid down during various proglacial lake stages that were higher than the present water level of Lake Erie. The upper subbottom reflector is mostly a time transgressive wave-cut unconformity that represents the initiation of Early Lake Erie and the general rise in lake level to its present level. The upper seismic unit is composed of postglacial sediments deposited in the deepening lake. In general both sediment units drape the underlying surface thus muting the extremes of the previous topographic relief.

ACKNOWLEDGEMENTS

So many people have provided assistance with the research and preparation of this report that it is not possible to mention them all. We would, however, like specifically to mention the people who were instrumental in the data collection phase of the project. Each cruise included Captain Dale Liebenthal, OGS; and some of the following technical staff members from the U.S. Geological Survey in Woods Hole; Ken Parolski, Dave Nichols, Barry Irwin, and Vee Ann Cross.

REFERENCES

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 Assoc. of Canada, Special Paper #30, p. 185-194.

Benson, J.D., 1978, Lake Erie shore erosion and flooding, Lucas County, Ohio: Ohio Division of Geological Survey, R.I. #107, 99p.

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 Assoc. of Canada, Special Paper #30, p. 149-170.

Carter, C.H., 1976, Lake Erie shore erosion, Lake County, Ohio: setting, processes, and recession rates from 1876 to 1973: Ohio Division of Geological Survey, R.I. #99, 105p.

Carter, C.H., and Guy, D.G., Jr., 1980, Lake Erie shore erosion and flooding, Erie and Sandusky Counties, Ohio: setting, processes, and recession rates from 1876 to 1973: Ohio Division of Geological Survey, R.I. #115, 129p.

Carter, C.H., and Guy, D.G., Jr., 1983, Lake Erie shore erosion, Ashtabula County, Ohio: setting, processes, and recession rates from 1876 to 1973: Ohio Division of Geological Survey, R.I. #122, 106p.

Carter, C.H., Williams, S.J., Fuller, J.A., Meisburger, E.P., 1982, Regional geology of the souther Lake Erie (Ohio) bottom: A seismic reflection and vibracore study: U.S. Army

Corps of Engineers, Coastal Engineering Research Center, MR 82-15, 109p.

Circé, R.C., and Fuller, J.A., in prep., Map Showing Geophysical Tracklines for Reconnaissance Geological framework study in the Ohio waters of Lake Erie:

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 Assoc. of Canada, Special Paper #30, p. 195-212.

Dames and Moore, 1974, Airport feasibility Study - Lake bottom geotechnical and geophysical studies: Dames and Moore consultants, reports 5-1 and 5-23 March, 1974

Fuller, J.A., (in prep), Postglacial depositional environments, sedimentary sequences, and sand resources in the west central portion of the western basin, Lake Erie:

Fuller, J.A., (in prep), Shallow-subbottom deposits at the southern end of the Pelee-Lorain cross-lake moraine, Lake Erie:

Hartley, R.P., 1961a, Bottom sediments in the island area of Lake Erie: Ohio Division of Shore Erosion, Technical Report #9, 22p.

Hartley, R.P., 1961b, Bottom sediments of Central Lake Erie: Ohio Division of Shore Erosion, Technical Report #6, 14p.

Herdendorf, C.E., Gruet, D.B., Slagle, M.A., and Herdendorf, P.B., 1978, Descriptions of sediment samples and cores from the Michigan and Ohio Waters of Lake Erie: CLEAR Technical Report #85, 445p.

Herdendorf, C.E., Braidech, L.L., 1972, Physical characteristics of the reef area of western Lake Erie: Ohio Division of Geological Survey, R.I., #82, 90 p.

Hobson, G.D., Herdendorf, C.E., and Lewis, C.F.M., 1969, High resolution reflection seismic survey in western Lake Erie: Proceedings, 12th Conference, International Association for Great Lakes Research, v. 12, p. 210-224.

Lewis, C.F.M., 1966, Sedimentation studies of unconsolidated deposits in the Lake Erie Basin: Univ. Toronto PhD dissert., 134p.

Lewis, C.F.M., 1969, Late Quaternary history of lake levels in the Huron and Erie basins: 12th Conference, International Association for Great Lakes Research, v. 12, p. 250-270.

Miller, B.B., McCoy, W.D., Wayne, W.J., and Brockman, C.S., 1991, Ages of the Whitewater and Fairhaven tills in southwestern Ohio and southeastern Indiana: in Clark, P.U., and Lea, P.D., eds., The last Interglacial-Glacial Transition in North America: Geological Society of America, Special paper 270, p. 89-98.

Morgan, N.A., 1964, Geophysical studies in Lake Erie by shallow Marine seismic methods: Univ. Toronto PhD dissert., 170p.

Pincus, H.J., 1960, Engineering geology of the Ohio shoreline of Lake Erie: Ohio Division of Shore Erosion, Technical Report #7, 7 sheets.

Sly, P.G., 1976, Lake Erie and its basin: Journal of the Fisheries Research Board of Canada, v.33, (3) p. 355-370.

Szabo, J.P., 1992, Reevaluation of early Winconsinan stratigraphy of Northern Ohio: in Clark, P.U., and Lea, P.D., eds., The last Interglacial-Glacial Transition in North America: Geological Society of America, Special paper 270, p. 99-107.

Wall, R.E., 1968, A subbottom reflection survey of the central basin of Lake Erie: Geol. Soc. America Bull., v. 79, (1) p.91-106.

Williams, S.J., and Meisburger, E.P., 1982, Geological character and mineral resources of south central Lake Erie: U.S. Army Corps of Engineers, Coastal Engineering Research Center, MR 82-9, 62p.

FIGURE CAPTIONS

Figure 1. Bathymetric map of Lake Erie showing tracklines and the location of cores, boreholes, and bottom samples.

Figure 2. Proglacial lake level phases and postglacial lake level recovery curves. Modified from Barnett (1985) (curve 1), Coakley and Lewis (1985) (curve 2), and Lewis (1969) (curve 3).

Figure 3. Pinger and boomer record from offshore of Ashtabula (line 17, cruise number 2) with line interpretation. Core taken at 1420 hour location shows two meters of muddy fine sand over 2 meters of silty bouldery clay (till).

Figure 4. Generalized cross section of units identified in seismic section and cores and borings used for ground truth.

Figure 5. Map showing the elevation of the bedrock surface beneath the Ohio part of Lake Erie.

Figure 6. Map showing the elevation of the top of the glacially related deposits beneath the Ohio part of Lake Erie.

Figure 7. Isopach map showing the thickness of the glacially related deposits beneath the Ohio part of Lake Erie.

Figure 8. Isopach map showing the thickness of the postglacial lake deposits beneath the Ohio part of Lake Erie.

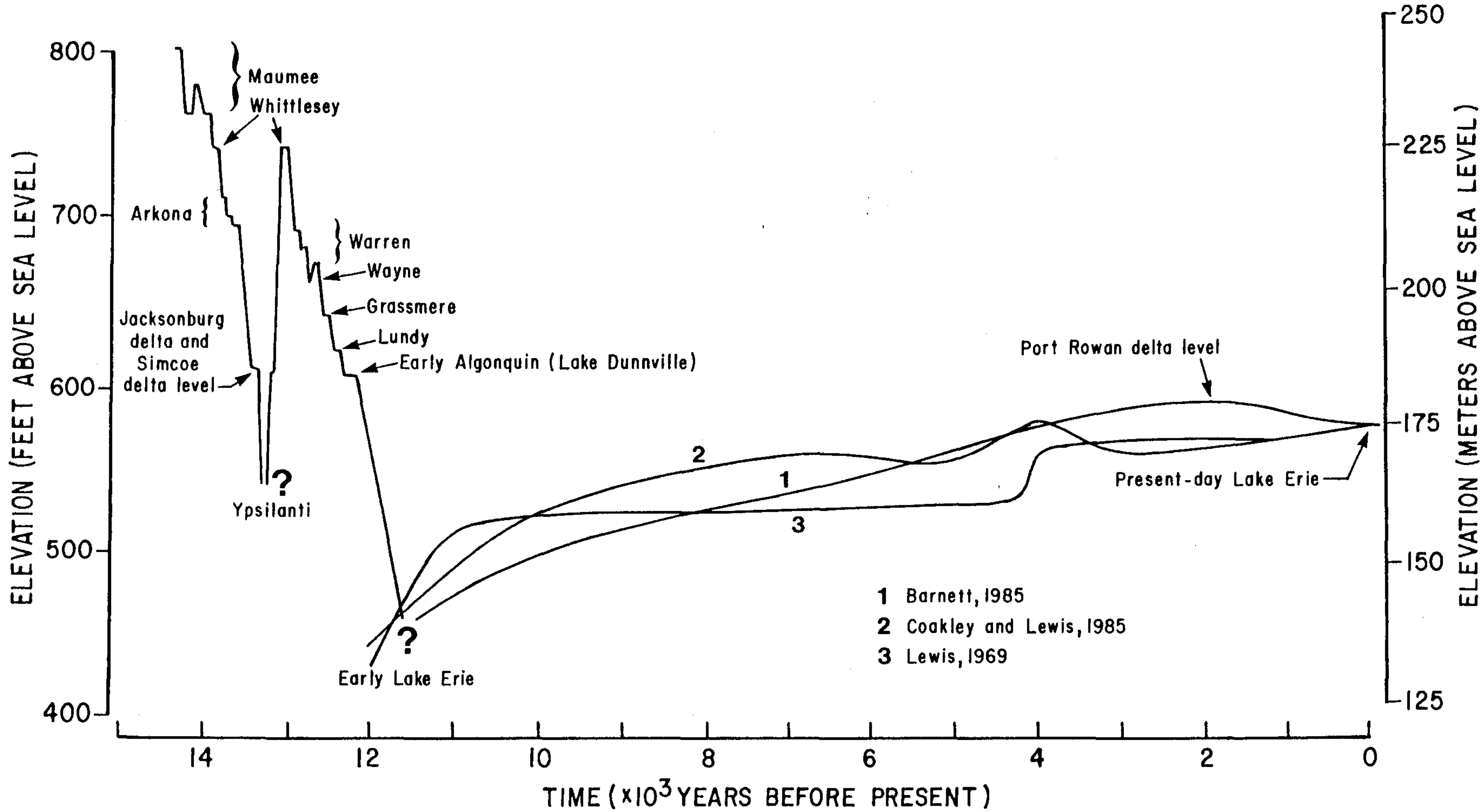


Figure 2. Proglacial lake level phases and postglacial lake level recovery curves. Modified from Barnett (1985) (curve 1), Coakley and Lewis (1985) (curve 2), and Lewis (1969) (curve 3).


CANADA
USA
ONTARIO
MI
LAKE ERIE
FIGURE 3
PA
OHIO
GSI TRACKLINES
KILOMETERS
0 10 20 30 40 50
0 10 20 30 40
STATUTE MILES
N
OHIO DIVISION OF GEOLOGICAL SURVEY
LAKE ERIE COASTAL
EROSION STUDY
TRACKLINE LOCATION MAP

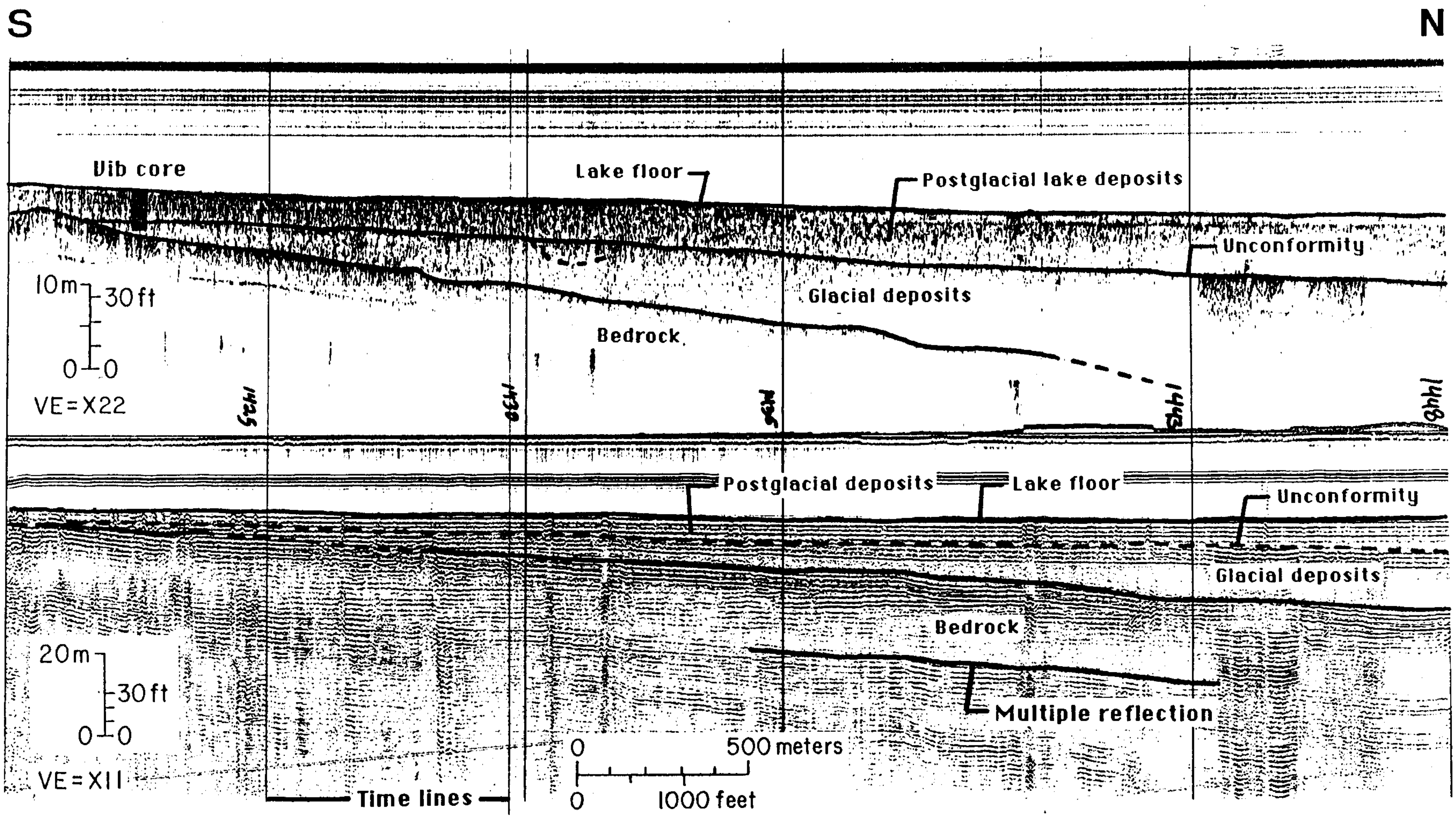


Figure 3. Pinger and boomer record from offshore of Ashtabula (line 17, cruise number 2) with line interpretation. Core taken at 1420 hour location shows two meters of muddy fine sand over 2 meters of silty bouldery clay (till).

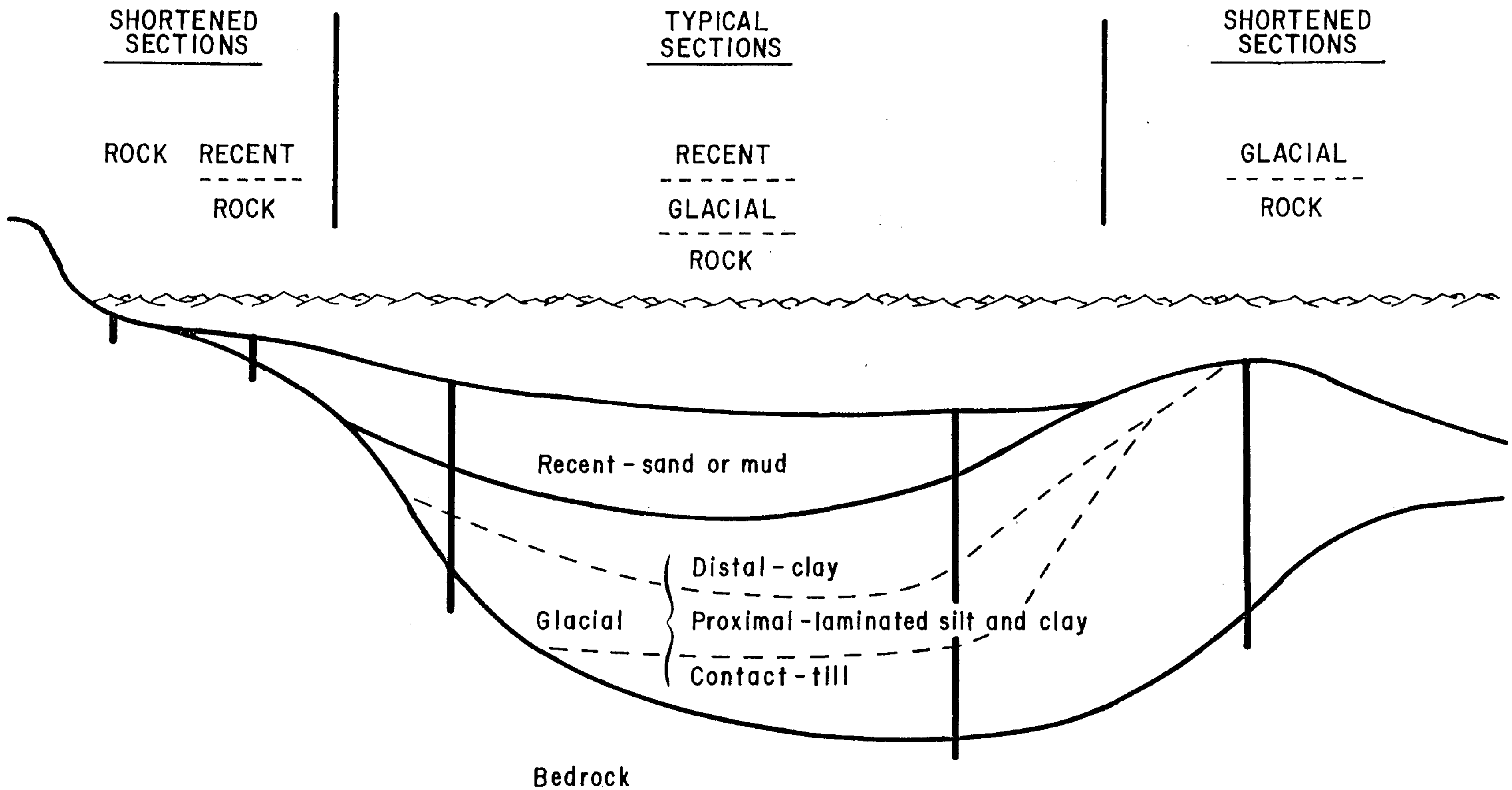
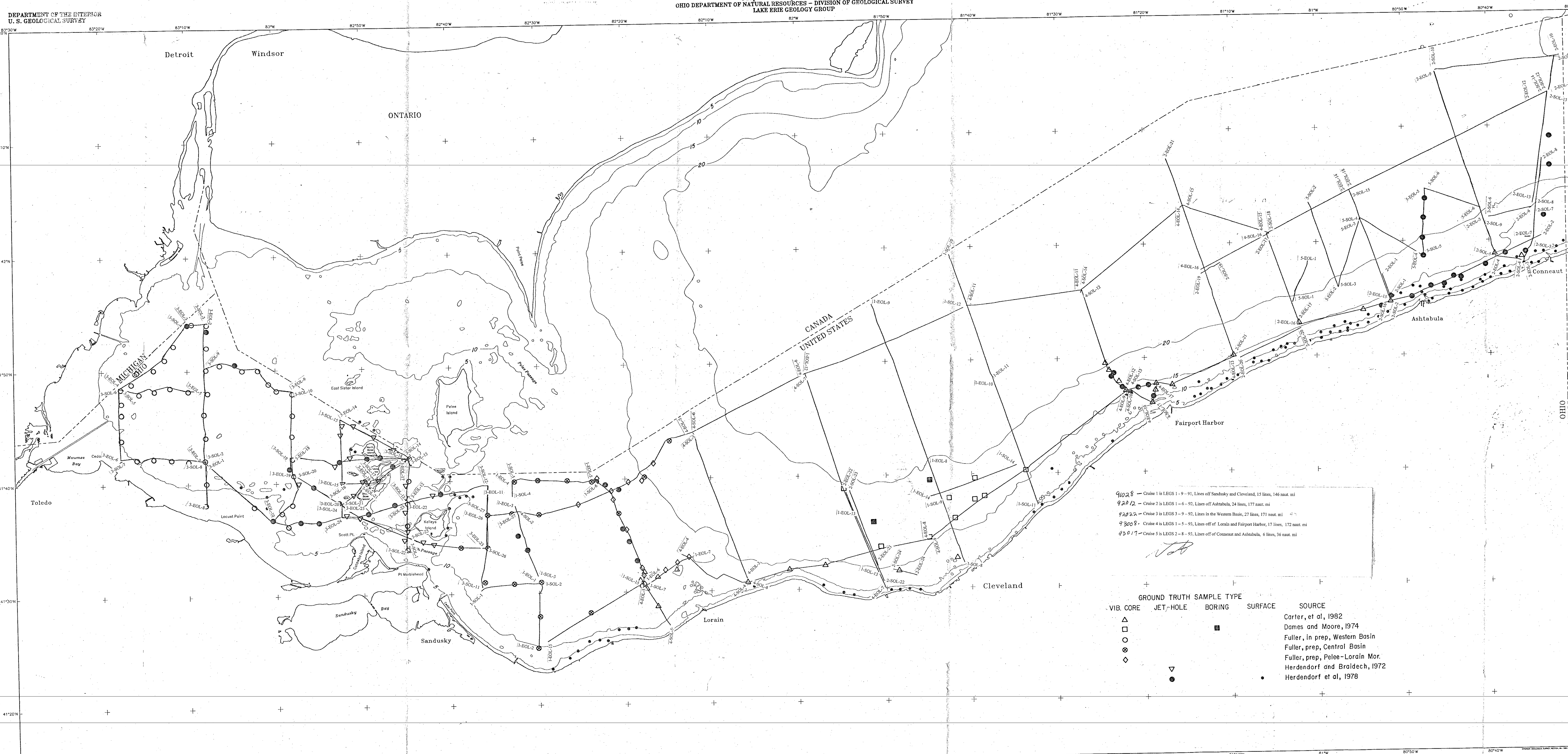


Figure 4. Generalized cross section of units identified in seismic section and cores and borings used for ground truth.

DEPARTMENT OF THE INTERIOR
U. S. GEOLOGICAL SURVEY

Prepared in cooperation with the
OHIO DEPARTMENT OF NATURAL RESOURCES – DIVISION OF GEOLOGICAL SURVEY
LAKE ERIE GEOLOGY GROUP

OPEN–FILE REPORT
95-220
SHEET 1 OF 5



Mercator projection

Latitude of True Scale = 42° N

Coastline and isobaths digitized from National Oceanic and Atmospheric Administration charts 14820, 14828, 14829, and 14830.
Not to be used for Navigation.

SCALE 1:200 000

BATHYMETRIC CONTOUR INTERVAL 5 METERS
INTERNATIONAL GREAT LAKES DATUM OF 1985 (LWD=173.5meters)

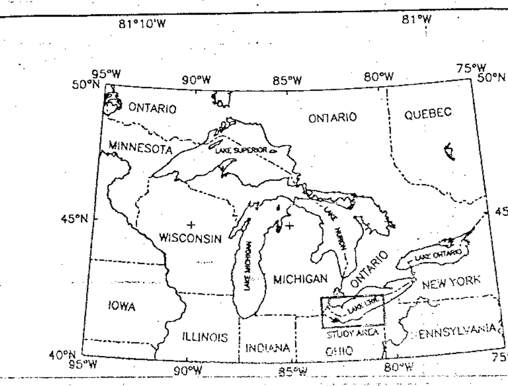


Figure 1. Survey area showing Bathymetry, Trackline, and Groundtruth locations used in interpretation

by
J. Fuller, R. Circé and R. Oldale
1995

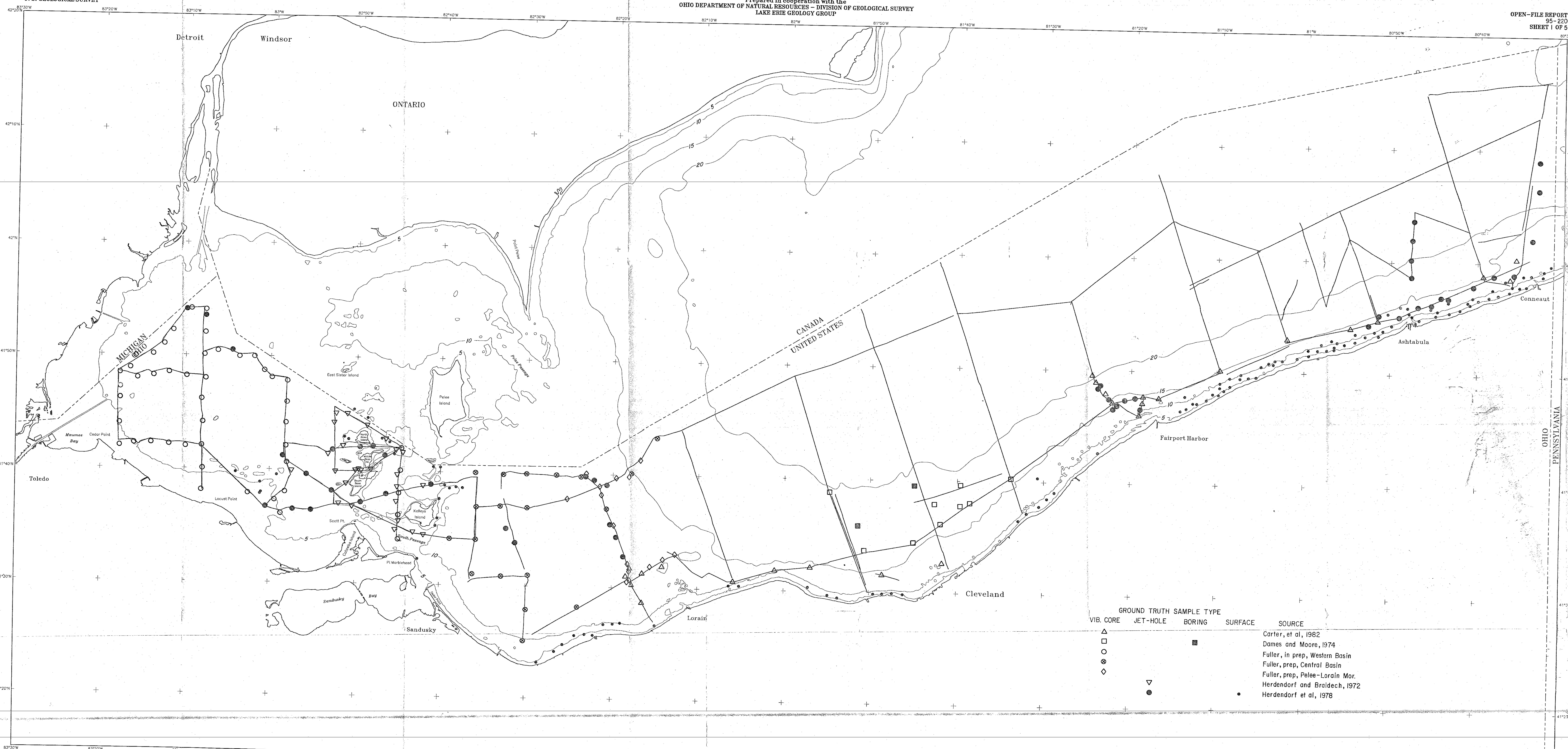
Manuscript approved for publication XXXXX x, 199X

With Line Numbers

DEPARTMENT OF THE INTERIOR
U. S. GEOLOGICAL SURVEY

Prepared in cooperation with the
OHIO DEPARTMENT OF NATURAL RESOURCES – DIVISION OF GEOLOGICAL SURVEY
LAKE ERIE GEOLOGY GROUP

OPEN–FILE REPORT
95-220
SHEET 1 OF 5



Mercator projection

Latitude of True Scale = 42° N

Coastline and isobaths digitized from
National Oceanic and Atmospheric Administration
charts 14820, 14828, 14829, and 14830.
Not to be used for Navigation.

SCALE 1:200 000

BATHYMETRIC CONTOUR INTERVAL 5 METERS
INTERNATIONAL GREAT LAKES DATUM OF 1985 (LWD=173.5meters)

Figure 1. Survey area showing Bathymetry, Trackline, and Groundtruth locations used in interpretation

by

J. Fuller, R. Circé and R. Oldale
1995

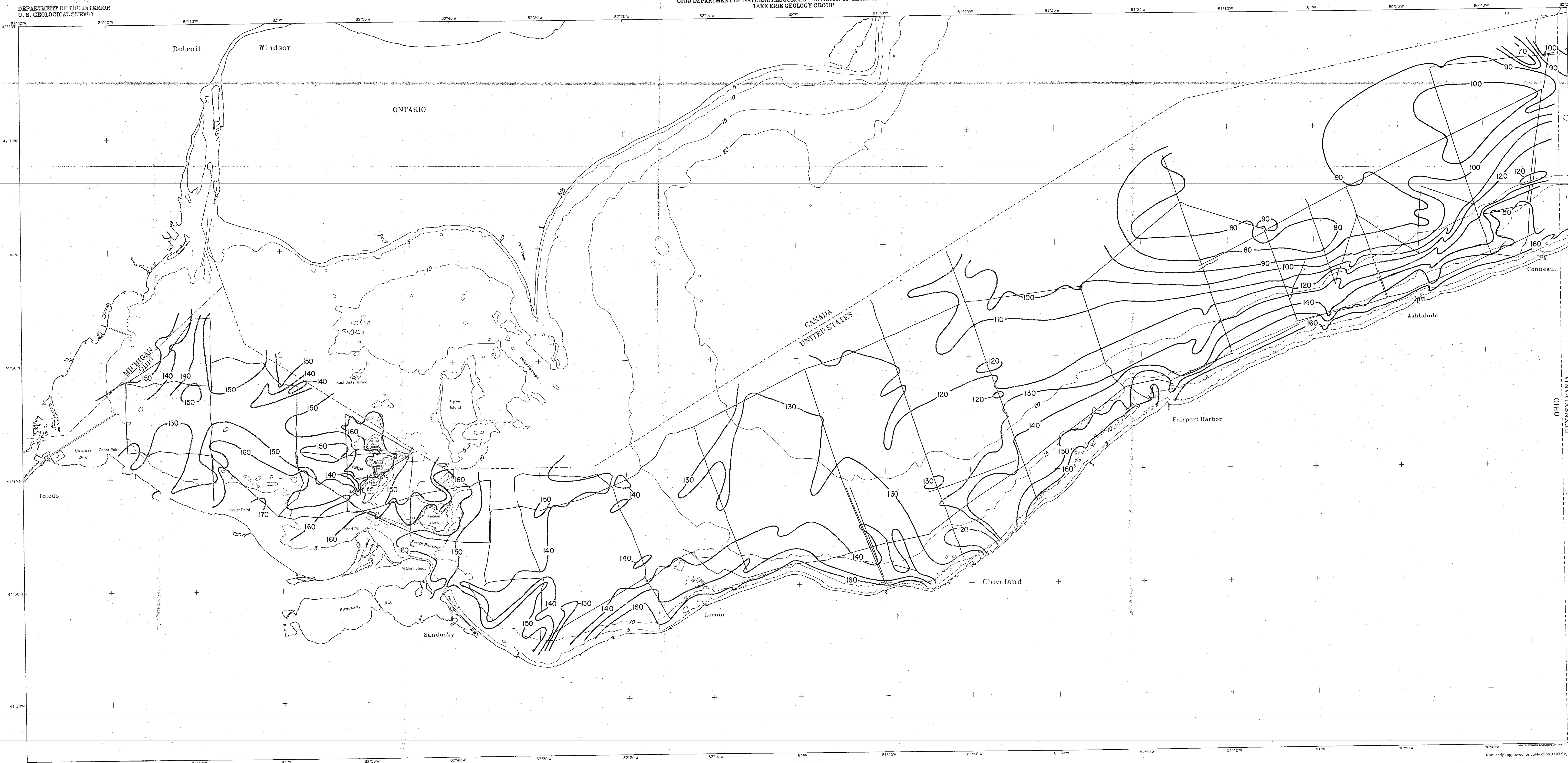
INTERIOR—GEOLOGICAL SURVEY, RESTON, VA—1994

Manuscript approved for publication XXXXX x, 199X

DEPARTMENT OF THE INTERIOR
U. S. GEOLOGICAL SURVEY

Prepared in cooperation with the
OHIO DEPARTMENT OF NATURAL RESOURCES – DIVISION OF GEOLOGICAL SURVEY
LAKE ERIE GEOLOGY GROUP

OPEN–FILE REPORT
95-220
SHEET 2 OF 5



Mercator projection

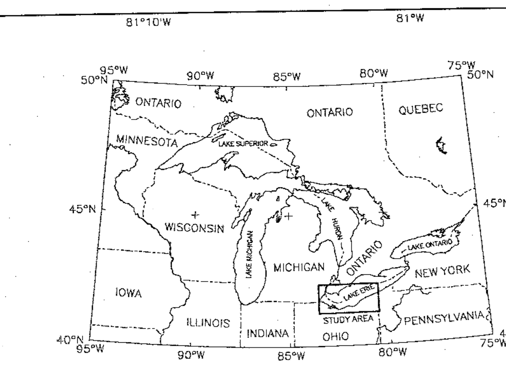
Latitude of True Scale = 42° N

Coastline and isobaths digitized from
National Oceanic and Atmospheric Administration
charts 14820, 14828, 14829, and 14830.
Not to be used for Navigation.

SCALE 1:200 000
0 10 20 30 STATUTE MILES
0 10 20 30 40 50 KILOMETERS

BATHYMETRIC CONTOUR INTERVAL 5 METERS
INTERNATIONAL GREAT LAKES DATUM OF 1985 (LWD=173.5 meters)

Figure 5. Elevation of the Bedrock Surface
CONTOUR INTERVAL 10 METERS
IGLD (1985)
by
J. Fuller, R. Circé and R. Oldale
1995



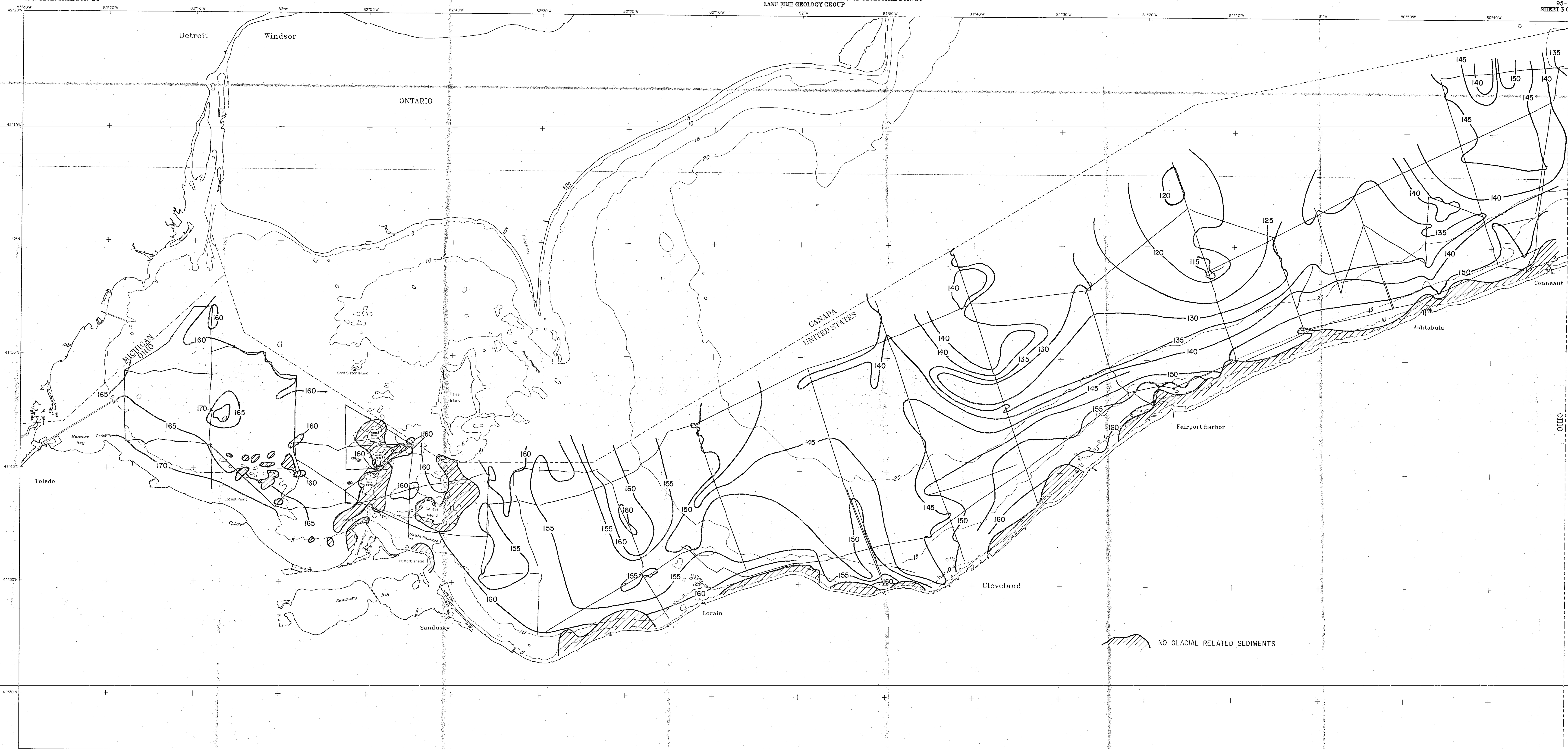
INTERIOR–GEOLOGICAL SURVEY, RESTON, VA–1994

Manuscript approved for publication XXXXX x, 199X

DEPARTMENT OF THE INTERIOR
U. S. GEOLOGICAL SURVEY

Prepared in cooperation with the
OHIO DEPARTMENT OF NATURAL RESOURCES – DIVISION OF GEOLOGICAL SURVEY
LAKE ERIE GEOLOGY GROUP

OPEN-FILE REPORT
95-220
SHEET 3 OF 5



Mercator projection

Latitude of True Scale = 42° N

Coastline and isobaths digitized from
National Oceanic and Atmospheric Administration
charts 14820, 14828, 14829, and 14830.
Not to be used for Navigation.

BATHYMETRIC CONTOUR INTERVAL 5 METERS

Figure 6. Elevation of Glacial Related Surface
CONTOUR INTERVAL 10 METERS
(5 METERS FOR DETAIL)
IGLD 1985
by
J. Fuller, R. Circe and R. Oldale
1995

Manuscript approved for publication XXXXX x, 199X

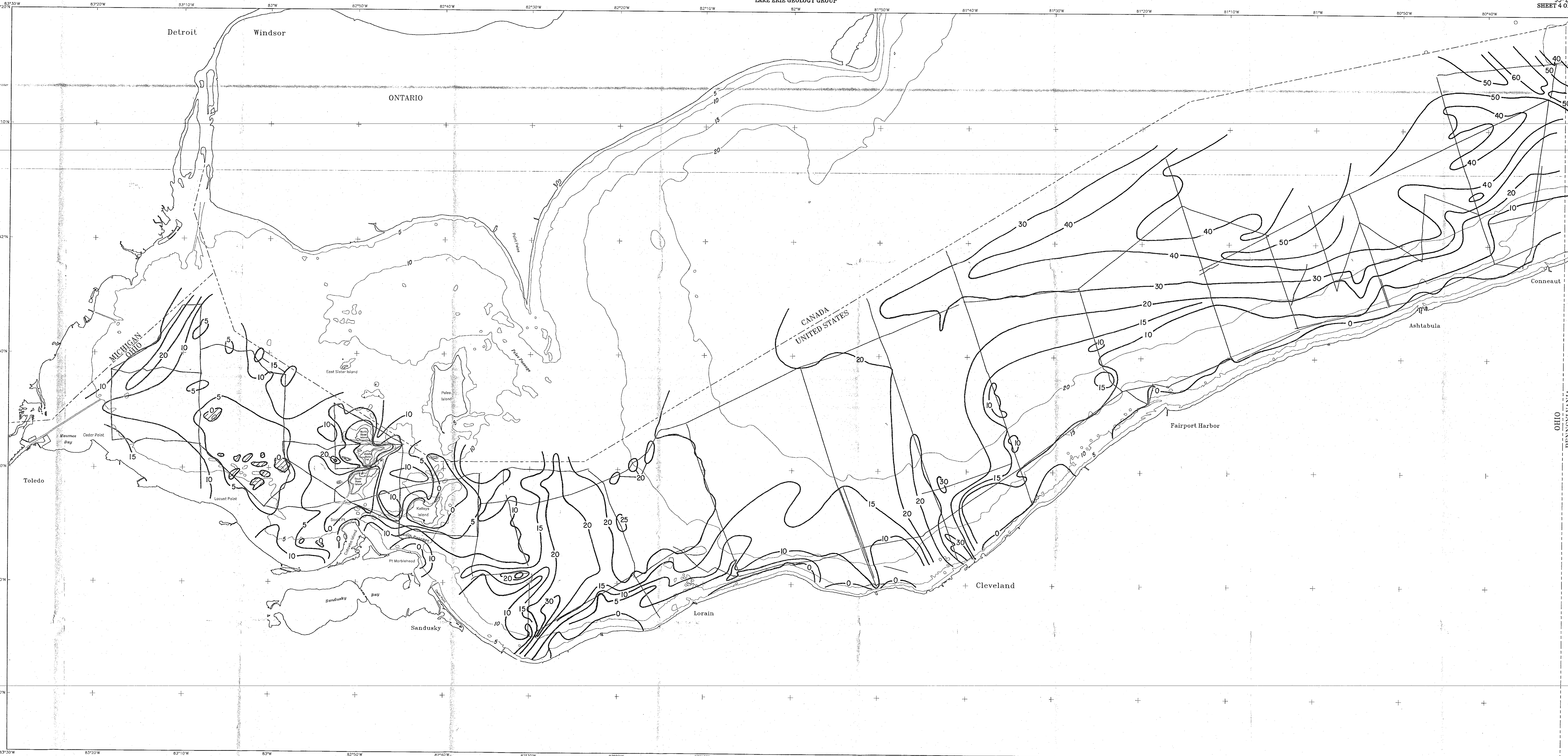
Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government

For sale by U.S. Geological Survey, Map Distribution, Box 25286, Federal Center, Denver, CO 80225

DEPARTMENT OF THE INTERIOR
U. S. GEOLOGICAL SURVEY

Prepared in cooperation with the
OHIO DEPARTMENT OF NATURAL RESOURCES – DIVISION OF GEOLOGICAL SURVEY
LAKE ERIE GEOLOGY GROUP

OPEN-FILE REPORT
95-220
SHEET 4 OF 5



Mercator projection

Latitude of True Scale = 42° N

Coastline and isobaths digitized from
National Oceanic and Atmospheric Administration
charts 14820, 14828, 14829, and 14830.
Not to be used for Navigation.

SCALE 1:200 000

10 0 10 20 30 STATUTE MILES

10 0 10 20 30 40 50 KILOMETERS

BATHYMETRIC CONTOUR INTERVAL 5 METERS
INTERNATIONAL GREAT LAKES DATUM OF 1985 (LWD=173.5 meters)

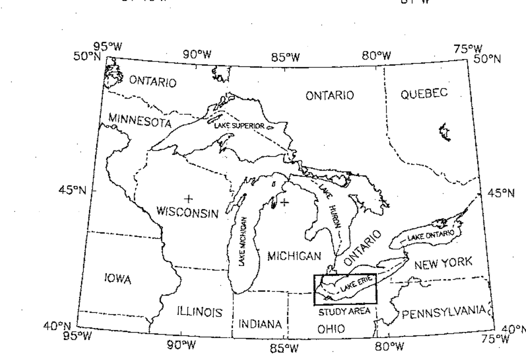
Figure 7. Glacial Related Isopach

CONTOUR INTERVAL 10 METERS
(5 METERS FOR DETAIL)

by

J. Fuller, R. Circé and R. Oldale

1995

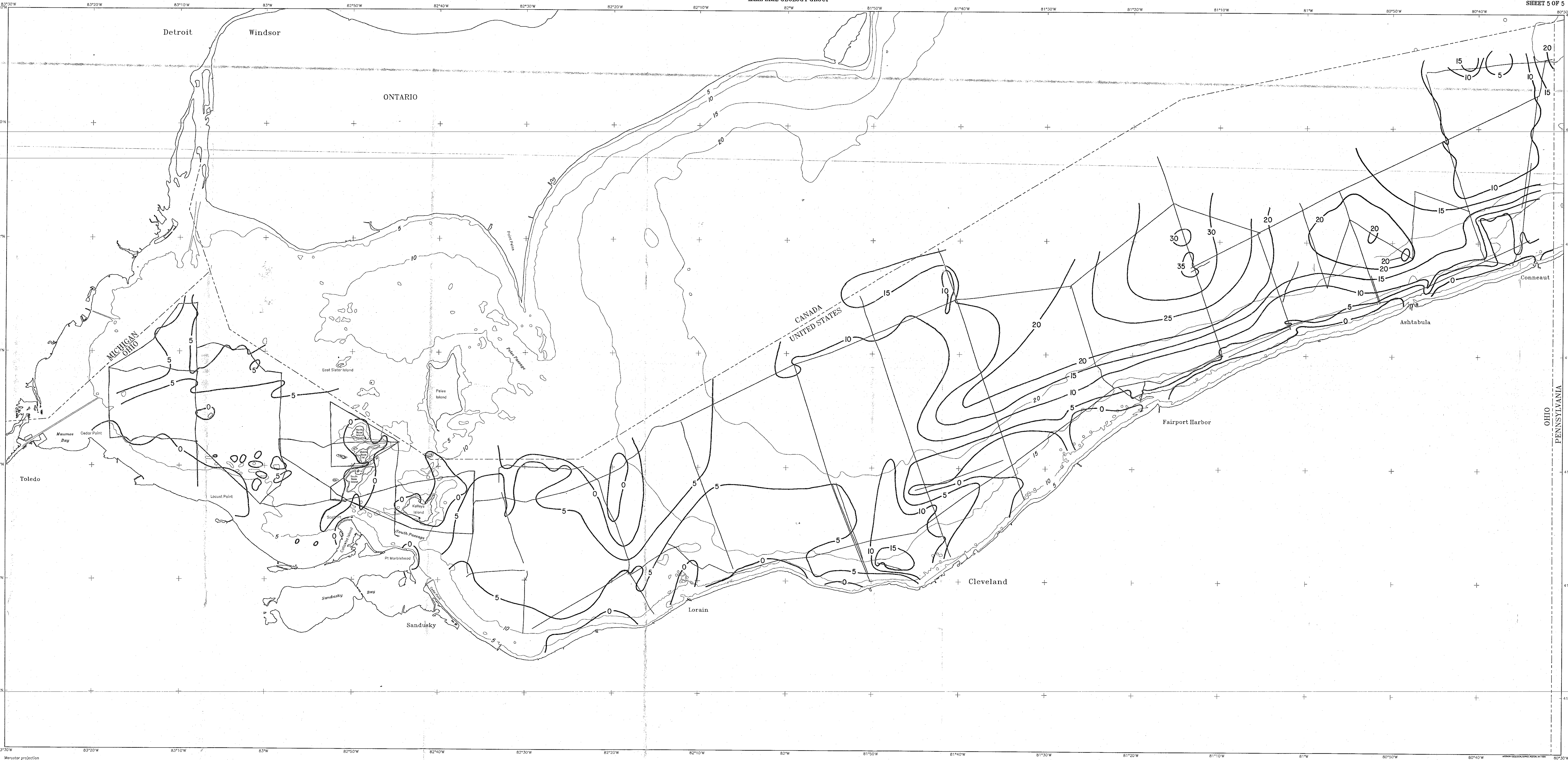


Manuscript approved for publication XXXXX x, 199X

DEPARTMENT OF THE INTERIOR
U. S. GEOLOGICAL SURVEY

Prepared in cooperation with the
OHIO DEPARTMENT OF NATURAL RESOURCES – DIVISION OF GEOLOGICAL SURVEY
LAKE ERIE GEOLOGY GROUP

OPEN–FILE REPORT
95–220
SHEET 5 OF 5



Mercator projection

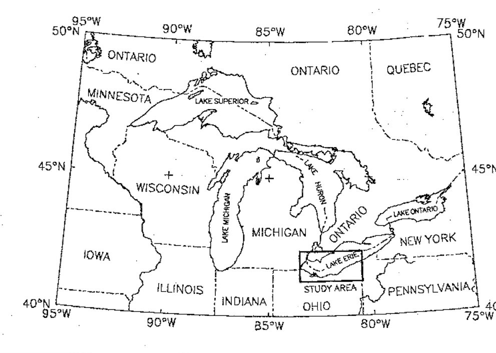
Latitude of True Scale = 42° N

Coastline and isobaths digitized from
National Oceanic and Atmospheric Administration
charts 14820, 14828, 14829, and 14830.
Not to be used for Navigation.

SCALE 1:200 000

BATHYMETRIC CONTOUR INTERVAL 5 METERS
INTERNATIONAL GREAT LAKES DATUM OF 1985 (LWD=173.5 meters)

Figure 8. Isopach of Recent Sediments
CONTOUR INTERVAL 5 METERS
by
J. Fuller, R. Circé and R. Oldale
1995



Manuscript approved for publication XXXXX x, 199X