Nearshore Sediments of Lakes Ontario and Erie

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Abstract
Nearshore sediments of the lower Great Lakes consist of extensive exposures of glacial sediment and bedrock and relatively small, discrete deposits of postglacial sediment. Postglacial deposits are of two types: 1) residual sediments formed on the crests of submerged moraines by re-working and 2) deposits produced by the accumulation of littoral drift. Residual deposits are important in Lake Erie where they occur on the cross-lake moraines at Point Pelee and Long Point and smaller moraines at Mohawk Point and Rondeau. Deposits derived from drift occur at the ends of the basins and at mid-shore positions where drift is intercepted by bathymetric traps or changes in the shoreline trend. Because of the roughly parallel alignment of the basins, the same basic drift pattern applies in both cases. Prevailing westerly winds result in net eastward drift in the eastern part of the Ontario basin and of the Erie sub-basins and periodic easterly storms in westward drift in their western parts.

The principal source of modern sediment is eroding shorebluffs of glacial sediment which currently contribute 1,700,000 m³ (Lake Ontario) and 17,500,000 m³ (Lake Erie) annually from the Canadian shore.

The average grain size of Canadian deposits is gravel - 5 per cent, sand - 70 per cent, silt - 20 per cent and clay - 5 per cent for Lake Ontario and 5 per cent, 50 per cent, 30 per cent and 20 per cent for Lake Erie. The average thickness of postglacial sediment as determined by jetting is 4 m. Pollen dating of shallow-water cores from western Lake Ontario gives an average accumulation rate since the rise in *Ambrosia* (120 years B.P.) of 1.7 mm/year.

Résumé
Dans la région inférieure des Grands lacs, les sédiments voisins du rivage consistent en de vastes affleurements de roches saines et de sédiments glaciaires, ainsi qu'en de discrets et assez faibles dépôts postglaciaries. Ces derniers sont de deux sortes: 1) les sédiments résiduels formés sur les crêtes des moraines submergées sous l'action du remaniement et 2) les dépôts attribuables à l'accumulation des matériaux détachés du littoral. Le lac Erié compte d'importants dépôts résiduels sur les moraines transversales des pointes Pelée et Longue et sur les moraines, moins grandes, de la pointe Mohawk et de Rondeau. Les dépôts issus des matériaux mobiles apparaissent aux extrémités des bassins et aux positions médianes du rivage, où ces matériaux sont interceptés par des collecteurs bathymétriques ou sous l'effet des modifications tendancielles du rivage. Du fait du parallélisme approximatif des bassins, le mouvement des matériaux suit essentiallement la même configuration dans les deux cas. La prédominance des vents d'oeust entraîne un net déplacement vers l'est dans la partie est du bassin de l'Ontario et des bassins secondaires d'Erié et des orages d'est périodiques, selon un déplacement vers l'ouest, dans leurs parties ouest.

La principale source de sédiments provient à l'heure actuelle de l'érosion des falaises de sédiments glaciaires, qui enlève du rivage canadien 1,700,000 m³ (lac Ontario) et 17,500,000 m³ (lac Erié) de terrain par an.

Quant à la grosseur moyenne des grains, les dépôts canadiens se composent respectivement, aux lacs Ontario et Erié, de 5 pour cent de gravier, de 70 et 50 pour cent de sable, de 20 et 30 pour cent de limon, de 5 et 20 pour cent d'argile. Selon jetting, l'épaisseur moyenne des sédiments postglaciaires est de 4 m. La datation au pollen des noyaux des eaux maigres du lac Ontario révèle, depuis la levée *d'Ambrosia* (120 années avant le temps présent), un taux d'accumulation moyenne de 1.7 mm/an.

Introduction
In keeping with the theme of the Symposium, this paper deals with the relationship of the distribution of modern sediments in the lower lakes to nearshore circulation and sediment loading. This type of analysis is in a more advanced stage for Lake Ontario and most of the discussion will centre on data from that basin. The Lake Erie surveys are still in progress and only a summary of available data for the sake of comparison is appropriate at this time.

Lake Ontario
Figure 1 shows the extent of the nearshore zone in Lake Ontario. The lakeward boundary is the 20 m contour. Width ranges from three to seven km and the zone accounts for about 10 per cent of the total area of the basin.

Sediment data for the nearshore are available from studies by Rukavina (1969, 1970), Rukavina and St. Jacques (1972) and Sutton *et al.* (1970). This has been combined in Figure 2 to provide a generalized map of sediment types.

The dominant bottom type is glacial sediment which is exposed over about 60 per cent of the area of the zone. Sample recovery of glacial material tends to be poor and little is known of its composition or texture. From acoustic evidence it appears to be mainly till, and underwater television surveys show it to be covered with a patchy, apparently thin veneer of sediment from sand to boulder in size. This suggests that this type of bottom has undergone and is undergoing erosion and concentration of coarse-grained residual deposits.

Bedrock is a minor component of the zone. Exposures occur at the western and eastern limits of the basin and account for less than 10 per cent of the zone area.

Unconsolidated postglacial sediment covers the remaining 30 per cent of the zone. It is concentrated in six widely-separated sediment bodies located at Hamilton and Mexico Bay at the ends of the basin, and at Toronto and Wellington

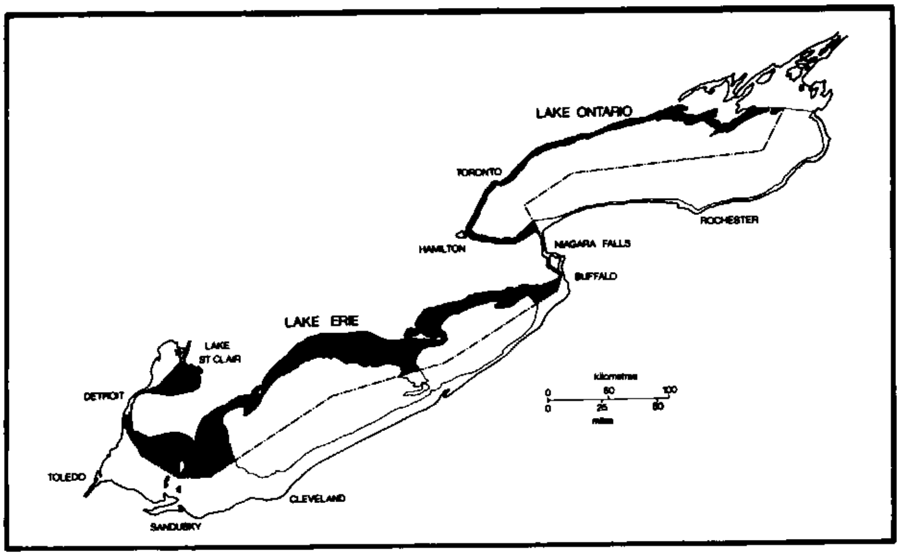


Figure 1
Extent of nearshore zone (0-20 m) in Lake Ontario and Erie.

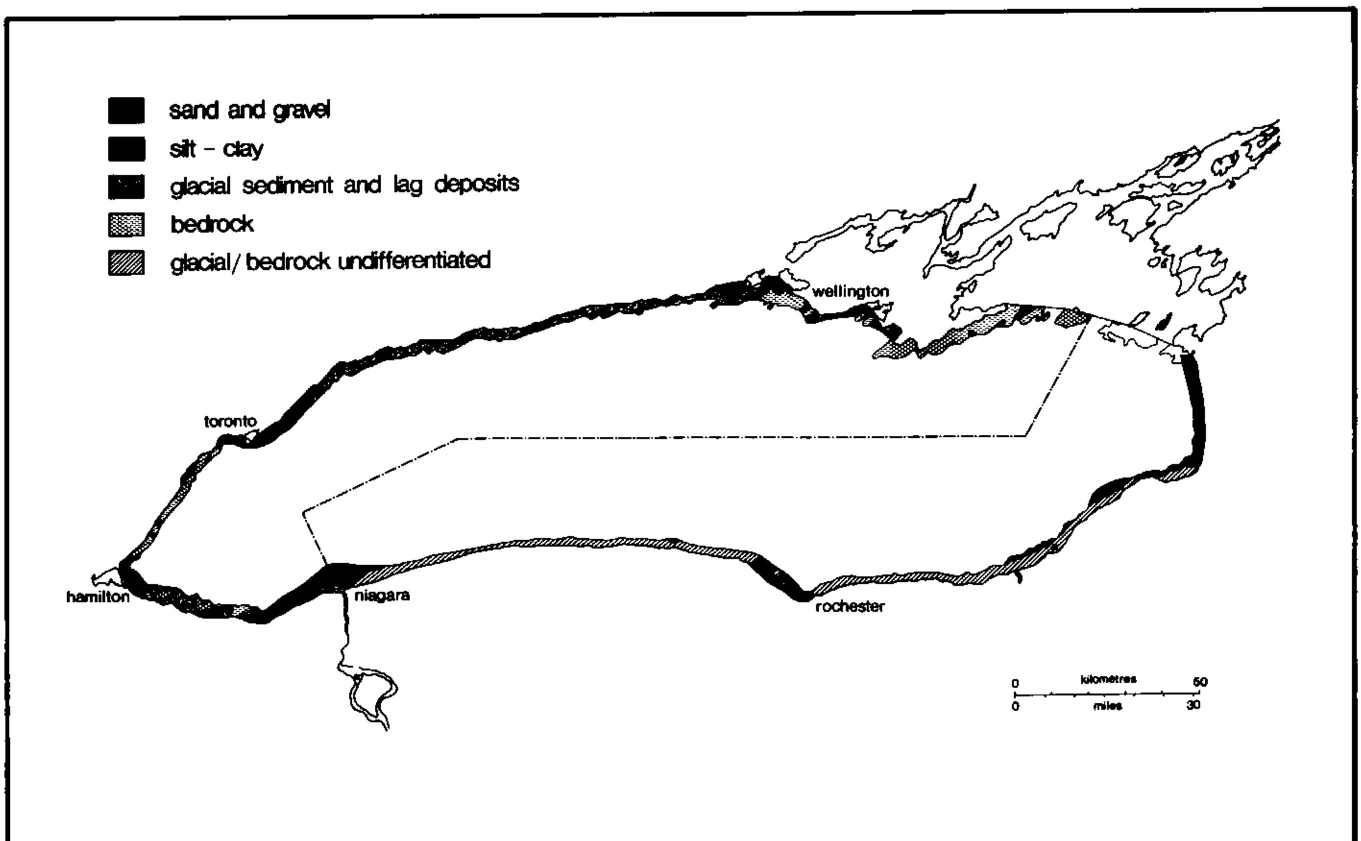


Figure 2
Nearshore sediment distribution of Lake Ontario (after Rukavina, 1975).

on the north shore and Niagara and Rochester on the south. What little sediment occurs in the intervening areas is in the form of narrow, intermittent beach deposits and small accumulations at river mouths and harbour entrances. Most of the sediment is in the sand and gravel size range. Grain size decreases lakeward and sand gives way to silt-clay basin sediments at the outer margin of the zone. All the deposits appear to represent accumulations of littoral drift at locations which conform with the net littoral drift pattern for the basin.

Figure 3 shows the net drift directions inferred from accumulation patterns around shore structures and from textural gradients. The pattern reflects the general wind conditions for the area; prevailing westerly and southwesterly winds are responsible for the net eastward drift in the eastern part of the basin and periodic easterly storms for the net westward drift at the western end. Sediments transported by the longshore currents accumulate at the ends of the basin and at mid-shore positions where drift is interrupted by major changes in shoreline configuration or orientation, or by fluvial barriers like the Niagara River.

Nearshore sediment is derived from three sources: stream discharge, eroding glacial deposits on the nearshore slope, and eroding shorebluffs. The data available on *stream discharge* (Ongley, 1973) suggest that the bedload component is negligible. Since most of the nearshore sediment is in the bedload size range, it is unlikely that stream sediment is a major component. Slope erosion of glacial sediments is an unknown factor and studies of profile changes are currently underway to assess its importance. Eroding shorebluffs appear to be the major source of nearshore sediment and the only one for which quantitative data exist on both volume and texture.

Figure 4 combines volumetric data from Marine Sciences Directorate erosion profiles (Haras, pers. commun.) with grain size data from selected

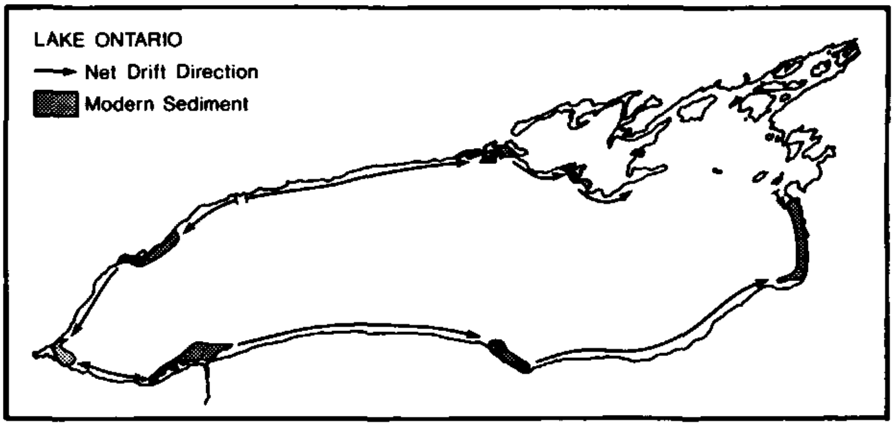


Figure 3
Net longshore drift directions, Lake Ontario.

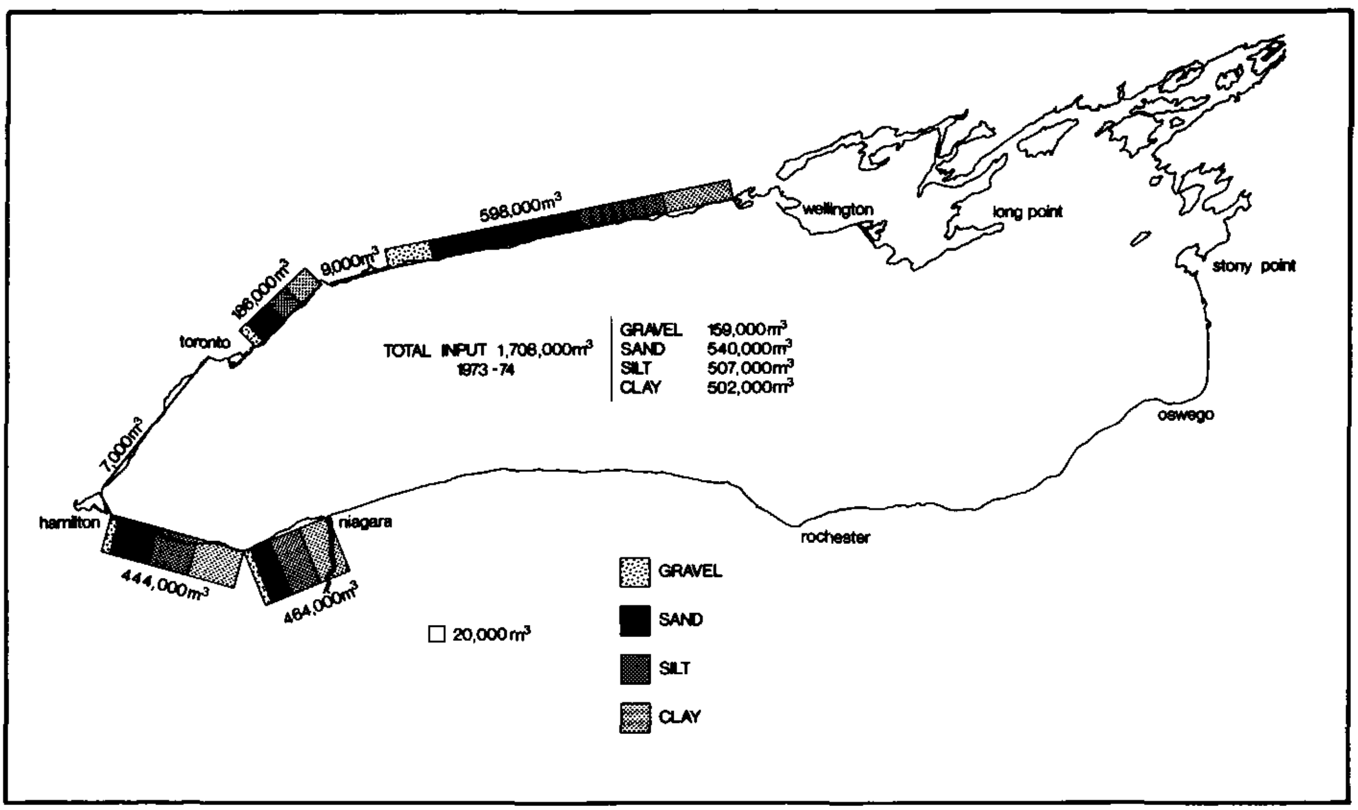


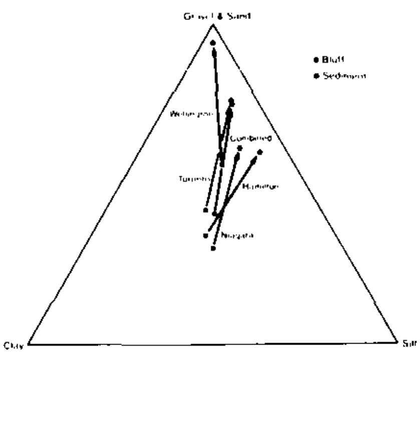
Figure 4
Annual sediment input to Lake Ontario from shore erosion.

profiles. The volumes shown represent sediment input during the period 1973 to 1974, a time of peak water levels, and Haras cautions that they may be five to 10 times higher than the long-term average. Total sediment input from the Canadian shore during this period was about 1.75 million m³, about equally divided between the north and south shores. Inputs are broken down into a number of reaches which correspond with the littoral drift directions discussed previously. This provides the opportunity to compare the textures and volumes of the deposits with those of their presumed sources.

Figure 5 is the textural comparison. The average value for the four deposits shows that the textural change from source to sediment involves a doubling of the sand and gravel per cent, and a reduction of the per cent silt by one-half and of the per cent clay by two-thirds. For individual deposits, several factors determine the resultant grain size. One of these is the texture of the source materials, and its effect is apparent from the diagram. Others include the degree of exposure to wave attack, the distance from the nearest source materials, and the position of the deposit within the basin.

The Wellington deposit is deficient in silt and clay because it is more than 10 km from the nearest source material and because it is exposed to prevailing winds of considerable fetch. This results in extending sorting of sediment and removal of the finer fractions offshore or alongshore to the east.

The Toronto deposit is in contact with its source materials but is relatively well-sorted because of its exposure to easterly storms of long fetch, and because of the opportunity for disposal of finer sediment down the steep offshore slope or along the shoreline to the west.



The Hamilton deposit, like that at Toronto, is in contact with its source material and is exposed to easterly storms of maximum fetch. Yet the deposit is relatively fine-grained. This appears to be the result of its position at the end of the basin where it acts as the terminus for westward drift. The effect of easterly storms in this case is reduced to the shifting of grain size boundaries with little net change of average grain size.

The Niagara deposit combines littoral sediment from the shoreline to the west with Niagara River sediment. The resultant pattern reflects the influence of the river currents at its eastern end and a complicated local circulation produced by the Welland Canal jetties and discharge at its western end. The result is a composite deposit with an average grain size similar to that at Hamilton.

In Figure 6 the volumes and average thicknesses of the four deposits have been reduced to average accumulation rates in mm/year and m³/year. For convenience, uniform accumulation is assumed over a period of 10,000 years, the approximate age of the basin. The annual increment in thickness ranges from about 0.3 mm at Toronto to 0.7 mm at Hamilton. Rates obtained from pollen dating of nearshore cores from Hamilton and Niagara are two to three times as high. These rates apply for the period since the rise in *Ambrosia*, i.e., the past 120 years, and presumably reflect the increased loading during the period of land clearing and settlement. Similar evidence of higher recent rates of sedimentation is provided by dredging figures for the harbours at Hamilton, Toronto, and along the north shore. In all cases the average volumes dredged annually exceed the computed accumulation volumes whereas they should represent only a portion of the littoral load.

Figure 7 compares the annual volumes of size grades eroded from the bluffs with those of the associated sediment deposits. Since only limited stratigraphic data are available for the sediments, it has been necessary to assume that the size distribution of surface sediment applies throughout the thickness of the deposit. There are other complications. The comparison involves the average increment in sediment volume, which appears to be smaller than the present volume increase, with an eroded volume which may be five to 10 times higher than average because of its association with peak water levels. There has been no allowance for sediment supply from subaqueous erosion and sediment removal by beach and dune storage has been ignored. In spite of these qualifications, this diagram should represent within an order of magnitude the partitioning of the bluff materials between the major sediment deposits and the basin deposits.

Lake Erie

The Lake Erie nearshore zone is larger and more complex than that of Lake Ontario because the basin is shallower and because it is subdivided into three sub-basins by shoals of morainal origin (Fig.1). In this case the nearshore zone accounts for almost half the total area of the basin.

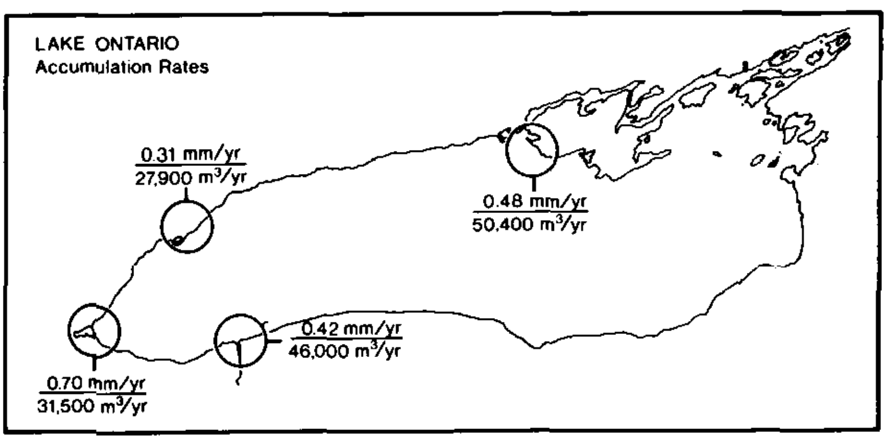


Figure 6
Accumulation rates of Lake Ontario deposits.

Sediment data for the nearshore zone are available from recent surveys by Rukavina and St. Jacques (1971, 1973) in the area east of Point Pelee and from earlier surveys by Lewis (1966) in the western basin. Figure 8 summarizes the sediment distribution.

In Canadian waters, glacial sediment is the dominant bottom type and is exposed over 45 per cent of the zone. Bedrock crops out in about five per cent of the area and post glacial sediment covers the remaining half. Till is exposed inshore and glaciolacustrine sediment offshore, both with a veneer of lag deposits. Postglacial sediment occurs in three major deposits centred on Point Pelee, Long Point and Buffalo. Average grain size is finer than in Lake Ontario because of the greater incursion of basin deposits, particularly at Point Pelee and Long Point. Sedimentation in the western basin is dominated by sediment discharge by the Detroit and Maumee Rivers (Kemp, pers. commun.). Littoral drift is important in developing the sand-rich deposits on the west coast of Point Pelee, the inshore slopes of Long Point, and opposite Buffalo. Drift is predominantly towards the east but reversals occur on the east sides of the major promontories and the patterns for the individual sub-basins are similar to that for Lake Ontario. Sediment supply is from eroding bluffs of the western and central basins and is about ten times that for Lake Ontario, 17,500,000 m^3 (Haras, pers. commun.). The submerged moraines at Point Pelee, Long Point and Port Maitland have crestal deposits of extremely well-sorted sands and gravels which appear to be formed in place by reworking of morainal material.

Research Needs

The preceeding discussion has summarized the current status of nearshore studies in the lower lakes as they relate to the interaction of modern sediment, source materials, and nearshore circulation. Further work is required in several areas:

1) The textural properties and erosion rates of the exposed glacial sediments and the mobility of the coarser grain sizes in these areas are unknown. Studies are now in progress at the Canada Centre for Inland Waters to monitor profile changes, to sample the glacial sediment and to record coarse particle movement with acoustic "pebble" tracers and by direct observation with a newly-developed underwater photologger.

2) The paths and rates of movement of suspended sediments alongshore and downslope into the basin require further study. Is there uniform dispersion of suspended sediment down the offshore slope or streaming at specific locations within the basin?

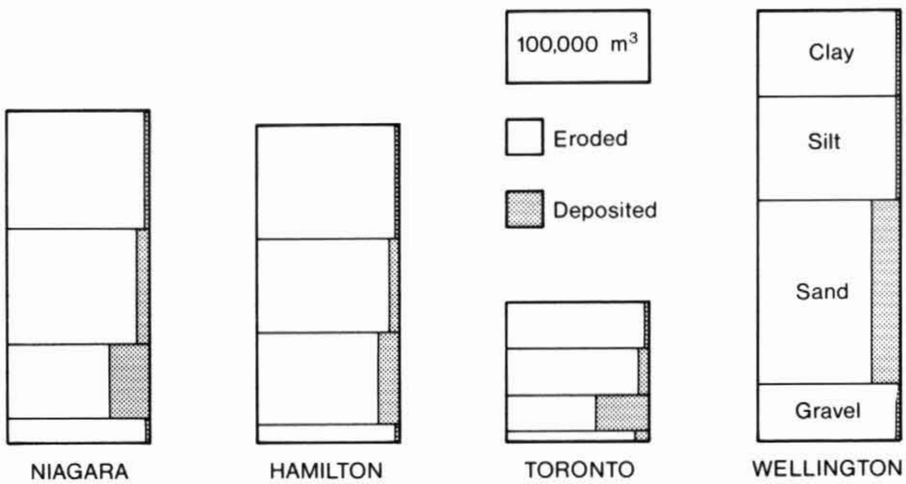


Figure 7
Volume and texture of source sediments vs. that of nearshore deposits.

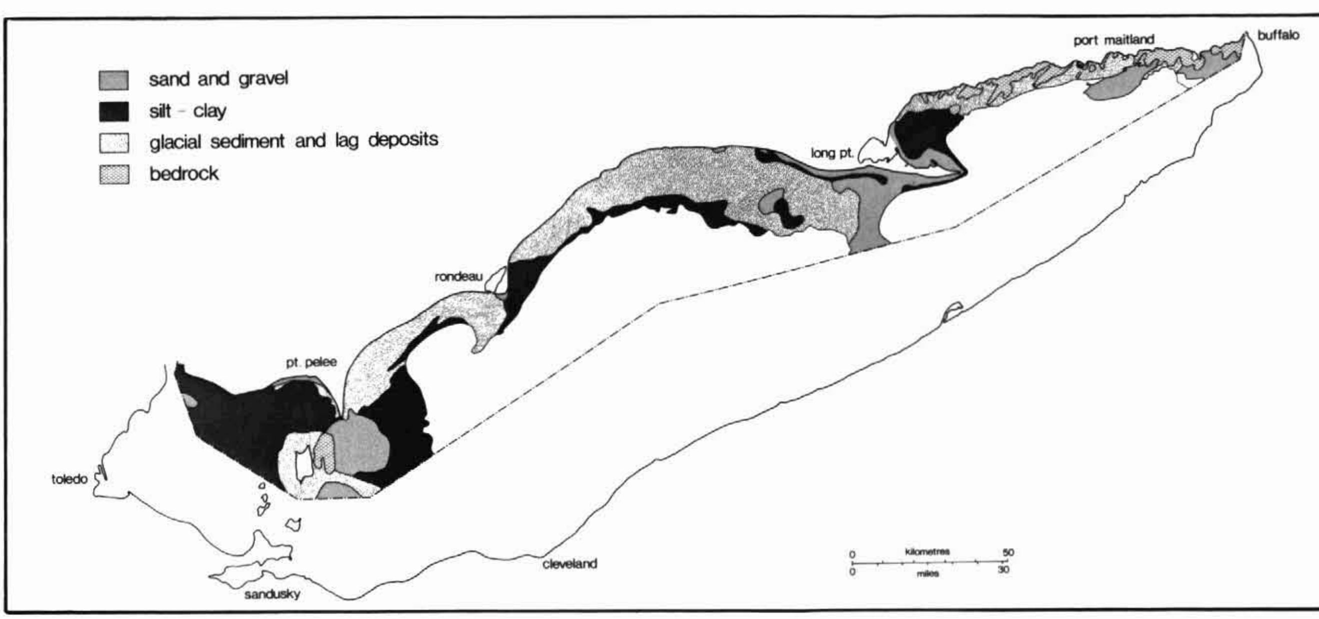


Figure 8
Nearshore sediment distribution of Lake Erie.

3) The directions of net longshore movement of sediment have been established but rates of littoral drift and details of sediment transport in response to various wave approaches are poorly known. This type of information is critical for site selection and design of shore and offshore structures.
4) The mechanism of transport of coarse sediment transverse to the shoreline and its importance relative to longshore transport requires study.
5) Data on the volumes and textures of beach, bay, and dune sediments are spotty and need to be expanded before a realistic sediment budget can be attempted.
6) Perhaps most important is the need for a complete stratigraphy of the nearshore sediments. This is essential for the understanding of the effects of short- and long-term water level variations on the evolution of the basin margins, which is the basis for the prediction of the form and scale of future changes.

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