RECONSTRUCTION OF THE GEOLOGIC HISTORY OF THE WELLINGTON BAYMOUTH BAR (SANDBANKS PROVINCIAL PARK) IN PRINCE EDWARD COUNTY THROUGH A STATISTICAL ANALYSIS OF SEDIMENT SIZE DISTRIBUTIONS

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RECONSTRUCTION OF THE GEOLOGIC HISTORY OF THE WELLINGTON BAYMOUTH BAR (SANDBANKS PROVINCIAL PARK) IN PRINCE EDWARD COUNTY THROUGH A STATISTICAL ANALYSIS OF SEDIMENT SIZE DISTRIBUTIONS

by Elizabeth Peat

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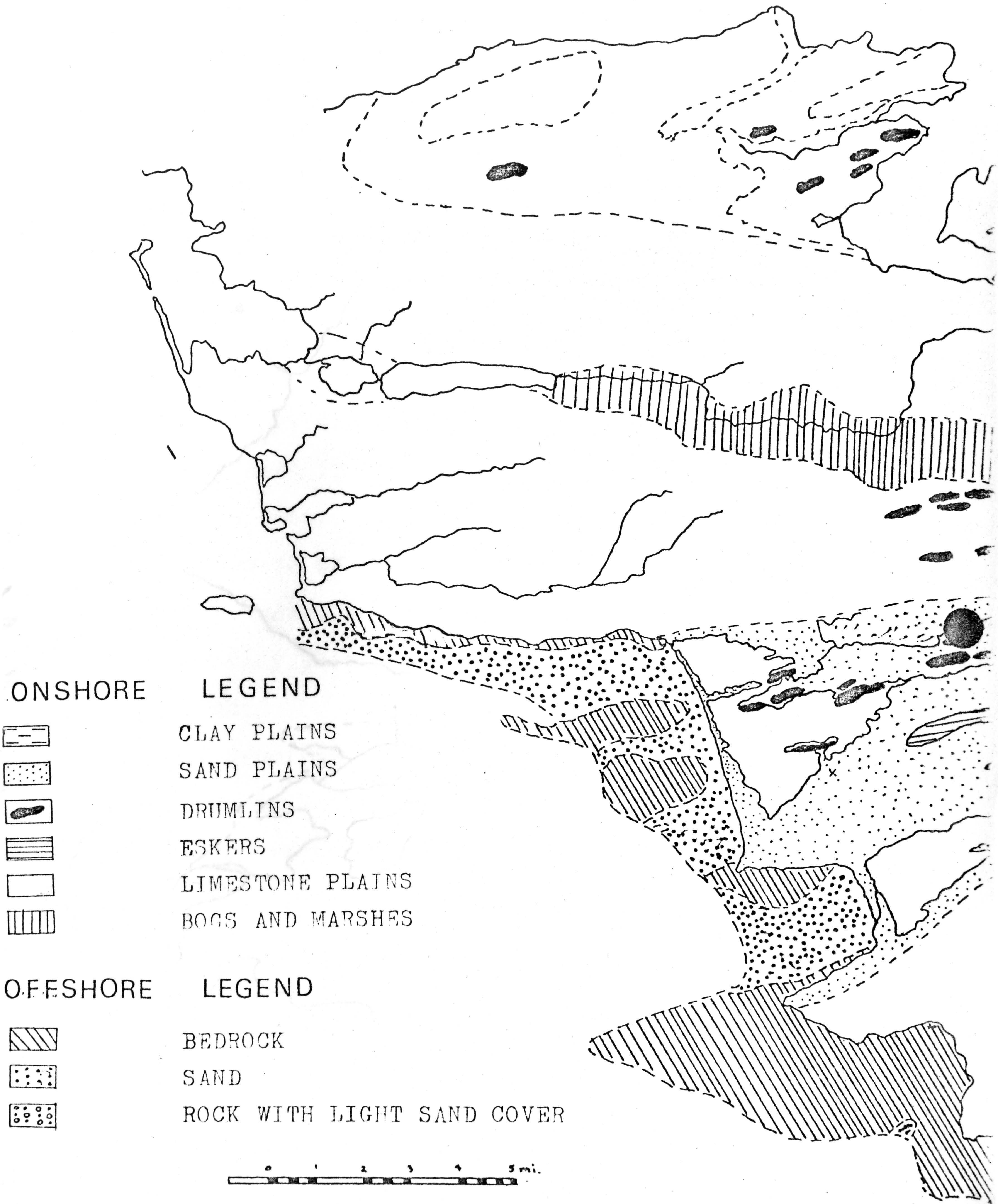
Figure 4


ONSHORE LEGEND
CLAY PLAINS
SAND PLAINS
DRUMLINS
ESKERS
LIMESTONE PLAINS
BOGS AND MARSHES
OFFSHORE LEGEND
BEDROCK
SAND
ROCK WITH LIGHT SAND COVER
0 1 2 3 4 5 mi.

PHYSIOGRAPHY:

The major form of topographic relief on the flat limestone plateau of the Prince Edward Peninsula is a direct result of the intensive glaciation; disruption of drainage; depression of the ground surface; and deposition of great thicknesses of glacial, glaciofluvial and glacio-lacustrine sediments in the south and west sectors of the peninsula.

As interpreted from the map of regional surficial geology published by the Prince Edward Conservation Authority in 1968 and included in Figure 4, the low plateau of limestone is overlain by either:

a. a shallow veneer of soils directly over the bedrock, less than thirty inches in depth;

b. lacustrine clay plains of approximately two to twenty feet in thickness;

c. a field of drumlins concentrated in the region immediately north and north-east of West Lake, approximately twenty to forty feet above the surrounding landsurface and partially buried by outwash sand;

d. Picton Esker, extending from the head of Picton Bay to a point about three-quarters of a mile east of West Lake, with a maximum elevation of fifty feet, also partially buried by overlapping sands;

e. a large complex of bog and marsh running west-south-west of Lake Consecon, with numerous unintegrated rivers paralleling this trend; and

f. a large sand plain extending in a fan shape from Picton to the East and West Lakes area, and thence under Lake Ontario, partially burying previous glacial landforms.

The most outstanding picture the physiography map presents is one of a large outwash fan extending west-southwest across the Prince Edward Peninsula, partially flooded to form two estuaries. The direction of ice movement, determined from the orientation of drumlins in the region, is from about seventy degrees east of north. The sand plain enclosing the drumlins and the Picton Esker, and even the co figuration of present-day West and East Lakes, closely parallels this direction of ice movement, forming a triangular wedge opening southwestward into the Lake Ontario Basin. Excellent evidence for glaciolacustrine encroachment and reworking has been determined from the esker and drumlinois material, as well as through drilling and offshore sampling. Within West Lake, strong drumlins appear in the form of Garrett and Tubbs Islands, with several subsurface topographic highs aligned with the other topographic features (Hobson and Mirynech). It is therefore evident that the last direction of ice flow was the controlling factor in the orientation and configuration of topographic features in the Prince Edward Region. Only relatively minor features have resulted from the subsequent redeposition of the glacial sands in Glacial Lake Iroquois/Frontenac or the later Lake Ontario.

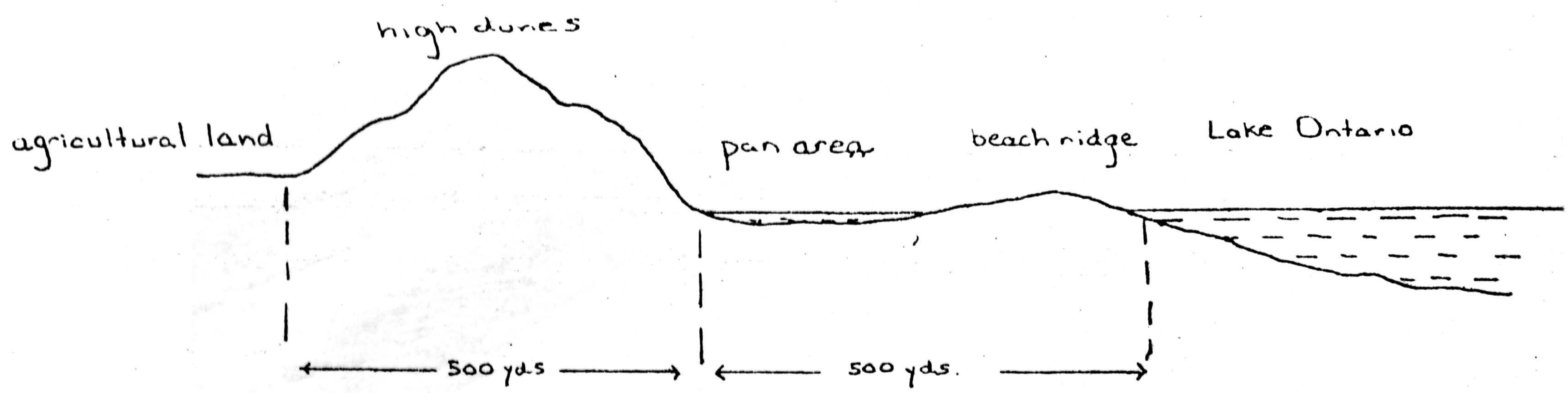
Within the immediate study area, one of these later features is the Wellington baymouth bar itself. This baymouth bar constitutes a narrow strip of emergent sand deposits, approximately five miles long and totalling two square miles. It is a few hundred feet wide near Wellington and widens to three-quarters of a mile at its southern end.

The northern sector of the bar has minimal relief, with the eastern shoreline low and swampy, sloping upward to a slightly higher central area (Figure 5). It is composed mainly of a mixture of sandy earth and small limestone pebbles, covered by coarse grasses and a few small trees. Proceeding southward along the bar, small and scattered accumulations of wind-drifted sand, covering a few hundred square feet each and increasing from a few feet high on the west shore of Lake Ontario, to ten feet on the easterly West Lake shore, are transitional to relatively continuous, partially vegetated dune fields. Gradually, at about the mid-point of the bar, the dunes appear to bifurcate into two separate areas - moderately sized dunes of the central area on the Lake Ontario shoreline, with occasional blow-outs, grading into a much higher dune ridge on the West Lake shore.

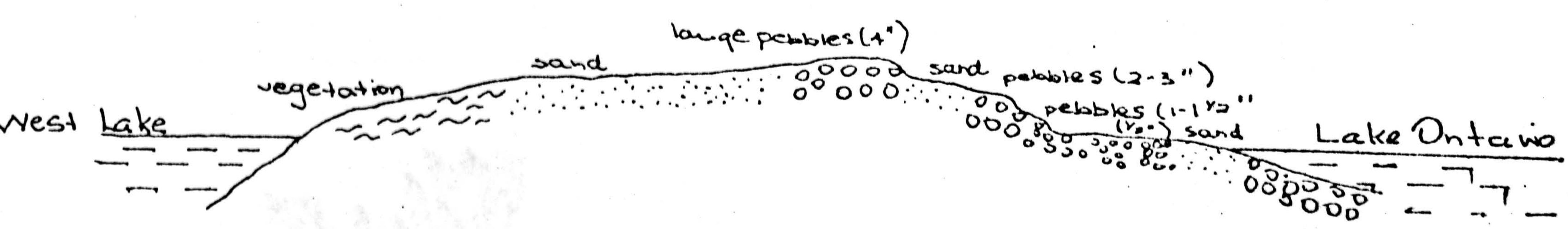
The southern third of the bar has the most striking topography, in the form of a relatively narrow foredune ridge above the Lake Ontario beach, with a wide and swampy pan area separating the massive high-dune pileups to the east, on the shores of West Lake and even just beyond the southern limits of the bar. Large wind draws, relatively continuous dune ridges across the bar in some instances, blowouts, exhumed paleosols and exposed cedar trunks all attest to past migration of large sand hills. However, it is worthy of consideration that there does not appear to be any interconnection between the presently forming foredune ridge and the relict high-dune system, with little evidence of sand migration across the swampy pan area in the southern sector of the baymouth bar. With the major rise in lake

CROSS SECTIONS OF THE

WELLINGTON BAYMOUTH BAR



Wellington Baymouth Bar - Southern end - cross section



Wellington Baymouth Bar - northern end section

Figure 5

levels this season (spring, 1973), the foredune ridge resembles more an offshore barrier island system, quite distinct from the piled-up dunes bordering West Lake.

DRAINAGE:

The major drainage system is to the southwest, in response to the gentle sout-westward dip of the bedrock, merging with the waters of Lake Ontario at an elevation of 246 feet above sea level (though lake level for 1973 has advanced far upward of this average elevation). Twenty-three-mile long Consecon Creek is the typical example, draining 73.4 square miles, with a stream gra ient of thirteen feet per mile. A number of streams flowing south-west and parallel to Consecon Creek enter West and East lakes. The intermittent nature of these streams, with peak flow limited to periods following heavy precipitation and snow-melt, has been attributed to the shallow depth of soil over the bedrock topography. This thin veneer allows rapid run-off, seepage into bedrock and only a low soil-moisture capacity. One of the most serious problems in the Prince Edward Region at present, is the shortage of steady water supply, and the intermittent nature of the numerous, short, unintegrated streams which drain the edges of the plateau.

The nature of the drainage system has a direct bearing on the amount and rate of sediment supply to the lake shore. The low stream gradient , rel tively short stream length, and intermittent flow would tend to minimize the carrying capacity of the streams which flow into West and East lakes.

At the present time, therefore, the fluvial sediment supply from the landward side appears to be minimal.

This present-day configuration of the drainage system may be interpreted from the physiographic map as being totally relict. The extensive sand plain, which fans southwest from Picton to West and East lakes and contains a nine-mile-long, partially-reworked esker and numerous southwesterly oriented drumlins, exemplifies a glacial outwash plain. The Picton Esker, which reaches almost into the head of West Lake, may be interpreted as the result of a glacio-fluvial stream flowing into an overdeepened estuary, as the glacial meltwaters merged with glacial Lake Iroquois or Frontenac. It follows, therefore, that a probably late glacial source for the offshore and baymouth-bar sands, in the vicinity of Wellington and Little Sandy Bay are the outwash sands derived from the north-east, during the final stages of recession of the last glaciers.

CLIMATE:

Climatological factors have played a dominant role in the original generation of the baymouth bar, and in the evolution and orientation of the dune systems through the influences of prevailing winds. With respect to temperature, the ice-cover on the Lake Ontario shore and the freezing of the dune surfaces tend to minimize any movement of the sand, for up to half the year. The relatively abundant precipitation in the Prince Edward Region also controls the entire nature of the dunes, through wetting and vegetation stabilization. The resultant wind-transported deposits are characteristic of a temperate, fairly humid climate; totally divorced from barren, desert-type dunes.

Climatic wind records (Table 2), published by the Canadian Department of Transport, indicate that the dominant wind direction for Main Duck Island (the closest station to Sandbanks Provincial Park) is from the west in the spring, south-west in the early summer, and south in the fall. Kingston, which is roughly sixty miles to the east, is affected by winds from the west in the spring, south and southwest in the summer and fall, and dominantly south-west in the winter months. The prevailing wind direction, therefore, appears to be from the south-west. The actual dune orientation seems to have been controlled to a large extent by the prevailing southwesterlies. In addition, these winds would have a considerable influence on surface currents and longshore transport.

A comparison of precipitation data (Table 3), taken from the Prince Edward Conservation Authority Report for the Water Year 1965-66 shows an annual total in the range of thirty inches, with a maximum for the Picton-Bloomfield area occurring fall and with minima generally in the spring and summer months. This table on comparative precipitations lists data for Picton, Bloomfield and Kingston. The relatively even distribution and abundance of precipitation in the area of the Wellington baymouth bar indicates a temperate, humid climate affecting dune development and/or stabilization.

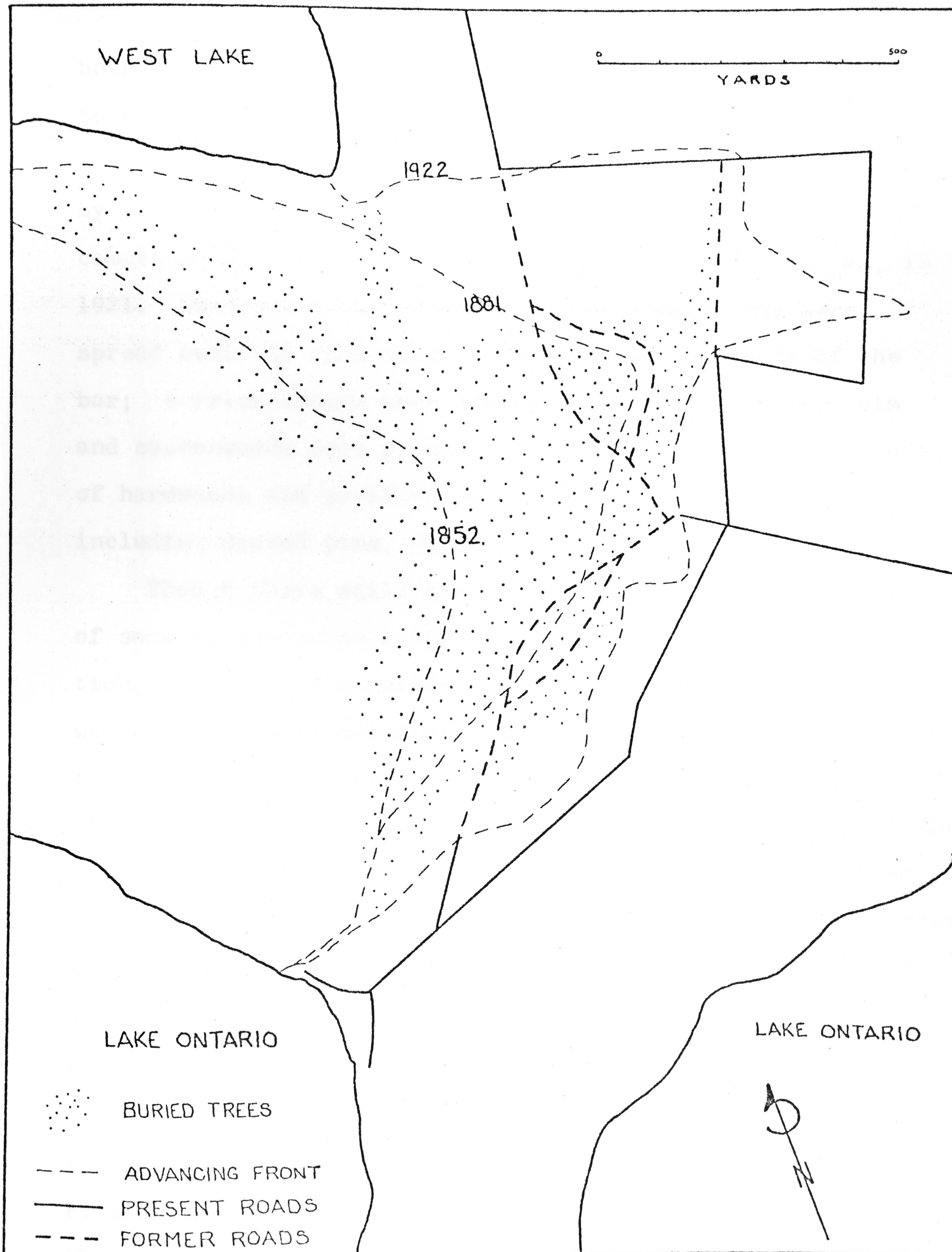
The freeze-thaw cycle of the southeastern Ontario climate has a pronounced influence on dune shape and internal structure.

HISTORICAL CONSIDERATIONS

Following the "Trail of the Black Walnut", the Quaker agriculturist migrated to the Prince Edward Region in the mid nineteenth cnetury. Equating the presence of black walnut and limey soils with the mild and fertile Carolinian Forest zone, these early settlers had no conception of the thinness of the soil cover on what was then a fertile, forested and stable landscape on the baymouth bar on the south-west shores of the Prince Edward Peninsula. The cedar and mixed hardwoods were harvested for timber, cattle grazed freely on the cleared land, cart trails cut along the bar.

Between 1852 and 1881, the sand began to drift, according to A.H. Richardson, local historian (Figure 6). The sand dune hills, assumed by most previous authors to have been confined close to the shore of Lake Ontario, dominantly in the southern part of the bar, began to move across the bar towards the north and eastern boundaries. The migrating sand covered acres of forest on the bar, extended the shores of West Lake, piled up into the high dune system of today, and transgressed onto the farm lands to the north and east. Between 1881 and 1922 the old road was abandoned twice as the sand steadily encroached. The old Evergreen Hotel was pulled down, other small buildings were abandoned and farmers deserted some of their fields which lay in the path of the sand movement. The migration of the dunes was relatively slow from 1881 to 1922, as traced by the shift in the position of the road (Figure 6), but by the time the sands had moved past the barrier of dense cedar at the southern

RECORD OF THE SAND ADVANCE



modified from A.H. Richardson

Figure 6

boundary of the Wellington bar, the local farmers appealed to the government for aid.

After several unsuccessful attempts at reforestation by the local farmers, the Department of Lands and Forests commenced an extensive and effective plantation program, in 1921. Hundreds of loads of brush and spoiled hay were spread over the open sand in the southernmost part of the bar; barrier fences were erected to trap the sands; elm and cottonwoods were planted. Since that time, a multitude of hardwoods and conifers were introduced to bind the soil, including Scotch pine, poplar, black locust, maple and spruce.

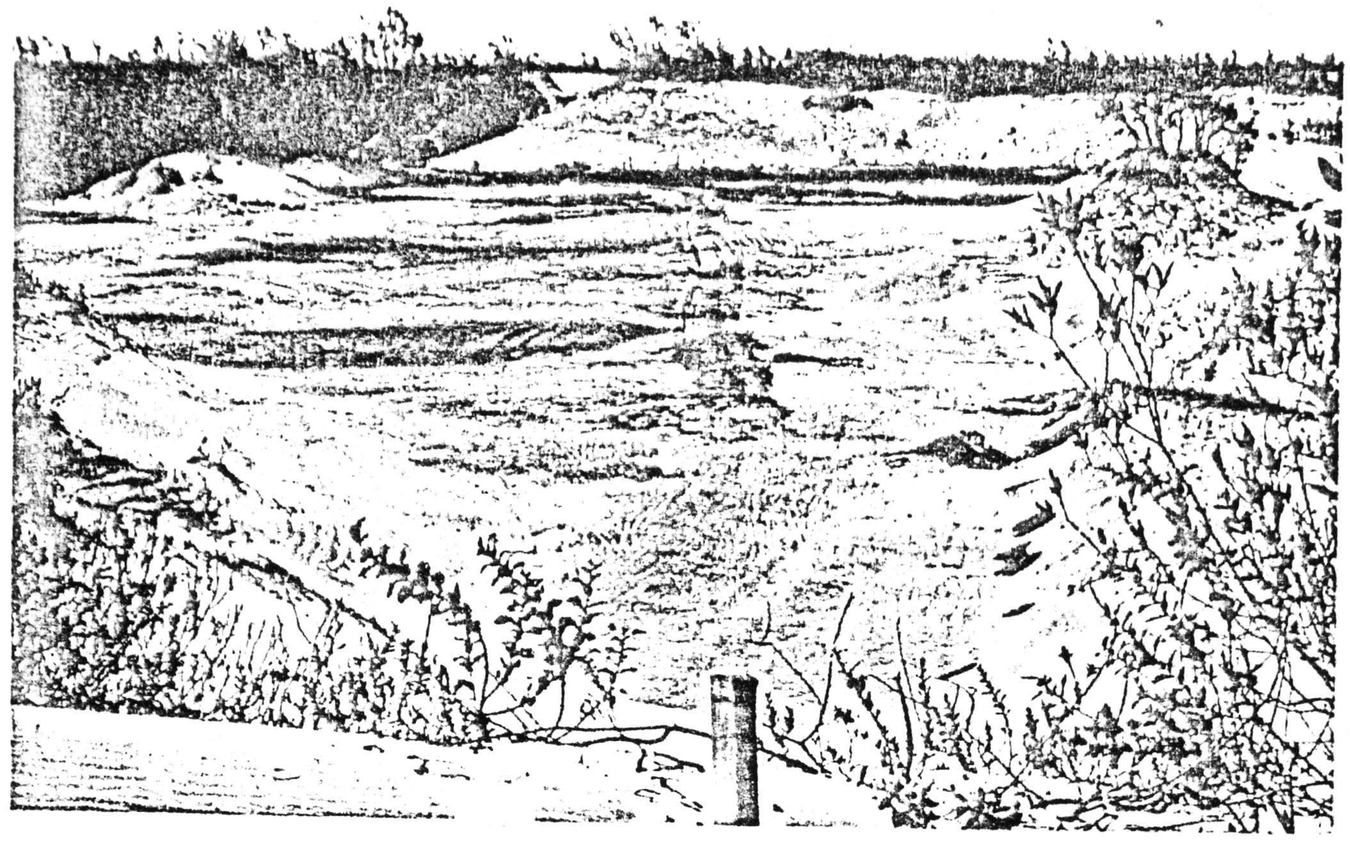
Though there still remained minor scouring, malformations of some of the transplants, and problems with natural regeneration, the program carried out by the Sandbanks Forestry Station was essentially successful. The plantations not only succeeded in preventing the drift of sand onto adjacent cropland, but also "minimized the effect of blowing sand on areas along the West Lake shoreline to the lee of the dunes" (Prince Edward Region Conservation Report, 1968). Woodward (1949) supported the success of the program in his report that the southernmost sand dunes had been essentially stabilized by the middle of the twentieth century.

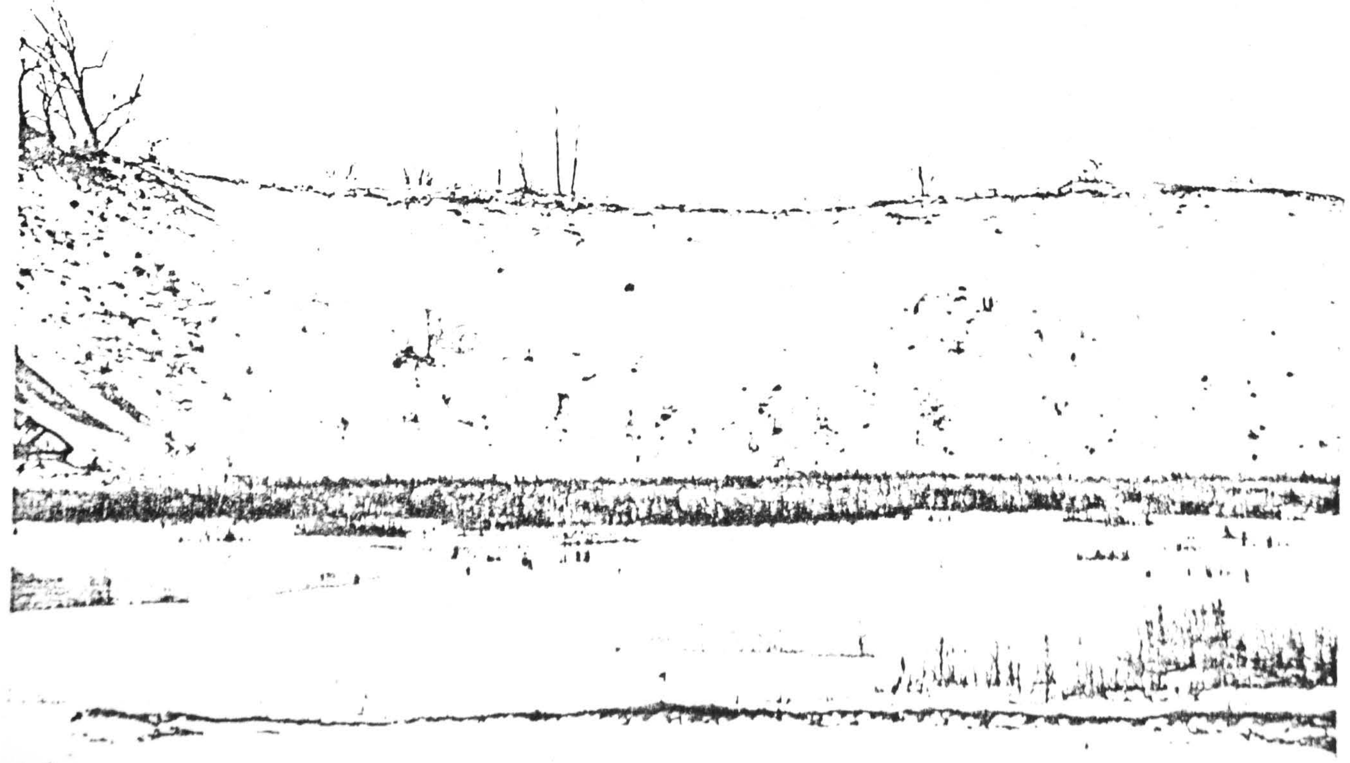
At the present time, the controversial sand quarry, operated by the Lake Ontario Cement Company until August, 1972 when the Pits and Quarries Act was brought into effect against it, is the centre for discussion of the nature of sand movement on the Wellington baymouth bar. This paper is an attempt to provide a basis of factual information from which to evolve a solution as to the geologic future of this massive excavation in the high-dune system.

Plate 6 - The sand quarry, excavated by the Lake Ontario Cement Company, as viewed from the remaining high dunes on the south-eastern shore of West Lake.

Plate 7 - A view of the reforested area adjacent to the excavated area, with a part of the plantation suffering possible wind eddy and scouring effects

Plate 8 - The oversteepened wall of the quarry, with evidence of slumping





heights ranging from over one thousand to approximately fifty feet above lake level, perspective and excellent oblique photographs were obtained. These were correlated to the vertical coverage available from a previous survey flown in the fall of 1972, for Dr. M.M. Fitzpatrick (Queen's University).

Followup and Seasonal Observations:

The study area was re-visited to observe both winter and spring conditions.

In the winter survey, special note was taken of any movement of sand, Due to freezing of moisture within the dunes, the frozen surfaces of the dunes themselves, and the ice and snow-covered beach of Lake Ontario, any new sand supply appeared to be cut off during the winter months. As little or no blown sand was visible on the frozen pan area, movement of sand from the foredune sytem to the high dunes bordering West Lake appeared to be minimal.

Spring observations consisted of a final field examination of both the Wellington and Outlet baymouth bars. Due to the extraordinarily high levels of the lower Great Lakes, the configuration of the Wellington baymouth bar was markedly altered. With the pan area between the foredune and high-dune systems flooded to a depth of over two feet in deeper spots, the foredune system was isolated in the southern sector of the bar, resembling a barrier island-type feature. The sand pit was also flooded, producing a shallow lake of several acres connected to West Lake. The only ground above

GEOLOGICAL RECONSTRUCTION OF THE WELLINGTON BAYMOUTH BAR

PLEISTOCENE HISTORY:

The Quaternary history, as it affected the land mass of the Prince Edward Region, has been discussed in the chapter on physiography. However, as the Pleistocene influences played such a prominent role in the initial shaping of the Wellington baymouth bar, the Quaternary history of the Ontario basin and control of sediment supply to the present south-western portion of the Prince Edward Region will be briefly discussed.

Hough (1958) provides the most concise interpretation of the Lake Ontario Basin, based on an earlier summary by Fairchild. In addition, Leverett and Taylor (1915), Stewart (1958), and Chapman and Putnam (1966) have reviewed the Quaternary history of the Great Lakes, to some extent.

In brief, all of the early lake stages, before the Iroquois, were considered to be narrow, ice-margin lakes. In Cary time, the glacial ice completely filled the Ontario basin, retreating in the Cary-Port Huron Interval. As drainage to the east was then possible, a low-water stage ensued, during which the exposed glacial till and sandy outwash plains were open to the wind. Due to considerable upwarp during this temporary retreat of the ice in the Cary-Port Huron interval, the Syracuse, New York outlet of the Vanuxem I stage was uplifted, generating another period of high water.

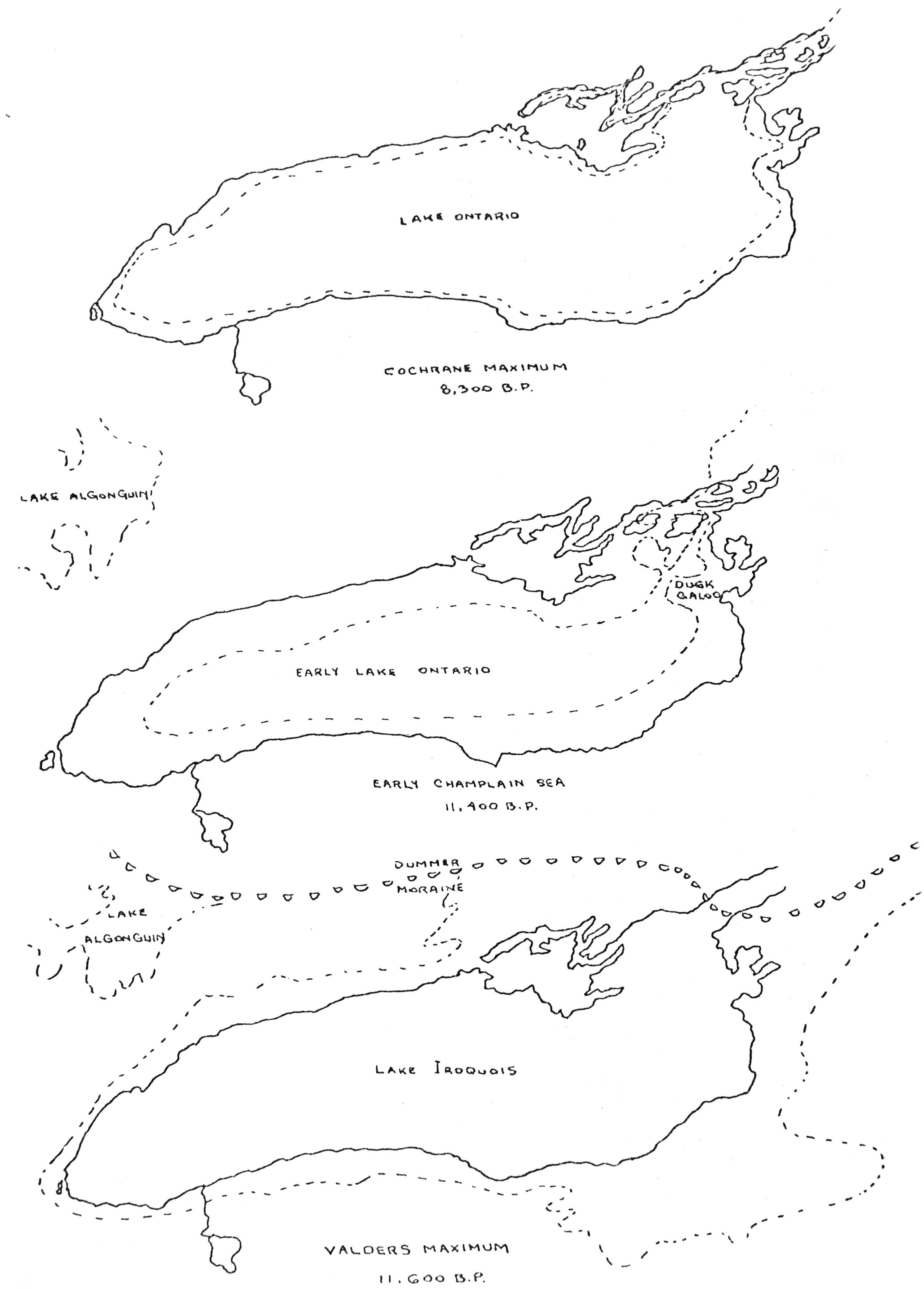
The next stage of wastage and rising water is assigned to the Two Creeks Interval. Boon (1970) considered the Picton Esker was generated during this period, approximately 11,600 years before the present. This recessional stage, with associated meltwater outwash plains, resulted in the Valders Maximum (Figure 34). The rising water levels in the Ontario Basin were once again a result of the blockage of eastern outlets; this time by the ice margin marked by the Dummer Moraine. (Figure 34) Glacial Lake Warren existed along the southern extent of the Ontario Basin, with drainage west into Lake Erie.

Within one hundred years the ice front retreated from the Valders maximum, with a channel south-west of Syracuse permitting drainage of the Ontario Basin to the level of Lake Vermont during the Fort Ann Lacustrine Phase. At this time, a continuance of meltwater sand and gravel was washed into the lake, with the coarser fraction being deposited near the shore of that time and the finer sand carried farther into the lake basin. The ice margin retreated still farther, drainage became possible through the eastern outlet, and early Lake Iroqois came into existence. As another outlet was opened along the margin of retreating ice, at Covey Hill, New York, Lake Frontenac or the last manifestations of Glacial Lake Iroqois came into being. These latter stages had a very strong influence on the distribution of sediment distribution in the Prince Edward Region.

By 11,400 years approximately, before the present, the early stages of Lake Ontario existed as about half its present extent. With the reworked glacial till and outwash exposed

Figure 34

PLEISTOCENE LAKE LEVELS



After Hough (195)

once again, a broad strip of blowing sand parallel to the presumed prevailing westerlies evolved, on the south and north margins of the Ontario Basin. The relict sand dunes along the north shore, at Presqu'ile, Prince Edward County, along the south shore between Oswego and Stony Point, New York, as well as smaller submerged baymouth bars along the south-eastern shore towards Rochester, are correlative with this period of low water.

With the final retreat of the Wisconsin Ice to the north-east and the opening of drainage via the St. Lawrence, Lake Ontario was formed, about 11,000 years B.P. (Karrow, 1961). Since that time, the final stages of meltwater caused the shoreline to migrate towards the present level, with the most active blown sands and dunes advancing and collecting as sand deposits along the shoreline of that time. Coleman (1937) reported fragmentary beaches with dune deposits associated with the more recent glacial lake level stages, supporting this assumption. With the effects of isostatic rebound of the St. Lawrence River Valley, a continuous deepening of the Lake Ontario Basin to the present day, along with a strong tilting to the north-east of the Iroquois Beach.

FORMATION OF THE OUTWASH PLAIN:

During one period when the ice sheet reached its last maximum advance front, the Dummer Terminal Moraine of the Vald rs Maximum, at approximately 11,600 years before the present, formed (Figure 35). Outwash spread away from the front in broad, complex deposits, with the glacial debris transported by and deposited from braided streams. This outwash generally formed a broad, low fan-shaped body, such as the Prince Edward sand plain, and may have gradually built up to considerable thicknesses above the glacially-scoured landscape. The wedge of glacial deposits on what is now the south-west shores of the Prince Edward Peninsula are seventy-five feet in average thickness (Hobson and Mirynech, in press). The Picton Esker was also a manifesta ion of this period of ablation, forming as an englacial meltwater stream flowing within the receding ice fron of the post-Two Creeks interval (Boon, 1970).

From the map of the bathymetry of West Lake and the offshore (Figure 35), the shelving nature of the area offshore from the Wellington baymouth bar may be seen, with the influence of topographic highs such as the drumlins reflected as submarine ridges flanked by slightly deeper areas. West Lake, on the other hand, is much shallower and displays a similar arrangement of emergent highs and submerged basins. Therefore, it may be assumed that West Lake is co-extensive with offshore Wellington Bay, with the entire area enclosed in the Prince Edward outwash sand plain.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+160
N
BATHYMETRY

Figure 35

sand and gravel, built up to just above lake level on glaical till and clay deposits, and sustained and enlarged by progressive, vigorous longshore drift by the prevailing winds from the west. The dynamic model of a baymouth bar, determined from stream table experiments, suggests that development occurs in a shallow bay opening onto a shallow offshore 'shelf' and flanked by resistant headlands, by progressive growth of a spit. Wave motion is almost normal to the shoreline, producing simultaneous growth from both sides.

In the case of the Wellington baymouth bar, a slightly oblique angle of oncoming wave motion resulted in the differentially greater accumulation of sediment in the southern sector of the bar, towards Owen Point. The statistical analysis of the sands in the southern portion of the bar indicates rapid deposition of beach sediments in what is now the broad pan area between the high-dune and foredune systems. These statistical parameters could well indicate a period of increased sediment supply due to the disruption of the stabilized land surface by the early settlers in the mid-nineteenth century. Through washing of sand into the lake edge by the agent of stream flow and subsequent movement by longshore drift eastwards along the bar, a new geometric form of the Wellington baymouth bar gradually evolved. Due to the effective termination of longshore drift by Owen Point, a bedrock ridge adjacent to deep water, preferential accumulation of sediments on the south and western shore of the bar resulted in a rapidly prograding shoreline, in an arced sweep. Upon depletion of the sand supply due to relative re-stabilization of the land surface, migration of sand toward the West Lake shores, possible increase in lake level limiting sediment supply, or a variety of other factors which would restrict the source of sand available to the longshore drift, the present stabilized beach with associated foredune ridge developed. Anomalies such as the isolated, steeply sloping and outsized dune anchored by vegetation on the pan flat (visible in Plate 33) or the massive pile-up of sand into a vegetated, peaked dune pile in the extreme southern boundary area of the baymouth bar appear to be stabilized remnants of the period of sand migration and disequilibrium; the first dune a relict of the previous topography, anchored by vegetation and the latter, freak dune influenced by the prevailing westerly winds in the area (west-south-west).

Therefore, the Wellington baymouth bar appears to be the polygenetic product of isostatic upwarping of an ice-deepened river mouth, primary glacial-outwash deposition of a shallow offshore 'shelf', and onshore winds generating the development of a spit from the headlands at Wellington by a vigorous longshore drift from the west. This drift transports reworked glacial sediments along the Lake Ontario shoreline of the Wellington baymouth bar. With the relatively recent disruptive influences of the surface equilibrium by the early farmers, the eroded sand apparently contributed to the present arc-like extension of the south-west portion of the bar, resulting in the bifurcation of the dune systems.

EVOLUTION OF THE DUNE SYSTEMS:

With a single, water-laid beach plain as a base, wind-blown sands, propagated by the prevailing west-southwesterly winds of the area, gradually elevated the area immediately behind the beach area into a beach ridge. Due to the influences of vegetation, these small foredunes assumed a hummocky character, and therefore may be referred to as a foredune chain. The prograding shore, sustained by sediments transported by longshore drift, and by the succession of subaqueous transverse sand dunes forming the series of sand bars offshore, influenced the full force of the oncoming waves and winds. A relatively linear shoreline developed perpendicular to the full force of the waves, while in the more protected lee of the baymouth bar, a scalloped shoreline developed, due to washover channels, blow-outs, and slumps.

Downwind from the aeolian blow-outs in the foredune chain, blow-out fans developed. Gradually, fields of bare dunes developed, migrating across the narrow reach of the baymouth bar until checked by vegetation. The propagation and movement of the dunes continued until the sediment supply was eventually limited; by depletion of the original sand source due rising lake levels or a limitation on the availability; by vegetation stabilizing the topography; and by leeward areas acting as sediment traps. Eventually, the Wellington baymouth bar assumed a heavily vegetated, hummocky terrain, probably closely paralleling the present-day topography of Outlet baymouth bar.

King (1966) suggests that "In many cases where the supply of sand is not too great, the coastal dunes are limited to fairly simple foredunes. These mainly form low ridges parallel to the shore, indicating that their source of sand is from the beach, and that their stabilization by vegetation is so rapid that the sand cannot travel far inland". The coastal dunes of the Wellington baymouth bar appear to follow this pattern. As they are typical of a humid and temperate, coastal lacustrine environment, vegetation would play a considerable role in their morphogenesis. Their source of sand does indeed appear to be from the Lake Ontario beach and hence, the evolution of the complex dune systems on the Wellington baymouth bar must be accounted for through other geological events.

The de-stabilization of the land surface due to a removal of vegetation with a resultant release of sand down to the lakeshore by streamflow appears to be the major controlling factor in the recent history of the baymouth bar of this study. With the clearing of the natural forests by the Quaker settlers, breaking of the thin soil cover by cart wheels, and cultivation of the sandy soil, the land-surface equilibrium was initially disrupted. A possible forest fire may well have produced an irrepairable imbalance in the land surface. The exposure of expanses of fine grained, well-sorted sands to the wind provided an abundant supply of sand to stimulate and allow partial migration of the dunes across the bar. In addition, both the seasonal shift in winds and the effects of stream flow would add sand to the eastward longshore drift, thereby causing an accumulation of the transported sand in the south-west area of the shoreline, due to the effects of Owen Point, and resulting in the prograding beach plain now represented as the pan zone. Upon stabilization of the sediment supply, a new foredune ridge formed. In this manner, the massive, high-dune system in the southern sector of the bar was effectively separated from the more recent foredune ridge, by the shallow and flat pan area.

The dune systems on the Wellington baymouth bar are the complex end result of a variety of genetic factors. From the occasional wind drift of the northern sector of the bar, through to the stretch of moderately-sized dunes interspersed with occasional blow-outs in the central area, to the distinctly separated, relict, high-dune system abruptly grading into the swampy fan area bounded by the presently forming foredune ridge on the Lake Ontario shore of the southern sector of the bar, the Wellington baymouth bar dunes have assumed a reflection of their geological history. Through an environmental analysis of the statistical parameters indicating the energy conditions of transportation and deposition, the succession of post-Pleistocene environmental conditions affecting the Wellington baymouth bar has been traced.