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SEDIMENTS OF THE SOUTHWESTERN CORNER OF THE CENTRAL BASIN OF LAKE ERIE

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A Cooperative Study of Lake Erie Coastal Erosion by the

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ABSTRACT

The Sandusky subbasin is separated from the remainder of the central basin of Lake Erie by the submerged Pelee-Lorain Moraine. Sediment vibratory cores were collected during 1981 in the southern part of the subbasin. Descriptive core logs, textural data, and distribution maps of the units show that deposits in the shallow nearshore areas and on the crest of the adjacent Pelee-Lorain Moraine are primarily composed of sand, apparently winnowed from the underlying till. In the deeper areas of the subbasin, the glacial unit (made up of till and glacio-lacustrine clay) underlies a unique soft gray mud. The soft gray mud was deposited in the post-glacial lake, as a transgressing unit, during its return to the basin. The level of this lake was controlled by the isostatic rebound of the sill on the Niagara Escarpment. Deposition of the unit continued in the post-glacial lake until the return of the upper-lake drainage through the Erie basin. The return of the upper-lake drainage to the Erie basin partly eroded the soft gray mud, added sand and organics from the eroding shore and deposited a shelly-sandy silt transition sequence. Finally this section of transition sediments was covered by a poorly consolidated fluid mud/silt that continues to accumulate today.

INDEX WORDS: Lake Erie, sediment cores, post-glacial history, central basin

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INTRODUCTION

PURPOSE AND SCOPE

The purpose of this investigation is to utilize information from cores to improve the surficial sediment maps of a portion of Lake Erie and provide data for shallow subsurface sediment maps. These maps will elucidate the post-glacial history of the Erie basin, and will allow evaluation of the area for sand deposits that may be of commercial value. The cores, which were taken in 1981, have since been used to help plan seismic-survey line locations. The offshore seismic-framework program was conducted in the early 1990's (Fuller and others, 1995) as part of the cooperative coastal study of the Ohio Geological Survey and the U.S. Geological Survey.

PHYSICAL SETTING

The study area includes 650 sq. kilometers of the southwest corner of Lake Erie's central basin (figs. 1, 2). Bedrock crops out along the western shore in bluffs as high as 6 meters (Pincus, 1960). The shore from Bay Point to Sawmill Creek (fig. 2) is dominated by a sand–spit barrier–beach complex that has a maximum relief of 4.5 meters (Carter and Guy, 1980). The shoreline from Sawmill Creek to just east of Vermilion is dominated by glacial deposits. Glacial-lacustrine sediments are most common west of Huron, in bluffs no more than 4.5 meters high. Till capped by a glacial-lacustrine unit is most common east of Huron, exposed in bluffs as high as 9 meters (Carter and Guy, 1980).

Bathymetry of the area outlines a small basin that extends northward into Canada and has an outlet at its southeastern corner. The basin is bordered on the south and west by the rise to land, and to the east by the rise onto the submerged Pelee–Lorain Moraine (Thomas and others, 1976; Sly, 1976), although the northeast corner of the study area extends across the crest of the moraine and into the main part of the central basin (fig. 2).

Resio and Vincent (1976) used wind data from around the basin to hindcast wave conditions at fixed locations during storms on Lake Erie and calculated their recurrence frequencies. Their hindcast 5-year deep-water waves (Resio and Vincent, 1976) are predicted to be large enough so that all of the study area is within wave base. Real world measurements of waves and winds from the NOAA weather buoy located 16 kilometers ENE of Kelleys Island (U.S. Department of Commerce) between July 1980 and December 1983, recorded a maximum wave of 3.0 meters and nine other events with waves as high as 2.5 meters. The maximum wind speed was 34 knots (17.0 m/sec) from the south during one of the 2.5 meter wave events. These real wave measurements again point out the susceptibility of the bottom sediments to wave energy, and also indicate that the activity is not limited to storm winds from the lake's greatest fetch.

Geologic Setting

Bedrock in the study area dips gently to the southeast as part of the east flank of the Findlay Arch (Herdendorf and Braidech, 1972). Bedrock along the west edge of the study area is a complex of Lower and Middle Devonian carbonates, whereas the bedrock of most of the area is part of the Upper Devonian Ohio Shale. An unconformity marks the top of the tilted Devonian rocks, with the overlying material being variably Pleistocene or Holocene.

During the Pleistocene Epoch, the area was covered by at least four major ice sheets, each of which was presumably followed by a series of proglacial lakes and subaerial exposure (Forsyth, 1971). The last set of these proglacial lakes began forming when the ice retreated from the Fort Wayne Moraine about 14,000 years BP. These lakes were held at a variety of levels depending on which outlet served as the drain. Abandoned shorelines can be seen perched on the landscape throughout the area as sand ridges. These sand ridges were the beaches, dunes, and offshore sand bars being deposited at the shore of these lakes. Glacial-lacustrine clays were being deposited in the more open water regions of the lakes and were burying the tills that had been previously deposited by the glacier. The proglacial lakes dominated the area until the ice front finally melted back from the Niagara Escarpment about 12,000 years BP. Following the final retreat of the ice from the Erie Basin, the central basin was effectively drained (Sly, 1976). The basin then began to re-flood because of the isostatic rebound of the outlet over the Niagara Escarpment (Lewis, 1969). The rebound caused an increasing sill elevation for the basin and caused a slowly deepening lake to occupy the Basin. Lake level briefly stabilized somewhere below present level (Forsyth, 1973; Lewis, 1969), temporally forming a restricted shallow lake environment. About 4,000 years BP, a rapid rise in lake level effectively set the stage for the environmental systems that are still in existence today. This rapid rise was caused by the full restoration of the runoff from the Upper Great Lakes drainage through the Detroit River (Sly, 1976), and by climate change (Forsyth, 1973).

Previous Work

Surficial sediment information and/or maps of the region were reported by Hartley (1960, 1961a, 1961b), Herdendorf and Braidech (1972), Herdendorf and others (1978), Lewis (1966), Sly and Lewis (1972) and Kemp and others (1977), Pincus (1960), U.S. Army Corps of Engineers (1953a, 1953b), Carter and Guy (1980), Williams and others (1980), and Fuller (1983, 1987, in prep.).

Subbottom sediment information has been provided by Morgan (1964), Lewis (1966), Kemp (1969), Kemp and others (1974), Herdendorf and Braidech (1972), and Fuller (in prep.). Limited seismic reflection coverage of the area was included in work by Morgan (1964), Lewis (1966), Wall (1968), Hobson and others (1969), Williams and others (1980), Carter and others (1982), and Fuller and others (1995).

METHODS

FIELD

A three-minute latitude/longitude grid was used to plan the coring stations (fig. 2). Field positioning and modifications of this grid were made with a Loran–C navigation system (chain 9960, stations Y and Z). The NOAA–NOS navigation chart (No. 14830) for the west end of Lake Erie with the Loran–C overprint was used as a base map.

At each station, a line depth, surface-sediment sample, and sediment core were taken. Sediment cores were retrieved using a 3-meter pneumatic vibratory coring device (Fuller and Meisburger, 1982) which was lowered to the bottom with only a lifting cable and air line connecting it to the vessel. The corer used a 2-inch PVC pipe as a combined core barrel and liner. Vertical control of the field bathymetry was done by relating them to the closest NOAA/NOS water level gauge (Marblehead or Cleveland). All elevations were then reduced to LWD (low water datum), relative to the 1955, IGLD (International Great Lakes Datum). Penetration and recovery of the sediment cores throughout the area were excellent except in the till and laminated glacial deposits. These deposits were firm enough or contained enough large gravel or boulders to stop penetration of the corer after only a short section of that sediment was penetrated.

LABORATORY

Cores were split first by cutting the core tube walls with a circular saw on opposite sides of the core, then a piece of stainless steel wire was drawn through the sediment to part it into longitudinal halves. A short section of the sediment near the top of each core was disturbed or lost due to the coring technique, but the internal structures throughout the remainder of the core were well preserved. A visual description and measurements of the unconfined compressive strength and shear strength were made. Representative samples were taken with a stainless steel spatula, put into beakers, weighed, dried (at < 80°C), and reweighed to determine water content for each of the major sediment units. Generalized logs of the cores, which include the above mentioned measurements as well as additional information, are included in Appendix A. Serial black-and-white photos were also taken of each core.

Fifty-four of the samples that were dried for water content values were later subsampled for size analysis. The Rukavina and Duncan (1970) F.A.S.T. technique for sediment texture analyses was used. This technique begins with a modified pipette analysis (modified from Folk, 1965) to break samples into sand/silt/clay percentages. If the sand fraction accounted for more than 7.5 weight percent (as it did in 19 samples), then that fraction was separated by wet sieving through a 4.5ϕ sieve, and further analyzed in a Visual Accumulation Tube (VAT) (Guy, 1969). The 4.5ϕ sieve is used not because it is a textural boundary, but because "Inclusion of the class below the sand-silt boundary in the settling tube analysis ensures that heavy minerals smaller that the 0.063mm sieve size but with a hydraulic size greater than 0.063mm will be represented. This is necessary if the sand-silt boundaries of both methods are to be compatible." (Rukavina and Duncan, 1970). A summary of the results of the grain-size analyses is included in Appendix B.

SEDIMENT UNIT DESCRIPTIONS AND DISTRIBUTION

SEQUENCE OF DEPOSITS

Till and laminated glacial sediments are the basal unit encountered in the cores, presumably these are directly overlying bedrock, as can be seen onshore. Including these glacial deposits, there are two general sediment sequences in the cores (fig. 3). In the shallower areas, the glacial deposits are covered by sand or sandy sediments. In deeper areas, the glacial deposits are covered by the soft gray mud that is in turn covered by fluid mud/silt. The change, from soft gray mud to fluid mud/silt, is made through a transition unit that commonly includes an admixture of shell fragments, sand, and organic mateial.

TILL AND LAMINATED GLACIAL SEDIMENTS

The lodgement tills (fig. 4) had an average size distribution of 22% sand, 38% silt, and 40% clay. The laminated till (fig. 5) had a similar size distribution (17% sand, 41% silt, and 42% clay) placing them both into the sandy mud field (Folk, 1965). In contrast, the average size distribution of the glacial-lacustrine clay (fig. 6) was 4% sand, 39% silt, and 57% clay placing it into the mud field (fig. 7). Well-defined trends in shear strength or compressive strength were not seen but the water content values (wt. water/wt. wet sample) of the glacial-lacustrine clays consistently averaged higher (24%) than those of the lodgement and laminated tills (both 17%). A structure-contour map of the glacial surface shows that the basin is centered near the center of the study area (fig. 8). The glacial surface was sampled along the east, south, and west sides of the study area, but was not penetrated along most of the north edge where the Sandusky subbasin continues northward out of the study area.

SOFT GRAY MUD

All of the cores which did not bottom in glacial material ended in a soft gray mud (fig. 9), while three of thé cores that did end in glacial sediments passed through a section of soft gray mud (CBC 15, 22, 27). Eighteen grain-size analyses on sediment from this unit were done with the results showing an average of 2% sand, 51% silt and 47% clay (fig. 7). Compressive strength and shear-strength values were both effectively zero and the water content of 48 samples averaged 38% (range, 30% to 45%). A generalized description is a soft, dark-gray (5Y 4/1) mud, with sparse pods or laminae of silt and organic-rich material, commonly containing in situ, articulated, *Sphaerium* bivalves (fig. 9). That these fragile bivalves were still articulated implies that they are in life position. The soft gray mud was found in all of the cores from the central portion of the Sandusky subbasin as well as in two of the four cores from the east flank of the Pelee–Lorain Moraine (fig. 10).

TRANSITION UNIT

The transition unit ranges, when present, up to more than 1.8 meters thick. In 8 cores, the transition from soft gray mud to the overlying fluid mud/silt is represented by an abrupt but subtle color break (5Y 4/1 to 5Y 3/1) (fig. 11). Size analyses from both sides of this color break (core CBC 36) show little change in weight percent sand but a significant increase in silt from the soft gray mud, (% sand/silt/clay, T/50/50), to the fluid mud/silt, (1/71/28). A thin transition section, marked by an admixture of shells and shell fragments (mostly broken *Sphaerium*), can be seen in core CBC 10 (fig. 12). The transition unit becomes more obvious as the percentage of coarser material increases, and as the thickness of the unit increases; for example in CBC 21 (fig. 13) the transition is marked by shell fragments with the addition of some sand and silt. Texturally, the transition unit (fig. 7) is a silt or sandy silt (Folk, 1965). The distribution of the texturally diverse transition unit, as with the soft gray mud, is primarily limited to the central portion of the Sandusky subbasin and to cores from the east flank of the Pelee–Lorain Moraine (fig. 14).

FLUID MUD/SILT

The fluid mud/silt (fig. 10), where present, is the uppermost sediment unit in the cores. On average, it is composed of 6% sand, 67% silt, and 27% clay (fig.

7), is very dark gray (5Y 3/1), and has no measurable shear or compressive strength. Water content averages 41% in 25 samples and ranges from 27% to 56% (wet sample weight). Distribution of the fluid mud/silt is similar to that of the soft gray mud and transition units. It fills in the low spots to mute the relief of the subbasin. It is not present on the crest of the Pelee–Lorain Moraine, but does occur on both of its sides (fig. 15).

SAND

Eight cores have sand at the top. Visual descriptions of these range from coarse to fine sand (see core logs, Appendix A). Textural analyses of sand from three cores on the moraine (CBC 7, 8, 9) ranged from sand/silt/clay percentages of 97/2/1 on top of the moraine to 52/30/18 for a sample from the east flank of the moraine (fig. 7). This represents the textural fields of sand, muddy sand, and silty sand (Folk, 1965). The distribution of offshore surficial sands is limited to near the Pelee–Lorain Moraine (fig. 15) and to a small area near Kelleys Island (CBC 25). The best-sorted and coarsest sands come from the west flank of the moraine.

DEPOSITIONAL HISTORY AND SUMMARY

The till, laminated till, and glacial-lacustrine clays are associated with the minor re-advances and overall retreat of the last Wisconsinan ice sheet (Totten and Pavey, personal comm.). Following the final retreat of the ice from the Niagara Escarpment (about 12,600 years BP) the deep proglacial lakes that had submerged the study area, were drained (Sly, 1976). During subaerial exposure, the area contained small shallow ponds and developed a fluvial system. The river that drained the western basin flowed southward through the Sandusky subbasin and then east into a channel cut through the Pelee–Lorain Moraine near its southern end (Sly, 1976; Williams and others, 1980).

With isostatic rebound, the lake returned to the area by about 10,000 years BP, when the water reached a level of 13.7 meters below LWD (Lewis, 1969; Coakley and Lewis, 1985). At this elevation, most of the study area, except the moraine and the nearshore areas to the south and west, would have been flooded, allowing lacustrine deposition of the soft gray mud. The exact nature of the remaining geologic history depends on which of the lake level rebound curves is used for interpretation (fig. 16).

Using the Lewis (1969) curve, the sequence of events begins with a slow rebound of about 3 meters over the next 5,500 years. This allowed time for shallow lake environments to become established. The till at the surface of the moraine was eroded, winnowed of fines, and a sand beach formed. The lake with its associated beach environments, slowly transgressed up and across the moraine crest (Fuller, 1984; in prep.). Nearshore silts and sands accumulated around the margin of the partly submerged Sandusky subbasin. The soft gray mud accumulated in the protected subbasin, connecting channel, and central basin east of the moraine. The Lewis (1969) curve suggests that at about 4,500 years BP the water level started a rapid rise of about 7.9 meters. The great influx of water associated with the rapid rise in lake level was most likely the agent responsible for the sediment unit described here as the transitional unit. This unit is made up of material eroded from the subaerially exposed deposits (sands, silts, and organic sediments) and mixed with broken shells winnowed from the upper part of the soft gray mud.

The scenario of events suggested by the Coakley and Lewis (1985) curve (fig. 16) is only slightly different. It suggests that the lake level continued to rise rapidly until about 8,000 years BP reaching a level of about 6.1 meters below LWD. During the rapid rise, glacial sediments were winnowed of fines leaving a sand lag that built a transgressing sand beach. This beach was pushed rapidly up and over the moraine flank. Elsewhere, nearshore silts and sands accumulated at the margin of the subbasin, and the soft gray mud accumulated in the subbasin, in the connecting channel, and in the central basin (east of the moraine). At some point, the crest of the moraine was submerged and the beach was pushed across the moraine's crest. The elevation of the moraine surface continued to be reduced by the planing action of the waves, and the sand continued to be pushed off into deeper water on the west side. This scenario suggests that most of the erosion of the moraine occurred from about 8,000 to 4,500 years BP while the water level remained stable at about 6.1 meters below LWD. During this period the moraine elevation was reduced to about 12.4 meters below LWD. The Coakley and Lewis (1985) curve suggests that at about 4,500 years BP, the water level made a rapid rise of about 9.8 meters and peaked about 4.9 meters above LWD. The peak was followed by a rapid decline to about 3.4 meters below LWD about 2,800 years BP. Again in this scenario, the great influx of water associated with the rapid variation of lake level, is the most likely agent responsible for the variety of sediment sections described here as the transitional unit. Sequences for the Barnett (1985) curve are similar to the others up to this point.

Probable correlative transition units have been noted by other authors. Kemp (1969) reported an upward increase in organic carbon across a horizon 0.3 meters below the sediment surface in a core taken between this study's core locations CBC 28 and 30. Lewis (1969), logged a similar color change 1.6 meters below the surface of a core from 32 km NNW of Kelleys Island. He described articulated bivalves in the sediments from below the color change, and described the unit with the color change as containing shell fragments and organic silt. The organic silt, which showed evidence of transport, had a radiocarbon date of 5750 ± 180 years BP (Lewis, 1969) and a pollen age of 5,000 to 4,000 years BP (Coakley and Lewis 1985). Lewis (1969) also correlated this horizon with increased drainage through the Erie basin from the upper-lakes.

Following the rapid changes of lake level that brought the lake to within about 3 meters below LWD, the rate of rise again slowed so there has been only 3.7 meters of rebound in the past 3,600 to 2,800 years (Lewis, 1969; Coakley and Lewis, 1985, respectively). Except for the transgressing shoreline that has followed the 3.7 meter rise, the present depositional environments have effectively been established since the end of the period of rapid lake level changes. These environments include: the high energy nearshore where there is sand, except in areas of rock ledges; a lower-energy fluid mud/silt accumulation near the basin center; and the inactive sand lag of the abandoned beach and nearshore complex on the crest and flanks of the moraine (this area is kept clear of the modern fluid mud/silt deposition by water movement due in part to wave activity). The scenario suggested by the Barnett (1985) curve still has levels decreasing from their high levels, rather than increasing to the present lake level. This would suggest a present regressive shore but would not significantly change the distributions of the modern environments.

The dramatic decrease in abundance of *Sphaerium* above the transition unit suggests that the present environment is not as hospitable for their growth as the environment during the slow rise of the lake level. The darker color of the fluid mud/silt may be caused by an increase in the entrained organic material due to lack of removal by the bivalves.

In summary the structure of the glacial surface clearly defines the subbasin morphology with the Pelee-Lorain Moraine restricting the east side from the remainder of the central basin. After the proglacial lake drained, the reduced water supply created a fluvial environment that drained through the southern end of the moraine with subaerial environments elsewhere. Little evidence of this environment exists in the cores except for a lag of sand and gravel at the surface of the glacial unit in some of the cores. Although information from these cores does not support a specific lake-level recovery curve, it does add support to the general idea of the curves. The distribution and population of *Sphaerium* in the soft gray mud support the interpretation that the unit is a post-glacial lake deposit tied to the return of a lake to the basin. Associated with this was the erosion of the shallower moraine where sand, being winnowed from the till, was pushed up the east side of the moraine and finally over the crest. The abrupt change in the environment, represented by the transition unit, supports the abrupt change in water levels caused by the addition of the upper-lake drainage. Erosion of the suddenly submerged shore deposits, their transport into the basin where they were added to the winnowed shell fragments of the eroded surface of the soft gray mud, was a short-lived environment. When stability of the water levels returned, deposition of the fluid mud/silt took over in the subbasin center. The moraine crest remains free of the fluid mud/silt due to the water movements affecting this slightly shallower area.

SOFT GRAY MUD CONUNDRUM

In this report the soft gray mud is attributed to deposition in the post-glacial shallow lakes ponded by the isostatically rebounding Niagara Escarpment. Whereas in Fuller and others (1995) the soft clay unit, equivalent here to the soft gray mud, with articulated *Sphaerium*, was included in the glacial-related sediment section because it was presumed to be a facies of the laminated glacial-lacustrine clays deposited at the distal end of the icebound lakes. This interpretation was due primarily to the correlation of the upper seismic reflector (Fuller and others, 1995) with the transition unit in some of the cores, as well as the expectation of having a seismic reflector representing the surface exposed subaerially due to the draining of the lake. It was further postulated that any post-glacial sediments, subaerial or shallow lake, which accumulated between the draining of the basin and the re-occupation of the basin by a lake could have been stripped away from the subaerial surface and incorporated into the building of the transition unit when the drainage of the upper-lakes returned to the Lake Erie basin.

Discussions with M. Tevesz (personal comm., 1995) have raised questions regarding this interpretation of the soft gray mud. Work in progress with Dr. Tevesz and others is expected to help resolve the depositional environment of the soft gray mud. The soft gray mud is more likely to have been deposited in the post-glacial, shallow lakes that were ponded by the isostatically rebounding Niagara Escarpment rather than in the ice-dammed proglacial lakes. The lack of exposures of the soft gray mud above the laminated glacial-lacustrine clays throughout western Ohio suggests that they were not as widespread a deposit as would be expected if they were a distal facies of the proglacial lacustrine clays. In addition the identification of the *Sphaerium* as *Sphaerium striatinum* (M. Tevesz, personal comm., 1995), a relatively shallow and warmer-water species, suggests that this is another problem with the cold and deep proglacial lake environment interpretation. The problem that remains with the post-glacial lake interpretation is the perplexing lack of a seismic horizon representing the subaerial surface that was produced by the draining of the proglacial lakes. Reinterpretation of the seismic records may show that the thickness of the "glacial related deposits" needs to be reduced, and the thickness of the "recent deposits" need to be increased from those reported by Fuller and others (1995).

SAND RESOURCES

None of the cores intersected buried sand deposits that can be considered commercial in size. The surficial sand deposits seen in the cores are extremely limited in extent and thickness and most of the sand is associated with the Pelee–Lorain Moraine. A closer-spaced sampling grid across the moraine would more clearly define the surface area and vertical extent of the sand and make revision of Hartley's (1960) volume projections possible. Restricted areas of thicker accumulations of sand should be present if there is the expected northward continuation of the depositional sequences proposed for the southern end of the moraine (Fuller 1984; in prep.). In summary, this sequence of events has sand winnowed from the till forming a beach. The beach increased in size as the water level moved up and over the top of the moraine. This resulted in a relatively thick but narrow deposit of sand stranded in deeper water along the west margin of the moraine and a thinner lag of sand left covering the east flank. If, in fact, there is a continuation of this sequence from the southern end of Pelee–Lorain Moraine, then a thicker sand section would be expected in a narrow band just west of the moraine crest but cores representing the deposit are spaced so widely that an attempt to calculate volumes is not presently practical.

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APPENDIX A

Core Logs

Core # -- Core number, see figure 2 for location
Water depth field -- field measured water depth in feet
Water Depth (LWD) -- Water depth in meters and feet below Low Water Datum (IGLD, 1955)
Loran-C --Y and Z station times for the 9960 Loaran-C navigation chain
Lat/long -- Latitude and longitude of sample station if available
Length -- Core length in feet/decimeters

TV -- Soiltest Torvane shear strength, measured in g/cm^2~tons/ft^2
PEN -- Soiltest Penetrometer compressive strength, measured in kg/cm^2~tons/ft^2
NW -- Water content, weight percent water, of wet sediment sample
Depth -- Distance below top of sediment core measured in decimeters
Lith. Log -- Sediment type in core and inclusions

fluid mud/silt	glacial-lacustrine deposit	Δ gravel
sand		F fossil mollusk
	till/laminated till	
sandy silty clay		O organics
soft gray mud	≈ laminations	W wood

Description -- Notes on sediment type, including texture, color, additional sediment inclusions, and presence of articulated *Sphaerium* shells (Sa)
Size % Sa/Si/Cl -- Dry weight percent sand/silt/clay
Facies type -- General sediment type classification

M – fluid mud/silt   S–C – sandy silty clay (transition unit in text)

S – sand   C – soft gray mud

T & TR – till and till related

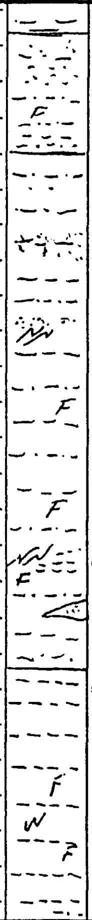
Core # CBC-1
field date 7-22-81
Water depth, field ft
Water depth LWD 12.588 m
41.3 ft
Loran-C
43 676.0 Lat. Deg/min 41/
57 030.9 Long Deg/min 81/
Length
feet 7.6424
dec. m 23.3

TV	PEN	NW wet %	D dm	DISCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0	mud, 5Y3/1		M
		34.0				
0.00	0.0					
			5			
0.00	0.0					
				silty clay, 5y4/1, with silt pods and shells		S-C
0.01	0.0					
			10			
				clay, 5Y4/1, with sparce silt pods, sparce shells		C
0.01	0.0	38.4				
0.00	0.0		15			
				Sa		
0.00	0.0			Ss		
			20			
0.00	0.0					
		41.2				
				Sa		
				Sa		

Core # CBC-2
field date 7-22-81
Water depth, field ft
Water depth LWD 12.588 m
41.3 ft
Loran-C
43 697.6 Lat. Deg/min 41/
57 044.0 Long Deg/min 81/
Length
feet 8.1
dec. m 24.6

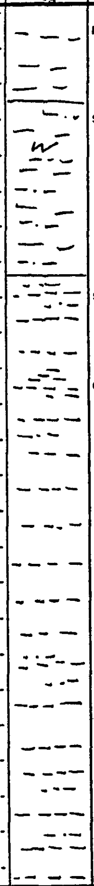
TV	PEN	NW wet %	D dm	DISCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0	mud, 5y3/1, with silt		M
0.08	0.3			muddy sand and sandy mud, 4Y4/1, with shell fragments		S-C
		21.6				
			5	mud, 5y4/1, with minor silt		
				sandy mud, 5Y4/1,		
0.03	0.0			soft clay, 5Y4/1, with sand pods and lamina, and shells		
				sand		
0.02	0.0			soft clay, 5Y4/1, with shells, minor silt, minor organic stains		C
		35.5	10			
0.01	0.0					
				Sa		
0.00	0.0		15			
0.02	0.0					
			20			
0.02	0.0			abundant Sa		
		37.2				
			25			

Core # CBC-3
field date 7-27-81
Water depth, field ft
Water depth LWD 12.588 m, 41.3 ft
Loran-C 43 704.9, 57 069.7
Lat Deg/min 41/
Long Deg/min 81/
Length feet 6.3968, dec. m 25.6



D (dm)	TV	PEN	NW wet %	DISCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
0–1				Mud, 5Y4/1		M
1				sandy mud, 5Y3/1	11/72/17	S-C
2.5			31.2			
3	0.00	0.0				
4.5				sandy silt-clay, 5Y4/1		
6	0.03	0.0				
6.5				sand pods		
9	0.00	0.0		sand lamina		
10				less sand below		
11.5			30.7		3/81/16	
12	0.00	0.0				
15	0.00	0.0		clay lamina		
18	0.06	0.0		soft clay, 5Y4/1, with minor shells and silt		C
21	0.05	0.0				
23			35.9		2/48/50	
24	0.03	0.0				
25						

Core # cbc-4
field date 7-27-81
Water depth, field ft
Water depth LWD 12.893 m, 42.3 ft
Loran-C 43 711.9, 57 095.9
Lat Deg/min 41/
Long Deg/min 81/
Length feet 8.0032, dec. m 24.4



D (dm)	TV	PEN	NW wet %	DISCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
0.5				mud, 5y3/1		M
2.5			34.3			
3	0.00	0.0		slightly sandy mud, 5y4/1		
6	0.00	0.0				
8				silty mud or soft clay, 5y4/1		C
9	0.02					
10.5				clay rich		
11.5			31.5			
12	0.00	0.0				
15	0.00	0.0				
18	0.00	0.0				
21	0.00	0.0				
21.5			30.6			
24	0.02					
25						

Core # cbc-5
field date 7-27-81
Water depth, field ft
Water depth LWD 13.503 m
44.3 ft
Loran-C
'43 718.7
57 122.1
Lat. Deg/min 41/
Long Deg/min 81/
Length
feet 7.38
dec. m 22.5

TV	PEN	NW wet %	D dm	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0	Mud, 5y3/1, with sparse silt pods		
0.00	0.0	39.1			3/70/29	M
			5			
0.00	0.0			Silty clay, 5y4/1, with sparse silt pods and shells		S-C
				clay, 5y4/1, firmer than above, less silt than abova minor organic staining and shells		
0.00	0.0		10		2/43/55	
0.00	0.0	40 9				
				Sa		
0.00	0.0		15			
0.00	0.0			Sa		C
		42.8	20		T/31/69	
0.00	0.0					
				Sa		

Core # cbc-6
field date 7-27-81
Water depth, field ft
Water depth LWD 14.112 m
46.3 ft
Loran-C
43 725.8
57 147.5
Lat. Deg/min 41/
Long Deg/min 81/
Length
feet 8.4296
dec. m 25.7

TV	PEN	NW wet %	D dm	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0	mud, 5y3/1, with minor silt		M
0.00	0.0	46.1				
			5	sandy		
0.01	0.0			clay, 5y4/1, with shells and organic staining		
0.01	0.0		10			
0.00	0.0	37.4				
0.03	0.0		15	Sa		C
0.04	0.0			silty		
0.04	0.0		20	silty		
0.04	0.0	32.9				
0.00	0.0 0.8		25	clay, 10yr3/1, mottled and silty		

Core # cbc-7
field date 7-27-81

Water depth, field ft
Water depth LWD 12.283 m
40.3 ft

Loran-C
43 733.1
57 174.5

Lat. Deg/min 41/
Long Deg/min 81/

Length
feet 4.1
dec. m 12.5

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0		medium sand, color lamina 2.5y3/2 grading to 5y3/2		
					} finer		
0.10	1.6						
			5				S
0.09	1.7	19.5			} finer	97/2/1	
					fine and medium sand interbedded with shells		
0.10	1.7						
			10		} coarser		
					muddy with shells wood minor gravel		
0.60	1.2				till, 10yr4/1, with minor gravel (angular)	20/40/402	T & TR
		17.5					

Core # cbc-8
field date 7-27-81

Water depth, field ft
Water depth LWD 12.893 m
42.3 ft

Loran-C
43 740.5
57 200.9

Lat. Deg/min 41/
Long Deg/min 81/

Length
feet 2.5584
dec. m 7.8

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0		muddy sand, 5y2.5/1		
					fine sand, 5y3/2, laminated with shells		
0.18	2.0	19.0			very fine sand and silt, 5y3/2, with clay breaks and shells		S
			5				
0.32	3.7				silty sand and gravel		
1.05	2.6	18.2			till with gravel, 10yr3/2	20/40/40	T & TR

Core # cbc-9
field date 7-27-81

Water depth, field ft
Water depth LWD 14.722 m
48.3 ft

Loran-C
43 747.5
57 226.7

Lat. Deg/min 41/
Long Deg/min 81/

Length
feet 5.8712
dec. m 17.9

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0		muddy sand, 5y3/1		
					} sandier		
		32.3				52/30/18	S
0.00	0.0				muddy sand, 5y3/1, with clay breaks		
			5		very fine sand and silt, 5y3/1		
0.28	0.7						
					silt and clay, 5y3/2, mottled and laminated		
0.27	1.2	22.4			} clay rich	4/75/21	S-C
			10		} clay rich		
					Sa		
0.17	0.2				Sa		
0.13	0.0		15				
					muddy sand and gravel, 5y3/1		S
					laminated till minor gravel, 10yr3/2		T & TR
0.98	2.3	15.5					

Core # cbc-10
field date 7-28-81

Water depth, field ft
Water depth LWD 13.594 m
44.6 ft

Loran-C
43 682.7
57 123.7

Lat. Deg/min 41/
Long Deg/min 81/

Length
feet 7.1176
dec. m 21.7

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0				
					mud, 5y3/1		M
0.00	0.0	45.3					
			5				
					shelley silt clay		S-C
0.00	0.0				soft clay, 5y4/1, with minor organics and shells		
					silty		
0.01	0.0						
			10				
		37.2			Sa		C
0.00	0.0						
					Sa		
0.00	0.0		15				
0.00	0.0	36.6					
			20				
0.00	0.0						

Core # cbc-11
field date 7-28-81

Water depth, field ft
Water depth LWD 13.381 m
43.9 ft

Loran-C
43 875.3
57 097.0

Lat. Deg/min 41/
Long Deg/min 81/

Length
feet 6.9536
dec. m 21.2

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0		mud, 5y3/1		
0.00	0.0	44.3					
			5				M
0.00	0.0						
0.00	0.0						
			10		soft clay, 5y4/1		
0.00	0.0	41.7					
0.00	0.0		15				C
0.00	0.0						
		40.3	20				
0.00	0.0						

Core # cbc-12
field date 7-28-81

Water depth, field ft
Water depth LWD 13.045 m
42.8 ft

Loran-C
43 668.3 Lat Deg/min 41/
57 071.2 Long Deg/min 81/

Length
feet 9.3808
dec. m 28.6

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0		mud, 5y3/1		M
0.00	0.0	35.7					
			5		soft clay, 5y4/1, with minor shells and organics		C
0.00	0.0						
0.00	0.0		10		Sa		
0.00	0.0				mud, 5y3/1 — top of duplicate section due to coring problem		M
0.00	0.0		15				
0.01	0.0	40.8			clay, 5y4/1		C
0.00	0.0		20		Sa		
0.00	0.0		25				
0.00	0.0	42.8			slightly firmer		
0.05	0.0						

Core # CBC-13
field date 7-30-81

Water depth, field ft
Water depth LWD 13.259 m
43.5 ft

Loran-C
43 711.0 Lat Deg/min 41/
57 162.3 Long Deg/min 81/

Length
feet 1.148
dec. m 3.5

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0		coarse sand and gravel, 10yr2/2		S
0.50	1.2				till, 10yr4/1, with gravel (angular)		T & TR
1.43	4.5	14.1				25/40/35	
			5				

Core # cbc-14
field date 7-30-81

Water depth, field ft
Water depth LWD 18.337 m
53.6 ft

Loran-C
43 770.1 Lat Deg/min 41/
57 239.8 Long Deg/min 81/

Length
feet 4.92
dec. m 15

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0		mud, 5y3/1		M
0.00	0.0						
0.00	0.0	40.3	5				
0.00	0.0				muddy sand, 5y3/1, with shells		S-C
			10		sandy clay with shells		
0.00	0.0				soft clay, 5y3/1		C
0.04	0.0	30.9	15		possible till at base		

Core # CBC-15	Water depth, field ft	Loran-C		Length
field date 7-30-81	Water depth LWD 16.947 m, 55.8 ft	43, 793.1 / 57 251.7	Lat. Deg/min 41/ / Long Deg/min 81/	feet 5.9696 / dec. m 18.2

TV	PEN	NW wet %	D dm	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0-	mud, 5y3/1		M
0.00	0.0	27.1			7/63/30	
0.00	0.0		5-			
0.00	0.0			silty clay, 5y4/1, with shells and organics		S-C
			10-	soft clay, 5y4/1, with organics		C
0.00	0.0	41.9			1/48/51	
0.00	0.0	32.1	15-		1/61/38	
0.49	1.2			till, 10yr4/1 over 5y4/1, with minor gravel		T & TR

Core # cbc-16	Water depth, field ft	Loran-C		Length
field date 7-30-81	Water depth LWD 15.697 m, 51.5 ft	43 785.1 / 57 225.3	Lat. Deg/min 41/ / Long Deg/min 81/	feet 8.2 / dec. m 25

TV	PEN	NW wet %	D dm	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0-	mud, 5y3/1		M
				silty clay, 5y4/1, slightly sandy		S-C
0.00	0.0		5-			
0.00	0.0	37.0			8/65/27	
0.00	0.0		10-	sandy mud, 5y3/1, cleaner at base		S
				soft till, 10yr4/1, with gravel		T & TR
0.45	0.7					
0.37	0.7		15-			
0.49	0.8					
0.44	1.0	17.9	20-		21/36/43	
0.50	1.0		25-			

Core # cbc-17
field date 7-30-81

Water depth, field ft
Water depth LWD 15.088 m
49.5 ft

Loran-C
43 762.2 Lat Deg/min 41/
57 212.8 Long Deg/min 81/

Length
feet 2.0008
dec. m 6.1

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0-		muddy sand, 5y3/1, on sandy mud		S
0.00	0.0	31.0					
0.86	1.4				till, 10yr4/1, with gravel		T & TR
			5-				
0.83/0.73	1.5	16.1					

Core # cbc-18
field date 7-30-81

Water depth, field ft
Water depth LWD 13.228 m
43.4 ft

Loran-C
43 756.2 Lat Deg/min 41/
57 187.2 Long Deg/min 81/

Length
feet 3.772
dec. m 11.5

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0-		fine sand		S
					till with gravel		T & TR
0.55	1.1						
			5-				
0.48	1.0	18.3					
0.46	0.9						
			10-				
0.47	0.8						

Core # cbc-19
field date 7-30-81

Water depth, field ft
Water depth LWD 13.167 m
43.2 ft

Loran-C
43 746.4 Lat Deg/min 41/
57 159.8 Long Deg/min 81/

Length
feet 0
dec. m grab samp

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0-		sandy mud over till		T & TR

Core # cbc-20
field date 7-30-81

Water depth, field ft
Water depth LWD 13.137 m
43.1 ft

Loran-C
43 740.4 Lat Deg/min 41/
57 134.3 Long Deg/min 81/

Length
feet 9.184
dec. m 28

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0-		mud, 5y3/1, with minor sand		M
0.00	0.0						
		36.3	5-				
0.00	0.0						
					Sa		
0.00	0.0						
			10-		silty clay with shells and gravel		S-C
0.00	0.0				soft clay, 5y4/1 and 5y3/1, with organics and shells		C
					Sa		
0.00	0.0		15-				
					Sa		
		39.5					
0.00	0.0						
			20-		Sa		
0.00	0.0						
					silty Sa		
0.00	0.0						
			25-				
		38.5					
0.00	0.0				sandy		

Core # CBC-21
field date 7-31-81

Water depth, field ft
Water depth LWD 13.167 m
43.2 ft

Loran-C
43 733.8
57 106.0

Lat Deg/min 41/
Long Deg/min 81/

Length
feet 9.5448
dec. m 29.1

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0				
					mud, 5y3.5/1, with silt and sand		
0.00	0.0						
		32.9				10/70/20	
			5				M
0.00	0.0						
0.00	0.0						
			10			9/62/29	
					sandy shell hash with mud		S-C
0.00	0.0						
					soft clay, 5y4/1, with organic stains		
		38.2				4/51/45	
0.00	0.0		15				
0.00	0.0						
			20				C
0.00	0.0						
0.00	0.0						
			25				
		36.7				1/46/53	
0.00	0.0						

Core # cbc-22
field date 7-31-81

Water depth, field ft
Water depth LWD 12.222 m
40.1 ft

Loran-C
43 725.8
57 082.2

Lat Deg/min 41/
Long Deg/min 81/

Length
feet 4.9528
dec. m 15.1

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0		mud, 5y3/1		M
					silty clay, 5y3.5/1, sandy		
0.00	0.0	30.0				21/63/16	
							S-C
			5				
0.00	0.0						
0.00	0.0						
0.02	0.0				soft clay, 5y4/1, with shells		
		36.1	10			4/52/44	C
0.00	0.0						
					clayey sand with shells		S
	3.4				laminated till, 5y3/3 with 10y3/2 and10yr4/2, with gravel		
		19.4				11/40/49	T & TR
1.00							
			15				

Core # cbc-23
field date 7-31-81

Water depth, field ft
Water depth LWD 11.948 m
39.2 ft

Loran-C 43 719.9 / 57 056.2
Lat Deg/min 41/
Long Deg/min 81/

Length feet 8.692
dec. m 26.5

TV	PEN	NW wet %	D dm	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0	mud, 5y2.5/1, with minor sand		M
				silty clay, 5y3/1, sandy		
0.05	0.0					
			5			S-C
0.02	0.0					
				fine sand		
0.02	0.0	28.6				
			10			
				muddy sand with shell hash		S
0.04	0.0			soft clay, 5y4/1, with minor silt		
0.04	0.0		15			
				Sa		
0.01	0.0	33.4				C
			20	Sa		
0.00	0.0					
				Sa		
0.00	0.0			Sa		
				Sa		
			25	Sa		

Core # cbc-24
field date 7-31-81

Water depth, field ft
Water depth LWD 11.704 m
38.4 ft

Loran-C 43 712.5 / 57 030.0
Lat Deg/min 41/
Long Deg/min 81/

Length feet 9.2168
dec. m 28.1

TV	PEN	NW wet %	D dm	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0	sandy silty clay, 5y3/1		
0.00	0.0			5y3.5/1 below		
		31.6	5		33/52/15	
0.00	0.0					
				less sand below		
0.00	0.0					
			10			S-C
0.00	0.0					
		34.9			6/62/32	
0.00	0.0		15			
				sandy with shells Sa		
0.00	0.0					
			20			
0.00	0.0					
0.00	0.0			soft clay, 5y4/1, with organic stains		
			25			
				Sa		
		34.0			10/50/40	C
0.00	0.0			Sa possible lag gravel		

Core # cbc-25   field date 7-31-81

Water depth, field ft; Water depth LWD 12.04 m, 39.5 ft

Loran-C 43 690.6, 57 012.5   Lat. Deg/min 41/   Long Deg/min 81/

Length feet 0.2952, dec. m 0.9

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0		sand, medium with gravel		S
					till, very hard		T & TR

Core # cbc-26   field date 8-7-81

Water depth, field ft; Water depth LWD 12.314 m, 40.4 ft

Loran-C 43 667.0, 57 138.3   Lat. Deg/min 41/   Long Deg/min 81/

Length feet 8.5608, dec. m 28.1

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0		mud, 5y3/1, minor silt pods		
0.00	0.0	42.0				5/53/42	
			5				M
0.00	0.0						
					sandy		
0.00	0.0						
			10	F	sandy mud and clay with shells		S-C
0.00	0.0	36.2			soft clay, 5y4/1, with organic stains	1/56/43	
0.00	0.0		15				
0.00	0.0			F			C
			20				
0.00	0.0			F	Sa		
0.00	0.0	36.0			Sa	5/75/20	
			25		possible lag gravel		

Core # cbc-27   field date 8-7-81

Water depth, field ft; Water depth LWD 13.838 m, 45.4 ft

Loran-C 43 704.1, 57 135.1   Lat. Deg/min 41/   Long Deg/min 81/

Length feet 10.0368, dec. m 30.6

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0		mud, 5y3/1		
0.00	0.0	48.8		F		3/53/44	M
			5	F			
0.05	0.0			F	silty clay, 5y3.5/1, with organics and shells		S-C
0.05	0.1	29.9			soft clay, 5y4/1, with organics	1/57/42	
			10	F	Sa		
0.03	0.0						
0.00	0.0		15				
0.00	0.0	32.5				2/58/40	C
0.00	0.0		20				
0.00	0.0						
			25	F	Sa		
0.02	0.0					4/42/54	
					glacial lacustrine deposit, 5y4/1 and 7.5yr4/2		
0.54	1.3	22.7	30			T/35/65	T & TR

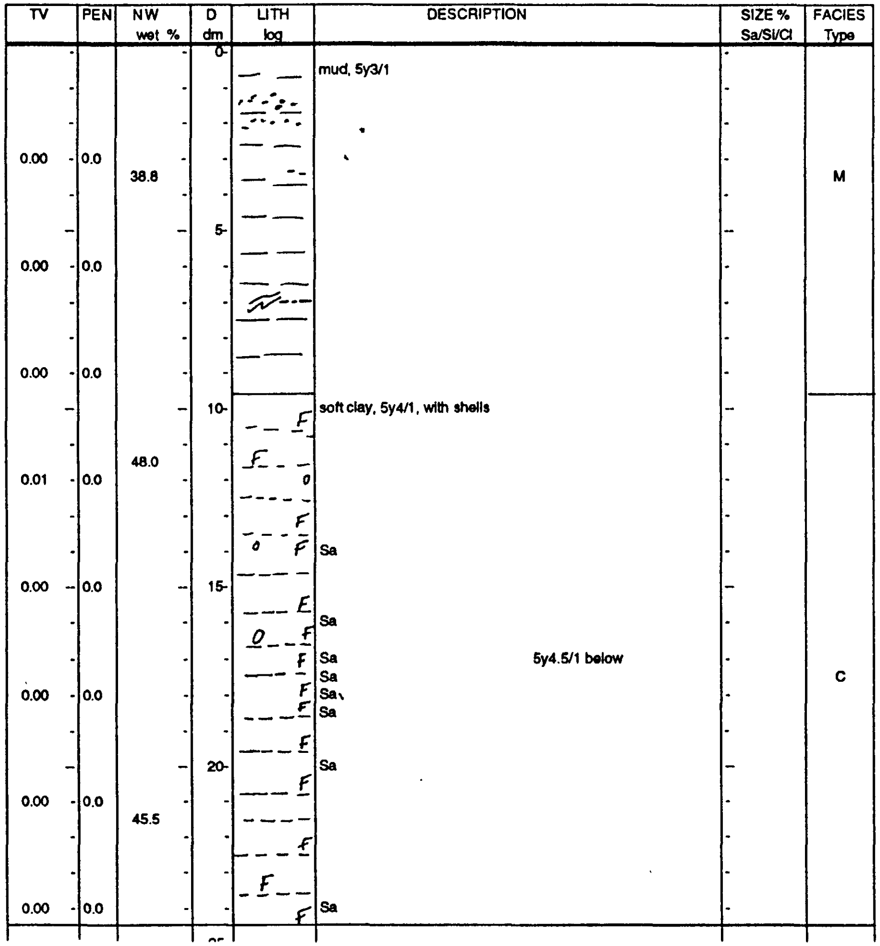
Core # cbc-28
field date 8-7-81

Water depth, field ft
Water depth LWD 13.533 m
44.4 ft

Loran-C
43 697.2
57 109.2

Lat. Deg/min 41/
Long Deg/min 61/

Length
feet 8.036
dec. m 24.5



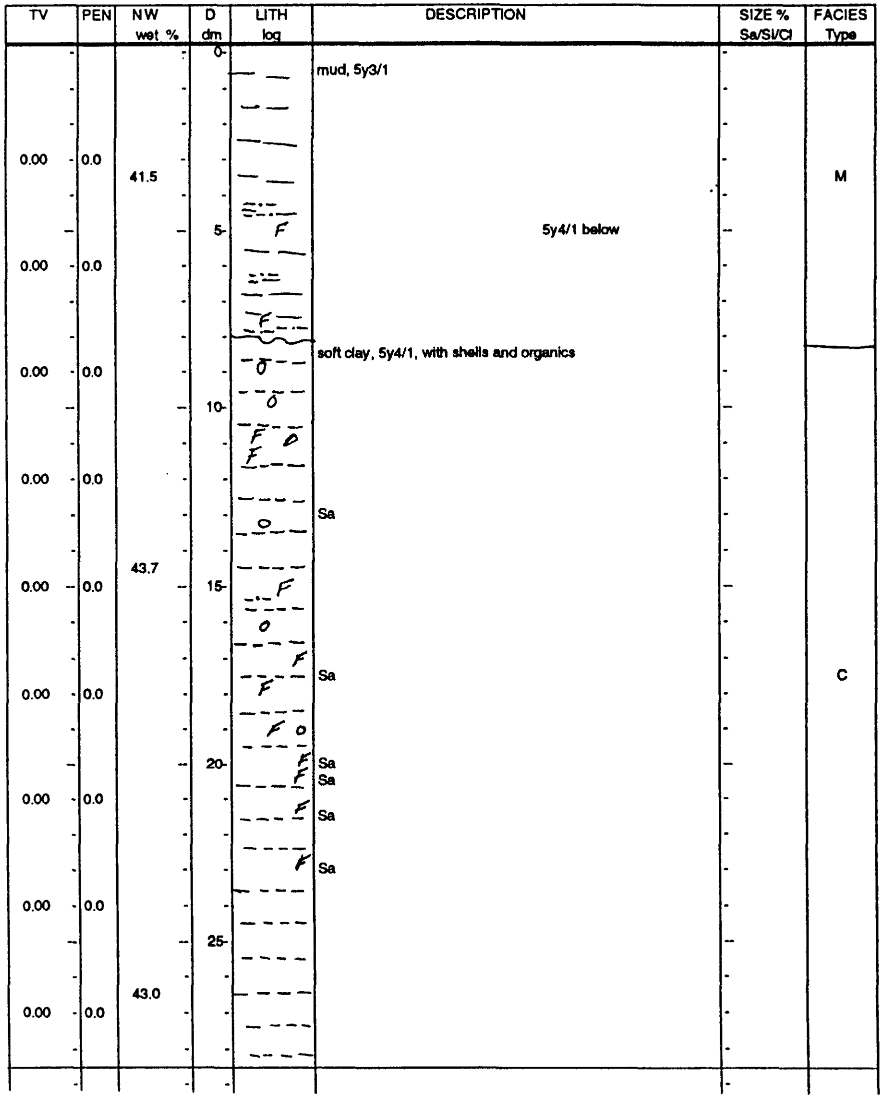
Core # cbc-29
field date 8-7-81

Water depth, field ft
Water depth LWD 12.924 m
42.4 ft

Loran-C
43 660.8
57 044.8

Lat. Deg/min 41/
Long Deg/min 81/

Length
feet 9.3808
dec. m 28.6



Core # cbc-30 field date 8-7-81

Water depth, field — ft; Water depth LWD 12.924 m, 42.4 ft

Loran-C 43 692.8, 57 084.0; Lat. Deg/min 41/; Long Deg/min 81/

Length: feet 9.1512; dec. m 27.9

TV	PEN	NW wet %	D dm	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0	mud, 5y3/1		M
				slightly sandy		
0.00	0.0	39.4		5y3.5/1 below	2/78/20	
			5			
0.00	0.0					
0.00	0.0					
			10			
0.00	0.0			clay, 5y3.5/1, with pods and shell fragremnts		S-C
0.00	0.0	43.1	15	soft clay, 5y4/1	T/48/52	C
0.00	0.0					
			20			
0.00	0.0					
0.00	0.0			Sa		
			25			
0.00	0.0	41.8				

Core # cbc-31 field date 8-7-81

Water depth, field — ft; Water depth LWD 12.314 m, 40.4 ft

Loran-C 43 683.2, 57 055.2; Lat. Deg/min 41/; Long Deg/min 81/

Length: feet 9.184; dec. m 28

TV	PEN	NW wet %	D dm	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0	mud, 5y2.5/1, with minor gravel		M
				silty clay, 5y3/1, with minor sand		S-C
0.00	0.0	34.3			5/79/16	
			5			
0.00	0.0					
0.05	0.0			5y4/1 below		
			10	less silt below		
0.04	0.0					
0.02	0.0	31.6	15		3/74/23	
0.01	0.0					
			20	sandier		
0.00	0.0					
0.00	0.0			Sa		C
			25	soft clay, 5y4/1, with minor organics		
0.00	0.0	40.1		Sa		

Core # cbc-32 Water depth, field ft Loran-C Length
field date 8-7-81 Water depth LWD 12.314 m 43 654.5 Lat. Deg/min 41/ feet 7.9704
40.4 ft 57 017.3 Long Deg/min 81/ dec. m 24.3

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0		mud, 5y3/1, with organic stains near top		M
0.00	0.0	47.4			5y3.5/1 below	7/64/29	
			5		sandier		
0.00	0.0						
0.00	0.0				silty clay, 5y3.5/1, with shells and minor sand		
			10				S-C
					soft clay, 5y3.5/1		
0.00	0.0	37.3			Sa		
					5y3/12 below		C
0.00	0.0		15				
0.00	0.0						
		39.2	20			T/46/54	
0.00	0.0						
					Sa		
0.00	0.0						

Core # cbc-33 Water depth, field ft Loran-C Length
field date 8-7-81 Water depth LWD 11.887 m 43 669.6 Lat. Deg/min 41/ feet 7.7408
39 ft 57 004.9 Long Deg/min 61/ dec. m 23.6

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0		mud, 5y2/1		M
					5y3/1 below		
0.00	0.0	39.1					
			5		sandier		
0.07	0.3				clayey silt and sand, 5y3.5/1		
0.04	0.0	29.0					
			10		more clay below		S-C
0.03	0.0						
					soft clay, 5y4/1, with organic stains		
					Sa		
0.00	0.0		15		Sa		
0.00	0.0						C
		38.9	20		Sa		
0.00	0.0				Sa		
0.01	0.0				o		

Core # cbc-34 Water depth, field ft Loran-C Length
field date 8-26-81 Water depth LWD 10.546 m 43 633.5 Lat Deg/min 41/ feet 7.3472
34.6 ft 57 006.5 Long Deg/min 81/ dec. m 22.4

TV	PEN	NW wet %	D dm	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0	mud, 5y3/1		M
0.00	0.0	42.5		sandier	11/37/16	
			5	silty very fine sand, 5y3/1, faintly laminated		S-C
0.26	2.2					
				silty clay, 5y3/1		
0.16	1.2			very fine sand and silt, 5y3/1, laminated		
			10	mottled silty clay, 5y3/1,		
		33.1		5y3.5/1 below	2/85/13	
0.02	0.0					
0.42	0.7		15	laminated till, 10yr4/2, with angular gravel		T & TR
		16.7			18/39/43	
0.58	1.6					
		15.3	20	flow structures less distinct	26/43/31	
0.70	1.9					

Core # cbc-35 Water depth, field ft Loran-C Length
field date 8-26-81 Water depth LWD 11.765 m 43 639.6 Lat Deg/min 41/ feet 10.0368
38.6 ft 57 032.1 Long Deg/min 61/ dec. m 30.6

TV	PEN	NW wet %	D dm	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0	mud, 5y3/1		M
		55.8		5y2.5/1 below		
0.00	0.0					
			5			
0.00	0.0			silty		
				silty clay, 5y4/1		S-C
0.00	0.0					
			10			
0.00	0.0	35.6				
				soft clay, 5y4/1, mottled with 4y2.5/1		C
0.00	0.0		15	Sa		
0.00	0.0					
			20	Sa		
0.00	0.0			Sa		
0.00	0.0			Sa		
			25			
				Sa		
0.00	0.0	40.4				
0.50	1.5	21.4	30	glacial lacustrine deposit, 5y4/1		T & TR

Core # cbc-36   Water depth, field   ft   Loran-C   Length
field date 8-26-81   Water depth LWD 12.375 m   43 645.6   Lat. Deg/min 41/   feet 9.3808
40.6 ft   57 058.3   Long Deg/min 81/   dec. m 28.6

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0		mud, 5y3.5/1		M
0.00	0.0	42.9				5/76/19	
0.00	0.0		5				
0.00	0.0					1/71/28	
			10				
0.01	0.0	38.4			soft clay, 5y3/1, with organic stain and shells	T/50/50	C
0.00	0.0		15				
					Sa		
0.00	0.0				Sa		
			20		Sa		
0.00	0.0				Sa		
0.00	0.0	40.7	25		Sa	1/41/58	
0.00	0.0				Sa		
					Sa		

Core # cbc-37   Water depth, field   ft   Loran-C   Length
field date 8-26-81   Water depth LWD 12.405 m   43 853.2   Lat. Deg/min 41/   feet 8.6264
40.7 ft   57 084.4   Long Deg/min 81/   dec. m 26.3

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Si/Cl	FACIES Type
			0		mud, 5y4/1, with shells near top		M
0.00	0.0	50.7					
			5		silty below		
0.00	0.0						
0.00	0.0		10				
0.00	0.0						
0.04	0.0	33.9	15		soft clay, 5y4/1 with 5y2.5/1,, with organic stains		C
0.03	0.0						
			20				
0.01	0.0						
0.01	0.0	41.6	25		Sa		
					Sa		

Core # cbc-38
field date 8-26-81

Water depth, field ft
Water depth LWD 12.71 m
41.7 ft

Loran-C
43 659.9 Lat. Deg/min 41/
57 110.0 Long Deg/min 81/

Length
feet 9.02
dec. m 27.5

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Sl/Cl	FACIES Type
			0		mud, 5y4/1		M
0.00	0.0	42.7			siltier		
			5	F Δ			
0.00	0.0						
0.00	0.0				silt lamina		
			10				
0.00	0.0	44.3					
				F W F F	shelly clay, 5y4/1		S-C
0.02	0.0	35.2	15	F O	soft clay, 5y4/1 mottled with 5y2.5/1, with minor organics		C
				F	Sa		
0.04	0.0			F			
				F	Sa		
			20				
0.00	0.0			FF	Sa		
				O F			
0.00	0.0				Sa		
			25	F			
0.00	0.0	37.2					

Core # cbc-39
field date 8-26-81

Water depth, field ft
Water depth LWD 9.9974 m
32.8 ft

Loran-C
43 824.0 Lat. Deg/min 41/
57 044.6 Long Deg/min 81/

Length
feet 8.7904
dec. m 26.8

TV	PEN	NW wet %	D dm	LITH log	DESCRIPTION	SIZE % Sa/Sl/Cl	FACIES Type
			0		mud, 5y2.5/1 and 5y3/1, with organic stain		M
0.00	0.0	41.2			silt clay, 5y4/1, with organics	4/80/16	S-C
			5				
0.00	0.0				siltier		
0.03	0.0						
			10	W			
0.05	0.0	30.7		Δ	siltier	2/69/29	
				Δ F	muddy sand with gravel and shells		
					glacial lacustrine deposit, 10yr4/1		
0.19	0.4		15	Δ	laminated till with glacial lacustrine clay, 10yr4/1		T & TR
0.17	0.2	25.4		Δ		8/43/49	
			20				
0.19	0.5			Δ	clay rich		
					micro laminations		
0.17	0.3						
			25		silt and clay interbeds		
0.20	0.3	25.9				3/41/56	

APPENDIX B

Grain Size Analyses

Core # - Core number, see fig. 2 for location
Int. (cm) - Sample interval in centimeters from top of core
Sa/Si/Cl% - Dry weight percent sand/silt/clay: T = trace
Mdϕ - Median phi of whole sample

Sand analyses

Meϕ (1981) - Phi mean as calculated by a modified version of the Benson textural analysis program
SDϕ - Phi Standard Deviation (Benson, 1981)
Sk - Skewness of sand fraction (Benson, 1981)
Kt - Kurtosis of sand fraction (Benson, 1981)
Mdϕ total - Median phi of sand fraction if sand % is greater than 7.5% of sample

Core #	Int. (cm)	Sa/Si/Cl %	Md ϕ	Me ϕ	SD ϕ	Sand Sk	Kt	Md ϕ
CBC-3	20-30	11/72/17	5.3	5.92	2.23	0.27	2.88	2.8
	110-120	3/81/16	5.8					
	230-240	2/48/50	>8.0					
CBC-5	30-40	3/70/27	6.7					
	100-110	2/43/55	>8.0					
	200-210	T/31/69	>8.0					
CBC-7	60-70	97/02/01	2.4	2.52	0.89	2.23	34.34	2.4
	120-125	18/39/43	7.4	7.07	3.06	-0.64	2.43	2.2
CBC-8	30-40	76/22/02	3.8	3.96	1.01	1.74	22.36	3.7
	66-77	20/40/40	7.0	6.85	3.14	-0.32	2.36	2.1
CBC-9	20-30	52/30/18	3.9	5.39	2.52	0.44	2.39	3.6
	90-100	4/75/21	6.4					
	170-175	22/40/38	7.0	6.71	3.17	-0.24	2.31	2.1
CBC-13	20-25	25/40/35	6.7	6.42	3.30	-0.23	2.10	2.2
CBC-15	30-40	7/63/30	6.6					
	120-130	1/48/51	>8.0					
	150-160	1/61/38	7.5					
CBC-16	55-65	8/65/27	6.1	6.71	2.29	0.14	1.9	3.7
	200-210	21/36/43	7.3	6.84	3.34	-0.37	2.39	1.4
	Int.	Sa/Si/Cl				Sand		

Core #	(cm)	%	Md ϕ	Me ϕ	Sdϕ	Sk	Kt	Md ϕ
CBC-21	30-40	10/70/20	5.5	6.15	2.16	0.36	2.49	3.6
	100-105	9/62/29	6.4	6.85	2.29	0.09	1.84	3.6
	140-150	4/51/45	7.6					
	260-270	1/46/53	>8.0					
CBC-22	30-40	21/63/16	5.0	5.73	2.23	0.40	2.75	3.6
	95-105	4/52/44	7.6					
	135-145	11/40/49	7.9	7.66	2.66	-0.42	2.82	2.7
CBC-24	50-60	33/52/15	4.6	5.41	2.34	0.37	2.87	3.6
	140-150	6/62/32	6.4					
	260-270	10/50/40	7.2	7.34	2.43	-0.10	1.69	3.5
CBC-26	30-40	5/53/42	7.6					
	120-130	1/56/43	7.7					
	230-240	5/75/20	5.9					
CBC-27	30-40	3/53/44	7.6					
	80-90	1/57/42	7.4					
	170-180	2/58/40	7.4					
	260-270	4/42/54	>8.0					
	290-300	T/35/65	>8.0					
CBC-30	30-40	2/78/20	5.7					
	150-160	T/48/52	>8.0					
CBC-31	30-40	5/79/16	5.4					
	140-150	3/74/23	6.0					
CBC-32	30-40	7/64/29	6.4					
	200-210	T/46/54	>8.0					
CBC-34	30-40	11/37/16	5.5	5.90	2.32	0.09	3.03	1.9
	110-120	2/85/13	5.7					
	160-170	18/39/43	7.4	7.11	3.03	-0.37	2.51	2.2
	200-210	26/43/31	6.6	6.18	3.34	-0.23	2.11	1.6
CBC-36	30-40	5/76/19	5.9					
	90-92.5	1/71/28	6.8					
	120-130	T/50/50	8.0					
	240-250	1/41/58	>8.0					
CBC-39	30-40	4/80/16	5.9					
	110-120	2/69/29	6.9					
	170-180	8/43/49	7.9	7.80	2.41	-0.38	2.60	3.1
	255-265	3/41/56	>8.0					

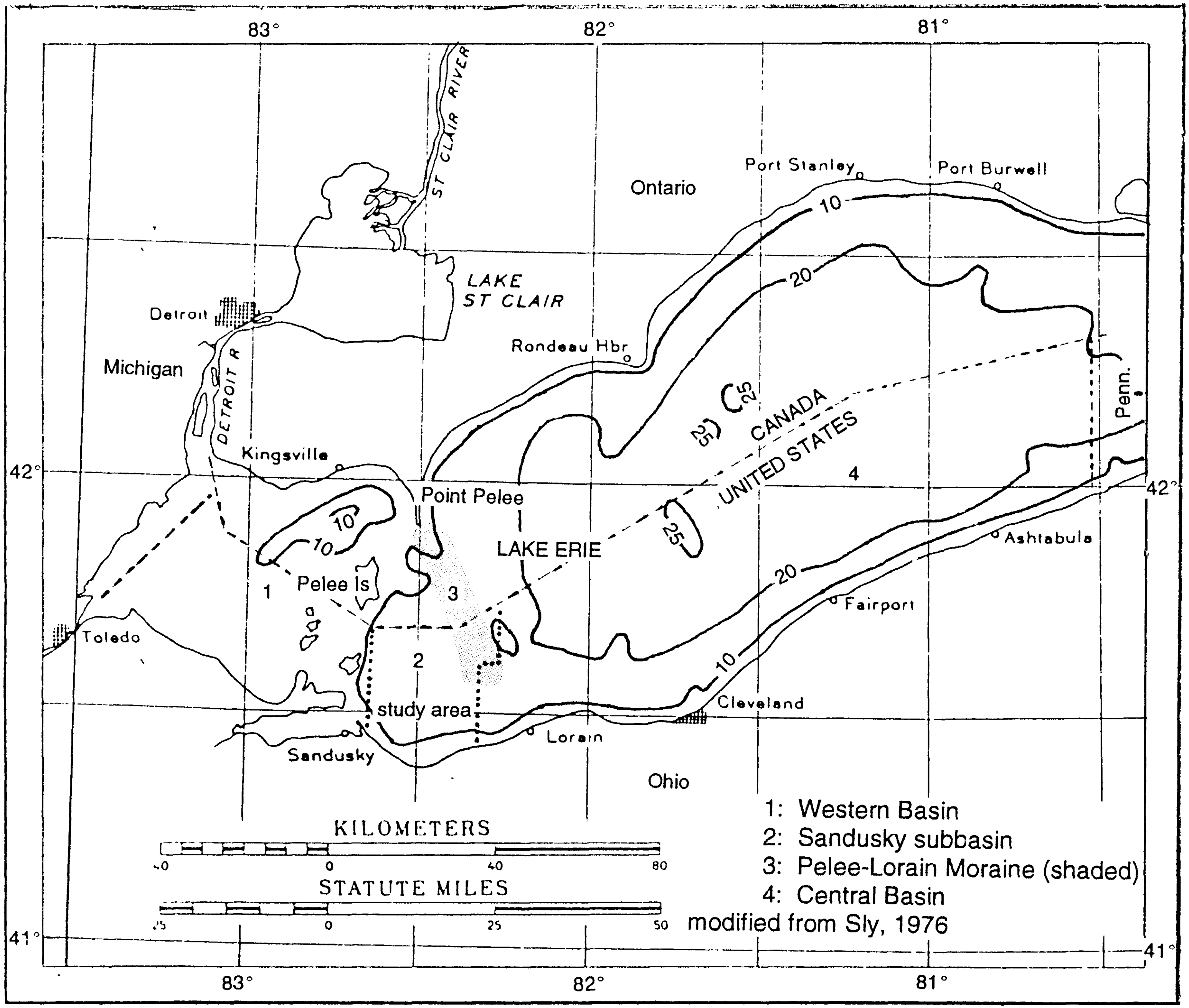


Figure 1. Location map for study area with generalized bathymetry.

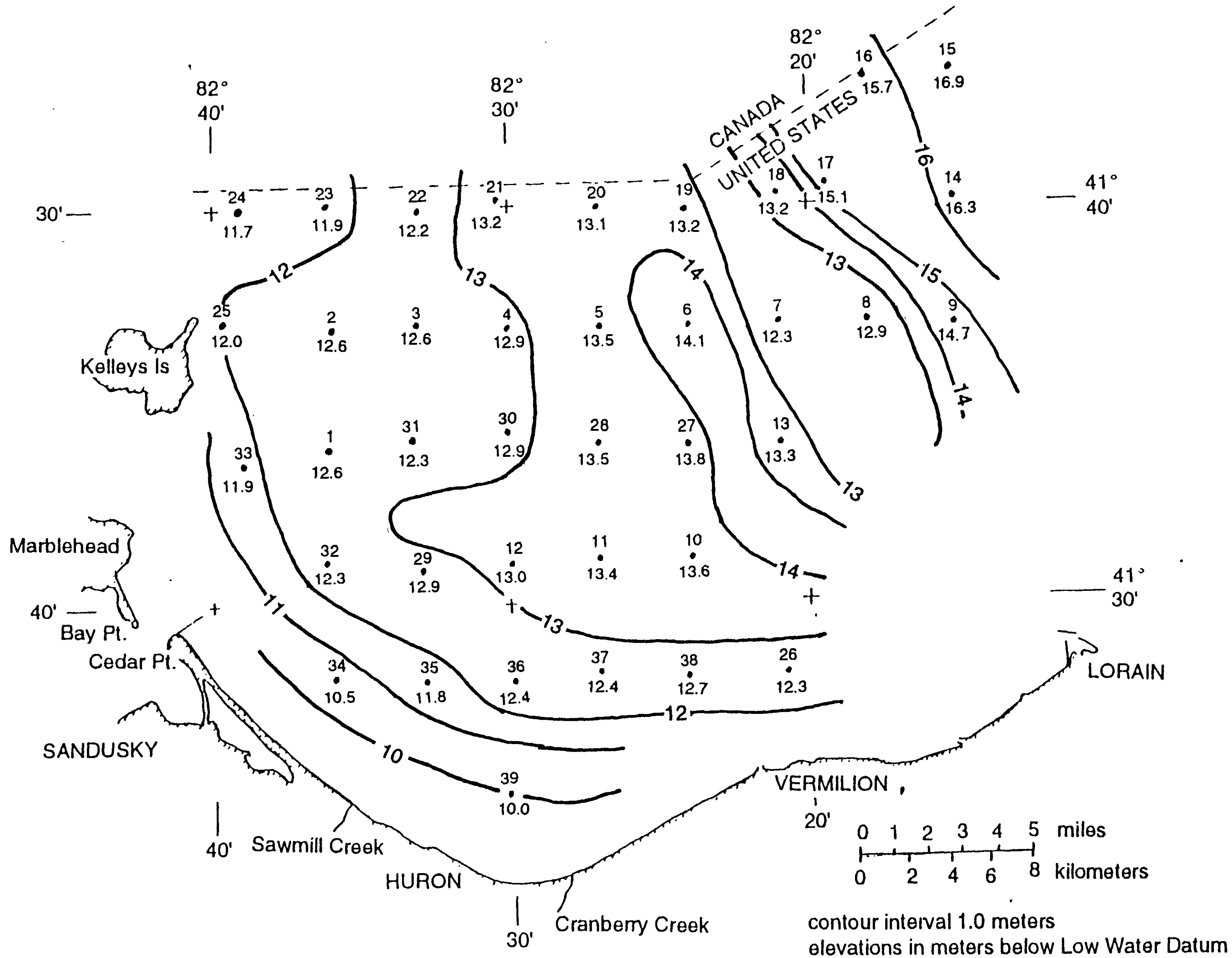


Figure 2. Bathymetry and location of cores in Sandusky subbasin
CBC core number above location dot, water depth below

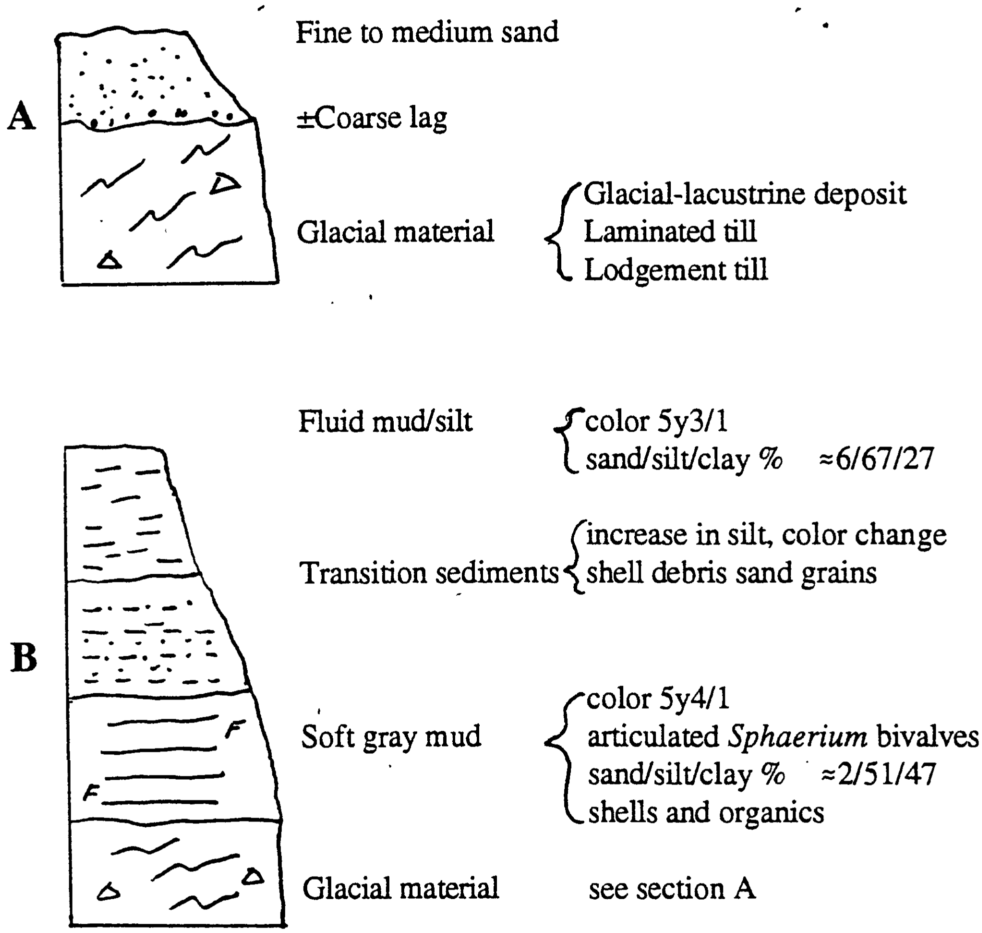


Figure 3. Typical sediment sequences.

A--Typical in shallow near shore areas and on top of the Pelee-Lorain moraine.

B--Typical in the deeper central subbasin areas and east of the moraine in the central basin.

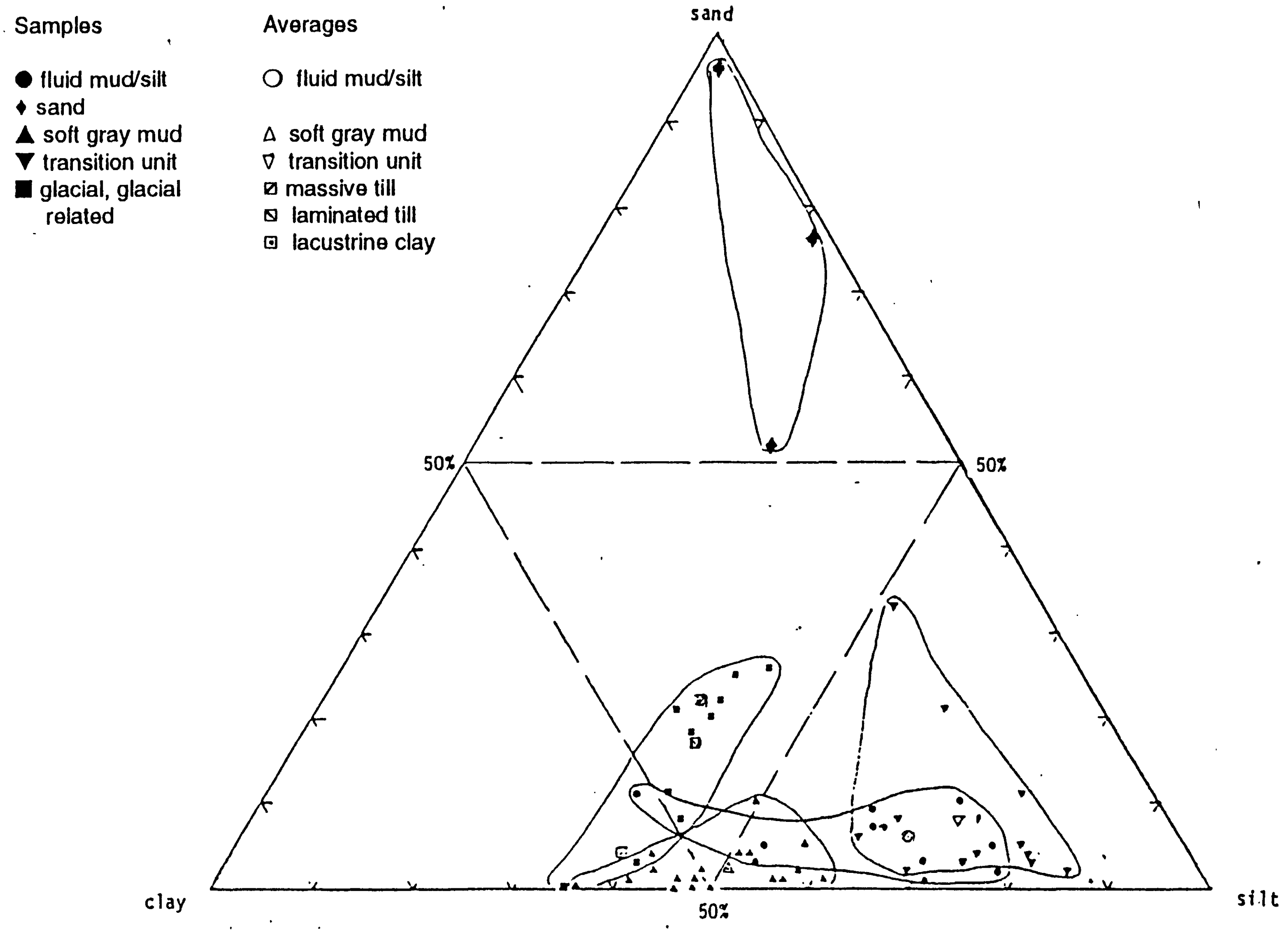


Figure 7. Sand, silt, clay percentages of sediment units from textural analysis. Sediment unit fields are circled with average for the unit also plotted.

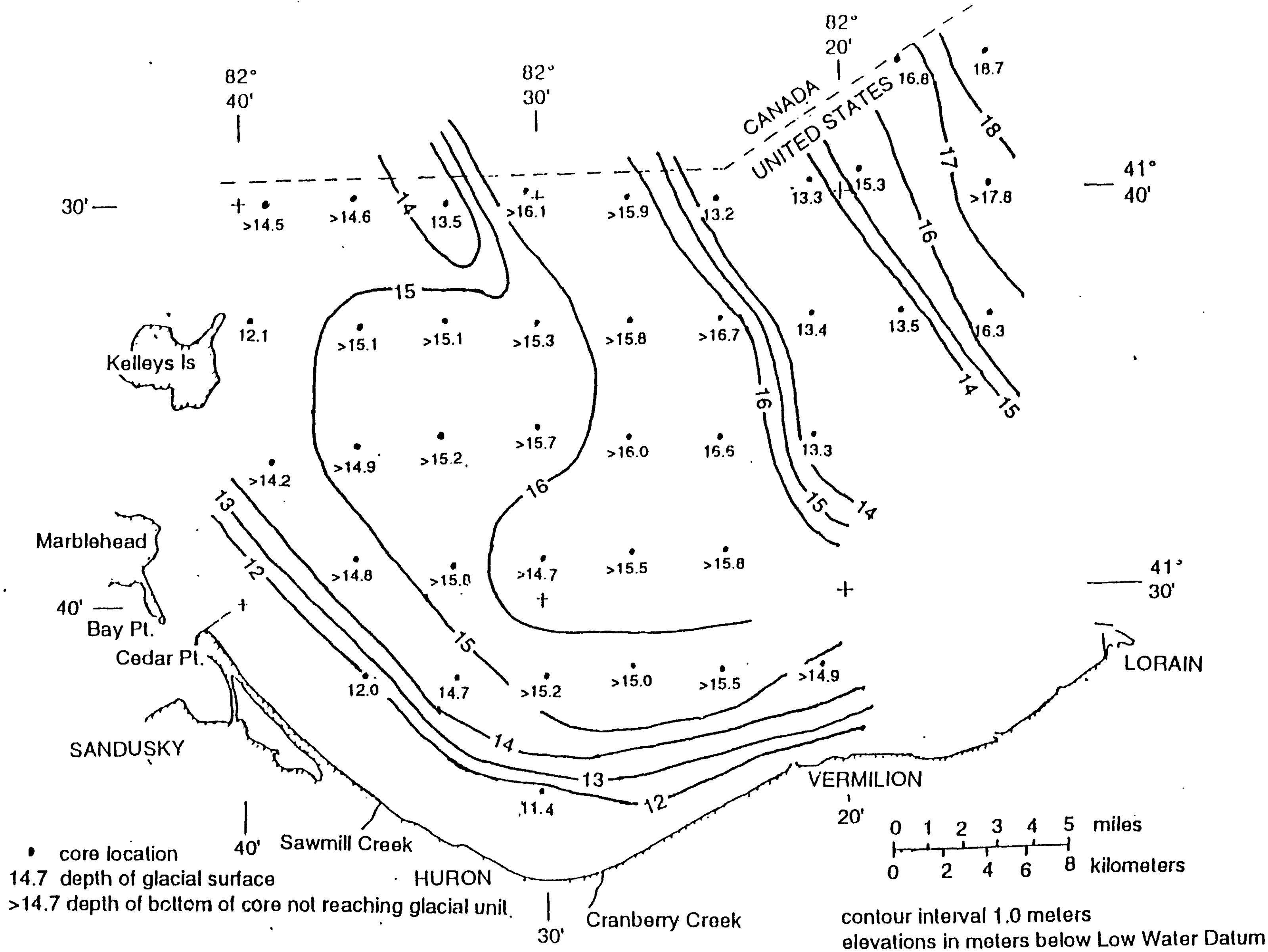


Figure 8. Structure contour of top of glacial unit (till or laminated glacial-lacustrine) showing Sandusky subbasin extending northward from study area and being restricted by islands on the west, the mainland on the south and the Pelee-Lorain moraine on the east. Note that glacial basin could be deeper than mapped here due to the number of cores in the basin that did not reach a glacial unit (> numbers represent the bottom of the core not reaching a glacial unit).

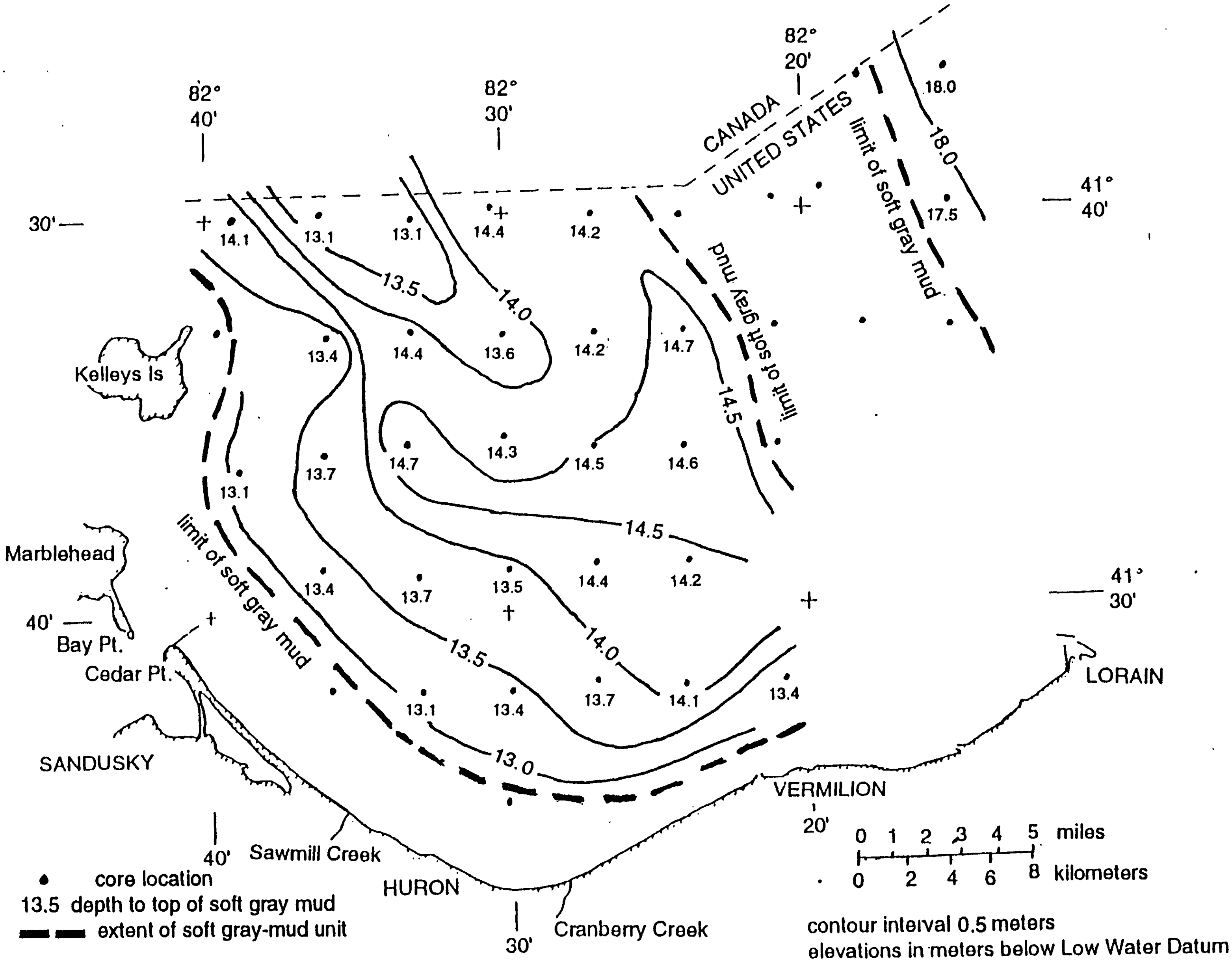


Figure 10. Structure contour on top of the soft gray mud. Unit is missing in the nearshore and on top of the moraine. Post-glacial unit deposited in transgressing lake, filling in the glacial surface. Units includes *in situ* articulated *Sphaerium* bivalves.

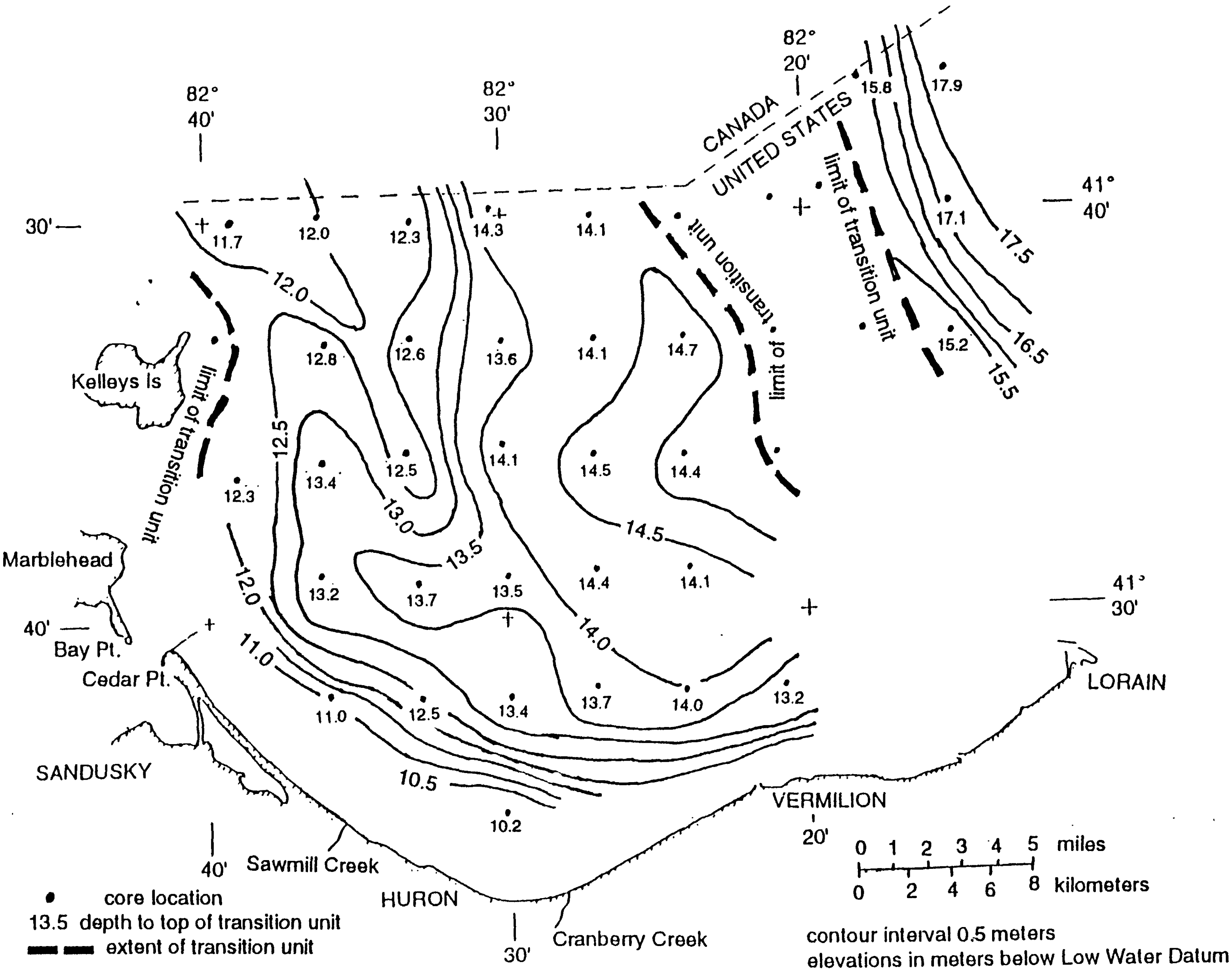


Figure 14. Structure contour of top of transition unit. Note lack of transition unit on the moraine and in the near shore. This unit was the result of the erosion and deposition caused by the rapid transfer of the upper lakes drainage through the Erie Basin.

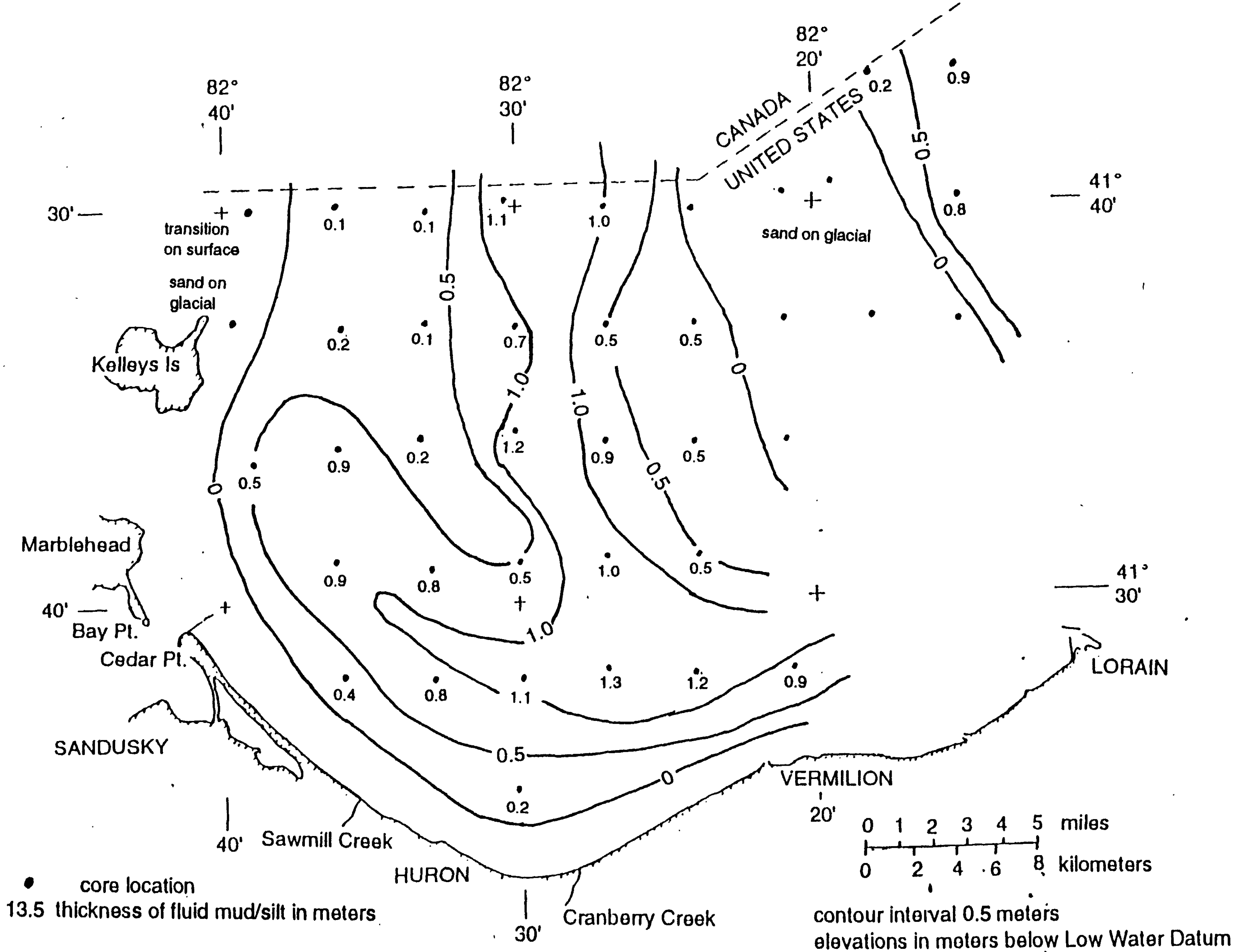


Figure 15. Fluid mud/silt isopach. Fluid mud/silt is the uppermost unit in the deeper-water section. It is thickest in the subbasin center which tends to mute the slope of the subbasin, filling in the deeper areas.

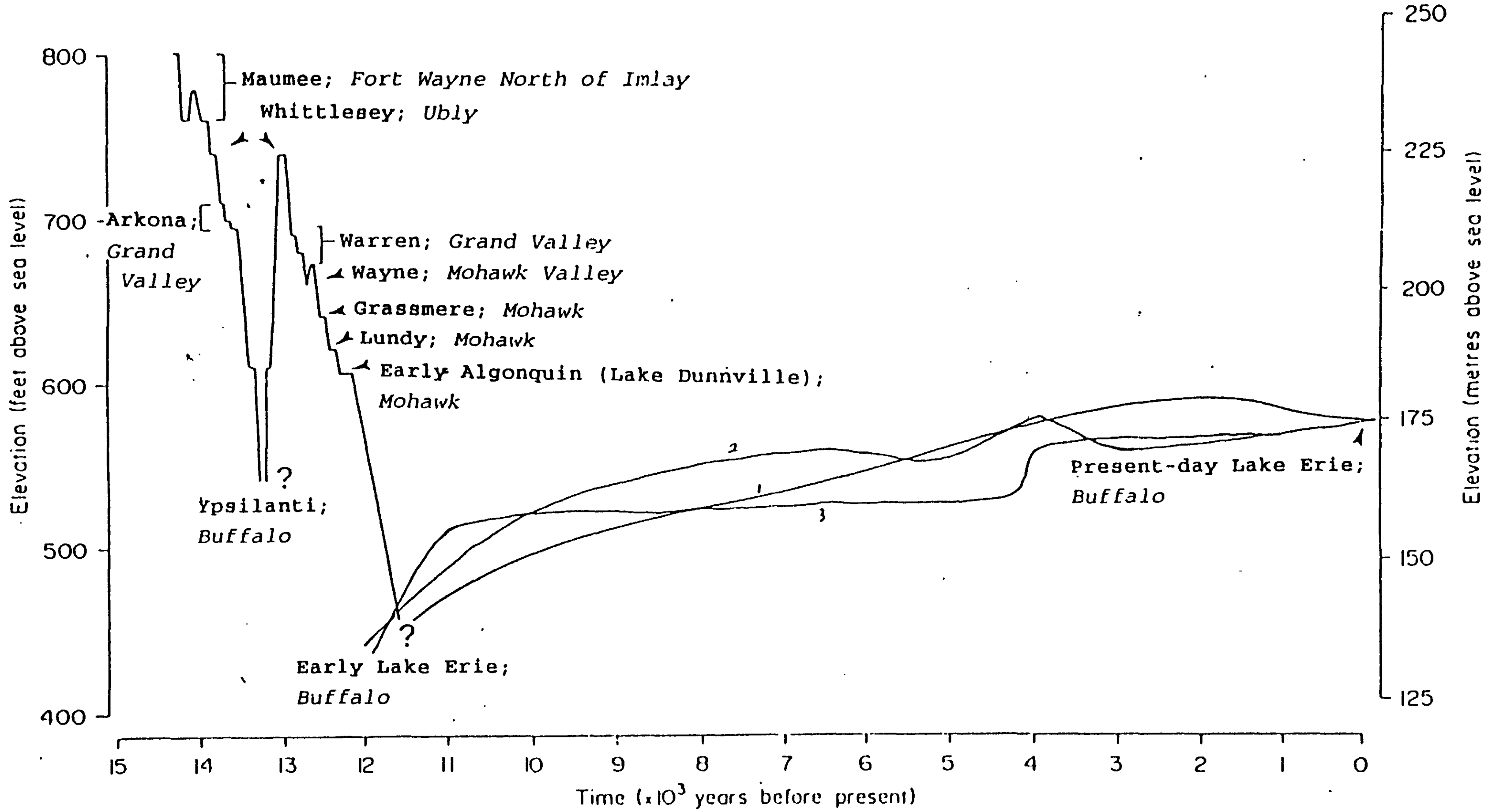


Figure 16. Ancestral Lake Phases and three proposed post-glacial recovery curves for the Lake Erie basin; probable outlets in *italics*, [1] Barnett, 1985; [2] Coakley and Lewis, 1985; [3] Lewis, 1969.
Modified from Barnett, 1985 and Calkin and Fenstra, 1985

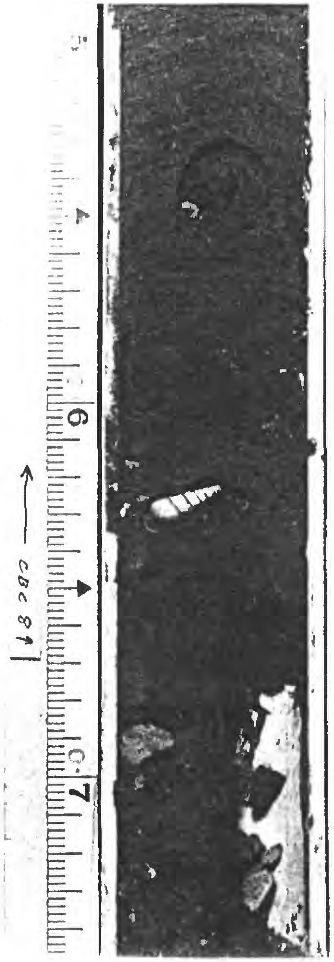


Figure 4. Till with sand unit above. Core CBC-8 50-74 cm. Trench sample taken for natural water. Circle in fine sand is Tore vane measurement location.

Figure 5. Laminated till, Core CBC-34, 174-199 cm.

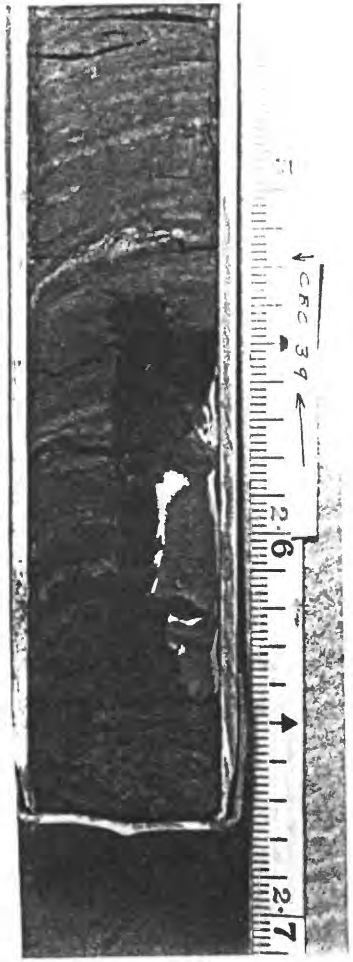


Figure 6. Pro-glacial laminated lacustrine clay, Core CBC-39, 246-267 cm.

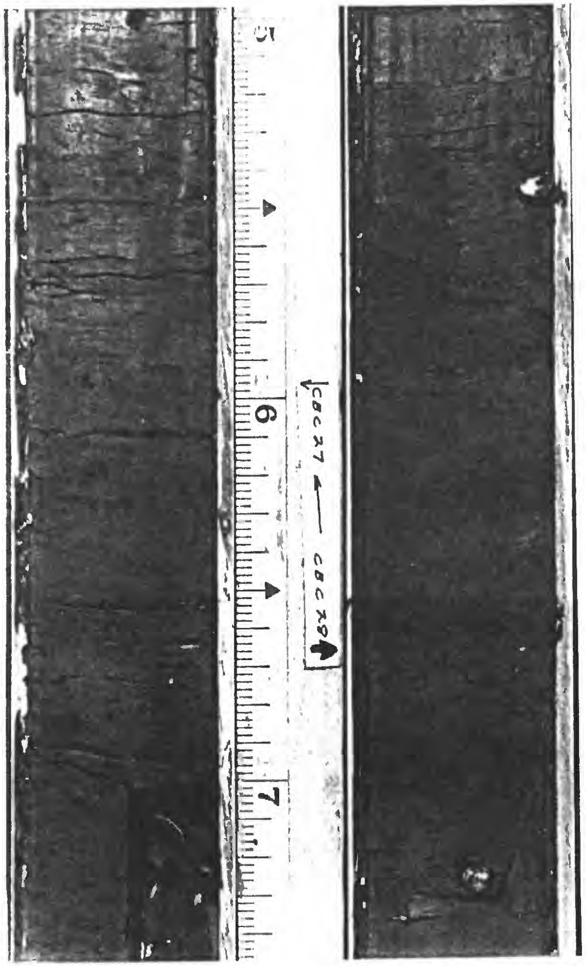


Figure 9. Post-glacial lacustrine soft gray-mud unit core CBC-27 and CBC-28, 151-175 cm, note articulated *Sphaerium* clam at 173 cm core CBC-28 which implies *is situ* position.

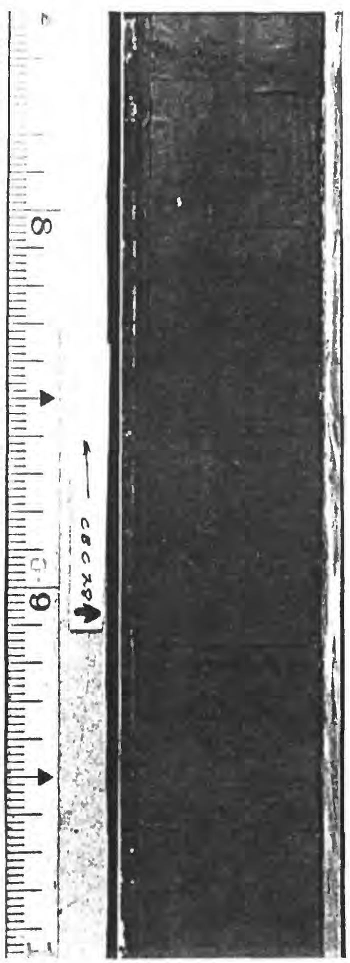


Figure 11. Color transition from soft gray-mud to fluid-mud/silt at 93 cm in core CBC-28

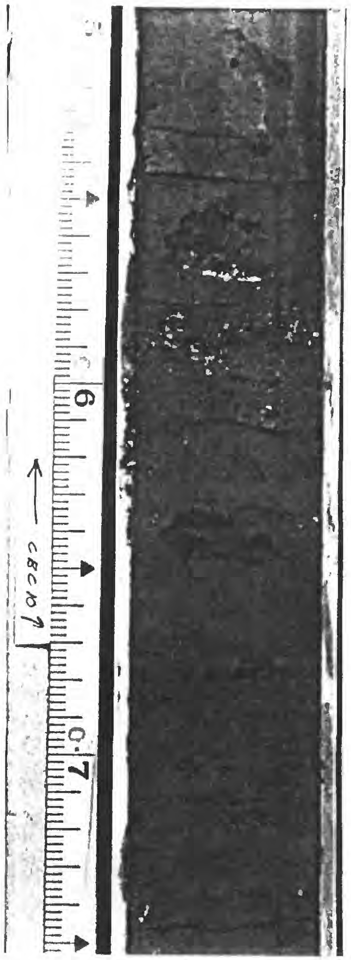


Figure 12. Shells in transition unit from 57 to 60 cm

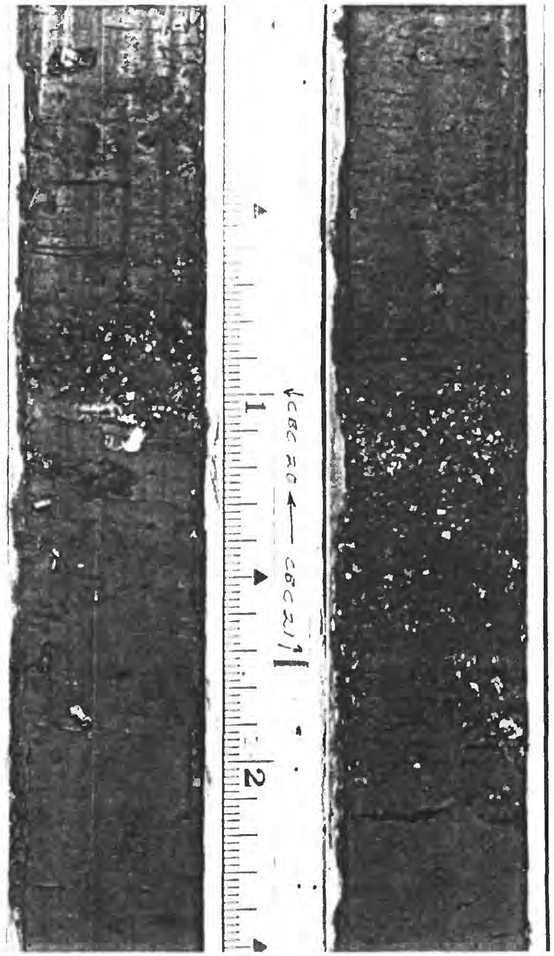


Figure 13. Sand and shells in transition unit in core CBC-20 from 108 to 111 cm and in CBC-21 from 109 to 120