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Management perspective

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EC Priority/Issue: This document addresses two EC priorities / issues:

(1) The DOE Great Lakes 2000 policy needs reliable information on the potential impact of climate change and global warming in the Great Lakes region. Long-term (prehistoric) climate trends can be interpreted from postglacial lake level trends obtained from sediment cores.

(2) Environmental stress caused by human activities have contributed to a deterioration in the health and natural biodiversity of the Point Pelee marsh. Basic geological and hydrogeological information is required to ensure the conservation of this fragile ecosystem.

Current status:

Data collected from numerous boreholes drilled within Point Pelee National Park have expanded our knowledge of subsurface sedimentary formations below Point Pelee, and confirmed previously-published ideas on postglacial lake levels in the Erie basin. Such information also casts light on long-term climate trends in the Erie basin. The detailed characterization of the subsurface sediments will also allow an understanding of the mechanisms and factors controlling the groundwater flow system, and the transport and fate of the contaminants to the Point Pelee marsh.

Next steps:

The information contained within this document will provide background information for a multi-disciplinary study to assess the geological and hydrogeological factors affecting the transport of contaminants to the Point Pelee marsh via the groundwater flow regime.

Subsurface sediment profiles below Point Pelee: indicators of postglacial evolution in western Lake Erie

John P. Coakley, Allan S. Crowe, and Patrice A. Huddart

Abstract: An extensive drilling program, undertaken along the western barrier bar at Point Pelee National Park, Ontario, Canada, yielded considerable subsurface sediment data relevant to the nature and lateral geometry of sedimentary units below the Point Pelee foreland. Four major sedimentary units were identified: a basal clay-rich till, a fine-grained glaciolacustrine sand, a medium-grained sand unit (subdivided into a poorly sorted shoreface sand and an aeolian (dune) sand derived from the shoreface sand), and an organic marsh (gyttja) deposit. The present study confirms the existence of a planar, wave-eroded till surface below the southern portion of Point Pelee at an elevation of approximately 164 m asl. Following this low-water period in the basin, lake levels rose abruptly to an elevation several metres above 172 m asl. This resulted in erosion of the upper part of the glaciolacustrine sand during a later period of stable higher lake levels, perhaps coinciding with the Nipissing flood event (about 4000 BP). This resulted in a planar surface at approximately 169.5 m asl. Several radiocarbon dates on basal gyttja from the marsh (averaging 3200 BP) reflect a subsequent drop in levels to about 2–3 m below present levels. Though undated, the initiation of shoreface and dune sand deposition is roughly coeval with the basal marsh deposits.

Résumé : Un important programme de forage, réalisé le long du banc barrière ouest du parc national de la Pointe-Pelée, Ontario, Canada, a fourni une multitude de données concernant les sédiments de subsurface, renseignant sur la composition et la géométrie latérale des unités sédimentaires sous-jacentes à la pointe de terre de la Pointe-Pelée. Quatre unités sédimentaires majeures ont été identifiées : un till basal très argileux, une unité de sable glaciolacustre à grain fin, une unité de sable à grain moyen (subdivisée en sable d'avant-plage pauvrement trié et en sable éolien (dune) dérivé du sable d'avant-plage) et un dépôt de marais organique (gyttja). Notre étude confirme qu'en dessous de la partie méridionale de la Pointe-Pelée, il existe un till limité par une surface aplanie qui est le résultat de l'érosion par les vagues, situé à une élévation approximative de 164 m au-dessus du niveau marin (a.n.m.). Cette période de basses eaux dans le bassin fut suivie d'une élévation très rapide du niveau des lacs, de plusieurs mètres au-dessus de 172 m a.n.m., ce qui a provoqué une érosion de la partie supérieure de l'unité de sable glaciolacustre durant toute la période ininterrompue de niveaux élevés des lacs, qui coïncidait peut-être avec la période des inondations de Nipissing (il y a environ 4000 ans avant le Présent). Le résultat a été le développement d'une surface plane se situant à environ 169,5 m a.n.m. Plusieurs dates au radiocarbone obtenues (moyenne 3200 ans avant le Présent) pour la gyttja basale du fond marécageux reflètent une baisse subséquente des niveaux de 2–3 m sous les niveaux actuels. Les dépôts des sables des sous-unités d'avant-plage et de dune ont débuté plus ou moins en même temps, quoiqu'il n'existe aucune datation pour le confirmer.

[Traduit par la rédaction]

Introduction

The interpretation of evolutionary trends in the coastal geomorphology and sedimentary processes of the Great Lakes over the last 10 000 to 15 000 years relies greatly on the subsurface sedimentary record and abandoned shorelines. As the last Laurentide ice sheet receded from the area, lake levels fluctuated dramatically and the nature of the deposits laid down reflected these changes. The influence of water-level changes was especially pronounced in the basin of Lake Erie, the most southern of the Great Lakes of North America (Fig. 1). The most significant trend in Lake Erie was the steady postglacial rise in levels (over 40 m) which has resulted in erosion or burial of most of the traces of earlier shoreline positions. Complete subsurface records are to be found primarily in the central deeps of the lake, where their recovery is difficult. For this reason, most of the studies carried out to date on the postglacial evolution of Lake Erie have relied on subsurface data from the three major cuspate forelands (Point Pelee, Pointe-aux-Pins, and Long Point) occurring along the north shore of the lake (Coakley 1976, 1985, 1992; Coakley and Lewis 1985; Trenhaile and Dumala 1978). These sites (Fig. 1) are the only readily accessible areas where subsurface sedimentary data can be collected. Nevertheless, the amount of such data remains very limited and interpretations regarding the relationships of these deposits with the known lake history are still being developed.

Recent groundwater investigations conducted at Point Pelee National Park included a very intensive drilling program which added considerably to the data base on sedimentary sequences at Point Pelee, the westernmost of the above-mentioned three forelands. The existing subsurface sediment data consisted of three boreholes in the park (Terasmae 1970) and six vibracores

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Fig. 1. Location map of Lake Erie and the three major coastal landforms of the north shore.

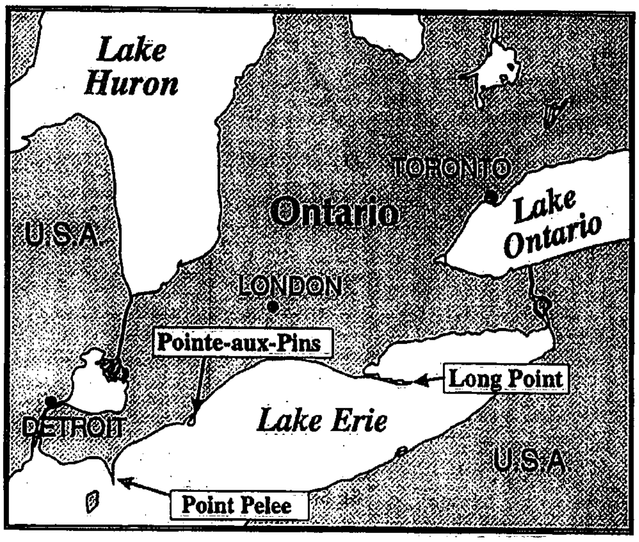
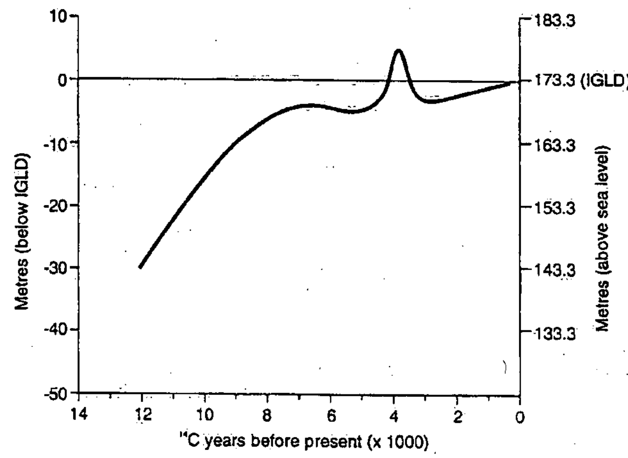


Fig. 2. Postglacial lake-level curve for the Erie basin (adapted from Coakley and Lewis 1985). IGLD, International Great Lakes datum (Lake Erie).



from the Pelee Shoal located to the south (Coakley 1985). The new data described here allow a more accurate assessment of the lateral extent of sedimentary units.

The objective of this paper is to present these new data and use them to examine and extend the existing knowledge of regional evolutionary events in the western basin of the lake. The lateral extent and the detailed granulometric trends associated with the sedimentary units throw new light on models of coastal evolution for the area published earlier (Coakley 1976).

Background on the postglacial history of the Erie basin

The postglacial history of the Lake Erie basin has been described in detail in earlier publications (Coakley 1985; Coakley and Lewis 1985; Prest 1970; Calkin and Feenstra 1985). Briefly, the northward retreat of the Wisconsinan glacier led to a massive ponding of meltwaters between the ice front and the Laurentian–Mississippi watershed. The sequence of high-level proglacial lakes in the Erie basin lasted until approximately 12 500 BP, when glacial ice left the Niagara Escarpment, causing the water in the downtilted Erie basin to drain into the Lake Ontario basin.

This drainage event brought into being the extreme low-level stage in the Erie basin, named Early Lake Erie (Hartley 1960; Hough 1966). This stage, estimated at approximately 40 m below present levels, was dated by Lewis et al. (1966) at between 12 700 and 12 370 BP. The area of Early Lake Erie was approximately half that of the present lake area, and comprised discrete water bodies largely confined to the Central and Eastern basins. The Western Basin, where the surface of the glacial sediment is less than 30 m below present levels, was presumably only partially flooded and drained via a river system into the Central Basin. Restricted pond-like water bodies probably occupied low-lying areas.

Lake-level trends 12 000 BP to present

Figure 2 illustrates lake level against time for Lake Erie, based on a variety of dated elevations throughout the lake basin and surrounding uplands (Lewis 1969; Barnett 1985; Coakley and Lewis 1985; Barnett 1987). The most important underlying components of this trend are (*i*) a long-term rise up to present brought about by isostatic rebound of the Niagara outlet; estimating from the lake-level curve, this rise was initially rapid just after establishment of Early Lake Erie (approximately 20 mm/a), but declined exponentially with time; (*ii*) an abrupt rise due to the Nipissing "flood" event (i.e., the permanent return of upper Great Lakes drainage to the Erie basin around 4000 BP); and (*iii*) a slow post-Nipissing rise in levels up to the present due to continuing uplift of the outlet area at a rate of approximately 0.10 mm/a (Kite 1972).

Postglacial shoreline evolution in the Lake Erie basin

Under the influence of the above events, the shoreline of Lake Erie changed dramatically during the 12 000 years since Early Lake Erie occupied the basin. Although relict shorelines related to high lake-level stages are preserved, shorelines for times of lower than present lake levels have been either obliterated by shore erosion or buried below metres of postglacial sediments.

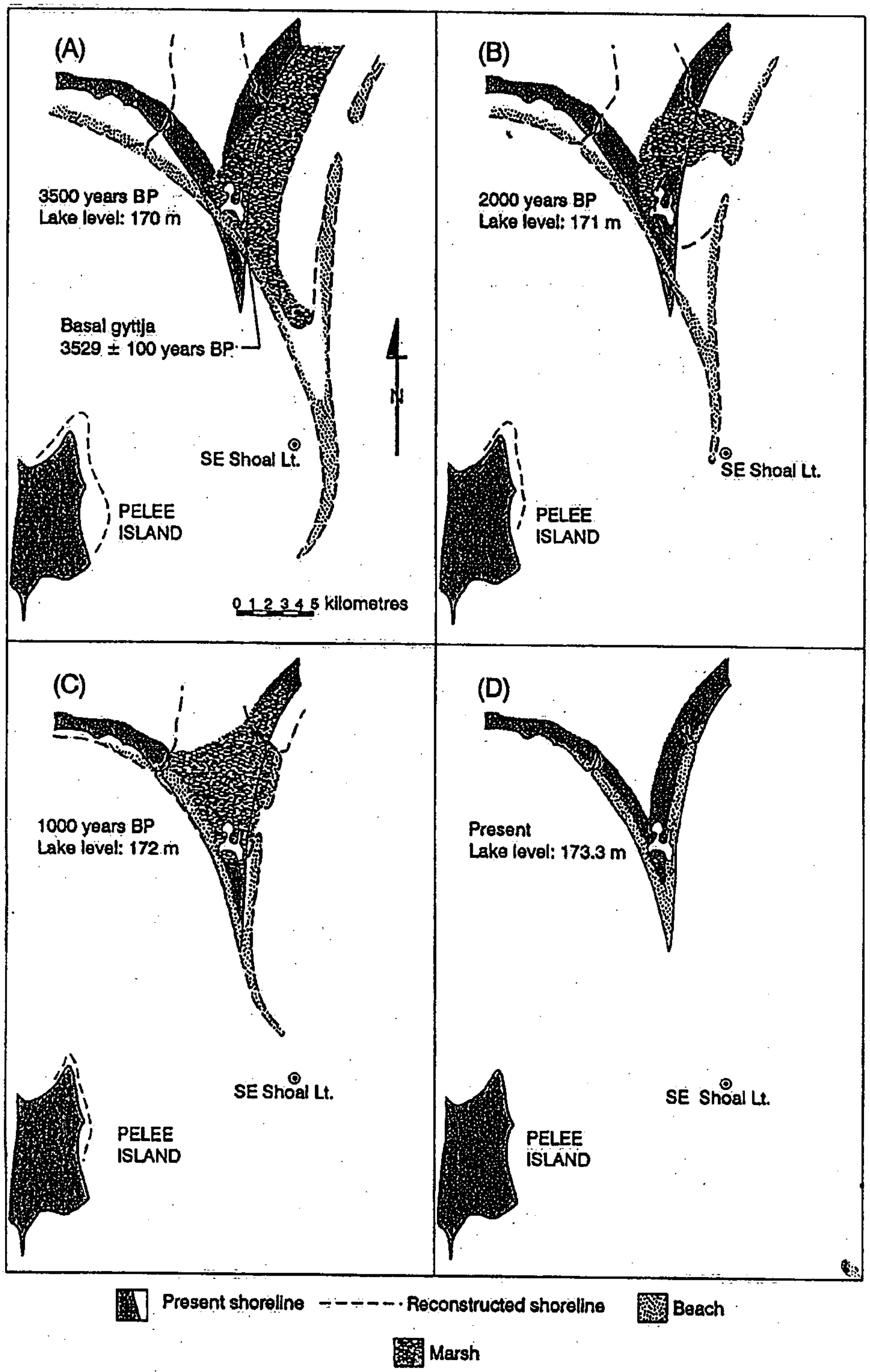
Evolution of Point Pelee

The Point Pelee cuspate foreland is approximately 50 km^2 in area and extends southward 15 km from the northwestern shoreline of Lake Erie. Pelee Shoal (or Southeast Shoal) is a large, sand and gravel platform to the south that forms the subaqueous extension of the point (Fig. 4).

It was initially postulated that Point Pelee was formed in the same manner as marine cuspate spits (i.e., by convergence of littoral drift from opposite directions) (Kindle 1933). Examples of such spits are the Dungeness Spit in the United Kingdom (Gulliver 1895) and the Pointe de La Coubre, France (Jouanneau 1974). This model, however, takes into account neither the dramatic lake-level history of the area, nor the presence of the shoal to the south.

Coakley (1976) presented an evolutionary model based on sediment data from three boreholes drilled in Point Pelee National Park in 1965 and six vibracores from Pelee Shoal

Fig. 3. Reconstruction of the formation and evolution of the Point Pelee foreland (from Coakley 1976). Locations of radiocarbon dates from previous studies are also shown.



(Fig. 3). Two radiocarbon dates on basal peat from the boreholes placed the initial marsh deposition (marking the initiation of the point as an integral foreland with enclosed marsh) at between 3000 and 3500 BP (Terasmae 1970).

New stratigraphic data from Point Pelee

Sample collection

During 1994–1996, 104 boreholes were drilled within Point

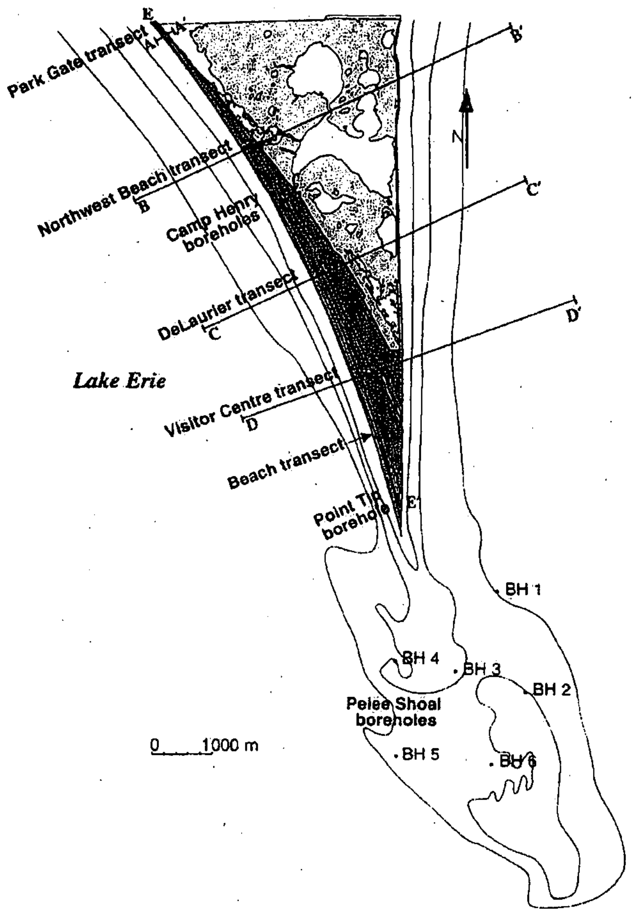
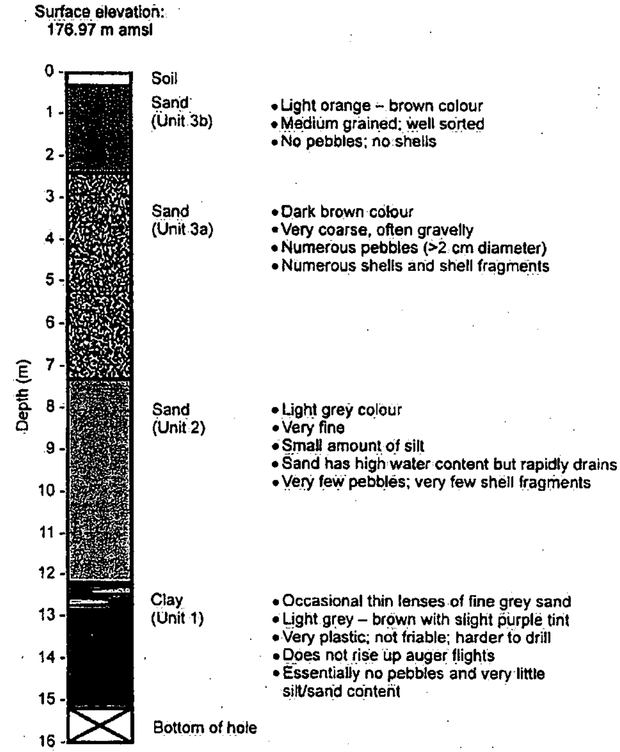


Fig. 4. Location of boreholes drilled during 1994–1996 in Point Pelee National Park and on the Pelee Shoal in 1974. Sections A–A′, B–B′, C–C′, D–D′, and E–E′ are given in Figs. 8–12, respectively. Bathymetric contour interval is 3 m.

Pelee National Park as part of a groundwater investigation. All the boreholes were drilled using a trailer-mounted, hollow-stem-auger rig. The boreholes were drilled along five west–east transects and at two sites equally spaced along the western barrier of the park (Fig. 4). The boreholes were logged and samples collected from 68 of these boreholes. All boreholes were drilled at least to the basal clay, with a few drilled well below the upper surface of the clay. The maximum depth was 15 m. Borehole positions and elevations were tied in to the Canadian National Topographic Survey benchmarks within the park.

Borehole samples consisted of loose sediments bagged on exit from the borehole during the augering (collected every 1.5 m or less), sediment adhering to the auger string collected from the lowermost augers when the augers were removed from the borehole, and push cores taken through the auger barrel. Care was taken to minimize the contamination of lower (finer) stratigraphic samples by coarser upper units as they were augured to the surface. Cores were also collected manually from the marsh and extruded, described, and subsampled in the laboratory. Subsamples for further analysis were taken and freeze-dried. More than 250 bulk samples were taken and about 20 m of core recovered.

Fig. 5. Representative sequence of sedimentary units generally encountered in the Point Pelee boreholes (based on borehole DL-06 from the DeLaurier transect). amsl, above mean sea level.



Stratigraphic classification

Boundaries between major units were first assigned visually according to both colour and textural changes logged during the augering, as well as experience in interpreting the responses of the auger rig when it encountered textural changes. These boundaries cannot be determined precisely because some imprecision exists in determining stratigraphic position of samples brought to the surface by the augers, and because of sampling problems caused by coring sand below the water table (e.g., "sand heave" into the auger cavity). However, our experience from augering over 100 boreholes at Point Pelee shows that the lowermost boundaries can be located within one auger flight, and thus are expected to be accurate within a metre. Although contamination of grab samples on the way up by materials closer to the surface occurs, care was taken to use only the innermost material from the borehole samples for grain-size analysis.

A typical sediment column, at borehole DL-06 along the DeLaurier transect (Fig. 4), is presented in Fig. 5 to illustrate the entire sequence of sedimentary units encountered in the western barrier ridge. The basal sediment (unit 1) is a dense, sticky clay, containing minor sand- and gravel-sized fractions, although some fine sand lenses were frequently noted at the top of the clay. At two boreholes in the eastern portion of the Camp Henry site, the basal clay was more friable (less plastic) and contained very large (up to 10 cm) rounded cobbles and pebbles. In all cases except within the marsh, the clay is overlain by several metres of sand, either a grey, well-sorted fine sand (unit 2), or a coarser sand (unit 3). The basal section of the upper sand (unit 3a) is usually darker brown in colour, rather coarse and gravely in texture, and frequently contains whole or broken shells (bivalves and gastropods). The upper sand (unit 3b) is generally lighter and more orange in colour, medium grained, and better sorted compared to the lower subunit, and contains no shell material. In the marsh, the sand units are absent and the clay is directly overlain by organic sediments (gyttja) of marsh origin (unit 4).

Sample analysis

A total of 110 sediment samples were analyzed for grain-size statistics. Most of the samples were analyzed at the Sedimentology Laboratory of the National Water Research Institute, Burlington, Ontario, using the combined sieve–SediGraph technique (Duncan and LaHaie 1979) at a resolution of 0.5 ϕ. The others were analyzed at the Department of Earth Sciences, the University of Western Ontario, using a standard ASTM sieve and hydrometer technique (1 ϕ interval). The samples selected for analysis represented the major sediment types identified in the field logging process.

Textural classification of Point Pelee sedimentary units

Grain-size properties for 84 of the above analyses, selected for having good coverage even in the "tails" of the size distribution, were analyzed to differentiate between the lithologic units and to interpret their environment of deposition. Classification of the various units was first made on the basis of a C–M representation followed by verification based on representative size-distribution curves. The former technique, proposed by Passega (1964), uses two-dimensional plots of the coarsest 1 percentile, C, against the median, M, to define spatial groupings of samples interpretable in terms of the relative importance of transport processes such as uniform, graded, and pelagic suspension (i.e., gravity settling) and bottom suspension and rolling. The technique was used by Coakley (1985) in earlier studies of borehole sediments below the Pelee Shoal to define genetic sediment groupings. The grain-size curves (Fig. 6) were used to characterize further the size-distribution signatures of the C–M groupings (Fig. 7) and to assist in process interpretation using the approach of Visher (1969). These were also useful in assessing possible gross contamination by other sediment units; such effects would be visible as discontinuities and random excursions of the basic curve.

Of the four major sedimentary units identified visually in the field, three were also distinguished by granulometric properties. However, not all units are present at all sites, nor are all the sedimentary units encountered in all boreholes along a transect. Their spatial distribution and vertical geometry are shown in cross sections (Figs. 8–12). Elevations of the subsurface units below the marsh and the east side of the point as shown in Figs. 8–12 were taken from hydrographic charts and unpublished survey notes by J.P. Coakley.

Unit 1

The basal unit in the deepest boreholes is a dense, purplish-grey, plastic clay till whose contact was readily identified by the drillers from its relatively high resistance to drilling. Its size-distribution curves are remarkably uniform over the area covered (Fig. 6A). Although drilling observations showed little coarse material and a greasy smooth texture, the size-distribution plots show significant amounts of sand and silt. However, the regular continuous nature of the grain-size curves indicates that this is not the result of contamination by the overlying sand units or sand lenses within the upper till.

Because of its diagnostic fine and poorly sorted texture, the unit is interpreted as a fine-grained till (most likely, Port Stanley Till or the Tavistock Till). Cowan (1976) considers the Port Stanley Till and the Tavistock Till to be contemporaneous, and Morris and Kelly (1997) suggest that the till on nearby Pelee Island is a hybrid of the two tills. Similar sediments were described as till by Terasmae (1970) and Coakley (1985) on the basis of geotechnical tests. They plot within the same field (field 1) in the C–M diagram (Fig. 7) and have grain-size curves identical to those of the basal sediments in the Pelee Shoal cores (Coakley 1985). They are also visually similar to tills outcropping along the shoreline farther to the east (Barnett 1987).

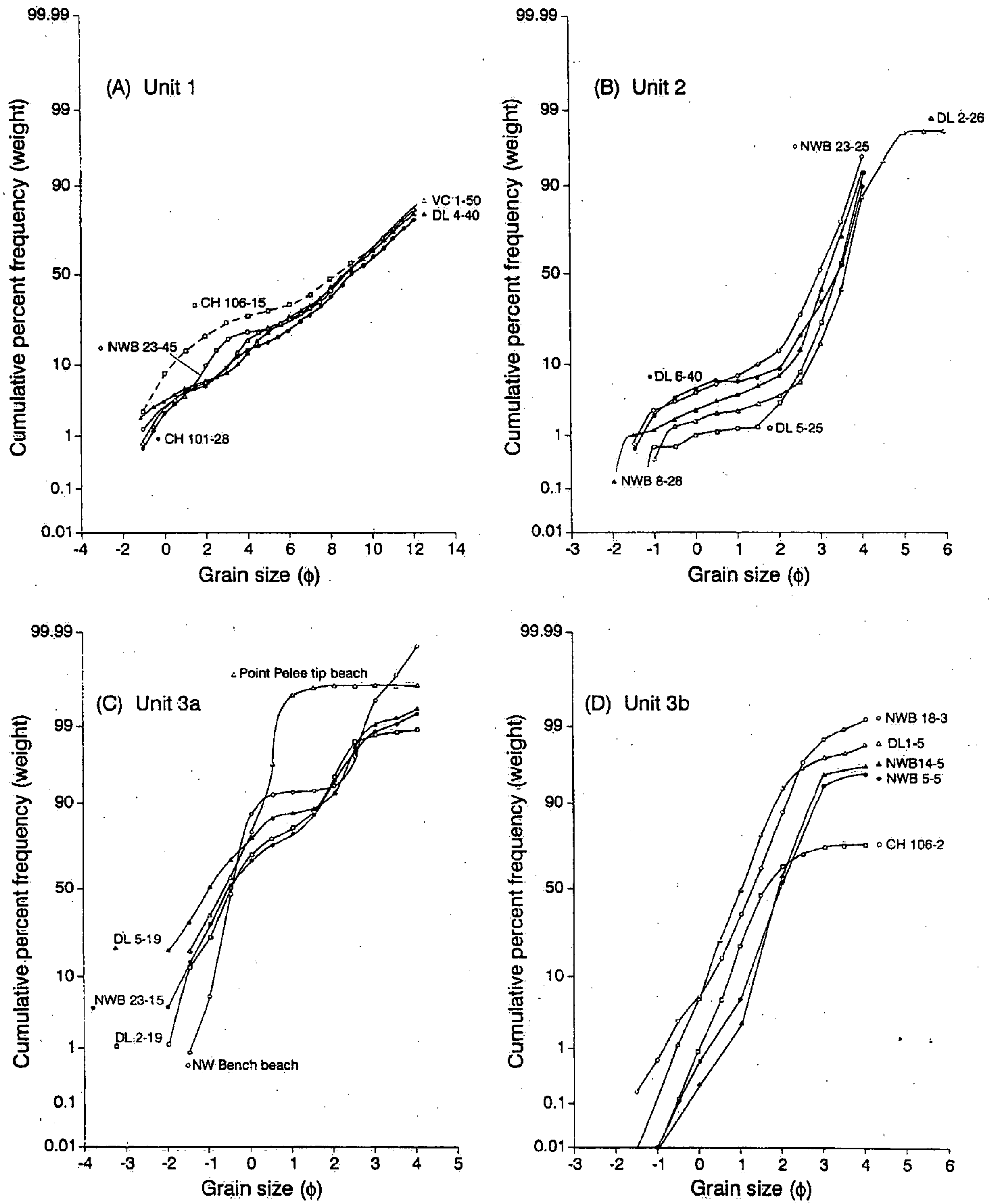
At boreholes CH-103 and CH-106 located approximately 200 m apart at the edge of the marsh at the Camp Henry site (Fig. 4), the unit was stiffer and reddish in colour and contained sand and rounded clasts up to 10 cm in diameter. Apart from the above visual differences, the sediment here is similar texturally to the till at the other sites, although the size of the pebbles and their rounded nature suggest the effect of a high-energy aqueous environment rather than glacial deposition. Furthermore, the reddish colour could indicate desiccation (and partial oxidation) resulting from periodic exposure to subaerial conditions. The rounded pebbles can therefore be tentatively interpreted as a lag deposit produced by wave erosion in an exposed, shallow-water environment (upper shoreface). Confirmation of this hypothesis must await further evaluation of the areal extent of the larger clasts. If the hypothesis of temporary desiccation and wave erosion is valid, then the elevation of this surface could approximate a temporary lake level stillstand. In the absence of any dates on this surface, however, it is impossible to relate it to the lake level history (Fig. 2).

Vertical transects through the sites (Figs. 8–12) show that the till forms a distinct north–south-trending high in the glacial sediments below Point Pelee. From an elevation of 172 m asl at the Park Gate transect, the surface of the till slopes southward to 164.5 m asl at the DeLaurier transect. Southward from here, its surface is apparently flattened by erosion, but slopes gently towards the west and the south to 164 m asl at the tip of the point.

Unit 2

Unit 2 is a light-grey, fine-grained, silty sand with a median diameter between 2.5 and 4.0 ϕ and good sorting (Fig. 6B). It is texturally distinct from the clay below and the coarser sands above, and forms a distinct field in the central portion of the C–M diagram (Fig. 7). Its fine-grained, well-sorted texture makes it unlikely that it was deposited in a shallow-water environment such as that existing immediately following Early Lake Erie. On the other hand, its relationship with the till (unit 1) and its textural similarity to fine glaciolacustrine sands mapped nearby in the Leamington area (Wagners 1972; Morris and Kelly 1997) suggest a glaciolacustrine origin, deposited at a distance from the melting ice front, subsequent to the deposition of the till. The near-contemporaneous deposition of these two facies is indicated by the fine sand lenses observed

Fig. 6. Typical cumulative grain-size distribution curves plotted on standard probability paper for the various sedimentary units sampled in the Point Pelee boreholes.



occasionally within the uppermost sections of the till, possibly reflecting oscillations in the local ice margin.

Unit 2 is absent from the eastern part of the Camp Henry site, the eastern two thirds of the Northwest Beach transect (Fig. 9), and in boreholes to the north (Figs. 8, 12). The fact that the sand, unlike the till, is absent from the north part of the park suggests that it is an erosional remnant of a once more extensive deposit; further evidence of this erosional phase is that, although the thickness of unit 2 increases from north to south (Fig. 12) and east to west (Fig. 9), its top surface is

Fig. 7. C–M diagram for Point Pelee National Park samples, with clustering identifying three distinct textural groupings 1–3 (broken lines) and units a and b in group 3. The legend identifies the transects from which the samples were obtained: CH, Camp Henry; DL, DeLaurier; NWB, Northwest Beach; PG, Park Gate; VC, Visitor Centre. Insert shows the original fields identified by Passega (1964).

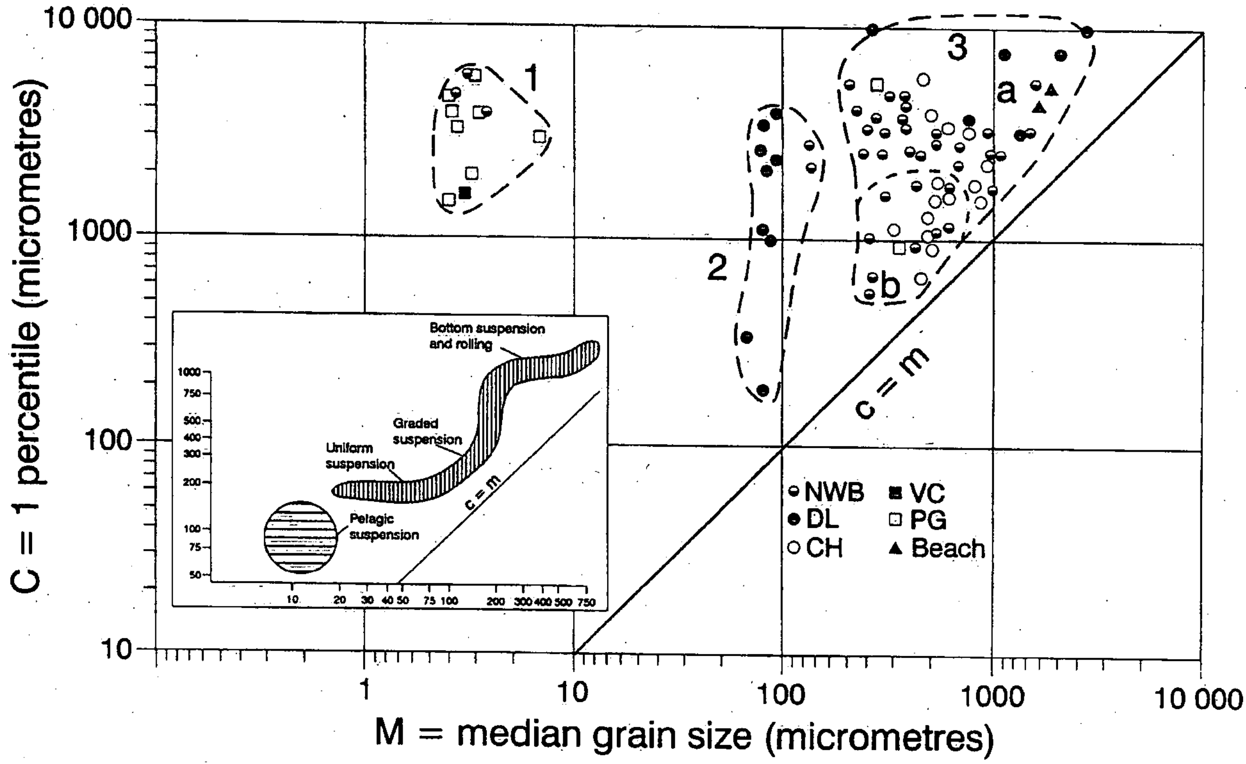
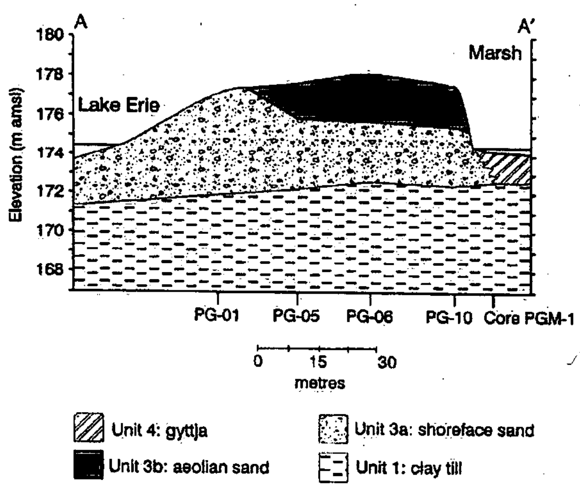


Fig. 8. West–east section A–A′ at the Park Gate transect on the western barrier bar showing borehole locations and sediment units.



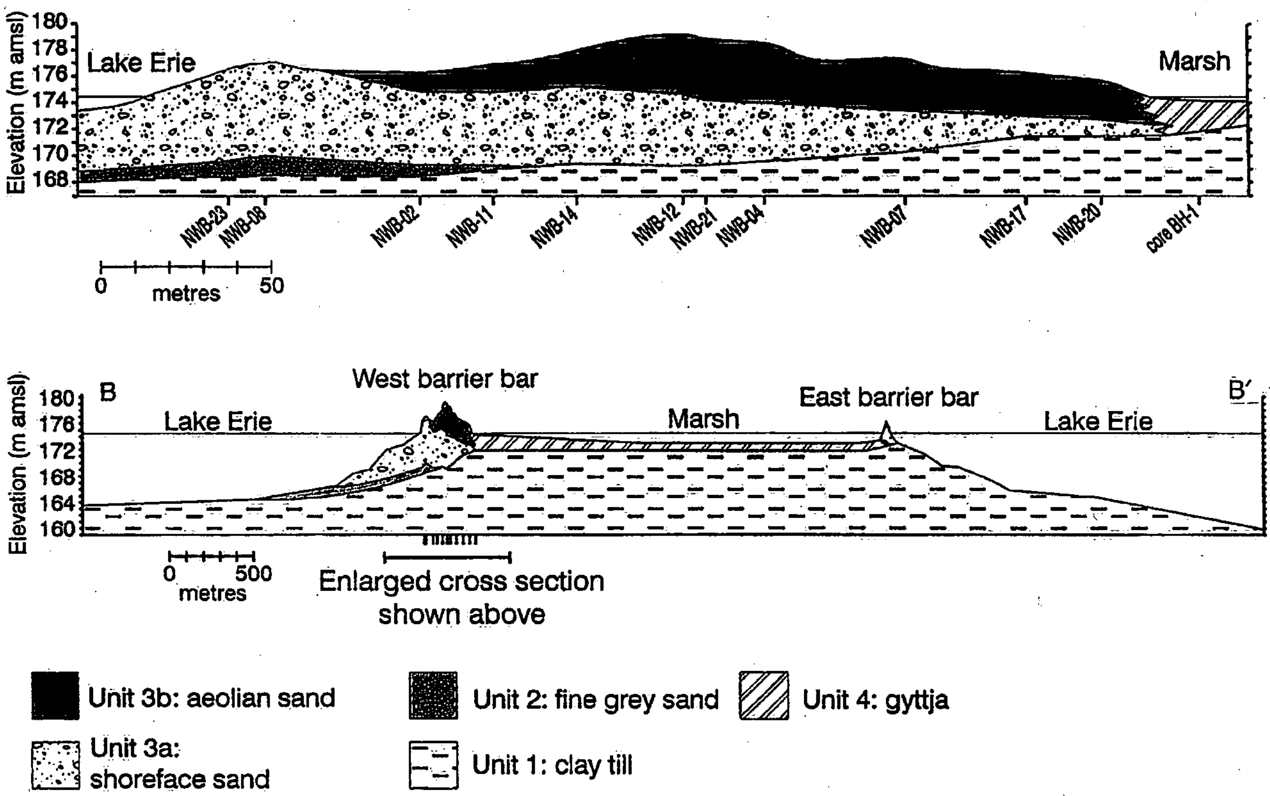
apparently planed off at an elevation of approximately 169.5 m asl. Its absence in the eastern part of, and to the north of, the Northwest Beach transect always corresponds to locations where the elevation of the till exceeds 169.7 m asl. This elevation, like that of the supposed beach gravels above the till in CH-106, could also refer to a stable lake level period at approximately 4 m below present datum. Here again, no means of dating this surface is presently available.

Unit 3

This unit overlies the fine sand or the basal clay in all boreholes and is best described as a brown, coarse to medium sand, generally containing >95% sand and gravel, with a median grain size ranging from −1.0 to 2 ϕ (Figs. 6C, 6D). It plots over a fairly large region in the C–M diagram (Fig. 7), covering C–M fields associated with bottom traction or rolling transport (unit 3a, upper right) and grain saltation (unit 3b, lower left). Field logs and grain-size curves for representative samples from unit 3a (Fig. 6C) show them to be poorly sorted, coarse-grained sand, containing numerous pebbly and gravelly lenses. The curves are clearly bimodal (a secondary mode occurs in the fine sand (3ϕ) range). Values of C–M for two samples collected from the present-day beach both plot within the area of unit 3a, prompting the suggestion that the samples at this end are associated with beach or upper shoreface aqueous environments. The beach–shoreface interpretation is supported by the common association with numerous whole gastropod and bivalve shells (up to 1.5 cm) and large shell fragments. Unit 3a occurs in all boreholes up to 7 m below the surface; it generally decreases in thickness toward the north.

Samples plotting at the other end of area 3 in the C–M diagram (designated unit 3b) are much different in grain-size characteristics (Fig. 6D). The grain-size curve is regular in

Fig. 9. West–east section B–B′ across Point Pelee at the Northwest Beach transect (bottom), with an enlargement of the western barrier bar showing borehole locations (top).



form, with a smaller median size (1–2 ϕ), better sorting, and unimodal distribution compared with unit 3a. Gravel content is very low (<1%) and could reflect minor sample contamination. The colour of these sands (orange-brown) is also different. These samples make up the surface sections of the nonmarsh areas, coinciding with the location of modern-day dunes, and because pebbles and shells are rare or absent, they are interpreted here as having an aeolian (dune) mode of deposition.

A noteworthy geometric feature is that the base of the aeolian unit (3b) rises (from east to west) toward the present waterline (Figs. 8–11). The elevation difference ranges from 1.8 m at the Visitors Centre to more than 4 m at the Northwest Beach transect. This upward slope could be related to concurrent lateral and vertical accretion of the west side of the point associated with the postglacial rise in lake levels discussed previously.

Unit 4

Conventional gyttja deposits consisting of organic debris form the surface in the low-lying areas of Point Pelee. Cores taken approximately 10 m inside the marsh at the Park Gate site and at the Northwest Beach transect show a total gyttja thickness of 1.70 and 2.44 m, respectively. In all cases, the gyttja directly overlies the glacial clay. The position of the gyttja–clay contact in these areas is situated at approximately 172.4 and 171.6 m asl or less than 2 m below the lake datum. Samples from the basal section of the organic deposits in the Northwest Beach core were dated at 3390 ± 70 and 3010 ± 70 BP (University of Waterloo Environmental Isotope Laboratory nos. WAT 2931 and 2932). These dates are in close agreement with earlier dates on basal organics from several sites below the marsh (Terasmae 1970; Coakley and Lewis 1985).

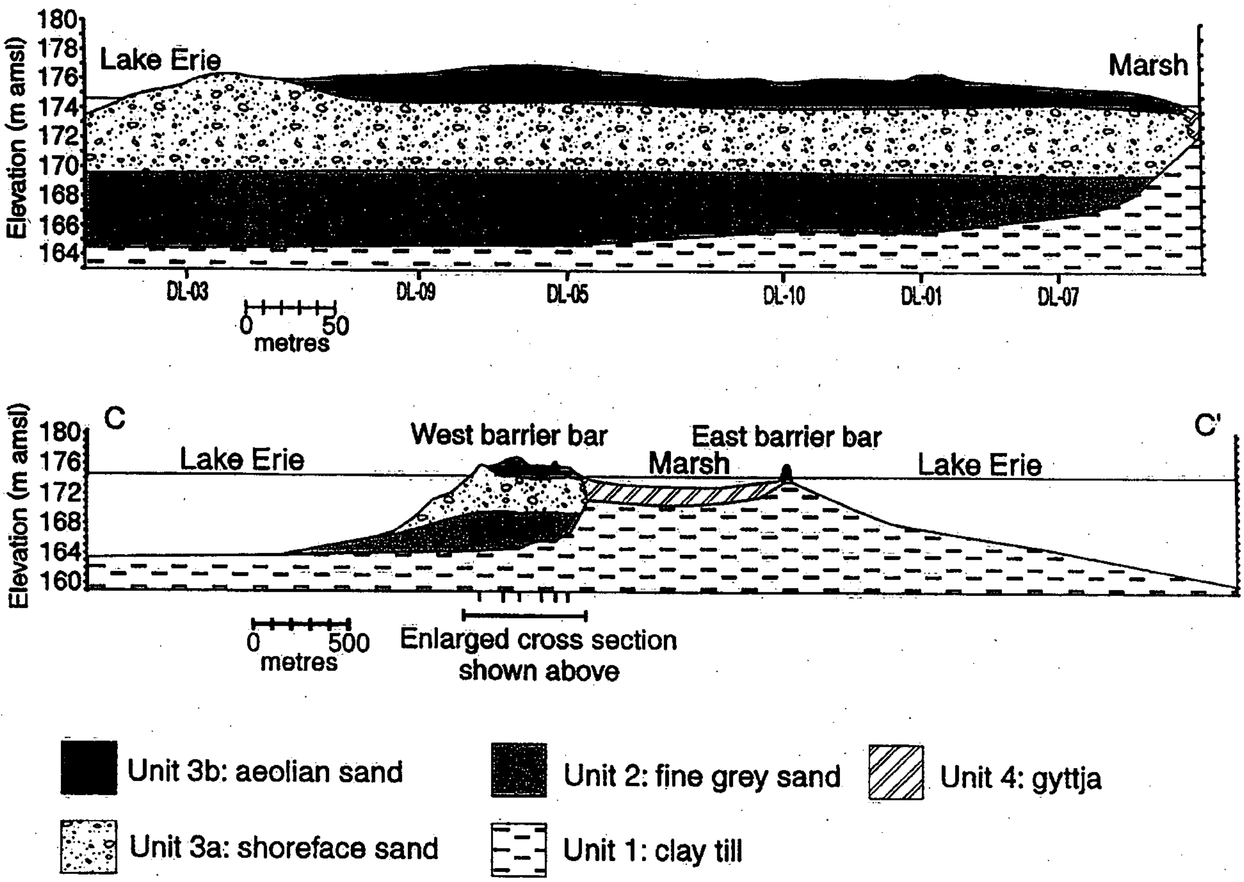
Discussion

The new borehole data from Point Pelee National Park add considerably to the existing data base for subsurface deposits in the nearshore zone of Lake Erie and provide stratigraphic evidence necessary for clarifying postglacial events and evolutionary trends in the coastal zone of the lake. It is useful to examine the impact that the new data have had on the preexisting ideas.

Stratigraphic sequences as indicators of lake-level change

The sedimentary sequence recorded in the new boreholes was generally similar to that of the surface units identified in boreholes drilled by Terasmae (1970) at Point Pelee. The basal sediment is a dense clay designated as a till. The till underlies the entire area and forms a flattened positive relief feature below Point Pelee from a maximum elevation of 172 m asl at the north entrance of the park to an elevation of 164 m asl at the DeLaurier site and south. Inland, it varies slightly in texture, colour, and nature of included pebbles, raising the possibility that it underwent postdepositional changes such as

Fig. 10. West–east section C–C′ across Point Pelee at the DeLaurier transect (bottom), with an enlargement of the western barrier bar showing borehole locations (top).

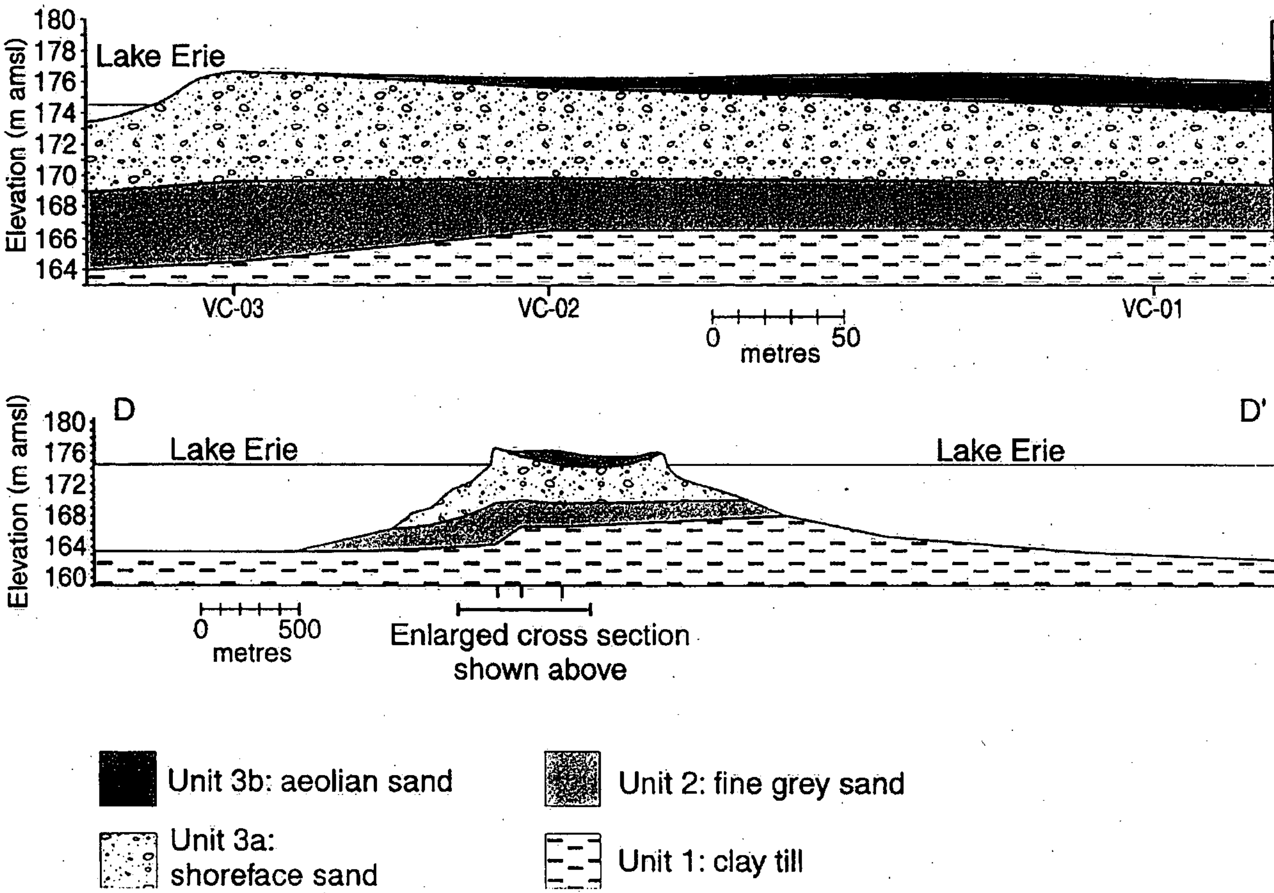


desiccation and erosion above an elevation of approximately 169.75 m asl or about 4 m below lake datum. If the hypothesis of temporary desiccation and wave erosion is valid, then this elevation could mark a period of stable lake levels. The till unit is also found below the Pelee Shoal, indicating its regional nature associated with glacial occupation of the basin prior to Early Lake Erie. Moreover, it lies at an elevation of approximately 163 m asl in the shoal area, indicating continuity in slope with the occurrences below Point Pelee. The difference between the elevations of the rounded cobble "beach" and the maximum elevation of the planed till ridge indicates that its top was at least 3 m above water and formed a shoreline promontory. The change in north–south slope of the till surface noted at the DeLaurier site (Fig. 12) and on a cross section in Coakley (1976, Fig. 2, p. 138) could then correspond to a wave-cut shoreface "notch" indicating a previous shoreline position. A similar notch is visible on the east–west transect at the Visitor Centre (Fig. 11), suggesting that the promontory at the time trended more southeast than the present foreland.

The fine, well-sorted glaciolacustrine sand overlying the till was encountered by Terasmae (1970) in only one borehole (near the Visitor Centre). This unit was not identified in the Pelee Shoal sediment sequences, indicating that either it was not deposited or it was eroded from that area. The latter possibility is deemed more likely, as there was no sign of transition to another depositional environment in the samples studied. The borehole data presented here define the northern limits of this facies and demonstrate for the first time the planed-off surface of this unit. The associated erosion event most likely occurred during a period when levels were at or slightly above approximately 169.5 m asl (or 4 m below present lake datum) in the basin. This event is likely coincident with the erosion of the till producing the rounded lag cobbles at the Camp Henry site at a similar elevation.

The shoreface sand (3a) and dune (3b) units and the marsh gyttja (4) unit were deposited under conditions similar to those at present. The age of the marsh is rather uniform at between 3000 and 3400 BP and, although a minimum elevation could not be determined below the main body of the marsh, at the borehole sites, it is approximately 172.4 m asl, or 1 m below the present lake datum. Only a few of the boreholes (at the Camp Henry site) encountered sand below the marsh gyttja, although Terasmae (1970) logged a thin unit of medium to coarse sand below peat in the central area (near the Northwest Beach site). On the other hand, the lowest position of the shoreface sand unit (3a) is around 169 m asl (Fig. 9), far below the marsh. This suggests strongly that the shoreface unit (3a) predated the marsh and grew lakeward from the till-cored

Fig. 11. West–east section D–D′ across Point Pelee at the Visitor Centre transect (bottom), with an enlargement of the western barrier bar showing borehole locations (top).



promontory, presumably as water levels rose and the Point Pelee structure evolved. Such a model is in general agreement with the evolutionary model of Coakley (1976) and with the west-side accretion shown in Fig. 3, except that it now places the origin of Point Pelee slightly before the average age of the marsh organics. A maximum age for Point Pelee must await the recovery of datable organics from the basal shoreface deposits.

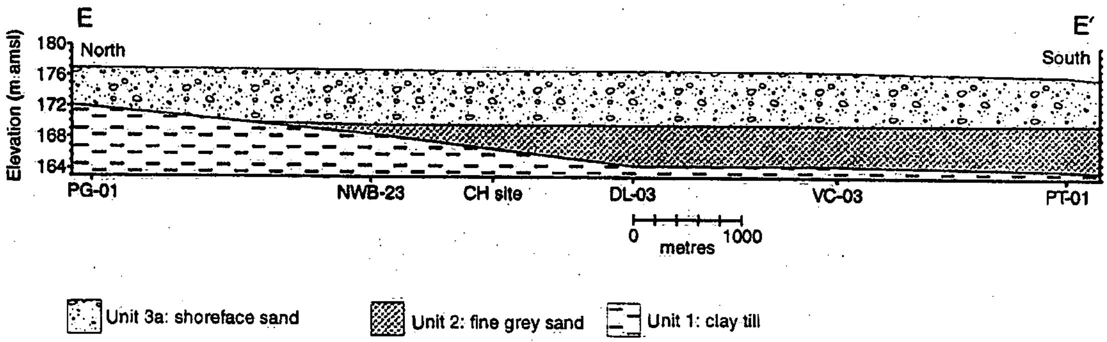
The westward rise of the contact between units 3a and 3b is a clear indication that the lake level was rising and that the dune deposits were tracking behind the lakeward advance of the shoreface and beach deposits (van Heteren and van de Plassche 1997). Although dates are unavailable, it is evident that this development occurred after the establishment of the marsh gyttja deposits (i.e., during the period of slow secular rise in levels from around 3000 BP to present). The ^{14}C dates obtained for the basal marsh gyttja in the boreholes are in close agreement with those previously obtained and indicate that the marsh developed over a relatively short time interval.

Implications for Point Pelee evolution

The borehole data confirm the assumptions implicit in the original interpretation (Coakley 1975). The presence of the broad, flattened, wave-eroded, and subaerially exposed platform below Point Pelee and extending southward has been confirmed. However, other new information of importance to Point Pelee evolution has been added, including the definition of a fine glaciolacustrine sand unit in association with the more widespread till facies. The surface of this sand unit has been eroded essentially planar, at an elevation of approximately 169.5 m asl, apparently prior to, or concurrent with, the erosion of the till, during a low-water period in the basin.

The presence of the above indicators of a fairly stable low water level period at or below 169.5 m asl suggests that that period must have been followed by a relatively abrupt rise in lake levels prior to the building of the modern Point Pelee foreland. Up until this time, the till promontory would have been subaerially exposed and most likely normally wooded, with no sign of a marsh. The flattening of the promontory was likely caused by water levels several metres higher than 172 m asl (the highest till elevation at the Park Gate transect (Fig. 8)). Such a level is close to, or above, present levels, and could have coincided with the so-called Nipissing "flood," of which evidence exists in other parts of the basin (Barnett 1985). The radiocarbon dates of around 3200 BP for the basal gyttja (at around 172 m asl, or almost 2 m below present levels) are evidence that lake levels subsequently fell to initiate the conditions leading to formation of the Point Pelee marsh.

Fig. 12. North–south transect E–E′ along the western shoreline of Point Pelee National Park showing borehole locations.



The steady rise since then is reflected in the increase in thickness, and the rise in basal contact elevation, of the surface dune sand unit (3b).

Summary

The large amount of new data on subsurface sediments at Point Pelee National Park has enabled a review of the original model of formation of the Point Pelee foreland. The new data greatly increase the level of stratigraphic and sedimentological detail for the subsurface sediments. This permits a better classification and correlation of the sediment sequence, and places these sediment units within a framework of coastal evolutionary processes in western Lake Erie over the past several thousand years. Grain-size and C–M analysis suggest that the basal fine sand noted in many of the boreholes was glaciolacustrine in origin. While confirming most of the assumptions used in the earlier evolutionary model for Point Pelee, the new data also brought forward evidence of a period of desiccation and wave erosion of the till promontory below the point during a low-water period prior to the formation of the spit–marsh complex. Radiocarbon dates obtained for basal organics in several of the boreholes average approximately 3200 BP, almost identical to earlier dates at widely separated locations within the marsh. This confirms a minimum age for Point Pelee. The several metre rise in elevation of the base of the dune unit is linked with the steady rise in lake levels since the formation of the point.

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