CHAPTER 69

BARRIER BEACHES AND SEDIMENT TRANSPORT IN THE SOUTHERN GULF OF ST. LAWRENCE

by

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ABSTRACT

Barrier islands and barrier beaches have developed across structurally controlled estuaries and embayments in the southern Gulf of St. Lawrence. The supply of sediments to the littoral zone and the subsequent accumulation of barrier deposits is a result of the reworking, transportation and longshore dispersal of sediments which are moved landward by tidal and wave-induced currents from the adjacent shallow sea floor. The size and stability of the barriers is controlled by the shoreline orientation.

INTRODUCTION

Barrier islands and barrier beaches have developed across structurally controlled embayments or estuaries in the southern Gulf of St. Lawrence, Canada. Distinct regional variations in the geomorphology of these barrier deposits are discussed in relation to shoreline orientation and to sediment dispersal patterns in the littoral zone. It is possible to explain the morphological variations in terms of the coastal zone processes and the sediment transport systems of the littoral, nearshore, and offshore zones. This synthesis of the barrier systems is based on a reconnaissance survey of the coastal zone (Owens, 1974a; Owens

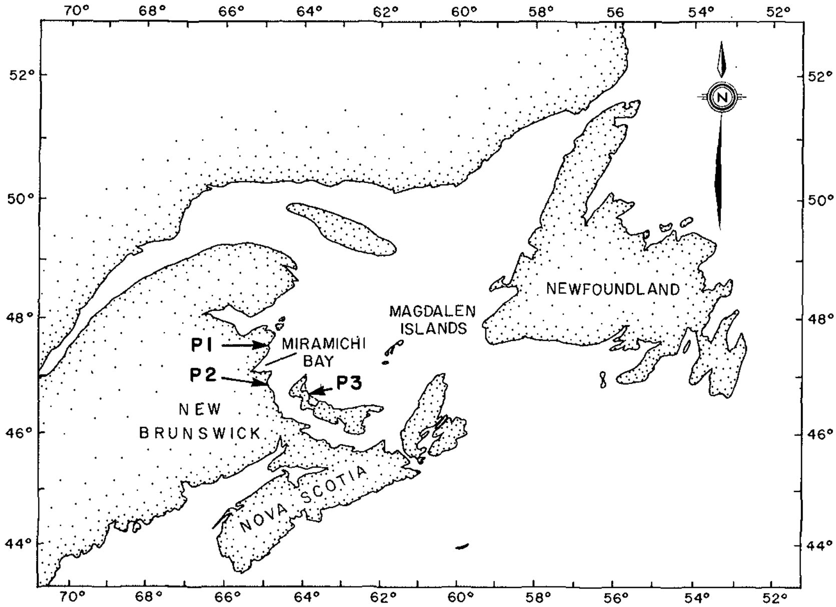

Figure 1: Location diagram of the Gulf of St. Lawrence, Canada. P1, P2, and P3 refer to the sites of profiles given in Figure 10.

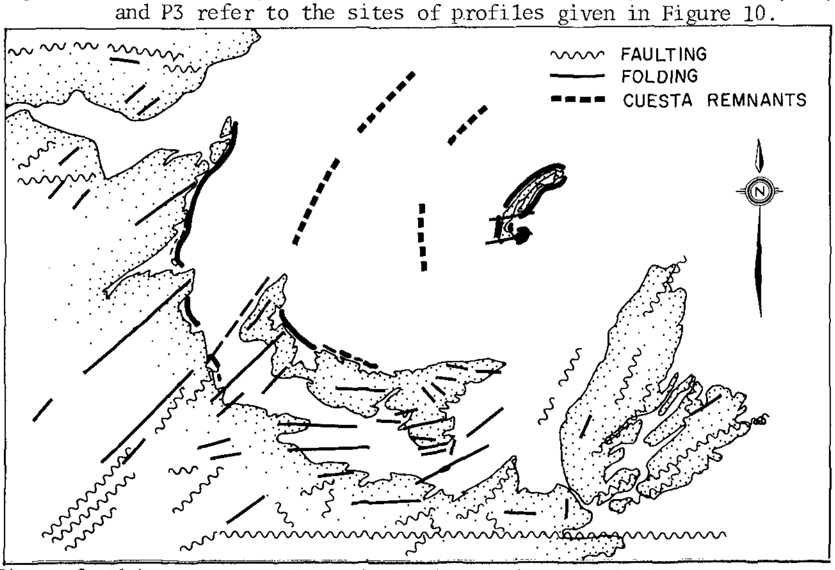

Figure 2: Major structural trends in the southern Gulf of St. Lawrence (after Owens, 1974a). Barrier beaches are indicated by a solid line parallel to the coast.

and Harper, 1972) and on a detailed sedimentological study of the Gulf of St. Lawrence (Loring and Nota, 1973).

The southern half of the Gulf of St. Lawrence is a shallow (< 200 m), semi-enclosed sea (Fig. 1) underlain by unresistant Permo-Carboniferous sandstones and shales which have been folded to form a broad northerly plunging synclinorium (Sheridan and Drake, 1968). The submarine morphology of this region is related to a preglacial drainage system which developed along lines of structural and lithological weaknesses. The Pleistocene ice sheets did not significantly modify this drainage pattern and the major effect of glaciation was the deposition of tills and moraines (Loring and Nota, 1973). After deglaciation the sea level was lowered to a maximum of -70 m as a result of isostatic readjustment. The glacial and fluvio-glacial sediments were then reworked during the subsequent marine transgression which followed the period of emergence. The present shoreline

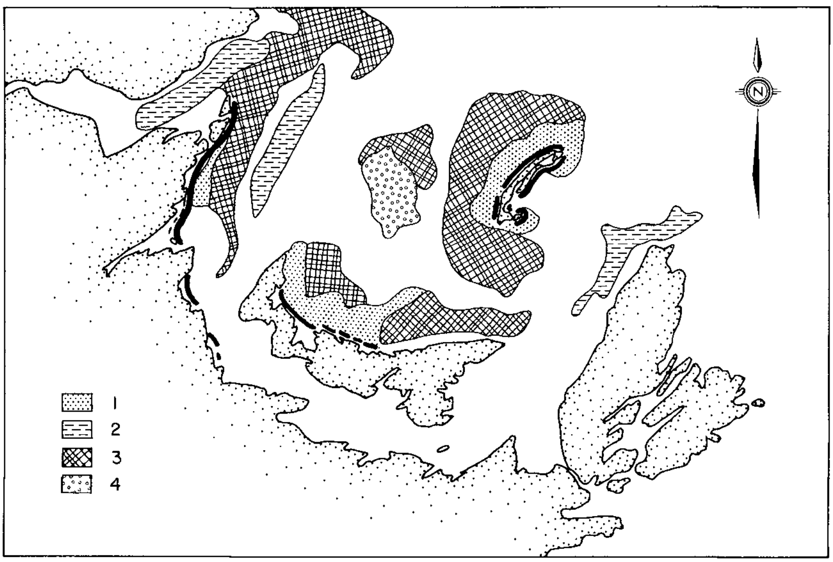

Figure 3: Sedimentary environments of the southern Gulf of St. Lawrence (from Loring and Nota, 1973).
1. Nearshore and coastal areas of active reworking and redistribution
2. Active deposition of fine-grained sandy and very sandy pelites
3. Areas of non-deposition with local reworking and formation of lag deposits
4. Offshore areas of active reworking and redistribution
Blank areas are zones of transition.

results from the submergence of the cuesta lowland and the subsequent development of barrier beaches across embayments and estuaries (Fig. 2) (Johnson, 1925).

SEDIMENT SOURCES

Where the unresistant sandstones and shales outcrop along the coast they are rapidly eroded by wave action resulting in shoreline retreat rates greater than 1 m/year. The supply of sediment from the sandstones is limited by the low relief (the cliffs are usually less than 5 m high) and by the short sections of the outcrops updrift of the barrier beaches (Owens, 1974a). Also, sediment from rivers which drain small catchment areas often does not reach the littoral zone as the drowned estuaries act as sediment traps. These terrestrial sources therefore do not supply large volumes of sediment to the coastal zone at the present.

Detailed analysis of bottom sediments in the southern gulf by Loring and Nota (1973) shows that reworking and redistribution is taking place offshore. A map of sedimentary environments (Fig. 3) indicates zones where glacial and fluvio-glacial deposits are being reworked (units 3 and 4). Fine-grained sediments are transported and deposited in deeper water (unit 2) while sands are redistributed landward (unit 1). Mineralogical analysis of material from the littoral and offshore environments (Loring and Nota, 1969) shows that these sediments are derived from the same source. Direct evidence for movement of sediment on the sea-floor is provided by bottom photographs and side-scan sonar records, which show fields of sand waves in water depths up to 54 m (Loring et al, 1970).

The reworking, sorting, and redistribution of bottom sediments on the shallow shelf results from tide- and wind-generated currents. Lauzier (1967) reported landward residual drift on the sea-floor adjacent to the coasts of eastern New Brunswick and northern Prince Edward Island (Fig. 4). These bottom currents can be related to the prevailing and dominant offshore winds along these coasts (Fig. 5) which cause a seaward movement of surface waters and generate a counter residual drift toward

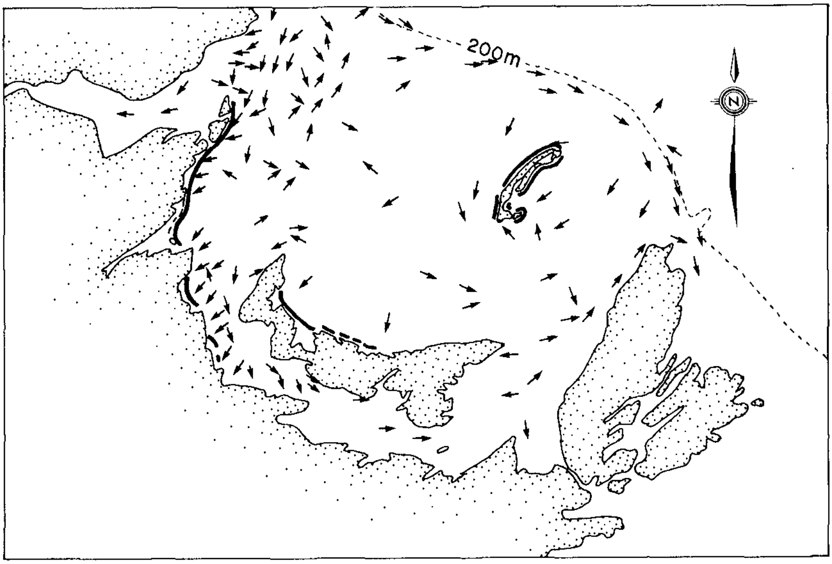

Figure 4: Bottom residual currents in the southern Gulf of St. Lawrence (after Lauzier, 1967). Barrier beaches are indicated by a solid line parallel to the coast.

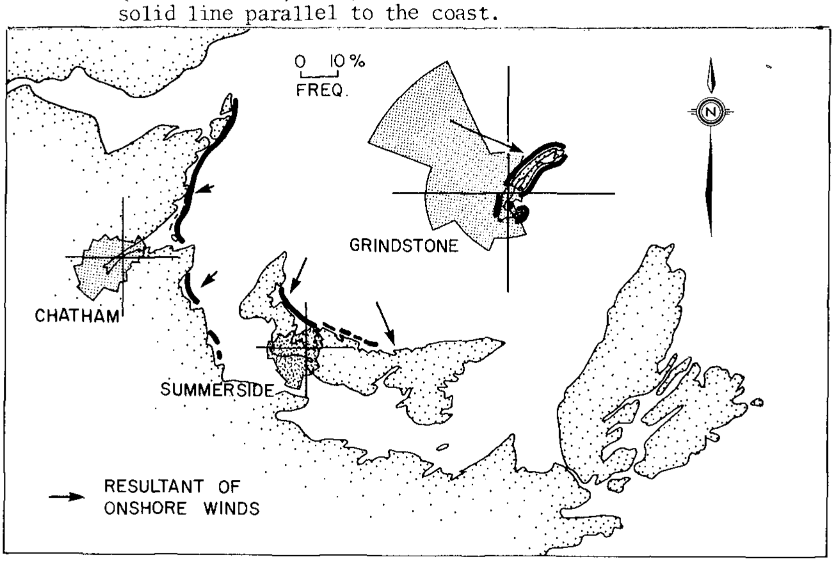

Figure 5: Wind frequency roses for Chatham, New Brunswick; Summerside, Prince Edward Island; and Grindstone, Magdalen Islands. The resultants of onshore winds are proportional. Barrier beaches are indicated by a solid line parallel to the coast.

BARRIER BEACH TEXTURE ANALYSIS

	INTERTIDAL			DUNE			
	n	$\bar{x}(\phi)$	σ	n	$\bar{x}(\phi)$	σ	UNIT
N.E. NEW BRUNSWICK	26	1.52	0.49	8	1.51	0.46	a
NEGUAC/MIRAMICHI	23	1.73	0.40	4	1.69	0.38	b
KOUCHIBOUGUAC	8	1.46	0.39	3	1.61	0.37	c
BUCTOUCHE	4	1.49	0.39	1	1.58	0.39	d
NORTH P.E.I.	6	1.93	0.38	7	2.09	0.38	e
ILES-MADELEINE (W)	15	1.67	0.32	6	1.67	0.37	f
ILES-MADELEINE (E)	17	1.87	0.36	5	1.95	0.36	g

Table 1: Summary of textural data for intertidal and dune sediment samples. The location of the units is shown in Figure 6.

the land. This provides the mechanism for the transportation of sand into the shallow nearshore zone where it is redistributed by tidal and wave-induced currents.

Textural analyses of intertidal and dune samples from the barrier beaches, collected at a 10 km interval (Owens, 1974b), show a high degree of uniformity in mean size and sorting values (Table 1; Fig. 6). The averaged mean grain size values for each unit range from 1.46ϕ to 1.93ϕ (0.36 mm to 0.26 mm) for the intertidal samples and from 1.51ϕ to 2.09ϕ (0.35 mm to 0.24 mm) for the dune samples. All the sorting values (σ) fall within Folk's "very well sorted" (<0.35) or "well sorted" (0.35 - 0.49) categories. This uniformity of textural characteristics, combined with the mineralogical homogeneity discussed by Loring and Nota (1969) suggests a common source for the barrier sediments.

The barrier beaches developed initially during the marine transgression and have migrated landward. The maintenance and extension of the barriers is dependant on a continuing supply of sediment. A major source of sand is onshore transportation from the adjacent nearshore and offshore zones.

SEDIMENT DISPERSAL

The southern gulf is a semi-enclosed sea, largely protected from Atlantic swells, and the wave environment is dominated by short period, locally generated, storm waves. Two factors limit wave generation, the relatively short fetches (<700 km) and the presence of sea and beach-fast ice for up to four months each year (Owens, 1974a; 1974c). This is also a micro-tidal environment with mean tidal ranges less than 2 m.

Discussion of separate barrier systems is possible as each set of barriers has developed across a particular embayment or estuary and is usually bordered by a bedrock outcrop. For this discussion the barrier coasts have been divided into seven units (Fig. 6) on the basis of morphology and sediment dispersal characteristics.

The northeast coast of New Brunswick (unit a) and the Neguac-

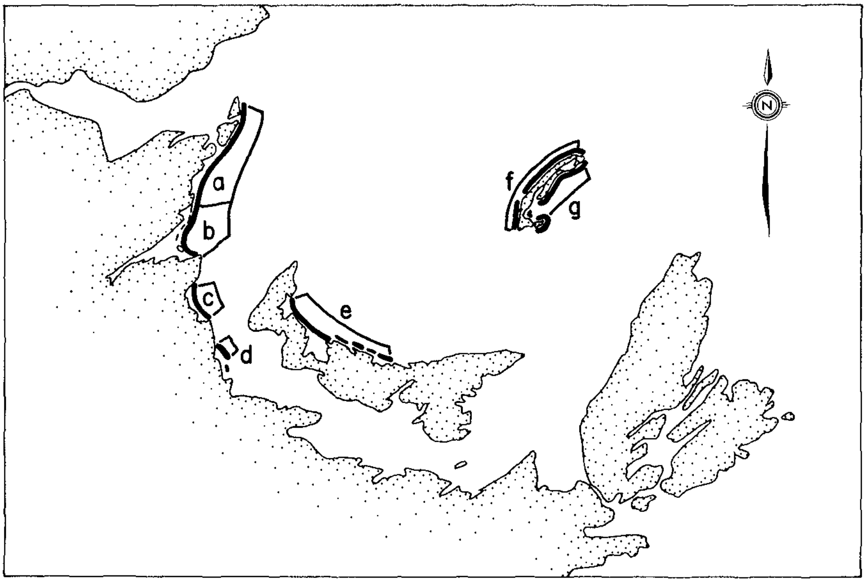

Figure 6: Barrier beach units in the southern Gulf of St. Lawrence.

a. Northeast New Brunswick
b. Neguac - Miramichi embayment
c. Kouchibouguac embayment
d. Buctouche Bar
e. Northern Prince Edward Island
f. Western Magdalen Islands
g. Eastern Magdalen Islands

Miramichi embayment (unit b) together form one of the major barrier systems in the southern gulf. Sediment is supplied to the littoral and nearshore zones from the shallow offshore sea-floor and is redistributed along the coast. Meteorological data from Chatham (Fig. 5) shows the predominance of winds from the southwest in this area, that is offshore, with the onshore wind vectors out of the northeast quadrant (Fig. 7). The direction of littoral transport is from north to south in response to wind-generated waves from the northeast quadrant (Owens, 1974a).

North of the Miramichi-Neguac embayment the barrier system is characterized by sediment bypassing and transport to the south. At Neguac, on the north shore of Miramichi Bay (Fig. 8) this dispersal pattern has led to rapid inlet migration and barrier extension (Owens, 1974d). A change in

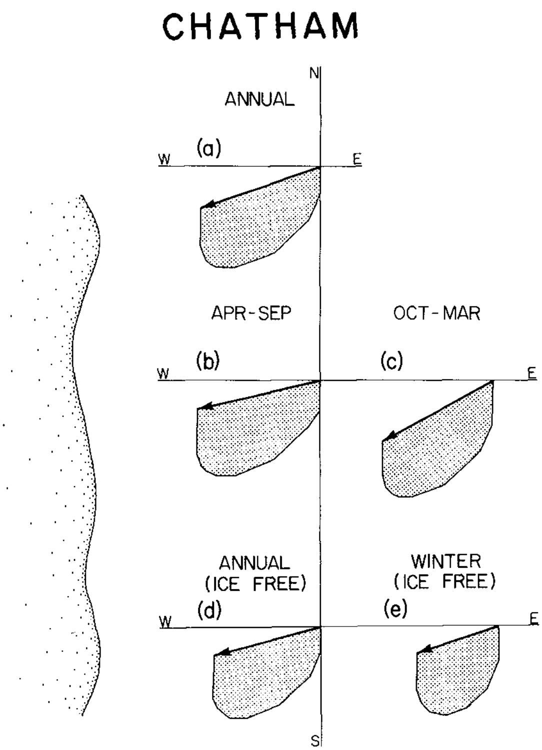

Figure 7: Vectors of onshore winds for the coast of northeast New Brunswick and the Neguac-Miramichi embayment, based on data from Chatham, New Brunswick. Shoreline orientation is assumed to be north-south.

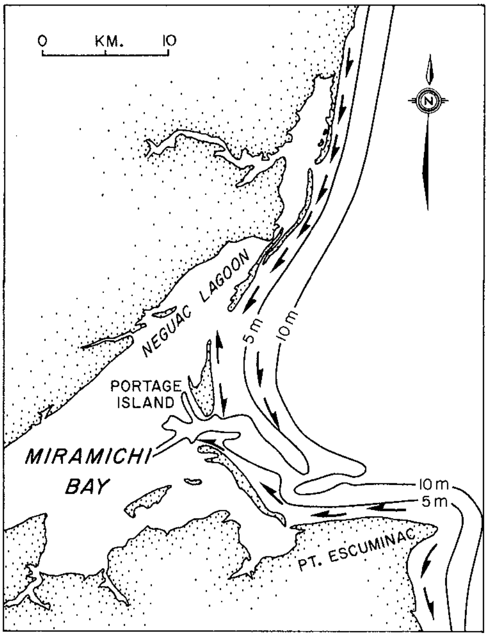

Figure 8: Generalized pattern of sediment dispersal (indicated by the arrows) in the littoral and nearshore zones of the Neguac - Miramichi embayment.

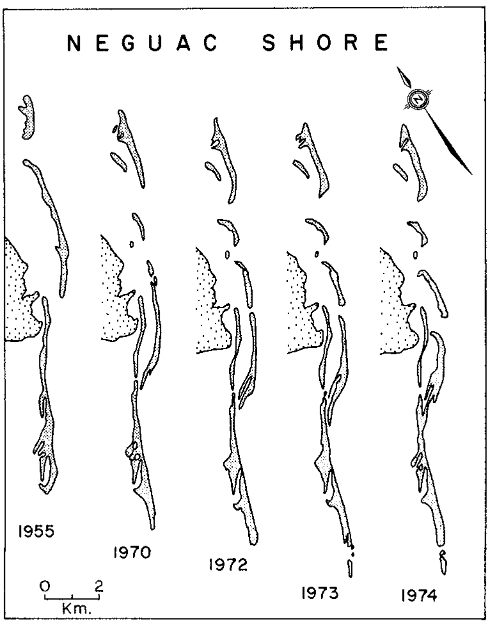

Figure 9: Shoreline changes at Neguac, New Brunswick, derived from vertical and oblique aerial photography. The location of this barrier system in relation to the adjacent coast is shown in Figure 8.

shoreline orientation at Neguac, due to the drowning of the Miramichi estuary, has led to the development of overlapping barrier islands (Fig. 9). In addition to distal migration and extension of the larger barrier islands, the smaller islands have reoriented to become more closely aligned to waves approaching from the northeast. Miramichi Bay acts as a sediment trap for material supplied by the river and for the southward littoral drift along this coast. There is an area on the south shore of the embayment where the drift is reversed (Fig. 8) as waves from the northeast generate westerly and northwesterly longshore currents. At Portage Island, although the prevailing direction of littoral drift is to the south, a reversal to the north can occur depending on the direction of wave approach.

The barrier beaches of this coast are generally low, less than 3 m above mean high water (profile P-1; Fig. 10), and are frequently washed over or breached by storm waves. Extension of the barriers at Neguac appears to result from pulses of sediment which are moved alongshore under storm-wave conditions, though no direct measurements have been made to confirm this.

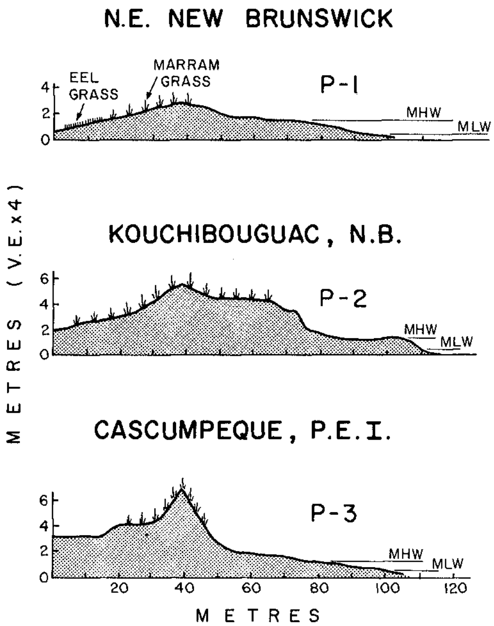

Figure 10: Selected profiles across three barrier beaches. These profiles are located in Figure 1.

Dates of profile survey:

P-1	10 June 1972
P-2	8 June 1972
P-3	1 August 1972

The barriers across the Kouchibouguac embayment (unit c: Fig. 6) are orientated to face the northeast and waves approach at a less acute angle to the shoreline as compared with the barrier systems to the north. As a result of this different orientation the longshore component of sediment movement is reduced, although littoral drift is still to the south. Sediment is supplied to the littoral zone by coastal erosion in updrift areas and by the onshore movement of material from the shallow offshore area (Kranck, 1967). Little sediment is lost from the embayment by littoral or nearshore drift around the rock headlands at the southern limit of this system because of a local drift reversal (Owens, 1974a; Fig. 13). The barrier beaches are up to 6 m above mean high water (profile P-2; Fig. 10) and are only infrequently breached by storm waves. This system is migrating landward (McCann and Bryant, 1972) but is relatively stable and is not undergoing major shoreline changes.

Buctouche Bar (unit d; Fig. 6) is a recurved spit which is growing southwards across a broad shallow estuary. Due to the relatively small fetch window created by Prince Edward Island the direction of wave approach is from the north. This induces a strong longshore drift component. The proximal section of the spit is very low and narrow, as this is a zone of sediment bypassing. The distal section is characterized by multiple, truncated recurved ridges which result from the southward and landward migration of the spit.

The extensive barrier islands and barrier beaches on the north coast of Prince Edward Island (unit e; Fig. 6) face the northeast and are characterized by relatively stable inlets and dunes up to 8 m above mean high water level (profile P-3; Fig. 10). This barrier system is similar in many ways to that of Kouchibouguac Bay. Sediment is supplied by the erosion of adjacent unresistant sandstone cliffs (Owens, 1974a; Fig. 8) and by onshore transport of reworked deposits from the shallow offshore zone (Fig. 3). The vectors of onshore winds, using data from Summerside, P.E.I. (Fig. 5), indicate the generation of littoral drift from northwest to southeast. Superimposed on this drift is a pattern of wave-induced currents which cause local reversals of longshore drift (Fig. 11). Longshore sediment movement is less than that for the northeast coast of New Brunswick as the angle of wave approach is not high

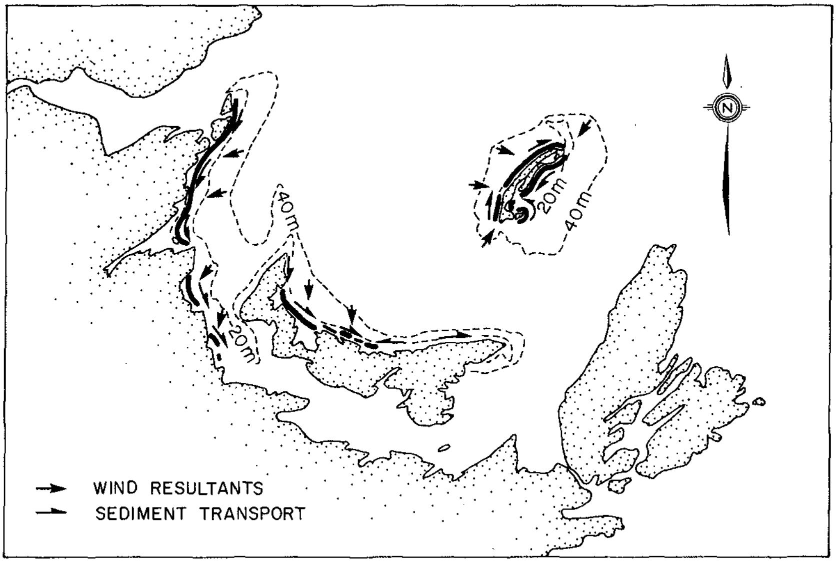

Figure 11: Onshore wind resultants and generalized pattern of sediment transport in the littoral zone of the southern Gulf of St. Lawrence.

due to refraction of the incoming waves across the shallow offshore sea-floor. There is a seasonal movement of sediment between the littoral and nearshore zones by the migration of submarine bars (McCann and Bryant, 1972).

The barrier beaches of the Magdalen Islands (units f and g; Fig. 6) are the largest single accumulation of littoral zone sediments in the Gulf of St. Lawrence and are exposed to waves generated from all wind directions. The prevailing and dominant winds are from the north-west quadrant (Fig. 5) and the east-facing coasts of the islands are a relatively sheltered environment, affected only by storm winds out of the northeast and by modified Atlantic swell waves which pass through Cabot Strait. The barriers and tombolos of the Magdalen Islands are anchored by a series of unresistant bedrock outcrops (Fig. 12) which are being rapidly eroded and supply sediment directly into the littoral zone. On the shallow shelf west of this barrier complex bottom sediments are being actively reworked and transported toward the Islands by wave-

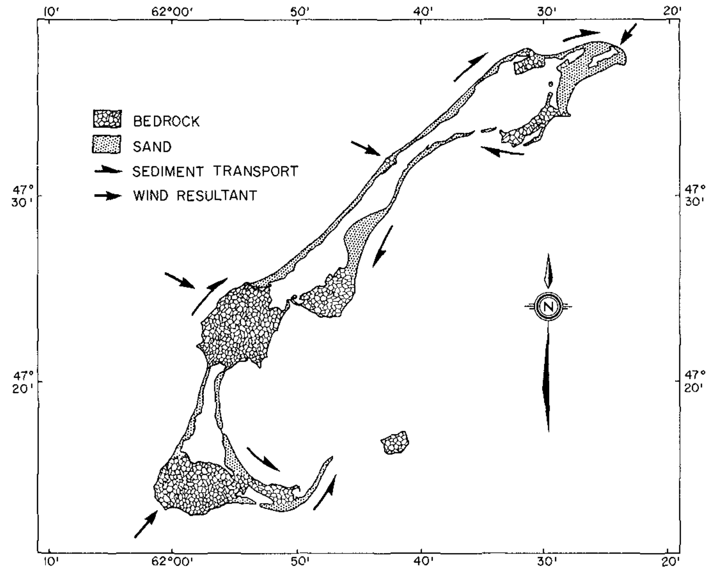

Figure 12: Onshore wind resultants and sediment dispersal around the Magdalen Islands, Quebec.

induced currents. Loring and Nota (1973) state that the bottom sediments grade from gravelly, poorly sorted sands to gravelly well sorted sands towards the west coast of the Islands (units 3 and 3c; Fig. 13). Dispersal of these sediments around the northern and southern extremities of the Islands leads to deposition of fine-grained sediments (unit 2; Fig. 13) in a sheltered zone, protected from waves out of the west and northwest.

The west facing barriers of the Magdalen Islands are a zone of sediment bypassing. Material fed into the nearshore zone from offshore is transported to the north and northeast in a series of large submarine bars and troughs. During periods of storm wave activity incoming waves break on the outer bars and generate currents in excess of 1 m/sec in the submarine troughs. Sediment is moved northward in these troughs as a series of large assymetrical sand waves. The barriers on this coast are relatively narrow, 500 to 1000 m wide, up to 6 m high, and are frequently eroded by storm wave action. By contrast the barriers on the

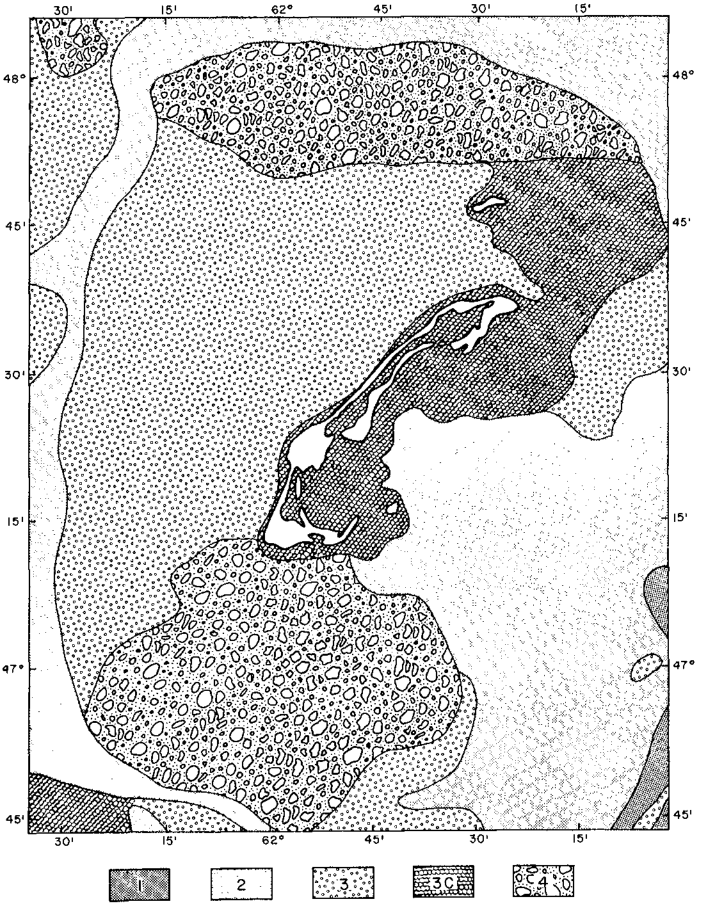

Figure I3: Distribution of surface sediments on the sea-floor adjacent to the Magdalen Islands (adapted from Loring and Nota, 1973).

1. Sandy Pelite
2. Fine Sand
3. Coarse-medium grained Sand
3c. Well sorted coarse-medium grained Sand
4. Gravel/Gravelly Sand

east coast of the Islands are in a lower energy environment, affected primarily by storm waves out of the northeast associated with the passage of cyclonic depressions. The broad pattern of sediment transport is from northeast to southwest with local reversals due to shoreline orientation, particularly at the southern end of this east-facing coast. The barriers are generally wider, up to a maximum of 2 km, and the nearshore bars are less complex and of lower elevation than on the exposed coast. This coast is a zone of sediment accumulation and beach progradation.

SUMMARY

With the rise in sea-level since the Pleistocene, barriers have migrated landward. As sea-level continues to rise this landward migration is still evident as indicated by the numerous outcrops of marsh and lagoonal deposits in the intertidal beach throughout the southern gulf. In addition, barriers have developed by the growth of spits across estuaries and embayments as sediment is transported alongshore by wave-induced currents. The distribution of barrier islands is related to the drowned lowland topography which has developed along structural trends and lithological weaknesses. Evidence from sediment studies in the offshore areas shows that bottom material is being actively reworked and redistributed on the shallow shelves and sand is transported into the nearshore zones for redistribution by nearshore and littoral processes. Differences in barrier morphology are related to the pattern of sediment dispersal along the coast which results from the direction of wave approach and the orientation of the shoreline. On coasts where the wave approach is at an angle to the shore, barriers are low and subject to rapid change by storm waves as these are zones of longshore transport and sediment bypassing. Where incoming waves are adjusted to the shoreline trend, because of refraction or because of the orientation of the coast, rates of longshore sediment transport are lower and the barriers are more extensive and more stable.

The barrier beaches of the southern Gulf of St. Lawrence are similar to those found elsewhere in the world. Although the processes and morphology are directly comparable with other barrier systems two characteristics give this region its uniqueness. (1) The gulf is a semi-enclosed sea and as a result the level of wave energy is much lower and the rates of wave-induced sediment transport are lower than on openocean coasts. In addition, this is a storm wave environment and there is a marked seasonal variation in energy levels. (2) Sea and beach-fast ice are present for up to four months each year (January to April). This prevents the operation of littoral processes during that period and any calculations of annual longshore sediment transport volumes must be reduced by at least 30 per cent. This is particularly important as severe storms are most frequent during the period between October and April.

ACKNOWLEDGEMENTS

The illustrations were prepared by A. Cosgrove and R. Sutherland of the drafting section of the Bedford Institute of Oceanography. Dr. D.H. Loring and D.E. Buckley critically reviewed the manuscript.

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