THE ORIGIN AND EVOLUTION OF A COMPLEX CUSPATE FORELAND: POINTE-AUX-PINS, LAKE ERIE

by

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ABSTRACT

The origin of Point-aux-Pins, a large, rounded, cuspate foreland protruding from the north shore of Lake Erie, is difficult to explain by conventional spit formation processes. Stratigraphic evidence from boreholes, nearshore sediment distribution surveys surface geomorphology, and previously published interpretations of Lake Erie levels were combined to produce an hypothetical model of how the Point originated and evolved since then. According to the model, the ancestral Pointe-aux-Pins began as a promontory caused by the intersection of the cross-lake Erieau moraine with the original lake shoreline, then located tens of kilometres lakeward of its present position. Lake levels at the time were about 30 metres below present datum (173.3 m above sealevel). The development of the foreland from approximately 12,000 years Before Present (B.P.) is reconstructed in the light of the physical evidence and latest concepts of Lake Erie postglacial evolution. Modern Pointe-aux-Pins dates from after the Nipissing "flood", at about 3500 B.P., when the thereto-submerged sandy spit platform was again subjected to wave action, leading to beach-ridge and dune formation. The age of the foreland of 3500 to 4000 years compares well with estimates based on the annual sand supply rate and the present sand volume in Pointe-aux-Pins.

RÉSUMÉ

L'origine de la Pointe-aux-Pins, large saillant triangulaire sur la rive septentrionale du lac Érié est difficile à expliquer par des processus classiques de formation de flèches littorales. Les preuves stratigraphiques obtenues par forage, les levés géomorphologiques de surface pour la répartition des sédiments précôtiers, et les interprétations déjà publiées sur les niveaux du lac Érié ont été combinés pour produire un modèle hypothétique sur la formation et l'évolution de la pointe. D'après ce modèle, la Pointe-aux-Pins anestrale a commencé sous forme de promontoire causé par l'intersection de la moraine qui traversait le lac Érié avec le rivage original du lac qui se trouvait alors à des dizaines de kilomètres au large du lac par rapport à sa position actuelle. La niveau du lac était à cette époque environ 30 mètres au-dessous du niveau actuel (173,3 m au-dessus niveau de la mer). Le développement du promontoire depuis environ 12 000 ans avant notre ère est reconstitué à la lumière des preuves physiques et des derniers concepts de l'évolution postglaciaire du lac Érié. La Pointe-aux-Pins moderne date d'après "L'inondation" du Nipissing, environ 3 500 ans avant notre ère, lorsque la plate-forme formée par la flèche de sable ainsi submergée a envore été soumise à L'action des vagues, entraînant ainsi la formation de crêtes de plage et de dunes. L'âge supposé de ce promontoire, soit 3 500 à 4 000 ans, se compare bien aux estimations basées sur le taux d'apport annuel en sable et le volume actuel du sable à la Pointe-aux-Pins.

MANAGEMENT PERSPECTIVE

This report proposes a reconstruction sequence for Pointe-aux-Pins, a prominent shoreline feature along the north Lake Erie shoreline, based on a variety of geological and stratigraphic indicators. It establishes the age of this important recreational and agricultural amenity, and the relationship between its evolutionary stages and postglacial water levels in the lake, and thus puts present shoreline processes into a more realistic, long-term perspective. Such a perspective is essential for managers in drafting plans for shoreline management, land-use, and lake-level regulation.

ANALYSE DE GESTION

La présent rapport propose une séquence de reconstitution de la Pointe-aux-Pins, forme de relief proéminente de la rive septentrionale du lac Érié, basée sur divers indicateurs géologiques et stratigraphiques. Il établit l'âge de ce lieu important à vocation récréative et agricole, ainsi que le rapport entre ses stades d'évolution et les niveaux d'eau postglaciaires du lac, et présente les processus de formation des rives actuelles dans une optique plus réaliste et à long terms. Une telle perspective est essentielle pour les gestionnaires chargés de l'élaboration de plans en vue de l'aménagement du rivate, de l'utilisation des terres et de la régularisation du niveau du lac.

1 INTRODUCTION

Pointe-aux-Pins, or Rondeau Peninsula, is a rounded cuspate foreland protruding some 7 km southward from the north shore of Lake Erie (Fig. 1). From its junction with the shoreline, the eastern limb of the cuspate foreland widens from approximately 0.5 to 2 km near its southern extremity. The southwestern limb, however, is much narrower (less than 100 m in places), and is occupied by the town of Erieau. The entire foreland covers approximately 50 km^2, 60% of which comprises an enclosed area of pond and marsh, Rondeau Bay. The bay is less than 4 m in depth, and much of the marsh that once existed along its northwestern shore has been drained for agricultural purposes.

The broader eastern limb of the foreland comprises a wooded beach ridge - dune complex, made up by a large number of sub-parallel ridges trending northeast to southwest, alternating with marshy swales, well-defined on aerial photographs (Fig. 2). These ridges are usually less than 5 m in height and are believed to have originated as storm beach ridges. The eastern limb of the foreland and the enclosed lagoon make up Rondeau Provincial Park.

1.2 Previous Work

A comprehensive literature search and bibliography on Pointe-aux-Pins was prepared under contract to Division of NWRI (Mann and Coakley, 1978). Most of the early references comprised engineering reports dealing with either the construction of harbour works, or with shore protection. The earliest scientific attempt to interpret the origin and evolution of Pointe-aux-Pins was by Wilson (1908), in which he cited the growth and eventual merging of two simple spits (growing in opposing directions) as the mode of formation. These merging spits were purportedly nourished from materials eroded from adjacent shorelines on both sides. A similar genetic scheme, involving deposition from opposing littoral drift sources was repeated by Wood (1951) and by Warren (1974). Wood was the first to link the system of linear ridges noted on the foreland to successive shoreline positions occupied as the east limb prograded lakeward. None of these writers took into consideration the possible role of glacial geology or lake level history in their genetic theories, nor otherwise explained why the foreland was formed at that particular place on the shoreline. Furthermore, became radiocarbon dates or pollen stratigraphic data were lacking in the area, so good estimates of the age of the foreland were questionable. Published ages range from older than 2300 years (Stothers, 1972) to 9000 years (Warren, 1974). Rukavina and St. Jacques (1978) placed the origin of Pointe-aux-Pins at 4000 years B.P.

Studies on the bottom sediments and glacial history of Lake Erie as a whole were initiated by Lewis (1966). More recently, surveys of nearshore bottom sediments in the Pointe-aux-Pins area were conducted by Rukavina and St. Jacques (1978). Rukavina (1983) compiled a more specific data record for the area around the foreland, consisting of bottom sample descriptions, short cores, and jetting probes into the subsurface material. Deeper borehole information in the area was provided by Lewis et al. (1973) on a series of sites to the southeast of the foreland. Further interpretation based on these boreholes appears in Creer et al. (1976), Davis (1979), Fritz et al. (1975), and Zeman (1979).

Other borehole drilling on the point itself was carried out by the Ontario Geological Survey (A.J. Cooper, personal communication 1982); Trow, Ltd.; Golder Associates; and Public Works Canada. Most of these borings were primarily for engineering and water supply purposes, and were not subjected to any geological interpretation. The water well logs used here were provided by the Ontario Ministry of

the Environment (London, Ontario). The kind assistance of these agencies is gratefully acknowledged.

2 DESCRIPTION OF DATA BASE

2.1 Sediment Data

The sediment data base comprises bottom sediment maps and subsurface profiles in the Pointe-aux-Pins area. The quality of the data compiled, and the accuracy of the sediment identification and description vary considerably, especially in the case of the engineering and water-well-log data. Therefore, although the geological interpretations given below (unless otherwise indicated) are the author's alone, as much of the base data as possible are included for independent assessment.

2.1.1 Bottom Sediments

Figure 4 shows the distribution of nearshore bottom sediment types close to Pointe-aux-Pins as reproduced from Rukavina and St. Jacques (1978). The distribution map is based on surface samples taken on a 2 km square grid, bottom photographs, and interpretation of north-south echosounder traverses run at 1 km spacing in the area.

a. Glacial till. The dominant bottom sediment type is glacial till, which crops out extensively off the southwestern shore of the foreland. A deposit of comparable size also occurs off the northeastern end. The till, though unidentified by Rukavina and St. Jacques (1978), is probably similar to the material identified by Creer et al. (1976) and Cooper (1977) as the Port Stanley Till, a clay-rich till deposited during the Port Bruce Stadial (about 14,000 years B.P.)

b. Glaciolacustrine clay. Though presently represented only in one small outcrop to the south of Pointe-aux-Pins and in an area to the west, these sediments appear to have originally overlain the glacial till. Subsequent erosion by wave processes has apparently removed the deposit from most of the area. These sediments are stiff clays, often laminated, and generally associated with the youngest high-level glacial lakes (Whittlesey to Warren, and their successors) which occupied the basin intermittently until around 12,500 B.P.

c. Postglacial and modern sediments. These sediments, comprising soft, silt/clay mixtures (mud, silt) in the deeper areas of the nearshore zone and grading shoreward into sandy mud and clean, sorted sands adjacent to the shoreline, are restricted to the eastern and southern portion of the area. On land the surface sediments consist of sorted sands (originally beach-deposited, but later modified by wind-related processes) and fine-grained organic sediments (muck) in the sheltered lagoonal and inter-dune topographic lows.

2.1.2 Nearshore subsurface sediments

Resolution of the vertical sequence of subsurface lake sediments was based mainly on long boreholes drilled approximately 20 km south-east of Pointe-aux-Pins (Lewis et al., 1973; Creer et al., 1976), and on short gravity cores and water-jet probes in the shallower areas (Rukavina, 1983). A 1 m long Benthos gravity core (LE81-19) taken by the author provided additional information, as did a 9.2 m piston core collected in 1977 by the University of Western Ontario (F-15). The location of these sample sites is shown in Fig. 3.

According to Creer et al. (1976), the lake bottom sediments at the long borehole sites were composed characteristically of glacial materials (glacial till overlain by glaciolacustrine clay) in the bottom portions of the cores, disconformably overlain by 9 m or less of postglacial materials (lacustrine mud). At depths less than 28 m below lake datum (173.3 m a.s.l.), Lewis et al. (1966) noted a thin zone of coarser sand and shells overlying the glacial sediments. This is clearly a lag concentrate of the coarser sediment fraction less easily transported by bottom currents. Shoreward and toward the west, the postglacial sequence thins considerably (by apparent truncation of the glaciolacustrine layer), and modern sediments directly overlie glacial till.

At the bottom of core LE81-19 (Fig. 3) collected from a depth of 23 m, a 10 cm thick layer was noted, which was made up of anomalously coarse materials (sand, fine gravel, shells, and oxidized wood fragments). The upward transition to fine, soft muds is gradational. Although the underlying material was not sampled in the core, its position atop the south-trending ridge (labelled the Erieau Moraine by Sly and Lewis (1972)), together with echo-sounder evidence, suggests that glacial till underlies the core materials. The coarse layer is clearly a lag concentrate deposit, indicating a period of differential removal of the finer fraction, presumably in shallower, more wave-agitated water. The texture of these basal sediments suggests strongly that when deposited, the water was much shallower than the present 23 m depth.

A large wood fragment collected from this layer was dated at 3140 ± 110 years B.P. (Before Present) (WAT-946) (Table 1). A radiocarbon age of 7000 ± 370 B.P. (WAT-970) was obtained on shells collected from the same layer. The large age discrepancy might be explained by the presence of highly calcareous silt matrix surrounding the shells, leading to contamination of the dated sample by "old" carbon. However, the two ages could also represent the time interval over which the lag deposit was developed, i.e., during conditions when water depths were probably less than 10 m below present levels.

2.1.3 Land-based boreholes

Figure 1 shows the location of 23 boreholes drilled on Pointe-aux-Pins itself, of which 22 were for non-geological purposes. The logs from these holes were nonetheless detailed enough to permit their use in geological interpretation. The other borehole, labelled OGS-1, formed part of the geological mapping and research work carried out by the Ontario Geological Survey (Cooper, 1977). The vertical sedimentary sequence noted in these boreholes generally consisted of clean, sorted sand and gravel (up to 10 m thick) overlying glacial sediments (Fig. 6). There were no clear signs of either a transitional unit (interlaminated fine sand, silt and clay) below the sorted sand unit, or a coarsening upward sequence in the postglacial sediments as was noted at Point Pelee and Long Point (Coakley, 1985). In the more shoreward areas where the foreland joins the mainland, however, layers of organic material or fibrous peat up to several metres thick occur below the sorted sand unit. Below the eastern limb of the foreland, this peat layer occurs at an elevation of 8 to 10 m below datum (b.d.), while below the southwestern limb, several such layers are preserved at elevations of 5, 2, and 0 m, i.e., at the datum level.

The peat layer below the eastern limb of the foreland overlies the glaciolacustrine clay substrate in the landward areas, and softer, apparently postglacial muds on the lakeward side. Below the southwestern limb, the upper peat layers are enclosed within the sorted sand unit, while the lowest layer overlies glacial sediment. The lateral extent of these peat layers could be traced for some distance below Rondeau Bay sediments (D.A. St. Jacques, unpubl. data, 1982).

2.2 Physiographic Aspects

2.2.1 Postglacial surface topography

The glacial sediment (till) surface below Pointe-aux-Pins demonstrates an abrupt rise below the town of Erieau (Fig. 6 B-B'). The till surface rises from lower than 10 m b.d. in the eastern portion of cross-section B-B', to 5 m or less, below Erieau and Rondeau Bay. This positive feature is also continuous with abathymetric high immediately to the south, the subsurface glacial sediment high interpreted at the site of core LE81-19 (Fig. 3), and is apparently linked with the sand-capped bathymetric high mapped by Carter et al. (1982) off Fairport, Ohio (Fig. 3). This evidence supports the interpretation of Sly and Lewis (1972) that the feature is the topographic expression of the cross-lake Erieau moraine (Fig. 3).

The glacial sediment surface offshore down to 40 m b.d. rises gently shoreward and is directly overlain in many areas by a thin coarse lag concentrate (Lewis et al, 1966; Davis, 1979). Below the east limb of the foreland itself, the glacial sediment surface is virtually level at approximately 10 m b.d. Both the gentle slope and the lag deposit are clear indications of a considerable period of wave abrasion in relatively shallow water. In the nearshore zone, the glacial sediment surface just to the east and south of Pointe-aux-Pins and also on the east flank of the Pelee Shoal area to the west shows a sharp break in slope at around 15 m b.d. (Rukavina and St. Jacques, 1978, Fig. 8). This feature is interpreted here as an "erosion notch", indicating a previous shoreline position.

2.2.2 Relict beach ridges on Pointe-aux-Pins

Apart from the inferred topography of the glacial sediment surface, another important physiographic indicator in the evolution of the Pointe-aux-Pins foreland is the well-preserved series of relict beach ridges (now dune-capped) which occurs on the eastern limb of the foreland (Figs. 1, 2). Close inspection of the planform and orientation of these linear features suggest the following:

a. The eastern limb of the foreland is migrating eastward, while the southern limb is receding northward. This is inferred from the large number of these ridges preserved in the former, and in their absence in the latter. In addition, modern rates of change for the southern shoreline averaged between +0.5 and +1.0 $m \cdot y^{-1}$ for the eastern limb (Boulden, 1975).

b. Except for the most easterly (and presumably younger) ridges, all are truncated at high angles by the present south shore. This suggests strongly that they once extended much further southward.

c. The directional trend of the westernmost (oldest) ridges is considerably more southwest than the present ridges, which trend almost north-south. The angle between these ridges is now more than 30°.

d. The transition from the older western ridges to the younger ridges to the east follows three distinct stages, labelled, A, B, and C in Fig. 1. Stage A, the oldest, is characterized by a linear to concave-lakeward trend. The point of rotation for the ridges in this stage is more or less fixed in location (point D), about 5 km south of its present position (point E). Stage C represents the present-day pattern, with beach ridge orientation at close to north-south. The ridges also show a definite convex-lakeward form in the more southerly areas, but change to concave-lakeward near their northern junction with the mainland.

The ridges appear to merge smoothly with the original (relict) shoreline, now separated from the lake by the beach accretion associated with foreland growth. Stage B marks the transition between the two stages above, and is characterized by sharp increases in concavity (lakeward) of the ridges, and by their sharp truncation by the younger stage C pattern.

e. The projection of the oldest identifiable ridge eastward passes to the south of borehole OGS-1, the southernmost point in which the peat layer was noted. Because this peat is probably of coastal marsh or lagoonal origin, it was likely deposited behind the earliest beach barriers to develop at the site of Pointe-aux-Pins. Thus, this projected beach ridge could correspond to the original shoreline of the foreland, and the radiocarbon age of the peat (averaging 5250 years) could place the minimum date of this event. This initial assessment will be discussed further in Section 3.2.

2.3 Postglacial Stratigraphy

The change in sedimentation noted in vertical sediment sequences from the Pointe-aux-Pins area can provide useful information on postglacial evolution in the Lake Erie central basin. This information would be much improved if reliable time-stratigraphic markers can be established in the sediments. The most useful and available markers are absolute radiocarbon dating of incorporated organic materials and relative dating by correlation of the fossil pollen profiles obtained with radiocarbon-dated sections from elsewhere in the Lake Erie area.

2.3.1 Radiocarbon dates

Table 1 presents a compilation of radiocarbon dates published (or made available from unpublished sources) in the vicinity of Pointe-aux-Pins. The dates listed were extracted from a more comprehensive listing of available dates in the Erie basin (Coakley and Lewis, 1985). The sites are plotted in Figure 3. The dates range from as old as 10,200 ± 180 years (GSC-330) on driftwood deposited in offshore muds (Lewis et al., 1966), to 3140 ± 110 years B.P. (WAT-946) taken on wood in a clayey, pebbly matrix below the modern soft muds in LE81-1a, about 15 km south of Erieau. The most important date was otained from peat below the eastern limb of the Point (WAT-378, WAT-379) at OGS 1 (dates no. 2 and 3 in Table 1). With the exception of the latter, all the dates were on material from fine-grained sediment, and thus were presumably related to organic material that moved down slope and was deposited in waters of some depth, rather than at the water-line. One date (5) was on shell material, and given the calcareous nature of the fine matrix, some contamination with inorganic (very old) carbonate carbon could account for its greater age compared to wood taken from the same position (4). The interpretation of these dates in terms of the lake level history of the area will be discussed in a later section. Insofar as sedimentation history is concerned, however, the relative scarcity of dates near the Point, limits the conclusions to be drawn to the following:

- Sedimentation of fine-grained material in the central sub-basin at the site of date (1) was occurring more than 10,000 years ago.
- The site of (2) was probably occupied by a coastal marsh (sheltered water) around 5200 years ago. Before that time, sedimentation at this site consisted of gray clayey silt with only minor organic matter.

2.3.2 Pollen stratigraphy

Pollen studies were published on cores taken from the central basin (Lewis et al., 1966 (Core 2226); Fritz et al., 1975 and Creer et al., 1976 (Core 13194)). The locations of these sites are shown in Figure 3. Interpretation of these authors regarding sedimentation trends in the area may be summarized as follows:

- The site of core 2226 probably stood above water at the time of the low-water stage in the basin (Early Lake Erie, approximately 12,500 years B.P.), judging from the lack of the basal non-arboreal (grass, herbs) pollen zone noted in more pollen profiles from the western basin.
- The pollen record at site 13194 revealed a more pronounced break in sedimentation lasting from around 12,500 to almost 8000 B.P. This break suggests a rather prolonged period of subaerial exposure of the glacial surface, or at least a similar period of non-deposition in rather shallow water (probably less than 5 m deep).
- In the soft postglacial muds making up the top portion of core 13194, a sharp rise in non-arboreal pollen was noted (T.W. Anderson, Geol. Survey of Canada, personal communication, 1982). Anderson correlated this rise with the abrupt influx of marsh pollen into the central basin at the time of the Nipissing drainage resumption into Lake Erie, which was estimated to have occurred around 5500 B.P. (Lewis, 1969)

3 RECONSTRUCTION OF THE POSTGLACIAL EVOLUTION OF THE POINTE-AUX-PINS AREA

By interpreting the above data, a reasonable picture of trends in lake levels (water depths) with time can be reconstructed. This interpretation can be combined with data on the elevation of the glacial sediment surface (2.2.1) to allow a reconstruction of the local shoreline evolution. Finally, by relating these shoreline patterns to the patterns of beach ridges on, and sediment profiles below Pointe-aux-Pins, the evolutionary sequence of this landform may be hypothesized.

3.1 Lake Erie Water Level History

The stratigraphical and geomorphological data described in the previous section, in combination with data from other parts of Lake Erie, were used by Coakley and Lewis (1985) to deduce the post-glacial history of water levels in the Erie basin (Fig. 5). Such an interpretation of lake levels is crucial in the reconstruction of the geomorphological evolution of the Point-aux-Pins foreland over this period of time. The relevant parts of this history are summarized below.

Lake levels in the three major sub-basins of Lake Erie during the Early Lake Erie stage (12,000 to 10,000 B.P.) apparently behaved in a rather complex manner, with inter-basin sills operating to maintain different levels in each sub-basin. The lake level history interpreted by Coakley and Lewis (1985), shown in Fig. 5, was based primarily on radiocarbon dates from the western sub-basin. In central Lake Erie, no radiocarbon dates corresponding to this initial period are available, so the original lake level had to be inferred from evidence such as the lower limit of the wave-eroded glacial sediment surface and the depth of the buried channel through the Norfolk moraine to the east. These indicate an initial level of approximately 30 m or more below present datum (Lewis, 1969).

From this elevation, lake levels rose relatively steeply in pace with isostatic rebound of the Niagara outlet, and the increasing inflows from glacial Lake Algonquin, then occupying the Upper Great Lakes. Levels in all sub-basins probably became confluent around 10,000 B.P. This phase of rising levels ended when retreat of the glacial ice opened lower northern outlets for Lake Algonquin, thus cutting off inflows from the upper lakes. When this effect is added to the drastically reduced rates of uplift at the outlet of the lake and climatic improvement throughout the region, it is conceivable that lake levels in the Erie basin might even had declined somewhat between 8000 and 5000 B.P. In fact, the scatter in the dated elevations suggests a relatively wide fluctuation in lake levels, possibly ranging from 5 to 15 m below datum (Coakley and Lewis, 1985). This overall reduced trend continued up until around 5000 B.P. by which time levels had reached approximately 5 m below present datum.

Between 5000 and 4000 B.P., the curve shows an abrupt rise to levels as much as 5 m above present datum. This rise is postulated mainly on the basis of data from eastern Lake Erie (Barnett, 1985). The rise was apparenty short-lived, and by around 3500 B.P., levels had fallen again to 3 to 5 m below datum. From this time, lake levels rose in a uniform fashion to their present position.

3.2 Reconstruction of Shoreline Positions, Central Sub-Basin

In reconstructing initial shorelines, it must be kept in mind that of all the Lake Erie sub-basins, the central sub-basin has likely been the most altered by postglacial lacustrine processes.

Unlike the other sub-basins, which are smaller and have bedrock close to the surface, this sub-basin was, from its inception around 12,500 years ago, a relatively large (approximately 7000 km^2) body of open water of less than 20 m depth. Thick glacial deposits also formed the shore. Intense postglacial erosion would account for the present low topographic expression of the cross-lake Erieau moraine and the prominent wave-abraded platform below the modern sediments along the north perimeter of the sub-basin noted by Lewis (1966). This relatively intense erosion and the occasional subaerial exposure of the nearshore platform (Davis, 1979; Lewis, 1966) are likely reasons for the scarcity of identifiable relict shorelines along the north and south edges of this sub-basin.

For this reason, I have had to use a combination of available stratigraphic data and inferences based on the intersection of the lake level plane with the original glacial sediment surface in the area in reconstructing the following shoreline positions. The reconstruction was made somewhat easier because it was not necesary to take differential isostatic uplift into account since the part of the sub-basin in question was located well to the west of the "hinge-line" for Early Lake Erie (Leverett and Taylor, 1915).

3.2.1 Reconstructed glacial sediment surface

Combining Lewis' (1966) interpretation of the topography of the glacial sediment surface (Early Lake Erie stage) with the borehole and core data described in Section 2.1, echograms from Rukavina (1983) and other sources, as well as seismic and vibracore data from Carter et al. (1982), an updated version of this original surface could be compiled for this area (Fig. 7). Sources of data used are also shown on the figure.

An effort was made to allow for the undetermined (but significant) amount of downward erosion that the surface has undergone especially in those areas close to shore. Two cross-sections (D-D', E-E') were drawn across the lake immediately west and east, respectively, of Pointe-aux-Pins (Fig. 8). It was then assumed that the present hinterland surface had not changed significantly (i.e., ignoring surface modification processes such as solifluction and subaerial erosion, for example), and that the glacial surface in the deeper offshore areas of the profile had been preserved in its original position by the initial postglacial sedimentation. The original glacial sediment surface in the apparently eroded areas in between could then be interpolated by connecting these surfaces with a smooth line (Fig. 8). This technique allowed me to prepare a contour map of the reconstructed postglacial surface in the central sub-basin of Lake Erie. Because this approach takes bottom erosion into account, it provides a more realistic picture of the initial postglacial sediment surface than other attempts (Lewis, 1966) using the present glacial sediment exposure.

3.2.2 Evolution Pointe-aux-Pins: 12,000 to Present

Data from Figure 5 on lake level history, when combined with the reconstruction of the topography of the original surface onto which Early Lake Erie was impounded, allow us to locate the initial shoreline at the 30 m depth contour (Fig. 7). This provides the starting point in reconstructing the evolution of Pointe-aux-Pins. This exercise must rely greatly on inference and hypothesis, as there are few precise indicators preserved that may be used in the reconstruction. The indicators having the most weight are:

- The morphology and changing orientation of the relict beach ridges visible on the eastern limb of the Point (Figs. 1, 2);

- The nature of the sub-bottom till and glaciolacustrine sediment surface, including the till high (~5 m b.d.) below Erieau and the very flat, almost-level, abraded glacial surface below the Point at approximately 10 m b.d. (Fig. 6);
- The subsurface peat deposit at 8-10 m b.d. at O.G.S. 1, having a C-14 age of around 5350 B.P.;
- The interpreted "erosion notch" at approximately 15 m b.d. to the east and south of Pointe-aux-Pins (Section 2.2.1.).

a. 12,000 to 8000 B.P.: The Erieau Moraine (Fig. 3) marks a stop made by the retreating Erie lobe of the Laurentide glacier, probably during the Port Bruce stadial. It is likely that, concurrently with the construction of the moraine, streams draining both the glacier and the hinterland to the north would flow along the ice-margin and would, over time, deposit large quantitites of sand as deltas at the northern end of the moraine. Examples of these ice-margin deltas were interpreted in association with the Norfolk moraine to the east (Barnett, 1985) and eroded remnants of large sand eposits occur almost exclusively in shoreline sections immediately west of all three Lake Erie forelands: Point Pelee, Long Point, and Pointe-aux-Pins. The combination of cross-lake moraines and large sand deposits updrift (with reference to the prevailing wind and wave direction) was probably instrumental in the formation and evolution of all these forelands.

After the inception of Early Lake Erie, the Pointe-aux-Pins area was probably occupied by a broad till-cored promontory, representing the surface expression of the Erieau Moraine. The tip of this foreland probably extended some 20 km further south than at present, and served as the focus for large-scale accumulation of sand derived from the deltaic deposits to the west and from local shoreline erosion in general.

During the period of rapid lake level rise (12,000 to 8000 B.P.), the dominant evolutionary trend is expected to have been the reduction in foreland areas and a net shoreward retreat. As levels stabilized, erosional shoreline features such as the "erosion notch" at around 15 m b.d. mentioned above were probably cut. The more stable levels then prevailng would have allowed further accumulation of drifted sand along the sides of the foreland, leading to the development of beach ridges and dune fields above lake level. At this time, maximum wave fetches (and greatest wave energy), would probably have been from the east, so the dominant littoral drift was likely from the east, around the tip of the foreland, to the more sheltered southwest-facing side. The result would be the eventual transformation of the till-cored promontory into an asymmetrical cuspate foreland, probably with an elongated sand spit at the end as is the case at Point Pelee. Although no peat dating back to around 8000 B.P. was encountered in OGS-1, the elevation of the peat found (approx. 9 m b.d.) is close to the lake level at that time, prompting the conclusion that a stream valley or lowland was located inland from the eastern side of the foreland (Fig. 9A).

b. 8000 to 4500 B.P.: The slower rate of lake level rise allowed the quasi-level nearshore platform off the eastern limb of the foreland to be eroded as the shoreline retreated. In the meantime, increasing wave fetch distances to the southwest (due partly to the development of Sandusky Bay) resulted in a shift in the predominant littoral drift direction from westward to eastward. The postulated large sand deposit west of Pointe-aux-Pins then probably served as a major supply for sand transported around the Point to the east-facing side. The orientation of the earliest beach ridges (Figs. 1, 2) supports this hypothesis. Furthermore, by 5000 B.P., marsh vegetation (destined to become the peat sampled in OGS-1) was established in the low-lying ponds or drowned stream valley located behind the beach ridge at the OCS 1 site. By around 5000 B.P., Pointe-aux-Pins probably appeared as sketched in Figure 9B.

c. The Nipissing "flood", ca. 4500 B.P.: Evidence from C-14 dated samples in the Erie basin suggest strongly that at around 4000 B.P., lake levels rose to about 5 m above datum (Fig. 5). The result of such an event would be the whole-scale drowning of much of the low-lying dunes and beach ridges then making up the Pointe-aux-Pins foreland. Depending on the elevation of the foreland, the site would then have been occupied by either a shoal or a low island (Fig. 9C). The more open-water conditions might have contributed to the development of the gently-sloping platform in the glaciolacustrine sediment surface below Erieau (Fig. 6). Most of the sand submerged by the rise would be dispersed in the area in the form of a sand-covered shelf, or spit platform (Meistrell, 1966).

One question that might be asked concerns the lack of any clear erosional or shore-related feature on topographic maps at around the 178 m (a.s.l.) contour, i.e., about 5 m above present datum. Perhaps the period involved was too short to leave a permanent record, or the offshore island/shoal provided sufficient protection from wave erosion.

d. Modern Pointe-aux-Pins, 3500 B.P. to Present: By 3500 B.P., however, lake levels had returned to close to their pre-"flood" positions. Parts of the spit platform were again exposed to shallow-water wave action, and storm-beach barriers gradually developed at the site. This marked the beginning of the modern Point-aux-Pins foreland (Fig. 9D), originally consisting of a straight-to-convex-lakeward beach barrier, facing southeast, and, facing the shorter fetch to the southwest, a lower, concave-lakeward barrier though which an inlet into the marsh was probably located. A possible contributory factor to the barrier development was the concurrent flooding and change in orientation of the ancestral Long

Point foreland to the east (Coakley, 1985), which would increase the wave energy from the east and accelerate erosion of bluff shorelines to the east of Pointe-aux-Pins.

As lake levels rose again from their post-Nipissing lows in response to uplift of the lake outlet, waves from the east and south east were still dominant, and with the abundant littoral drift supplied by the eroding bluffs to the east, the east side of Pointe-aux-Pins was able to maintain its position, and perhaps, to grow lakeward slowly. Subsequent barriers became more concave lakeward, indicating the inputs of sediments derived from the west as well, in other words, building out the eastern barrier at its southern extremity as well as at the base (Fig. 1, stage B). The south-facing barrier, however, being located at the updrift end of the next (west) shore reach, apparently received insufficient sediment supplies from either side to maintain its position, and continued to transgress shoreward. The sheltered lagoonal area between the barriers expanded as levels rose, and marshes began to grow along the lee side of the south-facing barrier (now found as peat at elevations of around 3 m b.d. in the cores near Erieau, Fig. 6).

From around 2000 B.P. to present (Fig. 9E,F), the principal morphological developments at Pointe-aux-Pins were the gradual shift in the orientation of both sides with changes in the direction of maximum fetch distances and wave energy from the east and west. The east-facing barrier grew, by accreting beach ridges, to become aligned more north-south as developments at Long Point and embayment by erosion of bluff shorelines to the east increased the fetch of east, rather than southeast,waves. Similarly, the expanding area of the Sandusky Bay area (on the Ohio shoreline directly south of Point Pelee) served to increase wave fetches from the south - southwest, resulting in a more east-west orientation of the south-facing barrier of Pointe-aux-Pins.

Littoral supplies of sand had by now apparently declined cosiderably, and although the eastern barrier was still accreting lakeward, it appeared to be doing so more at the expense of the low, rapidly retreating southern barrier, than as a result of inputs from the adjacent bluff shoreline. The ongoing modern recession of the south-facing limb of the Point (Boulden, 1975) and the lack of preserved beach ridges there indicate that this limb is a source of littoral sediment, while the prograding eastern limb is clearly a sink, i.e., a site of sediment accumulation. This is illustrated in the sharply defined truncation of the beach ridge system at its southern end, and in the more convex-lakeward form of the newer beach ridges of the eastern limb (Fig. 1, stage C).

3.3 Discussion and Summary

The above model of the postglacial evolution of Pointe-aux-Pins, though based on the best available evidence, remains only a hypothetical construct. Almost all of the indicators of previous shoreline position have apparently been obscured or obliterated by the subsequent transgression of lake levels and the resulting shoreline erosion, so a more factual presentation is not feasible at this time. Nevertheless, the above reconstruction of the evolution of this major landform along the Lake Erie shoreline is in agreement with what is known about the lake-level history, stratigraphy, and glacial geomorphology of the Lake Erie basin. Further investigation, especially in the form of more C-14 dates, is necessary in order to improve the reliability of the reconstructed sequences and their placement in time.

An independent way of assessing the approximate age of the foreland is to examine the present net annual sediment inputs to the Point, and compare this figure with the calculated sediment volume contained in the foreland. The only sediment now being added to Pointe-aux-Pins is littoral drift derived from the erosion of bluff shorelines and nearshore glacial deposits to the west and east. The section of shoreline serving as the sediment source extends from Port Alma in the west to Port Glasgow in the east (Fig. 3) (Rukavina and St. Jacques, 1978). Littoral sediments outside this reach move away from the Point. Rukavina and St. Jacques estimated the total annual sediment supply to Point-aux-Pins to be 38,000 $m^3 \cdot y^{-1}$ (17,000 $m^3 \cdot y^{-1}$ to the south limb and 21,000 to the east-facing limb). Because this figure is based on the total sand fraction in the source bluff material, including the fine 3 to 4 phi (0.125 to 0.062 mm) fraction that is rare in the present beach sediments, it is probably an over-estimation of the actual supply of spit-building materials. Also, a certain quantity of the littoral drift is continually being lost from the Pointe-aux-Pins littoral system by comminution or by one-way transfer to offshore deposits. Although these amounts cannot be estimated with any precision, they could result in the actual net littoral drift inputs being considerably lower than the above figures.

A good estimate of the total volume of sand-sized materials contained in Pointe-aux-Pins can be obtained using the cross-sections shown in Fig. 6. Because no tranverse sections were possible, the accuracy of the estimate depends greatly on the width assigned to the sand deposit. If an average width of 2 km is assigned to the east limb, 0.5 km to the south limb up to the harbour entrance, and 0.1 km for the remainder, then a figure of <u>195×10^6 m^3</u> is obtained. A reasonable error estimate for this figure would be around ±10%.

At a sand input rate of 38,000 $m^3 \cdot y^{-1}$ (Rukavina and St. Jacques, 1978), such a volume corresponds to an acumulation time of approximately 5100 years, assuming littoral drift as the sole source of the sand making up the point, and also that conditions and processes have remained constant. If pre-existing sand supplies from the original glacier-related deposits and the split platform are included, then the 3500 to 4000 year age proposed in Section 3.2.2 is well within reason, considering the imprecision inherent in the above figures.

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FIGURE CAPTIONS

Figure 1 Location map of Pointe-aux-Pins. Dots indicate location of boreholes used in the study. A,B,C,D,E refer to changes in beach ridge orientation discussed in text.

Figure 2 False-colour infra-red aerial photograph of Pointe-aux-Pins, showing complex pattern of accreting beach ridges on east-facing limb, and narrow barrier facing south.

Figure 3 Physiographic features of the Erie basin. Lake-based borehole and offshore coring locations referred to in text are also indicated.

Figure 4 Map of bottom sediments near Pointe-aux-Pins out to the 20 m depth contour (from Rukavina and St. Jacques, 1978).

Figure 5 Postglacial lake levels in the Erie basin (from Coakley and Lewis, 1985). Only dates and elevations from near Pointe-aux-Pins are shown; these are numerically keyed to Table 1. Arrows indicate the inferred direction to water surface and estimated depth of water at the time.

Figure 6 Vertical section through Pointe-aux-Pins along lines AA' and BB' (see Figure 1 for locations), based on the borehole and nearshore survey data (Rukavina, 1983).

Figure 7 Reconstructed postglacial topography in the central Erie sub-basin ca. 12,000 B.P. Shoreline position shown at approximately the -30 m contour by hatched pattern. Present shoreline is shown dashed. DD' and EE' are locations of vertical sections plotted in Figure 8. Location of contributing data sources is indicated by various symbols.

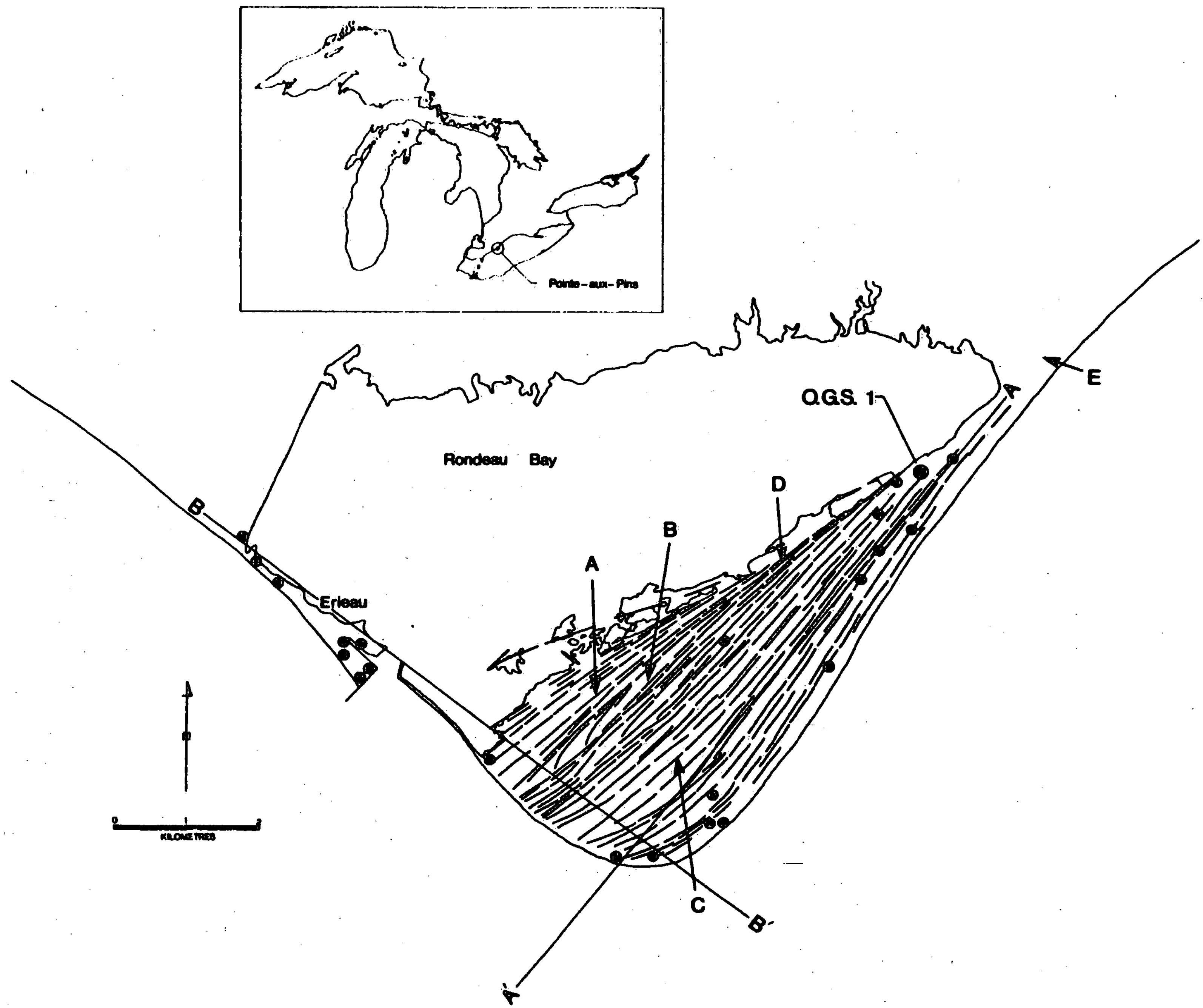
Figure 8 Vertical sections through central Lake Erie (see Figure 7 for locations) showing sub-bottom glacial sediment surface and reconstruction of original basin profile at time of Early Lake Erie.

Figure 9 Schematic reconstruction of stages in the evolution of the Pointe-aux-Pins foreland. Dots mark location of borehole OGS 1 and piston core LE81-19; present shoreline is shown dashed.

TABLE 1

List of C-14 dates in the vicinity of Pointe-aux-Pins

Reference No.	Elevation (m b.d.)	C-14 Age (y B.P.)	Laboratory No.	Material and Location
1	28.5	10,200 ± 180	GSC-330	Driftwood at base of offshore muds
2	6.3	5330 ± 250	WAT-378	Peat with shells and organic silt (OGS 1)
3	6.3	5180 ± 370	WAT-379	Peat with shells and organic silt (OCS 1)
4	23.5	3140 ± 110	WAT-946	Wood in shelly gravel below lake muds (LE81-19)
5	23.5	7000 ± 370	WAT-970	Shells from same layer as WAT-946
6	20.8	8250 ± 145	DIC-1329	Wood bits in muddy sand (Core 62, see Fig. 3)



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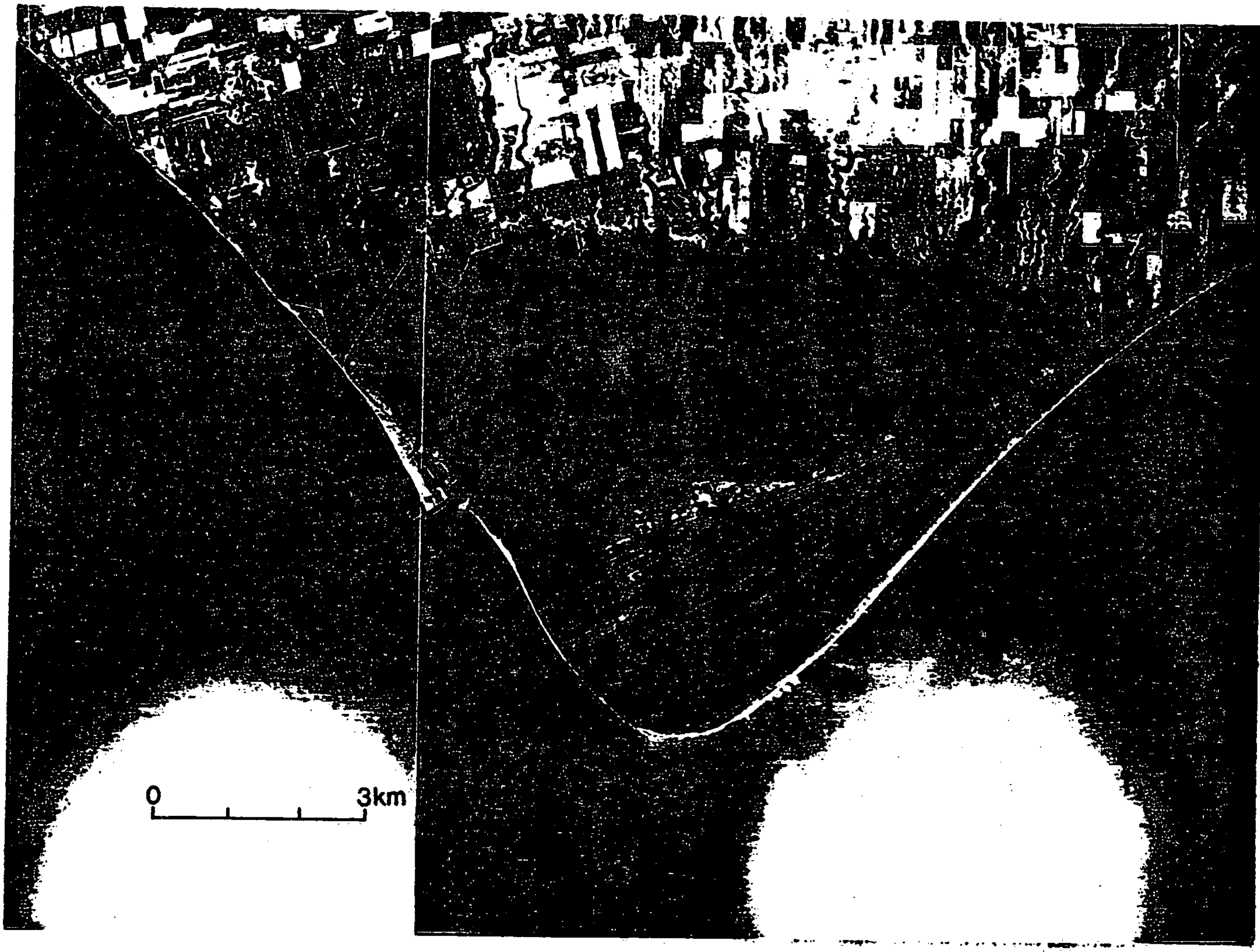

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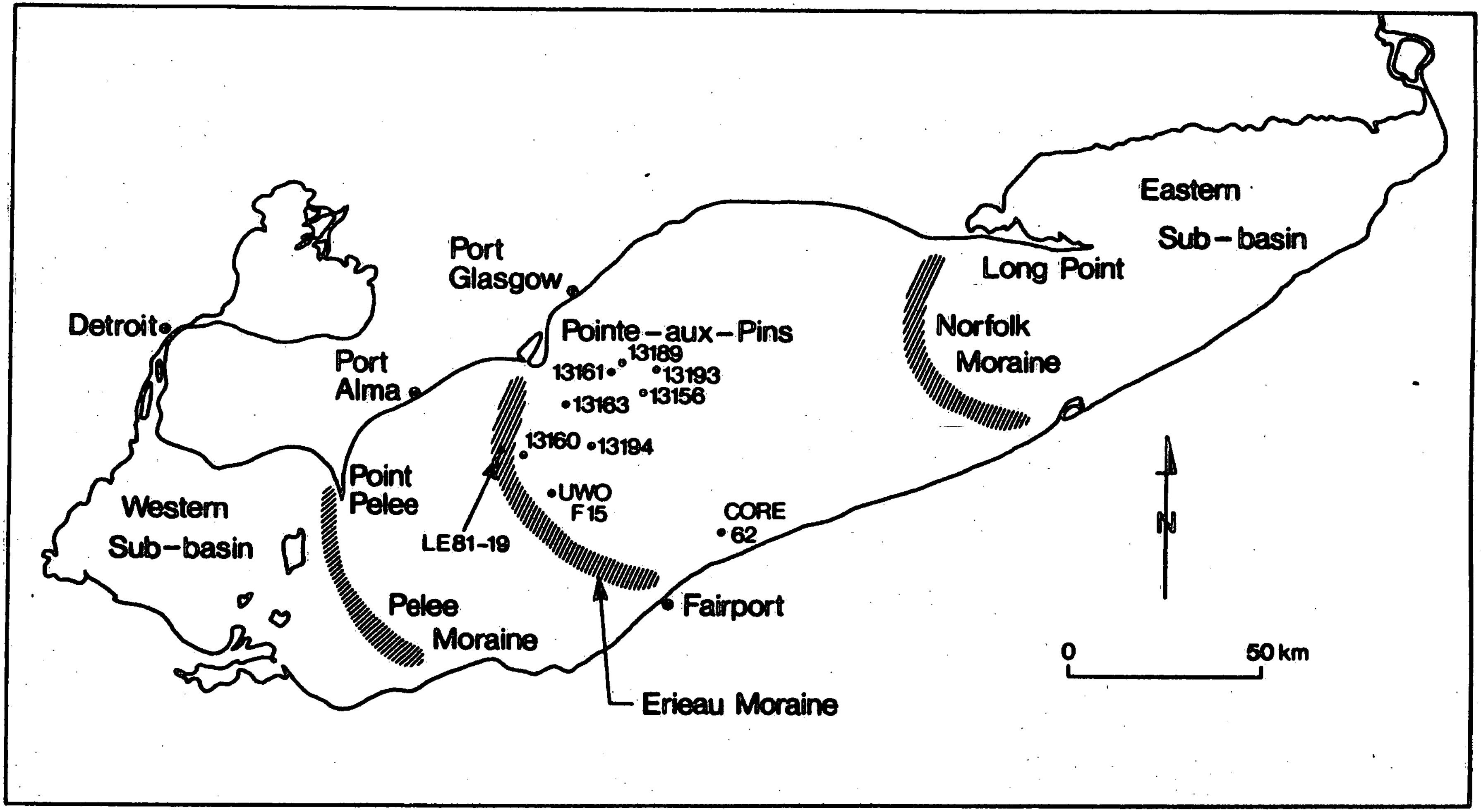

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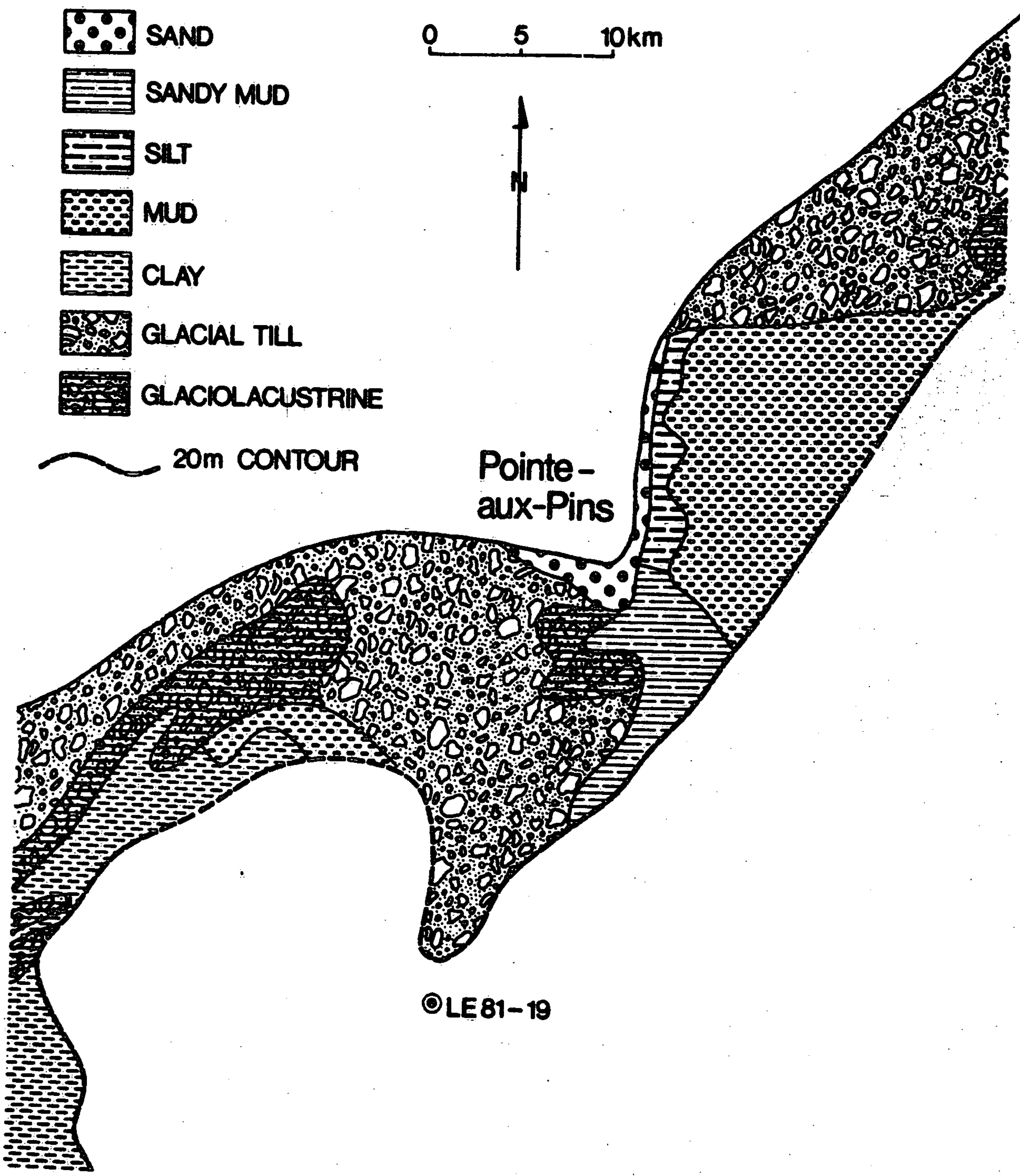

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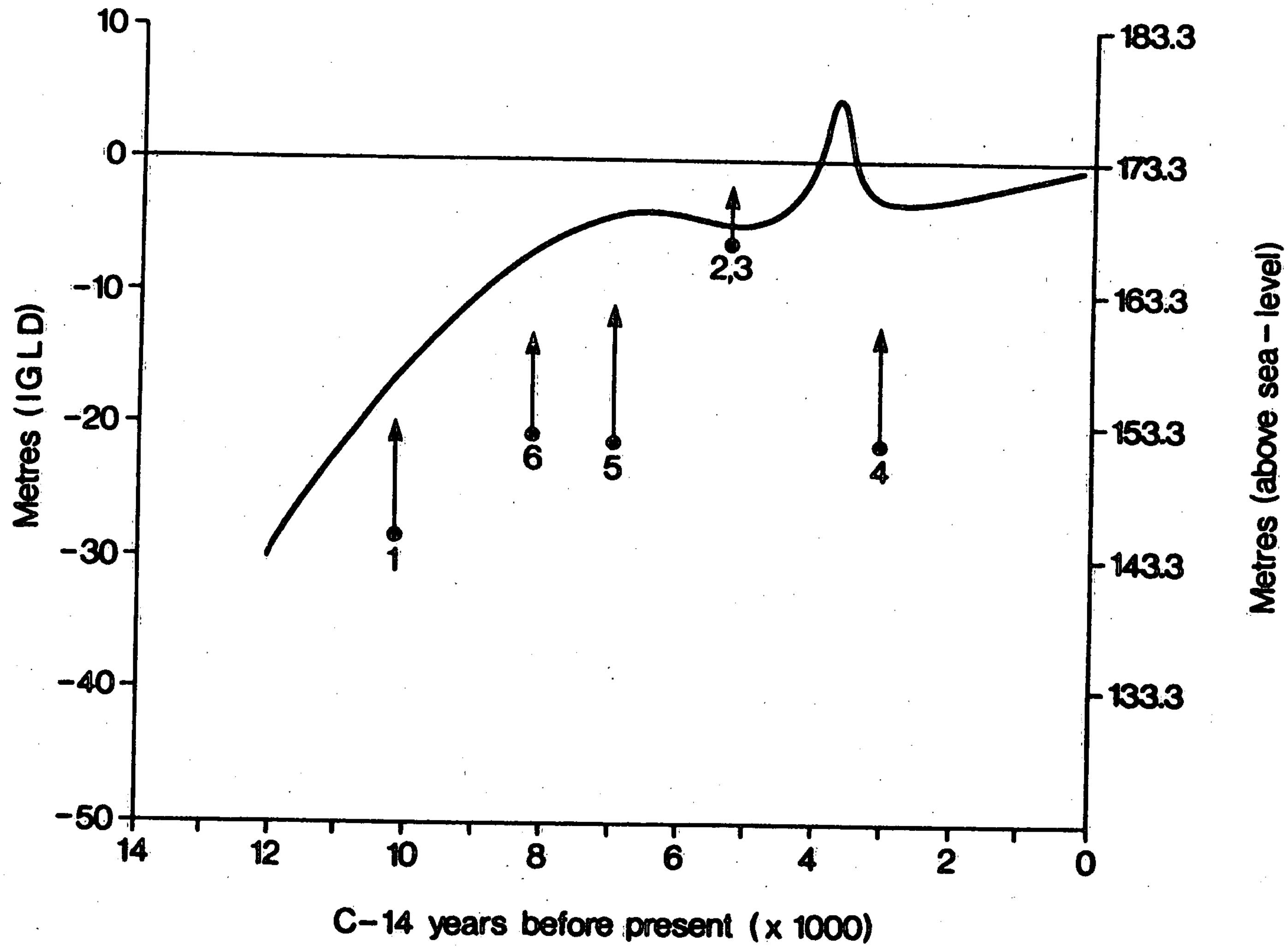

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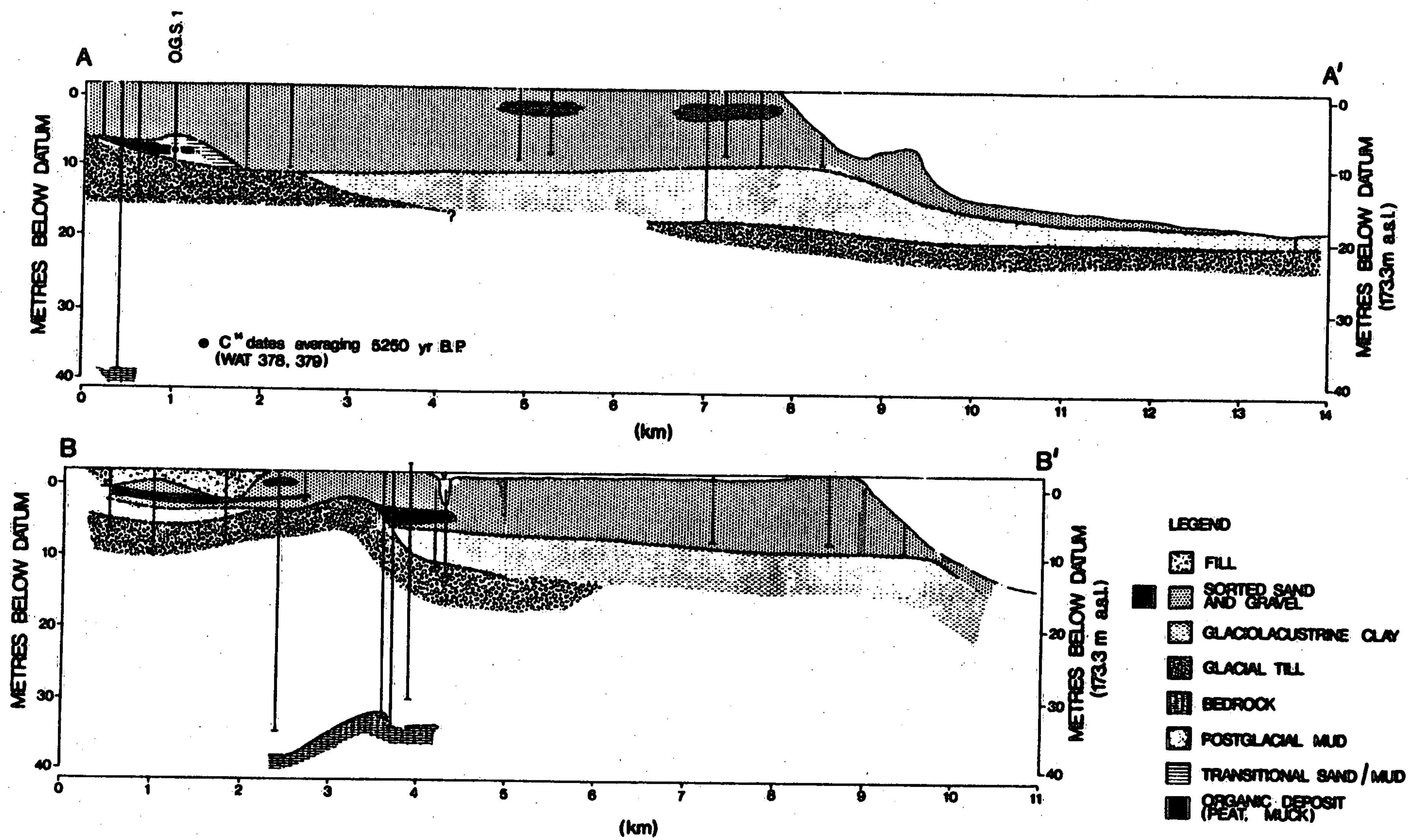

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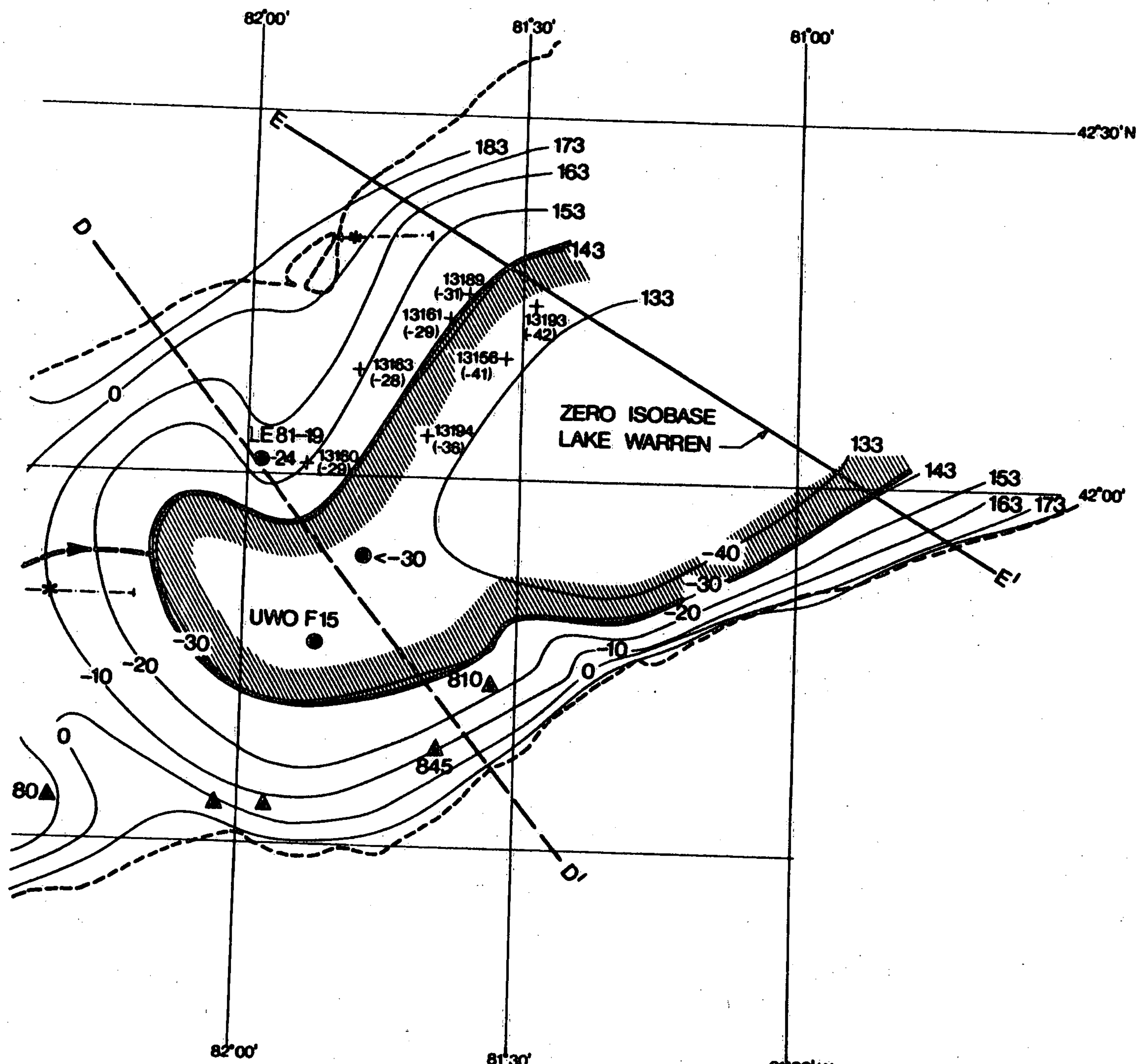

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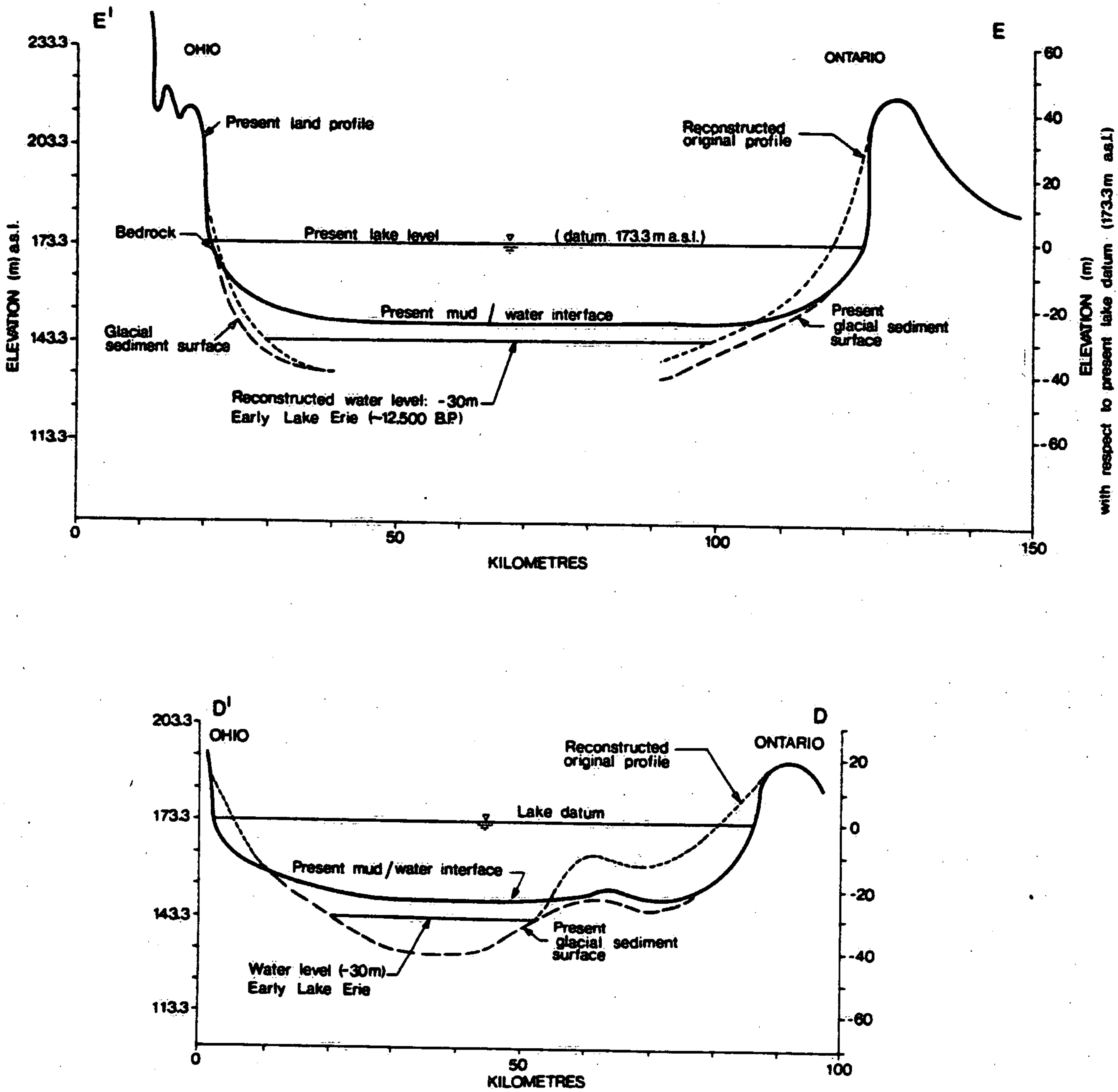

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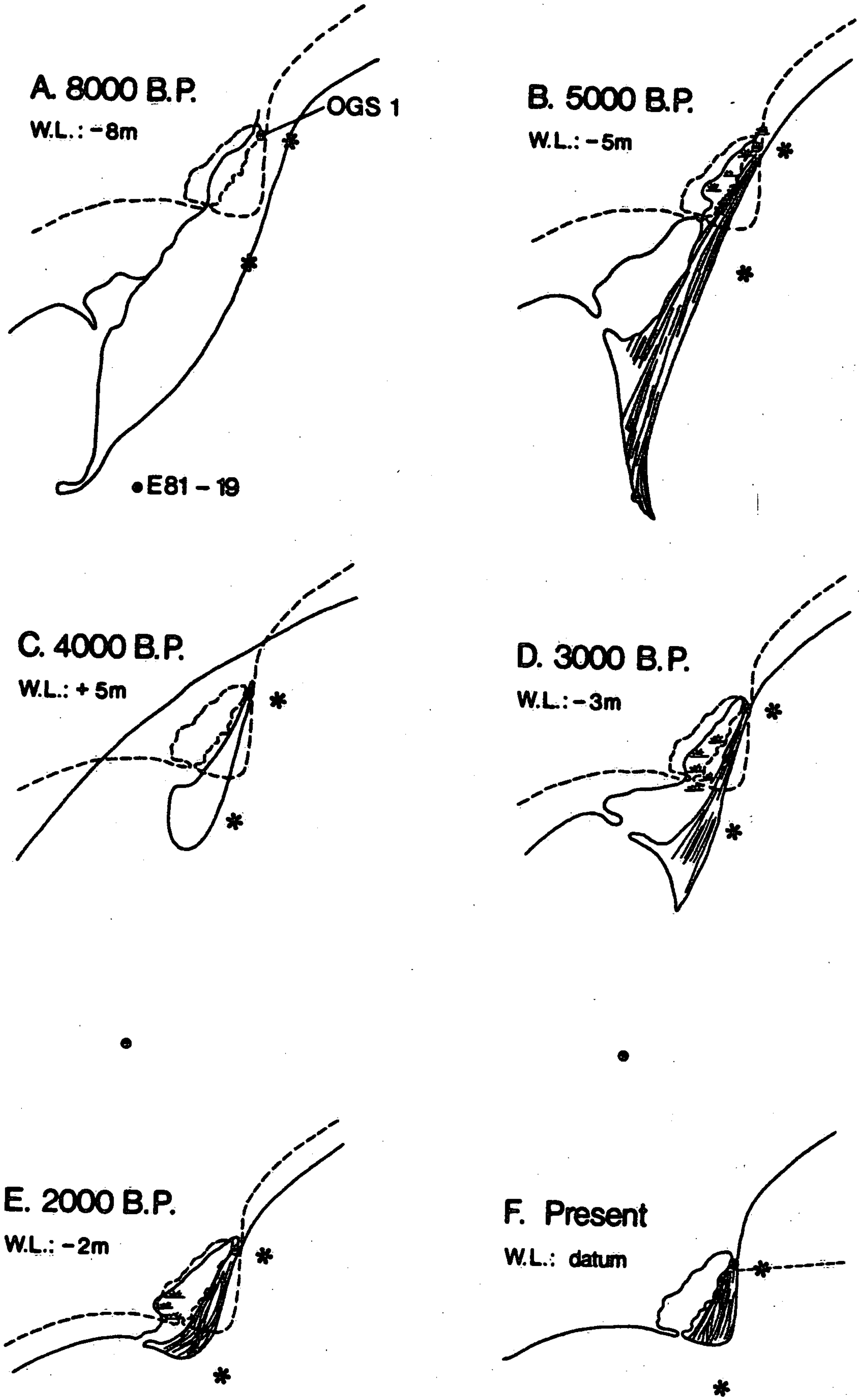

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