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The Hudson Bay Lowland: major geologic features and assets

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Abstract

The Hudson Bay Lowland is a vast (325,000 km^2), flat (average slope 0.5 m/km) physiographic region of Canada located to the southwest of James Bay and Hudson Bay. It is underlain by Paleozoic and Mesozoic rocks and bounded by Precambrian terrains. Thin Pleistocene till sheets, locally deposited on fluted terrains mantle most of the Lowland, and they are overlain by thin marine and coastal Holocene deposits which have formed during the ongoing regression from an early post-glacial sea, the Tyrrell sea. The present shores of the James Bay and Hudson Bay are but one stage of development of such regressive sequences. More than 90% of the vast emerged Lowland is covered by one of the largest cold wetlands and peatlands of the world. Up to 3–4 m thick peats have developed in the last 5000 years in inland fens and raised bogs.

Fresh water is the major resource of the area, both for hydroelectric power and/or irrigation on a continent wide scale. Other resources not yet fully evaluated, consist of mineral deposits on or near Precambrian inliers, hydrocarbons in the relatively thin Paleozoic sequence, and lignite, kaolin and quartz sand in Mesozoic terrains.

The damage generated by any development in the area, must be carefully weighted against the worldwide importance of this vast peatland on gaseous fluxes and atmospheric balance. Furthermore the coastal zone of the Lowland is a major staging and breeding ground for polar bears, migratory birds and other species. Perhaps assurance of preservation of the still pristine natural Hudson Bay Lowland should be achieved by establishing it as an international heritage park.

Introduction

The Hudson Bay Lowland of central-east Canada has several quasi-unique distinctions: it is one of the largest cold wetlands of this world essentially untouched by man, it developed close to centres of Pleistocene glaciations, and it bounds cold, mesotidal, mediterranean seas which cover the only remnant, sedimentologically active, intracratonic basin of those which covered North America in Paleozoic times (Fig. 1). The objectives of this paper are to illustrate major features of the Lowland and briefly analyze their exploitation potential. Original information gathered over more than a decade of sedimentological and biological multidisciplinary studies of the area is used as well as data from the scanty literature (Haworth et al., 1978; Glooschenko & Martini, 1978; Martini, 1982b; Martini, 1986).

Geology

Precambrian terrains bound the Paleozoic and

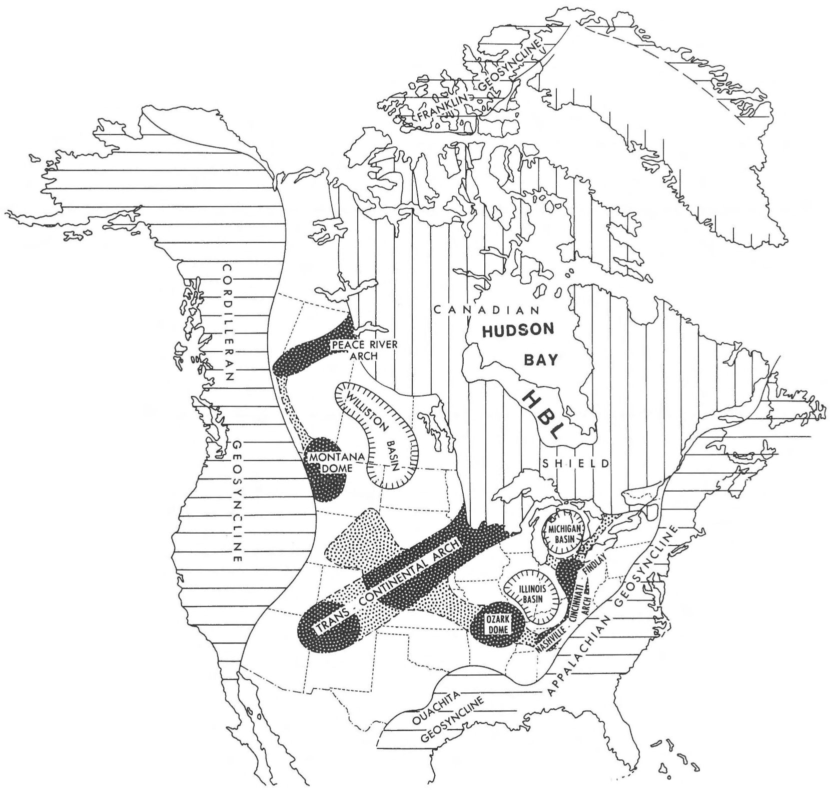

Fig. 1. Location map and Paleozoic basins of North America. HBL = Hudson Bay Lowland. (after Clark & Stearn, 1960).

Mesozoic rocks which form the substratum of the Lowland and most of the seafloor of James Bay and Hudson Bay (Fig. 2). Precambrian inliers of the Sutton Highlands subdivide the Lowland into two zones, a James Bay portion which occupies the geological Moose River Basin and another portion which corresponds to the Hudson Bay Basin (Sanford et al., 1968; Sanford & Norris, 1975; Sanford et al., 1979). These basins have been active since at least early Cambrian times. The origin of the basins is not clear, except that perhaps they are related to Precambrian downwarps associated with the cratonization of former plate collision zones (Stockwell, 1970; Baer, 1970; Donaldson, 1986). An alternative, or complementary hypothesis is that part of the Hudson Bay Basin is directly or indirectly associated with the impact of a large meteorite (asteroid) which may either have generated the crustal depression itself during the Precambrian or may have been influencial in localizing the collision

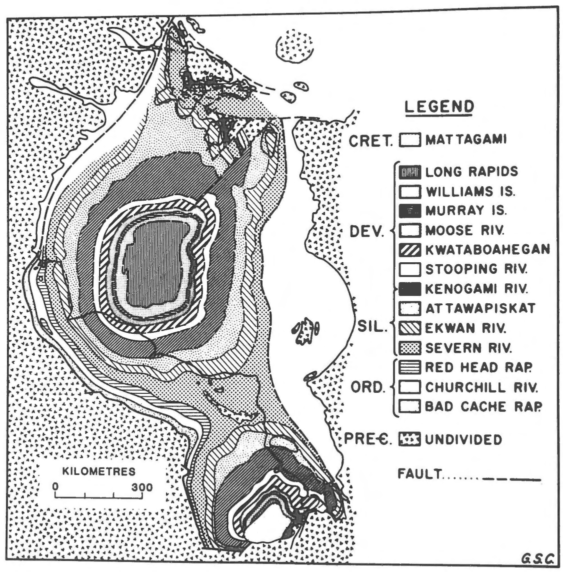

Fig. 2. Geological map of the Hudson Bay area (from Sanford & Norris, 1973).

zones (Beals, 1968). In any case, the Paleozoic sequences record shallow marine environments in both the Hudson Bay and Moose River (James Bay) basins (Sanford et al., 1968; Norris, 1986; Johnson et al., 1986). Well developed Silurian reefs rimmed the persistent Cape Henrietta Maria Arch which subdivided the two basins. Mud (now shaley red beds) was injected from the distal rising Appalachian mountains in Devonian times. Cretaceous sedimentation in the Moose River Basin produced lignite-bearing, fluvial sequences. These Mesozoic terrains contain potentially exploitable deposits of kaolinitic clays (fireclay) and of good quality quartz sand (Telford & Long, 1986). Since Cretaceous times the Lowland has undergone erosion, lately by Pleistocene glaciers (Lee, 1968; Prest, 1970; Shilts, 1982, 1986). The most recent geological events have been the Pleistocene glacial sedimentation followed by an early post-glacial marine submersion (Tyrrell sea) and a still continuing emersion responsible for a thin but widespread offlap sedimentary sequence, and paludification of the Lowland (Lee, 1968; Martini, 1981a, 1982a).

Climate

Similarly to large parts of Alaska, northern Canada, and most of Scandinavia and the U.S.S.R., the Hudson Bay Lowland has a humid microthermal *arctic* climate (Dcf under the Koppen system) (Chapman & Thomas, 1968; Maxwell, 1986). Its northern part, from latitude 58° 50′ N down to latitude 52°, has a mean annual temperature of −3.9° C, the southern part, from 52° N to 50° N, has an average of −1.1° C. Winters are cold with January temperatures varying between mean daily maxima of −15.6° C in the south and −17.8° C in the north, and respective mean daily minima of −26.7° C and −28.9° C. Summers can be rather warm with July average daily maxima of 22.8° C in the south and 20.6° C in the north. Precipitation varies between 66 and 61 cm from the south to the north and the snowfall is respectively 241 and 203 cm. There is no major variation in precipitation, except for a slightly drier, thus more fire-prone area in the northwest. Winds are consistent and strong. In the summer, intense fog patches form, particularly along the Hudson Bay coasts when cold tidal waters of the bay cover the wide warmer tidal flats.

The cold characteristic of the region is in part due to latitude, but mostly to the fact that the flat region is not protected from arctic air masses by any mountainous terrain, and, most of all, to the influx of arctic waters into Hudson Bay and James Bay through the narrow Fury and Hecla Strait in the northwestern corner of Foxe Basin and through the Hudson Strait. These arctic currents move counterclockwise and have a powerful refrigeration effect on the Lowland (Figs. 3, 4; Dunbar, 1951). By-products of such refrigeration are the presence of an ice-cover for at least six months of the year, and the development of permafrost at very low latitudes (Fig. 4; Markam, 1986). Freeze-up starts in the region in November and break up in May, with ice floes still present in the Bay in July. The ice-cover protects the substratum from any major changes during winter, but, at breakup time, it greatly affects the coastal morphology and sediments and it induces recurring ice jams in the rivers. The northward flowing rivers break first in the south and pile ice, waters and sediments against the still solid ice plugs of the lower reaches and deltas. The permafrost is a Holocene feature. It is still developing as the land emerges from the sea at an isostatic uplift rate of 0.75–1.00 m/century (Hunter, 1970; Webber et al., 1970). While there is no permafrost at the present shores, except in the northernmost part of the Lowland, continuous permafrost develops onland just south of the Hudson Bay, discontinuous permafrost farther south still, and sporadic permafrost in the southernmost parts of the Lowland.

Holocene landscape

Sedimentary features

The Hudson Bay Lowland is characterized by an emergent coastal landscape. Such a landscape is usually portrayed as a series of emerged gravelly beach ridges (Fairbridge & Hillaire-Marcel, 1977; Martini, 1981a). Indeed flights of raised beach

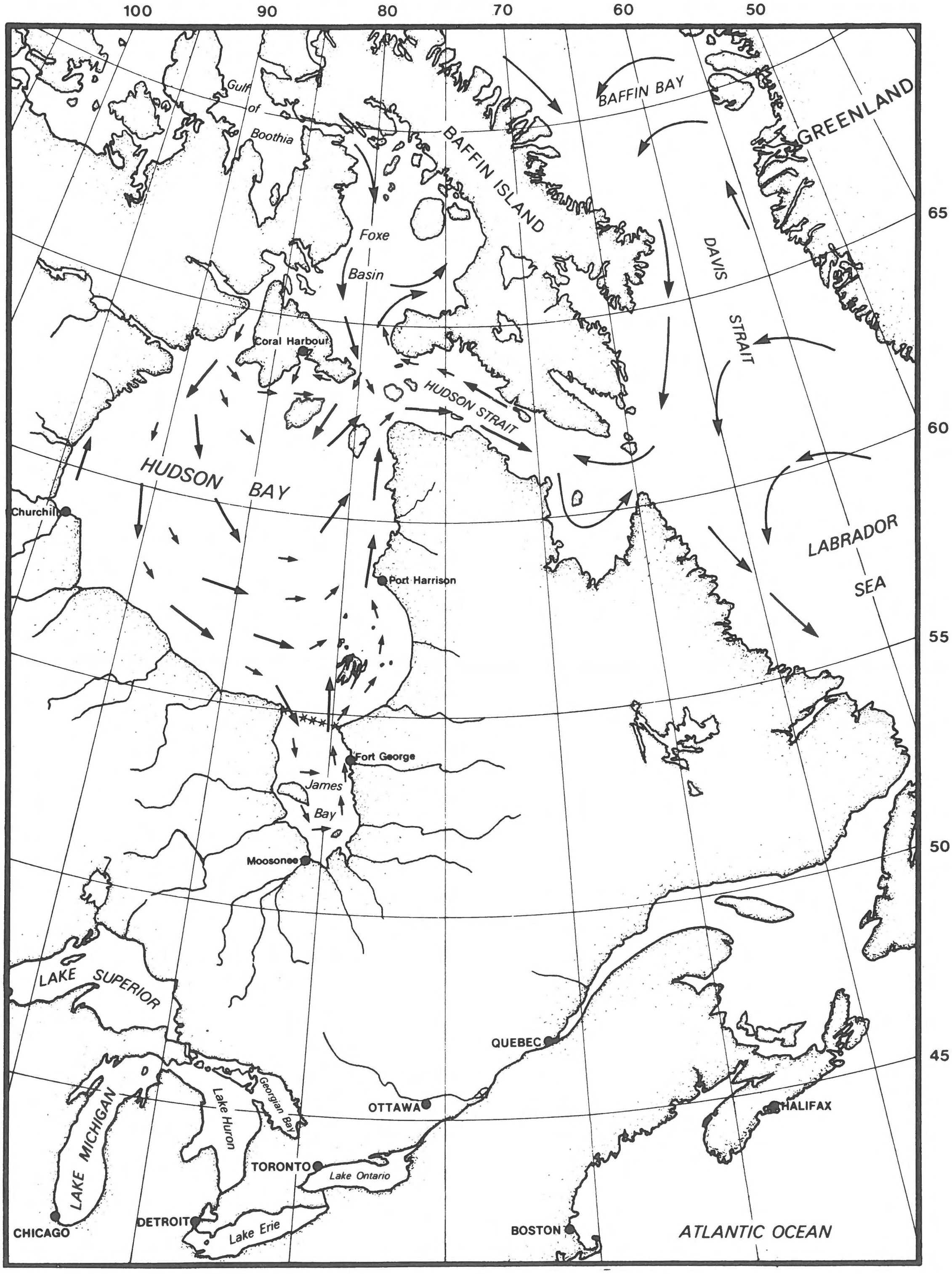

Fig. 3. Marine currents of the Canadian Inland Seas.

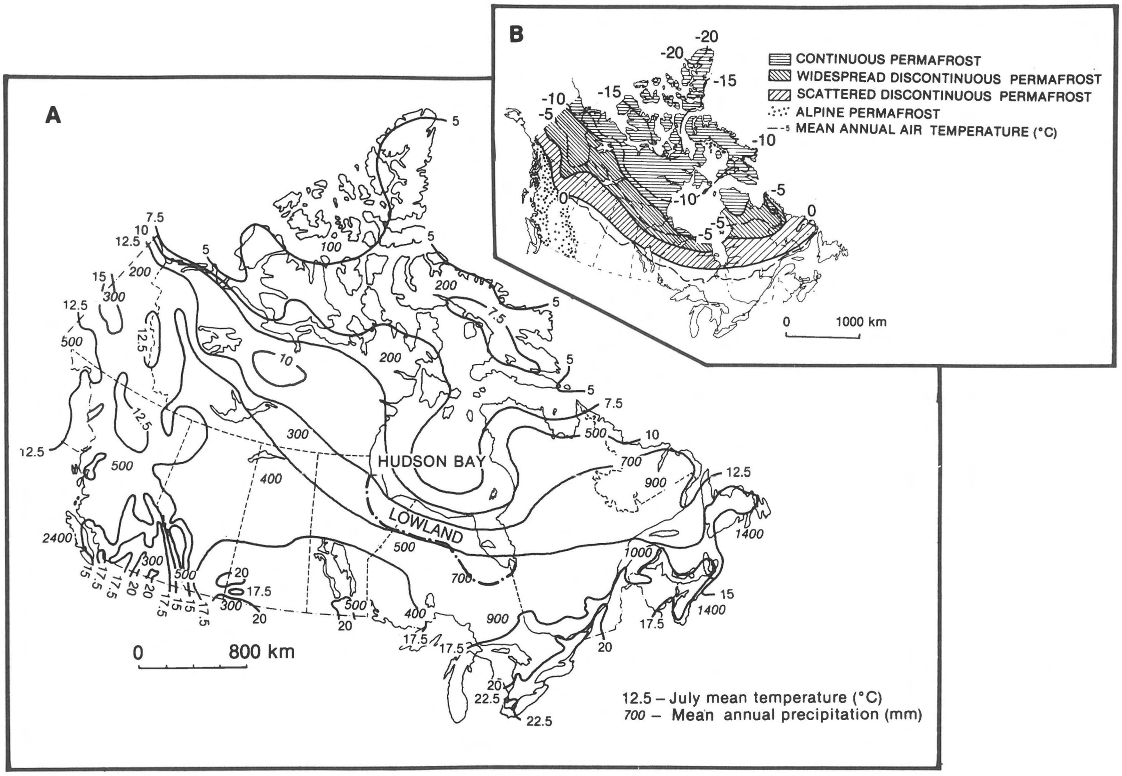

Fig. 4. Cold climatic conditions of central north Canada and the Hudson Bay Lowland. A. July mean temperature and precipitation; B. Permafrost map of Canada.

ridges and strandlines are major characteristics of the region, while a great variety of other features and deposits occur as well, both along the recent and the raised generally flat coasts. A major observation that is generally obscured by the 'beach ridge syndrome' is that those Holocene inland seas were and are mesotidal; thus vast, flat, subtidal and intertidal zones develop and are preserved in the Lowland.

Other features of the area are associated with the complex development of pre-glacial fluvial drainage channels which were later remolded by glaciations, were partially filled by glacial sediments and early post-glacial marine silts (up to 80 m thick), and are now occupied by the lower reaches of the larger rivers (Pelletier, 1968; 1986). Interfluvial regions lack or contain lesser amounts of marine fine deposits, because of lower sedimentation and/or because of erosion during emersion. The effect of differential erosion and fluting of bedrock and glacial deposits are more pronounced in the interfluvial promontory areas. Furthermore, the slightly steeper landscape of this zone develops various types of coastal beach ridges during emersion, and long narrow promontories which protrude as natural jetties across the tidal zone and trap fines (mainly sand and silt) in their updrift sides (Fig. 5; Martini, 1981a).

In these updrift embayments, vast, shallow intertidal flats develop and grade imperceptibly into marshes and inland fens. It is only in these vast intertidal flats and in some parts of the estuarine embayments where the continuous Holocene offlap sedimentary sequence is preserved. From the bottom up, such a sequence consists of: (a) shattered carbonate bedrock (due to vertical crustal isostatic movements and to Pleistocene permafrost conditions); (b) thin diamicts of various types; (c) sublittoral glaciomarine and marine argillaceous silts with a restricted pelecypod fauna and few

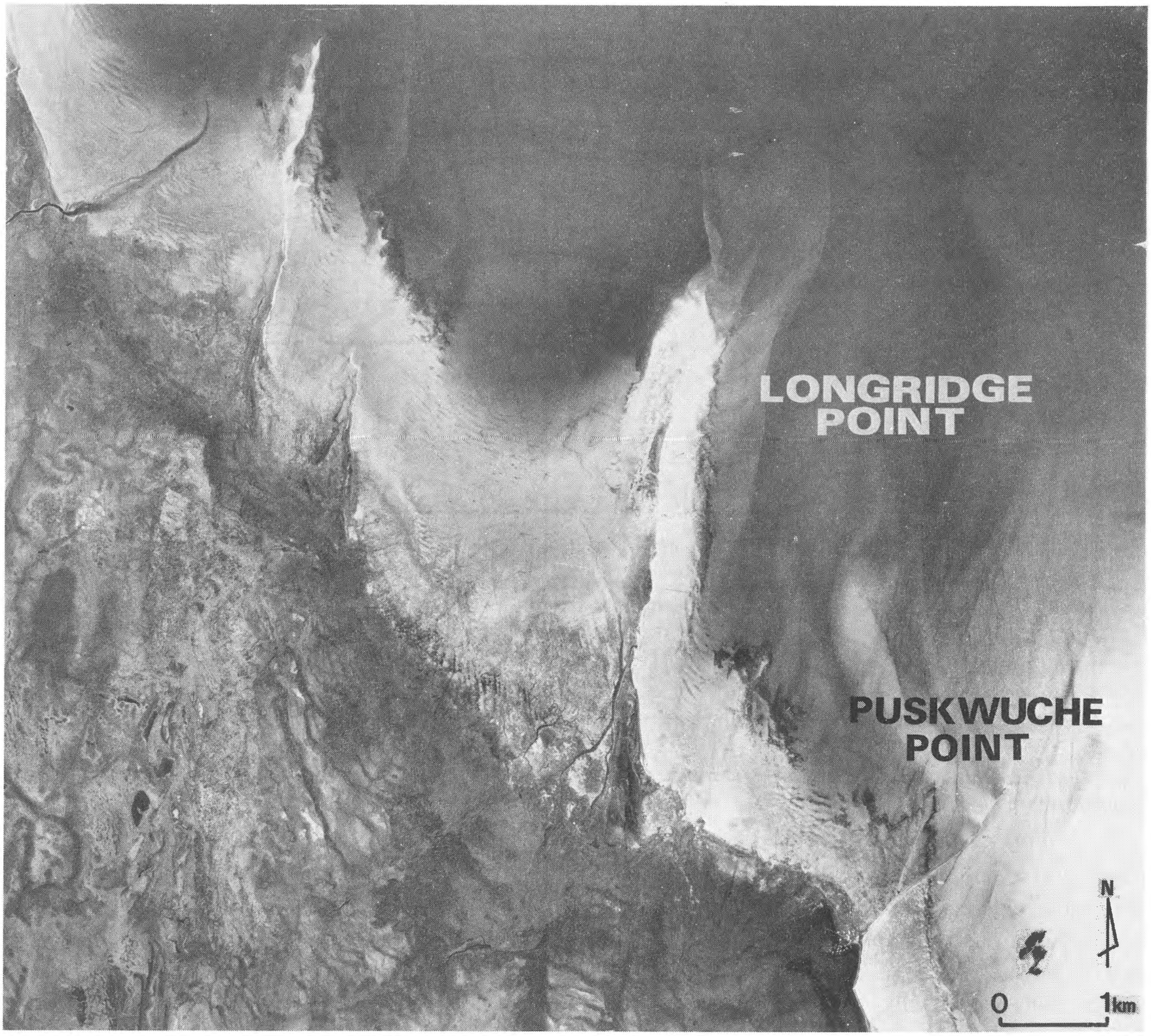

Fig. 5. Example of the coastal zone showing narrow transversal promontories and wide tidal flats on their updrift sides.

dropstones, some boulder sized; (d) subtidal and intertidal sandy deposits (up to 4 m thick); (e) well developed marsh sediments (up to 2–3 m thick); (f) organic deposits of freshwater marshes and inland fens characterized by up to several metres (2–3 m) of decomposed graminoid peats, locally containing some woody component. Thicker (up to 3–4 m) peats develop in more mature inland bogs.

The intertidal sediments of the Hudson Bay Lowland contain most of the characteristic features reported in similar deposits of other coasts, such as fining landward and upward sequences, a variety of ripple cross laminations, wavy bedding, flaser bedding, occasional herringbone crosslaminations, some bioturbation and rare body fossils, and crinkly marsh laminations. They differ from other reported intertidal sequences because of cold climate features such as sparse restricted fauna (no intense bioturbation ever occurs in these flats), presence of polymictic, rounded, ice rafted pebbles and occasional boulders locally redistributed by waves and currents, and generally thin marsh laminations bioturbated by root mats of *Puccinellia phryganodes* and slightly larger roots of *Carex sp.*, plants which characterize subarctic and arctic salt marshes (Martini et al., 1980; Martini, 1981b; Scott & Martini, 1982; Martini & Morrison, 1987).

Sediments are carried to the coast by rivers which cannibalize the thin Pleistocene and Holocene sedimentary cover of the Lowland and cut into the carbonate bedrock, and by longshore currents. The intertidal and shallow subtidal sediments of part of the coast are continuously resuspended by waves and ice gouging and are transported and ice rafted toward embayment depocentres. In certain areas the coastal erosion during emergence is complete or quasi-complete, and bare, frost shattered bedrock or thin tills may be exposed in the intertidal zone. Beach ridges develop primarily by storm waves on such a substratum which may be covered by a characteristic, thin, residual deposit called, for want of a better term, 'reconstituted coastal diamicton' (Martini & Protz, 1978). Such a residual deposit is composed of modified Pleistocene till material mixed with fossiliferous marine silts and sand, and with ice rafted fine and coarse angular fragments. The beach ridge deposits are characterized by a relatively well sorted coarse sand and fine gravel. The smaller ridges show plane beds alternating with landward inclined foresets which are formed as the ridges prograde slightly landward. High tidal flats (algal flats) develop behind the ridges and are eventually capped by salt marshes. As the land rises, incipient paludification occurs whereby fens and bogs form in interridge areas of southern regions where only sporadic and discontinuous permafrost occurs, and spruce forests on drier ridges. In northern, continuous permafrost regions of the Lowland, tundra forms near the coast. Farther inland, forest develops covering both the beach ridges and the interridge areas, the latter having been raised, thus sufficiently dried up by ice lenses and peat plateaus. Podzolic soils develop on the drier beach ridges (Protz, 1982).

Wetlands

Along the coast, in varying width depending on the slope of the land, there is a transition from the intertidal marshes inland to meadow marsh, thicket swamps and low shrub marsh. These change landward into coastal fens, and, in the north, into 'edaphic tundra' and peat plateaus.

The coastal marshes are not peat forming environments and are mostly characterized by a *Puccinellia phryganodes* association in the lower part and a *Carex subspathacea* association in the upper part.

More than 90% of the Hudson Bay Lowland is occupied by an unconfined wetland ('muskeg', Radforth, 1973), most of which has developed into a variety of peatlands with a variety of peat types and thicknesses, depending on location and climate.

Most of the Lowland is located within the Boreal Forest Region (taiga) of Canada (Hustich, 1957). The distribution of the wetland types and of the vegetation variation across the Lowland are dictated primarily by the strong north-south change in temperature, by the coastal-inland position, as well as by local topography and substratum which in the north is affected also by permafrost hummocks (Fig. 6; Riley, 1982; Zoltai & Pollett, 1983). The 'midboreal wetland region' B_{Mh} is characterized primarily by fens everywhere, some treed with tamarack (*Larix laricina*), bogs in the northern parts, swamps in parts of the southern interior (where some deciduous trees occur) and near streams, and forests (mainly spruce) on river levees. The 'high boreal wetland region' (B_H) is characterized primarily by fens and bogs and a northward increase in influence of permafrost with development of few peat plateaus and palsas. The 'low subarctic wetland region' (S_L) is characterized by a rapid expansion of peat plateaus associated with the increasing importance of permafrost. The 'high subarctic wetland region' (S_H) has continuous permafrost except at the coast. Lichen-dominated, treed bogs and peat plateaus prevail. In drier areas, that is, on higher raised beach ridges, or on river levees, woodlands occur, primarily of black spruce (*Picea mariana*), white spruce (*Picea glauca* near the coast) with, locally, some balsam fir, trembling aspen (*Populus tremuloides*), balsam poplar (*Populus balsifera*) and white birch (*Betula papirifera*).

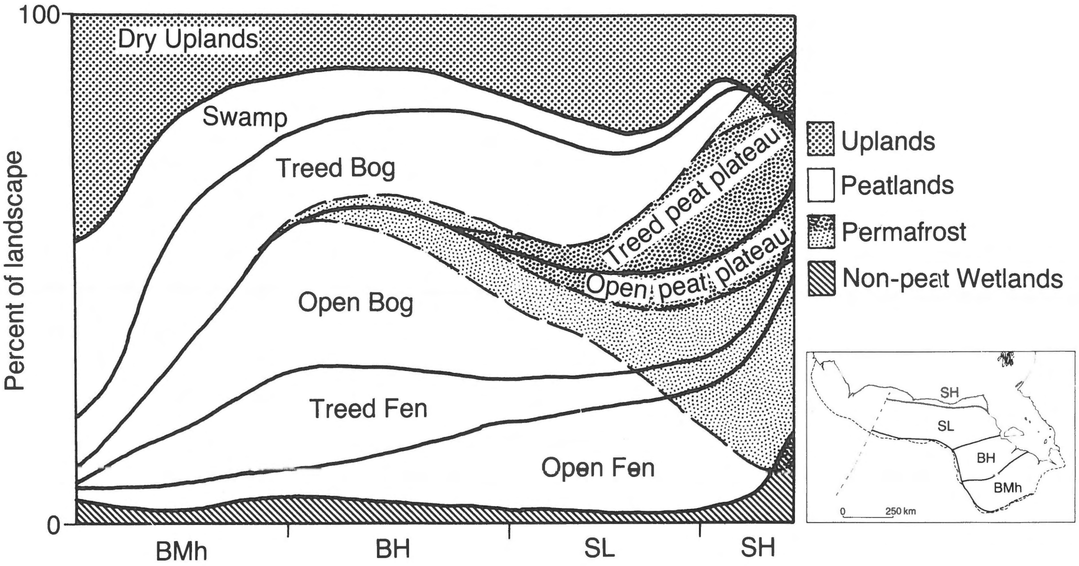

Fig. 6. Wetland types of the Hudson Bay Lowland (after Riley, 1982). SH: High subarctic; SL: Low subarctic; BH: High boreal; BMh: Middle subarctic.

Peat has developed in the Hudson Bay Lowland in the last 5000 years and has reached a thickness of up to 3–4 m in raised bogs, about 100 km inland, and about 2–3 m in inland fens. A quasi-regular increase in the thickness of the peat can be demonstrated from the shore inland, with the net rate of deposition in the southern part of the Lowland being approximately double that of the northern part of the Lowland (Cowell et al., 1983; Martini & Glooschenko, 1985). Where best developed, the peat sequence shows vertical transitions from decomposed, dark, sedge peat (fen) into a sphagnum peat (bog) with occasional woody fragments.

The wetlands are slowly drained by few rivers which experience a nival regime, that is, small discharge under an ice-cover during the winter, large short lived floods at spring breakup, low water conditions during the summer, and in the south, some fall floods associated with rain. It has been calculated that the total river discharge is on the order of 300 km^3/year (Prinsenberg, 1980).

Resources

The Hudson Bay Lowland is essentially untouched by man, except for some damming of rivers for hydroelectric power, and occasional drilling for hydrocarbons (unsuccesful) along the shores. The region has potential a wealth of mineralizations in the Precambrian inliers, and industrial minerals in the Mesozoic sequences, but perhaps the most important economic asset of the land is its enormous supply of freshwater (Johnson et al., 1986; Prinsenberg, 1980). Schemes for diversion of such waters to the Great Lakes of North America and then to the semi-arid midwest of the United States have been proposed, and vary from simple damming and diversion of flow of few major rivers, to the megaproject of damming the mouth of James Bay, transforming it into a gigantic freshwater lake (Milko, 1986). These schemes must be weighted against the potential damages to the present environment, particularly because those shores are used seasonally by polar bears and by some of the largest migratory bird populations of the world which come from South America and the United States up here to breed.

The major assets of the Lowland are related to the immense reserve of fresh water, potential peat resources, large migratory wildlife populations, and, perhaps most of all, the yet not properly studied but obviously important effect that such a vast peatland has on the gaseous flux and atmospheric balance of, for instance, methane, carbon dioxide, sulphur dioxid and nitrogen (Gorham, 1982). Parts of this region are protected under provincial and national wildlife parks. Its importance perhaps should lead to establishing an international heritage park, such that no modifying mega-projects are implemented which may render smaller localized parks ineffective.

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