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Les dunes littorales en Ontario : répartition et géomorphologie
Küstendünen in Ontario: Verteilung und Geomorphologie

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Résumé de l'article

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Géographie physique et Quaternaire, 1981, vol. XXXV, n° 2, p. 219-229, 9 fig.

COASTAL DUNES OF ONTARIO: DISTRIBUTION AND GEOMORPHOLOGY

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ABSTRACT Transverse dunes (foredunes), parabolic dunes, rare cliff-top dunes, and blowouts are found in Ontario. Many of these coastal dunes are land-locked on abandoned sand plains of partially drained early-post glacial lakes and seas. Others are part of coastal systems found at different stages of evolution along the Great Lakes. An idealized coastal system, as is for great part well developed at Wasaga Beach, includes the following elements: a few metres high foredunes partially deflated and breached by wave washover; low, long, narrow, marshy zones landward from the foredunes: the "pannes"; a wide sequence of numerous beach ridges capped by small (2 m high) stabilized foredunes, and separated by long shallow swales covered by water for several months of the year; intensely deflated transverse dunes which record raised coastlines of old lakes; and finally, high (up to 25 m) nested parabolic dunes showing progressive landward increase in height. These high dunes have developed over sandy, gravelly bars of early Holocene lakes, and have prograded for a short distance over lagoons. Most of the dune systems found along the Great Lakes have developed in the last 3-5000 years. Some of them have been intensely affected by man during the last two centuries, particularly by logging, agriculture, and recreational activities. Some dune fields have been completely flattened, others on the contrary have been reactivated by deforestation, and new dunes have formed and have migrated landward onto forests and cultivated fields.

RÉSUMÉ *Les dunes littorales en Ontario: répartition et géomorphologie.* On trouve en Ontario des dunes transversales, des dunes paraboliques et quelques dunes perchées au sommet de falaises. Plusieurs complexes dunaires sont aujourd'hui isolés du rivage et se rencontrent sur des plaines sableuses correspondant au fond de paléo-lacs et mers du Quaternaire post-wisconsinien. D'autres correspondent à des systèmes littoraux développés aux différents niveaux occupés jadis par les eaux des Grands Lacs. Un système dunaire typique comme celui de Wasaga Beach comprend les éléments suivants: des avant-dunes de quelques mètres de hauteur partiellement actives et sectionnées par le déferlement des vagues; des zones marécageuses basses, longues et étroites sises derrière les avant-dunes et appelées dépressions intra-dunaires; une série de cordons littoraux coiffés de petites dunes d'environ 2 m de hauteur et séparés par de longs sillons ennoyés durant plusieurs mois par année; des dunes transversales actives correspondant aux anciennes lignes de rivage des lacs; et finalement, des complexes de dunes paraboliques atteignant 25 m de hauteur migrant vers l'intérieur. Ces grandes dunes se sont développées au droit de flèches littorales sableuses ou graveleuses des lacs du début de l'Holocène et ont migré sur de courtes distances envahissant les lagunes avoisinantes. La majorité des systèmes dunaires des Grands Lacs ont été mis en place il y a 3000 à 5000 ans. Plusieurs ont été profondément modifiés par l'activité de l'homme au cours des deux derniers siècles, en raison de l'activité forestière, agricole et récréative. Quelques champs de dunes ont été entièrement aplanis, d'autres au contraire ont subi une réactivation à la suite de la déforestation, alors que de nouvelles dunes se sont édifiées et ont migré vers l'intérieur envahissant la forêt et les champs en culture.

ZUSAMMENFASSUNG Küstendünen in Ontario: Verteilung und Geomorphologie. Querdünen (Vordünen), Parabeldünen, seltene Kliffdünen und Windkassel findet man in Ontario. Viele dieser Küstendünen sind Land-umgeben auf verlassenen Sandebenen von teilweise entwässerten früh-postglazialen Seen. Andere sind Teile eines Küstensystems, welche man an den Grossen Seen in verschiedenen Entwicklungsstadien findet. Ein idealisiertes Küstensystem, das sich am Wasaga Strand zum grössten Teil gut entwickelt vorfindet, enthält die folgenden Elemente: einige Meter höhe Vordünen, teilweise abgeflacht und von Wellen überwaschen, tiefe lange schmale Marschgebiete landwärts von den Vordünen, die "Pfannen" eine breite Folge von vielen Strandwällen, von kleinen (2m hohen) Vordünen gekrönt, und getrennt durch lange flache Strandrinnen, für mehrere Monate des Jahres von Wasser bedeckt, sehr abgeflachte Querdünen, die erhobene Küstenlinien alter Seen anzeigen, und schliesslich hohe (bis zu 25m) Parabeldünen die landwärts an Höhe zunehmen. Diese hohen Dünen haben sich über Sand- und Geröllbänken von frühen Holozän Seen entwikkelt, und haben ein wenig über Lagunen vorgebaut. Die meisten der Dünen-systeme an den Grossen Seen haben sich in den letzten 3-5000 Jahren entwikkelt. Einige von ihnen wurden in den letzten zwei Jahrhunderten vom Menschen sehr verändert, teilweise durch Holzfällen, Landwirtschaft und Erholungs Tätigkeit. Einige Dünenfelder sind vollkommen eingeebnet worden, andere wurden im Gegenteil durch Abwaldung wiederbelebt und neue Dünen haben sich gebildet und landeinwärts migriert in Wälder und bebaute Felder hinein.

INTRODUCTION

OBJECTIVES

The objectives of this paper are to establish the distribution of major coastal dune and blowout areas of Ontario and to outline their major physiographic characteristics.

CLIMATIC CONDITIONS

Ontario was covered by continental glaciers as recently as 13,000 years ago in the south and approximately 8,000 years ago in the north (PREST, 1968). Ontario extends from approximately latitude 43° N to 57° N. On the whole its present day climate is classified as "modified continental", and it varies considerably from south to north. Strong cooling effects are associated with the large masses of water of the Great Lakes in the south, and of Hudson and James Bays in the north, partially covered by ice from 3 to 5 months of the year. Such a cooling effect is responsible for the later arrival of spring in areas closer to the Great Lakes than in the western continental regions of Canada.

Mean daily temperatures in January and July reach approximately −4°C and 22°C in the south and −25° and 17°C in the north (BROWN *et al.*, 1968; CHAPMAN and THOMAS, 1968). In the far north, discontinuous and continuous permafrost occurs under the protection of peat (BROWN, 1973). In the south, the ground is frozen for 5 months of the year, but a mid-January thaw of the surface occurs frequently, and has a considerable effect on the denudation of the land as overland drainage is established over frozen substratum.

Throughout the province there is a summer maximum and a winter minimum of precipitation, with a minimum (500 cm) occurring at the western boundary with Manitoba and a maximum (1000 cm) in mid-central Ontario and in parts (snow belt) of southwestern areas. Snowfall accounts for 15 to 30 percent of the annual total precipitation (BROWN *et al.*, 1968; CHAPMAN and THOMAS, 1968).

Wind speeds average up to 19 km/hr in the winter and 10-16 km/hr in the summer. Generally they are less than 30 km/hr, although occasionally their speed exceeds 40 km/hr. Whereas during the winter the northeasterly winds prevail, in the summer southwest and easterly winds are more frequent. Occasional northern winds are strong, but easterly ones are generally weak in the summer (BROWN *et al.*, 1968; CHAPMAN and THOMAS, 1968).

QUATERNARY HISTORY AND DISTRIBUTION OF DUNES

Ontario is an area bordered by the sea to the north (Hudson and James Bays) and four Great Lakes to the south. The morphology of its coastal area is greatly affected by the local geology, such as the rugged erosional coasts of the north shore of Lake Superior and easternmost Lake Ontario, underlain by crystalline Precambrian rocks; the long Bruce Peninsula, held up by the Silurian reefs; and the flat coasts of Lake Erie and Lake St. Clair, underlain by sandy plains, former bottoms of drained glacial lakes (POOLE *et al.*, 1968; CHAPMAN and PUTMAN, 1966; MARTINI *et al.*, 1970). Whereas the substratum is of fundamental importance in influencing the type of coast that develops, glaciation has molded some of the most striking characteristics of the geomorphology of Ontario. The glacial influence manifests itself in the regional reorganization of the drainage pattern, shifting the northward pre-Pleistocene drainage to a primarily southward pattern by creating large divides across central Ontario; in the formation of the basins of the Great Lakes, by enlarging pre-glacial river valleys; and in the molding of the recent coasts, some still influenced by isostatic rebound, another legacy of glaciation. Glaciers have distributed considerable amounts of sediment. The sands of Ontario are concentrated in early post-glacial fluvial outwash, deltas, and on the coasts of ancient and modern lakes and seas (Fig. 1). Well developed dunes are found along both the modern coasts of the Great Lakes and Hudson Bay, as well as along uplifted coasts of ancient lakes in southern Ontario and of the Champlain Sea in the eastern parts of the province. Whereas transverse and parabolic dunes and blowouts are common to all the coastal areas, no transverse dunes are readily recognized on sand bodies of ancient coasts. The localization of modern and ancient dunes is associated with local accumulation of sand in pocket beaches, and their orientations reflect the direction of prevalent winds across long fetches of antecedent lakes (Fig. 1). Along the coasts of Hudson-James Bay, dune morphology and intensity of blowouts are greatly influenced by wildlife activities, particularly polar bears that dig numerous sunning pits, locally destroying the sparse protective vegetation cover. In the south, several dune fields have been flattened out by man to facilitate agriculture, or old systems have been reactivated and expanded due to logging activities (ONT. MIN. OF NATURAL RESOURCES, 1974, 1977a, b).

EXAMPLES OF DUNE SYSTEMS

Different types of dunes are present throughout Ontario, but the best and most accessible examples comprise foredunes (transverse dunes) well developed along portions of Lake Huron (Grand Bend) and Lake Ontario (Sandbanks and Outlet), and parabolic dunes which are well represented in central Ontario and very good examples are present along the north shore of Lake Superior (Pukaskwa Park (PP) and Pic River), in Georgian Bay

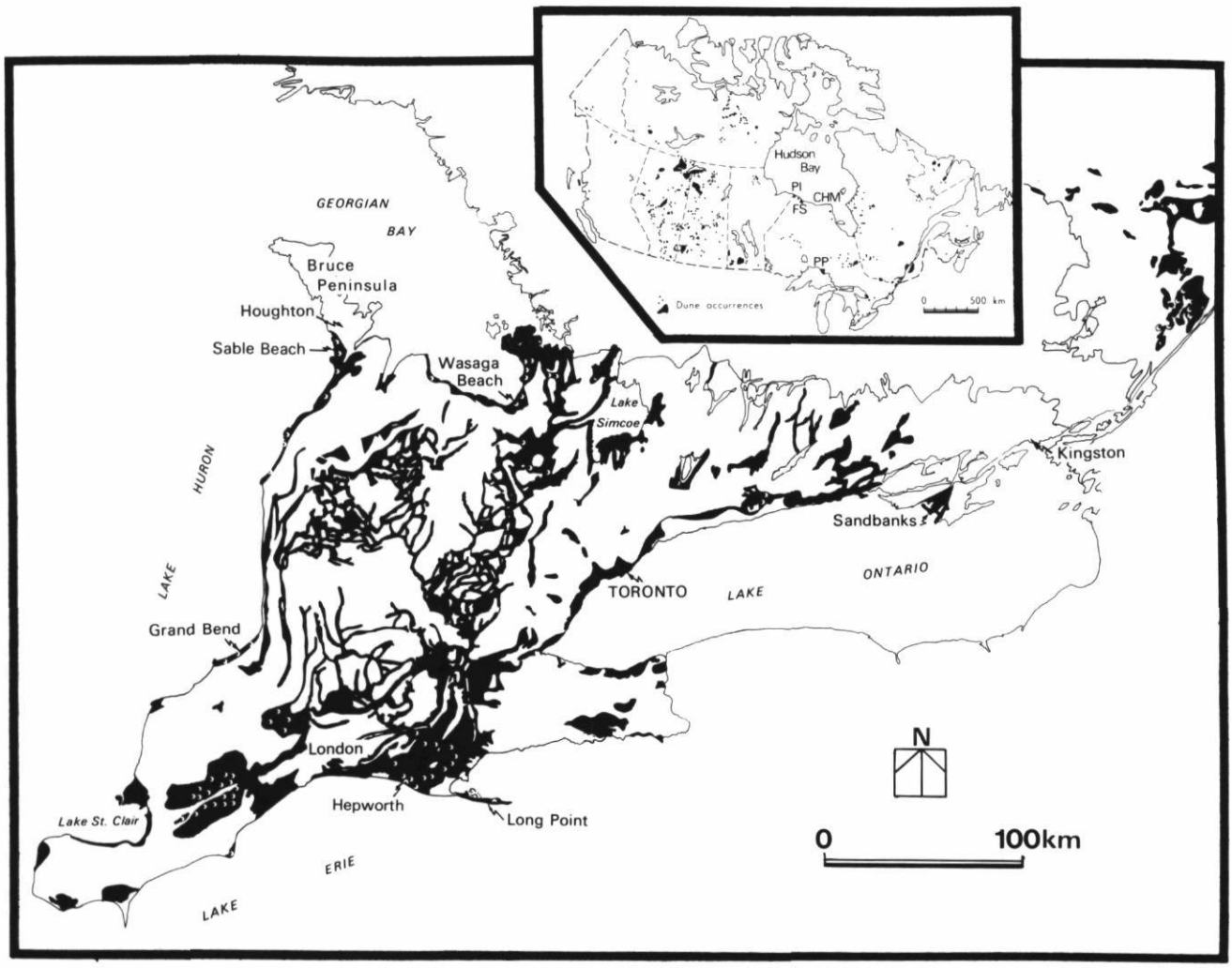

FIGURE 1. Sand distribution (black pattern) and dune areas (small white lunate symbols) in Southern Ontario (after CHAPMAN and PUTNAM, 1966; DAVID, 1977, 1979).

Répartition des dépôts de sable (en noir) et des zones de dunes (croissants blancs) dans le sud de l'Ontario (d'après CHAPMAN et PUTNAM, 1966; DAVID, 1977, 1979).

and in Lake Huron (Wasaga Beach and Grand Bend). Blowouts are found superimposed over the dunes, but become of prime individual importance on coastal systems of Hudson-James Bay (Cape Henrietta Maria (CHM), Fort Severn (FS)-Penn Island (PI) area), Georgian Bay and Lake Huron (area north of Wasaga Beach, Sable Beach), and Lake Ontario (Sandbanks) (Figs. 1, 2). Blowouts characterize flat sandy areas intensely used for agriculture in the Houghton area of Bruce Peninsula. One good example of active cliff-top dunes is located in the Hepworth area along the bluffs of Lake Erie.

Analysis of a few of these typical dune systems will suffice to elucidate major geomorphological features and historical development.

CLIFF-TOP DUNES

Cliff-top dunes are found in association with the Pleistocene coastal bluffs of the Great Lakes region (JENNINGS, 1967; KING, 1972). The example from Houghton in the Lake Erie basin best illlustrates the conditions that lead to the new formation of these features, or to the reactivation along the cliff edges of preexisting dunes (Fig. 1). In this particular case the bluffs are composed of a thick (15 m) sandy fill of a wide valley cut into Wisconsin tills. Strong onshore winds erode the loose sand from the face of the bluffs and deposit it into the separation air-bubble that forms at the top of the cliff. There, a high, wide dune develops (Fig. 2B). The dune is sparsely vegetated but fast growing trees

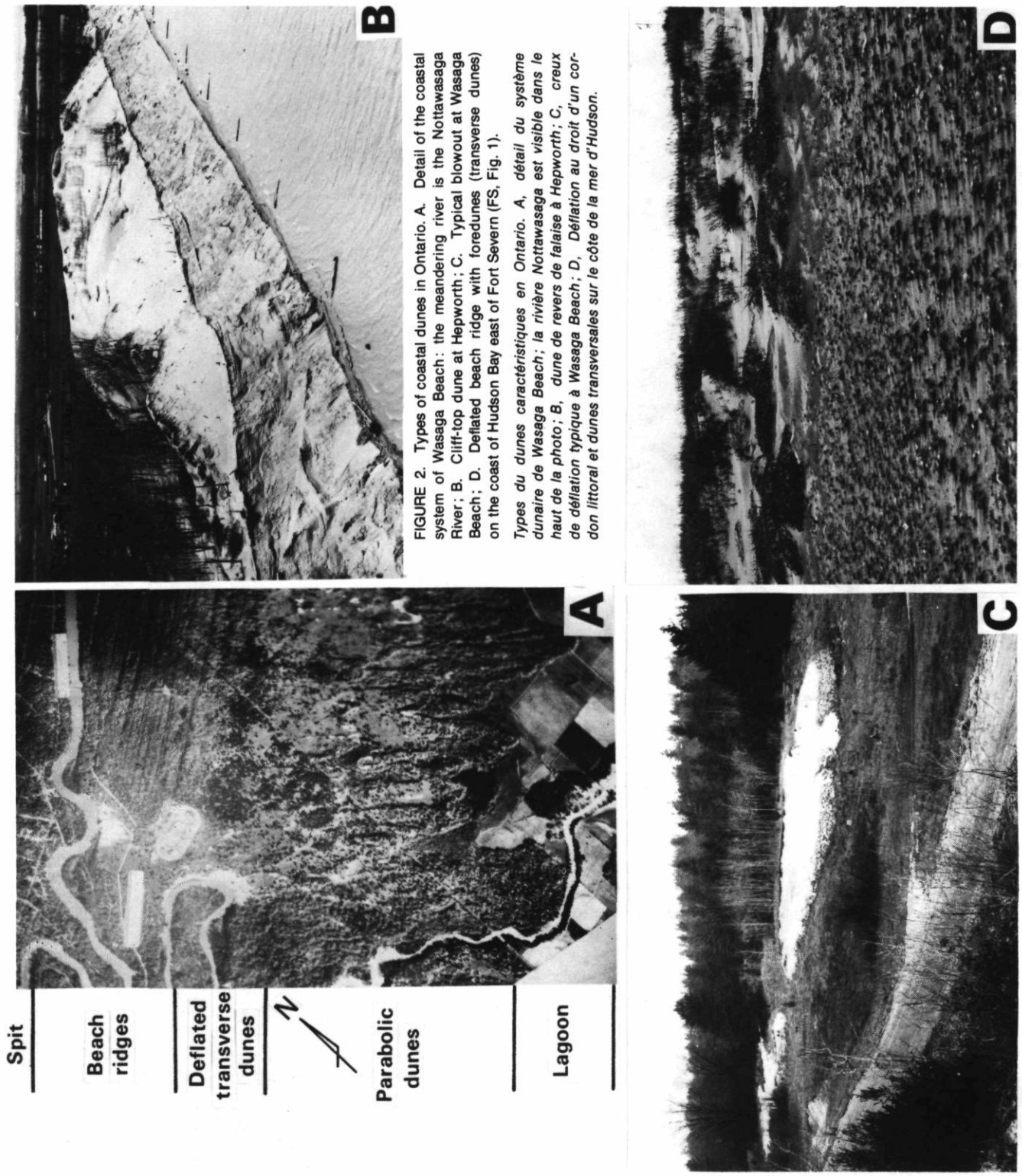

FIGURE 2. Types of coastal dunes in Ontario. A. Detail of the coastal system of Wasaga Beach: the meandering river is the Nottawasaga River; B. Cliff-top dune at Hepworth; C. Typical blowout at Wasaga Beach; D. Deflated beach ridge with foredunes (transverse dunes) on the coast of Hudson Bay east of Fort Severn (FS, Fig. 1).

Types du dunes caractéristiques en Ontario. A, détail du système dunaire de Wasaga Beach; la rivière Nottawasaga est visible dans le haut de la photo; B, dune de revers de falaise à Hepworth; C, creux de déflation typique à Wasaga Beach; D, Déflation au droit d'un cordon littoral et dunes transversales sur le côte de la mer d'Hudson.

(poplar) and grasses anchor its flanks and inland toe, leading to an embryonic parabolic form. The cliffs retreat at a rate of 0.5 m/year due to wave and wind erosion (ENVIRONMENT CANADA, 1975). The cliff-top dune regenerates itself and progrades at the same rate landward over flat, sandy, cultivated fields.

BLOWOUTS

Blowouts are part of most vegetated dunes and sand plains. They form wherever a sufficiently large disruption of the protective vegetative cover occurs, due either to natural events such as wave washover of foredunes, fire, digging and grazing by animals, or to logging, trampling and other human activity. After the blowout is generated it perpetuates itself by growing until it reaches a streamlined spoon shape, in aerodynamic equilibrium with the local dominant winds (Fig. 2C). The blowouts modify their environment and microclimate sufficiently to inhibit fast revegetation, and persist for a long time. Examination of airphotographs taken over a 30 year interval shows little change in the shape and localization of certain blowouts in parts of Ontario (ARBOUR, 1978).

Blowouts may lead to partial or complete deflation of dunes (GOLDSMITH, 1978). In the Bruce Peninsula the sandy plain of Hepworth has been deforested and has undergone intense agricultural activity (CHAPMAN and PUTNAM, 1966). During dry years, the sandy soils become exposed and the whole area is punctuated by shallow (less than 1 m), wide, shifting blowouts.

Along the northern coast of James Bay and Hudson Bay, where sufficiently large amounts of sand can accumulate over emerging beach ridges, sizable foredunes form (Fig. 2D). These are subjected to intense strong winds during the summer and early fall before the ground freezes. These foredunes are intensely used by bears during the summer, and some of their vegetation and streamlined shapes are disturbed, leading to numerous blowouts. As the coasts are uplifted through isostatic rebound, the ridges are covered by tundra vegetation which is unable to protect the sand, partially because it is locally disrupted and lifted by frozen ground phenomena. The sand dunes of this coast are deflated. Occasional local, high conical or parabolic remnant sand accumulations persist in the Hudson Bay Lowland where they are covered and protected by thick peat layers and forest.

TRANSVERSE AND PARABOLIC DUNES

Parabolic dunes are typical of vegetated regions and are the most characteristic forms of coastal areas (Fig. 2A; COOPER, 1958, 1967). Commonly, they are secondary features evolving from deflated transverse dunes. They form under on "increasing stabilizing effect of vegetation" where a relatively large amount of sand is available for a sufficiently long period of time (order of tens and hundreds of years) and can be transported by sufficiently strong winds (GOLDSMITH, 1978, p. 203). They are part of complex coastal systems which contain two or more components of the following idealized sequence of landforms: foredunes, raised beaches capped by transverse dunes locally highly deflated and with numerous stabilized blowouts, parabolic dunes increasing in height and size landward, and a lagoon totally or partially drained, in the back of the system (Fig. 2A). Parts of these systems are actively forming today, while others were stabilized at some stage of their evolution, and still others are found at different stages of disruption and reclamation by man.

1. Long Point

A good example of an incipient system is found near the tip of Long Point in Lake Erie (Figs. 1, 3). Long Point is one of three large spits that protrudes into the shallow lake from the Ontario coast (TRENHAILE and DUMALA, 1978; COAKLEY, 1976). The existence of the large spit at Long Point is probably associated with a shallow, substratum ridge, concentrating the sedimentation of sand derived from the erosion of sandy coastal bluffs to the west and driven by strong longshore currents. The spit has grown by the addition of landward recurved ridges, kept separated by partially filled swales which retain wetland conditions. Wave washovers are common. It is in these erosional washover areas that blowouts are initiated and evolve into incipient parabolic dunes migrating landwards (Fig. 3).

2. Pukaskwa Park and Pic River (PP)

A more advanced stage of evolution of the transverse-parabolic dune system can be found in restricted areas along the north shore of Lake Superior (Fig. 1). This coast is primarily rocky, but accumulations of sand occur in coves underlain by glacio-fluvial deposits, in part reworked onto lacustrine terraces during earlier stages of Lake Superior (PYE, 1969; BILLINGS, 1974; SAARNISTO, 1974; ONT. MIN. OF NATURAL RESOURCES, 1977c). Some of this material is being reworked by rivers and transported along the coast near the river mouths. However, more distant longshore distribution is inhibited by the narrow shelf and the steep subaqueous slopes of the lake. The sands that are not trapped in the proximal beaches, or blown inland, are quickly lost below wave base. The beaches of the Pukaskwa Park-Pic River area are narrow, steep, and develop discontinuous small foredunes frequently dissected by washover events (Fig. 4). Wide areas of sparsely vegetated irregular blowouts form behind the foredunes, and farther inland, well developed, stabilized, or reactivated parabolic dunes are seen ranging in height from 6 m (in Pukaskwa Park) to 10-20 m (near the mouth of Pic River) (Figs. 4, 5A, 5B). The distribution of the blowouts and the develop-

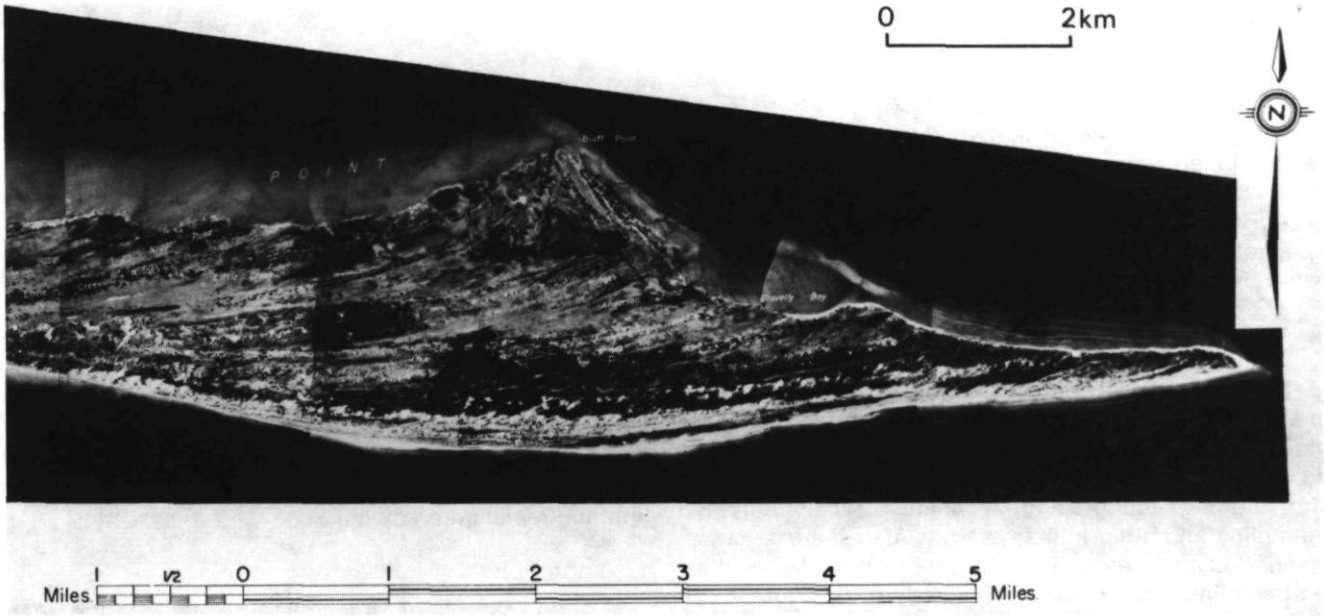

FIGURE 3. Tip of Long Point spit in Lake Erie showing recurved beach ridges and incipient parabolic dune-blowouts.

Extrémité de la flèche littorale de Long Point, lac Érié, montrant un système de cordons recourbés et des creux de déflation embryonnaires.

ment of the parabolic dunes are due in part to the orientation of the beach toward the open long fetch of the lake, to the local modification of the onshore winds by knobs of bedrock which localize areas of erosion and funnel winds, to forest fires, and in more recent times, to logging activities. Logging affects the dune systems in several ways. In parts of Pukaskwa Park, the cutting of several metres wide trails perpendicular and open to the coast have funneled onshore winds and established continuous paths from the beach-blowout area to inland developing parabolic dunes (Fig. 4). In the Pic River area, the beach and foredunes are continuously disturbed by vehicles used in logging activities. This results in the disruption of vegetation and the roughening of the sand surface (Fig. 5A). Onshore winds can then cut deeply into older dunes and supply sand to reactivate large nested parabolic dunes which are advancing actively and burying the inland forest (Fig. 5B).

3. Sandbanks-Outlet

A further stage of development, again a product of natural processes strongly affected by man's activities during historical time, is displayed along the northeastern shores of Lake Ontario, particularly at Sandbanks and Outlet (Fig. 6). In these two instances, the dunes develop on baymouth bars that have formed during the later stages of the rise of Lake Ontario, through reworking of local remnants of Pleistocene sands. These systems have four well defined zones (Fig. 6). The *foredunes* are an effective barrier for all but the highest storm waves, and protect a low, restricted, long, narrow,

FIGURE 4. Distribution of aeolian features on a small raised terrace in the Pukaskwa Park.

Répartition des formes éoliennes au droit d'une basse terrasse dans le parc de Pukaskwa.

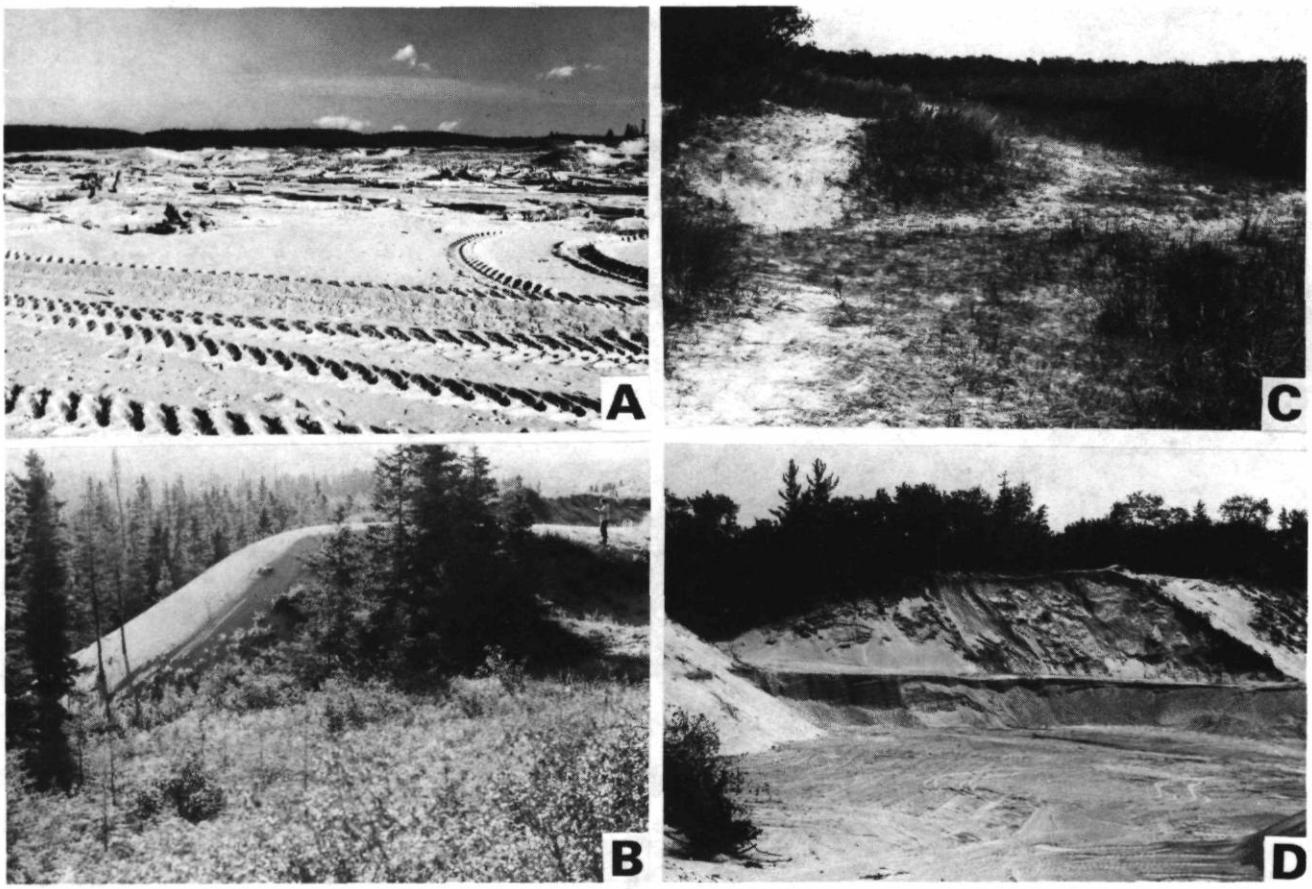

FIGURE 5. Typical coastal aeolian environment in Ontario. A. Beach area near the mouth of the Pic River, roughened by vehicles; B. Parabolic dune advancing over an established forest near the mouth of the Pic River; C. "Pannes" (wet areas) in the back of foredunes (to the right) at Sandbanks; D. Cross section through a parabolic dune system formed over a Nipissing gravelly barrier beach at Wasaga Beach.

Environnements éoliens caractéristiques en Ontario. A, plage perturbée par des traces de véhicules à l'embouchure de la rivière Pic; B, dune parabolique envahissant la forêt près de l'embouchure du Pic; C, dépression humide interdunaire à Sandbanks; D, coupe transversale d'un système dunaire développé au droit d'un cordon prélittoral à Wasaga Beach.

swampy zone which is locally called *pannes* (Figs. 6, 5C; ONT. MIN. OF NATURAL RESOURCES, 1977b; SMITH 1978). Landward from the pannes there are high dunes (up to 25 m high), most of which are covered by recent blowouts. These high parabolic dunes migrate into West Lake generating a linguate inner coast for the baymouth bar (Fig. 6). The present morphology of Sandbanks is a product of the relatively recent human activity in the area. Prior to the eighteenth century colonization of the area, stands of pine and hardwood stabilized the sandy areas. Logging had removed most of the forest by the mid-nineteenth century. The sands were remobilized and the high parabolic dunes were formed. Early in the twentieth century, reforestation was started to halt the movement of sand, and was intensified in the mid-twentieth century. At the present time, the area is used intensely for recreational purposes (picnic and camping), and appropriate land use planning and control is limiting the disruption of vegetative cover and the enlargement of the already widespread blowout zones (ONT. MIN. OF NATURAL RESOURCES, 1977b).

4. Grand Bend and Wasaga Beach

The coastal systems of Grand Bend and Wasaga Beach are much similar to each other, but the first has retained well developed foredunes, while the second has better defined beach ridges and large, high parabolic dunes (Fig. 1). Their evolution has spanned the whole of the Holocene history of the area. The early stages of Lake Warren are recorded in the Grand Bend area, and in both Grand Bend and Wasaga Beach there are good records of various stages of Lake Algonquin, Lake Nipissing, Lake Algoma (?), and finally of the more recent fluctuations of Lake Huron (Fig. 7; LEWIS, 1970; MARTINI, 1974, 1975; MARTINI and HOFFMAN, 1976;

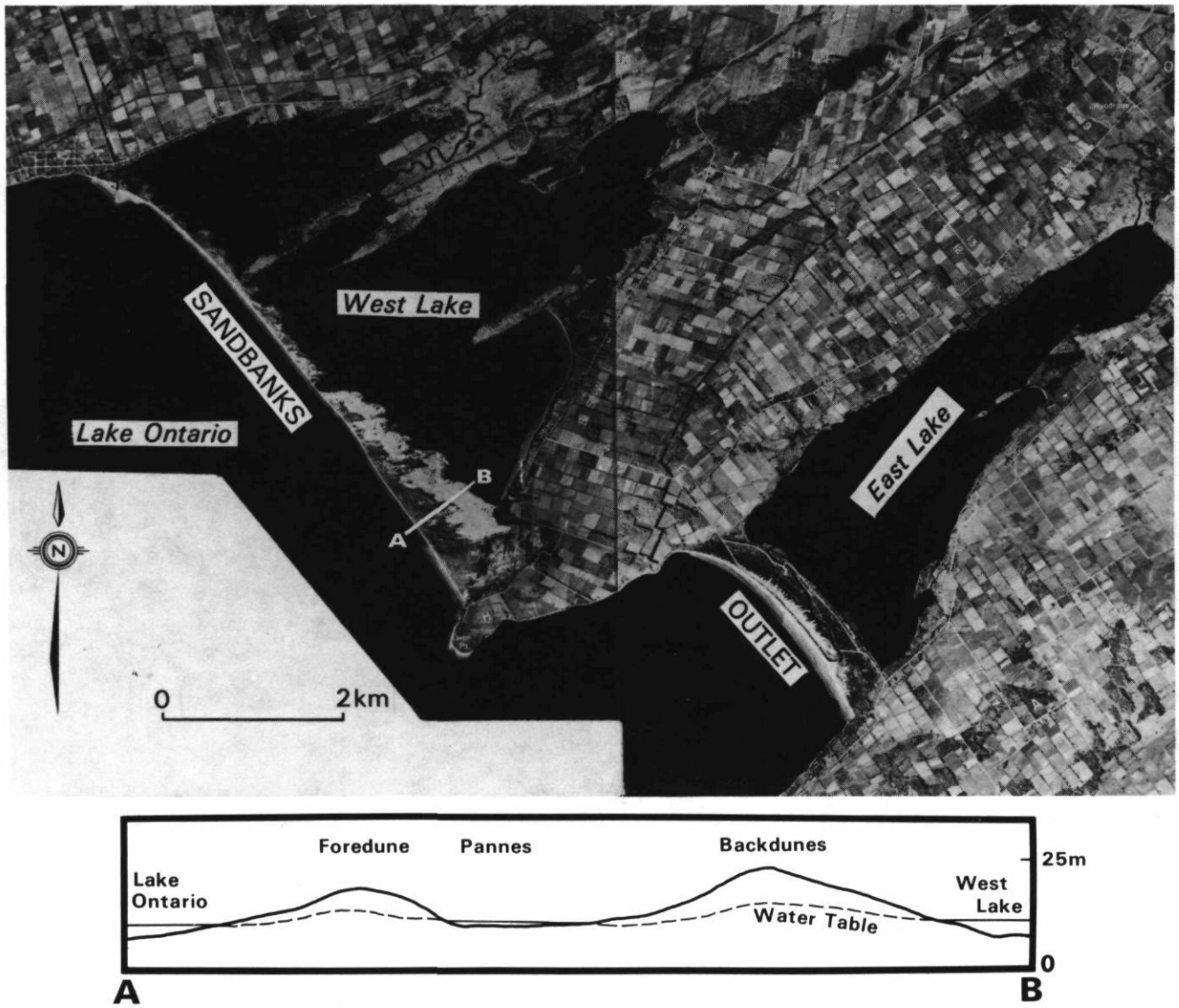

FIGURE 6. Air-photograph mosaic of the Sandbanks and Outlet area and diagrammatic cross-section through the coastal environments at Sandbanks.

Photo-mosaïque de la région de Sandbanks et d'Outlet et coupe transversale de la flèche littorale de Sandbanks.

ONT. MIN. OF NATURAL RESOURCES, 1974, 1977a; COOPER, 1979).

These two coastal systems have developed from pocket beaches facing long fetches of their respective lakes. Bedrock promontories and Pleistocene till bluffs have anchored the embayments where longshore drift could have accumulated a large amount of sand and gravel. In both cases, Lake Algonquin gravelly beaches and baymouth bars (in the Grand Bend area) are present (Figs. 8, 9). The Algonquin coastal reentrances were dammed farther lakeward by a Nipissing bar which started forming during the early transgressions of that lake (Fig. 7). The sequence of events that led to the present day geomorphology and surficial sedimentary sequences of these areas is better defined, exposed and documented in the Wasaga Beach area. The Nipissing bar enclosed a marly, clayish, peaty lagoon that persisted throughout the transgression and subsequent fluctuations of the lake (Fig. 8). Dunes may have been formed at this time, and wind-blown sand occurs interstratified within the lagoonal sediments (MARTINI, 1975). The oldest available ^{14}C date obtained from organic matter buried at the base of the high parabolic dunes, indicates that these dunes started forming approximately 2500-3000 years ago (MARTINI, 1975). This is the time during which dry conditions may have existed, and the Lake

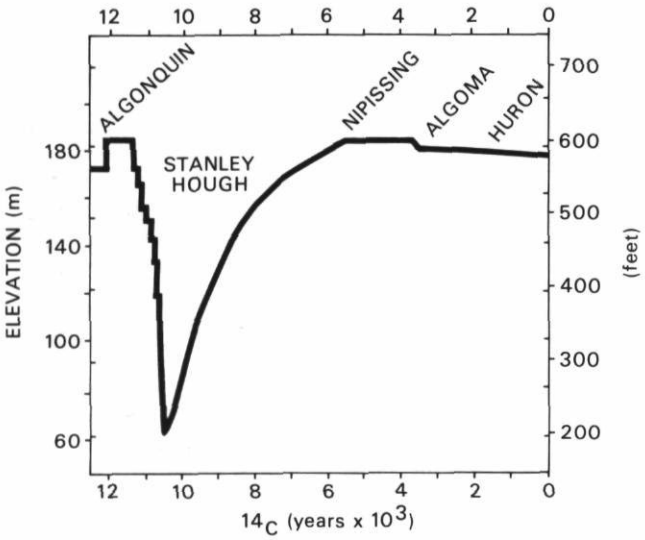

FIGURE 7. Variations in lake level in the Lake Huron Basin (after Lewis, 1970).

Variations du niveau du lac Huron au Quaternaire (d'après LEWIS, 1970).

Nipissing had lowered rapidly to the Lake Algoma lake level due to a period of rapid downcutting of the southern outlet through relatively softer bedrock layers (Fig. 7; LEWIS, 1970; ONT. MIN. OF NATURAL RESOURCES, 1974). Strong deflation of foredunes and exposed beaches, occurred and lead to relatively rapid buildup and stabilization of the high parabolic dunes over the Nipissing bar and, in part, over the drained lagoon (Figs. 2A, 5D). The resultant parabolic dune field is a complex one, with the largest and better developed dunes farther inland, and progressively smaller dunes nested between the arms of the older and higher landforms. The younger parabolic dunes cut off the supply of sand to the inland features and, in sheltering them, inhibited further downcutting of the deflated plains between the wings of the older dunes. This led to the arrest and subsequent stabilization of the dunes. The deflated planes that accompany each of the parabolic dunes are located at slightly different levels at Wasaga Beach. This may be due also to various other causes, one of which is the depth to watertable, which was progressively lowered as the Nipissing and Algoma

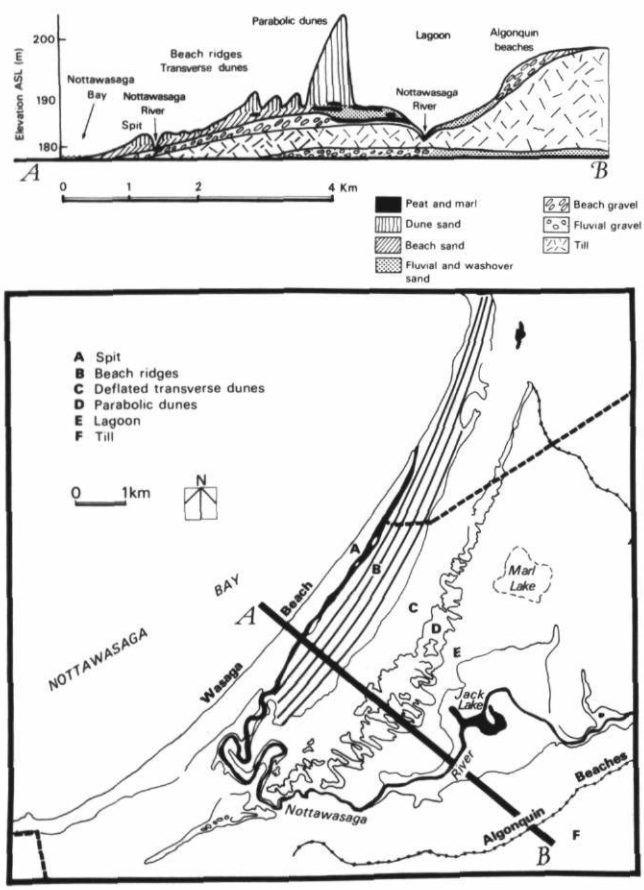

FIGURE 8. Map and diagrammatic cross-section of the coastal environments of Wasaga Beach (after MARTINI, 1975).

Carte et coupe schématique à Wasaga Beach (d'après MARTINI, 1975).

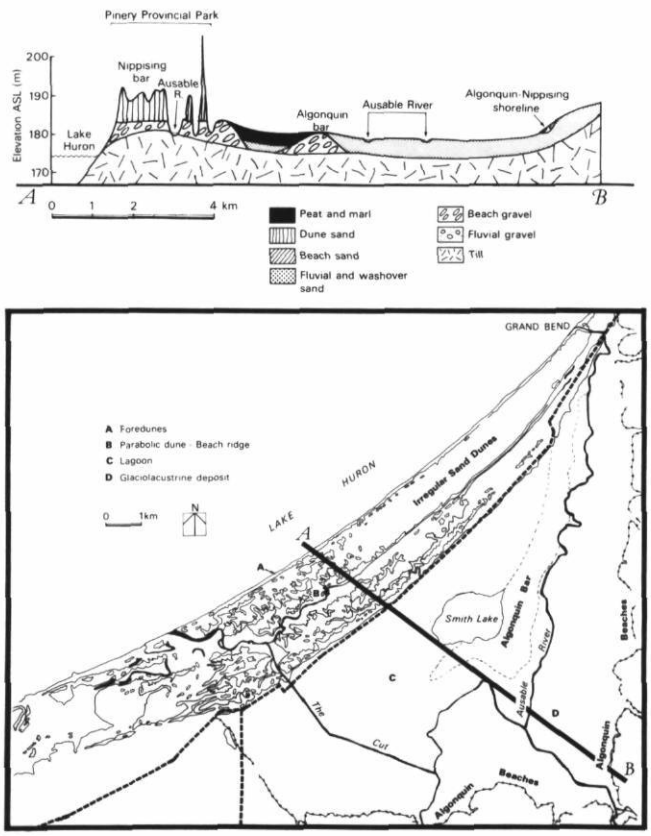

FIGURE 9. Map and diagrammatic cross-section of the coastal environments of Grand Bend (After ONTARIO MINISTRY OF NATURAL RESOURCES, 1977a).

Carte et coupe schématique à Grand Bend (d'après ONTARIO MINISTRY OF NATURAL RESOURCES, 1977a).

levels dropped towards the present day level in Lake Huron (Fig. 7).

While the stratigraphic record helps in establishing the possible starting time of the development of the large parabolic dunes (at approximately 2500-3000 BP), geomorphological analysis suggests that they were formed and stabilized quickly (few centuries perhaps) (MARTINI, 1975). The parabolic system is in fact rimmed lakeward by high transverse intensely deflated dunes, which are now stabilized, but which may have been the foredunes from which the parabolic systems started and developed during a relatively short, particularly unstable, period of time. These deflated transverse dunes change lakeward into a wide, well developed zone of "beach ridges", most of which are capped by small (1 m high) foredunes, only locally showing small stabilized blowouts. These "beach ridges" have formed in the last 2500 years, during the relatively regular lowering of the Lake Huron to its present day level (Fig. 7). Since the start of formation of these beach ridges the parabolic dunes have experienced minor blowouts, but they have remained essentially unchanged to the present day.

At Wasaga Beach, the localization of the village on the beach inhibits development of broad coastal ridges and foredunes. Instead, high foredunes are well developed at Grand Bend and, except for occasional wave washover, they protect effectively low marshy areas and high dunes farther inland (Fig. 9; COOPER, 1979; BOWLES, 1980).

SUMMARY AND CONCLUSION

Ontario is a glaciated area that has been covered in many parts by extensive saline and fresh water bodies since the last deglaciation. Rapid transgressions and regressions have formed widespread, thin, sandy deposits along the coasts of these lakes and seas. Numerous dunes have been and are still forming along those coasts. Some of the coastal systems are now landlocked following the draining of the lakes and the retreat of shorelines. Other coastal systems are still active near modern shores, and have evolved during the last 3000-5000 years.

Similarly to other vegetated coasts in the world, the most common coastal dunes in Ontario are the transverse (foredunes) and parabolic dunes. Occasional cliff-top dunes are present at the edge of sandy bluffs of Lake Erie. Blowouts may be present on every type of dune, but they achieve importance in their own right where the vegetation cover is unable to protect the sandy surfaces, such as along the shore of James Bay and Hudson Bay, where the grassy vegetation is disrupted by wildlife and permafrost phenomena, and as in parts of southern Ontario where intense agricultural practices expose bare soil.

The various coastal dune systems that have been observed in Ontario can be ranked according to their degree of development or disruption. Given sufficient time and sand supply, the ideal fully developed system is exemplified by the one at Wasaga Beach (Figs. 2A, 8). It consists of a lagoon (Nipissing in age) restricted by a gravelly bar, capped by large, old (approximately 3000 years) parabolic dunes. The parabolic nested dune field grades lakeward into recognizable partially deflated old raised transversal dunes, which in turn change into a well defined sequence of beach ridges and small dunes. This ancient system is bounded near the lake by a river and an incipient beach ridge and foredune. However, these last two modern elements of the landscape are better developed on other coasts of the Great Lakes, such as at Grand Bend and at Sandbanks. At those locations, partially deflated high foredunes protect long, narrow marshy zones (pannes) which separate the modern coast from inland high dunes. Whereas this generalized model of the landscape recurs frequently at different stages of development along all the coasts of the Great Lakes, human activities, primarily logging and recreation, have greatly affected some of the dune systems by reactivating them, such as at Sandbanks, locally on Bruce Peninsula, and along the coast of Lake Superior. In such cases the morphology of the coastal landscape has evolved in the last two centuries.

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