BEACH OBSERVATIONS ALONG THE EAST COAST OF CAPE BRETON HIGHLANDS NATIONAL PARK, NOVA SCOTIA

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Introduction

In 1983, field observations were carried out on three occasions - March, June and November, at selected beaches along the east coast of Cape Breton Highlands National Park (referred to as the Park). The study was begun in response to a request by park wardens to examine the stability of the main recreational beaches and to a request by park interpreters to provide a seminar on coastal processes and a field trip along the larger beaches. The latter was to assist the interpreters in developing beach walking tours for park visitors.

When preparing for the seminar and field trip, it quickly became apparent that there was very little detailed information about specific beaches in the Park. The only published information found was an ecological land classification which included a summary of coastal types by Eastern Ecological Research Limited (1978), a general description of the coastal environment of northern Cape Breton Island by Owens and Bowen (1977), geologic reports by MacLaren (1956) and Murray (1977) and discussions about the Quaternary history of the area by Newman (1971) and Grant (1971, 1975a, 1975b, 1977).

The objective of this report is to describe the basic physical characteristics of the main beaches, namely Ingonish South Bay, Broad Cove, Black Brook Cove and Neil Harbour (Fig. 1) and to address some of the concerns raised by park wardens about these beaches. In addition, the report examines the coastal changes which resulted from a severe storm during October 25, 1983.

The report provides background information for a field guide to the main beaches, some recommendations on beach management and suggestions for future research.

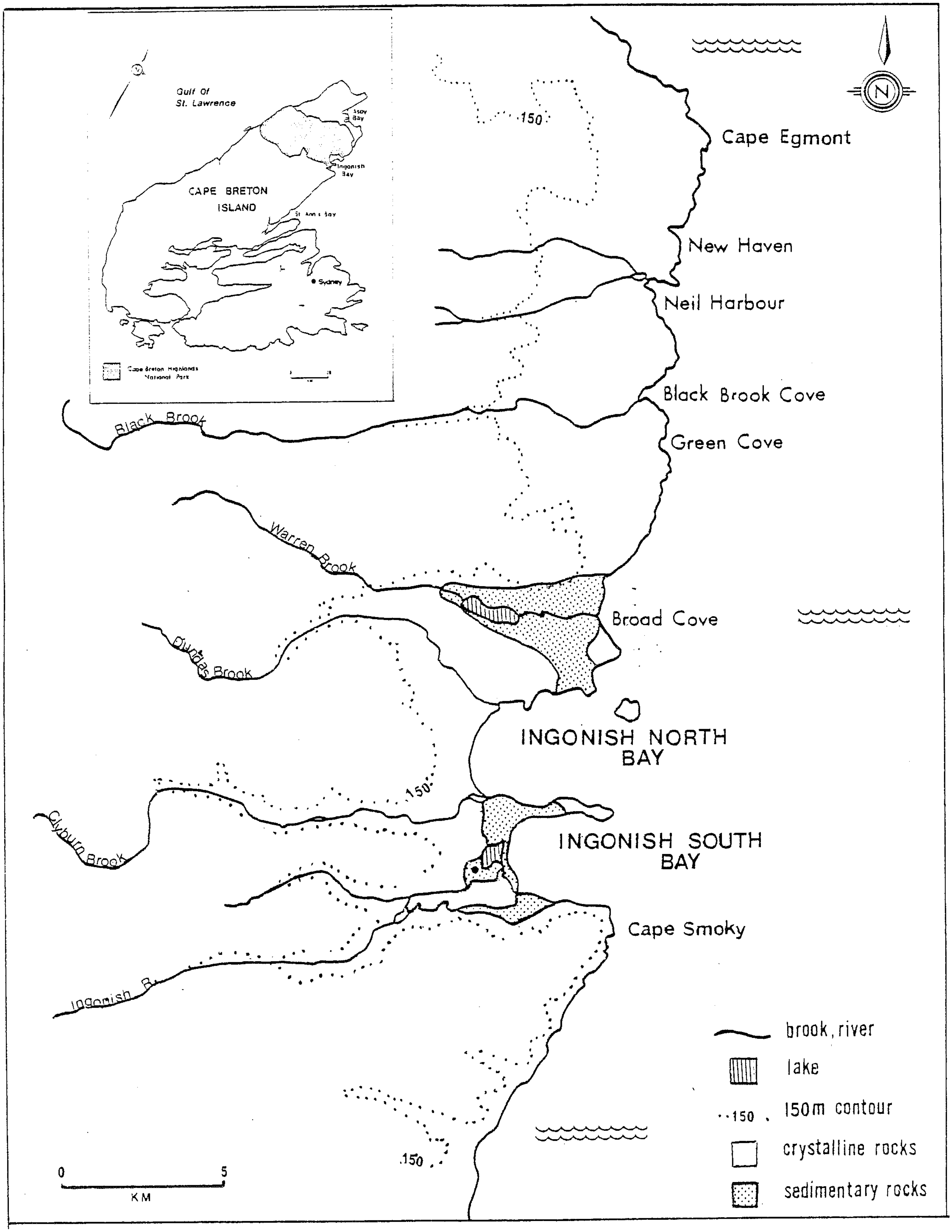


Figure 1. Location map and place names, northeastern Cape Breton Island.

Coastal Environment of Northeast Cape Breton Island

Geological Setting

The coastline of northeastern Cape Breton Island has been described by Owens and Bowen (1977) as a wave-exposed, upland, cliffed (5-100 m) coast with narrow coarse-sediment beaches. The general configuration of the coast is structurally controlled but glacial and post-glacial processes have made minor modifications.

Northeastern Cape Breton Island is largely a broad upland composed of resistant crystalline rocks of Devonian and Precambrian age (MacLaren 1956, Murray 1977, Keppie 1979). It has a dissected planar surface that gently dips from an elevation of 480 m in northern Cape Breton down to sea level along the southeastern part of the island. Goldthwait (1924), Johnson (1925) and others recognized the upland as an ancient peneplain surface that was resurrected by uplift following the removal of a sedimentary covering. It gained its altitude through a general upwarping of the region possibly during the Cretaceous Period some 63 to 135 million years ago. Subsequent submergence of the region has resulted in a remarkably straight coastline that stretches from Aspy Bay to St. Ann's Bay (Fig. 1). Where the old peneplain surface was tilted up steeply, the removal of weak Carboniferous beds left a steep, bold shore, eg. south of Cape Smoky. In contrast, north of Cape Smoky the crystalline surface, which some believe is older than Cretaceous age (Johnson 1925), slopes gently to the sea and is characterized by moderately sloping shore ramps which are the feather edge of the peneplain (Fig. 2). Only a small number of bays, eg. North and South Ingonish Bays, indent the coastline. They resulted from the erosion and partial submergence of lowlands developed on inliers of less resistant Carboniferous beds. Mainly gypsum, shale, limestone and sandstone of Windsor age are exposed within the lowlands (MacLaren 1956, Keppie 1979).

The detailed geomorphic features of the coast were produced by late Cenozoic glacial erosion and sedimentation and by changes in relative sea level. The general preservation of the peneplain upland surface suggests that there was little glacial erosion across the hard rock areas. Much of the glacial sedimentation, which is locally abundant at the outlets of the main river valleys, is derived from nearby sources, e.g. at the edge of the upland and in the lowlands. The veneer of glacial till that covers most of the area and the thick glaciofluvial deposits in the main river valleys are the primary source of sediment for modern beach development.

Newman (1971) and Grant (1971, 1975a, 1977) have discussed the glacial history of the study area however there is a difference of opinion about the timing and extent of the various ice advances. For instance, Newman (1971) postulated that a continental ice sheet overran Cape Breton Island after 20,000 yrs B.P. Grant (1977), on the other hand, believed that late Wisconsinan glaciers were restricted to a local ice cap which failed to cover all of the highlands; at an earlier stage the Island was crossed by a major ice sheet. It is difficult to assign absolute dates to many of the events that took place in the Quaternary. A general summary of the major events and how they affected northern Cape Breton Island is presented in Table 1.

Marine waters invaded the Laurentian Channel by 13,000 yrs. B.P. (Prest and Grant 1969) when sea level was estimated to be as much as 115 m lower than present (Newman 1971). The absence of strandlines on northern Cape Breton suggests either that most of the elastic and isostatic rebound following deglaciation was accomplished before the invading waters could

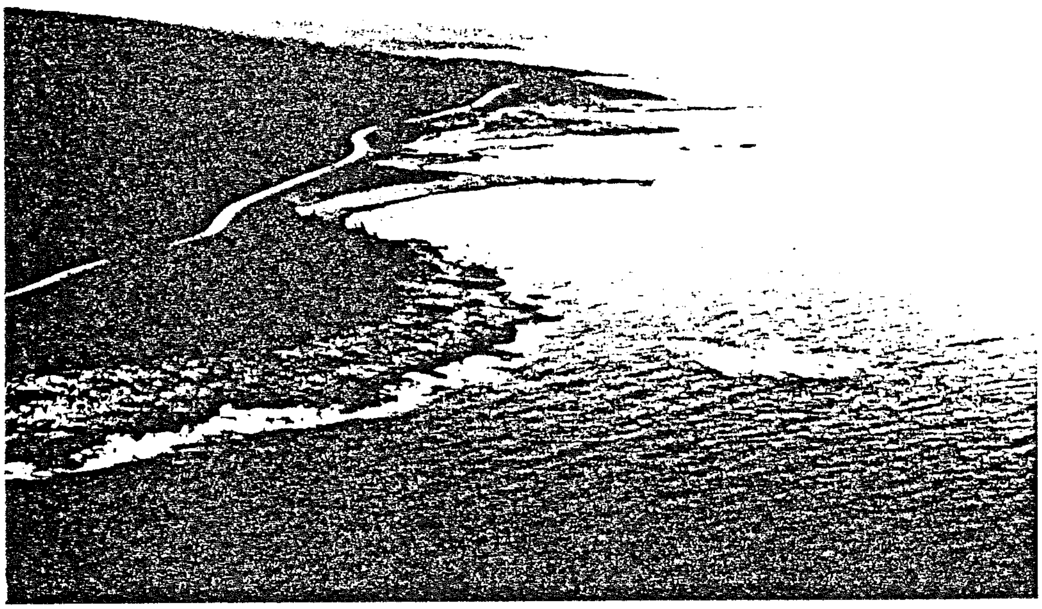


Figure 2. Aerial view of the outer coast near Green Cove. Moderate sloping rock ramps and boulder lag retreat shoals dominate this coast.

Table 1. Glacial and marine events as they relate to Northern Cape Breton Island (from Prest and Grant 1969, Newman 1971, Grant 1971, 1975, 1977 and pers comm).

Period	Event	Process and Consequences
(thousands of years BP) Holocene (9)	Deglaciation warmer climate	ice-free coast due to retreat of local ice; continued rise in relative sea level to present.
Late Wisconsin (10 toll)	Glacial Ice advance	colder climate, readvance of glaciers from local ice caps on highlands; ice flowed down major river valleys E and W of highlands but not much beyond present coastline; glaciofluvial deposits infill river valleys.
(13)	Marine Invasion	Prest and Grant - Marine waters enter Laurentian Channel and Gulf of St. Lawrence
Late to mid Wisconsin (15 to 30)	Glacial Ice advance	Newman - 'classical Wisconsin' ice from Quebec-Labrador moves southward over Cape Breton Island. Grant - ice readvances northward from centres on Continental Shelf and local centres, eg. Bras D'or Lakes; shelly till deposited; ice does not reach Cape Breton Highlands.
Mid-Wisconsin (30 to 39)	Interstade cool climate	ice recedes from highlands, lowland forest vegetation, organic layers develop along Bay St. Lawrence and Aspy Bay, periglacial features develop. Mastodon bones found at middle River (C.B.I. and in other parts of Atlantic Canada.
Early Wisconsin (60 to 70)	Glacial ice advance	Grant - Laurentide ice initially flowed from the north around Cape North and through Laurentian Channel; once thick enough ice overrode highlands as a major ice sheet; Richmond till deposited.
Sangamon (125?)	Interglacial warmer climate	higher sea levels etch rock bench along Atlantic Shores 6 ± 2 m above present sea level*, beach sediment and organics overlie bench at Bay St. Lawrence.

* Glacially rounded segments of the platform were noted (1984) along the coast from Neil Harbour to Ingonish - 1. Southside of cove, Black Brook Cove picnic area. 2. Green Cove. 3. Little Smokey (on Carboniferous sediments). 4. West side of Ingonish Island (on Carboniferous

develop them, or that sea levels in the late Wisconsin were never as high as at present. The only evidence of higher sea level is a discontinuous rock bench locally with beach gravel that lies at 6 ± 2 m above present sea level along parts of Cape Breton Island, e.g. Aspy Bay. Grant (1975a) concluded that higher sea level during the Sangamon Interglacial, earlier than 70,000 yrs B.P., was responsible for etching the rock bench. Quinlan and Beaumont (1981) made theoretical calculations of relative sea level (RSL) changes based on the assumed glacial ice configuration and the Earth's response to that ice load. They calculated for the southern Gulf of St. Lawrence that since 18,000 yrs. B.P. sea level initially fell and then steadily rose during the Holocene to the present level. Grant (1975b) has estimated that the rise in sea level over the past 5000 yrs was 30 cm/century.

Along the outer coast of northern Cape Breton Island elevations reach 150 m within a few kilometers of the sea but the present shoreline is characterized by lower relief (<20 m) rock cliffs and moderately sloping rock ramps (Fig. 2) overlain by a veneer of glacial till. Waves have reworked the till, carrying sands and muds offshore and leaving cobble-boulder deposits across the shore ramps, and as lag shoals and steep, narrow pocket beaches in the embayments. Waves also have cut hollows along joints in the crystalline bedrock exposed alongshore. One can view good examples of the outer coast morphology at the Green Cove park exhibit site.

During Holocene transgression thick glacial deposits within the lowlands, i.e. bays, were reworked by waves into large beaches which have slowly retreated to their present position. The physical characteristics of these beaches are discussed later in this paper.

Process Parameters

Northeastern Cape Breton Island is exposed to the North Atlantic. Offshore, the deep water median significant wave height (H_s) for the ice free season is 1.4 m and the 1-, 10-, and 100-year H_s is approximately 7, 10 and 13 m respectively (Owens and Bowen 1977, Neu 1982). The maximum predicted 100-year wave height is 24 m (Neu 1982). Along northeastern Cape Breton island the largest waves are recorded between October and March. However the wave energy reaching the coast is limited by the presence of sea ice for four months of the year. Wave energy is reduced at the coast at other times of the year also because the prevailing and dominant winds blow offshore. Occasionally storm surges, such as the one in October 1983, will strike the Cape Breton coastline as a result of cyclonic storms moving up the North American seaboard and intensifying just to the south of the study area. Furthermore, there are reports of 'tidal waves' striking northern Cape Breton Island during the early part of the 20th Century (McIntosh 1914-15). Their cause is unknown but McIntosh speculated that the 'tidal waves' were initiated by large submarine landslides nearby.

Tides along northeastern Cape Breton Island are mixed, mainly semi-diurnal. At Ingonish Beach the large tidal range is 1.37 m and it decreases alongshore toward the north and south (Canadian Hydrographic Service, 1983).

October 1983 Storm

On October 25, 1983 very strong winds, high seas and tides well above predicted values struck the Atlantic shores of Cape Breton Island. The development of the storm has been described by E.J. Oja (1984, p. 7) as follows:

> "The storm itself evolved from a weak low pressure centre 150 nautical miles southwest of Yarmouth at 8:00 p.m., Monday, 24th of October. During the next 6 hours, the low underwent "explosive" deepening and a rapid eastward motion. At 8 a.m., Tuesday, 25th of October, the low had reached a point 60 nautical miles south of Sable Island, where it slowed down and curved northeastward, attaining its deepest value of 980 mb by 8 p.m. of the same day. Having reached its peak strength, it drifted slowly northward during the night, passing just east of Cape Breton during the afternoon of Wednesday, 26th of October, and thereafter weakened and blew itself out in the northeastern section of the Gulf of St. Lawrence."

At Ingonish Beach winds began picking up from the north during the afternoon of October 24th. By 2300 hrs (AST) the winds swung around to the northeast and from 0400 to 1700 hrs on the 25th, the northeasterlies exceeded 50 km/hr. For the remainder of the day the winds remained above 40 km/hr but shifted more from the north. Winds peaked at 62 km/hr between 2300 hrs October 25 and 0000 hrs on October 26, then steadily blew from the north to northeast until 1000 hrs on October 26 when they abated to less than 10 km/hr. At Sydney winds of 65 km/hr were reported on the 25th, peaking at 2300 hrs when they reached 111 km/hr. East of Cape Breton, lighthouse reports indicated that winds of 111 to 140 km/hr blew late on the Tuesday and Bow Drill One, a drilling rig just west of Port-aux-Basques, Newfoundland, recorded winds of 70 to 93 km/hr throughout the day (Oja 1984).

Extreme pressure gradients over Cape Breton led to storm surge conditions. During the storm the astronomical tides were only 0.1 m less than the spring tides a few days earlier. Oja (1984) also reports that at Sydney and Point Tupper the evening tide of October 25 was 0.76 m and 0.6 m above the predicted astronomical tides. Along Ingonish Beach the resultant storm debris line was 4.7 m above mean sea level (msl). At Black Brook

Cove debris was thrown a maximum of 6.9 m above msl, although, the main debris line was at only 4.0 m elevation.

The METOC centre reported maximum seas offshore of 12 m near the low centre with seas of 7 to 9 m propagating into Cape Breton Island and breaking onshore (Oja 1984). Eight metre seas were also reported from ships and rigs lying in the path of the storm.

Along northeast Cape Breton Island, the storm struck hardest along the coast between Ingonish Harbour and New Haven (Fig. 1). To put the storm in perspective, locals at Neil Harbour report that "they had never seen the likes of such a storm before". "Fishing facilities which had existed for over 90 years were destroyed in the storm." Beach changes resulting from this storm are discussed later in this report.

Geomorphology of Selected Beaches Along Northeast Cape Breton Island

Ingonish Beach, South Bay

(A) Physical Setting.

Ingonish South Bay is one of two large bays that indent the coastline just to the north of Cape Smoky. The two bays are separated by a long narrow finger-like projection called Middle Head which is a remnant of an old Pre-Carboniferous surface exposed by the stripping of the overlying strata (Goldthwait, 1924). The south shore of Middle Head is characterized by 5 to 10 m high cliffs overlain by glacial till of variable thickness up to 5 m. Pocket beaches, composed of sediment derived from glacial till exist between the resistant rock outcrops. At Cape Smoky and along the south shore of the bay, granite cliffs covered by till rise sharply to elevations of 289 m. At the head of South Bay is an extensive beach system approximately 2.5 km in length. When describing Ingonish Beach, it is useful to divide it into four segments (Fig. 3). The system includes two barrier beach segments - one that nearly completely encloses Ingonish Harbour (segment A) the other encloses Freshwater Lake (segment C). Between the two barriers and at the northern end of Ingonish Beach are narrow beaches fringing low cliffs of glacial material overlying sedimentary bedrock (segments B and D).

At segment A the 25-60 m wide coarse cobble barrier is cut by an inlet which connects Ingonish Harbour to the sea. On the basis of recent air photos, it appears that the inlet has remained at or close to the present position since at least the early 1950's. However submerged flood delta deposits behind the north end of the barrier suggest that an inlet once existed there. It is also tempting to speculate that this barrier beach rests on a former glacial sill.The deeper basin of Ingonish Harbour (Fig. 3) and the fact that glaciers once flowed down the Ingonish River valley favour this hypothesis. Further research will be required to confirm the sill.

Between 1966 and 1975 there was an increase in the number of large washover fans along the lagoon side of the barrier which suggests a general lowering of the barrier crest height. In 1982 the barrier crest height was only 2.5 to 2.7 m above mean high tide level (N.S. Lands and Forests, 1982). The highest portion of the barrier is 7.4 m (above Canadian Geodetic Datum) at Ingonish Ferry just south of the inlet. A survey in 1984, from the concrete foundation near the northern end of the barrier to the lagoon, indicates that the barrier has transgressed 18 to 30 m over the last eleven years (B. Wilmshurst, N.S. Lands and Forests, pers. comm.).

Beach segment B is a bedrock anchor point for the two barriers. It reaches an elevation of 9 m within 50 m of the present shoreline. Today,

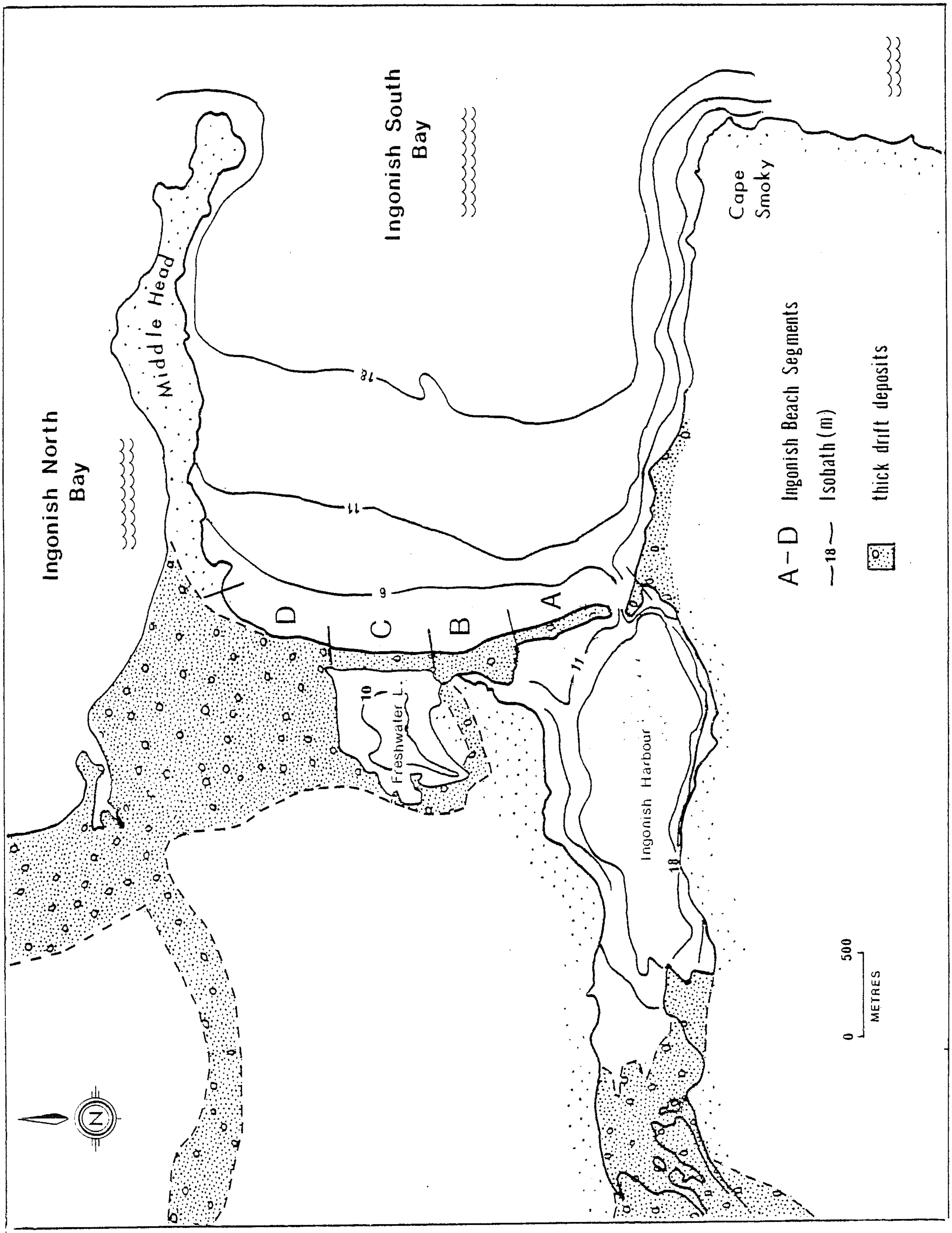


Figure 3. Plan map of Ingonish South Bay illustrating bathymetry and the extent of glacial drift deposits. For ease of description Ingonish Beach is divided into four segments A to D.

this portion of the beach is experiencing severe erosion and rip rap has been placed along 'Beach Crossing Road' to protect it from wave attack.

A more detailed description of beach segments C and D is provided on the basis of field surveys conducted in November 1983. Beach profiles 1 and 2 are representative of the barrier fronting Freshwater Lake and profile 3 is representative of beach segment D (Figs. 3, 4).

The barrier beach fronting Freshwater Lake has an assymmetrical shape with a very steep seaward slope and a wider more gradual sloping backshore (Table 2, Fig. 4). At profile 1, where the barrier is widest, the crest height is 4.7 m above msl but it decreases toward the north as does the seaward beach slope. Trees cover only the northern portion of the barrier near profile 2, however, the rest of the barrier is very stable as shown by the lichen covered cobbles which cover the backshore to within 10 m of the present beach crest.

The barrier consists of pebble to boulder size clasts ranging from 25 to >216 mm (B-axis measurements - Table 2). The largest clasts form the core and foundation of the barrier. They exist near low tide level (LTL) and just seaward of the main beach crest. On the upper beach slope the largest clasts are elongated or rod shaped, well rounded and imbricated. Across the backshore slope, the mean size of cobbles is 98 mm and 71 mm at profiles 1 and 2 respectively. The beach cobbles are primarily hornblende gneiss and biotite granite. Presently there is no large source of these clasts in the vicinity; hence, it is assumed that they were derived from glacial deposits brought in by eastward or coastwise flowing ice. Ingonish barrier is a lag component of these glacial deposits.

The character of beach segment D is considerably different from segment C. A parking lot covers most of the backshore, but till and rock

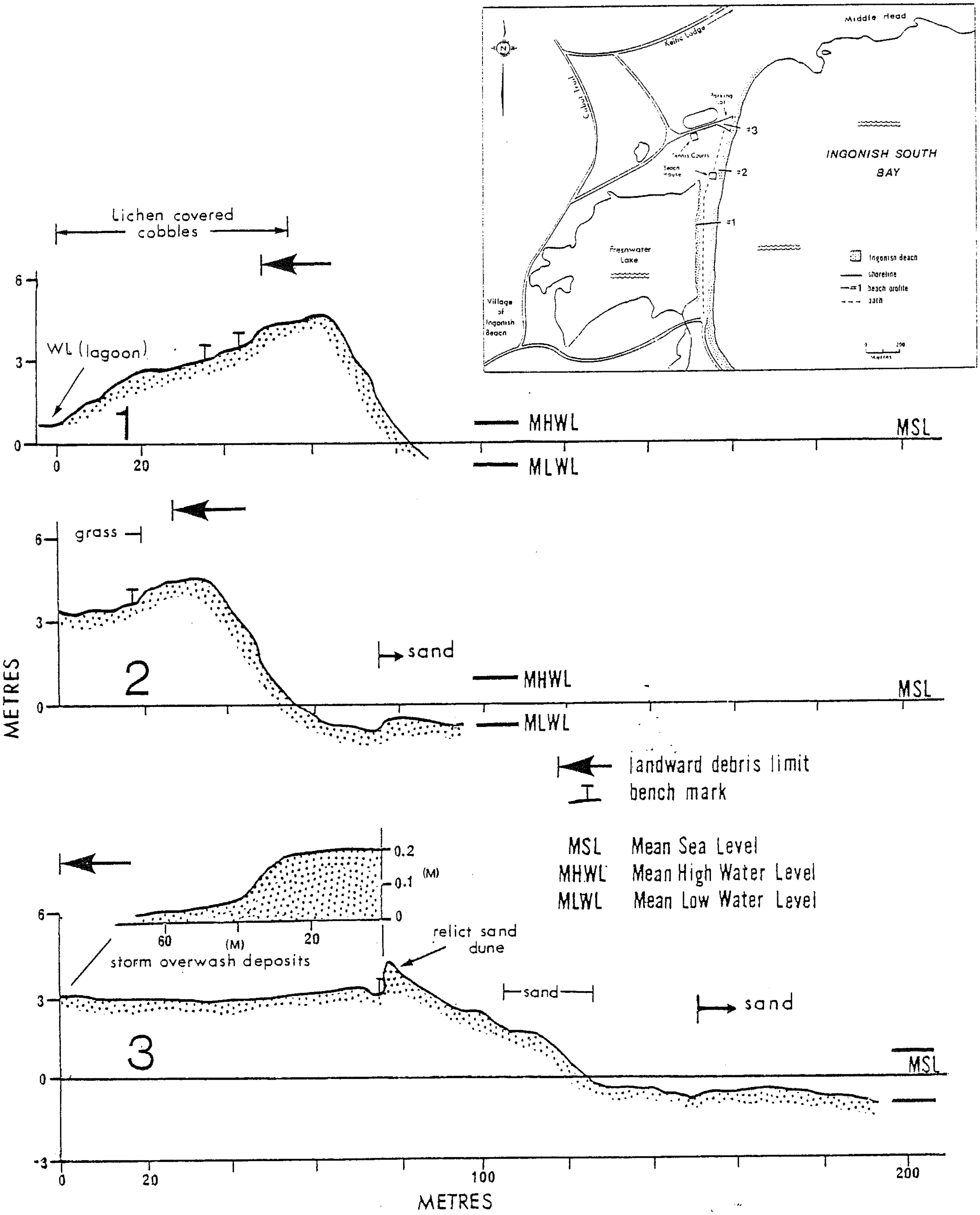


Figure 4. Three beach profiles were surveyed along Ingonish Beach on November 2, 1983. Profiles 1 and 2 represent the post storm morphology along the barrier fronting Freshwater Lake and profile 3 is representative of beach segment D (Fig. 3). The inset graph above profile 3 shows the

cliffs of 10 m elevation exist along the northern portion of the segment. At beach profile 3, the proportion of sand is greater, the seaward slope is more gradual, and the crest height is lower than at profiles 1 and 2 (Table 2). Relict sand dunes supported by a man-made wall presently exist along the beach crest. This is the portion of Ingonish Beach that is most intensely used for recreational activities.

Sediment characteristics vary across beach segment D. Sand is concentrated below high tide level and along the sand dunes whereas pebbles and cobbles of 41 to 151 mm clast size cover the upper beach slope. Smaller pebble-cobble clasts are scattered across the foreshore slope (Table 2). A small stream empties into Ingonish Bay within segment D and till deposits occur north and south of the beach; however, neither is an important source of beach sediment. Most sediment is thought to be presently derived from alongshore or offshore.

Offshore in South Bay the bottom slope is gradual (Fig. 3). Sand is reported in water depths of 3 m and 12 m on recent Hydrographic charts (Canadian Hydrographic Service, 1978), but the areal extent and thickness of sand is unknown. On the 1939, 1966 and 1975 air photos a small cresentic sand bar lies off beach segments C and D and inshore of a much larger crescentic sandbar. In November 1983 the smaller sand bar was only 17 to 20 m from shore at profiles 3 and 2 in water depths of less than a metre. Differences in bar morphology at the two survey sites are illustrated in Fig. 4.

(B) Seasonal Beach Changes

During the fall and winter one or more large pebble-cobble storm ridges develop along Ingonish Beach. For instance, in March 1983 the beach

Table 2. Morphological and sedimentological characteristics of Ingonish and Black Brook Beaches, Cape Breton Highlands National Park.

Beach	Profile No.	Beach Morphology: Total[1] Width (m)	Crest[2] Height (m)	Seaward[3] Slope (°)	Foreshore Slope (°)	Backshore Slope (°)	Mean Sediment Grain Size (mm): Backshore	Beach Crest	HTL	LTL
Ingonish										
	1	82	4.7	14.4	10.1	3.6	92	83	45	–
	2	38	4.6	11.3	7.6	–	–	71	37	154
	3	48	4.2	5.6	6.8	–	98	–	34	Sand
Black Brook										
	1	20	4.0	10.3	9.6	–	–	82	84	70

1 Mean sea level to lagoon or edge of beach sediment
2 Mean sea level to max beach height
3 Beach crest to low tide level
4 High to low tide levels
5 Beach crest to edge of lagoon

was fronted by a 2 to 2.5 m high storm ridge (Fig. 5a). However, during very large storms such as the October 25, 1983 event, the whole beach slope is combed down to produce a steep featureless slope. Some material is also deposited at or near the crest of the beach. In summer, wave conditions are more constructive, sand is moved upslope and several small swash ridges develop, which results in a wider beach.

(C) October 25, 1983 Storm

One of the most severe storms to strike this coast in recent times occurred in late October 1983. The severity of the storm is indicated by the displacement of lichen covered cobbles in the backshore of Ingonish Beach. During the storm, beach sediment at segment C was mostly combed down slope (Fig. 6). Some cobbles were transported over the barrier crest and 6 m beyond the former seaward limit of lichen covered cobbles. Even though the entire beach face was reworked by waves and the beach elevation increased, the integrity of the barrier was preserved. In contrast, along beach segment D, the entire beach was overwashed and the small sand dunes were nearly completely destroyed (Fig. 5b). An estimated 430 m^3 of sediment was transported and spread as much as 70 m inland across the parking lot from the beach crest (Figs. 4, 7). Sand to boulder size clasts (up to 280 mm in size) were transported. No correlation was observed between the size of clasts and distance transported possibly, because the smooth, hard-packed, parking lot surface reduced friction and enhanced bedload transport. Large cobbles were also transported considerable distances across the smooth grass backshore of profile 2, also possibly because of less friction. Other damage resulting from the storm included: the lifting of the lifeguard stand and changehouse off their foundations, the inundation

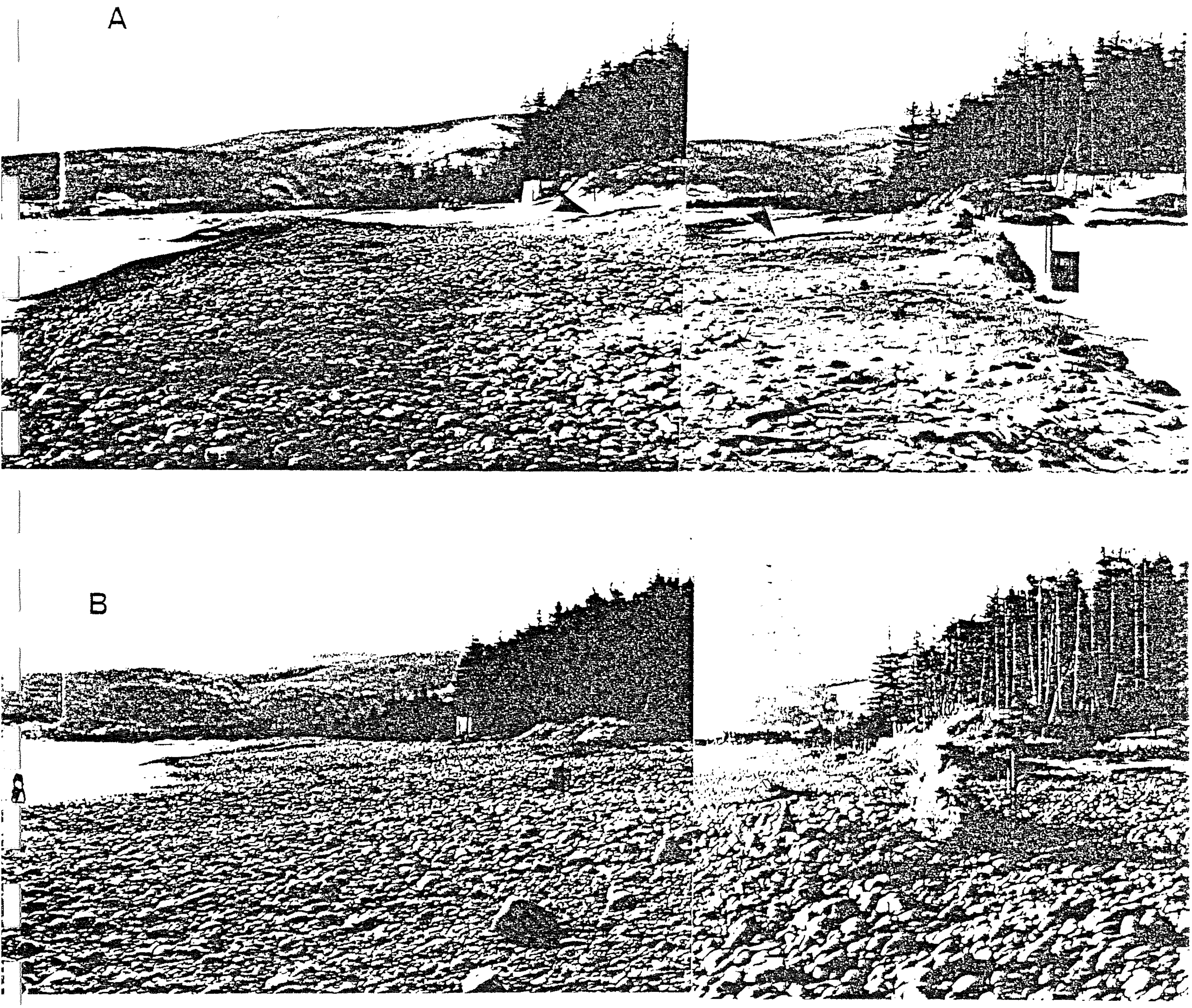


Figure 5. View of Ingonish Beach at profile 3; (a) on March 23, 1983 illustrating the winter storm ridge on the lower beach slope and the wind deflation surface along the upper beach; and (b) on November 2, 1983 illustrating the effects of the October 1983 storm surge. (Arrows indicate the same site on adjoining photos.)

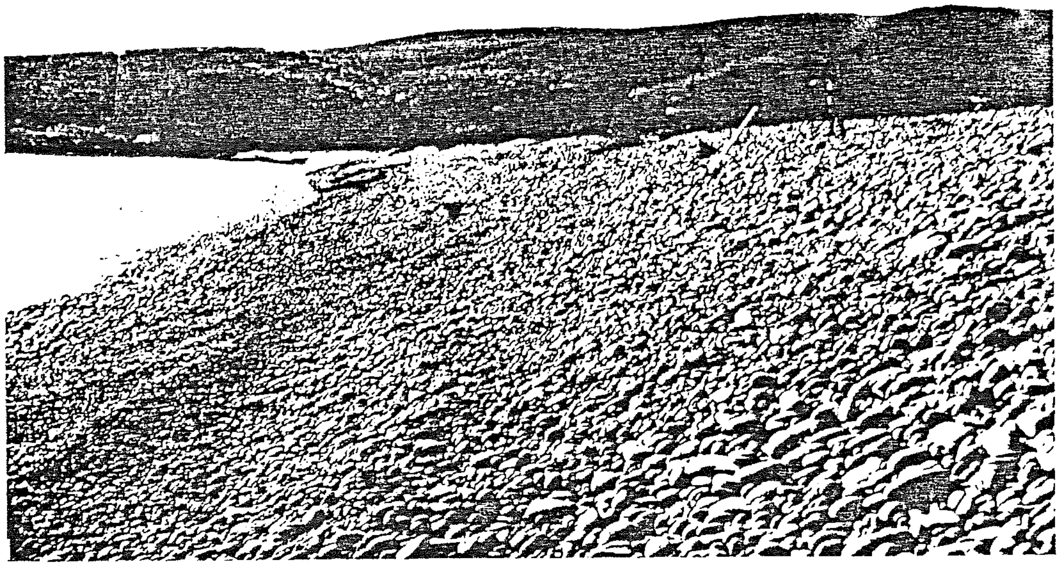


Figure 6. View of the steep foreshore slope produced at profile 1, Ingonish Beach during the October 25, 1983 storm; Note 1.5 m graduated staffs for scale (arrows). The largest cobbles are found at the base and near the crest of the beach.

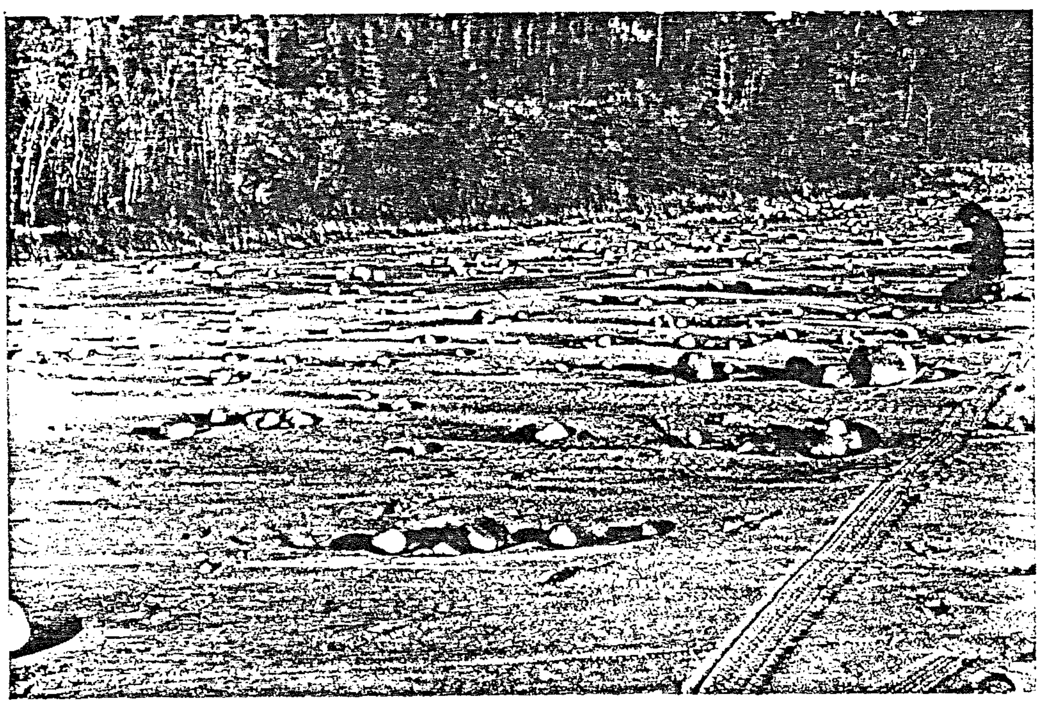


Figure 7. An estimated 430 m^3 of sand and cobbles was transported beyond the beach crest at profile 3, Ingonish Beach (see Fig. 3) during the October 1983 storm surge.

of the tennis courts (Fig. 4) by high water, the erosion and destruction of the newly paved road along beach segment B, the complete washover of the barrier fronting Ingonish Harbour and destruction of the lighthouse. Only a cobble lag shoal remains at segment A. Heavy damage was also experienced at wharves and numerous buildings along Ingonish Harbour. Beach segment C withstood the storm the best because its higher beach crest (Table 2) prevented large-scale wave overwash.

Broad Cove Beach

(A) Physical Setting

Broad Cove Beach is just over a kilometre in length (Fig. 8). Its width tapers from a maximum of 100 m adjacent to the mouth of Warren Brook to less than 5 m beneath the cliffs at both ends of the Cove. The beach marks the seaward extent of a former glacial valley that is presently drained by Warren Brook. Grant (1975) postulated that ice readvanced down the valley during the late Wisconsin - and stood at Warren Lake for considerable time. Outwash material from the glacier was deposited at the coast as a broad terrace which is the present site of Broad Cove campground. The outwash deposits are thickest adjacent to Warren Brook and pinch out over bedrock toward the north and south ends of the Cove (Fig. 8). The stratified outwash sands and gravels are the primary source of sediment for beach development in Broad Cove. The coastal cliffs which reach 15 m elevation are presently being undercut by waves and are slumping at times of groundwater saturation. Wave-cut notches have developed in the sedimentary rocks at the base of the cliffs and a rock platform extends some 800 m from shore to the north of Warren Brook (Eastern Ecological Research Ltd., 1978). Two interesting geologic features can be observed

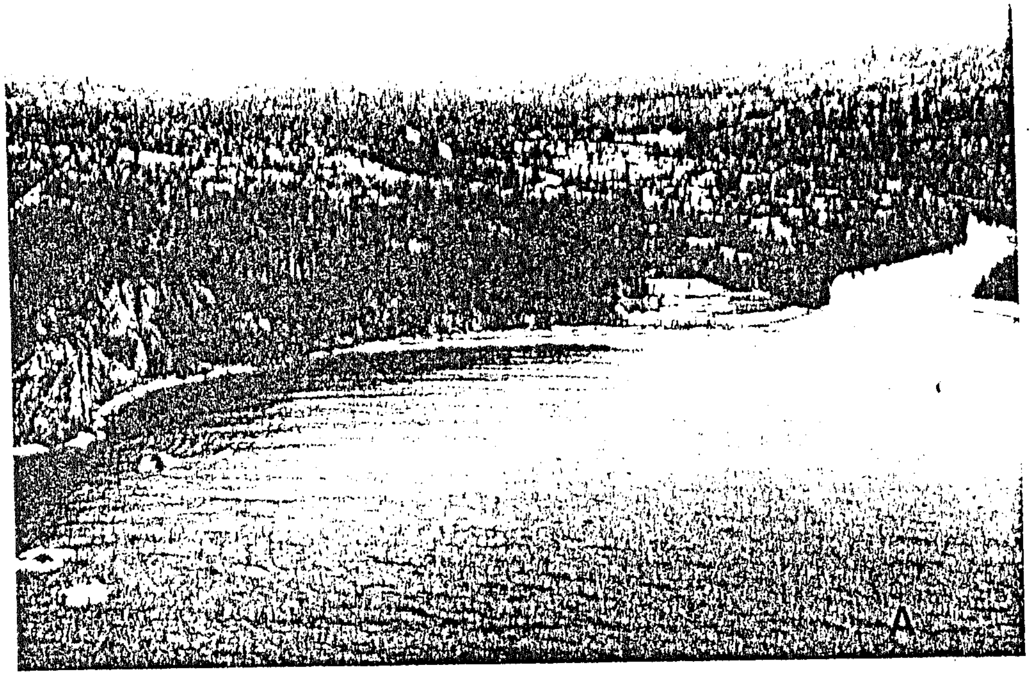
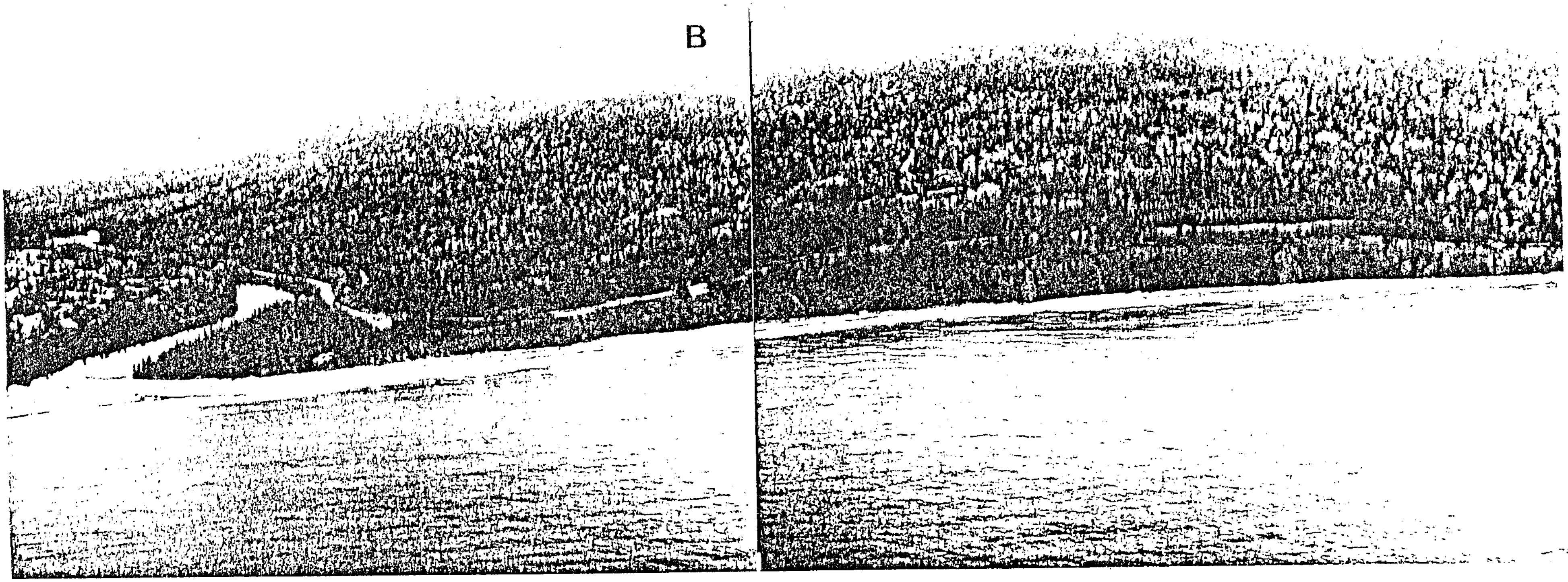


Figure 8. Aerial view of Broad Cove Beach (a) south and (b) north of Warren Brook. The coastal cliffs extend to a height of 15m. The cover of glacio-fluvial outwash deposits decreases in thickness away from Warren Brook. Glacial outwash sediments were carried from a valley glacier that stood at Lake Warren (in background of 8a).



along the northern part of Broad Cove beach. They are a large slump conglomerate or breccia deposit and some plant fossils which are preserved in finely laminated shales at the base of the coastal cliffs.

(B) Sediment Transport Model

On the basis of the 1983 field observations, a model is suggested for beach sediment transport at Broad Cove. Sediment falls to the base of the coastal cliffs following winter freeze-thaw cycles and the annual spring melt. The finer sediment flows farther downslope across the beach. During small storm events or strong winds, aeolian sands or wave overwash deposits can bury the colluvial deposits. The result, as observed in June 1983, is a sequence of alternate layers of colluvium and beach or aeolian deposits near the base of the cliffs. During major storm events, such as the October 1983 storm, waves rework the entire beach, cut back the coastal cliffs, (outwash deposits) and removed all talus along the rock cliff faces. Most of the eroded material appears to be added to the upper beach, which in turn is reworked by subsequent storms. The fines are carried offshore and the coarse clasts are reworked into swash ridges and beach cusps. From the evidence of thicker deposits of sand and gravel offshore at the south end of Broad Cove (Eastern Ecological Research Ltd., 1978), it is concluded that longshore drift is predominately north to south. Also, it is concluded that Warren Brook is more a sediment sink than a sediment source. Even though sediment is carried seaward during times of high river discharge, the presence of flood tidal deposits, overwash fans and sand dunes suggests that more sediment moves upstream and into the valley. The stream outlet is quickly closed off by beach sediment during periods of low stream discharge.

(C) October 25, 1983 Storm

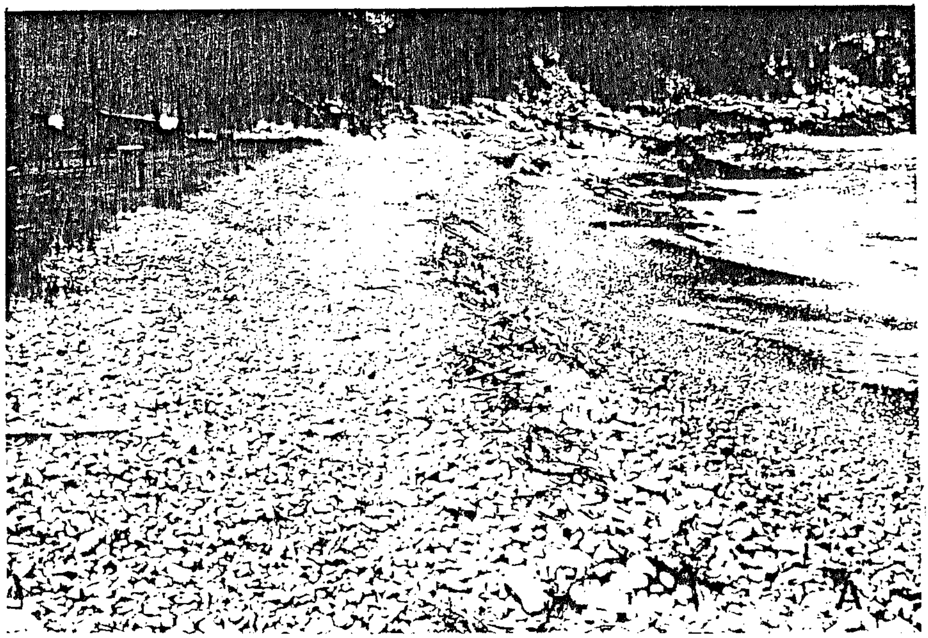
Following this storm, the beach south of the shore retaining wall was built up and extended by 7 to 10 m with the addition of sediment eroded from the cliffs behind. To the north of Warren Brook the glacial outwash deposits were severely cut back and the stairs, which provide access to the beach from the highway, were destroyed. Also, the shore retaining wall was undermined and sediment was removed from behind it. Large, thick washover fans filled in the mouth of Warren Brook but heavy precipitation during the storm led to the reopening of the stream channel, and the return of some sediment to the littoral system.

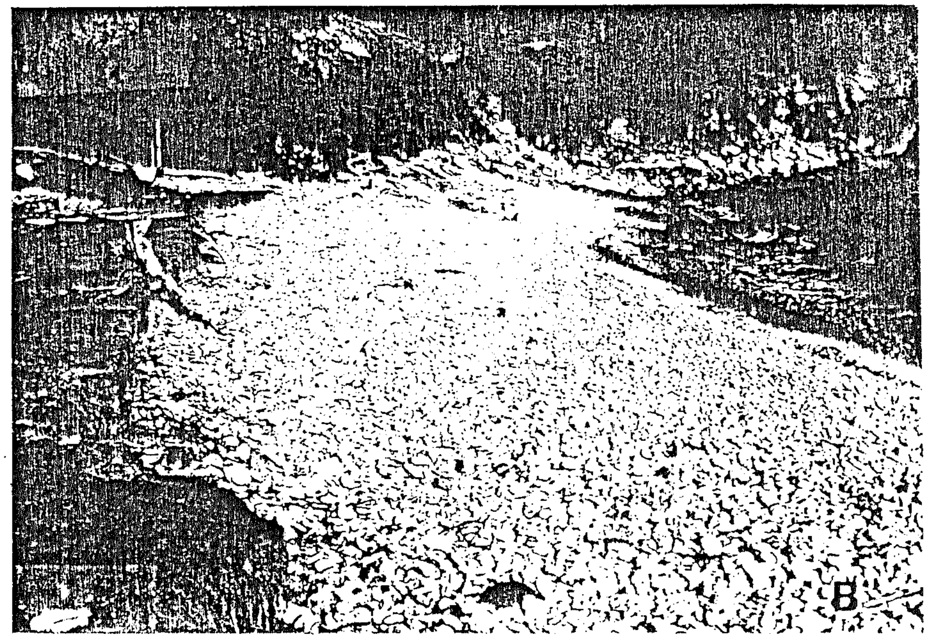
Black Brook Cove Beach

The pocket beach at the head of Black Brook Cove, although not very large, is one of the more accessible recreational beaches in the Park. In November 1983 a beach survey was completed to enable a comparison of the post-storm profile at Black Brook with that of Ingonish Beach (Fig. 9).

The backshore slope consists of two terraces; the upper one is presently a parking lot and the lower one has been sodded with grass for a picnic area. Beneath the sod is a deposit of till over bedrock. The present beach is composed of subrounded to well rounded pebblesand cobbles composed of granite and gneiss. Their size varies from 39 to 166 mm which is very similar to the coarse clasts on Ingonish beach (Table 2).

The smallest clasts cover the lower foreshore slope on both beaches, and below low tide level the more gradual slope at Black Brook beach is covered by boulders and sand. A similar foreshore slope was observed at both beaches but the crest height at profile 1 and 2 Ingonish Beach was slightly higher (Table 2).





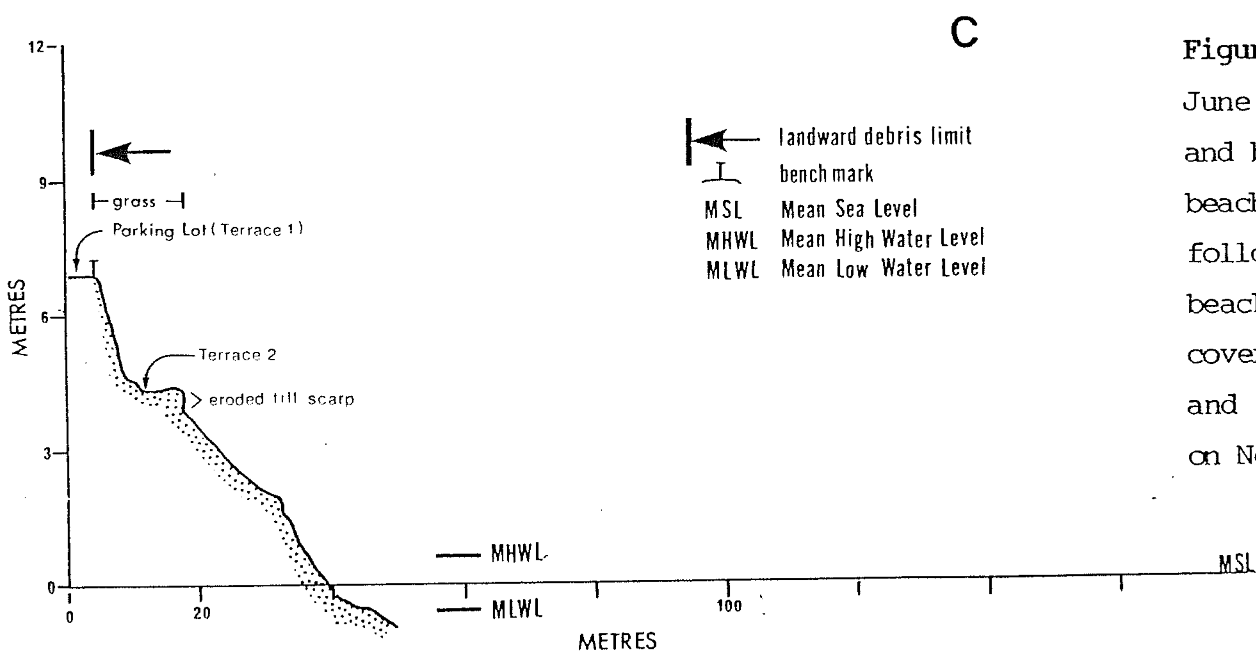


Figure 9. View of Black Brook Beach (a) June 25,1983 with a single swash ridge and beach cusps developing on the lower beach slope; (b) November 1, 1983, following the October storm surge the beach was combed down and the grass covered terrace was eroded back 1 to 2m; and (c) cross-sectional profile surveyed on November 1, 1983.

Before the October 1983 storm Black Brook Beach was characterized by a series of swash ridges and beach cusps. During the storm the entire beach slope was combed down and the upper beach was cut back 1-2 m resulting in a 0.5 m high scarp (Fig. 9b). Many subangular cobble clasts were derived from the eroded till and added to the upper beach. Other cobbles were tossed upslope to the main debris line 4.0 m above msl and some as high as the parking lot at 6.9 m above msl. The overwash deposits were blade to disc-shaped with a B-axis of 57 to 86 mm. Net beach change during the October 1983 storm was greater than the net change observed in photos between April 1979 and June 1983. Damage to park facilities was much greater along the lower shores adjacent to the mouth of Black Brook than at the pocket beach described above.

Neil Harbour Beach

One of the largest sand beaches along the eastern Cape Breton Highlands coast is the barrier beach at Neil Harbour (Fig. 1). The 200 m long barrier appears to have prograded from the south where it is wider and backed by relatively stable, vegetated, sand dunes. At the northern end of the barrier the beach form is much more ephemeral because of the shifting position of the tidal channel. Recent changes in the barrier morphology are illustrated in Fig. 10 using photography taken between May 1979 and November 1983.

Between May and November 1979 the central portion of the barrier prograded as the inlet shifted northward. Also, a long sand bar prograded northward nearly completely cutting off the tidal inlet and forcing the channel to flow even farther north. No photos were available in 1980. By February 1981 the barrier had not substantially changed even though the

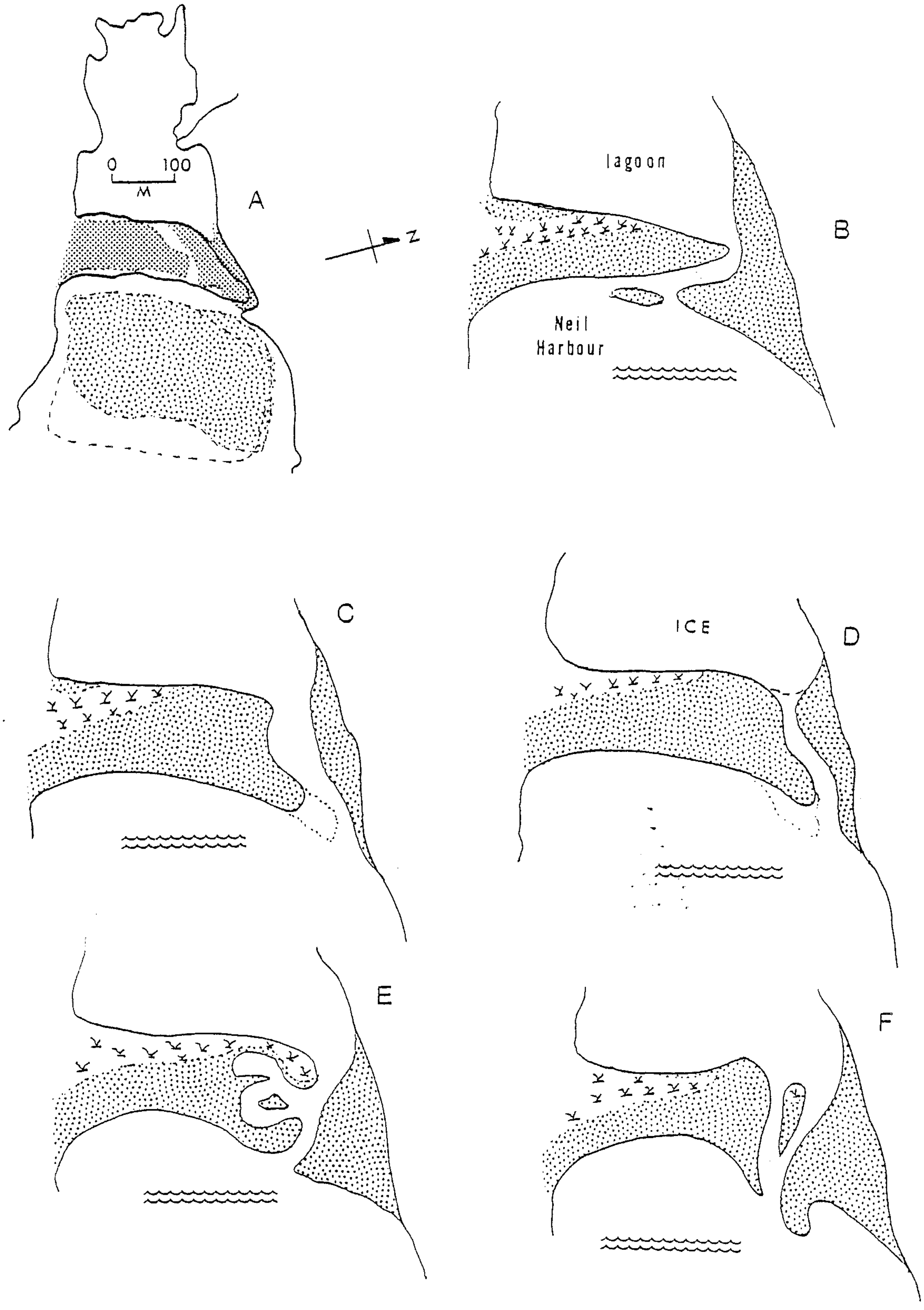


Figure 10. The tidal channel at Neil Harbour Beach continually shifts back and forth along the northern and central portion of the sand barrier. In (A) Differences in beach plan between 1939 (dark lines) and 1966 (shaded area) are shown with the reduction in size of the sand body observed offshore (shaded area is 1966). Sketches (B-f-not to scale) of changes observed along Neil Harbour Beach between May 1979 and November 1983 are illustrated - (B) May 1979, (C) November 1979, (D) February 1981, (E) June

tidal channel had shifted to the south again. The ebb tidal sand bar was gone and wave overwash had occurred along the southern portion of the barrier. No photographs were available for 1982; however, it is evident from photos taken in early 1983 that the backshore dune system had extended much farther north during the interim period. Also, the main tidal channel as it shifted south had cut into the duneline and water was ponded between the dunes and a recently built beach berm. In the October 1983 storm the barrier was breached along the narrow portion of the duneline and two tidal channels resulted. A relict portion of the duneline was left between the tidal channels. Where waves did not manage to cut through the duneline, they did erode a dune scarp. Ebb and flood tidal deposits also increased in size with greater sediment flushing through the channels.

From these brief observations it is concluded that: (1) the southern portion of the Neil Harbour barrier is the most stable part, (2) a substantial sand source must exist in Neil Harbour to allow the periodic buildup of the barrier, (3) as the barrier beach increases in width and length, the dune system also extends in height by trapping more sand, and the duneline extends northward, (4) if the tidal channel shifts alongshore by cutting into the dune line it leaves the barrier vulnerable to breaching during major storms such as the October 1983 event.

Effects of Man on Beach Stability

In recent years National Park's staff have altered the sediment distribution across beaches to produce aesthetically pleasing, i.e. sand, beaches for the tourists and built shore protection structures to protect recreational facilities from wave erosion.

At Ingonish Beach Park officials noted that less sand was covering the upper slope in recent years. Therefore, to speed up the natural process of sand moving upslope in summer, they bulldozed sand from the lower foreshore and spread it across the upper beach. It is not known how long the Park staff had been redistributing the sediment on Ingonish Beach. From our own photos we know that the operation took place in 1980, 1982 and 1983. Recently the Park officials became worried about their actions because in the fall and winter sand was blown inland across the parking lot and was presumably lost to the littoral system. Following observations in March 1983 it was concluded by the authors that only the sand above storm swash limit was lost to the interior by wind. The sand covering the mid-lower beach was returned to the sea by wave backwash and by a small subsurface stream which flows beneath this part of the beach.

In June 1983 an explanation for the abrupt change in beach morphology between beach segments C and D was discovered. It was found that before the Park's staff spread sand across the upper beach they would plane down the cobble storm ridges and transport the cobbles away (Fig. 11). For instance, in June 1983 they took the cobbles to Broad Cove Beach and dumped them in front of the shore retaining wall. The removal of cobbles resulted in a nice gradual slope on Ingonish Beach; however the loss of coarse material is very detrimental to the stability of the whole Ingonish Beach system. By removing the cobbles the beach crest elevation is lowered, the protective core of coarse clasts is reduced, and the beach slope is reduced. All of these factors lead to greater wave runup and washover. Furthermore, Ingonish Beach presently does not have a large source of coarse material for beach rebuilding and maintenance. Therefore the loss of sediment must either be made up by sediment derived from other parts of

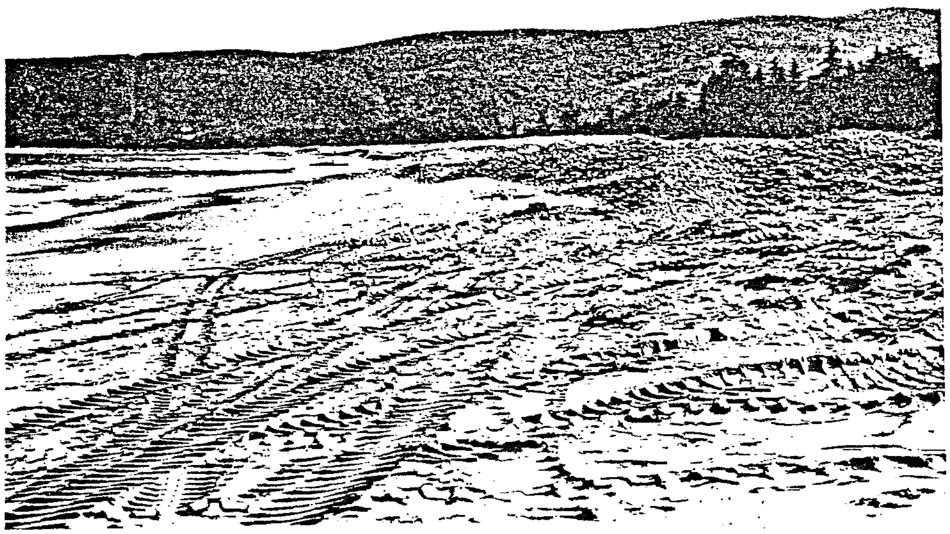


Figure 11. In June 1983 cobbles were removed along segment D (Fig. 3), Ingonish Beach, so that sand could be spread from the lower foreshore to the upper beach. The beach cobbles were trucked to Broad Cove Beach where erosion was occurring.

the beach, or the beach segment affected must adjust its profile to present wave conditions to maintain a dynamic equilibrium.

On October 25, 1983 the inevitable occurred when high water levels and large waves completely washed over Ingonish Beach at the site of cobble removal (Profile 3, Figs. 4,7). The great contrast in beach change at profile 1 versus profile 3 on Ingonish Beach graphically illustrates the effect of removing material, particularly the coarse clasts, from a beach.

Although some material can be derived from the till cliffs to the north of the beach, the input is much less than the amount annually trucked away from beach segment D. If the practice of removing cobbles continues then more sand will be lost to the hinterland because of more frequent wave overwash. Also the stability of the entire beach system could be in jeopardy because sediment will be transported from other parts of the beach to replace the lost sediment. Then the overall width of Ingonish beach will decrease and so will its ability to withstand storms. Such was the case at other beaches in Nova Scotia where beach sediment has been removed for construction aggregate (Taylor *et al.*, 1983).

At *Broad Cove Beach* a different set of circumstances has occurred. The National Park in an attempt to protect the campground facilities has built a high retaining wall along the glacial outwash terrace south of Warren Brook. The wall has effectively prevented shore erosion but at the same time has prevented waves from reworking the main source of sediment for beach maintenance. Therefore waves must acquire sediment from other parts of the Cove to maintain beach stability.

Presently the retaining wall has poor toe protection and is experiencing undercutting and severe corrosion by sea water. In June 1983, cobbles from Ingonish Beach were dumped in front of the retaining wall to help reduce wave undercutting, however during the October 1983 storm most of the cobbles as well as some of the boulders protecting the wall were removed. In addition, sediment was lost from behind the wall through large holes eroded along the base of the retaining wall, and around the ends of the wall because of bank erosion by surface water runoff. While the retaining wall has protected park facilities for some twenty years, it is possible that it also prevented the formation of a wider beach. Hence a trade-off has been made to allow park facilities to be placed so close to the sea.

Other activities by Park staff in the coastal zone are known to have taken place along Clyburn Brook and the golf coarse but there is insufficient information to make further comments at this time.

Recommendations

On the basis of the 1983 field observations along the east coast of Cape Breton Highlands National Park the following recommendations are made:

(a) Do not remove any further sediment from the beaches of the Park.

If sand beaches are an absolute necessity where cobbles now exist then try to restrict the movement of sand to the lower portion of the beach, ie, below higher high water, and deposit it overtop of the cobbles. Do not remove the cobbles.

At Ingonish beach attempt to maintain or increase the present beach crest height along segment D. This can be done initially by replacing the material overwashed into the parking lot in October 1983 back onto the upper beach slope. Since it is a mixture of sand and cobbles, the sand will have to be stabilized so that winds do not carry it inland.

snow fence established along the upper beach in a zig-zag pattern would help trap most of the sand moved during strong winds. However once trapped, the sand must be stabilized. The easiest method is through the planting of marram grass. The area of transplanting would then have to be prohibited to public traffic to allow the grass to grow. Apart from the above suggestion to initiate dune development, Ingonish beach should not be reshaped nor the sediment redistributed by man for a minimum of two years. This would allow two complete seasons (summer-winter) for a monitoring program to determine the natural processes that are reworking the beach and the rate of natural changes which are occurring. Previously it has been impossible to distinguish the effects of natural versus artificial changes to the beach.

At Broad Cove the shore retaining wall requires major repairs - improved toe protection, replacement of bottom panels and the infill of sediment behind the wall. If it is assumed that the wall is removed for safety reasons and is not replaced, then the bank that it protects will erode rapidly (estimated 1-3 m/yr) for the first few years until it can protect itself with a wider beach in front. Bank erosion would result in a wider entrance to the Warren River Valley and increased sedimentation at the river mouth. It is also possible that the beach south of the present retaining wall will increase in size due to the increased sediment input. It is recommended that cliff recession stakes be placed along the top of the cliff fringing Broad Cove Beach to determine the present rate of cliff retreat so that if the shore retaining wall is removed, a comparison of retreat rates can be made before and after the presence of the wall.

(b) New park facilities should be placed at greater elevations or distances from the sea than they are presently. On the basis of the storm swash limits measured along beaches after the storm of October 1983, facilities should be placed at least 6 m above msl, if they are to avoid damage during storms. Furthermore, parking areas, scenic viewpoints and picnic sites should not be placed at the end of wave cut hollows along the outer coast because waves tend to funnel up these hollows during storms and reach extreme coastal elevations, e.g. Laheys Point.

(c) A monitoring program of photographing and/or surveying the main recreational beaches should be instigated. Such a program provides a valuable source of information for beach management plans and the history of the park.

(d) Continue the program of beach walks to educate the general public and Park employees about the dangers of removing beach sediment and informing them about the fragile nature of beaches.

Future Studies

Many of the answers that we seek about the post-glacial history of northern Cape Breton Island may be found in and around Ingonish Bay. The following is a list of suggested topics for future study, possibly as university graduate theses. They would inform us on how the present shoreline has evolved during the Holocene and how it continues to readjust to rising sea levels.

(1) A shallow water seismic, bathymetric and side scan sonar survey of Ingonish South and North Bays would provide information on the location and

thickness of present sand deposits and relict glacial lag deposits. Also, evidence of former glacier limits may be found at the mouth of the Bays.

(2) A bathymetric survey and coring program in Freshwater Lake could provide control dates for the Holocene transgression and when the lake was cutoff from the sea by the barrier beach.

(3) Future monitoring of the barrier beach fronting Ingonish Harbour would provide information on how beaches destroyed in catastrophic storms either recover or reform farther inland in response to rising sea level.

Acknowledgements

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Appendix 1

Beach Profile Locations

Ingonish Beach

Ingonish Beach, Victoria County, is located in South Bay Ingonish, between Cape Smoky and Middle Head, Nova Scotia. Follow the Cabot Trail northeast from the village of Ingonish Beach turning right at the road leading to Keltic Lodge. Proceed down the first road to your right past the tennis courts to the beach parking lot. Three beach profiles were established on November 2, 1983 (Fig. 4). The compass bearings and other relevant information for each profile are listed in Table 3.

Profile 3 is located at the north end of the beach adjacent to the parking lot. The bench mark (BM) is the southern post of a sign at the back of the relict sand dunes. The temporary bench mark (TBM) is a 3/8" diameter steel rod located just landward of a low stone wall, which is beneath the relict sand dunes.

Profile 2 is approximately 200 m farther south and is seaward of the north wall of the beach house. The bench mark is a tree stump 17.4 m seaward of the main paved walkway and 3.8 m landward from the seaward edge of the grass. The stump is identified by a 3/8" diameter steel rod is on its south side (Fig. 12b).

Profile 1 is 260 m south of profile 2 on the barrier enclosing Freshwater Lake. The bench mark is a lone spruce tree 8.9 m seaward of the edge of a path running along the backside of the barrier. Two rock cairns are also

Note: In 1984 metal reinforcing rod was established just beneath the ground surface at each BM. A metal detector could be used to find the rods. Zero datum is the top of the rods.

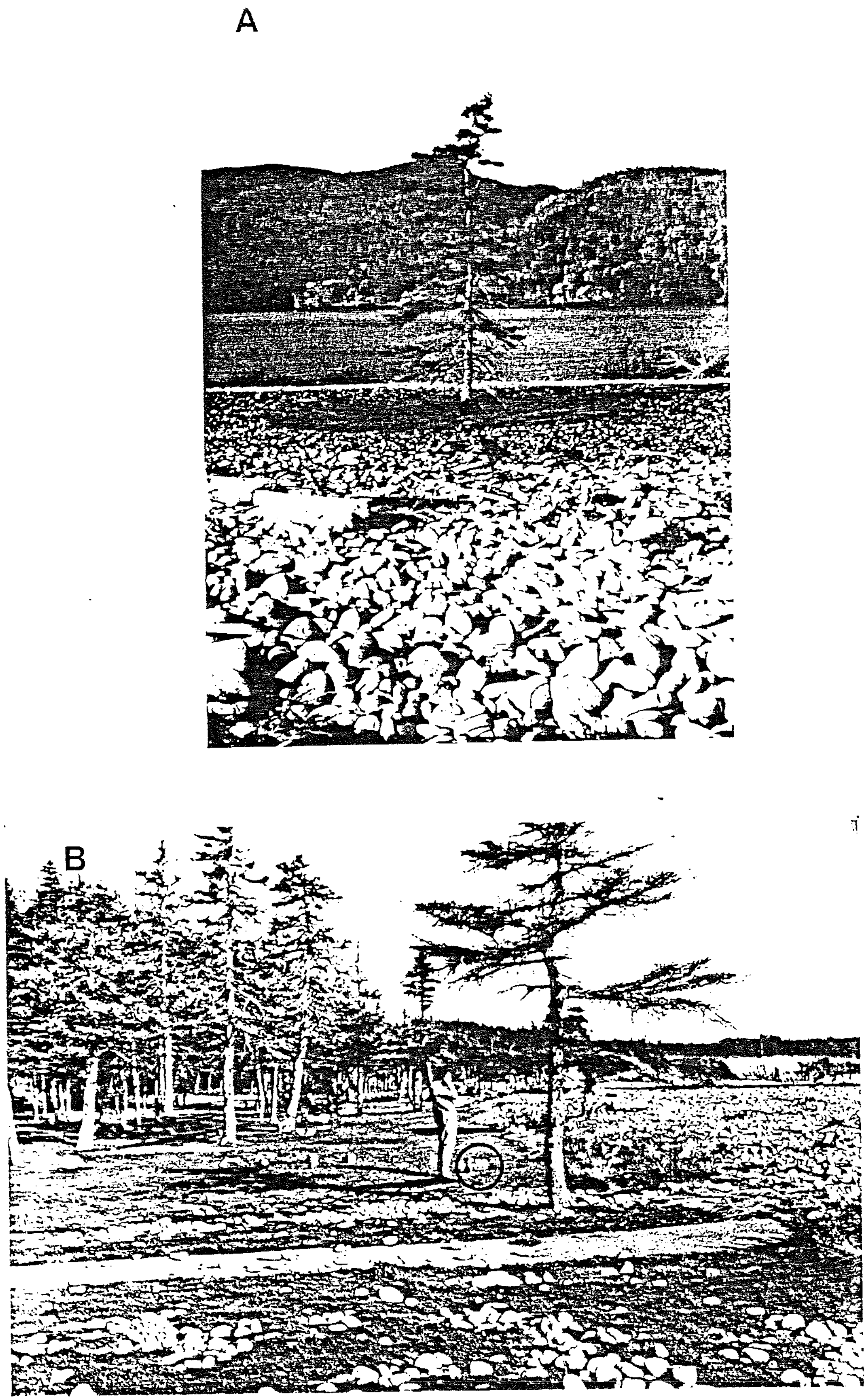

Figure 12(a). View of the backshore at profile 1 Ingonish Beach. The bench marks consist of the tree and two rock cairns (arrow) seaward of the tree. **(b).** View of the backshore at profile 2 Ingonish Beach. The bench mark is the tree stump (circled).

Table 3. Beach Survey Information for Ingonish Beach, November 2, 1983.

Profile No.	Distance (m) (BM-TBM)	Height (m) BM	Height (m) TBM	Profile Bearing (°)[1]
3	0.9	1.82	0.43	127
2	-	0.32	-	118
1	4.68	rock cairns		108

[1] All compass bearings were taken with a Brunton Compass - relative to Magnetic North Pole.

located along the profile line seaward of the tree (Fig. 12a). The most seaward cairn has a 3/8" diameter steel rod within it for identification purposes.

Black Brook Cove Beach

Black Brook Beach, Victoria County is situated north of the mouth of Black Brook at the head of Black Brook Cove. Follow the Cabot Trail north from the village of Ingonish to the bridge crossing Black Brook. Turn right at the first road past the bridge into the Black Brook picnic grounds parking lot (Fig. 13).

Proceed to the south end of the parking lot where there are three wooden posts blocking vehicle access to the picnic shelter (Fig. 13). The top of the most seaward post was used as the bench mark for a profile across this beach. The profile extends from the seaward side of the bench mark, across the grass terrace south of the access stairs, along a bearing of 125°, Magnetic North. The height of the BM was 1.0 m. No TBM was established during the survey of November 1, 1983.

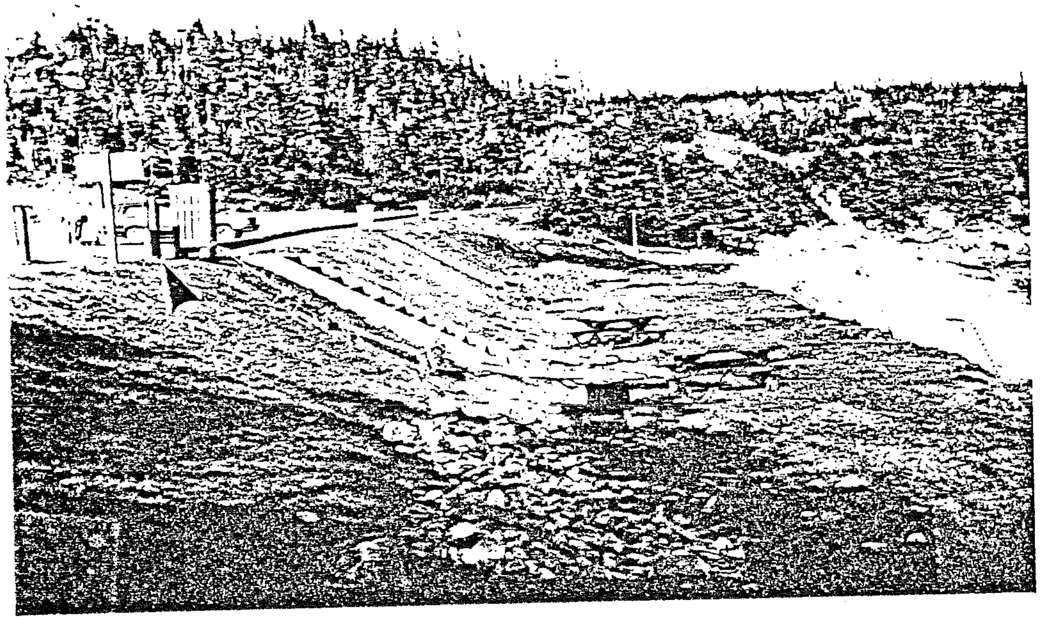

Figure 13. Photo of the beach profile established at Black Brook Cove.

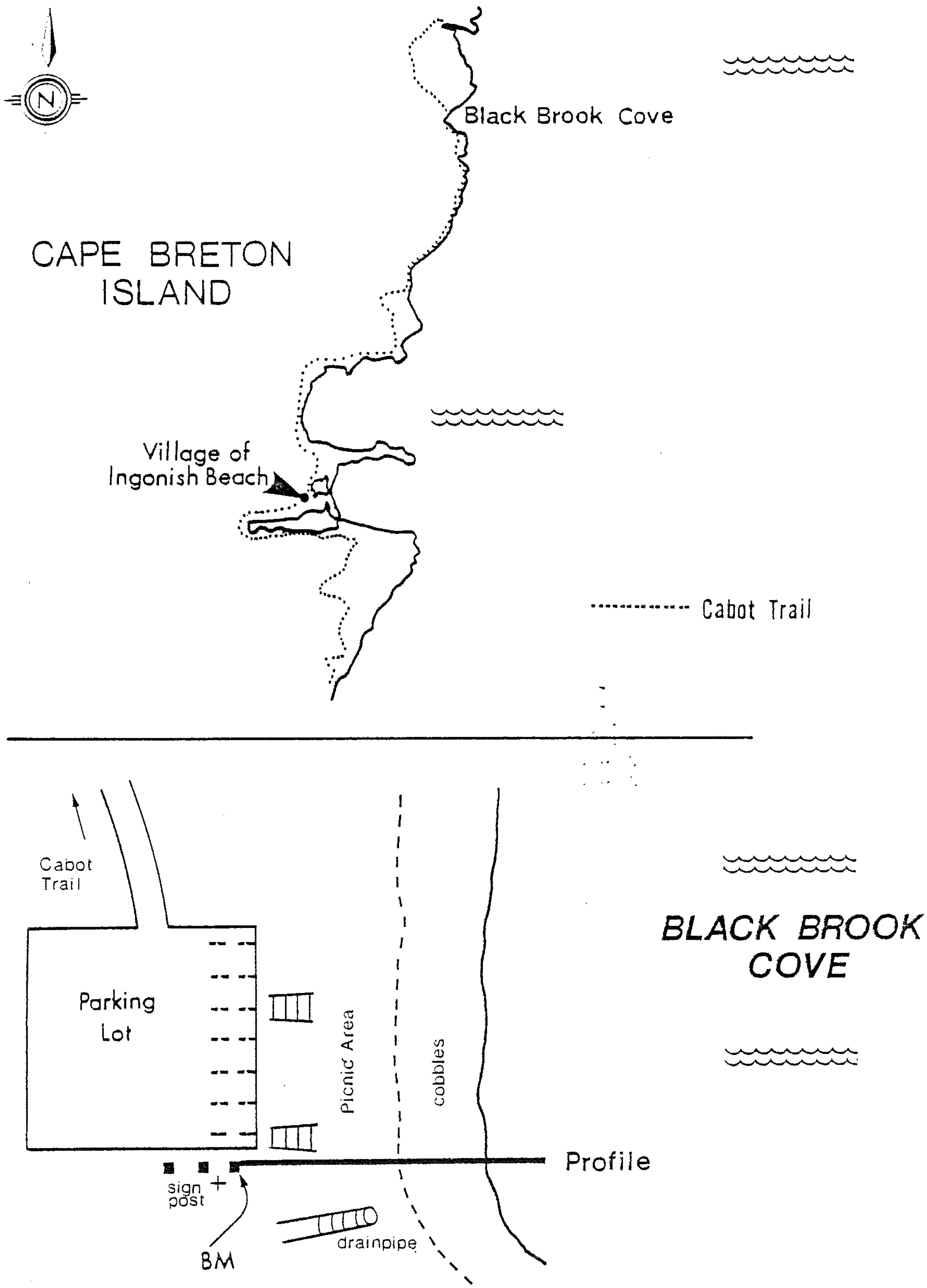

Figure 13. Location map of the beach profile established at Black Brook Cove.

Appendix 2

Beach Profile Data - Field Surveys

Introduction

A computer printout of field survey data is provided which lists information for all the beach profiles surveyed in November 1983 and June 1984 to document beach morphology. The survey data are listed alphabetically by beach name and profile number. An explanation is provided below.

Example of Computer Printout

```
1200                          (A)
Advocate Beach                (B)
AD -- 28/07/81 - 68           98     1     39     64
    (C)        (D)     (E)     (F)   (G)    (H)    (I)
-30----14---20-----4----30-----8 ...30-----12
(J)   (K)   (J)   (K)   (J)   (K)...(J)   (K)
```

(A) -Col. 1-5, -An arbitrary elevation used to initiate the first survey point high enough that the beach profile is not plotted below the x-axis.

(B) -Col. 1-20, -Beach Name

(C) -Col. 1-12, -Code for Beach Name and Date of Survey (dd/m/y)

(D) -Col. 13-15, -Number of paired survey points (J,K) listed for each beach profile.

(E) -Col. 16-20, -Water level (no data provided)

(F) -Col. 21-25, -Height of Bench Mark (in cm)

(G) -Col. 26-30, -Beach Profile Number

(H) -Col. 31-33, -The n^{th} paired survey points where high tide limit existed at the time of the survey (no data).

(I) -Col. 34-36, -The n^{th} paired survey points where low tide limit existed at the time of the survey (no data).

(J) -Repeater, -Distance (in decimetres) between the given survey point and the previous survey point.

(K) -Repeater, -Difference in elevation (in centimetres) between the given survey point and the previous survey point.

NOTE: The first survey point (0,0) of each beach profile is not listed, the data begin at the second survey point.

BEACH SURVEY DATA 1983-1984

```
 700
INGONISH BEACH
IB--02/11/83 27                 1
 30    35 30   37 30   14 30   33 41   55 51   27 52   08 37   08 47   20 30   16
 48    21 30   21 30   41 30   23 30   15 30   01 30   17 45-  12 30-  97 30-  78
 26-   28 13-  69 16-  50 30-  62 26-  54 30-  50 30-  25
 700
INGONISH BEACH
IB--02/11/83 35           32    2
 30-    1 30-   3 30   05 30    7 30   11 24   13 13   01 25   47 30   14 30   11
 30    11 30   01 30-  22 30-  48 30-  70 33-  64 15-  44 13-  70 30-  62 24-  44
 30-   48 30-  23 12-  18 30-  22 30-  09 29-  03 30-  07 20-  05 20   43 30    4
 30-   04 30-  08 30-  08 30-  04 30-  06
 700
INGONISH BEACH
IB--02/11/83 56           181   3
 50-   07 50-  03 50-  03 50-  03 50-  04 50-  03 50-  03 50   03 50-  02 50    7
050    09 50   09 50   05 50   01 49-  23 09   12 08  1133.5-  54 30-  24 30-  31
 30-   30 30-  24 30-  23 19-  01 30-  20 30-  31 30-  25 30-  08 39-  09 30-  45
 30-   36 30-  38 30-  38 22-  24 11-  128.5-  10 21   07 30-  16 30-  03 30-  17
 30    08 10   01 30   11 30   04 30   01 30   02 30-  01 30-  03 30-  06 30-   4
 30-   06 30-  04 30-  03 30-  07 30-  08 30-  14
 900
BLACK BROOK COVE
BC--01/11/83 21           105   1
006-   08 15-  75 13-  76 13-  67 30-  29 30   07 24-  05 03-  52 30-  49 30-  53
030-   39 30-  37 19-  10 08-  29 07-  12 15-  59 30-  64 22-  49 30-  26 30-  12
030-   32
 700
INGONISH BEACH
IB--15/06/84 18                 1
 30    10 44   15 30   31 30   34 30   30 43   16 30    8 30    3 23-  10 12-  94
  8-   52 10-  57  6-  29 18-  54 13-  25  8-  32 18-  30 13-  32
 700
INGONISH BEACH
IB--15/06/84 22           31    2
 12-    1 19   37 23   25 30   15 30   11 30    4 30-  16 20-  16 25-  47 22-  57
 12-   12 12    9 10-  32 11    1  9-  14 10-  34  8-   5 12-  42 12-  52  9-  14
 21-   28 19-  22
 700
INGONISH BEACH
IB--15/06/84 17           146   3
 11    43  7-   6  9   94  3-  34 20-  18 30-  26 30-  38 30-  16 24-  12 30-  10
 30-   30 30-  42 38-  32 23-  14 21-   7 22-  17 23-  24
 800
BLACK BROOK COVE
BC--15/06/84 18           105   1
  7-   10 17-  84 12-  66 14-  72 15-  40 40   12 28-   7  4-  14 10-   6 20-  44
 20-   56 20-  40 20-  36 20-  42 20-  22 21-  24  1    3 15-  63
```

Addendum

Observations of Ingonish and Black Brook Cove Beaches, June 1984

On June 15, 1984 an opportunity arose to resurvey the beach profiles at Ingonish and Black Brook Cove Beaches. The following is a summary based on a comparison of the recent survey with the one completed in November 1983. Unfortunately, the recent survey was completed on a rising tide hence information for the lower portion of the beach is missing.

Ingonish Beach

Quiet sea conditions had persisted for several days prior to the June survey. As a result, sand was being transported upslope in the form of a welded berm at high tide level.

Three profiles are insufficient to provide a complete picture of what is happening on Ingonish Beach. More information is required about changes to the beach south of profile 1. Nevertheless, the changes that were observed in the established beach profiles provide the following information:

(1) The absence of morphological changes across the backshore and upper beach suggests that no storms greater than the October 1983 storm surge had occurred since November. Sand and cobbles had been bulldozed back onto the northern end of Ingonish Beach from the parking lot but no apparent change was visible at beach profile 3 (Fig. 14).

(2) The upper limit of sand deposition was at or above the elevation observed in the fall of 1983. In June the upper limit of sand increased in elevation northward from profile 1 to 3 as the beach slope decreased (Fig. 14).

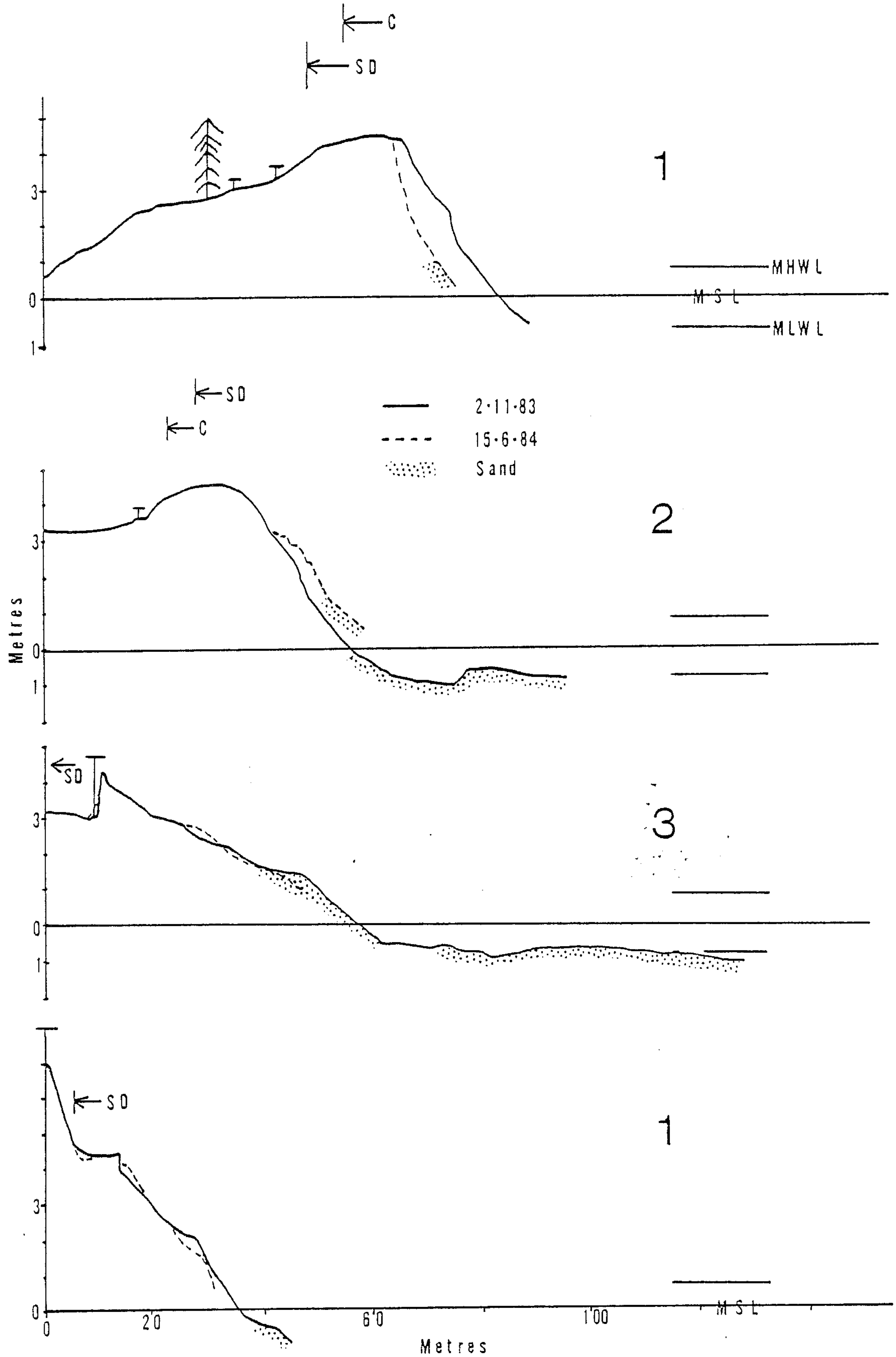

Figure 14. A comparison of beach profiles surveyed on November 2, 1983 and June 15, 1984 at Ingonish Beach (1-3) and at Black Brook Cove Beach (bottom profile). The storm debris (SD) line and the boundary between undisturbed (lichen covered) and mobile cobbles (C) were surveyed following the October 1983 storm surge discussed in the main text. Locations for the beach profiles are provided in Figures 4, and 13.

(3) Over the seven months profile 1 which is located across the Freshwater Lake barrier had retreated 6.2 m at msl. Its beach face slope was 33.6°, it was very unstable and is vulnerable to further attack if moderate to large wave conditions resume.

(4) Profile 2 which is located farther north alongshore had prograded with the addition of several small swash ridges.

(5) Profile 3 exhibited less change than the other profiles. Sand had returned to the beach but there was less on the mid-beach slope than in late 1983.

On the basis of these observations it can be concluded that cobbles and pebbles are being eroded from the Freshwater Lake barrier and transported northward to replenish sediment lost from that part of the beach. It is possible that sediment is also moving southward and offshore but visual observations indicate that erosion is continuing along south Ingonish Beach and no new sediment has been added to the barrier fronting Ingonish Harbour. No information is available for the nearshore or offshore zones.

It is concluded that Ingonish Beach is readjusting to the artificial changes which it experienced over the past few years. It appears that earlier conclusions may be right - that sediment is being removed from the barrier at Freshwater Lake to rebuild adjacent beach areas. Detailed monitoring (including more profiles) of this barrier over the next year is very crucial, particularly now that a decision by park officials has been made to leave the beach alone.

Black Brook Cove Beach

Black Brook Beach was recently cleaned of debris and cobbles deposited in the backshore during the October 1983 storm surge. In the cleanup process the cobbles were pushed back on the beach and the entire beach slope was planed down to a smooth slope. The erosional scarp cut in the October 1983 storm was now barely visible. Over the past few days prior to our survey on June 15, 1984, the waves had begun reworking the beach cobbles into a swash ridge near higher high tide level (Fig. 14 - bottom profile). Black Brook Beach appears to be fairly stable and it is anticipated that the waves will quickly rework the entire intertidal zone, and develop a series of swash ridges.

Acknowledgements

I wish to thank Warden Chip Bird for his able assistance in surveying the beaches in June 1984 and his enthusiasm to learn more about the beaches of Cape Breton Highlands National Park.