MARINE AND COASTAL GEOLOGY BETWEEN HARTLEN POINT AND JEDDORE CAPE NOVA SCOTIA

BY

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TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

Acoustic and sample data have been collected in a 600 km^2 area of the innermost Scotian Shelf along the Eastern Shore just east of Halifax. In addition sediment distribution has been mapped and rates of coastal change determined along the 40 km long coastline. Surface-towed sparker, V-fin, and 3.5 KHz reflection seismic records alongs with sediment samples show surficial material to consist of post-glacial sediment, glacial till, and bedrock. Sediment in the area occurs in patches, forms a thin veneer over bedrock, and fills depressions between bathymetric highs. The maximum thickness of sediments ranges up to 50 milliseconds (two-way travel time) or approximately 20 metres, in the offshore areas. Relict glacial till deposits are up to 30 msec. thick; some have drumlin-like forms.

An average annual rate of cliff retreat of .81 metres per year was recorded from six stations along the shore. Comparison of 1945 and 1974 air photos reveals an average annual retreat rate of .71 metres per year. This coastal retreat results in approximately two million cubic metres of unconsolidated sediment being supplied through erosion to the coastal zone. The geological evolution of the study area is interpreted as being strongly influenced by the Holocene transgression in water depths of less than 50 m. During transgression, coastal erosion of till cliffs may have been as rapid as at

present, thus supplying large amounts of sediment to the nearshore area. Where glacial till was protected during the marine transgression by barrier beaches the till was covered by lagoonal sediments and was consequently preserved from nearshore erosion.

ACKNOWLEDGEMENTS

This project was conducted under the guidance of Dr. D. J. W. Piper whom I wish to thank for his assistance in organization, field work and critical reading of the manuscript. Thanks are also extended to Dr. C. Milligan for his critical editing of the text.

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CHAPTER 1

INTRODUCTION

The study area is located on the Atlantic coast of Nova Scotia and is centered at longitude 65°15'West, latitude 44°40'North (Figure 1.1). The area mapped extends from the mouth of Halifax Harbour, thirty km along the coast to Jeddore Cape and twenty km offshore. The coastline has several long traverse inlets, some of which are partially blocked by barrier beaches.

PURPOSE

The primary objective of this study was to delineate the spatial distribution of bedrock, glacial till, and post-glacial sediment in order to contribute to an understanding of the late Quaternary evolution of the area. In addition morphological change of the coastline during the past 200 years was determined in order to determine the character and rate of coastal change. Examination of the present coastal processes allows one to account for past events and postulate future coastal changes.

The study involved several methods of analysis including (1) high resolution seismic reflection profiling and 3.5 KHz acoustic profiling, (2) surficial sediment sampling,

FIG. 1.1

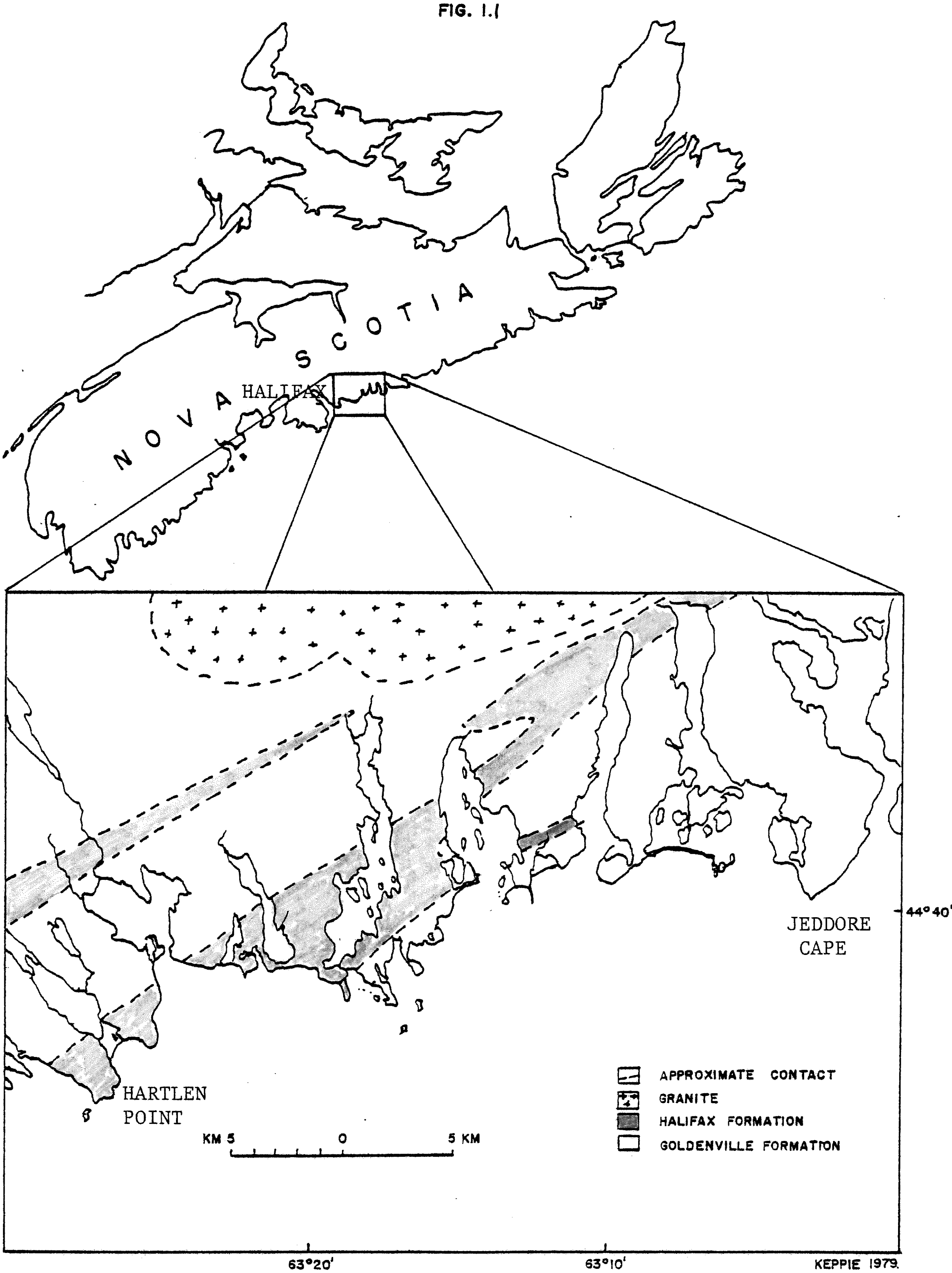


Fig. 1.1. Location of study area and bedrock geology

(3) cliff retreat survey.

1.1 Bedrock Geology

The study area is underlain by metasedimentary rocks of the Cambro-Ordovician Meguma Group, comprising intercalated Halifax Formation slates and Goldenville Formation quartzites (Keppie, 1979). The Musquodoboit batholith lies ten kilometres inland. The coastline is sub-parallel to the trend of the folds of the Meguma Group. There is a prominent structural lineation of right angles to the fold trend marked by lakes, streams, and coastal inlets; presumably this lineation was accentuated by the Wisconsinan glaciation. Inland bedrock outcrops are of higher relief than those on the coast, where most outcrops are at, or below, sea level.

1.2 Surficial Geology

The eastern part of Nova Scotia has an average thickness of three metres of till cover (Stea and Fowler, 1979). Outcropping at the shoreline are four types of till. They are, in decreasing order of abundance: (1) Quartzite till, which is derived primarily from the Goldenville Formation, (2) Lawrencetown till, a red till with a high proportion of clay, (3) Hartlen till, which is a compact grey till of uncertain origin, and (4) Slate till, derived from the Halifax Formation (Stea and Fowler, 1979). There are glaciofluvial deposits located five kilometres inland along Cow Bay and Petpeswick Inlet. Lawrencetown till occurs as drumlins along the entire shoreline with the highest concentration between Cow Bay and Chezzetcook Inlet. These drumlins average ten metres in height; the highest is 25 metres, while the average cliff height is about nine metres.

There are several barrier beaches along this section of coastline (Figure 1.2). The most extensive of these is Martinique Beach, which extends for 3.5 km from the mainland to a bedrock outlier called Flying Point. Other barrier beaches have developed near Meiseners Head, Story Head, Seaforth and Cow Bay. Sand and cobble beaches are present close to eroding drumlins; for example, Hartlen Point and Lawrencetown Beach.

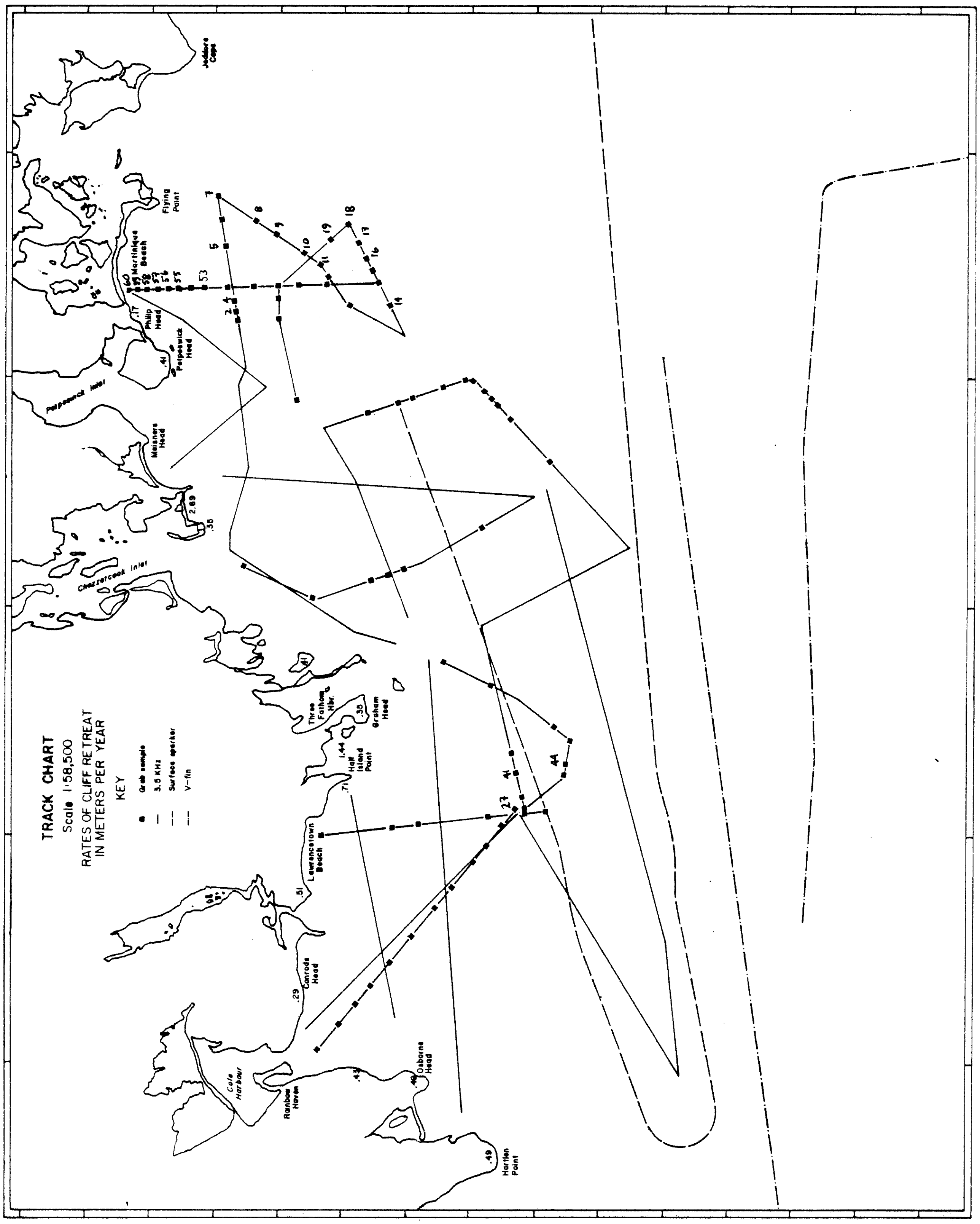


Figure 1.2. Detailed shoreline map.

CHAPTER 2

METHODS

2.1 Introduction

Most of the field work was carried out between the 25th and 29th of August, 1980, with the collection of 150 km of 3.5 KHz acoustic reflection profiles and 77 grab samples of surficial sediments. In March of 1980 and again in March of 1981 sparker seismic reflection profiles were collected from CSS Dawson. Several piston cores were attempted, one of which was successful. Surveys of cliff retreat have been made intermittently from August 1980 to April 1982.

2.2 Acoustic Reflection

The 3.5 KHz acoustic reflection profiles were obtained from the "Sylvia and Joyce", a rented 42' (12.8 m) Cape Islander fishing boat. The large deck aft proved sufficiently spacious for the ORE 3.5 KHz transducer, hydraulic winch, gasoline-powered electric generators, boom with pulley, and Shipec grab sampler. The EPC chart recorder was housed in the wheelhouse. Navigation was by radar to known points.

Surface-towed sparker and deep-tow V-fin sparker single channel, seismic reflection profiles were obtained on CSS

Dawson cruises 80-004 and 81-006. These acoustic data were used to map sediment types, locate areas suitable for sampling, and to prepare isopach maps of sediment and till.

V-fin and surface-towed sparker profiles provide high resolution and good penetration of the seafloor. These records show very clearly the interface between bedrock and sediment. They were also useful in interpretation of the 3.5 KHz profiles.

The 3.5 KHz and sparker profiles were interpreted in terms of: (1) strength of acoustic reflection, (2) degree of scatter of the reflection, (3) the form of the reflection in relation to the records from surrounding areas, and (4) correlation with surficial sediment samples.

2.3 Cliff Retreat: ground survey

Retreat was determined by setting survey stakes at six stations along the coastline, remeasuring the distance from the cliff edge to these stakes periodically. Preliminary selection of erosional headlands was made by examination of topographic maps, marine navigation charts, and air photos. Particular attention was given to known drumlin fields.

Staking was done with one inch (2.54 cm) angle iron which was cut into one-metre lengths. Stakes were placed at 30 metre intervals parallel to the shoreline. All the stations staked were drumlins, except at Hartlen Point, where a section of the till sheet was staked. All the drumlins staked had exposure to the open sea; some, in the eastern part of the area, rest upon nearly vertically dipping Meguma Group bedrock which limits erosion by waves. The cliff edge was defined as the break-point between the horizontal upper surface of the drumlin and the face of the cliff. In places where turf overhangs the cliff, the breakpoint was taken as the point where the line of the cliff would intersect the horizontal surface.

Several problems were encountered upon remeasurement of the staked headlands. At Collie Head the stakes were vandalized and not to be found, new stakes were set up in the summer of 1981. Telephone poles running the length of a till cliff at Hartlen Point were used as reference points for recession. Unfortunately these poles were removed and another telephone line was erected farther inland. Only one of the stumps remains.

2.4 Cliff Retreat: Airphoto Interpretation

Calculation of cliff retreat over a longer time period was made by comparison of 1945 air photos and 1975 orthoprints. A coastline map was compiled, from 1945 air photos, at the office of the Nova Scotia Department of Lands and Forests. Acetate film was used as an overlay and 1975 orthoprints were used as the base map.

Two lines were drawn on the acetate, one to represent the waterline and one showing the cliff edge. Features such as roads and railroads were plotted as reference points. Because the orthoprints and the airphoto map are the same scale, recession measurement was a simple process.

Cliff retreat was measured by superimposing the two maps and tracing the 1974 coastline onto the acetate map. Elevations were taken from the contoured orthoprints.

Two methods of obtaining the average cliff height were used. The first method involved measuring the cliff height every 100 metres along the entire coastline from contours on the orthoprints, then taking an average cliff height from these measurements. The second method involved using the same set of cliff measurements but dividing the coastline into zones of similar drumlin heights. These zones are: (1) Hartlen Point to Lawrencetown Head, (2) Half Island Point to Rudeys Head, (3) Storey Head to Jeddore Head (see appendix for data).

2.5 Sampling

A total of 77 Shipek grab samples were taken in conjunction with acoustic profiling. One shore piston core was taken during the Dawson 81-006 cruise.

Grab samples were described briefly at the time of collection, subsampled if the volume was sufficient, and stored in labelled glass jars. Small coarse-grained samples, often with Lithothamnion fragments, were not statistically valid for analysis and, therefore, were not used. When samples were of insufficient volume, the area was sampled two or three times until either a large sample was obtained, or the area was abandoned due to lack of sediment.

2.6 Sample Preparation

Gravel samples with sparse fines were wet-sieved through -2 ø, 0 ø, and 4 ø stainless steel screens. The silt and clay fraction was ignored. The remaining sample was dried, cooled and sieved according to methods of Piper (1974).

The core was split, described and X-radiographed according to methods described by Piper (1974). X-radiographs were taken at 20 cm intervals on the Picker portable X-ray unit in the Geology Department. Contact prints were made from the X-radiograph negatives.

2.7 Carbon-14 Date

A few shell fragments were taken from the 1.34 metre depth in the core, washed, and sent to Krueger Geochron Laboratories, Cambridge, Massachusetts. The age of the shell fragments is 11,770 $\pm$ 330 years (GX 8093).

CHAPTER 3

ANALYSIS OF ACOUSTIC RECORDS

3.1 Introduction

Acoustic profiles are arranged in three groups, depending on their resolution. The best resolution came from the 1981 V-fin profiles, while the surface sparker records are adequate, in most cases, for distinguishing the sediment type and thickness. The 3.5 KHz profiles are adequate for telling the bottom type, but, in most cases the penetration is poor. Three distinct types of surface acoustic characters are seen in both sparker and 3.5 KHz records. Attempts at sampling provide some ground truth for these three types of reflector, which are identified as bedrock, till, and post-glacial sediment. Each is described below using a series of type examples.

3.2 3.5 KHz

3.2.1 Bedrock

The characteristic features of bedrock are strong, very irregular reflections which commonly show phyerbolae (Figure 3.2.1). Surface sampling yields lithothamnian and rock fragments. The acoustic basement is usually defined as being the strongest, lowest, acoustic reflector. This being so, most of the seafloor would be defined as acoustic basement but not necessarily bedrock because there is generally no

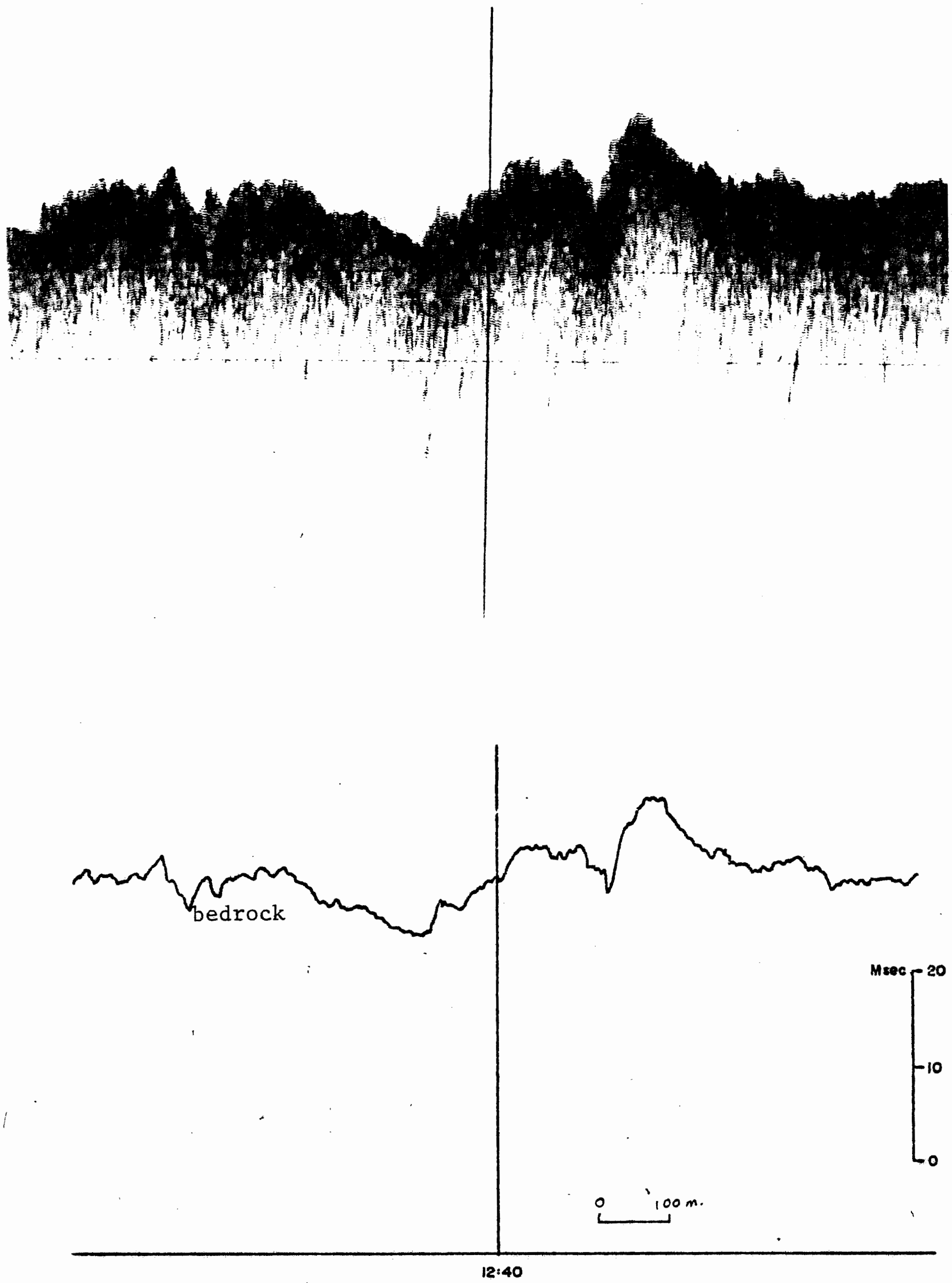


Fig. 3.2.1 3.5 KHz. record showing bedrock

penetration through the sediments.

3.2.2 Glacial Till

Till has an acoustic signature midway between bedrock and sand. The strength of the reflection is less than that from bedrock owing to its lower reflection coefficient, and the surface of the material is also less irregular. Figure 3.2.2 shows an area 1.5 km off Martinique Beach which sampling showed to be sand and gravel. The underlying acoustic horizon which outcrops at A is interpreted to be glacial till on the basis of its composition as seen from sampling, and the superposition of sediments.

3.2.3 Post-Glacial Sediments

It is generally known that sand gives a strong, smooth acoustic reflection (Barnes, 1976; Letson, 1981). Figure 3.2.3 shows a good example of sediment infill in a basement depression. The lack of internal stratification may be a function of the acoustic profiling system rather than evidence of non-stratified sediment. This record shows an unidentifiable reflector near the bottom of the basin, however.

3.2.4 Uses and Limitations of the 3.5 KHz Record

The main use of the 3.5 KHz acoustic profile is in determining the type of seafloor. Even with no penetration the seabed facies can be determined by using the above

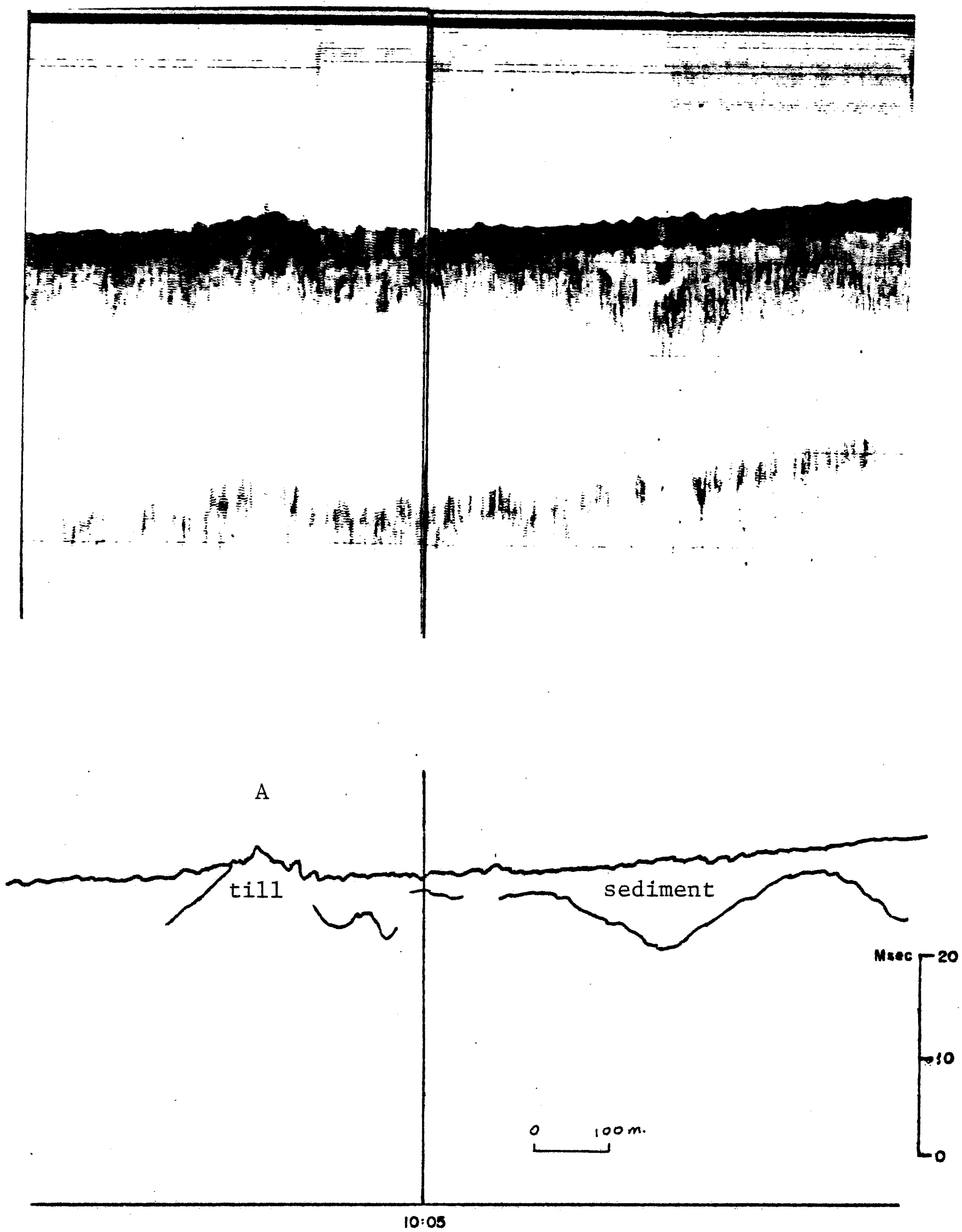
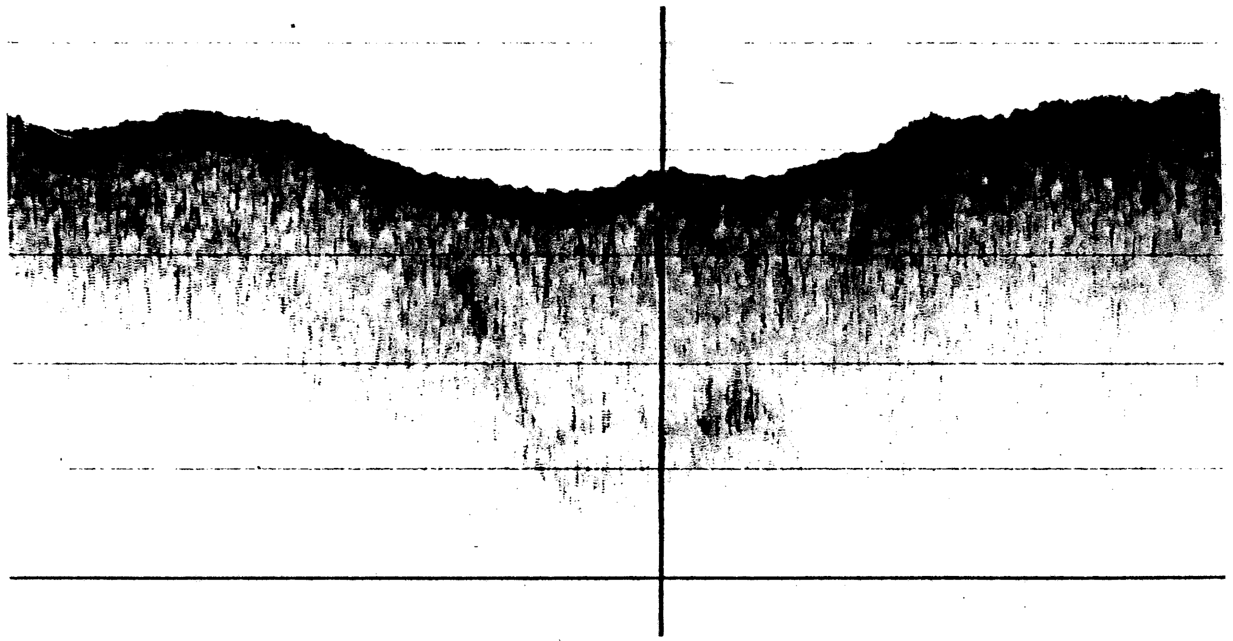


Fig. 3.2.2 3.5 KHz. record showing glacial till and sediment



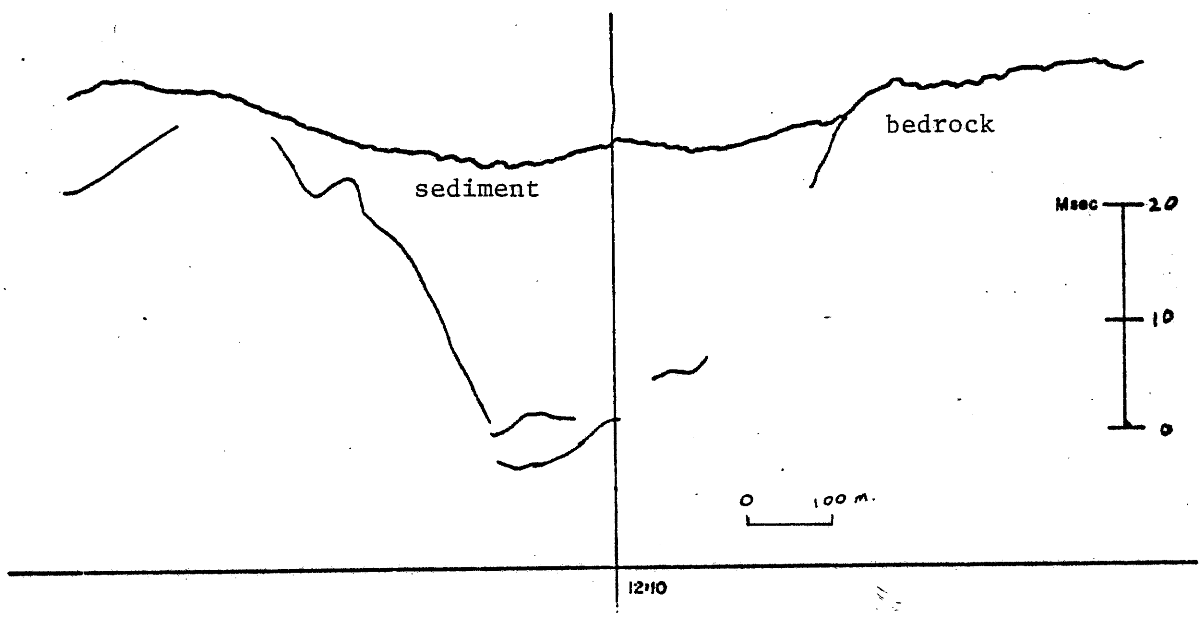


Fig. 3.2.3 3.5 KHz. record showing post-glacial sediment and bedrock

criteria. Thickness of sediment, and of till in some cases, can be measured in about 50 percent of the places where till or sediment is present. The records were used while they were being collected to aid sampling of sedimentary basins and to avoid bedrock.

The 3.5 KHz system used during this study has performed better in the past and also since this survey was done. Reasons for the marginal success of the system are twofold: (1) In shallow water the transmission pulse is too strong. This causes the first acoustic reflection to mask the later ones; (2) The reflection coefficient between sand and water is high, producing near total reflection of the transmitted pulse. The 3.5 KHz system works better in deeper water, where the sediment type is silt or clay.

3.3 Surface-Towed Sparker

3.3.1 Bedrock

On the surface sparker record, bedrock is characterized by a very irregular outcrop surface. Figure 3.3.1 shows an area eight km south of Osborne Head. The actual dip of the outcrop at point A is about 15^{o}, hyperbolae can be seen in the record, as can the relative strength of reflections from rock and sediment. Thin sediment, less than 1.5 metres, over bedrock appears transparent due to the width of the acoustic signature.

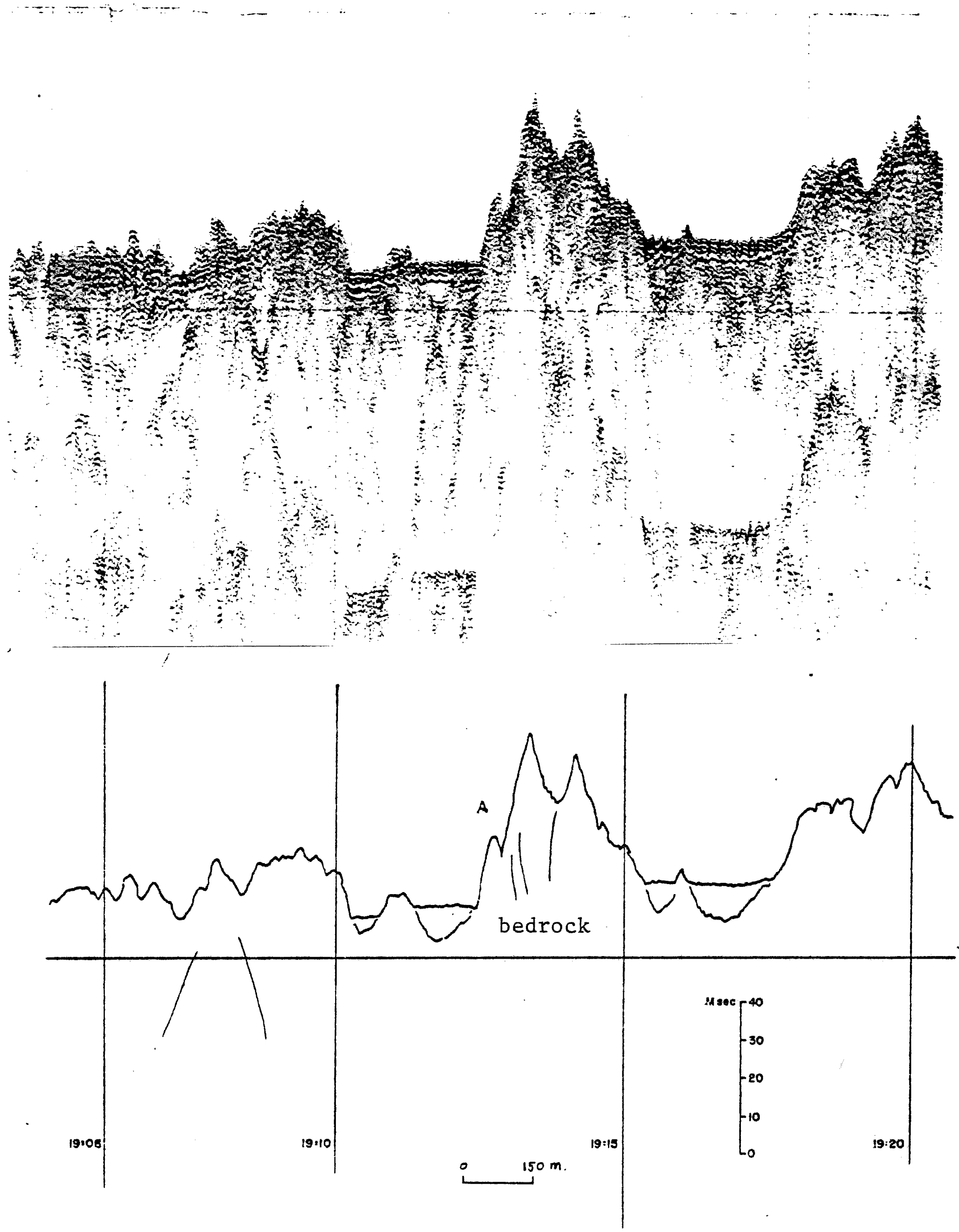


Fig3.3.1 Surface sparker record showingbbedrock

3.3.2 Glacial Till

Till appears less transparent than marine sediments in the surface sparker record. One very good example of bedrock overlain by till, and post-glacial sediment comes from an area 11 km south of Jeddore Cape (Figure 3.3.2). Here a 30 millisecond layer of till overlies bedrock and outcrops through the sediment of 2213. The dip of the till outcrop at 2215 is approximately seven degrees, assuming the velocity of sound in water is 1500 m/s.

3.3.3 Post-Glacial Sediments

Many examples of sediment on the seafloor could be taken from the surface sparker records. If one assumes the velocity of sound to be 1500 m/sec through the sediments, then, in the offshore area, the thicknesses vary from veneers to over 30 metres. The limit of resolution for measurement of sediment thickness is about 1.5 metres. Because the acoustic signature is five milliseconds wide, it is difficult to distinguish closely spaced reflectors. The basin in Figure 3.3.3 is located 14 km south of Meiseners Head. This clearly shows bedrock overlain by a transparent sediment, which is, in turn, overlain by another sedimentary unit. Acoustically transparent sediments have been described by Barrie and Piper (1981) and Letson (1981) as muddy sediments. The overlying sediments are interpreted as those of the sand

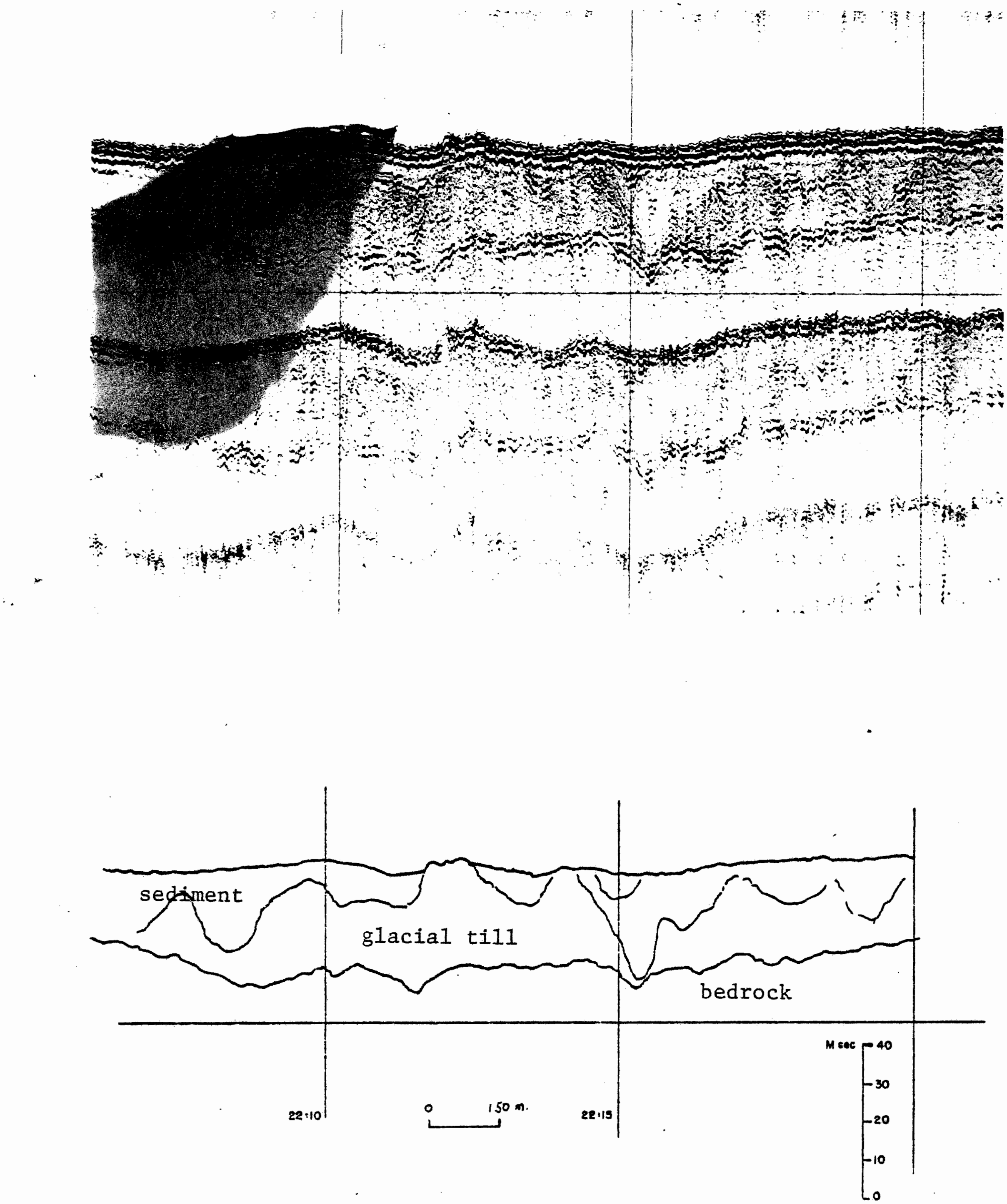


Fig. 3.3.2 Surface sparker record showing sediments and glacial till

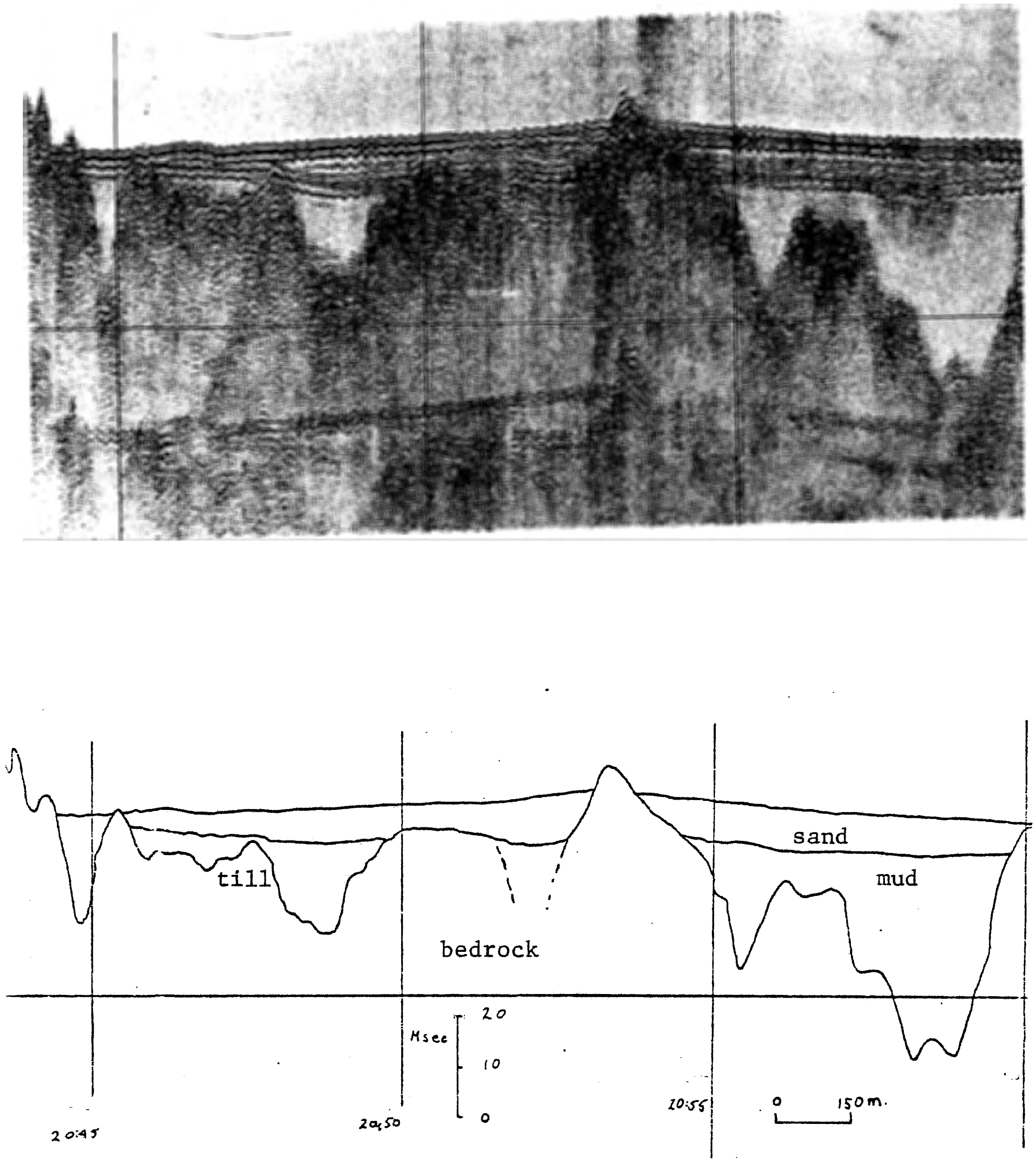


Fig. 3.3.3 Surface sparker record showing post glacial sediment and glacial till

facies similar to those described by Piper et al. (in print) in the Port Mouton area of Nova Scotia.

3.3.4 Uses and Limitations of the Record from the Surface-Towed Sparker

The record from the surface-towed sparker is useful in determining sediment thickness and the type of acoustic reflector. From thses records it is possible to distinguish till from sand from mud, even when they are interlayered. Penetration and resolution are good, making interpretation easier and more sophisticated than the 3.5 KHz system.

The width of the acoustic signature is the major problem with this type of seismic reflection record. Because the band width is five milliseconds wide, features less than this thickness are invisible. This can be a problem in describing the type of acoustic reflector.

Surface sparker line collection by the CSS Dawson is limited to offshore areas during fair weather. The Dawson cannot easily navigate the shallow water nearshore making its usefulness limited. Another limiting factor is the high cost of ship time for such a survey.

3.4 Deep-tow V-fin

The V-fin is a sparker-type seismic profiler which is towed below the sea level. These profiles were collected during the CSS Dawson cruise 81-006.

By towing the transceiver behind and below the ship, most of the noise from the ship and the sea surface is eliminated. This results in a high quality acoustic profile.

3.4.1 Bedrock

Bedrock is manifest on the seismic reflect-on profiles as a strong reflection of the acoustic pulse. The outcrop surface is commonly irregular and strongly undulating. Hyperbolae are usually present. The acoustic basement can also appear rather smooth, as in Figure 3.4.1. This is due to a thin cover of sediment filling depressions, thereby producing a smooth reflection. The hyperbolae are present indicating point sources suggestive of bedrock.

3.4.2 Glacial Till

On the V-fin record, glacial till appears as an acoustically translucent material. Relative to the acoustic reflection of sand or mud, the till appears grey (Figure 3.4.2). Sediments can be seen at 0831, glacial till is present between 0835 and 0840, bedrock occupies the area after 0842. Till is not widespread in the V-fin record.

3.4.3 Post-Glacial Sediment

On the V-fin record two types of sediment can be seen; they are sand and mud. On the record they appear grey and transparent respectively. In all cases the less acoustically transparent sediments overlie the acoustically transparent sediments. In other words, sand overlies mud, in several areas, at distances of 10-20 km offshore. Figure 3.4.3 shows part of the record 18 km south of Martinique Beach. The basin in Figure 3.4.3 is bounded by bedrock on the east and west in which mud is partially overlain by sand.

3.4.4 Uses and Limitations of V-fin Records

The V-fin acoustic profiling system is useful in delineating sedimentary basins in unconsolidated sediments and distinguishing bedrock, till, sand and mud from each other. As with the surface sparker, V-fin profiles are expensive and the V-fin is restricted even more than the surface sparker to deep water.

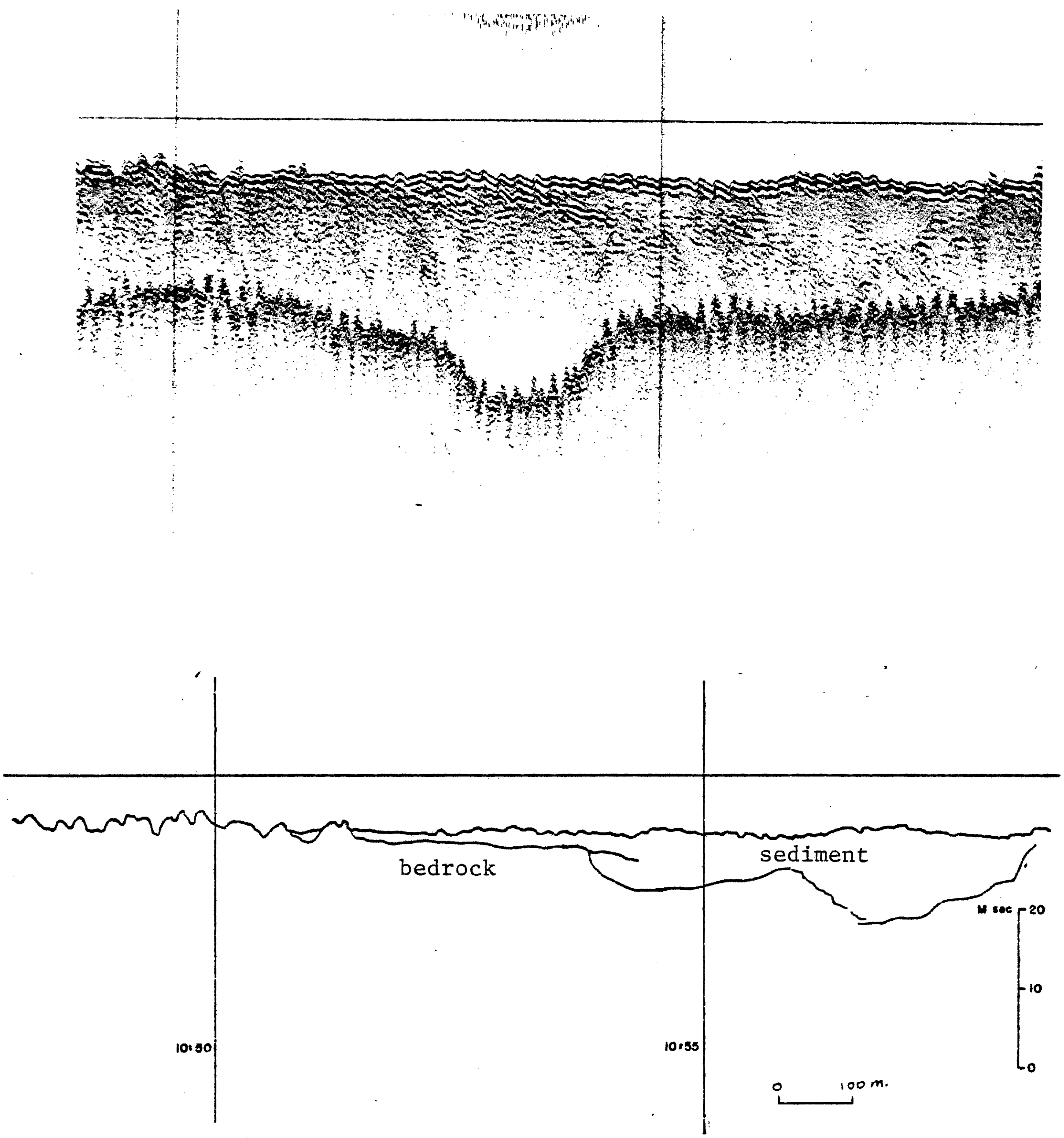


Fig. 3.4.1 V-fin record showing bedrock and post-glacial sediment

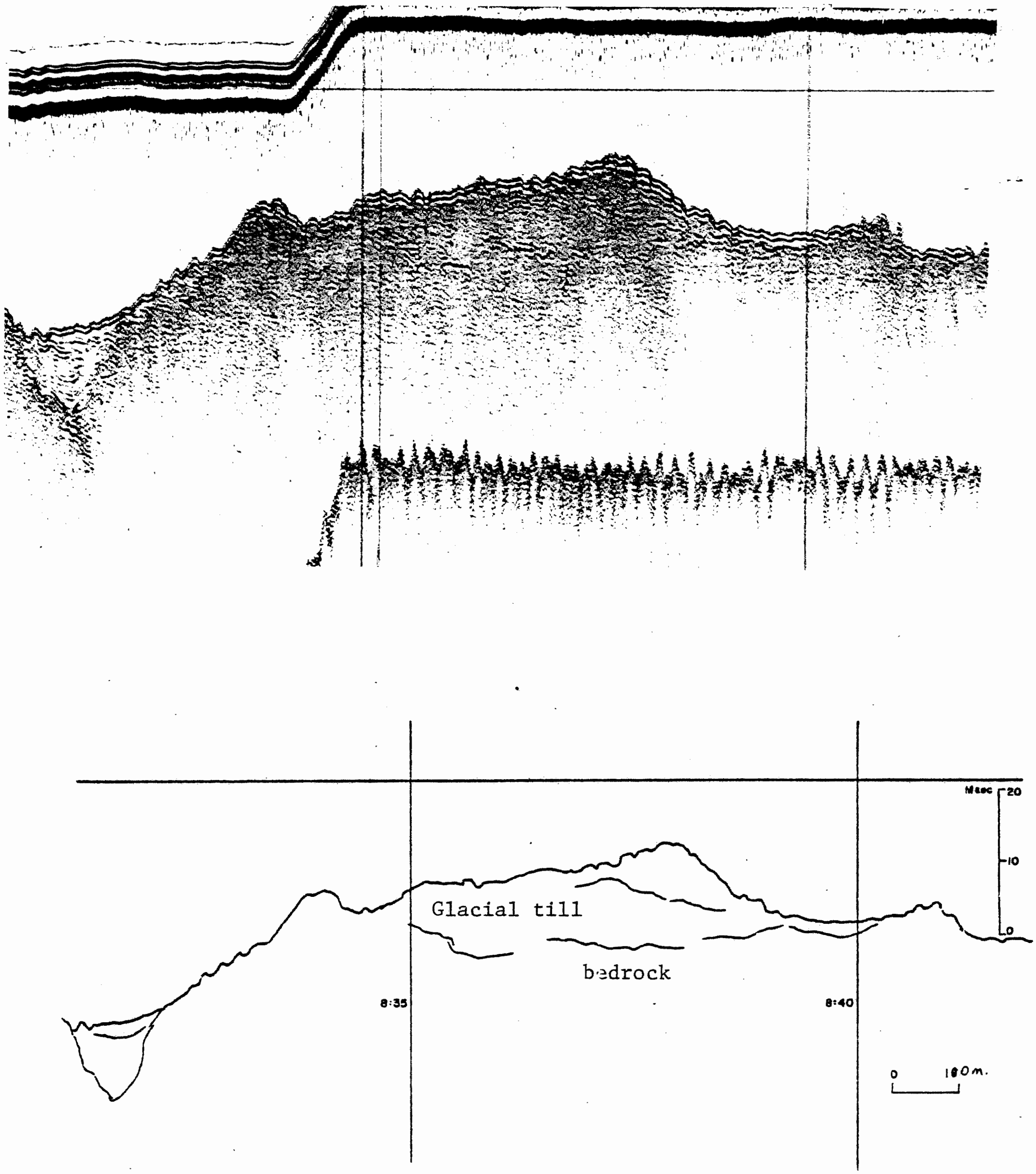
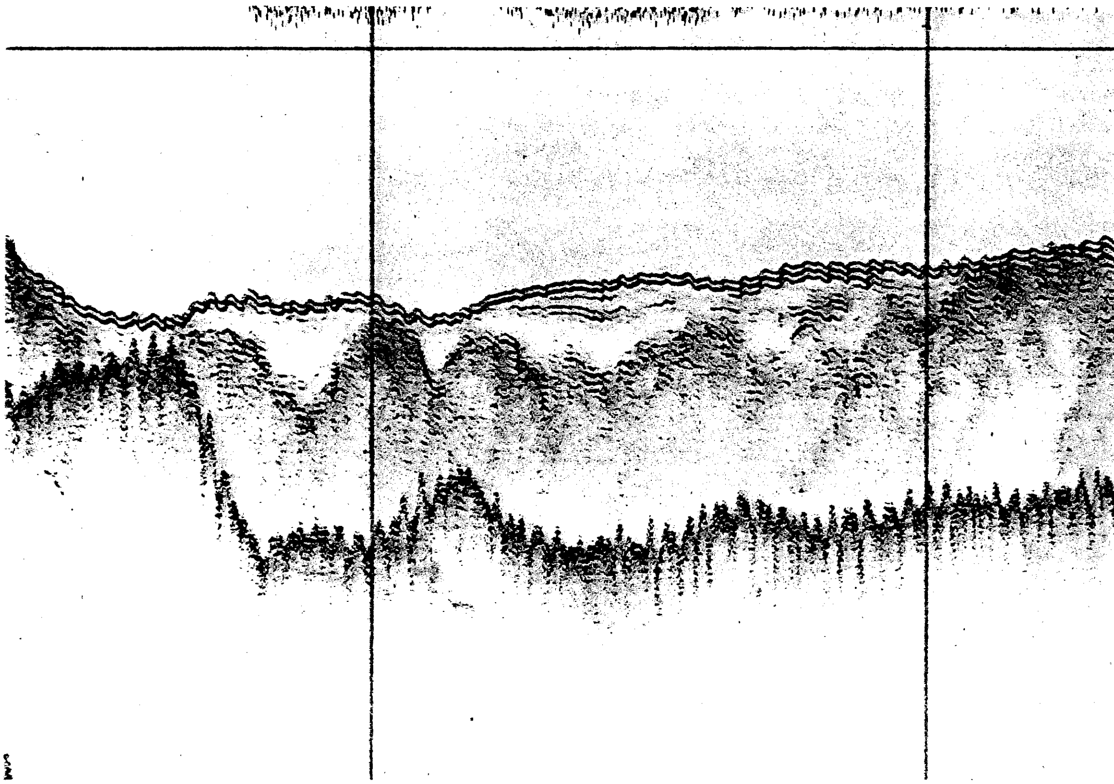


Fig. 3.4.2 V-fin record showing glacial till



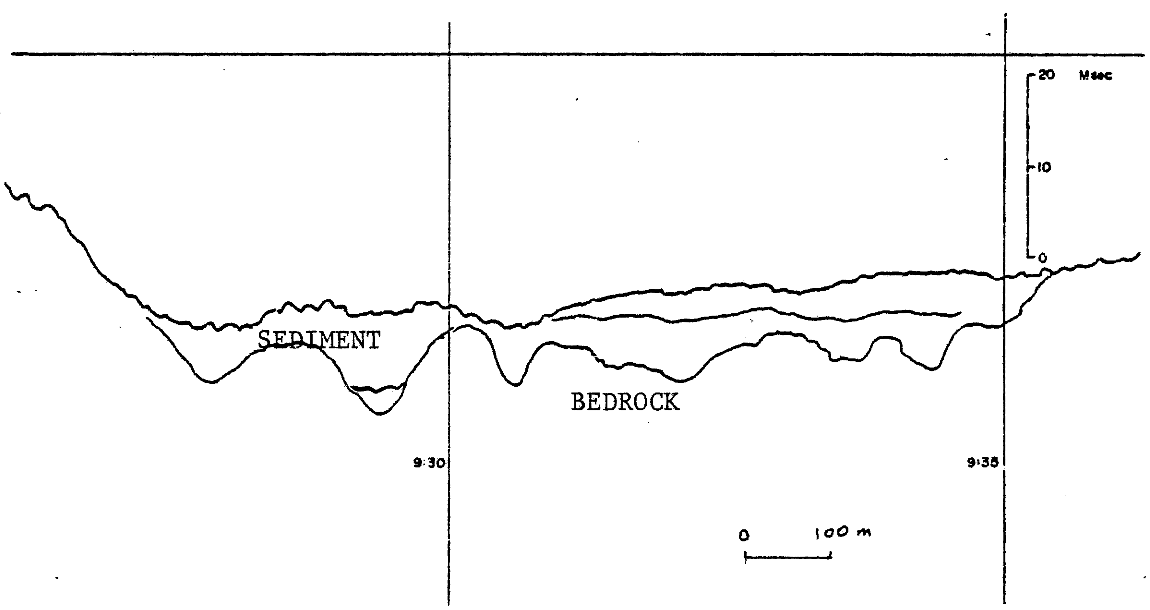


Fig. 3.4.3 V-fin record showing post-glacial sediment

CHAPTER 4

BATHYMETRY AND SURFICIAL SEDIMENTS

4.1 Bathymetry

A bathymetric chart was contoured at five metre intervals from data presented on Canadian Hydrographic Chart #4347 (Figure 4.1).

4.2 Distribution of Surficial Sediment

The distribution of sediment offshore is presented in the form of one map which shows both thickness and extent of the sediments (Figure 4.2). These maps were compiled with direct data from grab samples and from interpretation of acoustic records. Bedrock, glacial till, and post-glacial sediments.

Major bedrock trends are seen offshore near the 50 m isobath and extending seaward from Three Fathom Harbour and Petpeswick Head. The bedrock outcrop offshore seeming to be an extension of the plunging anticline which forms islands at Clam Bay and shoals off Jeddore Cape.

Till platforms are generally located between bathymetric highs or shoreward of outcropping bedrock. Offshore from Chezzetcook Inlet, there is a till platform with a drumlin

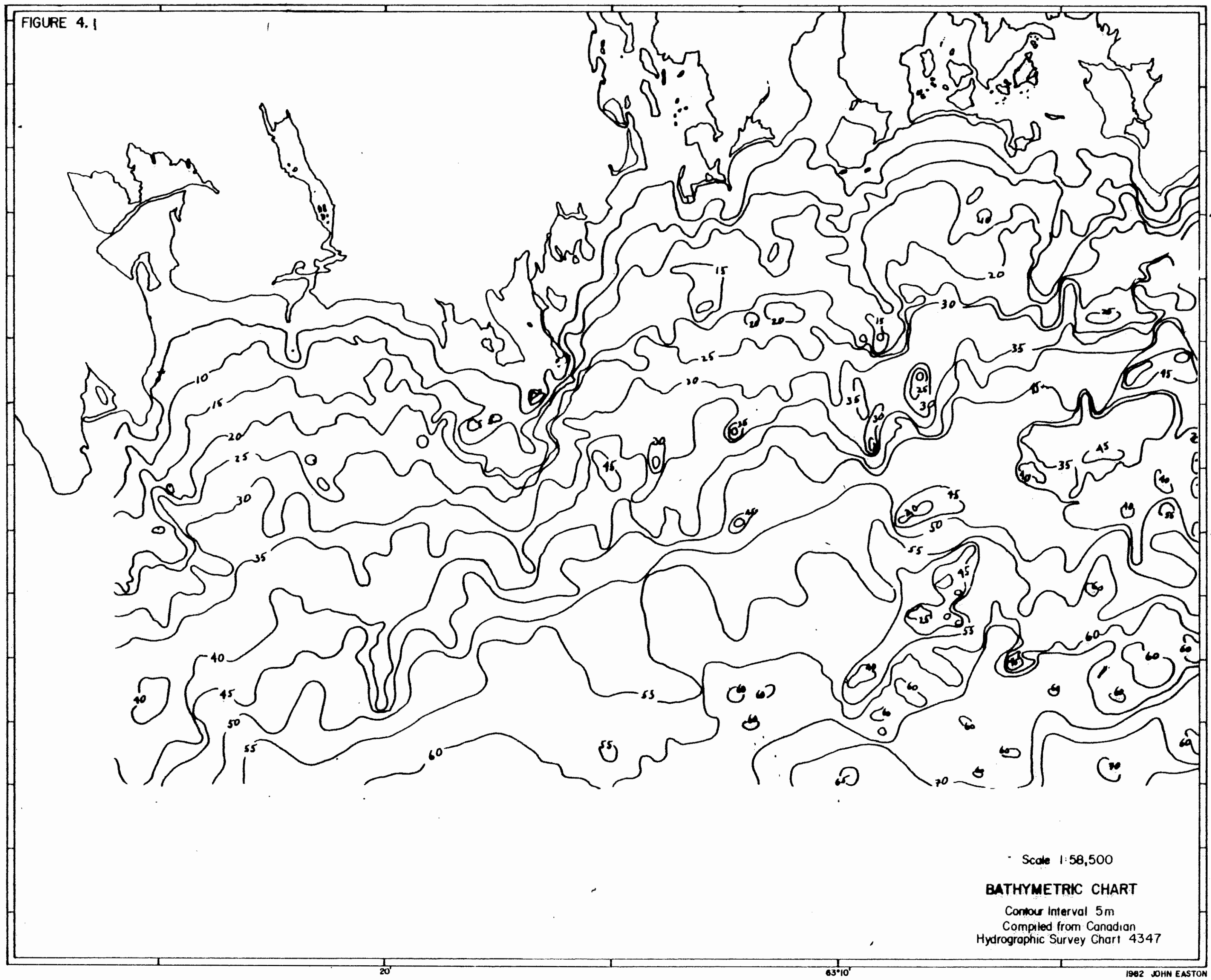


Figure 4.1. Bathymetric chart.

Figure 4.2. 1) Showing surface sediment type.

2) Lines show thickness over acoustic basement. Schematically the reader is referred to the track chart to see where data is sparce.

Figure 4.2

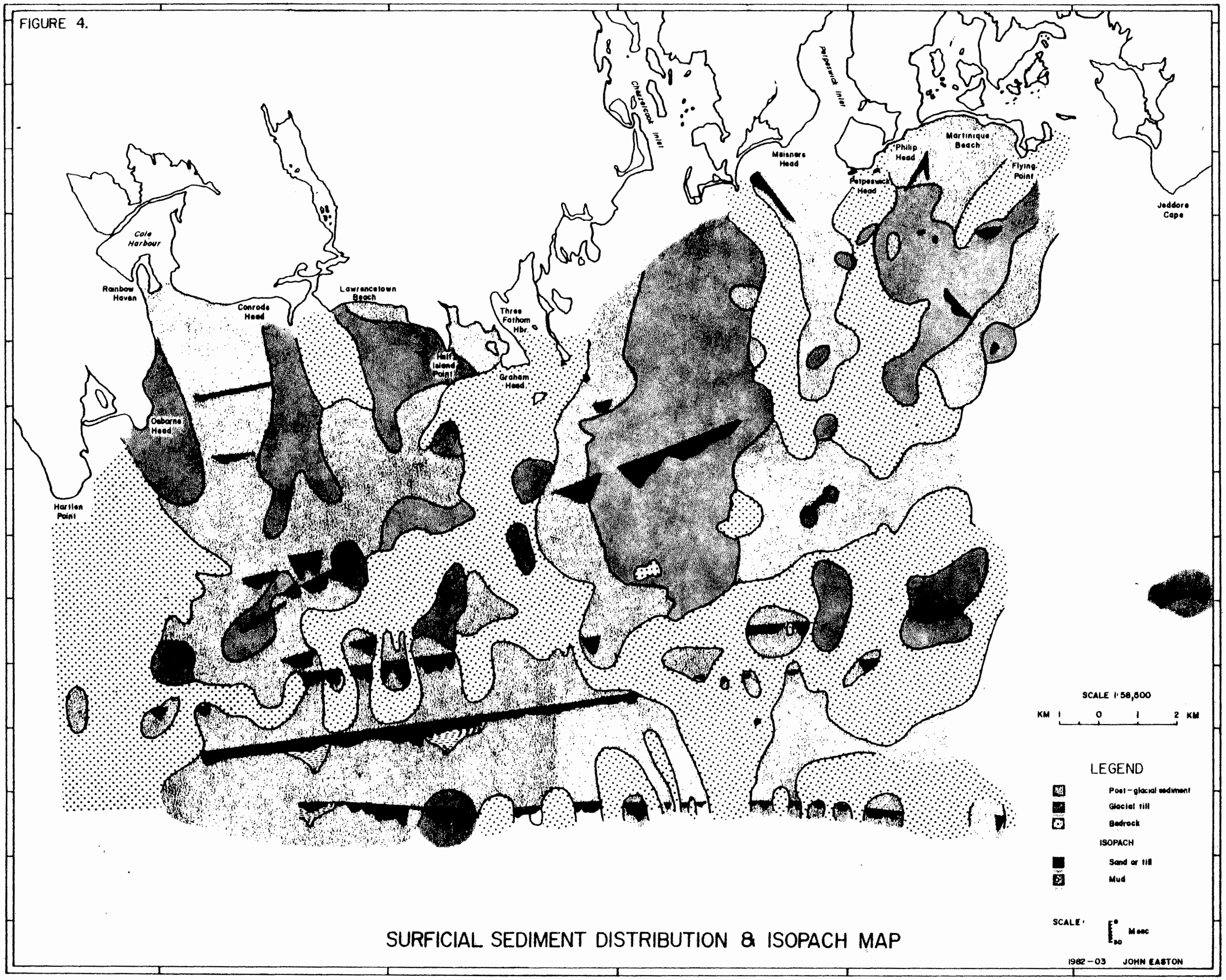


FIGURE 4.

SURFICIAL SEDIMENT DISTRIBUTION & ISOPACH MAP like form near the centre. Shoals on either side of this till platform are presumably partially responsible for the preservation of the till. In other places, to the west of this area, till is present behind bedrock highs.

Surficial sediment sampled in the study area is sand or gravel size. Sand commonly lies in linear depressions extending from Cole Harbour, Chezzetcook Inlet, and Petpeswick Inlet. In the areas further offshore, sandy material is seen to overlie muddy sediments and, to a minor extent, glacial till.

4.3 Grain Size

Twenty-three of the 60 statistically significant samples were analysed. Nineteen of these samples are from the Martinique Beach area, the other three are from the area off Cole Harbour. Figure 4.3 shows the sample locations. Probability plots have been made on data from samples analysed at 1/4 phi intervals.

Characteristic plots of gravels in the eastern part of the study area are seen in Figure 4.3.1. The gravelly samples tend to have a bimodal grain size distribution while the coarsest clasts lack sphericity and roundness. Within sample number 517-80-44 incongruity exists in grain size distribution (Figure 4.3.2). There is a well defined gravel

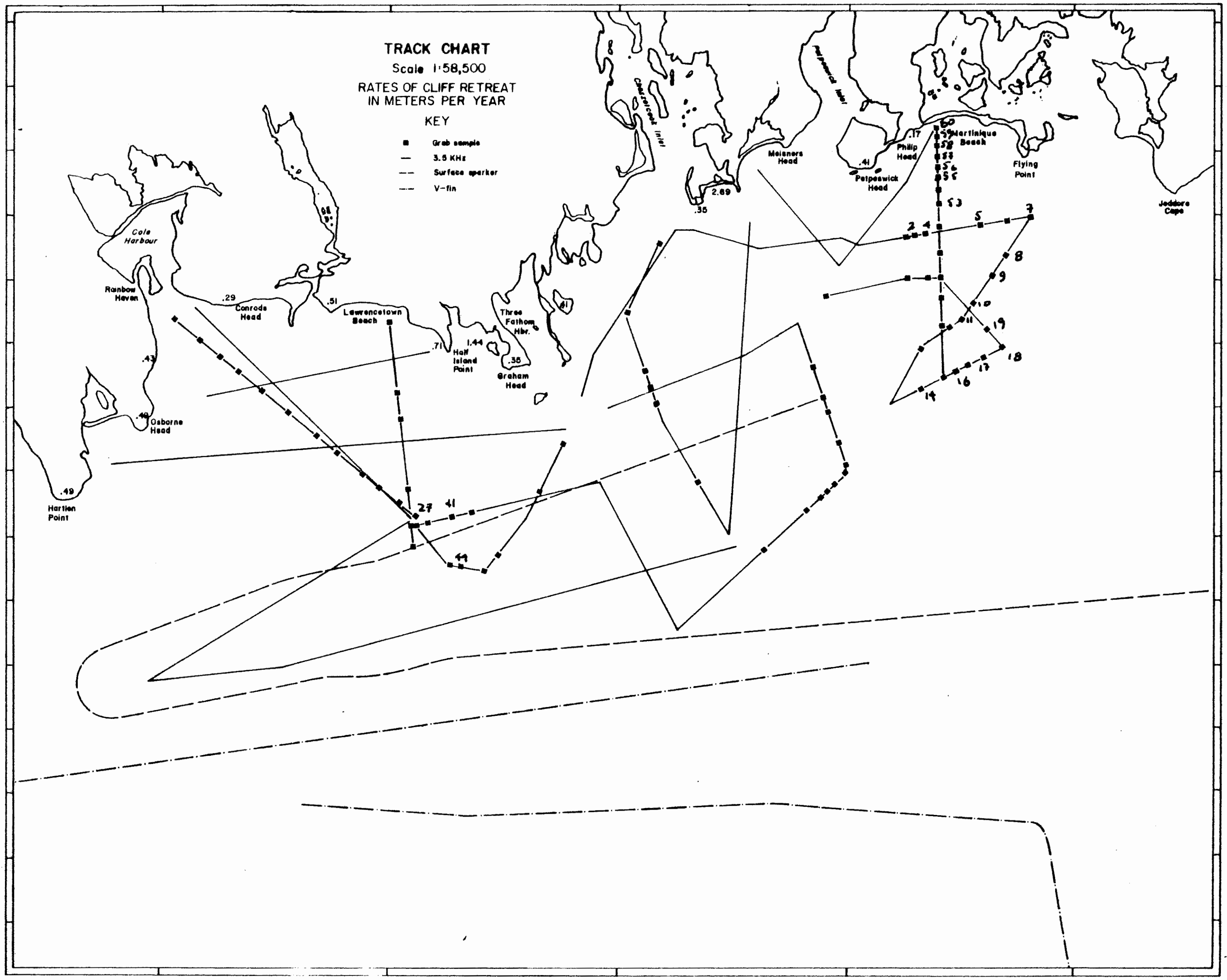


Figure 4.3. Showing rates of cliff retreat, track charts, and sample locations.

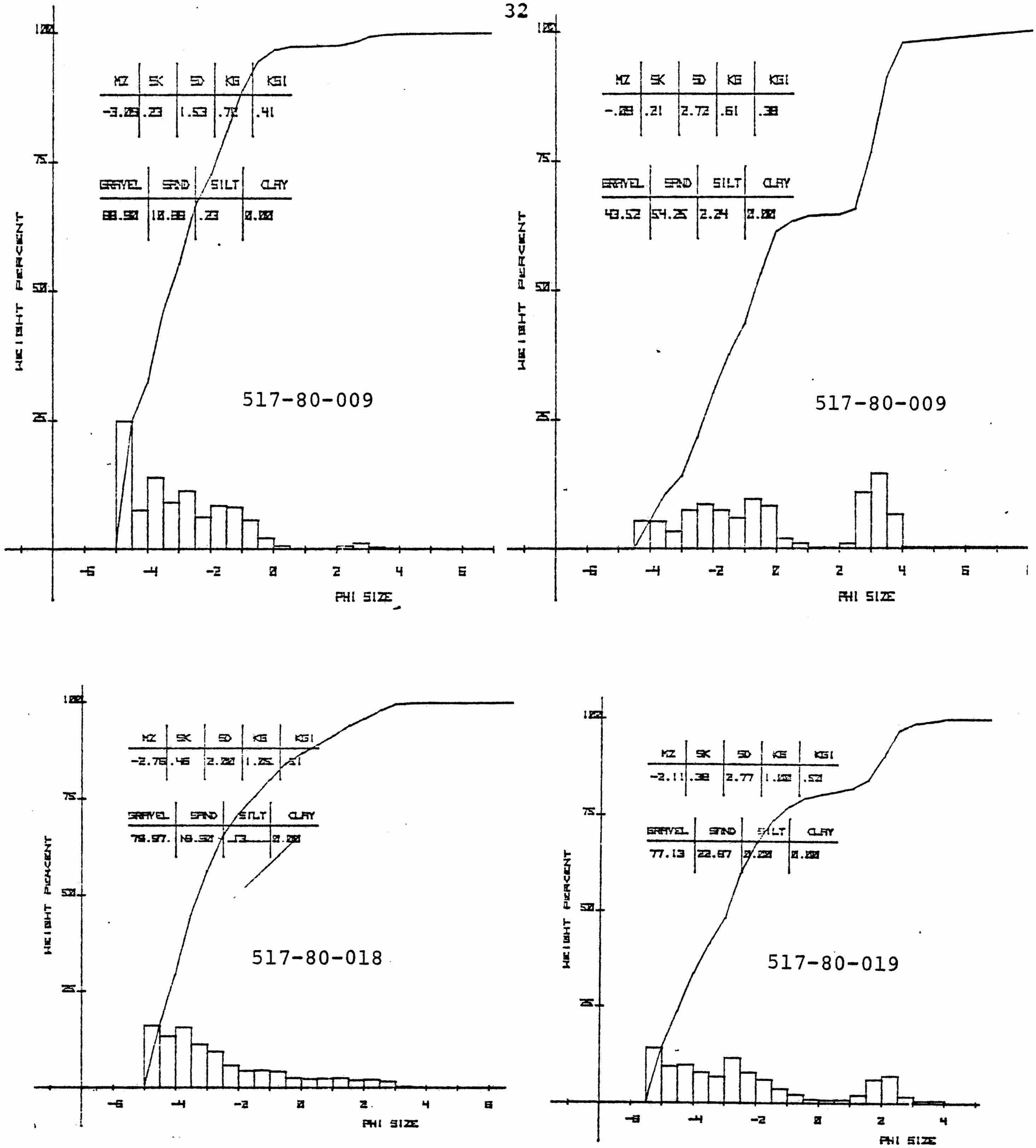


Figure 4.3.3. Characteristic ogives and histograms of selected sediment samples.

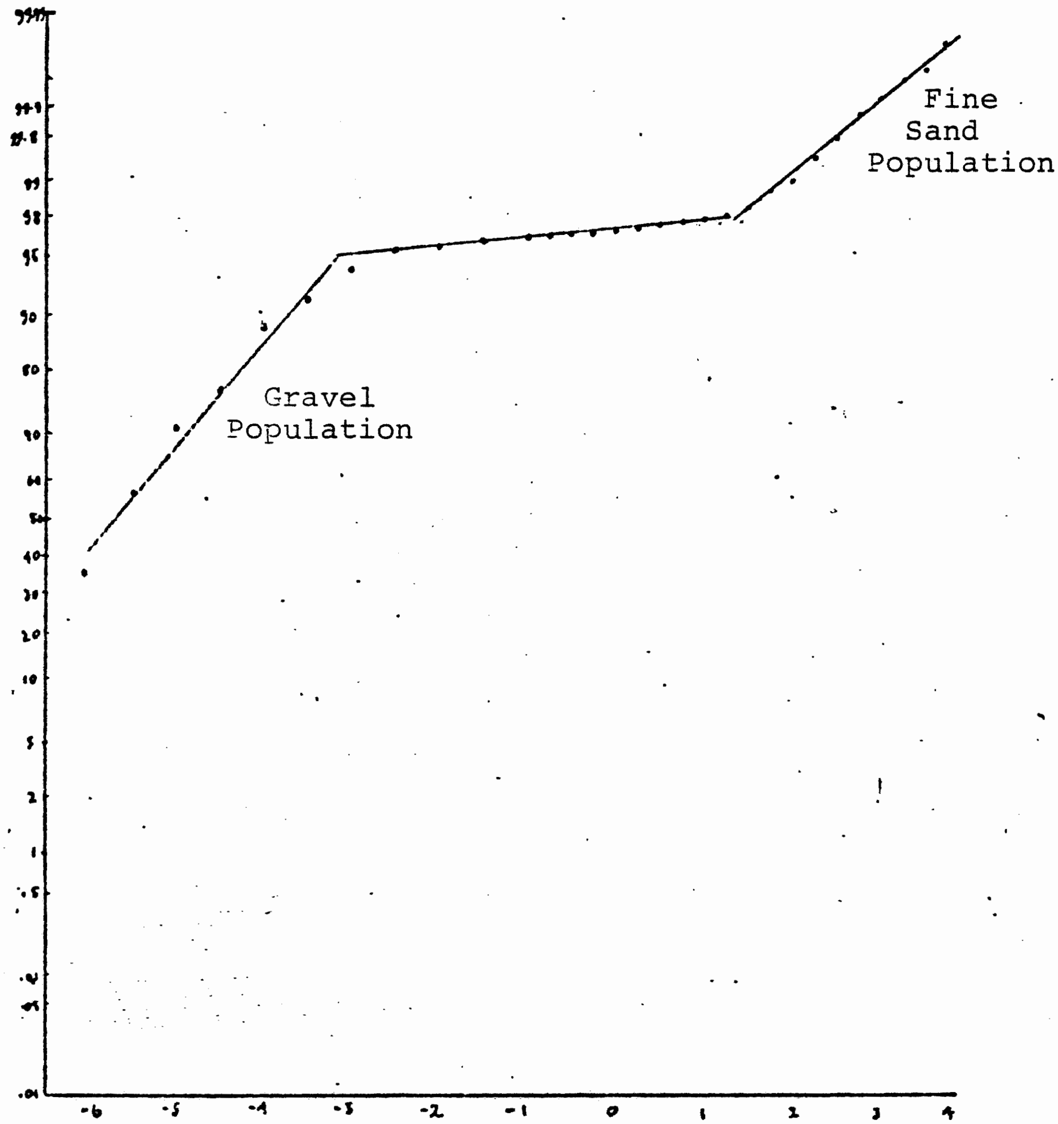


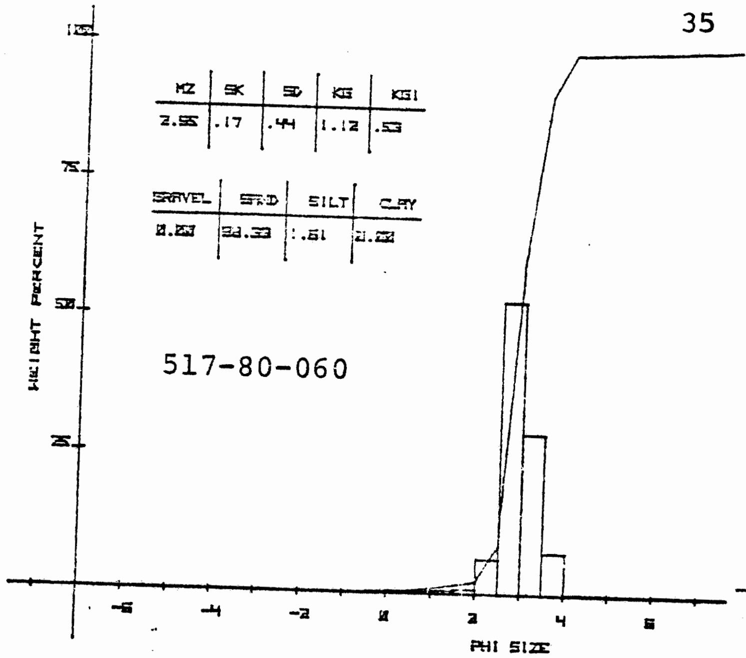
Figure 4.3.2. Probability plot of sample 517-80-44 showing distinct gravel and fine sand populations.

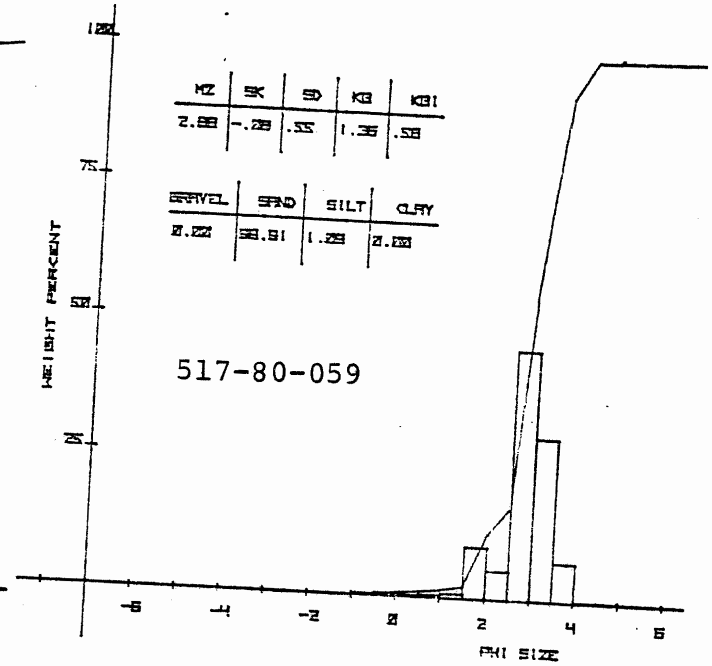
population, and virtually no coarse sand yet there is a well defined medium to fine sane population. This grain size distribution is thought to represent winnowing of the sand fraction during transgression and infilling of medium and fine sand once the wave energy in the area decreased with further transgression. This explanation depends on the presence of a coarse grain size in the original material.

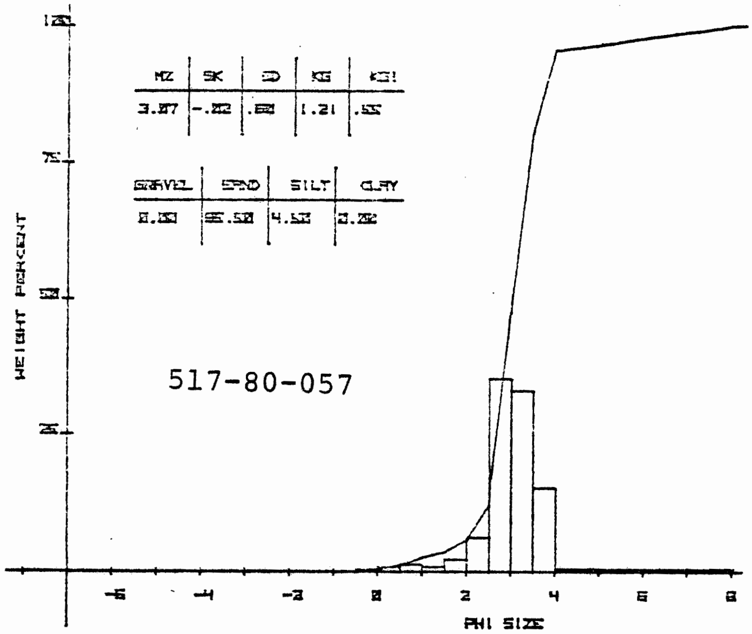
Characteristic plots of sand sized material in the Martinique beach area are shown in Figure 4.3.3. With the exception of sample 517-80-56, which has a mainly silt sized paterial, the samples are well sorted fine sand. It is not known how the grain size changes from a till facies area to the sand facies.

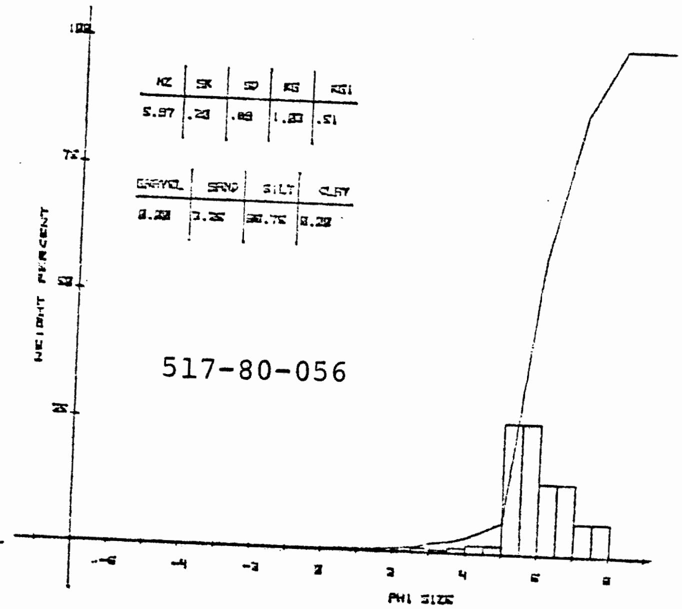
4.4 Isopach Map

Information of sediment thickness is limited mostly to surface sparker and V-fin lines, hence the compilation of a contoured isopach map is difficult. The isopach information is combined with the sediment distribution map. The isopach diagram shows sediment thickness (including till) up to 50 msec. The greatest sediment thicknesses are found in the areas farthest offshore below the 50 m isobath. These thicker sequences are generally acoustically transparent sediments and usually overlain by sandy sediments. Till is a minor, yet significant, portion of these offshore sediments; it occurs









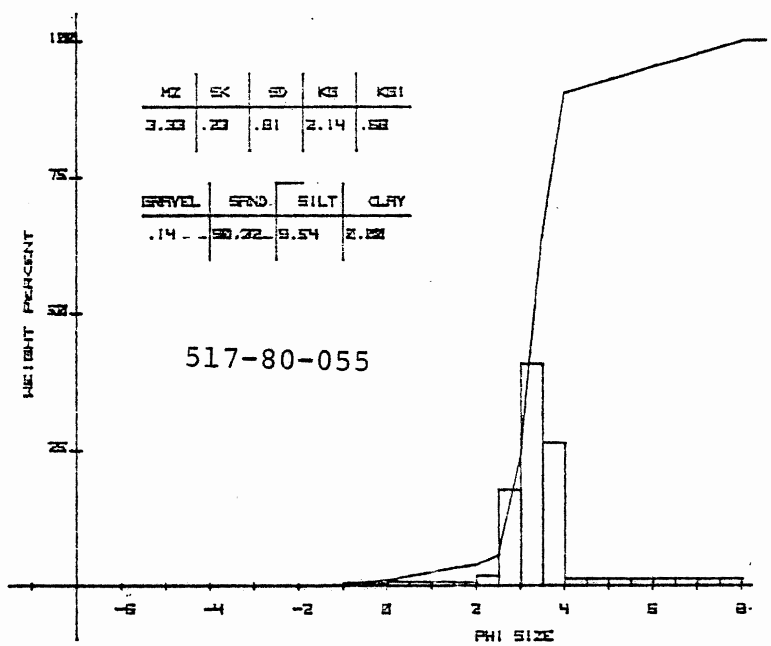


Figure 4.3.3. Characteristic ogives and histograms of selected coarse-grained samples.

either underlying sand or outcropping on the seafloor (Figure 4.2).

CHAPTER 5

COASTAL PROCESSES

5.1 Air Photos

A study of the coastal area was made with the aid of 1945 air photos, on loan from the Nova Scotia Department of Lands and Forests, and 1975 orthoprints. Comparision of the two sets of photographs allows one to estimate average erosion rate over a 29 year period, thereby ensuring a more accurate yearly rate of erosion than the single year measurements. Figure 4.3 shows the yearly erosion rates at the headlands as calculated from air photos. The volume of sediment removed calculated by methods described in Chapter 2 is similar regardless of the method of measurement used. The mean cliff height method shows 1.67×10^6 cubic metres of sediment removed. The other method shows 1.73×10^6 cubic metres of sediment eroded. The average annual rate of retreat over the 29 year period was 0.71 metres per year. A plastic copy of the basemap (scale 1:10,000) has been deposited with the Atlantic Geoscience Centre, Bedford Institute of Oceanography.

5.2 Cliff Staking

Data from direct survey measurements provide accurate measurement of cliff retreat at six stations. During the summer of 1981, summer students of the Atlantic Geosciences Centre remeasured the stations along the Eastern Shore. The appendix contains their measurements and those done by the author in 1982. Erosion rates range from .29 m/y at Philip Head to 1.5 m/y at Graham Head.

5.3 Coastal Processes

There are several areas along the Eastern Shore that have undergone a marked morphological change through the last two hundred years or, indeed, the last 30 years. The Atlantic Nepture Chart series of the mid 18th Century contains a chart of the eastern shore. Although this map could not be used to do quantitative measurements it can be used in a discussion of coastal processes.

According to studies of former sea-levels (Scott, 1980, in press; Piper et al. 1982) the sea level 11,000 years ago was as much as 35 metres below its present level. The rate of sea level rise has been constant for the past few hundred years at about 0.3 m per 100 years (Scott, 1980). Hence, at the time of the Atlantic Neptune map, 1963, (Figure 6.1) the ocean was about 0.6 metres lower than at present.

Inspection of Figure 5.3 reveals several areas which were considerably different from the 1864 British Admiralty Chart, or the present coast line. The Martinique Beach area,

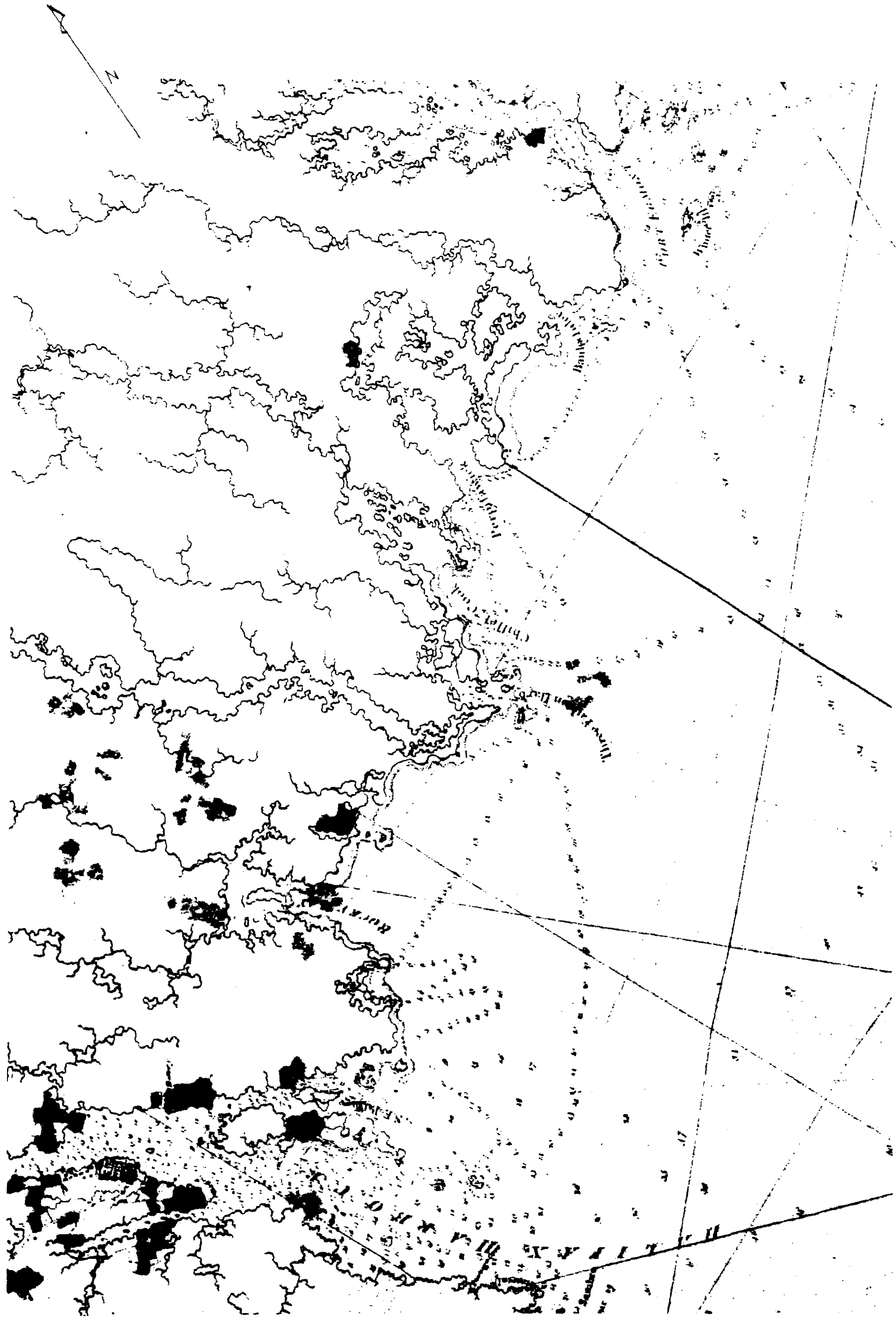


Fig. 5.3. Atlantic Neptune Chart of 1763 showing the study area.

in the 18th Century, was essentially a barrier island, and appears considerably wider than at present. The inlet at the eastern end of the beach has opened, allowing increased water and sediment exchange with lagoon. It is likely that a barrier beach once extended across the gap between Flying Point and Cape Jeddore. The barrier beach has since receded to its present position and will, in the future, recede even further, leaving Flying Point as an island (Bowen, 1975) thereby opening more of the lagoon to open sea conditions. This process involves the movement of large amounts of sand from the high energy environment into the lagoon, where it becomes trapped. Not all sand is involved in this migration to the lagoon; relict sand deposits are seen off shore from Martinique Beach and Meisener's Beach.

Along the coast to the west, between Graham Head and Half Island Point, there was a drumlin as little as 35 years ago. Today all that remains is gravel lag and a sand bar. This study does not deal directly with the redistribution of those sediments, but it is clear that till covers the bottom seaward of the missing drumlin. It is clear that the 1763 map closely resembles the 1945 air photos. Hence one becomes suspicious that human, rather than geological factors, have contributed to the demise of the drumlin.

In the Cole Harbour area the river mouth had been extensively diked with outward flowing sluce gates, which allowed the grazing of cattle in the former lagoonal area. After 1945 the dike broke permitting the marine transgression. At the present time a natural barrier beach/lagoon system has formed some 30 m shoreward of the previous shoreline.

Finally, Cow Bay is an area where, in the 1950's, beach sand was taken for aggregate. This, in conjunction with natural processes, has caused the repositioning of the beach farther back in what was the lagoon. It is clear that the till cliffs at Hartlen Point and Osborn Head have eroded significantly in the past 200 years. Extrapolation of current rates of retreat indicates that $1.4 \times 10^6 m^3$ of sediment would be removed from this headland during this 200 year period.

CHAPTER 6

DISCUSSION

The study area is underlain by resistant bedrock presumably of the Meguma Group. Bedrock trends which are parallel to the shoreline can be seen as extensions of the anticlines outcropping on land at Three Fathom Harbour and at eastern Clam Bay. The Clam Bay anticline forms the distinct lineation on the bathymetric chart at the 50 m isobath. Bedrock highs can also be seen trending normal to the coastline from Three Fathom Harbour and Petpeswick Head. Associated with these bathymetric highs are valleys.

Bathymetric lows and sedimentary basins delineated on acoustic profiles provide information about the course of former valleys during the recent history in the study area. Whether these valleys are subaerial or subglacial in origin (Barnes, 1976) is uncertain. Acoustic records provide some information on the mode of infilling of these depressions.

Figure .1 shows the inferred drainage pattern prior to the deposition of glacial till and post-glacial sediments. Major channels beneath the sea floor can be seen in the bedrock off Cole Harbour and Chezzetcook Inlet, and to a lesser extent, due to poor geophysical coverage, off Jeddore

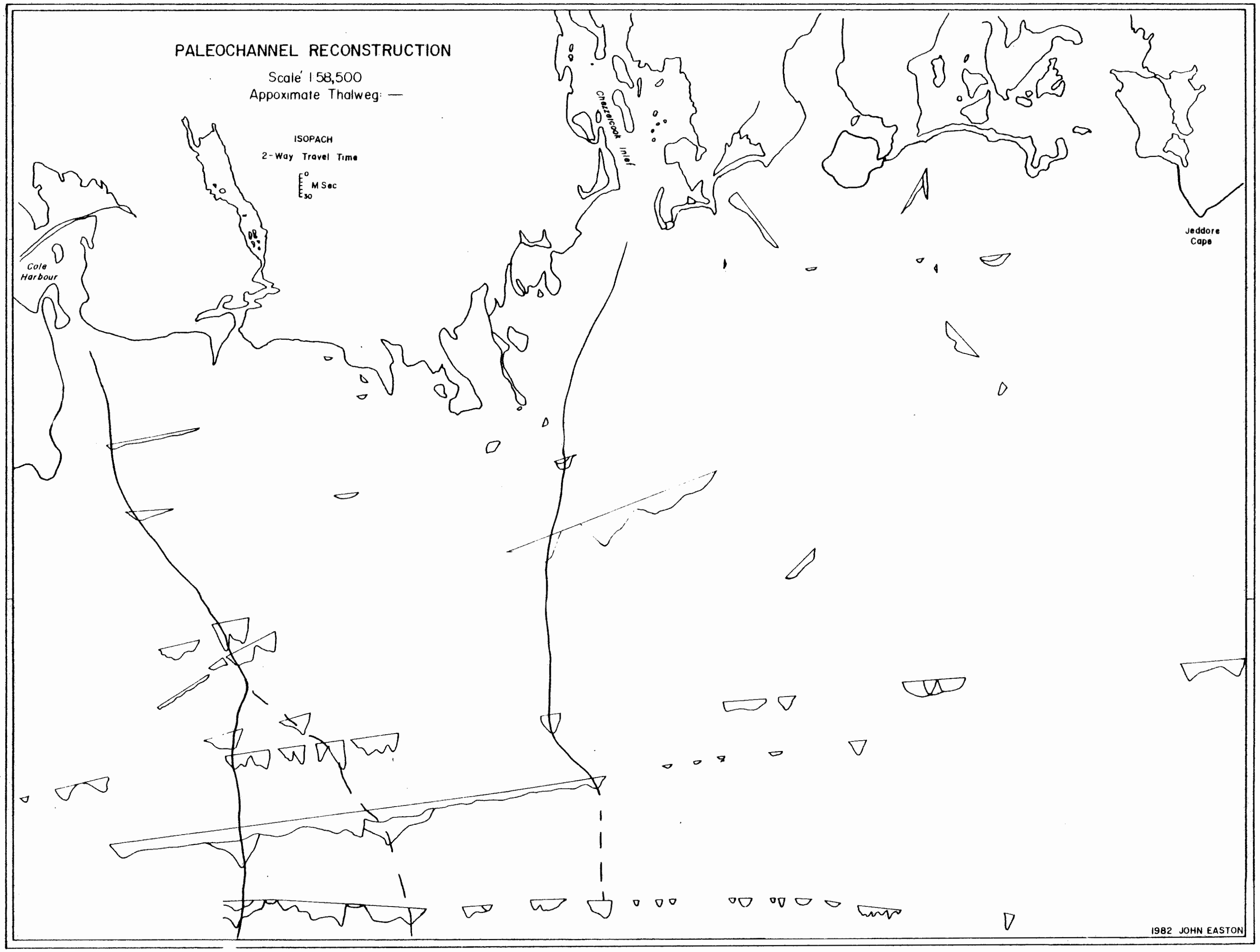


Figure 6.1. Paleochannel reconstruction showing possible river channels.

Cape. Some deductions about the time of infilling of these channels can be made from the type of sediment enclosed in the depressions.

In the Cole Harbour area post-glacial sediment, and minor glacial till, fills the channels. The presence of glacial till suggests that part of the channel was filled during the Wisconsinan glaciation, while sediment in these same channels suggests that this may have been the locus of outflow from ablating glacial ice. The possible bifrucation south of Cole Harbour suggests they were sub-ice valleys.

Bedrock channels in the Chezzetcook area are partially filled with glacial till. Presumably this area was not a significant post-glacial outflow channel, because the glacial till remains intact. There is, however, a linear sand body extending offshore from Chezzetcook Inlet between bedrock on the west and till on the east. There is a 25 millisecond thickness of post-glacial sediment in this subsurface depression attesting to the presence of a glacial channel in at least half of the valley.

The composition of the gravel size component of samples indicates that Lawrencetown till existed throughout the area. Samples 23 and 44, contain granite, gabbro, and Meguma clasts. This indicates that drumlins composed of Lawrencetown till were at least one feature of the submerged landscape. The preservation of till sheets during a marine transgression is a problem which deserves some attention, because some authors believe till did not survive the Holocene transgression (King, 1980). There is one concentration of till located seaward of Chezzetcook Inlet, another concentration appears on the 80-004 record to the east of the study area. Other minor till pockets are scattered throughout the area.

If sea level was 35 metres lower than the present level, the proto-Chezzetcook Inlet would have existed between what are now bathymetric highs of Graham Head and Petpeswick Head. Fluvial systems from both the Petpeswick Valley and the Chezzetcook valley would have flowed down the same tributary to the sea. If landward migrating barrier beach systems were characteristic of the coastline at this time, preservation of lagoonal sediments and underlying valley drumlins would be possible. This "in-place" drowning mechanism (Reading, 1980) is envisioned as a method for preserving till deposits in the area.

The probability plot of sample 44 suggests that till may have simply survived the transgression. Because glacial till is compact and fairly resistant to erosion, protection of the till by a seaward outcrop of bedrock on boulders may explain its preservation to sub-littoral depths. Erosion and winnowing of part of the till outcrop would lead to an accumulation of boulders and cobbles, thereby aiding the preservation of the basal part of the till sheet and thereby leave this characteristic bimodal grain size distribution.

Below the 50 m isobath, a transparent acoustic reflector can be seen underlying surficial sediments, this is not present in shallower water. The 50 m isobath is taken to represent the zone into which the late Wisconsinan ice sheets did not penetrate. The type of environment (ie. the depth below sea level) cannot be stated because these areas have not been sampled. It is clear, however, that the mud must have been deposited below sea level before, or during glaciation, and that postglacial sandy sediments overlie this acoustically transparent mud horizon.

Measurement of cliff retreat reveals an average retreat of 0.81 metres per year. From air photographs taken 29 years apart, the calculated average erosion rate is 0.71 metres per year which is almost three times that found by Letson (1981) in Mahone Bay. Extrapolation of this erosion rate through the last 10,000 years is probably an over-simplification because there is evidence that the sea level rise has not been constant over this time period (D. Scott, pers. comm.). Nonetheless, the exercise seems worthwhile.

Over 10,000 years, the 0.71 m/year rate would result in 7.1 km of erosion, this placing the paleo-shoreline at about 7 km from the present coastline. This line approximately coincides with the 45 m isobath, which is 10 m deeper than the estimate of the position of sea level 11,000 years ago postulated by Piper et al. (1982) but less than the estimate of maximum lowering on the eastern shore of Cape Breton Island by Wang and Piper (in press). This line also marks a change in the bathymetric character of the seafloor, as well as a change in the sediment type (Figure 3.1 sediment distribution). Till past this line becomes patchy and limited to bathymetric highs, the amount of rock outcrop increases, and the thickness of sediment becomes greater.

CONCLUSIONS

The preexisting topography of the offshore area seems to have a strong effect on the type and amount of sediment deposited. Valleys in the bedrock have been delineated and are thought to have been occupied by late Wisconsinan euglacial or proglacial outwash systems. Glacial till can be seen in the innermost Scotian Shelf on echo sounder records. Till in the bedrock valleys indicate that the valleys were not occupied by streams during the ablation of the late Wisconsinan glaciers.

Incomplete marine erosion of the coastal till has led to patches of till, which are in places extensive, surviving the post-Pleistocene transgression. The location of till units indicates processes by which the till survived the transgression. They are: (1) burial of till behind barrier beaches by lagoonal sediments, (2) protection of till by bedrock outcropping seaward, (3) deposition of till in bedrock hollows. Grain size data shows characteristic grain size curves for both till and sand fractions. Several coarse grain samples show a well defined gravel and fine sand fractions with no coarse and medium sand, indicating winnowing of glacial till and redeposition of fine sand at a later time.

Sand overlying mud indicates changing wave, tidal, and current conditions. Since no grain size data from these distal sands or muds were obtained, it is impossible to quantify this statement. Clearly, during mud deposition the environment was less energetic than during sand deposition. The present sediment distribution pattern indicates sediments are not in equilibrium with current depositional processes.

The coastline between Hartlen Point and Jeddore Cape is characterized by rapid erosion of drumlin cliffs, and by estuarine environments. Drumlins that lie on bedrock are eroding less rapidly than valley drumlins, because wave energy is dissipated on shoals.

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APPENDIX

Coastal Erosion

The height of till cliffs were measured from contoured orthoprints at 100 metre intervals and recorded. The coastline was then divided into three segments, each representing a different morphological area. The areas are:

(1) Hartlen Point to Lawrencetown Head - an area of perdominantly till cliffs.

(2) Half Island Point to Rudeys Head - which is a drumlin occupied area.

(3) Storey Head to Jeddore Cape - which is a drumlin coast with several large inlets and barrier beaches.

The surface retreat was calculated by tracing the present coastline on the 1945 map then using a 10 m^2 grid. The two dimensional retreat was measured in order to fine the volume of sediment removed. The results are on the data sheet.

DATA SHEET

		Area of Sediment removed (m^2)	Height of till cliff (m)	Summary statistics
Area 1	Hartlen Point	37,000	1,1.5,1.5,2.5,5,5,5,5,12,11, 5,2,2,2,10,15,5,5,20	
	Osborn Head		5,20,9,10,15,15,2,2,2,	
	Pensey Head and Conrods Head	28,000	2,12,15,10,3,11,11,11 5,10,12,18,19,15,15,15,10,10, 5,5,5,5	$n = 54$, $\bar{x} = 10.9$ m sd = 5.34 m
	Lawrencetown Head	9,400	10,15,25,20,10	
Area II	Half Island Point	18,200	5,10,10,20,23,25,19,5,8,15,15, 18,18,15,8,18,18,20,15	
	Eroded Drumlin	150,000	9 measurements @ $\bar{x}$ for entire area 8.74 m	$n = 43$ $\bar{x} = 11.7$ m sd. = 5.92 m
	Graham Head	7,100	5,5,5,8,20,20,10,2,2	
	Rudeys Head	8,300	5,6,10,10,5,5	
Area III	Storey Head	41,000	5,10,5	
	Collies Head	20,800	2,3,4,5,5,1,1,1,1,4,10,15,10,1	$n = 28$ $\bar{x} = 4.52$
	Philip Head		5,10,5	sd = 3.58
	Nauffis Head	4,600	1,1,2,1	

Survey of Cliff Retreat

1) Philip Head

Stake #	Az. of Measurement	1980	1981	1982
Dal Geo 101+	141°	2.65 m	2.62 m	
102	138°	5.1	4.57	
103	159°	3.81	3.76	
2) Collie Head				
Dal Geo 104+	139°		14.0	13.9
105+	169°		14.5	14.6
106+	154°		4.85	4.2
3) Graham Head				
Dal Geo 107	100°	8.26		
107	180°	11.05	7.74	
108	215°	10.13	8.54	
108	166°	9.93	8.83	
108	280°	6.03		
109	244°	2.44		
4) Lawrencetown Head				
Dal Geo 110	180°	9.6		
111	180°	8.8		
112	180°	5.4		
5a) Hartlen Point				
Telephone Poles 1		16.9		15.3
2				
3				
b)				
Dal Geo 113	129°	5.55	2.54	
114	140°	9.48	8.87	
115	144°	5.91	5.31	

\+ Stakes are now missing.

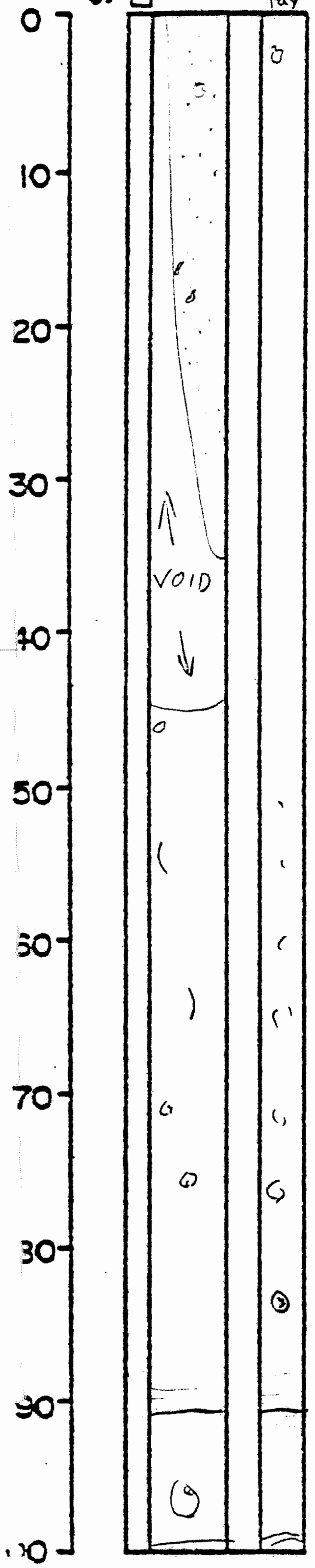
CORE 80-006-59 DEPTH IN CORE 0-100

LOCATION EASTERN SHORE

WATER DEPTH 50 m

Described by: S. EASTON

SMEAR DISTURB X-ray



DESCRIPTION

SAMPLE RECORD

several small gravel clasts

0-35 - DISTURBED - medium to coarse sand c̄ some gravel and shell fragments

35-47 VOID

1cm³ pebble

Medium Sand

olive grey (5Y4/1)

fine to medium sand c̄ no internal structures. colour is also homogenously olive gray (5Y4/1)

shell fragment

shell fragment

shell frag

shell frag.

pebble

laminations of medium and fine sand

silty layer

shell

silty layer.

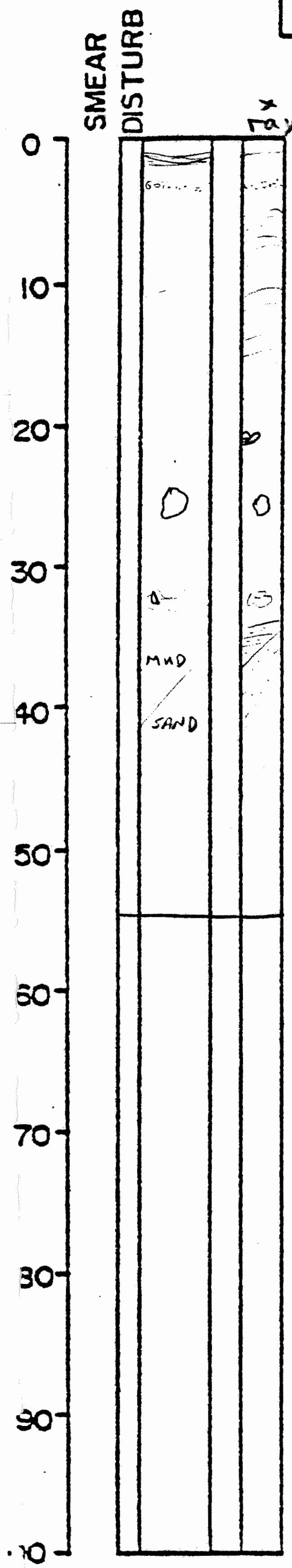
General comments:

CORE 80-006-59 DEPTH IN CORE 100-156

LOCATION EASTERN SHORE

WATER DEPTH 50 m

Described by: J. EASTON



DESCRIPTION

silty layer

shell fragments in silty lens.

105-115
laminated medium to fine grained sand. c̄ many small shell fragments.

121 complete shells

125 pebble

shell fragments

135-145 cm
laminated sand and mud olive gray (5Y 4/1)

fine → med sand.

END OF CORE

SAMPLE RECORD

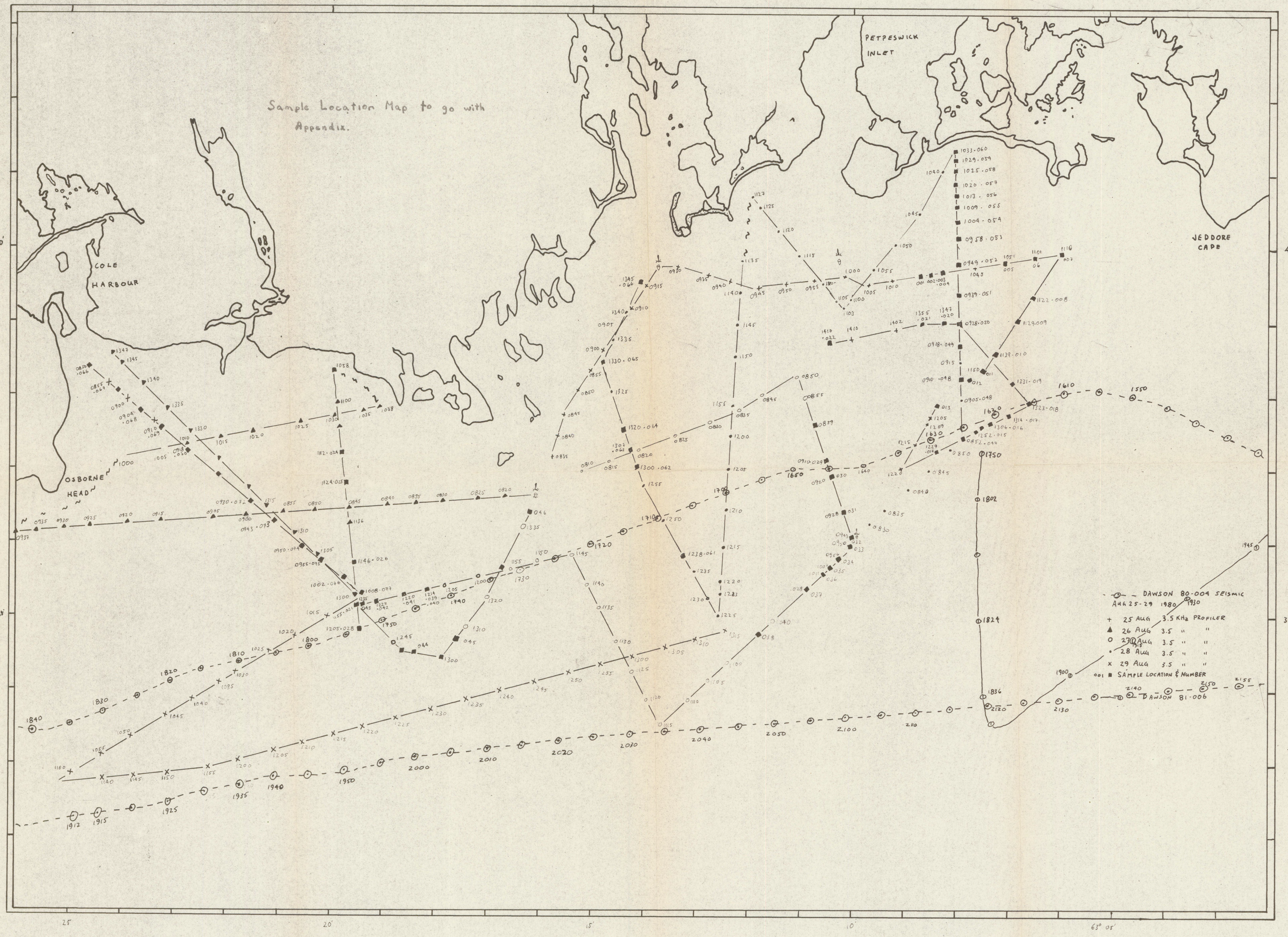
134 - for C-14 age date
11,~~770~~ ± 330 yrs

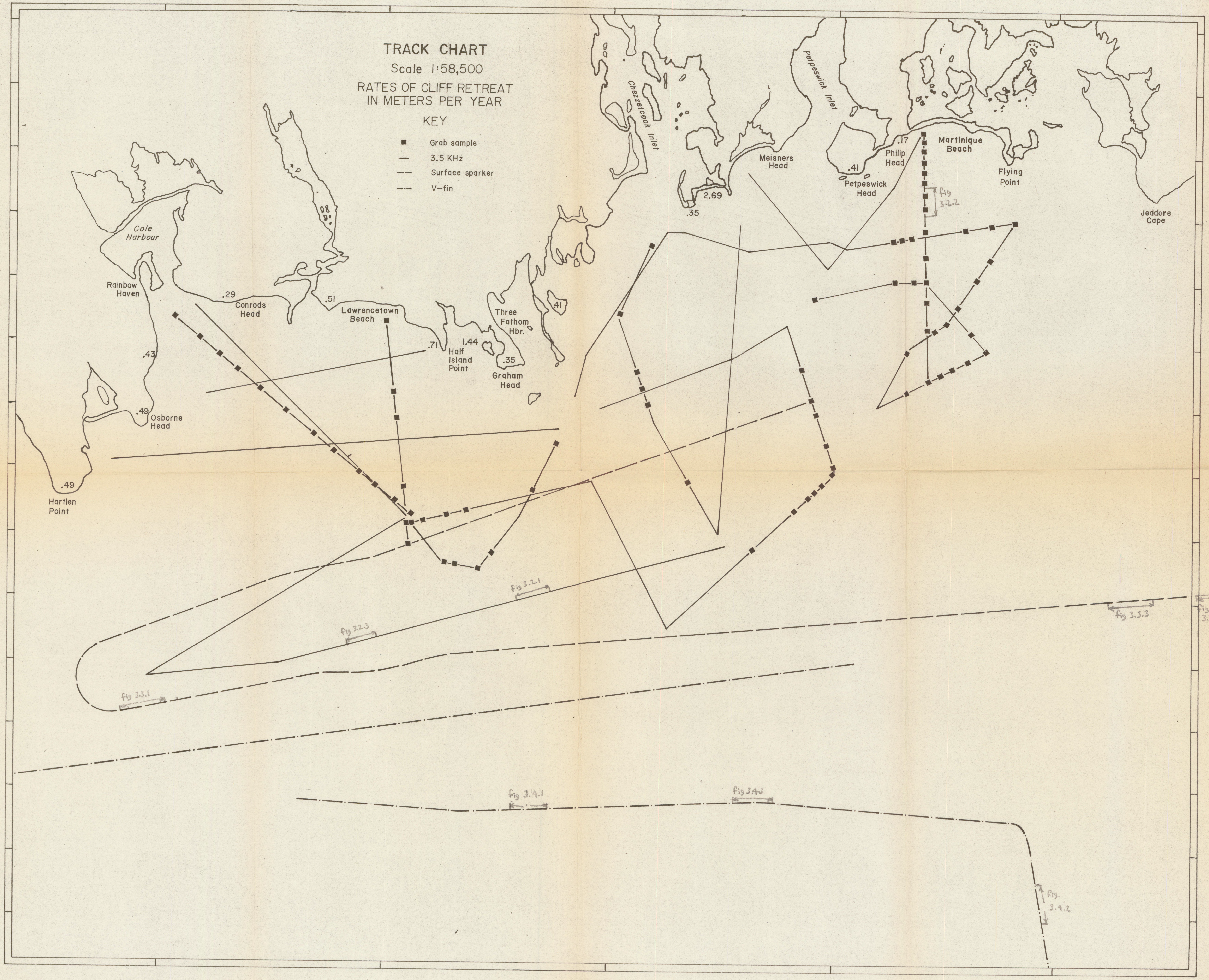
General comments:

GRAB SAMPLES 517-80- , OSBORNE HEAD TO JEDDORE HEAD, AUGUST 1980

SAMPLE #	WATER DEPTH (m)	SEDIMENT TYPE
001	21	med. sand, fine gravel, and some Lithothamnion fragments
002	21	Fine gravel and medium sand, one cobble
003	22	Trace fine sand
004	22	Fine sand
005	18	Fine sand
006	18	Coarse sand and Lithothamnion
007	17	Fine sand, rare gravel
008	23	V. fine sand
009	24	Coarse sand and gravel
010	27	Fine sand
011	30	Fine sand
012	32	Fine-med. sand (small sample)
013	34	Med. sand and fine pebbles
014	32	Gravel, 2 cm, rare coarse sand
015	37	Med. sand
016	37	Fine sand
017	35	Fine sand
018	34	Fine pebble gravel
019	32	Gravelly fine sand
020	25	Coarse gravel, some coarse sand
021	23	Gravelly sand
022	23	Cobbles, rare sand
023	5	Fine sand
024	18	Med. sand and small pebbles
025	21	Fine sand
026	26	Fine sand, much organics
027	31	Fine pebbles, (1 cobble)
028	39	
029	36	Small amount of sand (2 starfish, Lithothamnion fragments)
030	37	Med. pebbles, trace sand, considerable Epifauna on pebbles
031	39	Pebbles and coarse sand, larger cobbles with Lithothamnion on one side
032	46	Sandy gravel
033	46	Sandy gravel
034	46	Trace med. sand
035	47	Cobbles and med. sand
036	48	Trace sand
037	48	Cobbles and med. sand
038	51	Trace med. sand
039	32	Pebbles and fine sand
040	32	Sandy gravel
041	34	Sandy pebble gravel
042	32	Sand and Lithothamnion fragments
043	34	Gravelly sand
044	38	Cobbles and sand
045	37	Trace sand

SAMPLE #	WATER DEPTH (m)	SEDIMENT TYPE
046	22	Fine Sand
047	22	Coarse sand and Lithothamnion fragments
048	28	Coarse sand and pebbles (1 shell)
049	28	Coarse sand and shells
050	26	Trace coarse sand
051	24	Pebbly sand Lithothamnion fragments, much organics
052	19	Small pebbles and fine sand
053	21	Fine sand and
054	19	Sand and gravel
055	17	Fine and coarse sand
056	14	Mud med silt
057	14	Silty sand
058	11	Fine sand
059	9	V. fine sand
060	8	Fine sand
061	38	Cobbles and pebbles
062	30	Coarse sand
063	22	Pebbles and medium sand
064	22	V. coarse sand
065	14	Sand
066	3	Fine sand
067	5	Fine sand
068	9	Fine sand
069	11	Fine sand and shell fragments
070	15	Fine sand and live clams (2-10 mm)
071	17	Coarse sand and shell fragments
072	21	Coarse gravel, Lithothamnion and shell fragments
073	23	Med. sand
074	26	Med. sand
075	26	Med. sand
076	24	Coarse sand
077	32	Pebbly sand


Sample Location Map to go with Appendix.
COLE HARBOUR
OSBORNE HEAD
PETPESWICK INLET
JEDDORE CAPE
44° 40'
40° 40'
35'
35'
DAWSON 80-004 SEISMIC
AUG 25-29 1980
+ 25 AUG 3.5 KHz PROFILER
▲ 26 AUG 3.5 " "
O 27 AUG 3.5 " "
• 28 AUG 3.5 " "
x 29 AUG 3.5 " "
001 ■ SAMPLE LOCATION & NUMBER
DAWSON 81-006
25
20'
15'
10'
63° 05'


TRACK CHART
Scale 1:58,500
RATES OF CLIFF RETREAT
IN METERS PER YEAR
KEY
Grab sample
3.5 KHz
Surface sparker
V-fin
Cole Harbour
Rainbow Haven
.29
Conrods Head
.51
Lawrencetown Beach
.71
Half Island Point
1.44
Three Fathom Hbr.
.35
Graham Head
.41
Chezzetcook Inlet
.35
2.69
Meisners Head
Petpeswick Inlet
.41
Petpeswick Head
.17
Philip Head
Martinique Beach
Flying Point
Jeddore Cape
.43
.49
Osborne Head
.49
Hartlen Point
fig 3.2.2
fig 3.2.1
fig 3.2.3
fig 3.3.1
fig 3.3.3
fig 3.3.2
fig 3.4.1
fig 3.4.2