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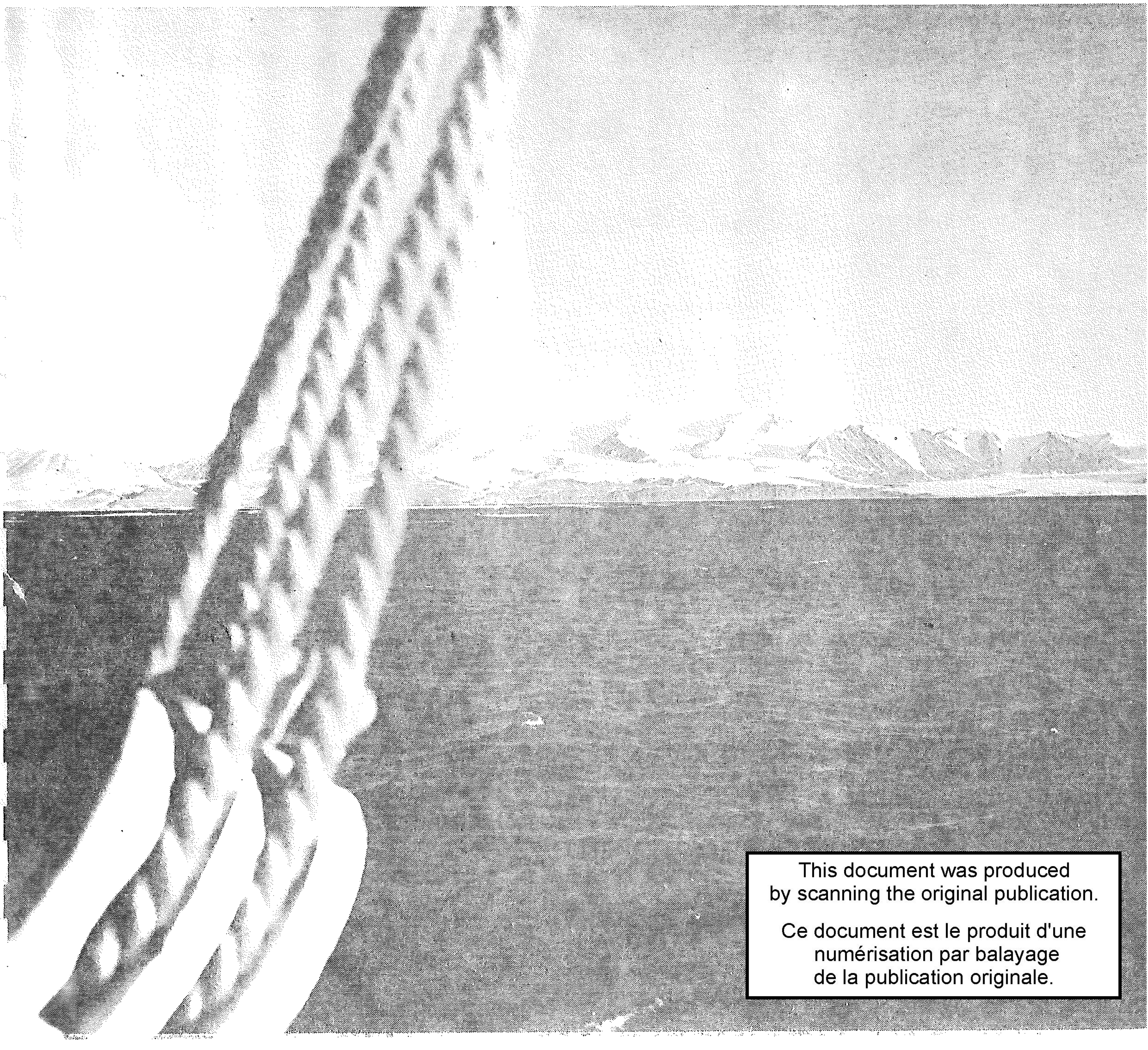
COASTAL GEOLOGY AND SCENERY
SOUTH SHORE, NOVA SCOTIA



FIELD TRIP A: COASTAL AND MARINE GEOLOGY OF THE SOUTH SHORE, NOVA SCOTIA

By

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INTRODUCTION

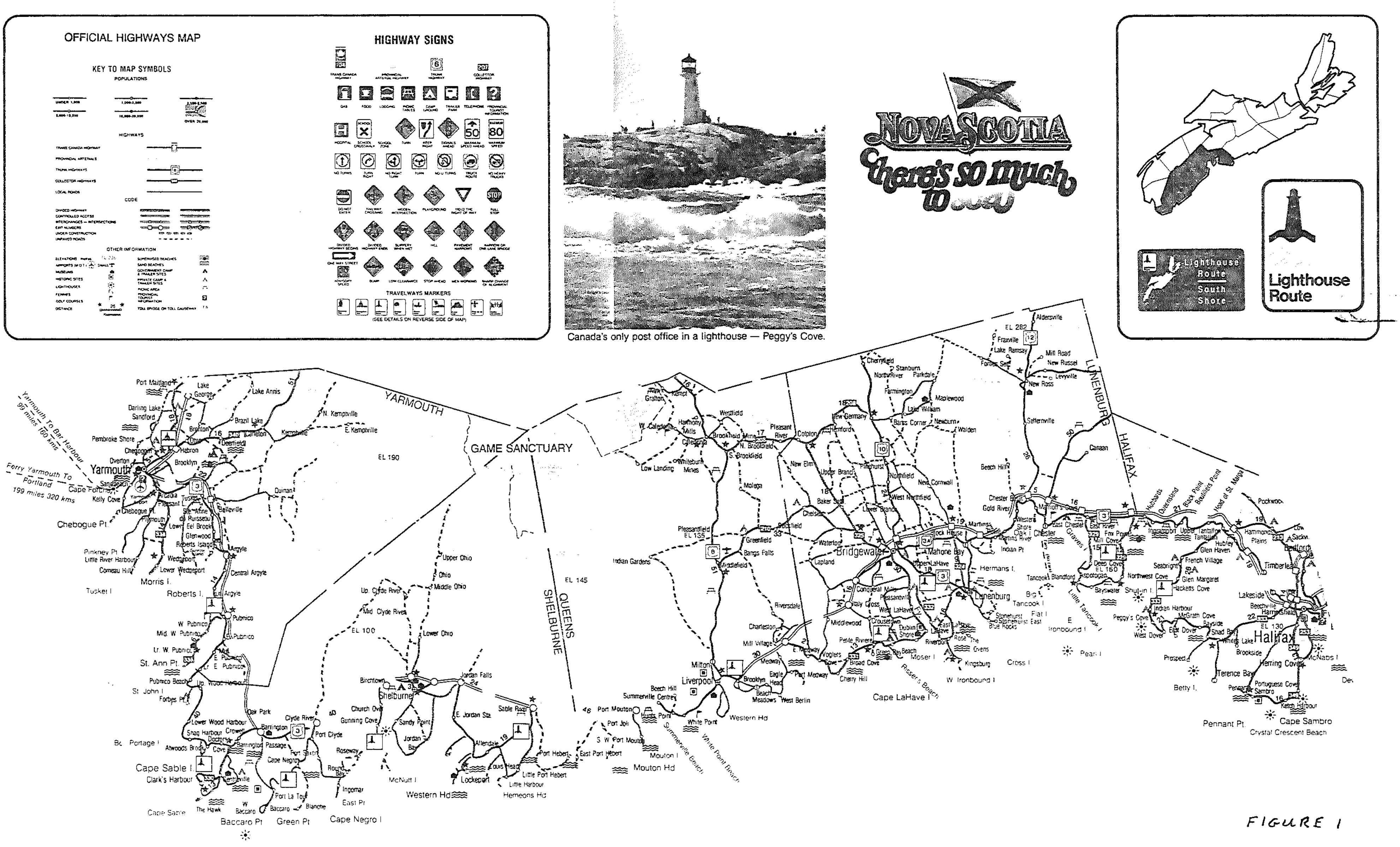
The field excursion is designed to provide a one day overview of the glacial and marine geology of the South Shore of Nova Scotia. Although many of the stops will focus on various bedrock and till exposures and other geologic features, time is also allocated to enjoy the historic and scenic beauty of the numerous coastal fishing villages. The trip originates in Halifax-Dartmouth and follows the main highway to Green Bay, Lunenburg Co. The route will then follow the coastline back to Halifax via Lunenburg, Chester and Peggy's Cove (Fig. 1).

Much of the offshore character of the South Shore cannot be viewed easily from land; hence, background geological information has been compiled by David Piper to provide participants with reference material that will be useful both during and following the excursion. The field guide is edited by Bob Taylor and the information on Risser's and Crescent beaches is written by Peter Ricketts. The trip leaders are Bob Taylor and Peter Ricketts. We acknowledge the logistics support provided by the staff of the Atlantic Geoscience Centre and the Bedford Institute of Oceanography both in terms of producing this field guide and organizing the excursion.

GEOLOGICAL AND GEOMORPHOLOGICAL BACKGROUND

1. Bedrock Geology

In many parts of the South Shore (particularly east of La Have estuary), bedrock outcrops on land are sparse due to a thick cover of glacial till. The rock types present (Fig. 2) are slates and metagreywackes of the Cambro-Ordovician Meguma Group (divided into the Goldenville Formation quartzites and the Halifax Formation slates), Devonian granite intrusions, thin Carboniferous Windsor Group sediments, and lower Mesozoic



Canada's only post office in a lighthouse — Peggy's Cove.

FIGURE 1

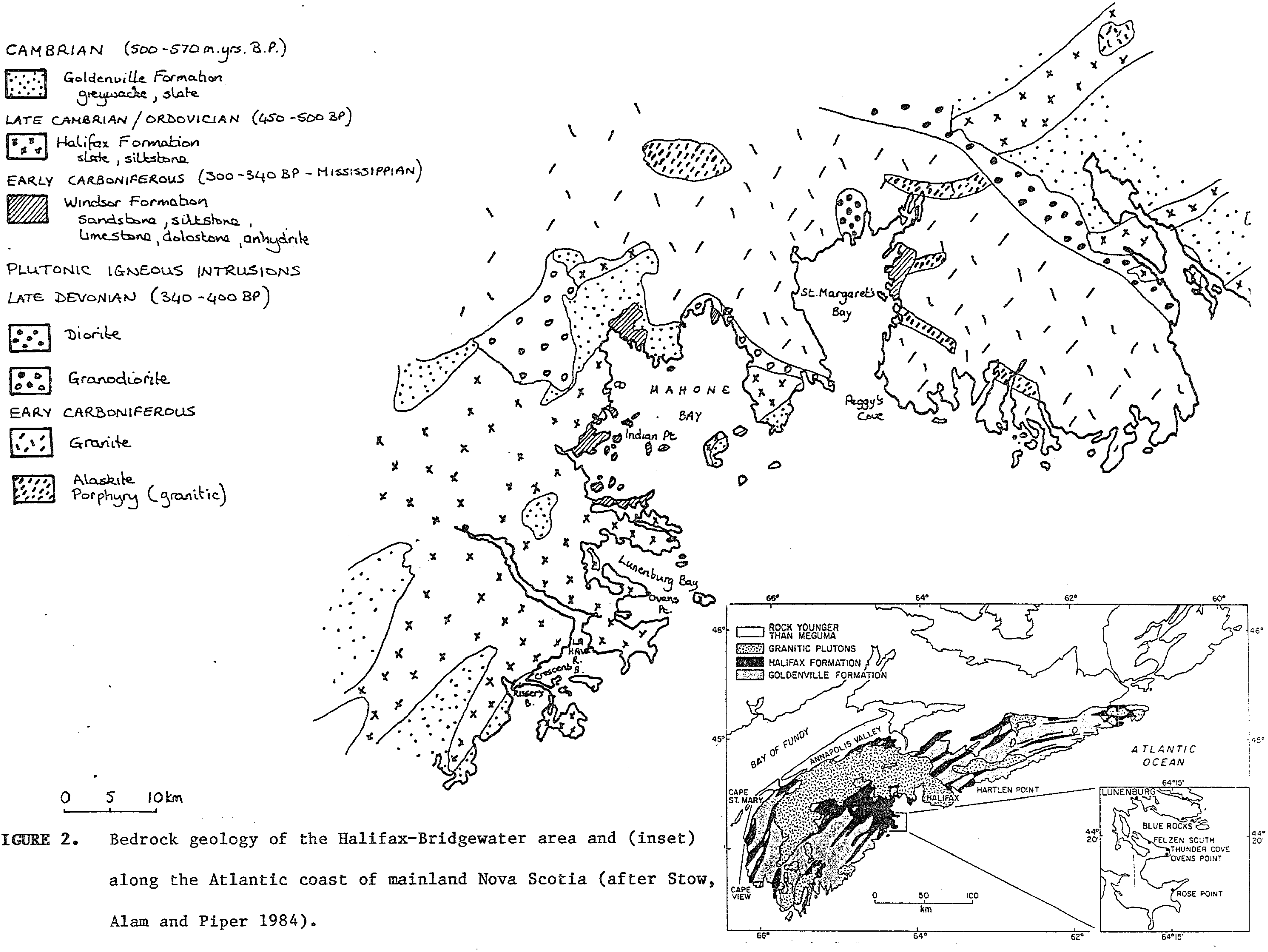


FIGURE 2. Bedrock geology of the Halifax-Bridgewater area and (inset) along the Atlantic coast of mainland Nova Scotia (after Stow, Alam and Piper 1984).

mafic intrusions (notably the Shelburne Dyke). A series of major, plunging anticlines and synclines has been mapped in the Meguma Group (Taylor, 1969), with a spacing of 1 to 10 km, but smaller scale folds and faults are difficult to map because of the lack of marker horizons. In some cases, however, the folds appear to have an *en echelon* pattern (Jones, 1975). Cameron (1956) and Fyson (1966) suggested that the prominent south-southeast geomorphic trend of much of the Atlantic coast is due to faults and associated fractures along that trend. Although few such faults have been identified by mapping on land, they have been mapped from magnetic anomaly patterns in Mahone and Lunenburg Bays. They appear to cut both Meguma and granite bedrock (Piper *et al.*, in press). Essentially the bedrock geology of the innermost part of the Scotian Shelf (Fig. 3) is a continuation of that observed on land.

2. Physiography and geomorphic evolution

The overall trend of the Atlantic coastline of Nova Scotia is west-southwest, approximately parallel to both the strike of the Meguma basement and the continental shelf break. Along the South Shore the coast is indented by a series of depressions trending normal to the coastline (south-southeast). From east to west the largest inlets are Halifax Inlet, St. Margaret's Bay, Mahone Bay, Lunenburg Bay, La Have estuary, and Green Bay (Fig. 1). These depressions commonly have overdeepened basins, and Halifax Inlet, St. Margaret's Bay and Mahone Bay have pronounced sills.

Coastal topography seldom exceeds 30 m and farther inland low rounded hills, occasional high knolls (<200 m) and broad shallow, poorly drained depressions characterize the landscape. The sharpest visual contract in the landscape is between the bare granitic rock surface near

Peggy's Cove and the low rolling, sediment rich terrain of the Lunenburg drumlin field.

The structural trend (west-southwest) of the Meguma rocks is reflected on land as ridges along the flanks of anticlines, e.g. Ovens and Rose Points, Lunenburg Bay. At sea, this trend is represented by a series of ridges and depressions which are well developed to the south of Lunenburg as far seaward as the 50 m isobath. Seaward of the 60 m isobath, bathymetry becomes irregular with few linear trends. There is a series of sinuous valleys 1 to 2 km wide and 20 to 50 m deep that are locally discontinuous and in places widen into flat-floored basins. Similar channels cross the sills at the entrance to St. Margaret's and Mahone bays, and are clearly seen in northeastern Mahone Bay and in Lunenburg Bay. In places they too are discontinuous. Offshore, isolated shoals rise above the plateau-like seafloor between the valleys.

Drumlins, are conspicuous features on land, particularly in the coastal area from Head of St. Margarets to the LaHave estuary where they form the famous Lunenburg drumlin field. At sea, they are well preserved only in sheltered waters of St. Margaret's and Mahone bays, where they are commonly flat topped. Extensive coastal shoals have developed offshore from areas where there are abundant drumlins on land, for example in Lunenburg Bay. Similar eroded till platforms are developed off drumlin islands and headlands.

The earliest stages of geomorphic evolution of the South Shore are uncertain. Goldthwait (1924) suggested that parts of Nova Scotia might represent an exhumed pre-Carboniferous surface. According to Barnes (1976), the very thin Carboniferous outliers in St. Margaret's and Mahone bays suggest that the present landscape is close to the sub-Carboniferous surface.

The principal first-order physiographic feature in the Maritime provinces is the tilted peneplain which descends from 600 m above sea level in northern Cape Breton to intersect with sea level along the Atlantic coast of Nova Scotia, producing the overall straight trend of the coastline (Goldthwait, 1924). This peneplain has been generally regarded as mid-Cretaceous in age (King, 1972) although Cooke (personal communication, 1980), by comparing offshore sediment thickness against post-peneplain erosion, has suggested that it is probably Miocene. Occasional outliers of Cretaceous clay in low-lying areas in central Nova Scotia suggest this peneplain originally had considerable relief.

Nova Scotia has probably experienced intermittent glaciation since at least the mid-Pleistocene. Minor glacial advances onto the South Shore area probably developed about a South Mountain ice cap (Grant, 1977) but more extensive glaciations saw a coalescing of Maritime centres and southward flow of ice across Nova Scotia from New Brunswick (Nielsen, 1976; Wightman and Cooke, 1978; Grant and King, 1984). Thus the South Shore must have experienced multiple glacial erosion events, but with only a few basic erosion patterns. The age of the glacial erosion features along the South Shore is thus unknown, but most of the erosion appears to be pre-Wisconsinan.

The most prominent glacial erosion features are the deep basins, trending normal to the coastline, e.g. Halifax Inlet. The deepest basins are almost all developed on granite (Fig. 3): northeast Mahone Bay, St. Margaret's Bay, and the Mouton Bay-Liverpool Bay area (where the edge of the batholith marks the coastline). However, granite also forms resistant peninsulas at Aspotogan and Peggy's Cove: in the former case the metamorphic aureole in Meguma rocks appears to be the most resistant lithology.

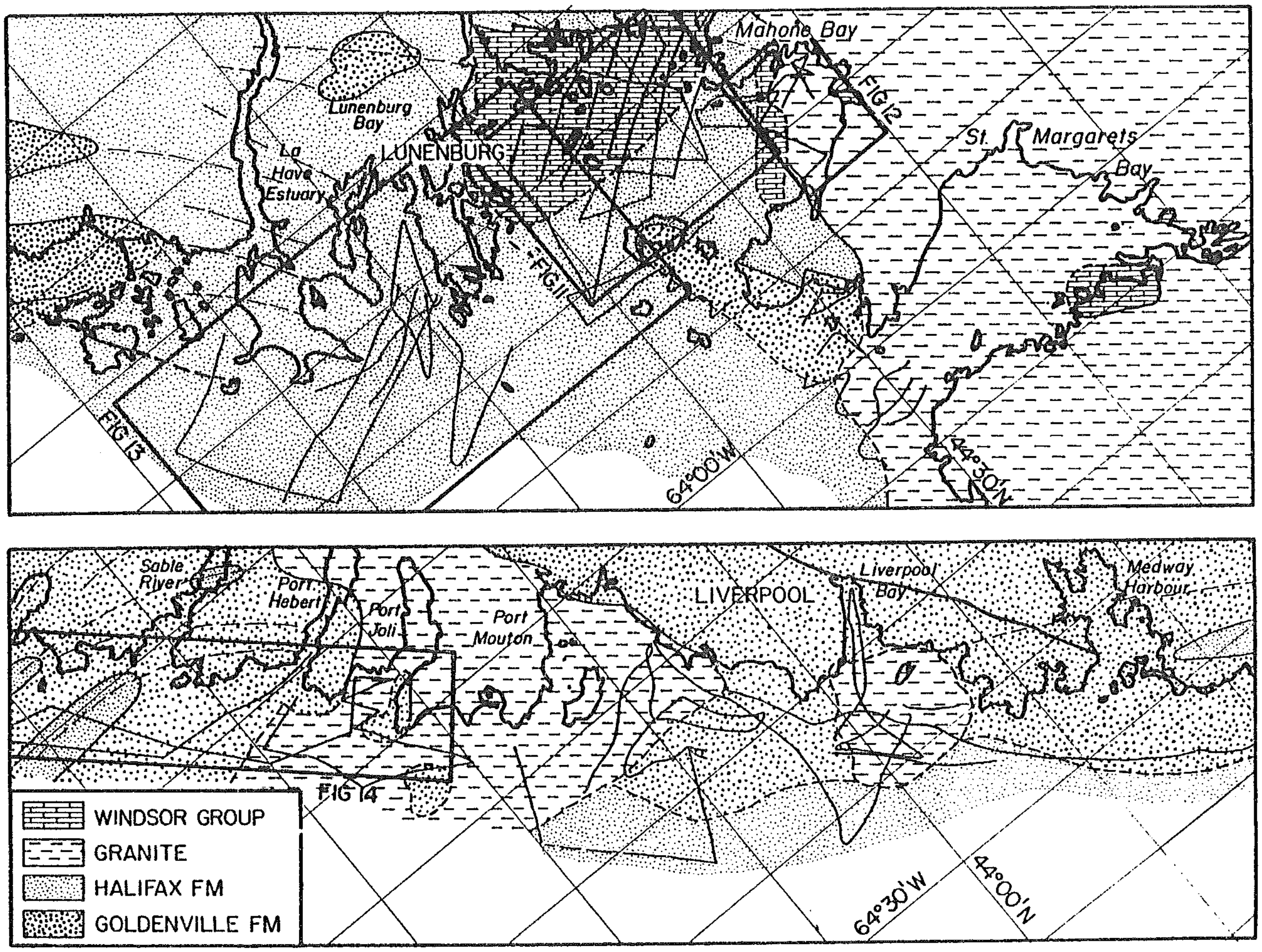


FIGURE 3. Bedrock geology of the coastal and inshore areas of the South Shore. Geologic boundaries offshore are based on magnetometer profiles (thin lines).

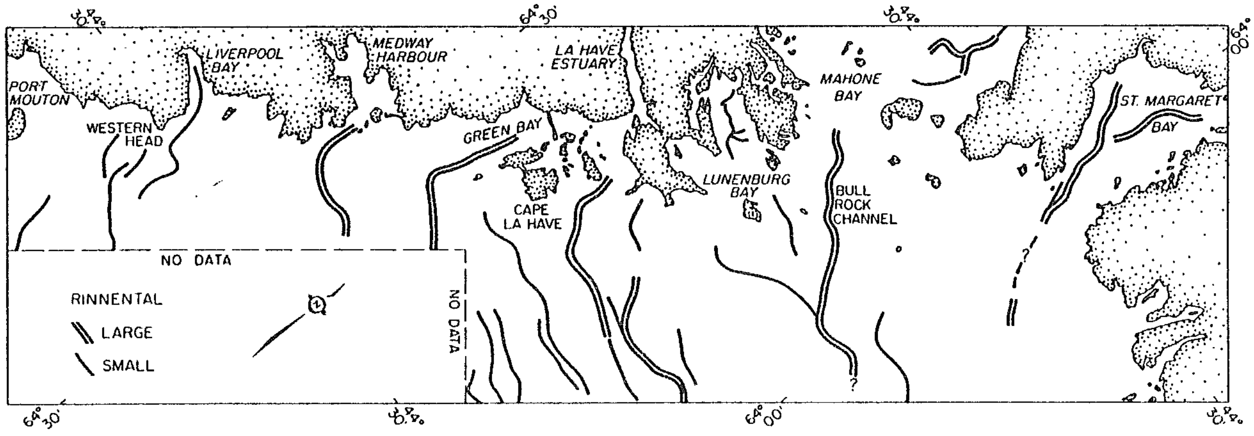


FIGURE 4. Distribution of steep sided, narrow channels interpreted as rinnentaler (after Piper et al., in press).

It is not clear whether a particular spacing or orientation of joints results in particularly favourable conditions for erosion However it appears that granite erosion is promoted by the widely spaced joint pattern.

Basin erosion is also pronounced in the area of the Lunenburg drumlin field, and may represent a major southward flowing ice stream confined on the west by North Mountain and Cape Blomidon (Grant, 1963).

The morphological evolution of the bedrock surface during the Pleistocene glaciations seems to be the result of two distinct processes, glacial quarrying and meltwater erosion, which were concentrated in preexisting major river valleys. Pleistocene fluvial valleys probably acted as conduits funnelling major ice flows. Quarrying and plucking by glacial ice excavated depressions where joint patterns were favourable, notably in some granite areas and on the north-dipping flanks of Meguma anticlines, particularly in lithologies that include some greywacke. The importance of this process in the geomorphic evolution of the Halifax area was described by Goldthwait (1924).

Steep sided sinuous channels with irregular talwegs (long profiles) cut both till and bedrock (Fig. 4) have been interpreted as rinnentaler that were cut by subglacial melt water (Piper et al., in press). In shallower water some of these channels may also have a subaerial history. They are too narrow and sinuous to be eroded by glacial ice, but their irregular 'up and down' talweg (Barnes and Piper, 1978) and discontinuous, anastomosing pattern suggest their origin is not solely fluvial.

Both basins and channels are found in regional depressions, which are probably related to pre-glacial drainage patterns. Glacial quarrying is most efficient in ice streams flowing through broad valleys (Flint, 1971) and subglacial meltwater will also be concentrated in these valleys.

In any glaciation extensive enough for ice to move southwards across the Minas Basin and South Mountain, stagnation would occur on the South Shore during the retreat phase as a result of marine incursion in the upper Bay of Fundy, thus setting up conditions for extensive sub-ice drainage. A complex history of valley cutting is probable inshore and farther offshore. Those channels that cut till must be younger than the last glacial advance in the area, but it is unlikely that all the glacial erosional features date from the late Wisconsinan. The depth of some of the channels, incised 40 m into bedrock (Fig. 5), required more time for erosion than would be expected during a single glacial retreat. Thus, at least some of the channels are older, and may have been repeatedly flushed and refilled by sediment during successive glaciations. The channels aided and accelerated the glacial quarrying process, while the larger depressions in which they occured concentrated sub-glacial melt water during deglaciation.

The principal modification of till offshore took place by wave erosion in the coastal zone during the late Wisconsinan sea level lowering to -120 m and the subsequent transgression. Probably 95% of the original till was eroded, leaving only a discontinuous veneer, except where till is preserved beneath younger sediments in depressions. Coarse fluvioglacial sediment is of morphological significance only within nearshore rinnentaler, many of which have thick gravel sequences.

Slowly rising sea level over the last 10 Ka has resulted in the overall form of the coastline being that of submergence, with drowned valleys and mid-bay barrier beaches. Silled basins that were formerly lakes have been invaded by the sea (Barnes and Piper, 1978). As sea level has risen, successively higher drumlins have been subjected to wave erosion

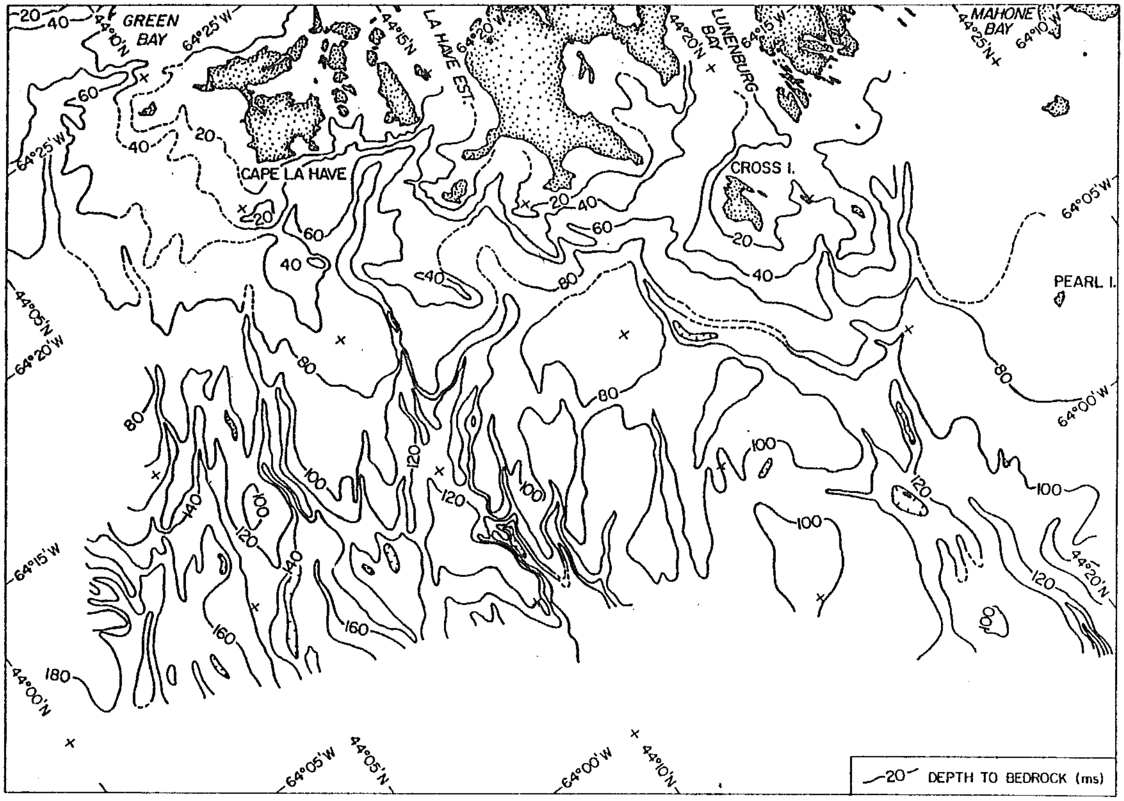
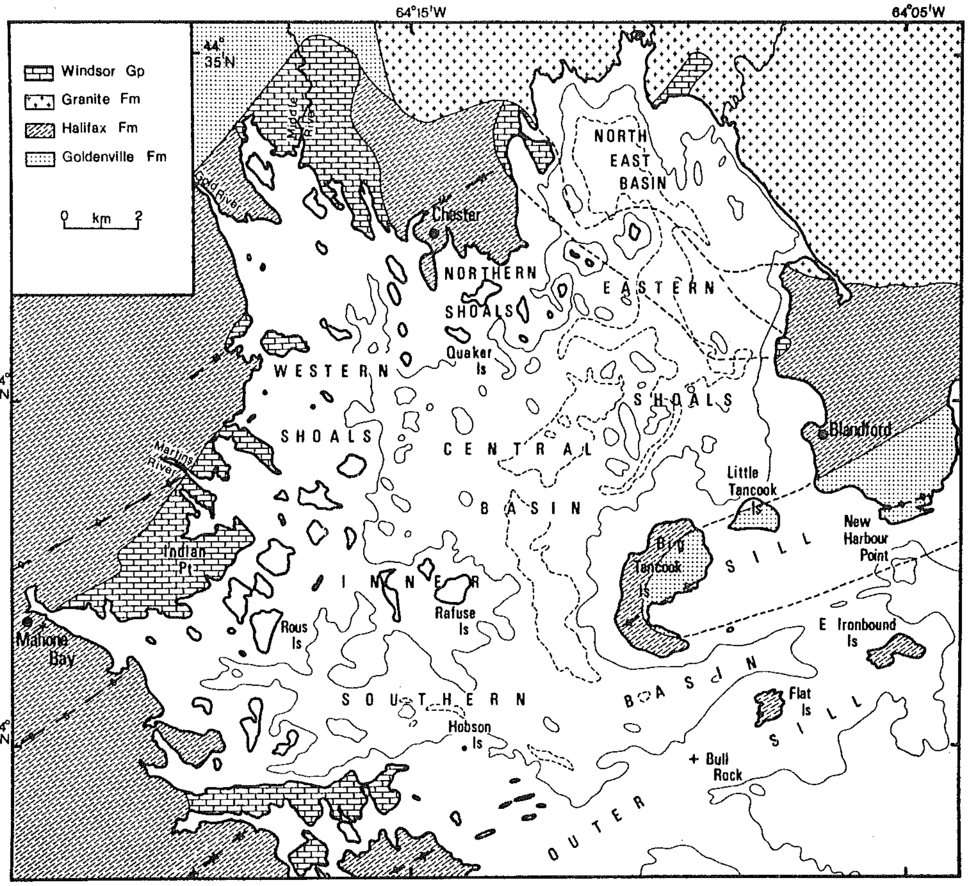


FIGURE 5. Depth to bedrock (milleseconds below present sealevel at 20 ms intervals) in the area south of LaHave Estuary - Mahone Bay.



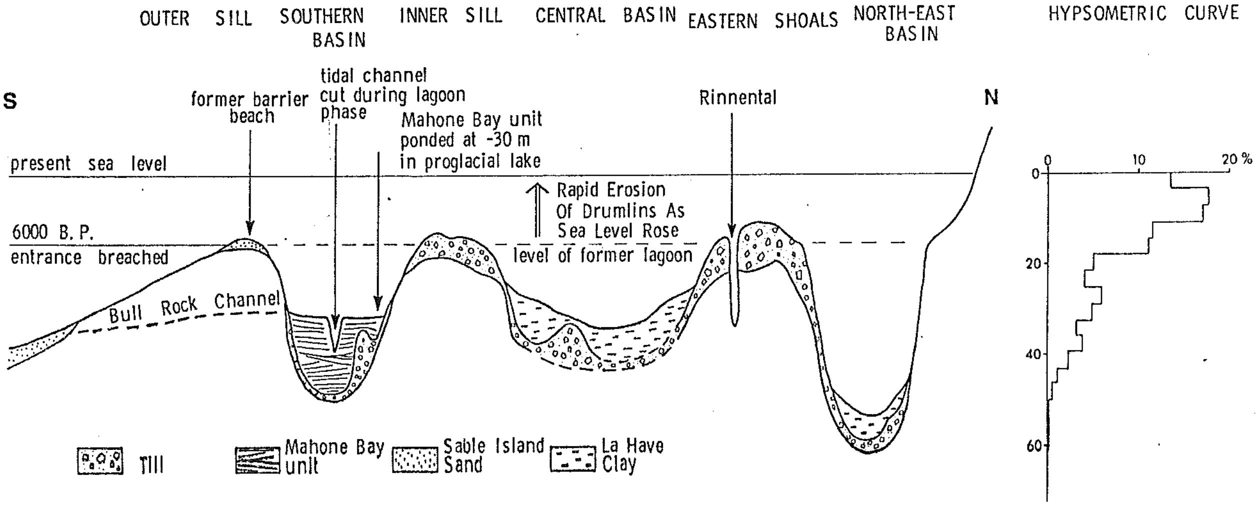


FIGURE 6. Schematic north-south cross-section illustrating distribution of stratigraphic units and development of physiography as sea level *rose*. Hypsometric diagram shows extent of different water depths (from Barnes and Piper, 1978).

leaving extensive lag shoals offshore and yielding a continual supply of sediment to the coastal zone.

The morphology of the sea floor controls the location and intensity of wave erosion as sea level rises. Mahone Bay has a shallow bedrock sill at -14 m that was breached by rising sea level about 4.5 Ka BP (Fig. 6), but only when the sea reached about -10 m was there sufficient exposure to open ocean waves for rapid erosion of till to take place. As a consequence, there is a widespread shallow terrace in Mahone Bay at 0-10 m water depth, which then drops off steeply until the ponded basin floor at around 29 m is reached. There is a similar effect in St. Margaret's Bay, where although the maximum sill depth is 58 m, the entrance to the bay would have been very narrow until the sea reached approximately -25 m. In contrast, Lunenburg Bay is not silled, and has no prominent terrace, except in 0-2 m water depth (the origin of which is unclear).

In addition, wave destruction of drumlins exposes drumlins farther landward to wave attack, especially as sea level rises to submerge the planed-off shoal (Fig. 7a). This is very clearly seen in Mahone Bay, where flat-topped till shoals record former positions of sea level at the time drumlin erosion took place (Fig. 7b). Small shoals in water depths of 17-19 m are common, and were probably planed off by a lake or lagoon at this level before marine incursion across the outer sill. In the exposed areas southeast of Rafuse Island, shoals lie in 7-15 m of water. The destruction of these drumlins led to erosion of drumlins at 3-6 m below present sea level around Rafuse Island, and the removal of this protection permitted the present rapid erosion around Rous Island.

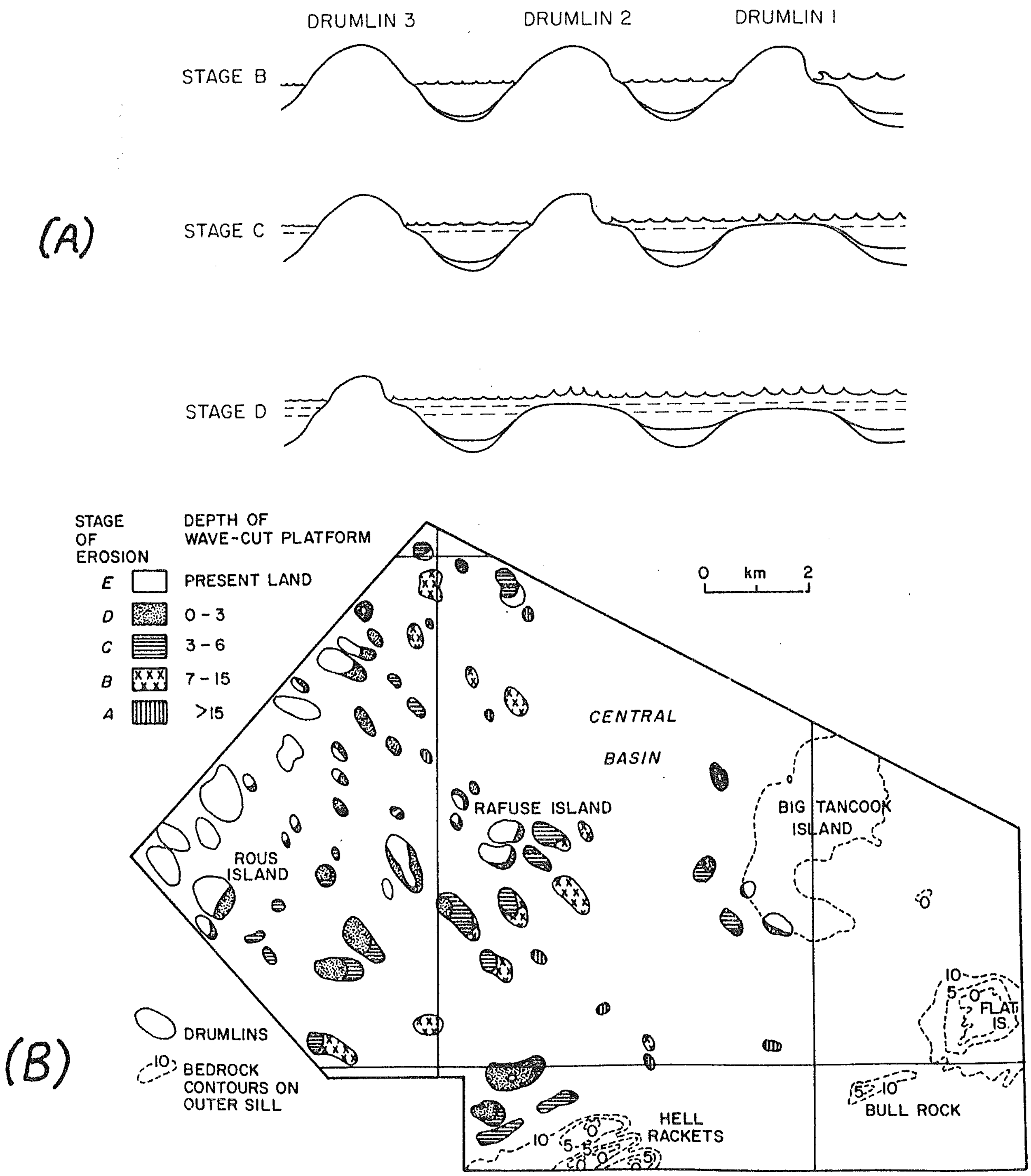


FIGURE 7. (A) The sequential erosion of drumlins with rising sealevel is illustrated. The stages correspond to those shown in (B) for the drumlins of southwest Mahone Bay. Stage A represents drumlins completely planed off at a depth of 18 to 19 m, prior to marine incursion; Stage B is erosion from the time of marine incursion to about 3 Ka BP; Stage C represents 3 Ka to 1.5 Ka BP and Stage D is erosion in the last 1.5 Ka.

3. Late Wisconsinan and Early Holocene Sedimentation

The timing and character of Wisconsinan ice advances in the Maritimes are not yet known with certainty. The stratigraphic record on land in Nova Scotia was summarized by Grant and King (1984) (Table 1). A widespread red till sheet overlies scattered organic beds ascribed to isotopic stage 5. This till sheet has a northerly provenance, including clasts from New Brunswick. It is overlain in places by a hybrid till, soils or organic beds some of which yield dates in the range of 32 to 39 Ka BP. Younger tills have local derivations from ice caps within the Atlantic Provinces (Grant and King, 1984). Post-glacial sediments suggest rapid deglaciation between 16 and 11 Ka BP (Prest and Grant, 1969).

The mid-Wisconsinan red till sheet represents a glacial advance that probably reached the edge of the Continental Shelf. As this ice retreated, it lifted off to form ice shelves over the deep basins on the Scotian Shelf. A line of moraines on the Scotian Shelf marks the grounding line of this mid-Wisconsinan ice shelf (King and Fader, 1985).

Quinlan and Beaumont (1981, 1982) have modelled glacio-isostatic sea level changes in the last 20 Ka in Atlantic Canada. Their model suggests that the classical late Wisconsinan (18 Ka BP) ice margin was close to the present coastline with a maximum sea level lowering of 50-60 m on the Scotian Shelf. King (1970) recognized a widespread terrace at -120 m on the Scotian Shelf, which appears to mark the lower limit of reworking of till and glaciomarine sediment, and which is interpreted as marking the maximum Wisconsinan lowered stand of sea level.

Thin and commonly coarse loose tills of apparently local derivation occur throughout the South Shore region, comprising granite or Meguma detritus (Nielsen, 1976). This till occurs locally as drumlins, as for

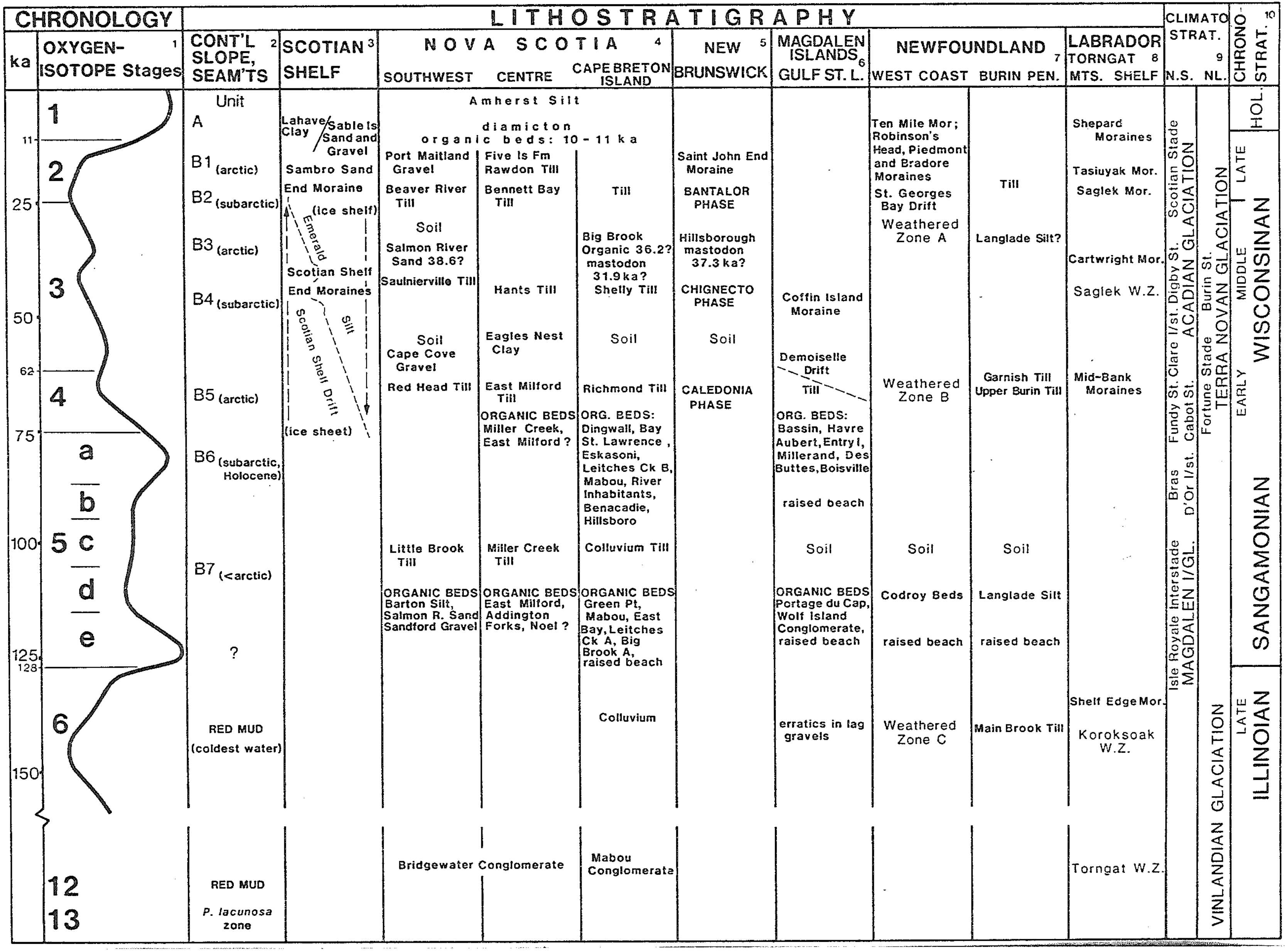


TABLE 1 Correlation chart of lithostratigraphic units in Atlantic Canada. (after Grant and King 1984).

example, in northern St. Margaret's Bay, or at Port Joli. The extensive Lunenburg drumlin field (Flint, 1971) lies between St. Margaret's Bay and La Have estuary. Most of the drumlins consist of a red till (Lawrencetown Till of Stea and Fowler, 1981) including a variety of far-travelled lithologies: including basalt from North Mountain, granites and metamorphic rocks from the Cobequid Hills, and Carboniferous and Triassic sediments from central Nova Scotia (Nielsen, 1976). This correlates with the widespread early to mid-Wisconsinan red till sheet elsewhere in Nova Scotia (Grant and King, 1984). Around La Have estuary (Fig. 8), a few of the drumlins comprise predominantly Meguma lithologies (Slate Till of Stea and Fowler, 1981).

A well consolidated grey till beneath some of the drumlins in the Lunenburg area (Nielsen, 1976, p. 37; Hartlen Till of Stea and Fowler, 1981) may be pre-late-Wisconsinan, as may also be the Bridgewater Conglomerate (MacNeill, 1972), but there are neither dates nor lithostratigraphic relationships to confirm this.

Stea (1982) studied the lithology, texture and geochemistry of tills in central Nova Scotia, north of the Lunenburg-Halifax region. He recognized five distinct till units: (1) Miller Creek Till (>52 Ka BP) deposited by flow across the Cobequid Highlands and equivalent to the widespread red till elsewhere in Nova Scotia; (2) East Milford Till (>38 Ka BP) deposited by ice from New Brunswick; (3) Hants Till, deposited by ice flow across the Cobequids in the Late Wisconsinan; (4) Bennet Bay Till, deposited by flow from North Mountain, Nova Scotia, in the Late Wisconsinan, prior to 14 Ka BP; and (5) Rawdon Till deposited by westward flowing ice, about 12 Ka BP. According to Stea (1982), the late Wisconsinan ice margin probably extended south of the present Nova Scotian coastline between about 38

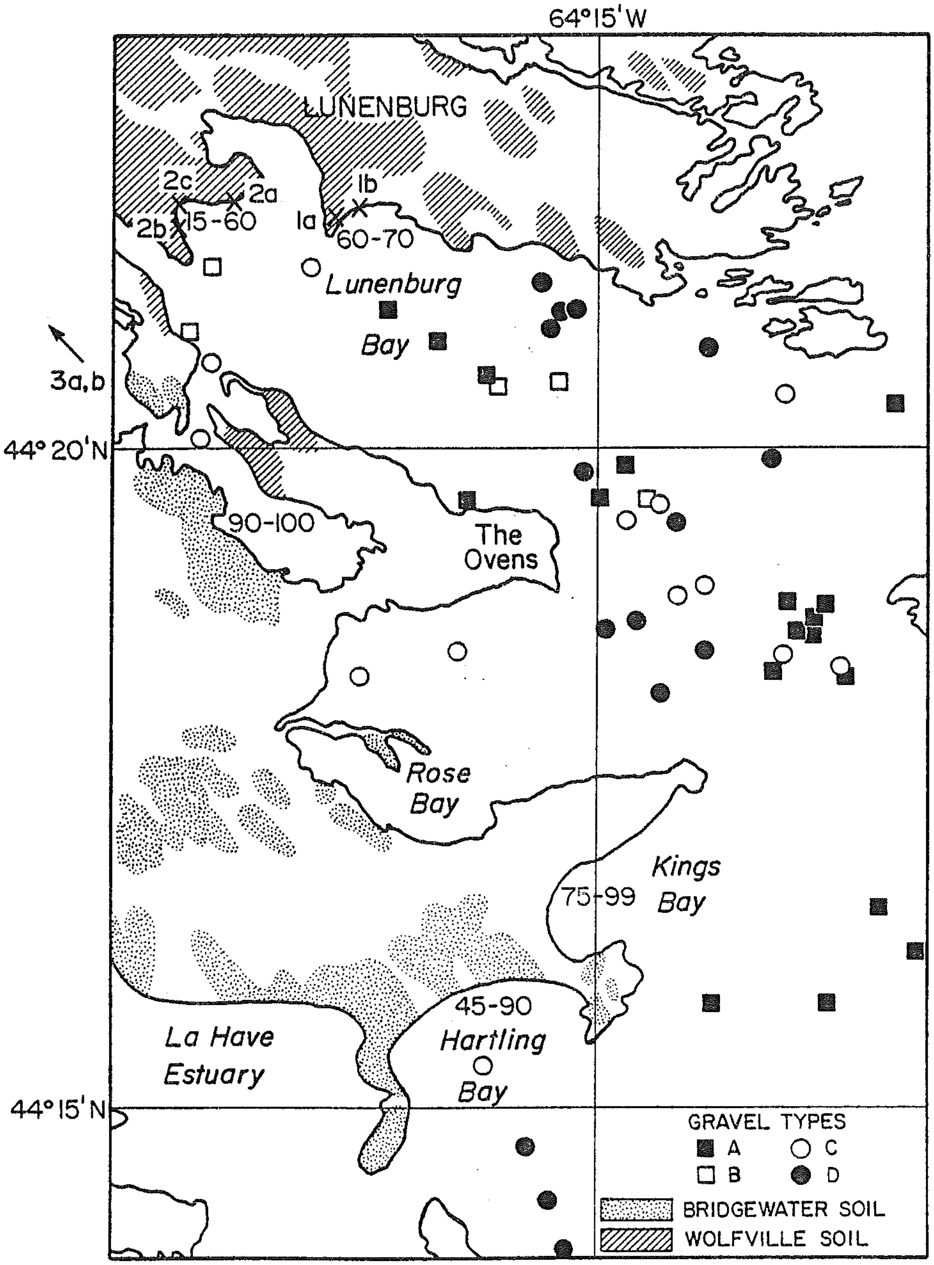


FIGURE 8. Petrology of gravel samples, Lunenburg Bay. A: slate only; B: slate and Meguma sandstone; C: slate, Megume sandstone, rare exotic clasts; D: principally exotic clasts. Soil types on land are Wolfville soil = red till drumlins (Lawrencetown till); Bridgewater soil = slaty drumlins. Numbers are percent Meguma lithologies in tills.

Ka and 25 Ka BP, with later ice flows being much more localized in extent (till units 4 and 5).

The glacial history of the inner shelf between Halifax and the LaHave estuary has been determined based on the interpretation of high resolution seismic reflection profiles and from piston cores. Environmental interpretations are based on sedimentology and the benthic foraminifera and dinoflagellate cyst assemblages in the cores; and the morphology of acoustic stratigraphic units. Age control is provided by radiocarbon dates and pollen assemblages.

Drumlinoid mid- or late Wisconsinan till is widespread on land in the Lunenburg drumlin field. A discontinuous till sheet, probably late Wisconsinan in age, can be traced about 5 km seaward of the outermost headlands ("late till"). Beyond this, acoustic profiles show a complex sedimentary sequence overlying an older, dissected, possibly mid-Wisconsinan, till that mantles bedrock ("early till"). The oldest sediment (unit a) overlying early till is acoustically transparent and is draped over the till surface (Fig. 9,10). Study of piston cores indicates that it comprises an upward-fining sequence of gravel through sand to laminated mud deposited in a proglacial environment. It is overlain by acoustically stratified sediment (unit b) that tends to fill depressions and may comprise outwash sands and gravels, which pass northwards into the late till. A major unconformity above these older sediments probably results from coastal planation following a late Wisconsinan lowering of sea level,to around -120 m. Above the unconformity acoustically stratified sediments (unit c) comprise gravels and sands passing upward into laminated muds. This unit was deposited in an ice-margin environment as late Wisconsinan

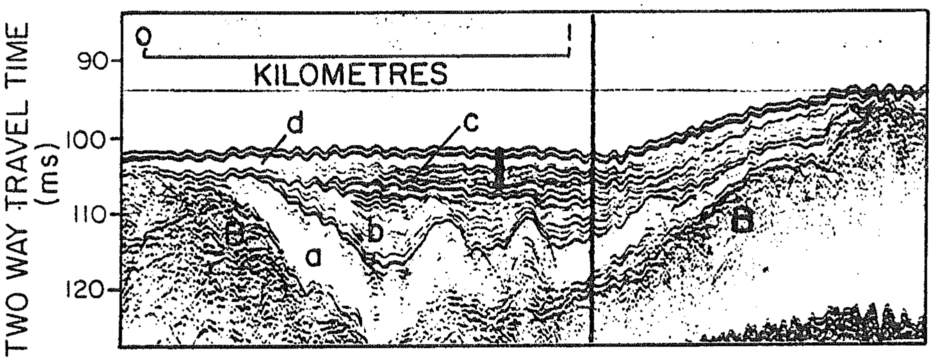


FIGURE 9. Seismic reflection profile from Bull Rock Channel, Mahone Bay showing bedrock (B) and acoustic units a, b, c and d.

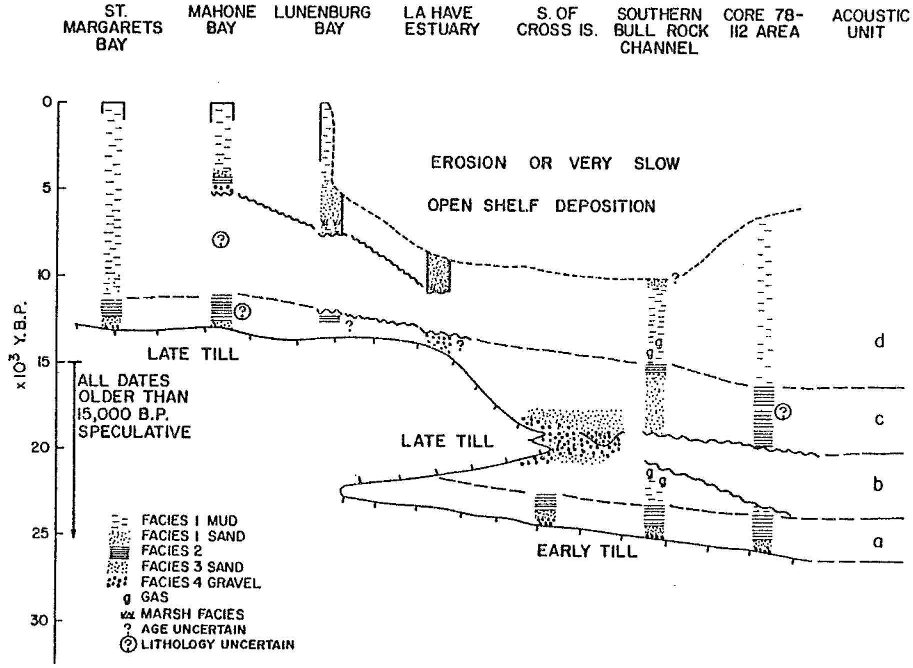


FIGURE 10. Schematic model of the distribution of acoustic stratigraphic units in the major bays of the South Shore and changes recorded with distance seaward (left to right on diagram); after Piper et al. (in press).

ice retreated and sea level rose. Holocene sands and muds have subsequently accumulated in basins.

Figure 10 summarizes the age and distribution of these late Quaternary sediments. The Holocene sands and muds correspond to the LaHave Clay and Sable Island sand and gravel described by King (1970). Foraminiferal assemblages in the cores indicate conditions either similar to or shallower than those at the present core surface. The base of the unit is diachronous, with approximate dates ranging from 4.5-5 Ka BP in Mahone Bay, 8 Ka BP in St. Margaret's Bay, 7 Ka BP in Lunenburg Bay, 11 Ka BP in the La Have estuary to more than 14 Ka BP in the basin south of Cross Island.

Acoustic unit c appears similar to parts of the Emerald Silt of King (1970). In nearshore areas the microfossils in facies 2 (Fig. 10) indicate accumulation in fluvially influenced estuarine environments and palynological samples imply a late glacial (13 Ka years) to early postglacial (10-12 Ka) age. In offshore areas, the inferred age is older than 14 Ka years, and microfossils suggest a "warm" ice margin marine environment. The lower parts of facies 2 indicate a high rate of sediment deposition and rather low organic productivity. The passage to facies 3 is gradational. Facies 3 is a marine deposit, probably from an ice-margin environment.

Acoustic unit b corresponds, where cored, to sands and gravels apparently lacking marine fossils. It underlies acoustic unit c, passes laterally into till and thins rapidly southwards. Whether it is a marine or terrestrial deposit, or both, is uncertain. It is more than 14 Ka old, but its precise age is unknown.

The late till extends only a short distance south of the present shoreline, between Cape La Have and Pearl Island, and interfingers with acoustic units b and c. It has not been recognized elsewhere. At its seaward limit, it is older than 14 Ka and is thus tentatively correlated with the classical late Wisconsinan ice advance.

Acoustic unit a forms a widespread drape over bedrock, till, and locally, stratified sediments. It is lithologically similar to acoustic units b and c, with facies 2 passing down into 3 and 4. Microfossils at the top of facies 2 suggest a "warm" ice-margin environment. There is no direct evidence of age of this unit, but it overlies the early till.

Early till extends seawards to the Pennant Point moraine as a discontinuous sheet, and it thus appears to be at least 26 Ka old (King and Fader, 1985).

4. Relative sea level changes

The Atlantic coast of Nova Scotia has experienced a variable rate of relative sea level rise of 1.5-7 mm/a over the last 7 Ka years (Grant, 1970; Scott, 1977; Scott and Medioli, 1978, 1982). Data from the St. Margaret's Bay - Green Bay area (Fig. 11) suggest a steady rise of sea level from -35 m, since 11 Ka BP. The earlier history of relative sea level is uncertain. The maximum late Wisconsinan sea level lowering on the Scotian Shelf corresponds to widespread terrace at -120 m on the Scotian Shelf, across which there are pronounced changes in sediment characteristics. Quinlan and Beaumont (1981) have modelled sea level changes due to glacial ice loading, and predicted the migration of a marginal bulge following ice retreat. They suggested that late Wisconsinan ice limits slightly seaward of Grant's (1977) 'minimum model' most closely fit geological data on Holocene relative sea level change throughout Atlantic Canada. They predicted that relative sea level has risen continuously on

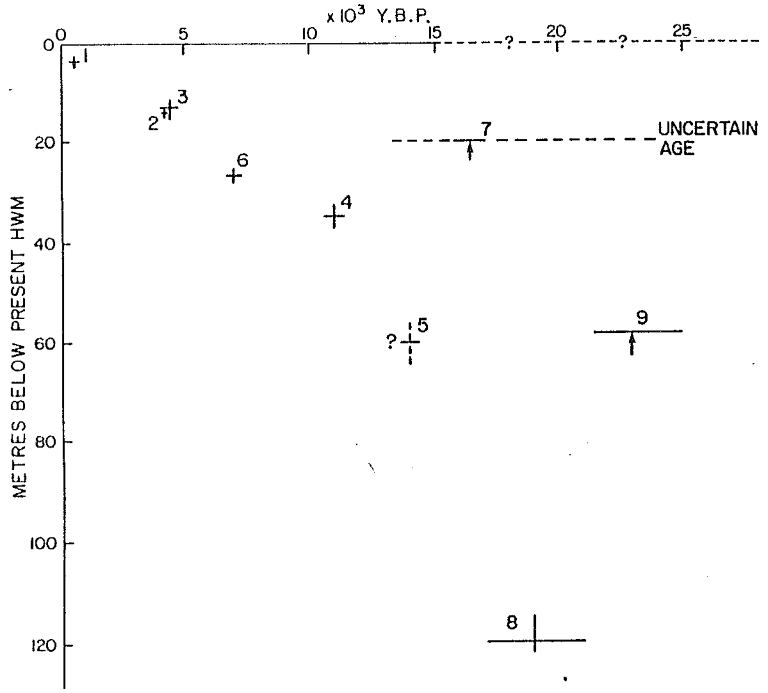


FIGURE 11. Relative sea level changes based on C^{14} dates from the South Shore. The time scale prior to 15 Ka is speculative.

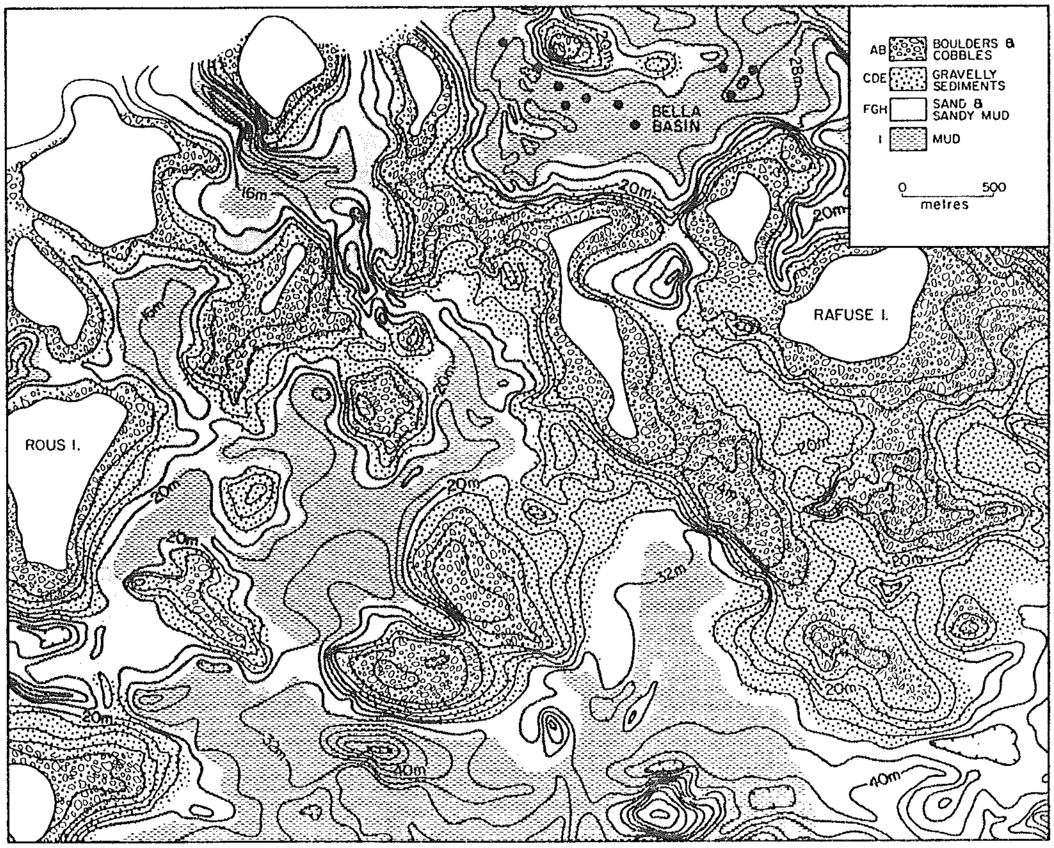


FIGURE 12. Physiography and facies distribution in Southwestern Mahone Bay (after Letson, 1981).

the outer shelf since a late Wisconsinan minimum, but that along the Atlantic coast of Nova Scotia there was a short period of falling relative sea level following deglaciation, succeeded by a continuous rise.

5. Surficial sediment distribution

Surficial sediment distribution has been mapped using acoustic profiles and bottom samples. Muds accumulate only in sheltered bays, e.g. Mahone Bay and St. Margaret's Bay and muddy gravelly sand occurs as a sediment veneer over till in the same bays (Fig. 12). Sands are found on beaches and shore faces, and in basins on the innermost part of the open shelf, with a rapid transition to sandy gravels or gravelly sands, offshore. This boundary is referred to as the 'sand line' (Piper *et al.*, in press).

Modal sand sizes increase seawards across the inner shelf from 3.5 phi nearshore to as coarse as 1 phi a few kilometres offshore. Except in enclosed bays, sand grain size distributions are negatively skewed, which suggests that fine sand and silt have been winnowed out. Sedimentary structures suggest that large amounts of sand are occasionally transported in suspension, presumably by storm currents.

Gravels seaward of the sand line are often very well sorted, in contrast to the gravels and sandy gravels at the edge of sand-filled basins landward of the sand line. The overall distribution of heavy minerals suggests that they are derived from nearby till and transported only short distances within the nearshore zone. Clay mineralogy also parallels source-till mineralogy, but is not sufficiently distinctive to permit monitoring of sediment dispersion.

6. Evolution of contemporary sediment

As a result of the work of Letson (1980) in Mahone Bay, the evolution of contemporary sediment is best understood in the sheltered bays with abundant drumlins. Here sediment is derived almost exclusively from reworking of eroded till. Cliffs are eroded most rapidly by storms during spring thaw. Wave erosion of till cliffs leads to the development of a wave-cut platform, veneered by boulders and cobbles, that serves to dissipate wave energy. Some sand is transported in the coastal zone to the sheltered lee sides of the islands. Under fairweather conditions both sand and mud accumulate near the outer edge of the platforms and on the upper basin margin (Fig. 13). In these basins, muds show a decrease in sand and coarse silt content away from the shallow margins. Storm resuspension of this sediment leads to very episodic deposition of laminated silts and muds from suspension fall-out in the basins. The storms also produce inverse graded beds on the platforms, and varying intensities of storm conditions lead to polymodal sediments on the platforms. In the case of Lunenburg Bay, the correlation of heavy mineral assemblages with nearby lag gravels suggests that most sand is only dispersed over short distances.

In more open bays sandy sediments predominate. The paucity of drumlin sources of sand, the seaward changes in modal size, and the evidence for dispersal of some heavy minerals (e.g. pyroxene at Port Mouton) all suggest substantial mobility of sand. Winnowing of very fine sand and silt occurs in all but the most sheltered bays. Yet the spatial heterogeneity of heavy mineral assemblages and their variation in a northeast-southwest direction suggest that the total distance of sand transport is small, and mostly restricted to onshore-offshore movement.

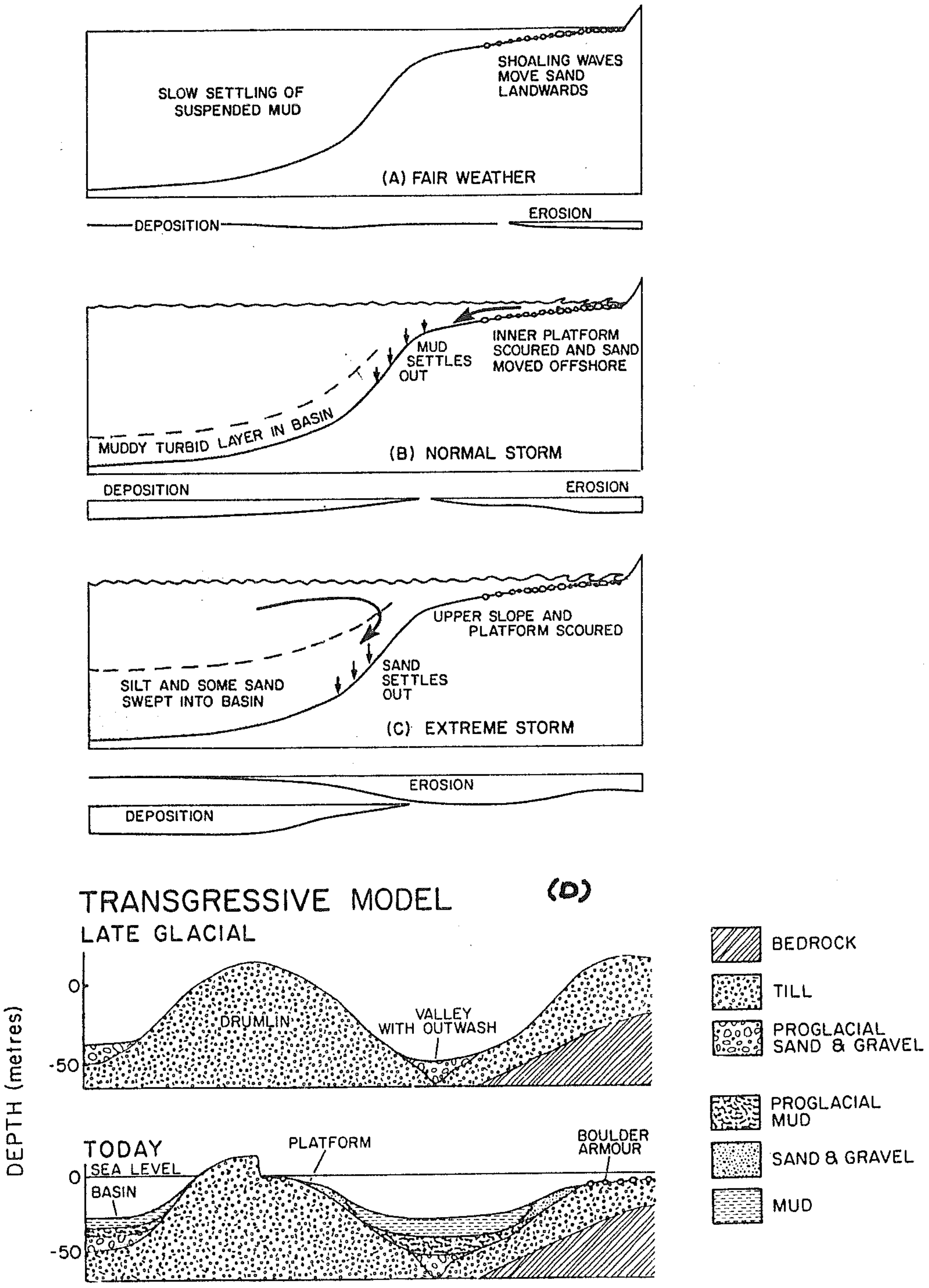


FIGURE 13. Process models for low-sediment, wave dominated fjords showing: (A) fairweather; (B) normal windy; (C) exceptional storm conditions and (D) a summary facies model for a transgressive setting such as the South shore of Nova Scotia (from Piper *et al.* 1983).

The seaward limit of sorted sands at the 'sand line' marks the transition from predominantly onshore-offshore sediment transport of the nearshore zone to the predominantly longshore transport of the inner shelf (Swift, 1976). The 'sand line' thus represents the seaward limit of the influence of islands and shoals in blocking major longshore movement of water. The abrupt coarsening of grain size suggests a sudden increase in shear stress seaward of the 'sand line', and heavy mineral distribution supports an easterly longshore transport of sand.

There is little evidence concerning the role of storms in these sandy and gravelly sediments. The landward fining of modal sand size suggests that dissipation of large storm waves in shoaling water has a greater influence on sediment distribution than the increasing influence of small waves as water depth decreases. Storm graded sand beds, tens of centimetres thick, suggest much greater sediment flux on the inner shelf than in the sheltered bays.

A Holocene sediment budget suggests that till cliff erosion is insufficient to account for observed nearshore sand; much of this sand must have moved shorewards with the Holocene transgression. Barrier beach history suggests this maybe accomplished either by catastrophic failure of beaches, and their subsequent re-establishment farther landwards or through the steady landward migration of barriers by washover processes.

The Coastline

The coastline of the South Shore has been systematically mapped by Munroe (1982) and selected beaches have been discussed in more detail by Bowen _et al._ (1975) and Taylor _et al._ (1985). These shores are storm-wave dominated and characterized by sharp seasonal contrasts in wind, wave and ice conditions. Storm waves, generated by cyclonic depressions passing northeastward across the region, have annual deep water significant wave heights in the 7- to 8- m range (Neu, 1982). The semi-diurnal spring tidal range increases from 2.1 to 2.5 m in a westward direction (Fig. 14). Seasonal ice duration is near zero along the outer coast but can last for several weeks to three months in the sheltered upper basins of the larger bays, depending on climatic conditions.

Along the South Shore, wave exposed bare granitic rock shores exist to the east of St. Margaret's Bay. Beaches are few and little material is added to the nearshore by wave erosion. Within St. Margaret's Bay and farther west, bedrock shores are less common and are primarily composed of Meguma rock. Unconsolidated shores make up an estimated 61% of the coastline, much of which is till cliff.

In sheltered areas the till cliffs are vegetated and appear stable, but in exposed areas are steep and are eroding rapidly. Cliff erosion takes place by a combination of marine and subaerial erosion. During storms, waves undercut the base of the cliffs. This process is probably very episodic. On the southwest coast of Nova Scotia, Grant (1976) recorded 10 m retreat during a single storm on a cliff that had otherwise appeared stable for many years. Subaerial erosion occurs through groundwater seepage and surface runoff which can lead to mass wasting and slumping. Surface runoff often leads to gully erosion of the cliff face. Freezing and ice wedging tend to shatter rock faces which leads to the buildup of talus at the base of the slope.

Cliff top erosion rates are variable alongshore. Rates of cliff erosion have been estimated from sequential cliff top positions from air photographs or ground surveys and long term monitoring of cliff retreat is

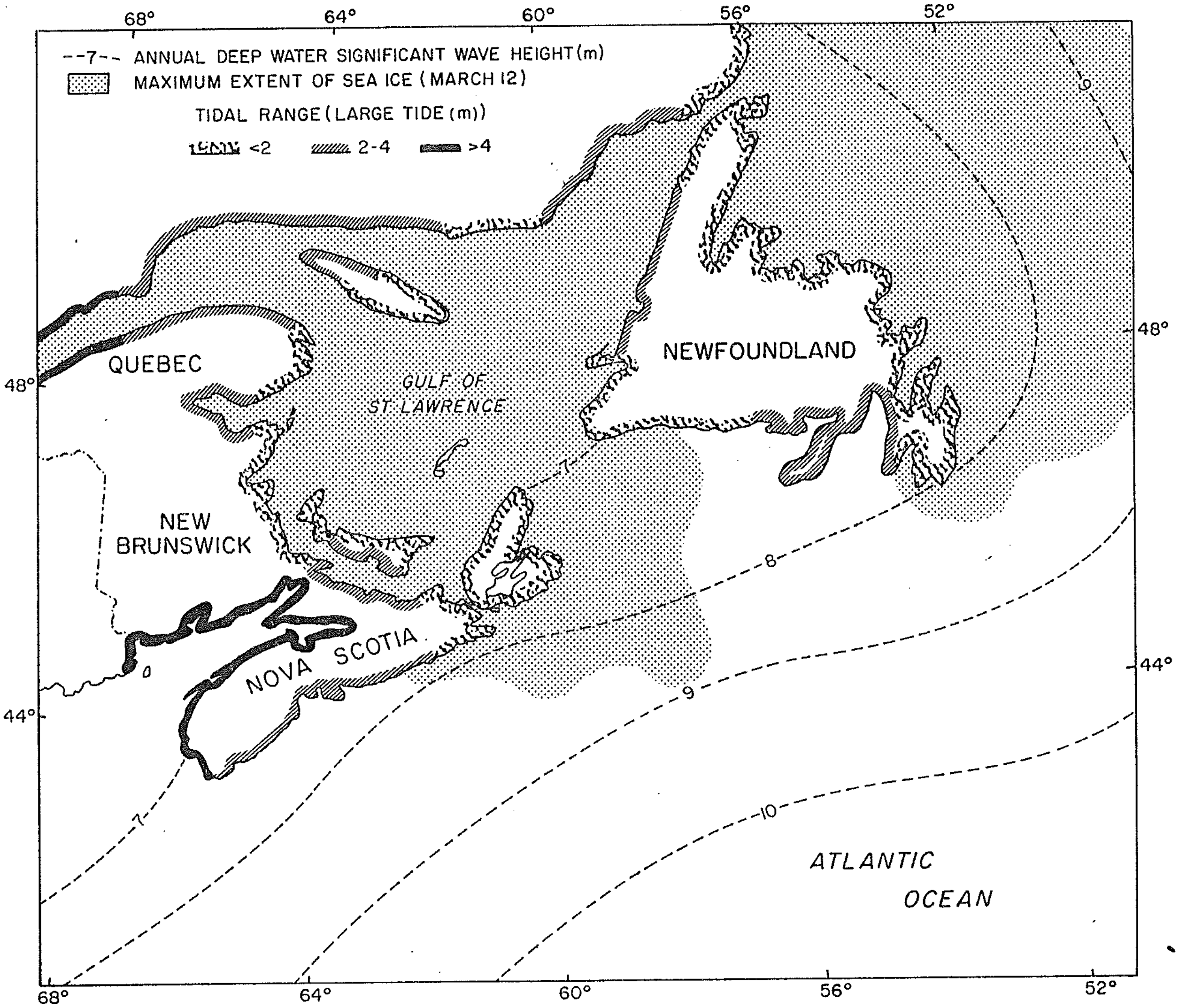


FIGURE 14. Range of coastal processes which affect the shores of Atlantic Canada including the South Shore of Nova Scotia.

continuing. Although not the sole determining factors, exposure and fetch are useful indicator of erosion rates. Cliffs retreat at rates of 1 to 3.3 m/a when they are fully exposed to the open sea (Taylor *et al.*, 1985), whereas cliffs exposed to fetch lengths of 2-5 km retreat at around 0.25 m/a (Urquhart, 1977). As till cliffs retreat, the wave cut platform widens and dissipates an increasing amount of wave energy, so that cliff retreat progressively slows. The cliff face becomes less steep as subaerial erosion predominates over marine erosion. Till cliffs with a bedrock footing retreat much less rapidly, and erosion is principally by subaerial processes.

On slowly eroding drumlin coasts in areas that freeze over in winter, boulders released from the till are concentrated in the intertidal zone by winter ice, to form a resistant boulder armour.

Beaches may be classed into three main types: shingle beaches; poorly sorted beaches fed by actively eroding drumlins; and sand beaches, with little or no active sediment supply, that are usually backed by low sand dunes. Many of the beaches enclose lagoons, and evidence of continuing sea level rise and coastal retreat is widespread. On these beaches occasional storms cause extensive washover, and tidal channels allow rapid lagoonal sedimentation, leading to the overall retreat of beaches. Only a few beaches show signs of short term progradation, e.g. Kingsburg, where sediment supply is greater.

Steep shingle beaches, backed by a rocky shore or lagoon, are common on the more exposed coastlines. Beaches with actively eroding drumlin sources are generally poorly sorted, with gravelly sand and boulders close to the drumlins, and medium or fine sand in a down drift direction. Such beaches are relatively uncommon and are found mostly east of Cape La Have.

Many of the large beach systems of the South Shore have little or no active supply of sediment from drumlins, and consist of fine to very fine sand with small quantities of local bedrock pebbles. They are often backed by dunes which are frequently eroded by wave washover or by the recreational activities of man.

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FIELD TRIP

ROUTE LOG

Vans depart Dartmouth-Halifax at 08:30. Travel along highway 103 until exit 12 to the town of Bridgewater. Drive south along the west bank of the LaHavre estuary to Crescent (STOP 1) and Risser´s (STOP 2) beaches. These stops emphasize differences in coastal management practices along the South Shore. Retrace route to the village of West LaHavre and cross the estuary by ferry at 12:00. Follow highway 332 south through Riverport to the village of Kingsburg and Hirtles beach (STOP 3), Hartling Bay. This site illustrates some of the effects of glacial deposition on coastal planform and beach sediment. Travel north along highway 332 to the Ovens Park (STOP4-a Geologic and scenic view point), through the Lunenburg drumlin field and on to Lunenburg via Corkams Island.(LUNCH) STOP 5 at the Mug-Up restaurent and a visit to the Houston North Gallery in Lunenburg. The town will be viewed on foot and by van. Leaving Lunenburg drive northward along 324 to Mahone Bay which offers a scenic view. From here drive along highway 3 to the Gold River (possible STOP at a recent cut in Quartzite till) and then back onto the main highway at the Chester exit. Between Hwy 3 and 103 there is a good view of Mahone Bay (stop 6). To make up time the route follows Highway 103 instead of Hwy 3 which is recommended to anyone who returns to the South Shore. At exit 5 we travel south along 333 and the eastern shore of St. Margaret´s Bay to Peggy´s Cove (STOP 7 a scenic view) for sunset about 16:30 hrs.. Following a walk around the village and the glacial sculptured terrain, return to Halifax-Dartmouth via highway 333 by 18:30.

ROUTE AND STOP DESCRIPTIONS

1. As we travel from the Bedford Institute of Oceanography (BIO) toward the outskirts of Halifax you will notice a change in the bedrock from the thick-bedded sandstones of the Goldenville Formation (at BIO), to the metamorphosed rusty brown slates of the Halifax Formation (in Halifax). Both are Cambrian to Ordivician in age and are of the Meguma Group. Just beyond Halifax on Hwy.103 Devonian age granites outcrop. They were intruded following the Acadian Orogeny. The only deposits of a younger age within the city limits are Pleistocene glacial deposits eg. drumlins of Citadel Hill and George´s Island. There are also small exposures of Bridgewater conglomerate (refer to Geological Hwy. Map). It is an iron-cemented,non-stratified to poorly stratified deposit composed of angular fragments of the Meguma bedrock. Bridgewater conglomerate has been suggested to be a breccia, a till and a gravel of pre-glacial, Early Pleistocene and Late Wisconsinan age. Better exposures of the conglomerate are found in the Bridgewater-Lunenburg area.

2. A brief stop at a high point along Hwy 103 provides an excellent view of the head of St. Margaret´s Bay, one of the largest indentations along this portion of the Nova Scotian coast.

3. From here until just east of exit 8 (Chester turnoff),Hwy 103 the surficial deposits are mainly GRANITE TILL (a greyish-orange to yellowish-brown with granitic cobble clasts). Pockets of ABLATION TILL (bouldery deposits with sand matrix) are also mapped by Stea and Fowler,1981. Near Chester glacial striae suggest a NW - SE movement of glacial ice.

4. Between Hwy exit 8 and 9 Meguma rocks ie.Goldenville Quartzites, outcrop to the north of the road and a thin bed of Carboniferous limestone lies to the south and adjacent to Mahone Bay. Surficial sediments are composed of QUARTZITE TILL (bluish-grey, containing greywacke, gneiss and quartzite clasts). A large deposit of ABLATION TILL exists along Middle River but is better viewed when we return along Hwy 3 later in the day.

5. From just west of the Gold River, and along the western side of Mahone Bay to LaHavre estuary the underlying bedrock is Halifax Formation slates.

6. Bridgewater (pop. 6669) founded in 1812, it has continued to be a lumbering and manufacturing town. Situated at the head of the LaHavre estuary, water depths of 19-23m. allow the passage of vessels from the sea to the wharf at the south end of town. The long sinuous channel in the LaHavre estuary has been interpreted as rinnentaler (Piper et al. in press).

7. Slight detour at West LaHavre to enjoy the scenery along the river. Note also the historic site of Fort Sainte Marie-de Grace,first visited in 1604 by DeMonts and the fort was built in 1632--one of the oldest European settlements in Nova Scotia. Dublin Shore is also very picturesque.

STOP 1 and 2 Crescent and Risser´s Beaches - see notes on the next page.

STOP 1 and 2

Coastal Management in Nova Scotia - good and bad examples from the South Shore : Risser's Beach and Crescent Beach, Lunenburg County.

Introduction

The management of Nova Scotia's beaches has become an increasingly important problem over the past fifteen years. Traditionally, beaches in the province have been used as important sources of sand and gravel for the construction of everything from airport runways to residential driveways. Some beaches have been literally wiped out by this practice, but fortunately provincial legislation during the 1970s has effectively controlled the mining of beaches. However, new pressures have developed and as tourism and other recreation pressures increase from year to year, damage to the fragile environments of beaches and dune systems is reaching critical levels in many locations. Three categories of beaches can be identified: 1. provincial parks; 2. protected beaches; 3. undesignated beaches.

Nova Scotia does not have any comprehensive approach to coastal management per se but there are two distinct ways by which the province can enter the management process. Under the Beaches Preservation and Protection Act of 1975 sand and gravel removal is prohibited unless specifically authorised by the Minister of Lands and Forests. The Act applies to all beaches below the mean high water level, but a wider area can be included if a beach is designated as a 'protected beach'. In addition, certain activities likely to cause damage to the beach, such as driving over it or removing vegetation, are restricted. However, the Act is specifically orientated towards the problem of beach mining and is not designed to deal with other management issues such as the natural erosion of beaches and dunes.

The only other mechanism by which beaches and can be managed under provincial control is if they are designated as Provincial Parks. When so designated, the area concerned becomes subject to management by the Parks Department under the Department of Lands and Forests. Given the coastal orientation of tourism in the province, concern for the specific problems of coastal parks has become of increasing interest to park managers and some progressive management techniques are currently being employed. Apart from these two mechanisms, it is possible for the province to become involved when provincial property, say a road, becomes threatened by coast erosion. In such cases, responses are piecemeal to say the least.

We shall visit two beaches in Lunenburg County which display contrasting aspects of beach management in Nova Scotia. Both beaches are located within Green Bay (Figure 1-1 and are actually within sight of each other. They have been subjected to a constant rise in sea-level, which has been measured in the vicinity of 3 mm per year over the last 50 years or more (Figure 1-2 Consequently, there is a tendency for these beaches to retreat unless the supply of sediment is sufficient to offset higher water levels. Crescent Beach comes under the third category of beaches that is undesignated and subject to ad hoc problem solving techniques. Risser's Beach on the other hand is both a protected beach and a provincial park, and has been the location of some of the most innovative approaches to erosion control and dune management yet undertaken.

Crescent Beach

As shown in Figure 1-1 Crescent Beach is a swash-aligned tombolo beach linking George Island to the mainland of Nova Scotia, and forms the head of Green Bay. It has been the subject of number

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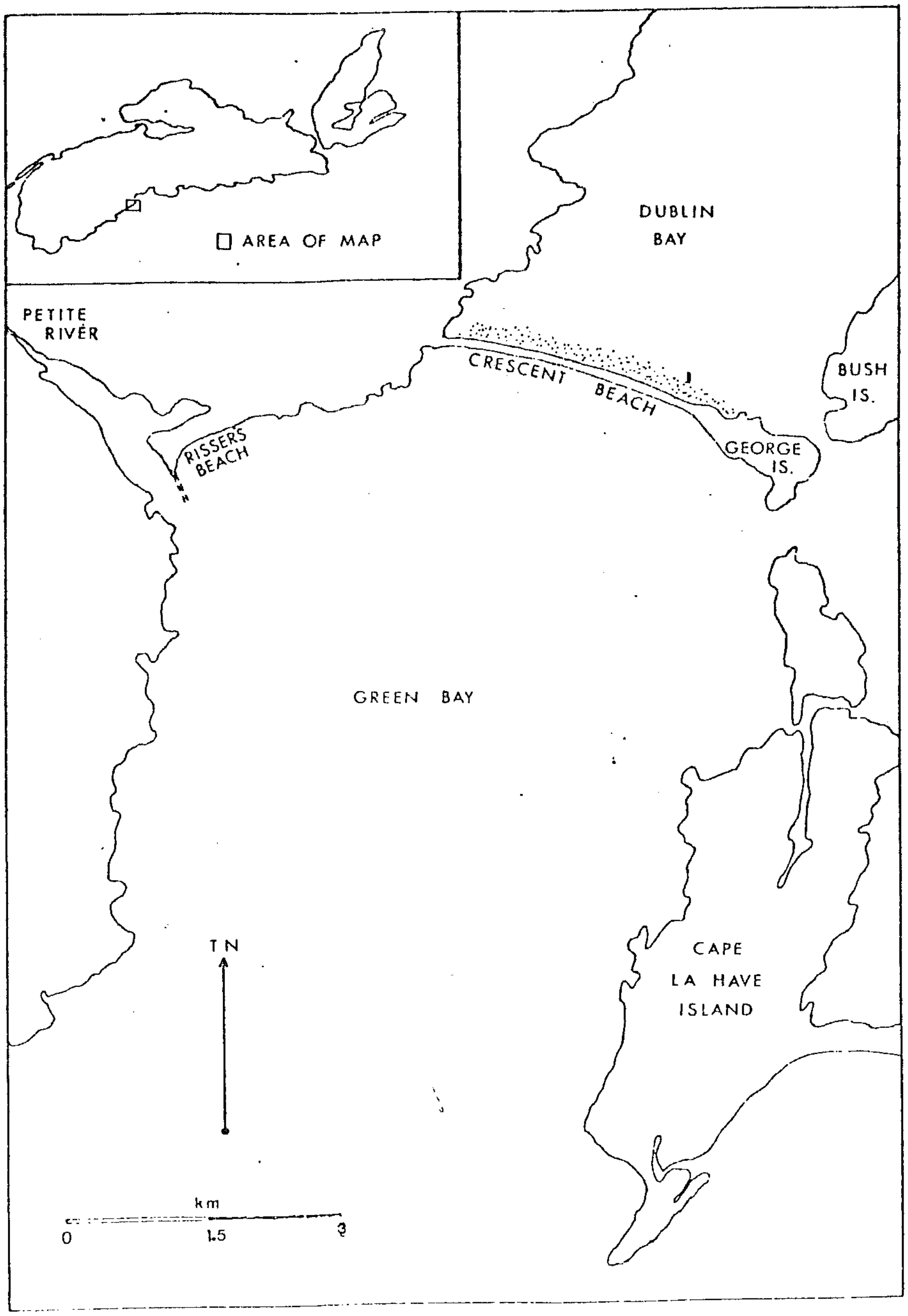

FIGURE : 1-1 CRESCENT BEACH AND RISSER'S BEACH

(from Wittmann, 1982)

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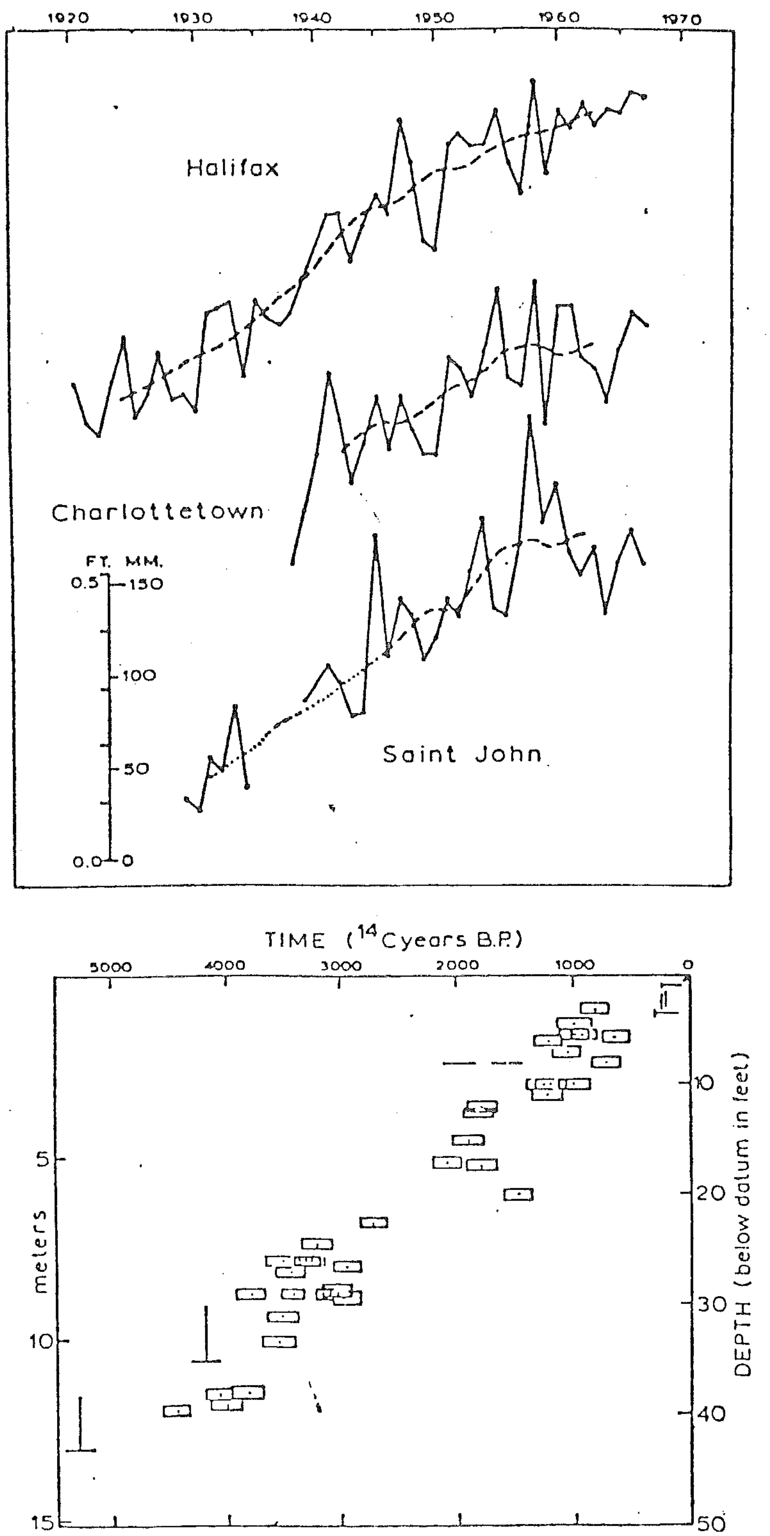

Figure 1-2. Evidence of recent sea level rise in the Maritime Provinces (after Grant, 1975).
(above) Trend of rising sea level illustrated by tidal records (dashed line is 10-yr. moving mean).
(below) Time-depth plot of presently submerged features, formerly at or below highest tide level.

of recent studies (Bowen et al., 1975; Wittmann, 1982) which show that the beach has been undergoing significant recession and degradation. High silica content and the lack of weaker fragments in the beach sediments suggest that the beach is receiving little in the way of new sediments from locally eroding drumlins. Sediment movement is predominately onshore/offshore, with material being re-cycled between the beach and Green Bay. With no new input the tombolo must retreat in order to survive. However, the construction of an asphalt road has fixed the tombolo in one position, and as a result erosion has replaced retreat. Figure 1-3 depicts the changes that have occured between 1955 and 1976, with the most notable changes affecting the dunes and salt marsh. Bowen et al. state that at the turn of the century the dune system ran along the entire length of the tombolo and an extensive salt marsh separated the dunes from the tidal flats to the north. Before the construction of the road, Crescent Beach was used as a vehicle link between the island and the mainland. It was, therefore, a vital communications link for the islanders. In 1905, a breach resulting from a storm was quickly repaired by local residents. Whole spruce trees were dumped into the breach in order to allow the dunes to rebuild around them and also to reduce wind loss of sand into the salt marsh. By 1920 the dunes had completely recovered. Then, during the mid-20s, a severe fire destroyed much of the dune vegetation and part of the salt marsh. Roots were so badly damaged that the dunes have never recovered. Increased wind erosion of the dunes caused sand accumulation to smother the burned salt marsh, and this too has never recovered to its pre-fire state. A series of breaches during the 30s and 40s resulted in piecemeal efforts to protect the dunes. Rip-rap was placed into breaches and in 1938 the first of a series of wooden retaining walls were constructed. The eastern end failed during the late 1940s and even old car bodies were used to try and stop the breaching.

In 1951, the provincial government took over Crescent Beach and the Department of Highways constructed the present road in 1956/7. Continued erosion of the beach and dunes has caused the department to use rip-rap to protect the road and in 1972 the latest of the wooden revetments was built as part of a labour intensive, job creation programme. However, tradition dies hard and the placing of boulders to block vehicle access to the beach was met with such a public outcry in 1970 that the Highways Department had to remove them. Currently, ad hoc attempts to protect the beach and dune system are failing because of inappropriate design and concern by the Highways Department for protecting its road rather than the tombolo.

Risser's Beach

In contrast to Crescent Beach, Risser's is not a natural feature but rather a spit which has built up behind a solid groyne that was constructed in the early 1900s (Figure 1-4)Located at the entrance of the Petite Riviere estuary, the groyne was constructed to aid shipping by fixing the location of the navigable channel and by preventing bay-mouth bars from developing across the river mouth. Thus, sediment starvation has never been a problem at Risser's Beach but rather too much sediment. Natural longshore drifting of older sediments and recently eroded local sediments caused the once shifting bars to build up behind the groyne into a more permanent bay-mouth spit. The spit formed into a relatively stable beach arc backed up by a dune system colonised by grasses, shrubs and trees. The development of a healthy, sandy beach attracted more and more people to use Risser's for recreation, and increasing demands upon the beach and dune systems began to take their toll upon the fragile ecosystems. As the importance of shipping in the Petite Riviere declined over the years, the groyne fell into disrepair and increasing amounts of sediment migrated into the river channel and were lost from the beach. In addition to the depleting supply of sediment remaining on the beach, visitor use of the area increased substantially when Risser's was developed as a provincial park in 1973. Particularly vulnerable were the beach and dune grasses. In some places, the vegetation was completely removed by trampling, and paths cut into the dunes soon began to erode by wind deflation.

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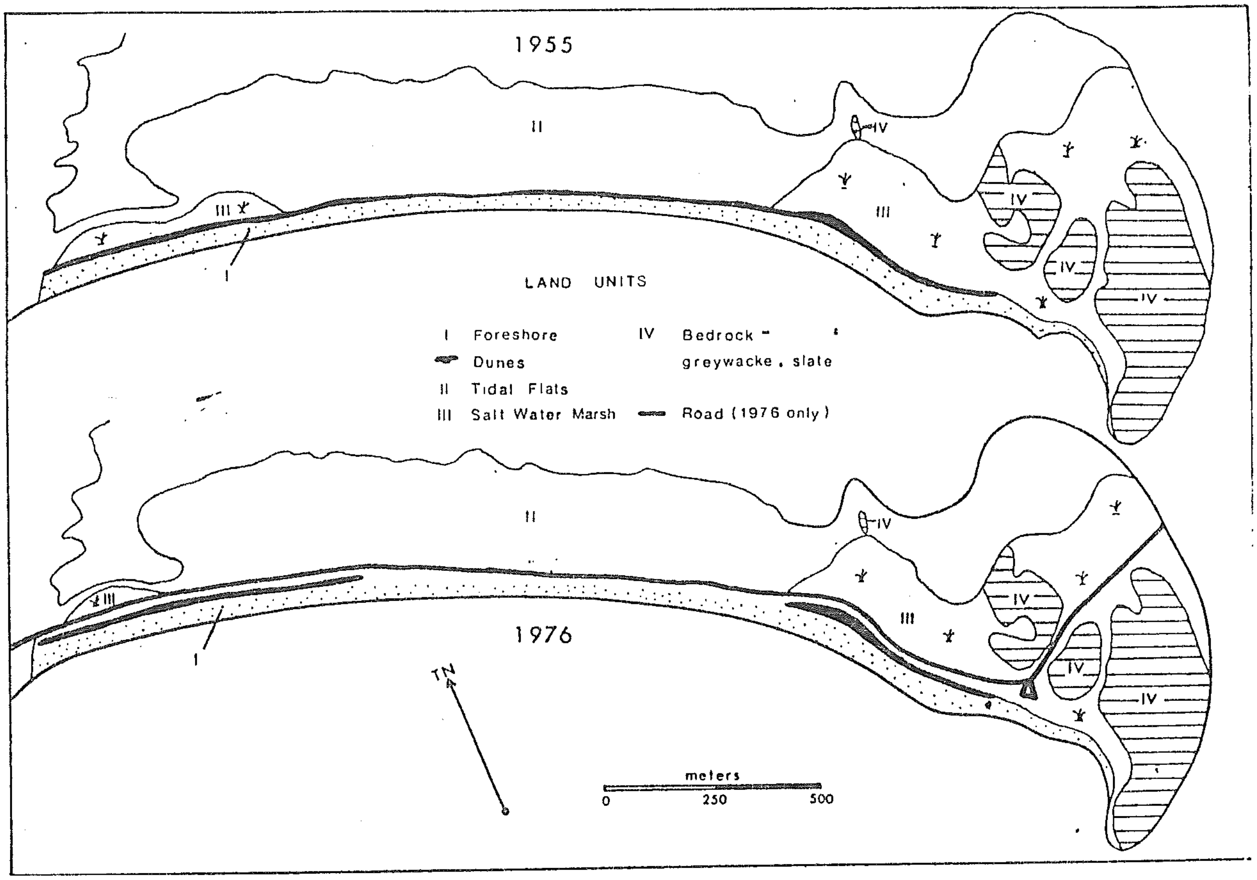
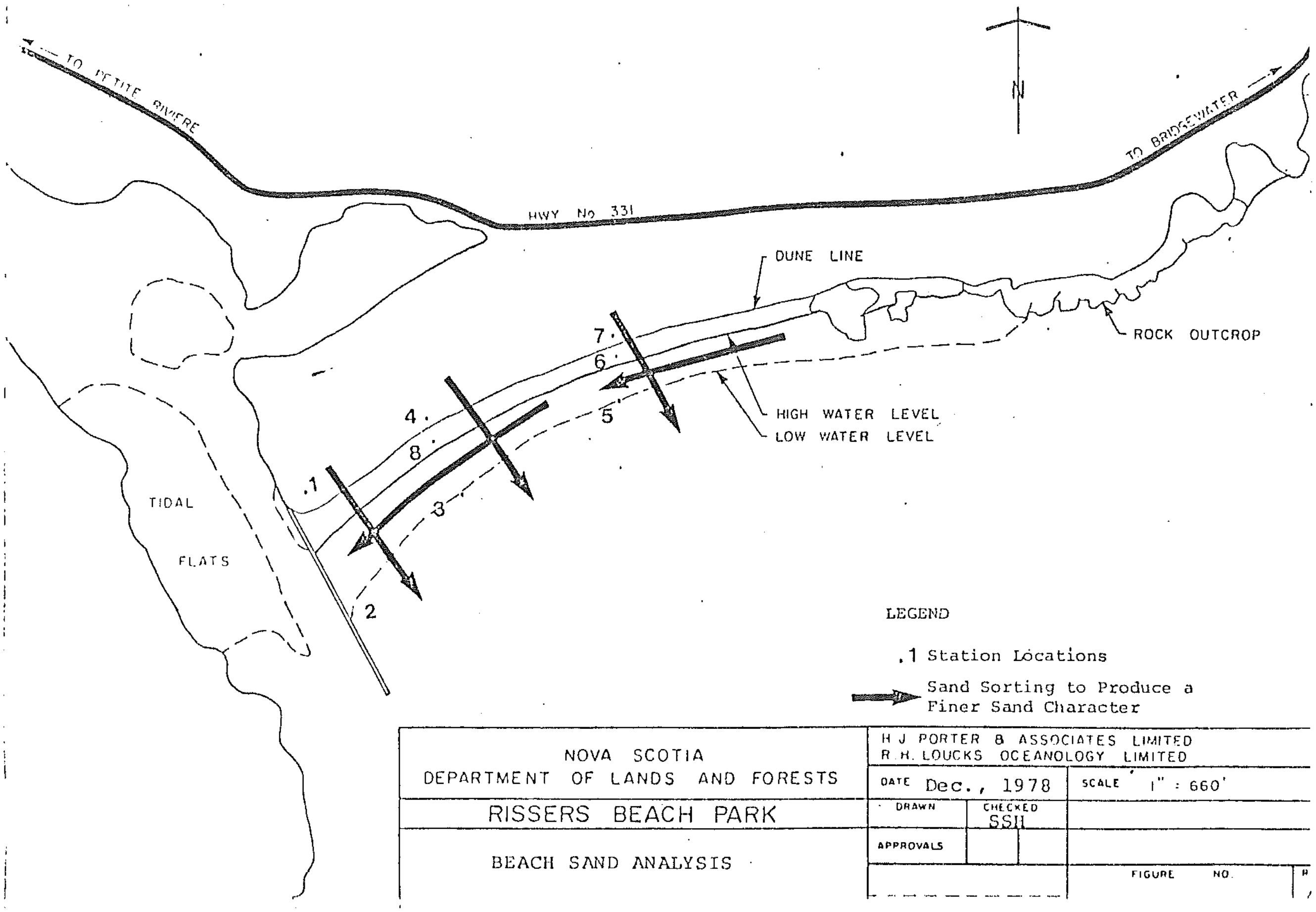


Figure 1-3. Comparative land-unit maps for 1955 and 1976 for Rissers Beach (after Wittmann, 1982).

Figure 1-4. Location of shoreline groyne and direction of sediment transport at Rissers Beach based on sediment size analysis of samples collected from the sites marked.



Severe blowouts in the dune system occured at the same time that increasing wave action was causing erosion of the foredune, producing a pronounced scarp face at the dune foot. Under this two-pronged attack from in front and behind, the dune ridge began to retreat. In 1976, the rate of retreat had reached one metre per year and the situation had become serious.

The provincial parks department recruited the services of a Halifax environmental consultancy company, H.J. Porter & Associates Ltd., and R.H. Louks Oceanology Ltd. to undertake a study of the erosion problem at Risser's and to recommend a course of action. After studying sediment characteristics and wave conditions, the consultants decided that lack of sediment supply was not the problem, and that if sediment loss over the groyne and misuse of the dunes could be prevented the system would be able to recover with little assistance. They recommended four courses of action :

1. Repair and strengthen the groyne. The groyne was almost completey rebuilt with rock-filled gabions (cribs) breaching gaps that were allowing sand to penetrate in to the river, and increasing the height to retard sand migration over the top. The groyne acts rather like a headland, and following its repair the beach has returned to a stable arc form.
2. Repair the wave damage to the foredune and upper beach. Methods were chosen that would use only natural materials, such as trees, and would encourage depositional processes. Large trees were laid along the beach in front of the dune in order to increase accumulation along the upper beach, while smaller trees and snow fencing were used to fill breaches and blow-outs. Hundreds of small conifers were tied into the face of the dune to prevent wind from blowing the sand off the dunes and to entrap sand blown there from the beach. These methods have proved successful in retaining sediment from the now widening beach. Almost all evidence of the wave-cut scarp has disappeared as the toe of the foredune has built up over the past six years. Also many of the blow-outs and breaches in the dune system have been filled in, or are being filled in, by accumulating sediments.
3. Repair the damage to dunes and vegetation due to human activity. Accompanying the restoration of the foredune and upper beach system, the dunes have been selectively re-vegetated with marram grass in order to restore denuded areas and to help retain sand in newly accumulating areas. Many of the previously damaged areas have been successfully recolonised; however, the success of the planting is largely due to the fourth course of action.
4. Education of the public and management of human activity. The whole restoration project has been accompanied by an innovative public education programme. A local artist was employed to draw up signs which would educate people about the effect of certain activities upon the dune system. Management of traffic, including the construction of boardwalks and restricting vehicle movement has also allowed damaged areas to recover. In addition, information boards and brochures were distributed around the park to explain the restoration programme to the public users. This process proved so successful that no significant vandalism of protection works has occured and users are respecting the beach and dune system by not encroaching onto the areas that have been identified as under restoration.

In comparison, Risser's Beach and Crescent Beach represent two forms of coastal management in Nova Scotia; one highly innovative and effective, the other piecemeal and generally ineffective. The inconsistencies in management approaches reflects the different uses and different ownerships and jurisdictions along the coast, but as development pressures increase there is mounting concern on behalf of environmental analysts that the province must seek to achieve a more consistent and more comprehensive approach to coastal management issues.

8. LaHavre Ferry will be used if possible to reach the east side of the river. Nearby if time allows there are outcrops of Bridgewater conglomerate at Pentz.

9. Riverport is a major fish processing centre in a pretty part of the Lahavre River. Several drumlins exist at Riverport and are found scattered all along the road leading to Kingsburg and Hartling Bay.

STOP 3- Hirtles Beach, Hartling Bay

The coastal planform of Hartling Bay is dominated by four large drumlins connected by Hirtles Beach. Offshore the bathymetry is governed by the strike of the bedrock (Fig 3-1) and the nearshore is blanketed by a cover of medium grained sands. The bedrock surface is said to represent the seaward extent of the peneplain (mid-Cretaceous or Miocene age) that decreases in altitude southward across Nova Scotia. The central portion of Hirtles Beach is sandy and exhibits a more gradual slope than the rocky shores to the east and the cobble beach farther to the west. Sediment for beach development is derived from the adjacent drumlins which are receeding at a rate of 0.1 to 1.5 m/a. Slumping and gullying are major agents of erosion at the edge of these drumlins. Composition of the drumlins is 53% mud,39% sand,and 8% gravel (Urquhart,1977). The larger clasts remain at the base of the drumlin whereas the fines are carried offshore. Most beach sediment is derived from the more rapidly eroding (1.5m/a) drumlin at the eastern end of the bay. Rates of erosion for the western most drumlin is only 0.1m/a. Urquhart,(1977) concluded on the basis of scanning electron microscopy that the origin of sediments within Hartling Bay were 42.3% subaqueous, 7.2% eolian and 50.5%. glacial sediments.

F 11

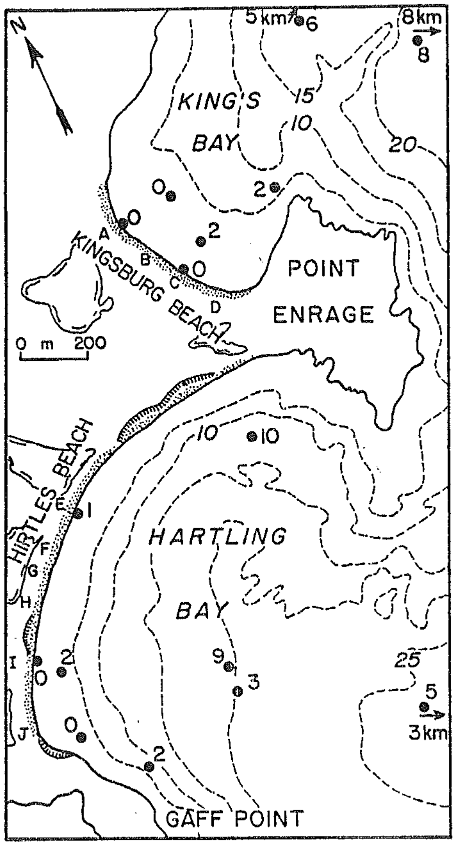


Figure 3-1. Location map of Hartling Bay and survey locations.

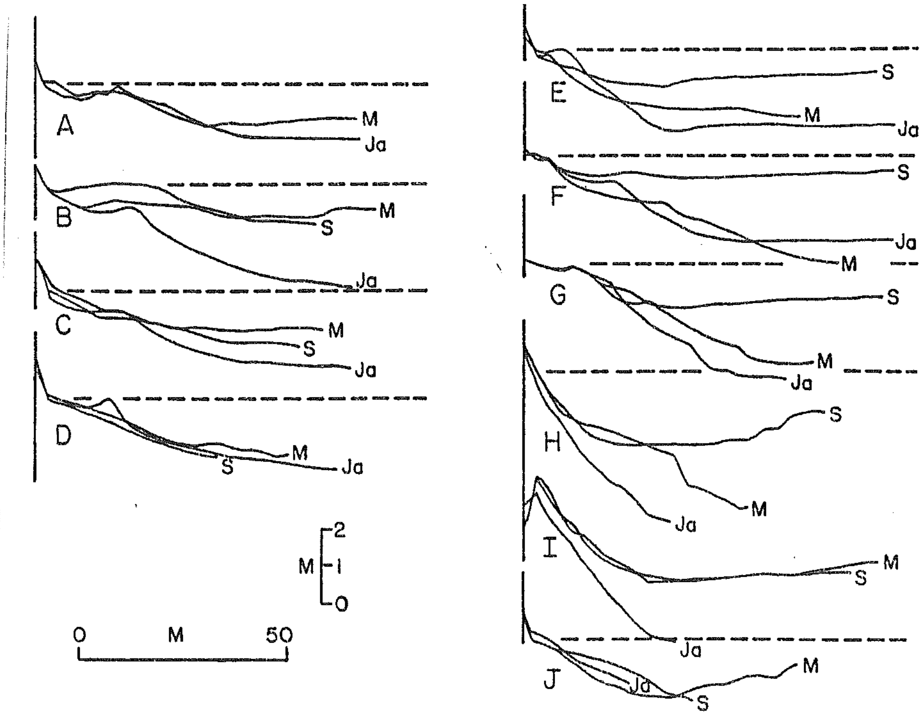


Figure 3-2. Sequential beach profiles at Hirtles Beach (after Urquhart 1977).

F 12

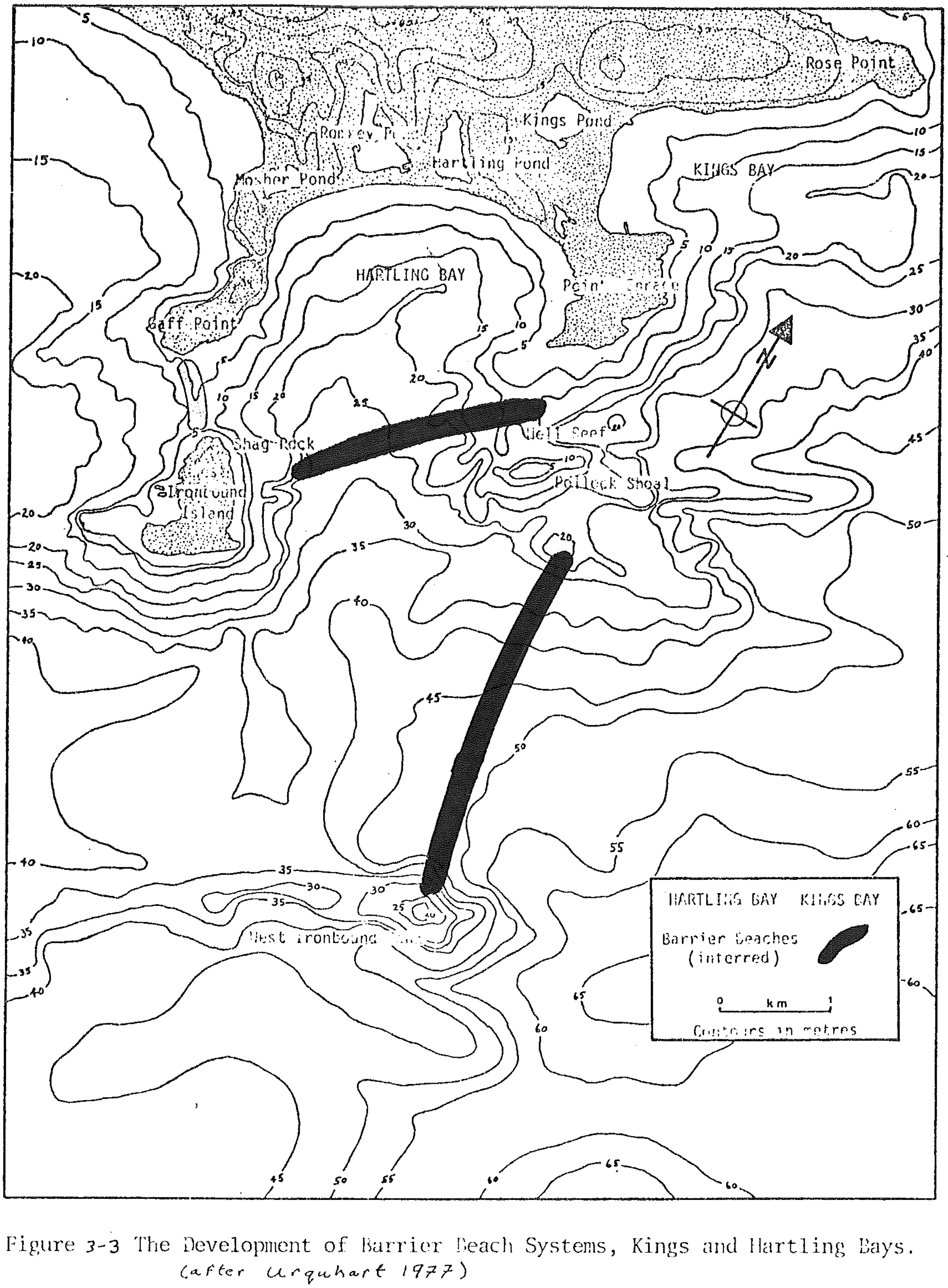


Figure 3-3 The Development of Barrier Beach Systems, Kings and Hartling Bays.
(after Urquhart 1977)

Sequential surveys of the beach suggest that the profile is steepest in winter and built up to its maximum in September (Fig 3-2).

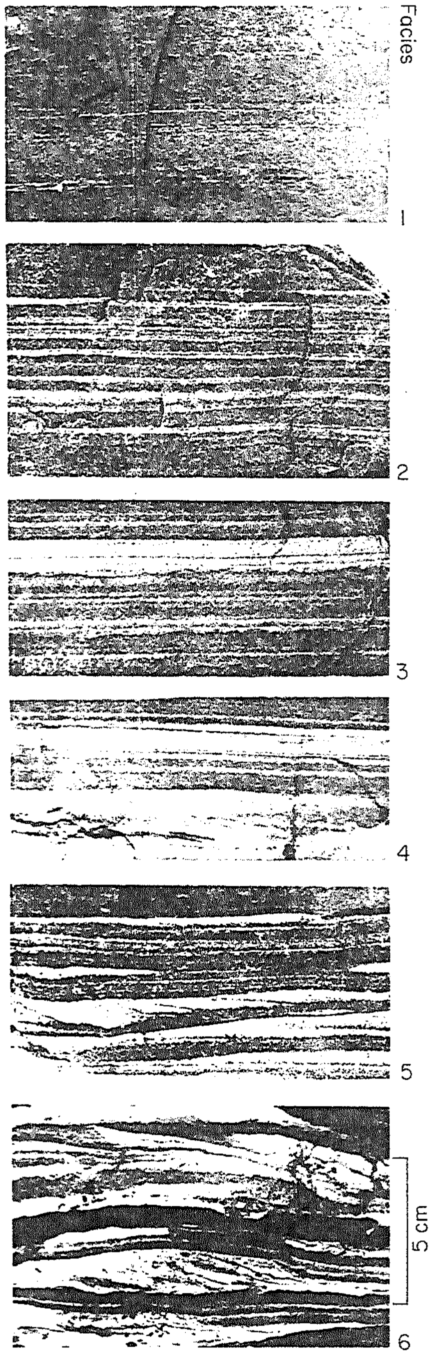
As at several of the other South Shore bays, it is hypothesized that barrier beaches once existed farther offshore and that the present beach is a product of Holocene transgression. At Hartling Bay a barrier beach existed at West Ironbound Bank an estimated 9-8 Ka BP. and another more recent barrier may have connected West Ironbound Island and Hell Reef (based on relative sea level changes) about 7 Ka BP(Fig 3-3). In-situ peat at 3.1 m water depths provide evidence of a former brackish lagoon. Failure of the barrier beach about 2.5 Ka BP. and an influx of saline water killed the peat and the beach continued to retreat landward to its present position.

STOP 4- Ovens Park

This site is known locally for its coastal blowholes or thunderholes where the waves roll into and break against the walls of caves eroded by the action of the sea. The noise in the caves is especially good when the tides are in their lower stage and a good sea is running from the south or southeast.

The Ovens is also reknowned for its gold rush of 1861 when $120,000 worth of gold was extracted from the quartz veins in the rock and from beach sand and gravel. People still pan for gold during low tide here.

The site offers also one of the best exposures of Halifax Formation rocks(Fig 4-1). Stow et al. (1984) concluded that these rocks are a thick shaly flysch (marine sedimentary sequence) succession showing various scales of cycles of recemented shale and siltstone facies.



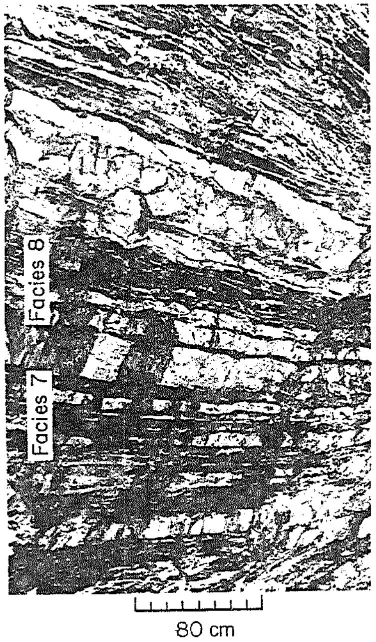


FIG. 4. Photograph illustrating sandstone facies 7 (thin-bedded, 1-10 cm) and 8 (thick-bedded > 10 cm). For details see text.

cure primary structures, and there has been considerable plastic strain in many outcrops.

Facies (1): Shale, SIL/SH < 5/95; structureless, rare[1] siltstone lenses. (Facies 7–9 of Lane 1980, are equivalent.)

Facies (2): Shale dominant, SIL/SH < 25/75; infrequent, very thin (< 1 mm), indistinct and/or discontinuous, parallel to wavy, siltstone laminae; gradational and sharp boundaries, rare normal grading. Rare thin sandstone beds. (Facies 4 and 6 of Lane 1980, are equivalent.)

Facies (3): SIL/SH ≈ 40/60; frequent, thin (1–2 mm), regular, parallel siltstone laminae; rare low-amplitude long-wavelength ripples; gradational and sharp boundaries, some normal grading. Rare thin sandstone beds. (Facies 5 of Lane 1980, is equivalent.)

Facies (4): SIL/SH ≈ 50/50; common, thin (2–4 mm), regular, parallel siltstone laminae; low-amplitude long-wavelength ripples; rare lenticular laminae; gradational and sharp boundaries, some normal grading and loaded or scoured bases. Rare thin sandstone beds.

Facies (5): SIL/SH ≈ 60/40; very common, thin to thick (3–6 mm), parallel siltstone laminae, lenticular laminae, convolute laminae; low-amplitude long-wavelength ripples, fading ripples; gradational and sharp boundaries, normal grading, internal parallel and cross-lamination loading, scouring and injection structures. Thin sandstone beds rare to frequent.

or: SIL/SH ≈ 60/40; very common, thin to thick (3–6 mm), regular, closely-spaced, parallel siltstone laminae. Thin sandstone beds rare to frequent.

Facies (6): Siltstone dominant, SIL/SH ≈ 75/25; very common, thick (4–10 mm), parallel siltstone laminae, lenticular laminae, convolute laminae; fading ripples, gradational and sharp boundaries, normal grading, internal parallel and cross-lamination, loading, scouring, injection structures and mudstone rip-ups. Thin to medium-bedded sandstones rare to frequent.

Facies (7): Sandstone, thin-bedded (1–10 cm), commonly flat sharp base, also with flutes, scours and load casts, rarely gradational; sharp or gradational top; beds commonly lenticular, internal parallel and cross-lamination, with fading-ripples at top; normal grading common, rarely massive, partial Bouma sequences present (CDE).

Facies (8): Sandstone, medium to thick-bedded (> 10 cm, up to 2 m); commonly flat sharp base, also scoured, loaded or channelled; sharp, gradational or eroded top; internal parallel and cross-lamination, the fading-ripples at top; shale partings, siltier and shalier zones indicate amalgamation common; shale rip-up clasts locally abundant, rare pebbly sandstone; normal grading, indistinct grading and massive, partial Bouma sequences present (AB, AE, BCD).

Figure 4-1 Facies descriptions of the Halifax Formation (after Stow et al. 1984).

The lower part of the sequence resembles modern deep sea channel levee complexes; the upper may have accumulated principally from turbidity currents on a rapidly prograding continental shelf, possibly north Africa.

10. A short drive will bring us to First South and the back road to Lunenburg. Note: the drumlins now exhibit a reddish-brown colour. They are mapped as LAWRENCETOWN TILL by Stea and Fowler (1981). This type of till is also common in the vicinity of Halifax and it often contains erratics transported from the Bay of Fundy region.

STOP 5- LUNENBURG

At last folks we are at our LUNCH stop where one of the finest seafood chowders awaits you at the Mug-Up restaurant. Following lunch we will visit the Houston North Gallery (prints and carvings from the Arctic) and should have some time to walk about the lower town -try the wharf area and Montague or Cumberland Streets- and then we will drive around other parts (Fig 5-1).

Lunenburg (pop-3014) is shown on the Canadian $100 bill and is often used as a setting for TV commercials. Founded in 1753 it was planned by the British but settled by German, Swiss and French settlers . It has always been a major fishing port but became well-known as a ship building centre following the success of the Bluenose schooner in the 1920´s and Bluenose II built in 1963. The Bounty was launched from here and sailed by a Nova Scotian crew to Tahiti to make the movie Mutiny on the Bounty. Two buildings that you should see are the Lunenburg Academy (1895) and St. John´s Anglican church (1753) the second oldest protestant church in Canada.

F16

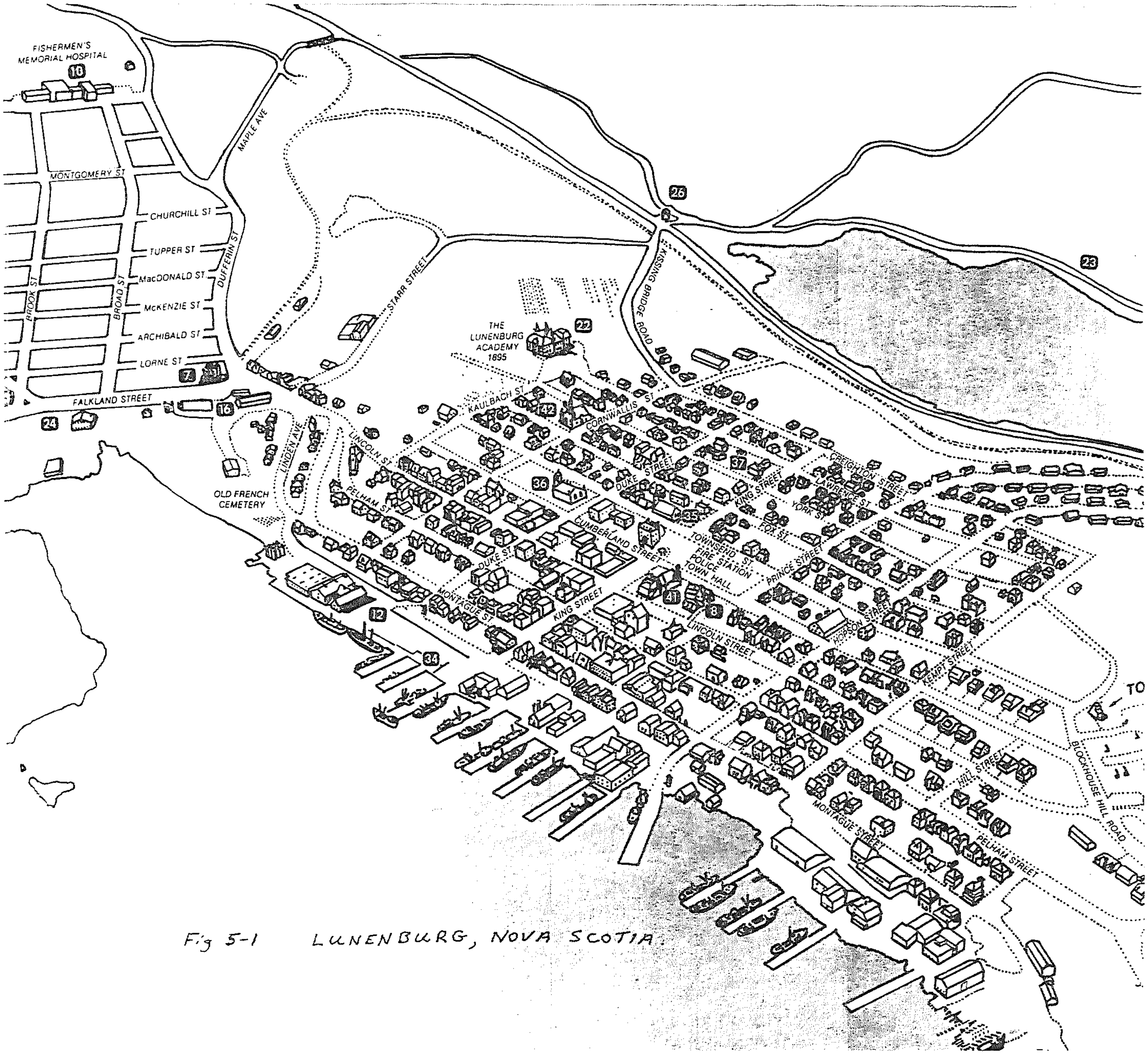


Fig 5-1 LUNENBURG, NOVA SCOTIA

11. A brief stop will be made in the town of Mahone Bay because it provides a scenic view of the town and numerous churches. This was the site where the American privateer ´Young Teaser´ was blown up by an British deserter so that a British Man of War at the entrance to the bay did not capture him. All along this coast privateering and later rum-running and other illicit activities have gone on because the numerous islands offer plenty of cover from the authorities.

12. Along Hwy 3 we begin to retrace our path eastward but this time along the coast. Note the changes in the bedrock and till exposures. OAK ISLAND buried treasure by Captain Kidd has been searched for since the first shaft was discovered in 1796. Planks were found at 6.1m,9.2m, and at 27.6m but then water rushed in at29m and it was not until some time later that three chests were discovered at 46m.

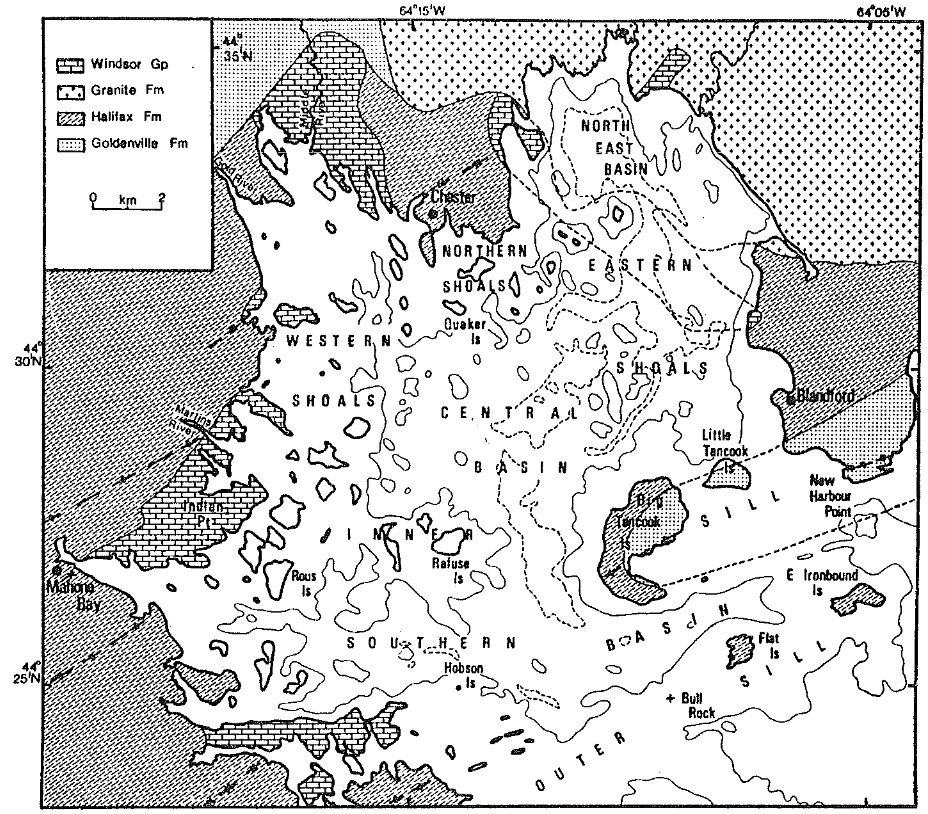
13. Gold River which is one of the largest rivers along this part of the coast illustrates the scarcity of sediment entering the coastal zone from fluvial sources. Note the cut in the Quartzite till at the village of Gold River and the Ablation till at Middle River.

14. A good view of Mahone Bay is provided near exit 8 where we will rejoin the main highway.

STOP 6- Mahone Bay

Once a graben in the Carboniferous, the present bedrock surface is largely an exhumed pre-Carboniferous surface. The northeastern part of the bay was overdeepened by glacial erosion and till sheet and drumlin deposits cover the western portion of the bay (Fig 6-1).

F 18



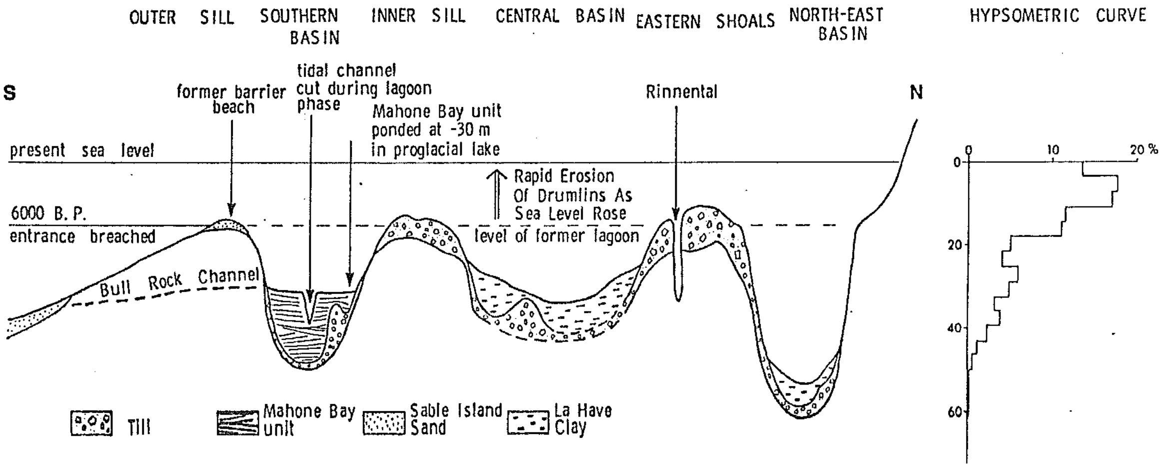


FIGURE 6-1 Schematic north-south cross-section illustrating distribution of stratigraphic units and development of physiography as sea level *rose*. Hypsometric diagram shows extent of different water depths (from Barnes and Piper, 1978).

Sub-glacial channels formed when ice stagnated following the marine incursion of the Bay of Fundy about 14Ka BP.. A Mahone Bay unit (75m. thick)of stratified silts lies behind the outer sill at the entrance to the Bay. The silts are proglacial sediments whose absence in the northern part of the Bay suggests that stagnant ice covered the upper bay when the Mahone Bay unit was deposited (Barnes and Piper, 1978).

As sea level rose a barrier formed 8-6 Ka BP. seaward of the outer sill plugging the Bull Rock channel with sand. Occasional openings produced a lagoonal sequence on top of the Mahone Bay unit. Final breaching of the barrier occurred around 6 Ka BP. and led to rapid erosion of the drumlins within the upper bay. A terrace developed between -14m and present sea level and it is most pronounced in the northwestern portion of Mahone Bay.

15. The route south along Hwy 333 takes us back into Devonian Granites and LAWRENCETOWN TILL in the area of Seabright.

STOP 7- Peggy´s Cove

The unique character of Peggy´s Cove is provide by the coastal barrens of ice-sculptured Devonian granites, perched boulders, roche moutonees and low scrub growth. The terrain has been subjected to numerous ground fires but it once was well forested. The coastline from here to Halifax is dominated by bedrock with only small bayhead pocket beaches. At the lighthouse in Peggy´s Cove note the fracturing and weathering of the granite but **beware of the waves which can easily sweep you out to sea if you get caught on these slippery rocks.** The village offers many settings of famous paintings and is fun to photograph if the weather and lighting cooperate. Have a coffee and take a leisurely stroll through the village as this marks our last stop.