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Meetings

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See table of contents

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Meetings

THE COASTLINE OF CANADA

This conference, which dealt with littoral processes and shore morphology, was held in Halifax, Nova Scotia, from May 1 to 3, 1978 under the sponsorship of the Geological Survey of Canada. It was the first national meeting on the subject, and drew about 150 delegates from Canada, the United States and Europe. The 37 papers from 50 authors covered scientific subjects, generally, but included a generous view of emerging technology with highlights on computer modelling, satellite imagery, monitoring instruments and the undertaking of SCUBA and submersible operations. Although the technical program was designed to cover the physical processes, two papers on biological activity were presented.

Processes occurring in all major coastal areas of Canada were discussed in some detail within the framework of a general overview. The summation by E.H. Owens on the status of coastal research in Canada was a fitting commentary to the work in progress, and to the comments of the introductory speaker. This meeting was good and, as well as passing out acknowledgements to those many servants behind the scenes, we think the organizers should receive the thanks due them:

S.B. MCCANN - Atlantic Geoscience Centre, Geological Survey of Canada, Bedford Institute of Oceanography, Dartmouth, Nova Scotia.

C.F.M. LEWIS - Terrain Sciences Division, Geological Survey of Canada Ottawa, Ontario

G.V. MIDDLETON - Department of Geology, McMaster University, Hamilton, Ontario

N.A. RUKAVINA - Hydraulics Research Division Canada Centre of Inland Waters, Burlington, Ontario

We also think that the organizers showed considerable wisdom in holding all sessions consecutively and in the same hall, as everything was immediately available to everyone.

Under the program chairmanship of S.B. McCann, the meeting opened with introductory comments by J.O. Wheeler, Depty Director-General of the Geological Survey of Canada. Dr. Wheeler remarked on the timeliness of the meeting with regard to information required for shore-zone management, characteristics and processes of the coastline, and the task that lies ahead involving the description of the 240,000 km coastline of Canada, of which only 3 percent has been completed. He noted the multidisciplinary approach needed, as well as the multidisciplined scientists required to carry out the coastal investigations, e.g. engineering, physical chemistry, biology, oceanography, geomorphology and sedimentology. Although coastlines have their analogues all over the world, Dr. Wheeler remarked on the uniqueness of all Canadian coasts; they are icebound for part, or all of the year, and have been affected by isostatic rebound. Canadian coasts are also diversified with respect to beach materials, tidal range (0 in the Great Lakes to the world's highest in the Bay of Fundy), hydrodynamic energy spectrum, and both emergence and submergence. The main emphasis in Canadian coastal studies must focus on the following: erosion rates, sediment budgets, processes, and the role of ice. Dr. Wheeler concluded with his views on "coastal husbandry" and the need for pooled talents to meet its challenges.

Basically the Canadian coastal program involves the following: *inventory, scientific problems*, monitoring, application, synthesis, technology and publication. At the conference, all facets were covered by the various speakers, with special attention given to more than one topic by the three keynote speakers invited to address the meeting. These speakers introduced the daily technical sessions: Paul D. Komar from the School of Oceanography, Oregon State University, United States spoke on "Sand Transport on Beaches"; J.O. Norrman of the Department of Physical Geography at the University of Uppsala, Sweden gave his address on "Coastal Problems and Research in Sweden"; and Cyril J. Galvin formerly of the United States Corps of Engineers entitled his talk: "Tidal Inlets".

Supporting this fine, overall roster of participants was an informative poster session held in the lecture hall in the evening. The displays demonstrated several activities, as well as important coastal atlases of parts of Canada now available from the publishers. On exhibition were the following projects:

POSTER SESSION

COASTAL MAPS AND CLASSIFICATION

Gifford Miller, INSTAAR	E. Baffin Island, Ungava Bay, Labrador
Patrick McLaren, GSC	Labrador Coast
Peter Rosen, GSC	Makkovik Area, Labrador
John Shaw, CCIW	Great Lakes Atlas and Shore Damage Survey
Colin Duerden, EPS	Coastal Zone Atlas for Bay of Fundy
John Welstead, BRANDON UNIVERSITY	Bay of Fundy
Bob Stewart, MCMASTER UNIVERSITY	Minas Basin, Cliff Erosion
Peter Lewis, INUVIK RESEARCH LAB	Yukon Beaufort Sea Coast

OTHER MATERIAL

Shoreline Situation Report, Accomack Country	V.I.M.S.

Environmental Geologic Atlas of Texas Coastal Zone	Bureau of Econ. Geol., University of Texas at Austin
Chedabucto Bay, Shoreline Map	Marine Sciences Paper #4, E.H. Owens
Coastal Studies Exhibits, Gulf of St. Lawrence, Minas Basin, Bay of Fundy Iceberg Scouring	Geological Survey of Canada
Amoco Cadiz Oil Spill	Geological Survey of Canada

Rather than summarize each paper as presented at the meeting, we are publishing each abstract as submitted by the authors. The full proceedings of the conference will be published by the Geological Survey of Canada in 1979, and will constitute a full volume. Brian McCann is assigned the job as editor. All correspondence regarding this volume presently under preparation can be made directly to Dr. McCann, Department of Geography, McMaster University, Hamilton, Ontario L8S 4M1. The abstracts are as follows:

WAVE AND CURRENT FORCES IN A MOBILE SAND BAR SYSTEM

D.A. HUNTLEY, Department of Oceanography, Dalhousie University, Halifax, Nova Scotia, Canada, B3H 4J1

Extensive geomorphological studies show that the sedimentary coastline of the Southern Gulf of St. Lawrence is, in many locations, highly mobile. In an attempt to improve understanding of the hydrodynamic forces responsible for this mobility, water velocity measurements were made in July 1977 in a region of mobile nearshore sand bars off Tabusintac Beach, near Tracadie, New Brunswick. Three two-component electromagnetic flowmeters, two water-elevation staffs and a time-lapse camera recording run-up were used simultaneously to monitor flow conditions in the first offshore bar system; the flowmeters were aligned to measure the three orthogonal components of flow, and to estimate the vertical profile of velocity. The beach was also surveyed several times across the bar system to monitor bar mobility.

During the week-long experiment a variety of summer wave conditions was experienced, ranging from very calm conditions to 1.3 m breakers, breaking first on an outer bar 100 m offshore and then breaking a second time at the inshore bar system. During these latter conditions the suspended sediment load in the water was extremely high and longshore currents in excess of 70 cm/s were measured. A particularly interesting aspect of the data is that, during the experiment, the nearshore bar was observed to move onshore a distance of 2 to 3 m under the flow meters, partially burying the tripod on which the sensors were mounted.

Two particular aspects of the data will be discussed. First, the horizontal and vertical flows can be combined to give the Reynolds's stress at a point and hence estimate the bottom stress acting on the bed material. The structure of this stress and its variability relative to the bar system will be discussed. In addition, measurements of longshore currents in the vicinity of the bar system will be described.

SIMPLE MODELS OF NEARSHORE SEDIMENTATION

A.J. BOWEN, Department of Oceanography, Dalhousie University, Halifax, Nova Scotia, Canada. B3M 4J1

Any understanding of the relation between the incident waves and the topography of a beach is greatly complicated by the fact that the beach is rarely, if ever, in equilibrium with the existing wave field. The morphology depends on some complex integral of past wave conditions, an integral apparently heavily weighted towards periods of high waves. In principle, one can approach the problem by monitoring the beach topography as a function of the changing wave climate and this approach has indeed lead to some new insights, some new phenomenology and new problems, but not, generally to quantitative results. The real situation is perhaps too complex to parameterise without some guidance as to the relative importance of various possible processes.

Simple, theoretical models are particularly useful in defining these possibilities. However, as the models are generally idealised to some very simple, equilibrium situation, their relevance to the real world is certainly questionable. Nonetheless the mathematics involved may be formidable. As a result a number of interesting suggestions have appeared in the literature only to vanish almost without trace.

There are essentially two types of simple sediment transport models: (1) for steady flow (or quasi-steady such as a tidal current) as the predominant transporting agent. Waves, turbulence or bottom topography perturb the flow producing differential movement of sediment. This is not generally the relevant parametisation for beaches but a model of this type has been used to describe the generation of transverse bars i.e. perpendicular to the shoreline. (2) When the wave orbital velocity is the predominant agency for moving sediment, probably the normal case on a beach, except perhaps locally in the surf zone. The transport is then determined by the perturbation of the orbital velocity at the fundamental frequency (which is oscillatory, giving no net transport) by either (i) steady flows or drift velocities associated with waves, (ii) low frequency motions - tides, surf beat and, (iii) higher harmonics of the incident wave.

Using some of the basic concepts introduced by Bagnold, relatively simple models can be formulated including the constraints on sediment movement provided by the topography i.e. that it is more difficult to move material up slopes.

The results have direct relevance to the estimate of equilibrium profiles and the formation of bar systems.

DEPTH OF DISTURBANCE IN SEDIMENTS AND PATTERNS OF SCOUR AND AGGRADATION UNDER STORM-WAVES AND CURRENTS IN A BARRED NEARSHORE ENVIRONMENT

BRIAN GREENWOOD, Scarborough College, University of Toronto, Toronto, Ontario, Canada
PETER B. HALE, Scarborough College, University of Toronto, Toronto, Ontario, Canada.

Morphological changes in the nearshore zone on sandy coasts are most rapid and significant during high-energy storm events, at a time when monitoring such changes is extremely difficult. Tests with the implantation of an array of rods and free sliding washers (depth of disturbance rods) suggest that spatial patterns of, (i) the maximum depth of sediment movement, (ii) the net bed surface change and (iii) the total aggradation/degradation can be determined for specific storm-wave conditions. Steel rods (1 or 2 m in length, 0.5 cm in diameter) exposed to a height of 0.45 m above the sand surface together with a washer (0.6 cm internal diameter) placed on the sand surface constitute the depth of disturbance rod set in place by SCUBA divers. Vertical migration of the washer reveals maximum scour during the storms, while bed surface change was measured relative to the top of the rod. The accuracy of the depth of disturbance results was evaluated against similar determinations made by examining the vertical incorporation of tracer material and the erosion or reactivation surfaces revealed in peels of box cores taken close to the rods. Direct surface observation revealed bedform generation which was undisturbed by the presence of the rods. Problems encountered were: (i) accurate location of rod positions both initially and subsequent to the storm under poor visibility conditions; (ii) loss of rods by extreme erosion or aggradation; (iii) removal or bending of rods fouled by kelp; (iv) biogenic activity (lobsters) around rods at surface; (v) difficulty in excavating washers in areas of high aggradation. Sixty-two rods implanted on a single crescentic outer bar and monitored before and after two storm events revealed specific patterns of sediment mobility and morphological changes during the events.

SABLE ISLAND SAND WAVES AND RELATED SHORE PROCESSES

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Sable Island has been the focus of petroleum oil exploration for a number of years, both onshore at West Point and offshore in deeper water with drilling by semisubmersible rigs. In the past year, drilling has moved into the shallow water on West and East Bars, through the use of a jack-up rig.

During the course of exploration and in performing environmental studies prior to siting of drill rigs, a considerable wealth of data has been accumulated by Mobil Oil Canada, Ltd.

Data are presented on the changing shape of the island over historical time and in recent years. An interrelationship between the depth of East and West Bars and the location of East and West Points is presented.

Sand waves are mapped in a number of localities resulting from detailing bathymetric surveys. The movement of sand and sand waves is analyzed in the light of repetitive surveys, sidescan sonar mapping, 3.5 kHz profiling, boomer/sparker profiling, current measurements, sampling and size analysis and vibracorer/borehole data.

STORM-WAVE CLIMATOLOGY: A STUDY OF THE MAGNITUDE AND FREQUENCY OF GEOMORPHIC PROCESS.

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Increasingly the search for understanding of morphological change in the coastal zone is shifting to measurement of the effects of high wave-energy events associated with the passage of storms. However, at present little more than a post-mortem analysis has been made of single events and to date few methods of assessing the relative magnitude and frequency of occurrence of individual events exists. There is a clear need for: (i) indices of storm magnitude, which reflect their potential impact in the coastal zone, and (ii) methods of determining recurrence intervals for events of similar magnitude, if any generalizations about 'extreme' events are to be made. Since mid-latitude depressions are characterized by winds of varying speeds, directions and durations, to arrive at a meaningful index of storm intensity a method has been developed to produce a storm-wave climatology based on meteorological data. This is then used to rank wave-generating events and predict their return periods. A basic wave hindcast procedure (S-M-B) is used to generate theoretical deepwater wave heights, periods and cumulative energies for specific storm events. Examination of 33 full years of wind data for one location in the Southern Gulf of St. Lawrence allows determination of: (i) general patterns of storm events (e.g. average number of storm events per month for both individual and all wind directions, annual average frequencies of occurrence by month and by direction etc.); (ii) frequencies of occurrence of maximum significant wave heights by direction; (iii) frequencies of occurrence of total storm-wave energy generated by specific storm-wind events and (iv) recurrence intervals for storms of a particular magnitude defined by either maximum wave height or maximum total energy. It is likely that total storm-wave energy is most important for net longshore sediment transport, whereas maximum wave height may be more important in dramatic morphological changes such as barrier breaching.

SOME COMPARISONS BETWEEN BARRIER BEACHES OF PRINCE EDWARD ISLAND, NEWFOUNDLAND AND EASTERN UNITED STATES

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The well-developed barrier beach and island chain along the United States Gulf and East Coasts from Texas to southeastern Maine shows a continuum of ecological change and various physiographic types which are currently being classified by the authors. For most coastal scientists in the United States, the North American system ends in Maine, and the extensive barrier systems along many portions of the Canadian Maritime Provinces have been largely ignored in the coastal literature. A preliminary survey was made of vegetation and physiography on the Prince Edward Island-Malpeque Barrier System (Brackley Beach), Two Gut Beach and Stephenville Crossing Beach in southwestern Newfoundland, and a spit near Beachside in northeastern Newfoundland to determine how these northern barriers compare with those of the United States. This paper will deal with preliminary comparisons and attempts to place the Canadian beaches into an overall classification system along with United States barrier systems.

Initial findings show a much greater range of physiographic structures, ranging from heavy cobble and shingle to fine sand, in the Canadian systems than along a comparable section further south. Barrier island vegetation along Prince Edward Island is much like southeastern Maine, New Hampshire, and northern Massachusetts, except for the dominance of spruce in the maritime forests of Prince Edward Island. While dune vegetation (dominated by *Ammophila breviligulata*) in southwestern Newfoundland is similar to Prince Edward Island and New England, certain major differences were also found, particularly the turf-like nature of vegetation on cobble beaches. Salt marshes of Prince Edward Island are much like those in New England, but change significantly in Newfoundland. *Spartina alterniflora* marshes are poorly developed in southwestern Newfoundland, and *S. patens* was missing in those areas studied. The presence of *Myrica gale* at the salt marsh edge is a significant difference between United States and Newfoundland marshes. Salt marshes near Springdale in northeastern Newfoundland show strong boreal and subarctic affinities, and are quite different from those of southwestern Newfoundland, Prince Edward Island and the United States. Beach vegetation on a barrier spit of cobbles consists primarily of dense *Agrostis-Festuca* turf along with *Juniperus communis* shrubs. Typical strand species of more southern beaches are lacking. Such turf-like vegetation, and the salt marsh composition, are more like that of northern Europe than of the United States. The significance of these ecological and geological variations will be considered as they relate to barrier beaches of the United States and the general distribution of typical coastal ecosystems in eastern North America.

CHANGEABILITY IN SMALL FLOOD TIDAL DELTAS AND ITS EFFECTS, THE MALPEQUE BARRIER SYSTEM, PRINCE EDWARD ISLAND

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Temporal changes in flood tidal delta morphology are investigated for two small tidal inlets in the Malpeque barrier system, northern Prince Edward Island. Hardys Channel, the larger of the two inlets, is approximately 130 m wide at the throat with a maximum depth of 8 m below low low water. The flood tidal delta extends 1,000 m landwards and 2,500 m in an alongshore direction, and has undergone considerable modification since the earliest recorded aerial photography coverage in 1935. Palmer Inlet is wider but shallower, with a maximum depth of 4 m at the throat. Its flood tidal delta extends less than 900 m landwards and 1,800 m along the coast; similarly, it has undergone a comparable sequence of alterations since 1935.

The changes recorded by aerial photographs in the period 1935-1973 are documented, emphasizing those occurring since 1958. Field work carried out since 1972 has contributed information on recent modifications, bedforms and tidal currents, and the coastal environment. The most striking changes recorded in the flood tidal deltas are channel migration, the development of new channels and the closure of others - with associated changes both in water movements across the flood tidal deltas and in the sites undergoing accretion. The responses indicate the possible effects of inlet migration, or the formation of inlets nearby, on channel patterns in the flood tidal delta. They also demonstrate the degree of temporal changeability in small flood-tidal deltas. Current measurements recorded at one of the inlets indicate the possible impact of this constant changing in channel patterns on ebb flow characteristics close to the inlet throat, where inlet migration might be affected.

VARIATIONS IN TIDAL-INLET MORPHOLOGY AND STABILITY, EASTERN NEW BRUNSWICK

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At the present time there are seven tidal inlets along the composite barrier-island system extending from the northern end of Tabusintac Lagoon southwards across the Miramichi embayment. The inlets display wide variations in channel dimensions, in morphology of associated sand bodies, and in both locational and cross-sectional stability. Such variations are indicative of the range of tidal-inlet conditions occurring in the southern Gulf of St. Lawrence.

The Tabusintac barrier is 19 km long, forming a straight to slightly convex coastline, and encloses a shallow lagoon which is elongated parallel to the barrier. The barrier itself is narrow, of low relief, and highly mobile, responding to strong southward littoral drift in the order of 200,000 m^3 yr^{-1}. This mobile barrier extends southward, overlapping the northern end of the Miramichi segment of the composite barrier system. Most of the Miramichi barrier is a broad, highly vegetated and relatively stable island complex, forming a concave shoreline, across the mouth of a large, funnel-shaped estuary.

Small, ephemeral and locationally unstable tidal inlets are characteristic of the Tabusintac barrier segment. Inlet-throat cross-sections are less than 700 m^2 with maximum depths of 3 m, and associated tidal deltas are small and poorly developed. In plan form, the Tabusintac inlets display an updrift offset condition. This condition is intensified southwards at the northern extremity of the Miramichi embayment, where extreme overlapping inlet-offset occurs. In contrast, large, permanent and dynamically stable tidal inlets are characteristic of the Miramichi barrier segment. These inlets are relatively symmetrical in plan form, and have large, well-developed deltaic sand bodies associated with them. The largest inlet channel, Portage Channel, has a cross-sectional area of 18000 m^2 and a maximum depth of 15 m, and has remained at its present location for over 140 years.

The factors governing the range of inlet conditions in the composite barrier system are related to: 1) differences in the hydrodynamics of estuarine inlets and lagoonal inlets; 2) regional configuration of the barrier shoreline and the physical dimensions of the enclosed estuarine and lagoon systems, and; 3) inlet positions relative to dominant longshore transport direction.

ANIMAL-SEDIMENT RELATIONSHIPS IN THE UPPER REACHES OF THE BAY OF FUNDY

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Distribution of the dense populations of invertebrates found in the upper reaches of the Bay of Fundy is controlled by tidal elevation and sediment properties. Muddy sands of the middle intertidal zone generally support the highest densities. Stable mudflats are dominated by *Macoma balthica* and *Corophium volutator*; mudflats with high water contents resulting from rapid deposition, such as at Windsor, Nova Scotia, are dominated by siltation-tolerant organisms such as *Heteromastus filiformis*. Storms and hurricanes result in catastrophic mortalities, with shallow-burrowing organisms being the most profoundly affected.

Burrowing and feeding activities of organisms have locally profound influences on the sediment. The upper 3 to 5 cm of intertidal flats are generally completely bioturbated. Sediment movement may be either impeded or accelerated by organisms: high densities of tubicolous polychaetes may impede the normal development and movement of bedforms; resuspension of fecal and pseudofecal material from the flats contributes significantly to the suspended sediment load of the lower part of the water column.

Organic carbon content of the sediments is very low; the high densities of benthic invertebrates are therefore, likely supported via efficient nutrient cycling driven by tidal flushing. A significant amount of carbon is tied up in resuspended excreta during each tidal cycle. As suspended sediment from the lower part of the water column is significantly higher in carbon than are intertidal sediments themselves, nutrient recycling by organisms plays an important role in the carbon budget of these areas.

TIDAL CURRENT FLOW AND SAND BAR DEVELOPMENT IN COBEQUID BAY (BAY OF FUNDY), NOVA SCOTIA

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Cobequid Bay is located at the eastern end of the Bay of Fundy. The area is renowned for its large tides which have a mean range of 11.6 m near the entrance to Cobequid Bay. As in macrotidal areas elsewhere, tidal currents dominate the sedimentary environment. The semidiurnal, reversing currents reach speeds as high as 2.0 m/s. No major rivers presently enter the bay and most of the strongest wave energy is expended on bedrock headlands and at the seaward end of the sand-bar complex. Of a number of process variables, tidal range has the largest effect in determining the morphology of the large-scale sedimentary features. Sand deposition is concentrated primarily in the centre of the bay as an extensive intertidal to subtidal channel-bar complex, 5 to 15 m thick, underlain by local accumulations (up to 10 m) of premodern (possibly Pleistocene) sediments and bedrock. The sand bars are elongate features, 1 to 5 km long, that are aligned roughly parallel with the tidal currents, are asymmetrical in transverse and longitudinal section, are tapered towards their seaward ends, and are covered with megaripples (length 1 to 12 m) and sand waves (length 5 to 30 m). The sediment and geometry of the sand bar complex evolved from the erosion and reworking of Pleistocene sediments and Triassic bedrock in and around the bay by wave and current action, and from the input of glacio-fluvial sediments into the head and along the margins of the bay during the past 4000 years as sea level rose and as the Bay of Fundy system reached resonant dimensions and the large tidal range was established. The general pattern of ebb and flood dominant areas indicates that circulation in the sand bar complex resembles a large ebb tidal delta. The observed geometry and morphology of the sand bars is maintained by the time-velocity asymmetry of the tidal currents, by the opposing ebb and flood cross-bar components of flow that develop during the high-water sheet-flow phases of the tide (while the bar crests are submergent), and by the low-water channel-flow phases of the tide (while the bar crests are emergent).

SEDIMENT TRANSPORT IN THE INTERTIDAL AREA OF THE MINAS BASIN, NOVA SCOTIA CORRELATIONS BETWEEN BEDLOAD MOVEMENT AND HYDROGRAPHIC FACTORS

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This paper describes the results of a bedload transport study using a radioactive tracer method in the Minas Basin. The calculated transport rates were related to measured hydrodynamic parameters.

The experiment was conducted on an intertidal sand bar of the Minas Basin, Bay of Fundy (Nova Scotia). Synthetic sand (glass beads of equivalent diameter to the natural material), containing 0.5% of Gold-198 activated to two Curies, was dumped on the bar surface during low tide, and the resulting dispersion was monitored over a 16-day period using a scintillation counter. The location of each count was fixed using a sextant. The movement of the center of gravity of the dispersing radioactive cloud and the depth of reworking were determined using the Courtois (1966) and Sauzay (1967) tracer balance method. The mean calculated thickness of the mobile sediment layer was 0.14 m and reached maximum values of 0.3 m (determined from core samples). The net average movement per day was 1 m^3/m, however, the presence of mobile bedforms on the sand bar often complicated the quantitative estimations of sediment transport. The bedform migration rate was evaluated by sequential photography of the bar surface using a helium-filled balloon. At one location, bedforms were observed to move 1.9 m/d.

Continuous wave measurements were taken to determine the effect of wave action on the depth of burial of the tracer. The depth of sediment reworking is maximum under waves approaching from the west quadrant. Under conditions of wave approach from any other direction reworking was invariably less than 10 cm.

A line of 5 Aanderaa current meters was installed across the bar and measured continuously the current (speed and direction) lm above the bed. The plotted progressive residual current vectors determined from these meters, showed variations of the current velocity between the neap tide to spring tide phase and spring tide to neap tide phase. Variations in the residual current (speed and direction) are manifest in the east-west direction. A relationship between the fluctuation of the east-west component and the sediment tidal movement has been calculated and a correlation of 0.87 has been established. Results will be compared to predictive sediment transport calculations using the Meyer-Peter equation.

PATTERNS OF SEDIMENT ACCUMULATION IN THE MACROTIDAL AVON RIVER ESTUARY, BAY OF FUNDY

JOSEPH J. LAMBIASE, Geology Department, McMaster University, Hamilton, Ontario, Canada.

The Avon River estuary is in central Nova Scotia, and is part of the northeastern arm of the Bay of Fundy. Three major rivers discharge into the estuary which is approximately 16 km long and up to 2 km wide.

The Avon estuary is macrotidal with a maximum tidal range of 15.6 m at lunar perigee. Tidal currents are the only hydraulic process significantly affecting sediment transport and distribution. Maximum bottom-current speeds increase from 0.6 m/s at the estuary mouth to 1.7 ms at the head of the system. Every location in the estuary is either flood-current, or ebb-current dominant.

Sediment transport paths define net flood and net ebb-sediment transport zones whose positions are a function of hydraulics and local physiography. Intertidal sand bodies lie at the junction of two or more transport zones.

There are three major intertidal sand bodies at the estuary mouth and another three within the estuary. The three at the mouth form an ebb tidal delta that is similar in form to many mesotidal ebb tidal deltas. However, in the Avon, the sand bodies and channels are larger than in most mesotidal systems, and there are no barrier islands.

One intertidal sand body near the estuary head is part of another ebb tidal delta while another sand body is a tidal point bar. The third sand body is a flood tidal delta that resembles a mesotidal flood tidal delta.

There are three major bedform classes in the system including ripples, megaripples and sand waves. Surface bed configuration reflects maximum flow conditions, and flow regime increases from the estuary mouth to the head.

Mean grain size decreases sharply from the estuary mouth to the head. This results in an inverse relationship between mean grain size and current speed. The relationship is produced by a hydraulic sorting process that prevents coarse sediment from reaching the estuary head.

THE SEDIMENTARY CHARACTER OF THE MINAS BASIN SYSTEM, BAY OF FUNDY

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An intensive (two year) study was conducted on the general sedimentary character of the Minas Basin system in order to answer some fundamental questions on its historic development and the overall presently existing conditions of sedimentation. This was done by analysis of the sediment budget of the basin, and by an assessment of the origins, transport paths and depositional sites of clastic material.

The post glacial history of the region was determined in order to clarify the evolutionary trends in the characteristics presently existing. Conclusions were based on the analysis of marginal cores (20), subtidal vibrocores (12) geophysical seismic data (sparker, 200 km; and sub bottom profiling 200 km), and previously existing information.

Measurements were taken of those processes considered to control the sedimentary character (i.e. tidal range, temporal and spatial current patterns, wave spectra, meteorological conditions, fresh water discharge and man's influence).

It was estimated that $4.8 \times 10^6 m^3$ of sediment has been accumulating annually within the intertidal and subtidal zones. Assumming a continued sediment supply and accounting for the effects of sea level rise (15 cm/century) and cliff line recession (200 cm/year) it is projected that the Minas Basin could silt to present low water level in 6000 years. Comparisons of bathymetric charts compiled during 1858 and 1976, show that sediment accretion in Cobequid Bay was faster than in Minas Basin *sensu stricto*, and that the siltation to low water in this region could occur in 750 years. Extensive intertidal sand bars at the head of the bay represent material that has accreted since glacial times.

Coarser material (> 63 microns), is derived predominantly from Triassic sandstone and glacial outwash cliffs which border the basin. Wave action causes rapid undercutting of cliffs which are up to 100 m high. The derived material is moved predominantly within the intertidal zone as bedload. Radio isotope tracer studies of the movement of this material have shown that sediment is moving eastwards into Cobequid Bay at rates of $0.3 \times 10^{6} m^{3}$/year.

Suspended material (3 to 30 microns) is derived predominantly from the open sea, and from degrading cliffs of glacial till. Rivers also act as a source of this material albeit to a lesser extent than the cliff line source. Residual transport patterns of suspended sediment have been determined, based on 200 hours monitoring of the water column. A general headward transfer of material closely parallels the pattern of residual movement of water. The residual transport of sediment varies from $0.8 \times 10^{-2} m^{3} m^{-2}$/tide to $2.8 \times 10^{-2} m^{3} m^{-2}$/tide. The concentration of sediment in suspension varies from < 1 mg/l in the centre of the basin to > 1000 mg/l within the estuaries, joining the more open basin. Measurements of suspended sediment concentration derived from digital satellite records have been used to compute the volume of material in suspension for any particular time interval. It was computed for example, (using 250,000 data points) that during May 4, 1974, $0.25 \times 10^{6} m^{3}$ of material was in suspension.

Radio-carbon dating of cores has shown that the tidal range in the Bay of Fundy has been increasing from 6300 years B.P. to the present.

Prior to 6300 years B.P. the input and transport of material to the system was limited; Material was derived mostly from a fluvial source, and transported to the centre of the basin where it accumulated to form a lens shaped silty-clay unit. As the tidal activity increased through time, the overall supply, transport, and subsequent accretion of sediment increased. The conditions presently observable in the Minas Basin appear to be the most dynamic to have occurred since deglaciation, and perhaps the most dynamic ever to have occurred in this region. A large part of the collected data is presently being used to calibrate a presently existing numerical model of the Bay of Fundy tidal amplitude. Field information will be used as input to the calibrated model to predict short term (1 to 1000 tidal cycles) sediment transport and deposition patterns in the basin, and to evaluate the effect of tidal power development on the defined sedimentary character.

BEACH SEDIMENT BUDGETS AND HOLOCENE SEA LEVEL CHANGES: NOVA SCOTIA AND LABRADOR

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Detailed studies have been made of nearshore sediments on the Atlantic Coast of mainland Nova Scotia (with A.J. Bowen, M.J. Keen, J.R.J. Letson and E. Urquhart) and in Makkovik Bay, Labrador (with R.J. Iuliucci and P. Rosen).

In Nova Scotia, erosion of till cliffs is a significant source of sediment to the nearshore zone. Rates of supply can be determined from ground survey and air photographs. Exposed drumlins are retreating at rates exceeding 2 m per year.

However, landward transgressions of sands derived from earlier drumlin cliff erosion, at lowered stands of sea level, appears a more important source of sand. Overdeepened nearshore basins have acted as sinks for such sands; beaches to landward are generally sediment deficient. Where there is a gradual offshore increase in water depth, and abundant eroded drumlins on the inner shelf, then sediment rich beaches are common even where there is little or no present sediment supply. Heavy mineral analysis suggests that longshore transport of sand from one beach system to another was volumetrically unimportant during transgression. A quantitative model is presented for the Nova Scotia coast from Peggy's Cove to Liverpool, showing sand sources and sinks in the coastal zone over the last 10,000 years.

In Makkovik Bay, sea level is falling, so that there is no transgressive sand supply. Tidal current scour of early Holocene sediments is unimportant as a source of sand to beaches. Early Holocene river-derived sediment, maintained in the nearshore during slow regression, may be locally important.

RECENT MORPHOLOGICAL CHANGES IN AN ESTUARY ALONG THE EASTERN SHORE OF NOVA SCOTIA AND THEIR RELATIONSHIP WITH RELATIVE SEA-LEVEL RISE

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Maps and air photos of Chezzetcook Inlet dating back to 1766 are used to reconstruct morphological changes that have occurred during the last 200 years.

Although the 1766 map lacks detail it appears that there was significant infilling of Chezzetcook Inlet between 1766 and 1854. Between 1854 and 1945 little morphological change took place; however, between 1945 and 1974, significant changes again appear with the result that salt-marsh area dramatically increased between 1945 and 1974.

The area appears outwardly to be emergent with surfaces rising relative to sea level. However, it is known from studies of relative sea-level rise in Chezzetcook that relative sea level is actually rising faster now than in the past. Hence increased sedimentation rates are masking the effects of rising sea level. There are several mechanisms that may be responsible for the increased sedimentation: the first European settlement 300 years ago, infilling the deep channels, or a decreased tidal range as indicated in the legend of the 1766 map.

THE MORPHOMETRY OF SHORE PLATFORMS WITH SPECIAL REFERENCE TO THE GASPE COAST

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Shore platforms should be classified according to the morphogenic environments in which they occur. Quasi-horizontal platforms, terminating abruptly in a low-tide cliff, typify the rocky coasts of Australasia, the Pacific islands, and elsewhere along the Pacific rim. In the northern hemisphere, however, shore platforms generally slope seawards (1 to 3^{o}) without a marked break in slope at their seaward margins. Relatively continuous shore platform exposures occur between Trois Pistoles and the Forillon peninsula, a distance of 420 km along the southern shore of the St. Lawrence estuary. The platforms are cut in middle Ordovician flysch, consisting of steeply dipping beds of shale, dark gray argillites, and interbedded graywackes, calcisiltites, and calcareouswacke. Although primarily wave cut, the effect of frost action is manifest on these platforms, although its relative role has yet to be assessed. Platform morphometry in this storm wave, mesotidal environment is more akin to those in the swell wave, meso- or microtidal environments of the southern Pacific than those in the storm wave, macrotidal environments of northwestern Europe. This suggests, and confirms evidence from elsewhere, that tidal characteristics are more significant than wave intensity *per se* in determining the shape of platform profiles. It can be demonstrated that most aspects of platform morphometry are determined by a variety of tidal factors, with the exception of platform width, which is a function of coastal erodibility (in turn, a function of wave intensity and rock hardness). Analysis of tidal data and the derivation of a still-water frequency-elevation curve, permits identification of the elevation of most frequent storm wave activity, and the degree of concentration of this activity within the tidal range. These curves explain the slope, mean elevation, and profile configuration of wave-cut shore platforms. The presence, slope, and height of the low tide cliff (or ramp), and the high tide ramp may also be explained by the distribution of wave activity, rather than by any recourse to changes in relative sea level. It is proposed that tidal duration curves are a vital element in the explanation of all shore platforms, irrespective of whether their formation is by wave action or by chemical or physical weathering processes.

GEOMORPHOLOGIE DU LITTORAL DE LA COTE-NORD DU SAINT-LAURENT: ANALYSE SOMMAIRE

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L'étude porte sur les 1,200 km linéaires de côte entre Baie-Comeau et Blanc-Sablon. L'ensemble de cette côte a été cartographié en 1972 et 1973 à partir d'une classification de la zone côtière établie dans le cadre de l'Etude des Rives du Saint-Laurent du Ministère des Travaux publics du Canada. Une étude très détaillée des 150 km linéaires de côte entre Sept-Iles et Mingan a par la suite été menée entre 1974 et 1976 avec une subvention de la Commission Géologique du Canada.

Dans un premier temps se dégagent trois environnements physiographiques: 1) une côte indentée de nature complètement rocheuse; 2) une côte régulière constituée de dépôts meubles érigés principalement en de vastes deltas fini-glaciaires; 3) une ĉote où, à un substratum rocheux, se superpose une couverture de formations marine, estuarienne et littorale réparties entre les aspérités de ce substratum et où les formations littorales évoluent principalement par tombolos.

Dans un deuxième temps ces environnements physiographiques se subdivisent en plusieurs secteurs homogènes définis au point de vue géomorphologique (nature de la surface, énergie et dissection du relief), sédimentaire (granulométrie et genèse) et dynamique (érosion, sédimentation ou stabilité relative).

Dans un troisième temps l'étude de séquences photographiques et de documents permettent de mettre en relation les caractéristiques du littoral avec les sources de sédiments mobilisés et permettent de saisir l'évolution récente de cette côte d'émersion en perte de vitesse.

PHYSICAL CHARACTERISTICS OF THE SOUTHEASTERN BAFFIN ISLAND COASTAL ZONE

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The morphology and sedimentological characteristics of the littoral and inshore marine environments of the coastal zone along southeastern Baffin Island have been mapped as part of the Eastern Arctic Marine Environmental Study (EAMES). The coastal zone is defined as the area between 20 m aht (the maximum limit of storm wave activity) and 20 m blt (the maximum wave base). Generalized maps of morphology and sediment characteristics produced at scales of 1:250,000 and 1:1,000,000 are based on air-photo interpretation supplemented by low-level aircraft observations and ground-truth data. Specific sediment and morphologic data were obtained from Frobisher Bay and Hall Peninsula.

The coast of southeastern Baffin Island is generally steep and rocky due to the tectonic and recent glacial history of the area. Localized areas of sediment beaches do occur, and generally coincide with or lie immediately below Pleistocene beaches. Sediment in the littoral zone is mostly sand-sized or coarser, including a high proportion of cobble beaches. Areas of extensive tidal flat and those regions protected from severe wave action may have considerable quantities of finer-grained sediment.

Sediment input to the littoral environment is primarily a function of the Pleistocene history of the adjacent area. Wet-based ice moving out of Frobisher Bay during the last glaciation implaced large volumes of marine and glaciomarine sediment along the land bordering the bay. Reworking of these deposits by glaciofluvial, fluvial and marine agents resulted in localized deposits of sediment that were subsequently elevated above the sea during isostatic readjustment. These deposits are the primary sediment sources for contemporary littoral deposition, and their composition is strongly reflected in the modern littoral grain-size distribution. In areas over which glacial deposition was minimal, *in situ* granular disintegration of the bedrock is the prime sediment source. Reworking of these materials in the littoral environment generally results in the removal of the finer grain-size fractions leaving a residue of coarse sand and gravel. High proportions of coarse silt are added locally to the littoral zone by meltwater streams draining active glaciers in the region.

A map of the coastline density (length of coastline in 10x10-km grid squares) at a scale of 1:1,000,000 provides a convenient visual presentation of the variation in coastline configuration across the region. In general fiord areas have lowest coastline densities, whereas shallow marine areas are most dense. There is a strong correlation between areas of high coastline density and shallow marine gradients.

A recent rise of relative sea level along eastern Baffin Island is documented by the submergence of river valleys and the burial of *in situ* terrestrial vegetation beneath beach sediment. The extent of sea level rise is greatest ($\geq$ 2 m) along the outermost east coast and decreases to the west. Radiocarbon dates suggest that the onset of submergence occurred between 700 and 2000 years BP.

PROCESSES RESPONSIBLE FOR THE CONCENTRATION OF GIANT BOULDERS IN THE INTER-TIDAL ZONE IN LEAF BASIN, UNGAVA.

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The inter-tidal zone in Leaf Basin, Ungava is characterized by concentrations of giant boulders. At the sites studied these boulders range in height from 1 m to > 4 m, and have a spatial density of from 10 to 80 boulders per 1,000 m^2. Between the inter-tidal zone and the upper marine limit at 180 m above sea level there is a distinct absence of similar large boulder concentrations, except for a few localized occurrences, Above the marine limit, the till-covered surface is characterized by numerous perched blocks.

For these three vertical zones, observations and measurements on the size distributions of the boulders, on their spatial arrangements, on their lithologic provenance, and on associated morphological features, point towards four origins for the boulder concentrations of the present inter-tidal zone. The primary origin is the slow but inexorable seaward transport of glacial boulders from the upper marine limit, by a combination of ice- and water-related processes throughout the post-glacial marine emergence. The three origins of secondary importance are: (1) local provenance from glacial till in the present inter-tidal zone, (2) frost plucking of low outcrops on the shoreline and subsequent dislodgement of the blocks by littoral procces, and (3) transport to the inter-tidal zone of large boulders in the bed of the rivers which debouch into Leaf Basin (particularly during spring break up). In amplification of this last point a major boulder barricade has been constructed by ice rafting and ice push at the present high tide mark (8 m above mean sea level where the river current encounters the barrier presented by the Leaf Basin ice cover. Two very similar boulder barricades at 20 m above sea level and at 60 m above sea level along the Leaf River Valley may indicate the high tide mark associated with former periods of sea level stability during the general post-glacial emergence.

COASTAL MORPHOLOGY OF THE MAKKOVIK REGION, LABRADOR

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The Makkovik region (55^{o}N, 59^{o}W) is a highly indented fjord-type coast that is characteristic of much of the Northern Labrador coastline. A straight line distance of 19 km along the Labrador Sea comprises 173 km of shoreline. Makkovik Bay, which is 31 km long, is the major embayment. The tidal range is 1.4 m, and maximum significant wave heights seaward of the area are 7.3 m, with 16-second periods. The wave activity is curtailed by ice cover about six months each year.

Both modern and relict coastal forms are related to variations in wave energy. Relative estimates of wave energy are made by comparing the heights of the wave wash zone in rocky areas.

High energy shorelines (wave-wash zone > 6 m) face the Labrador Sea and consist of bedrock cliffs up to 40 m high. These shorelines are nearly devoid of sediment except for small, isolated cobble beaches at the heads of structural embayments. There is little or no development of boulder barricades along rocky, high energy shorelines.

Low energy shorelines (wave wash zone 0 to 2 m) occur in the bays, and are characterized by a more diverse shore morphology. Narrow sand beaches with poorly developed back-beach zones are the dominant coastal form. The sources of beach sediments are glacial deposits which flank the bays, and recent fluvial deposits. Rock outcrops are ubiquitous but typically small and intermittent. Accretional coastal landforms occur in inner Makkovik Bay, including cuspate spits, transverse bars, longshore spits, and tombolos. Fringe marsh forms over sand or rock in the intertidal zone in protected areas. Boulder barricades are a nearly continuous feature along low energy shorelines.

Moderate energy shorelines (wave-wash zone 2 to 6 m) are transitional, and consist of pocket cobble beaches, rocky headlands, and sand beaches. The sand beaches often have a well-developed back beach because they are exposed to higher wave activity than low energy shorelines.

Raised beaches in high energy settings are isolated cobble deposits representing preservation of a storm berm. They occur as vertically continuous sequences extending from the contemporary beach up to 35 m above present sea level or as perched cobble deposits above rocky shores. In low energy settings, raised beaches are continuous uplifted sand ridges that closely represent a mean water level.

THE EASTERN COAST OF JAMES BAY, QUEBEC

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The eastern James Bay coastline is 650 km long and extends in a south-north direction from the mouth of the Nottaway River (51°20'N) to Point Louis XIV (54°37'N). The coastline, developed along a lowland and extensive plains, has been carved out of crystalline Precambrian rocks of the Canadian Shield and unconsolidated Quaternary deposits. It is a very irregularly shaped coastline, characterized by many hundreds of embayments, peninsulas, and islands composed of rock and unconsolidated deposits ranging from a few square metres up to more than 10 km^2 in size. The gently sloping shores and foreshores (1- to 3-degree slopes) have wide, muddy or sandy tidal flats in bays although the tides range from 1.4 to 3 m for the highest spring tides.

From a morphological point of view, the James Bay coastline is an emerging coast of the skjar type, characterized by a low energy budget. Although their action is restricted to the ice-free period (about six months of the year), wave and currents are the main agents of shore morphology. Active ice processes are in evidence everywhere, producing various erosive and sedimentary features which are not usually entirely destroyed by wave and current action. Frost action is also an active process acting upon rock surfaces and producing some minor periglacial features elsewhere. The mean annual air temperature is -1°C in the south (Fort Rupert), and -4° in the north (Point Louis XIV). Biological activity in shore evolution is very restricted. Most of the coast lies within the predominantly forested part of the Boreal forest region, while the coastline north of the Roggan River (54°22'N) is dominated by barrens. Ducks and geese abound in the marshes found along the coastline.

Coastal accessibility from either land **or** sea is difficult because of the irregular coastline, the abundant islands, the shallow water, the extensive peat bogs, and the numerous large rivers flowing into James Bay, but it offers beautiful aerial landscape views. Attractive and significant names have been given to major coastal features.

Although the coast has been occupied for many centuries by the native Cri Indians, its discovery by Henry Hudson and Thomas James, at the beginning of the seventeenth century, and the establishment at Fort Rupert and Old Factory, since the eighteenth century, of trading posts by the Hudson Bay Company, has left this region largely unoccupied and relatively unexploited. Before it becomes polluted and destroyed by the exploitation of modern-day activity, it is recommended that the eastern coastal area of the James Bay be recognized as a national park.

HUDSON AND JAMES BAYS: A LOW ENERGY, EMERGENT COASTLINE

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The coastline of Hudson and James Bays in Ontario and Manitoba is the longest low gradient, emergent, shoreline in the world. It maintains an uninterrupted offshore slope of about 0.5 to 1 m/km over a distance of approximately 1700 km. The land has been subjected to active rebound for the last 7000 to 8000 years, and is still rising at a rate of approximately 1m/100 yrs.

The Ontario coast consists of three main morphologies: coasts dominated by abundant parallel beach ridges; coasts dominated by estuarine systems; and coasts with promontories and transverse ridges.

All three types of coastlines are represented in the southern part of James Bay where our detailed studies have been undertaken. Longitudinal beach ridges fringe upper tidal flats of southern and eastern sides of promontories or of coasts where storm waves are not greatly damped by extensive sandy flats. The longitudinal ridges vary in elevation from 1.5 to 2 m (composite sandy and gravelly ridges), to 0.3 to 0.5 m (migrating coastsl sandy bars), and, in sandy flats, to 0.2 m (sinusoidal sandy waves). Promontories and transverse ridges are related to bedrock highs or glacial depositional features modified by deposition of coastal sands and gravels. A marked anticlockwise marine current in the southern part of James Bay redistributes the fluviatile materials to the east of estuaries, onto extensive, featureless, low lying tidal flats.

With emergence, incorporation of these features into the peatland complex is manifested through a progressive paludification of the landscape, and in older parts of the Lowland, only high ridges and promontories (larger than 1 m) with well developed coniferous forests, remain as recognizable marine landforms.

LE LITTORAL DU S.E. DE LA MER D'HUDSON: UN RELIEF DE CUESTA

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De la pointe de Louis XIV jusqu'au golfe de Guillaume-Delisle, soit une distance de plus de 300 km, la côte marine à caractère linéaire s'offre en un relief de cuesta qui fournit l'essentiel de sa définition. C'est en fait tout le grand arc de la mer d'Hudson qui se présente ainsi; il constitue la bordure d'un vaste bassin qui aurait été aménagé dans le Bouclier par un impact météoritique et, au Protérozoique, comblé de sédiments calcaires, dolomitiques et gréseux de même que de coulées volcaniques.

Les strates rocheuses, dont l'orientation du pendage varie sur toute la longueur de la côte, ou prend une orientation radiale, soit vers le centre de la dépression aux environs des îles de Belcher, se redressent ainsi de quelques degrés, présentant des fronts de cuestas tournés vers l'intérieur des terres.

L'activité érosive sous toutes ses formes a ainsi mis en relief de longues crêtes dissymétriques qui prennent une ampleur remarquable dans les régions de la Grande-Ile, des golfes de Manitounouc et de Guillaume-Delisle, alignant parfois de doubles cordons parallèles qui atteignent en moyenne 30 m de haut parfois plus de 300 m. Les dalles rocheuses des revers font face à la pleine mer où occupent parfois la côte est des golfes et des détroits; ils plongent doucement sous les eaux, établissant un rivage presque rectiligne et portent les multiples plages et cordons de blocs glaciels, construits tant par les glaces actuelles que celles sous la commande des eaux de la mer de Tyrrell. Les revers quant à eux forment des abrupts et de hautes falaises tombant parfois directement à la mer au droit des côtes ouest des golfes et des détroits, ou dominant le socle cristallin à l'intérieur des terres. L'exploitation d'axes structuraux a permis le dégagement de vallées subséquentes et conséquentes qui créent des fronts en dentelles qu'une érosion différentielle découpe parfois en escalier de géants.

On rencontre ainsi, de la Grande-Ile jusqu' aux premières îles de Nastapoca, plusieurs sections de côte qu'on peut distinguer selon les divers arrangements des cuestas. De la côte à pergélisol, avant la pointe de Louis XIV, se détachent de multiples îles et îlots taillés en autant de basses cuestas qui mènent à la Grande-Ile, longue de plus de 50 km, remarquable à la fois par des fronts raides mais aussi de très vastes revers. Le littoral qui conduit aux environs de Poste-de-la-Baleine ne conserve cependant que quelques segments de roches sédimentaires, lambeaux de plus vastes surfaces, appuyés sur un socle cristallin à peine taillé en petites baies, à plages de sable et de blocs. Les îles de Maintounouc, avec leur couverture basaltique en reliev inversé, dominent le golfe du même nom du sommet de leurs éboulis et de leurs fronts arqués, et isolent une seconde côte à dailles dolomitiques, terrasses d'argile à pergélisol, et à tourbières à palses. Le même revers de laves noires se poursuit cette fois sur la terre ferme en une côte des plus uniforme mais impressionnante, et prolonge vers le nord les cuestas insulaires. Les fronts y sont de plus en plus élevés et la depression du golfe de Manitounouc trouve une continuité dans leurs vallées subséquentes. Quelques trouées, sans doute de percée conséquente, défoncent ce relief littoral; la petite-rivière de la Baleine occupe la plus importante d'entre alles. C'est finalement avec les premières îles de l'archipel de Nastapoca et les très hautes cuestas taillés en châteaux-fort et dominant le golfe de Guillaume-Delisle, que nous saisissons un des relief le plus spectaculaire du Québec.

THE SOUTHEASTERN COAST OF HUDSON BAY: A CUESTA MORPHOLOGY (Translation)

From Cape Jones to Richmond Gulf, a distance of over 300 km, the regular seacoast is defined by a cuesta morphology as its dominating feature. The great arc of Hudson Bay is also a major element, consisting of the edge of an extensive basin which is believed to have been created in the shield by a meteorite impact, and which was subsequently filled in the Proterozoic by calcareous, dolomitic and sandstone sediments as well as by lava flows. The orientation of the angle of dip varies along the entire coast in a radial configuration centering on the centre of the depression near the Belcher Islands. The angle of dip itself lies back several degrees, resulting in cuesta faces fronting inland.

Erosion in all its forms has sculpted long asymmetrical ridges which reach remarkable size in the Long Island, Manitounuk Sound and Richmond Gulf areas. In some cases double parallel ridges reach an average height of 30 m, at times more than 300 m. The rock slabs of the backslopes face the open sea, of the eastern side of the coastal sounds and straits, they slope gently beneath the sea, creating a nearly straight coastline characterized by numerous beaches, and by rows of blocks, transported by sea-ice as much at the time of the Tyrell Sea as at present. The backslopes themselves form high and abrupt cliffs falling directly into the sea to the right of the western coast of the gulfs and the straits; otherwise the crystalline shield is dominant inland. The working of structural axes has resulted in the emergence of subsequent and consequent valleys creating toothed cuesta faces which are occasionally formed into "giant staircases" by differential erosion.

From Long Island to the first islands of Nastapoca, several coastal sections may thus be distinguished according to the various cuesta arrangements. Along the permafrost coast, before Cape Jones, numerous rugged islands and islets stand out as well as low cuestas. They culminate in Long Island, more than 50 km in length. This island is remarkable both for its steep bluffs and for its extensive backslopes. However, the littoral which leads to the Great Whale River area only retains a few sections of sedimentary rock, remnants of a once extensive area, and superimposed over a crystalline shield which is slightly sculpted into small bays with sand beaches and blocks. The Manitounuk Islands, with their basaltic cap of inverse relief, dominate the Manitounuk Sound by the summit of their screes and embayed faces, and cut off a second coast characterized by dolomitic slabs, clay and permafrost terraces, and palsa bog. The same backslope of black lavas continues to the north, this time on the mainland, creating a highly uniform but striking coast. The cuesta faces here become higher to an increasing extent and the Manitounuk Sound depression continues to the north in the form of inland subsequent valleys. A few gaps, undoubtedly pierced by consequent streams, interrupt this littoral relief; Little Whale River occupies the largest of these gaps. In conclusion, this landscape created by the first island of the Nastopoca archipelago and the very high and rugged fortress-like cuestas dominating Richmond Gulf, is one of the most spectacular of Quebec.

REMOTE SENSING FOR COASTAL STUDIES IN CANADA

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Given the extent of Canada's coastline, the dynamic nature of events and processes in the shore zone and the difficulty of observing and monitoring such an area, one would expect attention to be given to the possibilities of using remote-sensing systems for coastal studies. The extent to which this is being done will form the focus of this review paper.

From recent remote-sensing studies in the coastal zone, two types of investigation can be identified. These may be designated as static and dynamic. The most common type of static study is coastal zone and wetlands mapping. The types of results that have been produced from different data sources will be presented.

Remote-sensing becomes more exclusive in being able to produce data when it is used in a dynamic mode for monitoring rapidly changing environments. Such a situation is seen in studies of water temperatures, sea-ice monitoring and investigations of sediment concentration, examples of which will be presented.

Although a visual presentation for an area is important, there is a need to provide more quantitative data through remote-sensing. Correlations between satellite and ground data are being established which now make this possible.

In 1978, microwave data will become available in an experimental basis for several test areas in Canada. The implications of this and future developments will be briefly considered.

UNMANNED SUBMERSIBLE PROBES ARCTIC SHORE ZONE

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Frequently a better understanding of coastal processes and morphology is attained through studies of the offshore environment. This is perhaps particularly true for shorelines of submergence and emergence. An unmanned, self-propelled, tethered submersible complete with navigational and survey instrumentation is potentially capable of conducting a systematic study of this offshore zone seaward of the 3-m depth contour.

In March 1977, a joint industry-government project was launched to assess the feasibility of utilizing the unmanned submersible, TROV (Tethered Remotely Operated Vehicle), for a marine geological-geophysical survey of the submarine shore zone off Drake Point, Melville Island. TROV's ability to cope with, and operate effectively in the severe Arctic environment was also of major concern. TROV was lowered into 30 m of water through a hole in the polar ice at Panarctic Oils' experimental flowline route. A digital echo sounder, sub-bottom profiler and side scanning sonar generated a three-dimensional view of the bottom morphology. A 16-mm video camera afforded visual observation of seabed morphology, sediment character and distribution, bottom current conditions, aquatic and benthic life, and a view of the underside of the sea ice. An articulating arm could probe the sea-floor and retrieve samples. A range-range positioning system employing suspended transponders, mini-computer and an XY plotter was capable of producing a track plot of the submersible's course. TROV remained stable and manoeuvred responsively during its four dives. Despite a variety of technical problems, the objectives of the venture were achieved. This technology allows for the simultaneous collection of multi-disciplinary data necessary for a comprehensive evaluation of coastal processes and dynamics. The unmanned submersible will probably have its greatest application in environmentally hazardous areas such as the frozen Arctic coastlines.

TOWARDS THE GEOTECHNICAL CLASSIFICATION OF THE GREAT LAKES SHORELINE BLUFFS

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On the Great Lakes, extensive shoreline inventory and mapping activities, for long term planning and environmental impact purposes, have led to an increasing need for concise geotechnical classification schemes suitable for strip mapping.

This paper presents a review of the predominant hydraulic and geotechnical controls on the instability and erosion rates of the Pleistocene bluffs occurring along the Canadian Great Lakes shoreline. Emphasis is placed on the relationship between wave power impacting on the shoreline and long term (150 year ±) erosion rates illustrated by data from Lake Erie. Short term deviations from the long term correlations are caused by such factors as large storms and wind set-ups, lake level variations, changes in bottom topography, changes in slope morphology and geology, etc. These "events" which are significant over the short term must not be confused with long term trends.

For large scale mapping (1:10,000) the following is recommended:

1) Strip maps of wave power impacting on the shoreline should be part of the geotechnical classification.

2) Strip maps of long term erosion rates superimposed with codes or symbols representing present failure modes are fundamental to classification. The two major modes of failure are: a) *surficial*, including sloughing and flows, and b) overall or *deep seated*, including slides and falls.

3) Geologic cross-sections of the stratigraphy along the length of strip maps are required for the materials input.

4) Since bluff erosion-instability relationships are cyclic, the size and frequency of land-

sliding may be a useful additional code to add, particularly in the case of very large landslides which may have a cycle of 30 years ±.

For small-scale mapping projects, accumulated detail leads naturally to detailed classification based on morphology, geology and failure processes. While very valuable for short term planning, this type of work is very expensive and may not bear much relationship to true long term natural trends in an overall region.

The application of these ideas to a regional shoreline mapping project at the west end of Lake Erie will be presented.

PREDICTION OF TIME-AVERAGED PATTERNS OF POTENTIAL SHORELINE EROSION, TRANSPORT AND DEPOSITION IN THE TORONTO WATERFRONT, LAKE ONTARIO, CANADA

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Shoreline change in the Toronto Waterfront is partly a response to the natural spatial variability of the time-averaged patterns of wave energy flux. Monitoring such changes and the effective wave processes over any lengthy period is a prodigous task and, as an alternative a numerical model is used to simulate the interaction between shoreline geometry and shoaling waves. Thirteen wave conditions (defined by height, period and direction of approach) characterizing the annual hindcast spectrum are used to predict alongshore gradients of wave energy flux. Identification of time-average *net effects*, which produce the dominant water and sediment transport patterns, is achieved by a summation procedure whereby the individual effect of any condition at a shoreline point is weighted according to its frequency of occurrence. Zones of potential erosion (increasing alongshore energy flux), transport (constant alongshore energy flux) and deposition (decreasing alongshore energy flux) are shown to correlate with established historical trends.

POST GLACIAL EVOLUTION AND MODERN PROCESSES AT POINT PELEE, LAKE ERIE

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In order to understand the role of modern processes in coastal morphological changes in the Great Lakes, one must differentiate between those effects that are due to modern coastal processes and those related to the coastal regime existing thousands of years ago. The shoreline configuration of the Great Lakes at the close of the last glacial period was conceivably very different from that of today, as lake levels were generally lower, and isostatic rebound of the area from the weight of the ice sheet was more rapid. As a result, accretionary coastal landforms which contain both modern and relict elements exist in some areas.

One such area is Point Pelee, a large (80 km^2) cuspate foreland, projecting southward from the northern shore of western Lake Erie. Using interpretations of the existing literature on post-glacial stratigraphy and glacial history of the area, as well as the results of our own investigations, we present the hypothesis that Point Pelee originated as a much larger feature approximately 4000 years before present when lake levels were 3 to 4 m lower than today. Since that time the Point has retreated to its present position at estimated rates of 2.5 m/y (northward) and 0.25 m/yr (westward). Rates of shoreline evolution based on the historic record (post-1918) reach as high as 3 m/yr for large sections of the east side while other sections have remained stable or show accretion over this period.

Our investigations into modern dynamic processes indicate that the role of post-glacial lake level rise is now overshadowed by that of storm wave action, storm surges, nearshore currents, and cultural effects. Wave activity on the east side, although less frequent, is considerably more intense than on the more sheltered west side. The east side is also more prone to surge-induced washover of beach materials into the marsh and backbeach areas during periods of high lake levels such as those during 1972 to 1976. Calculated net littoral drift rates on the west side (at ca. 4000 m^3/yr) are also much less than on the east side (ca. 25,000 m^3/yr toward the south), and are directed northward. Short term current-meter records and sediment distribution patterns on the shoal area immediately to the south indicate that the dominant sediment transport direction there is toward the east. under the influence of seiche-related currents.

On the basis of the above factors, a conceptual model of sediment sources and dispersal patterns in the Point Pelee area is presented.

COMPUTER SIMULATION OF RECURVED SPITS

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Under conditions of large supplies of material for longshore drift material, and a dominant wind and wave direction, spits of sand and gravel form where coasts change direction or some obstruction occurs.

Yasso (1964) has shown that the geometric form of the outer edge of such spits fits a logarithmic spiral, convex seaward. The spiral has the relationships $r=e^{\theta \cot \alpha}$, where α is the constant angle that the tangents to the spiral make with the radii at each intersection.

Two spits in Lake Erie meet the criteria of a supply of material from eroding cliffs and a dominant wind-wave direction: Long Point on the north shore at a change in coast direction, and Presque Isle on the south. Both are continuously and presently increasing in length. Presque Isle, surveyed in 1900, had a logarithmic spiral with an α value of 35°. A later map of 1957 requires an α value of 27° to obtain an adequate fit. The major difference between spirals of different α values occurs in the curvature of the outer end, i.e. near the geometric origin.

This translated into geomorphic terms can be seen as the orientation of the sand ridges which are frequent on such spits. With time, the angle of the "recurved ridges" approaches that of being parallel to the shoreline as the spit develops and the α value tends to zero.

Since the base of the spit is normally fixed, the lengthening of the spit is accompanied by a movement of the origin of the logarithmic spiral downdrift, a change in the angle of the "recurved" end and a decrease in the α angle of the curve. This is reproduced by computer plotter and fitted to time sequences of Long Point and Toronto Island and others.

MORPHOLOGY AND SEDIMENTOLOGY OF MULTIPLE PARALLEL BAR SYSTEMS, SOUTHERN GEORGIAN BAY, ONTARIO

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The morphology and sedimentology of six sand beaches in southern Georgian Bay was investigated during the summer of 1977. The nearshore zone on two of these beaches, Christian Island and Wasaga Beach, was characterized by the presence of well developed multiple (4 to 8) parallel bars, and these beaches were selected for more intensive study. Individual bars can be traced unbroken for distances exceeding 1.5 km, though bars closest to the shore are shorter and more irregular in shape. Spacing between the bars is 20 to 40 m and increases only slightly in the offshore direction. They are typically symmetric or slightly asymmetric landward and range in height from 0.1 m to 0.4 m with height increasing somewhat offshore.

Sediments are characteristically fine (mean size 3.0 ϕ to 3.75 ϕ) and sedimentary structures in the bars are predominantly interbedded landward-, and seaward-dipping ripple cross-bedding. Units of massive or structureless beds are common in cores taken on the outer bars and troughs and possibly reflect rapid deposition from suspension. The seaward slope is characterized by interbedded units of plane bed and ripples. However, units of mega-ripple cross-bedding, commonly found in this zone in other areas, are absent. This probably reflects the fine sediment size which may lead to a direct transition from ripples to plane beds as bed velocities increase.

The major control on the occurrence of the multiple parallel bars appears to be the very gentle offshore slope (0.005 to 0.01) which, in conjunction with the limited fetch length, results in a high breaker index (spilling breakers). Unlike many of the bar systems studied in areas with a similar wave climate, rip cell circulation appears to be unimportant in the formation and maintenance of the bars.

THE MORPHOLOGY AND PROCESSES OF THE LAKE SUPERIOR NORTH SHORE

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The Ontario shore of Lake Superior is the product of the association of the events of deglaciation, differential isostatic uplift, and oscillating water levels of the post glacial lakes occupying the basin as it was revealed from beneath ice.

The present water level has been sustained for only two to three thousand years, but the discontinuous presence of an offshore rock platform bearing till remnants and running beneath present and raised beach materials is incompatible with the duration of present wave activity. Though glacially scoured and modified by present waves, it is suggested that Lake Superior lies coincident with the rock shore of a Sangamon(?) lake.

The present shore consists mainly of glacial and post glacial sediments from beneath which rock features are slowly being exhumed. The rock shore retains its glacial smoothing, present rock wear being limited to local abrasion and quarrying in the surf zone. Present beach materials are largely the product of backshore erosion of previously deposited beach or fluvial sediments. Commonly, only large boulders are present, these resting on late glacial varved clays with little or no fine materials involved. Very little offshore sediment transport takes place except near mouths of rivers of high sediment discharge from debris choked valleys. Though shallow offshore bar areas occur, much of the offshore zone reveals only a few centimetres of sediment on glacial clays.

Present wave activity has rounded and sorted beach materials to a greater degree than those of the raised beaches, but the large content of previously worn materials can be misleading. Storm events are those which shape beach plan and profile. Ice push is significant only locally but snow bank compaction of the beach face is common. Beach fast ice provides Spring protection but results in well sorted microfeatures being superimposed on the beach face after melt of ice bearing wave thrown materials.

ICE SCOURING AS A COASTAL PROCESS, BYAM CHANNEL, QUEEN ELIZABETH ISLANDS

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Nearshore sediments in Byam Channel beyond the 7-m isobath are relict glacial-marine consisting of 33% sand, 45% silt and 22% clay with variable amounts of gravel and larger-sized material. The sediment texture changes linearly with depth, the shallower water deposits being coarser, better sorted and positively skewed relative to deeper-water deposits which are fine-grained, poorly sorted and less skewed. These relationships are explained, not by a typical depositional coastal sedimentation model, but by the increasing influence of ice impinging and scouring the bottom as depth decreases.

During Holocene isostatic uplift, the relict glacio-marine sediment is brought into decreasing water depths where moving ice blocks scour the substrate leaving long linear tracks approximately 2 m deep and flanked on either side by embankments 1 m high. As an ice block moves through the sediment, the following events occur: (i) new sediment is exposed in the scour track and its embankments thereby enabling currents to winnow surficial silt and clay; (ii) currents increase in the area surrounding the grounded ice block causing erosion of the terminal and lateral embankments; (iii) burrowing organisms preferentially inhabit the softer sediment of an embankment contributing to the suspension and removal of fines; (iv) the moving ice block itself may raise a flurry of sediment in its wake enabling fines to go into suspension; (v) after the scour track and embankments have reached stability, the foregoing cycle of disturbing processes will be re-initiated when a new ice scouring event buries and mixes the surficial lag deposit and exposes new sediment; (vi) under ice tidal currents increase as depth decreases contributing to erosion and removal of exposed fines. By these processes, the relict sediment is reworked by ice, resulting in the observed textural relationships with water depth.

COASTAL ENVIRONMENTS ALONG THE NORTHERN SHORE OF SOMERSET ISLAND, N.W.T.

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Somerset Island is fringed by shores which are representative of many coasts in the east-central part of the Canadian Arctic Archipelago. The northern coast of Somerset Island can be divided into six coastal environments. They are the gravel beach, sand plain, barrier beach-lagoon, rocky shore with pocket beaches, cliffed and deltaic environments. The gravel beach, backed by well developed raised beach ridges is the most common, it covers 50 to 55% of the shoreline between Garnier Bay and Aston Bay, Somerset Island. Observations of the sedimentologic and geomorphic characteristics of the raised beach, the active beach and the nearshore were completed to establish differences within and between the coastal environments. The beach sediments closely reflect differences in geology and processes acting upon these shores. For instance the rocky shores with pocket beaches are in an area of Precambrian granitic rocks, whereas the sand plain environment is underlain by less resistant Paleozoic sandstone.

The seasonal character of sea and shore ice determines the length of time during which littoral processes can operate in the arctic. Field observations from 1972 to 1976, along the north shore of Somerset Island indicated wide variations in littoral processes both seasonally and geographically. Only during the summer of 1974 were the beaches significantly changed by higher energy waves. The continual presence of ice either offshore or onshore, limited the fetch and prevented large wave production or protected the beach against significant changes during the other four years. Moreover the impact of sea ice varied along the coast, those reaches west of Cape Rennell were more affected by sea ice than the shores further east along northern Somerset Island.

DELTAIC PROCESSES AND DELTA MORPHOLOGY, MACKENZIE DELTA, N.W.T.

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The Mackenzie River delta is the second largest in North America, exceeded in surface area only by the Mississippi. Annual river discharge and nearshore Beaufort Sea wave-power data indicate that the Mackenzie, like the Mississippi, is characterized by the dominance of river forces over wave forces and its morphology, therefore, should be primarily river-controlled. This control is verified to some extent by the very low offshore gradient which the Mackenzie has been able to maintain at its delta front, lower even than that off the Mississippi. Unlike the Mississippi, however, the Mackenzie does not have the rapidly advancing parallel distributary levees and digitate outline form that are usually considered typical of a river-dominant situation. Rather, it has developed a lobate shoreline configuration with funnel-shaped channel mouths. These appear to result from the absence of salt-wedge stratification in Mackenzie distributaries with the result that river effluent deceleration and expansion are controlled by jet diffusion and bottom friction rather than by the buoyant expansion common at the Mississippi delta front. Nor does the Mackenzie show any evidence of recent extensive subaerial delta progradation in spite of river dominance. Shoreline erosion caused by extreme summer and fall storms on the Beaufort Sea is not repaired during the spring flood when most sediment is discharged. The presence of bottom-fast ice out to a depth of about 2 m off the delta shoreline during this flood turns the 0 to 2-m zone into an area of sediment bypassing rather than the one of accumulation that it would be in a non-arctic environment. The Mackenzie delta, then, in spite of river dominance, is not similar morphologically to the Mississippi in many respects and illustrates both the effects of arctic conditions on deltaic evolution and the dangers of the commonly made assumption that the Mississippi is "typical" of river-controlled deltas.

GENESIS OF MORPHOLOGIC FEATURES ON THE WESTERN DELTA FRONT OF THE FRASER RIVER, BRITISH COLUMBIA

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Distinctive features on the active western front of the delta include: sand swells, mud pools, and dendritic drainage patterns on the tidal flats; sea valleys and sand waves on the slope.

Low amplitude (<0.5 m), long wavelength (50 to 100 m) sand swells have developed along the northern part of the tidal flats at the inside margins of a 15 km^2 V-shaped area, bounded by jetties, which is open to the sea. The swells have been generated by tidal currents and refracted surface waves. Sand composing these bedforms may be supplied from the adjacent distributary of the Fraser River, by littoral drift from the south and (or) by erosion of the central part of the V-shaped area.

Similar sand swells also are present adjacent to the upper flats marsh immediately to the north of the main channel. These features may have formed from sand carried north from the main channel before the jetty on the north side of the channel was extended across the entire flats. The swells are stable and are gradually being fixed by bullrush communities.

The above field of sand swells extends from the marsh at a shallow angle. Mud has accumulated between the swells and the leading edge of the marsh. At present, however, the surface of this mud flat is being dissected by a dendritic network of creeks draining the topographically higher marsh.

Sea valleys incise the delta slope off present and former channel mouths. The valleys may be maintained by cascading, oversteepened, freshet deposits and by tidal currents.

Segments of the slope on which muds are being deposited are essentially featureless; those mantled with sand have extensive fields of asymmetric waves (3 m amplitude; 30 m length) generated by flood-tide currents to water depths in excess of 100 m.

MORPHOLOGY AND LITTORAL PROCESSES OF THE PACIFIC COAST OF CANADA

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The Pacific coast of Canada is dominantly a rocky, rugged area of islands, inlets, and fjords flanked by high mountain ranges. The morphology of the coast is controlled by structural trends of the western Canadian Cordillera, but has been modified during the Pleistocene Epoch by glacial erosion of both unconsolidated sediments and bedrock, and by deposition of till and stratified drift.

Although wave and current energy and relief differ appreciably in the various coastal environments, the dominance of resistant rocks and the low input of terrestrial detritus result in a paucity of littoral sediments in most regions. Exceptions include: (1) areas backed by cliffs of unconsolidated Pleistocene sediments or nonresistant bedrock; (2) fjords and protected embayments where deltas are forming under low wave-energy conditions; (3) exposed coastal areas where deltas are forming (e.g. the Fraser and Skeena River deltas) or where littoral currents transport sediment along the coast from river mouths to nearby depositional sites; (4) pocket beaches between resistant headlands; and (5) sheltered, very low energy sites characterized by intertidal mudflats.

The landforms and sediments associated with former postglacial shoreline positions provide evidence of the nature of earlier coastal environments. Following the late Wisconsinan glacial maximum a marine transgression to a maximum elevation of about 200 m occurred on the inner coast. During this and the following regressive phase, which resulted in large part from isostatic adjustments in the crust, voluminous outwash was deposited locally in many coastal areas. Middle and late Holocene sea levels apparently were relatively lower than at present, and the subsequent rise in sea level has been accompanied by erosion at many coastal sites. Adjustments in land-sea positions are continuing, but to date have been documented only for the southern Georgia Depression.

THE STATUS OF COASTAL RESEARCH IN CANADA

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Modern research into coastal dynamics and the investigation of the coastal environments of Canada date from the mid-1960s. Although interest in coastal research problems has increased steadily during the past 10 years, the number of scientists actively involved in the field is still relatively small. One major effect of this situation is that the present data base is highly variable in terms of an inventory of shoreline types or coastal environments and an understanding of littoral processes. A few areas, such as the southern Gulf of St. Lawrence, have been studied in considerable detail by a number of groups over the past 10 years. In this region the basic form-process relationships and the sediment dispersal patterns are well defined. Elsewhere, many sections of the coasts are virtually unexplored, particularly in the upper Great Lakes, Hudson Bay, and much of the Arctic.

This review of the status of coastal research in Canada will focus on two important applied aspects of shoreline dynamics: (1) the level of understanding of natural changes, both in an historical context and in the prediction of future natural changes; and (2) the understanding of the impact of man on shore-zone processes and morphology, and the prediction of the effect of proposed coastal engineering projects on the natural shoreline. In addition, an assessment of the level of understanding of the coastal environments of Canada will be presented in order to direct attention toward areas where future studies will be required.

A review of the data base for Canada's coasts reveals the present limited extent of our knowledge. Although the standard of research is generally high, in terms of organization the coastal sciences are very young in age. Recent and present research programmes are characterized by individuals or small groups that are scattered geographically in universities, government agencies, or the private sector. From a personal viewpoint, the development of multidisciplinary research groups, involving specialists in physical oceanography, geology, and biology, to train scientists, as well as to initiate and carry out research programmes, must take high priority in planning for the immediate future. The development of a coordinated approach to fill in the large gaps in our knowledge of our coasts will require a greater awareness of the problem areas by the funding agencies and a larger commitment of funds to address these problems.