SURFICIAL SEDIMENTS OF BAIE VERTE, NEWFOUNDLAND

J. Shaw

Geological Survey of Canada
Open File 2457 (1992)

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Box 1006, Dartmouth, Nova Scotia,
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NEWFOUNDLAND MDA 2

Contribution to Canada-Newfoundland Cooperation Agreement on Mineral Development 1990-1994, a subsidiary agreement under the Economic and Regional Development Agreement. Project funded by the Geological Survey of Canada

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INTRODUCTION

This report is the result of a geological research program initiated as part of the Canada - Newfoundland Cooperation Agreement on Mineral Development. The program aims to determine the potential of Newfoundland inner shelf areas to host marine placers, particularly gold placers. The impetus behind the program was a report, prepared by C-CORE (SOLOMON and EMORY-MOORE, 1989) for the Newfoundland Department of Mines and Energy, which assessed the placer potential of the offshore surrounding Newfoundland. Following guidelines suggested by C-CORE the northeast coast of the island (Fig. 1) was selected as a priority study area.

The data which are analysed here were collected on two cruises by vessels based at the Bedford Institute of Oceanography, Dartmouth, Nova Scotia. Cruise 90-013 utilised a large survey vessel, C.S.S. Hudson, and took place in June 1990 (SHAW and WILE, 1990). The results of gold assays and geochemical analyses of samples obtained during the cruise were released in Open File Report 2294 (SHAW et al., 1990). These data showed that gold was present in a number of samples collected in Baie Verte and in Notre Dame Bay, off the east coast of the Baie Verte Peninsula. As a consequence of these encouraging results, more detailed surveys of Baie Verte, as well as other areas, were conducted during cruise 90-035 in July and August 1990, using a much smaller vessel, C.S.S. Navicula (SHAW, BEAVER and WILE, 1990). The results of analyses of samples collected during this cruise are reported in Open File Report 2417 (Emory-Moore, 1991).

This report describes the Quaternary sediments and characteristics of the seabed within Baie Verte. The results of assays and geochemical analyses of seabed samples collected during both cruises can now be placed in a proper geological framework.

GEOLOGICAL BACKGROUND

Onshore Quaternary geology

LIVERMAN and TAYLOR (1990) indicated that the island of Newfoundland shows a concentric zonation with regard to surficial sediments. Baie Verte (Fig. 1) lies within the outermost of their four zones, Zone 4 (exposed bedrock and marine sediments). Most of the bay is bordered by Unit 2, bedrock concealed by vegetation, with a discontinuous till cover (<50 percent by area). A large area of Unit 1 occurs on the east side of the outer bay, extending north from Lower Green Cove, with a smaller patch on the west side in the vicinity of Marble Cove. Unit 1 consists of "exposed bedrock having little or no sediment cover". Deposits of Unit 8, "marine clay, sand, gravel, and diamicton", occur at the head of Baie Verte, extending from Pine Cove to a short distance beyond the head of the bay, and along the west coast as far as Sisters Point.

The background to Late Quaternary events on the Baie Verte peninsula is decribed by

LIVERMAN and ST. CROIX (1989). An early ice flow phase consisted of north to northeast flow over the southern part of the peninsula, diverging east and west over the centre of the peninsula. Later flow was controlled by local topography. The large-scale maps published by DYKE and PREST (1987) indicate an ice margin seaward of Baie Verte at 14,000 BP, and well inland by 13,000 BP.

Ice retreat was accompanied by relative sea-level changes, dominated in this area by crustal rebound. GRANT (1989 a) shows a marine limit in the region occurring between +75 and +100 m. Interpolation of his isobases (p. 428) suggests a marine limit in Baie Verte of approximately +90 m. The relative sea-level curve for the region would presumably be similar in form to those for northern and western Newfoundland (GRANT, 1989 a), with a rapid early postglacial fall and a relaxation after approximately 8,000 BP.

A number of radiocarbon dates assist in constructing a chronology of ice retreat and the accompanying sea-level change. An intact valve of Hiatella arctica collected from an elevation of +72 m at Deer Cove is dated at 12,400±110 BP (McNEELY, in press). It is overlain by till, and appears to be evidence of a late ice readvance in the area (D.R. GRANT, pers. comm., 1991). Falling postglacial sea levels are registered by several dates: at Fleur de Lys Harbour, at the mouth of Baie Verte, shell at +21 m is dated at 9,930±130 BP (GRANT, 1986). Approximately 5 km inland from the head of the bay, shell at +50 m is dated at 11,520±180 BP. A similar distance inland from the head of Ming's Bight, gyttja samples at +114 m, dated at 9,510±160 BP and 10,400±160 BP (GRANT, 1989 b), record the absence of ice from the region.

Offshore Quaternary geology

Hitherto, nothing was known of the Quaternary sediments within Baie Verte, and little of those on the shelf outside the bay. Concerning the latter, DALE and HAWORTH (1979) presented the results of a study of Late Quaternary sediments on part of the shelf in this region. Their surficial seismic facies map showed five units. The uppermost unit, Unit 1, was acoustically transparent, and corresponded with gray, clayey silty mud in cores. Units 2 and 3 were seismically stratified and semi-stratified respectively - Unit 2 corresponded with muds containing small amounts of gravel. Unit 4 was nonstratified, and was interpreted as till. Unit 5 was bedrock. Extensive areas of Unit 1 were mapped in White Bay and Notre Dame Bay. A complex pattern existed north of Baie Verte, with all units occurring. Unfortunately, a broad zone near the coast was not surveyed.

METHODOLOGY

Details of survey techniques are given at length in reports on cruises 90-013 (SHAW and WILE, 1990) and 90-035 (SHAW, BEAVER and WILE, 1990). The data gathered during cruise 90-013 (C.S.S. Hudson) comprised Huntec DTS high-resolution seismic reflection data, airgun data, 12 kHz bathymetric data, grab samples and gravity cores. Very little sidescan sonar imagery was obtained due to equipment malfunctions.

The bulk of the data used for this report was collected during cruise 90-035 (C.S.S. Navicula). Data were collected using a Seistec high-resolution seismic reflection system, a Datasonics Bubble Pulser system, a Klein sidescan sonar system, the ship's Elac echosounder, a van Veen grab sampler, an Alpine gravity corer, and a seabed camera system. Navigation was by Loran-C and radar.

Grab samples from the C.S.S. Hudson cruise were assayed and geochemically analysed by C-CORE under contract - results are reported in Open File Report 2294 (SHAW et al., 1990). Grab samples collected from Navicula were also analysed by C-CORE, again under contract to the Geological Survey of Canada, and results are reported in Open File Report 2417 (EMORY-MOORE, 1991). Seabed photographs from cruise 90-035 are shown in the report by SHAW, BEAVER and WILE (1990).

THE COASTLINE OF BAIE VERTE

Baie Verte is a 20-km long embayment on the Baie Verte Peninsula of northeast Newfoundland (Fig. 1; Enclosure 1). The coastline is rugged, with hills rising to several hundred metres within a kilometre of the sea. The coastline at the mouth of the bay, on the eastern side, consists of steep rock cliffs. Within Devil's Cove, talus slopes extend to the water's edge, and a small pocket gravel beach is present. Cliffs extend down the east coast of the bay as far as the north side of Green Cove. A small gravel pocket beach is developed in Lower Green Cove and more extensive gravel beaches are located within Green Cove.

South of Green Cove the coast is somewhat less rugged, with small beaches developed between bedrock headlands. From the sea it was observed that large boulders litter the shore at Pumbly Point, possibly indicating glacial diamict at the coast in this area. Farther south, in Pine Cove a gravel beach is backed by a low bluff apparently composed of glacial diamict {probably the Unit 8 deposits described by LIVERMAN and TAYLOR (1990)}.

At the head of the bay, intertidal flats are present at the mouth of the Baie Verte River. North of the settlement of Baie Verte, the west coast is bordered by wooded, steep rocky slopes, with narrow gravel beaches between headlands. Beaches are fewer in number north of Duck Island Cove, the exceptions being small sandy beaches within Coachman's Harbour. Elsewhere at the

west side of the bay mouth the coast is rocky.

Human activities within the bay

The settlement of Baie Verte is a major regional centre. It has a large public wharf which is used by coastal tankers. Several smaller wharves are located in the vicinity. The only other community is Coachman's Cove, at the west side of the outer bay. A second large wharf is located in Upper Duck Island Cove, site of the asbestos plant of Advocate Mines Ltd. Large spoil tips dominate the landscape here. During August 1990 intensive fishing activity was observed in the outer bay, in particular Devil's Cove and Deer Cove.

ENCLOSURE 1: BATHYMETRY AND SURVEY TRACKS

This enclosure shows the tracks of cruises 90-013 (C.S.S. Hudson) and 90-035 (C.S.S. Navicula) superimposed upon the bathymetry of the bay, derived from Canadian Hydrographic Service Chart 4521. For the purpose of description the bay is divided into an inner and an outer part, with the outer bay located seaward of Duck Island.

The outer bay

The most prominent feature of the outer bay is a deep trough which extends northeast from the vicinity of Grassy Island and contains depths which are typically greater than 275 m. The trough has a maximum depth of 324 m northwest of Deer Cove and shallows to a sill with a depth of 192 m at the mouth of the bay, just north of Ming's Islands.

Away from the trough, the sea floor of the outer bay is irregular, with extensive shallow areas, shoals, and small rocky islands, including The Sisters, Tin Pot Islands, and Grassy Island. Shallow shelves are located in coastal embayments at Devil's Cove (average depth 28 m), Deer Cove (46 m), Coachman's Harbour (28 m), and, to a lesser extent, Marble Cove (28 m).

The inner bay

The inner bay is relatively shallow, with a gently-shelving seabed in most areas. A maximum depth of 71 m occurs west of Pine Cove. At the head of the bay, offshore from the settlement of Baie Verte, the maximum depth is only 18 m. However, just beyond the public wharf the bay shallows rapidly towards the intertidal areas at the mouth of the Baie Verte River.

Survey tracks

The tracks of cruise 90-013 (C.S.S. Hudson) consist of a number of cross-lines at the head of the bay; several lines extend into deeper water offshore. The tracks of cruise 90-035 (C.S.S. Navicula) are more closely spaced than those of Hudson. They do not extend to the head of the

bay because of the shallow water at the mouth of the Baie Verte River. Neither do the tracks extend into Ming's Bight, since the latter is not charted on chart 4521, and Navicula has a considerable draft (3.5 m). After further consideration, Ming's Bight was eventually surveyed in 1991 using Navicula (Edwardson et al., in prep.).

ENCLOSURE 2: GRAB SAMPLES AND SEABED PHOTOGRAPH LOCATIONS

The seabed samples collected on Hudson 90-013 consisted of 11 van Veen grab samples and 3 IKU grab samples. On cruise Navicula 90-035 a total of 36 van Veen grab samples were collected. In the outer bay the samples are clustered in shallow embayments rather than evenly distributed. This results from an attempt to focus on sand and gravel deposits in shallow water rather than on deeper, muddy sediments.

At each sample site a black and white seabed photograph was taken (Appendix 1). As can be seen from the enclosure, there is usually a discrepancy between sample and photograph locations - the vessel generally drifted a short distance before each photograph was taken.

Three gravity cores were collected on cruise 90-035 - the locations are shown on Enclosure 2 and core logs are contained in Appendix 2.

ENCLOSURE 3: TOTAL THICKNESS OF QUATERNARY SEDIMENTS

The bedrock surface underlying the Quaternary sediments is either poorly defined or not apparent on data collected with the Seistec system. While the Bubble Pulser data have poor resolution, the location of the bedrock surface is generally indicated by a very strong reflection.

The thickest sediments are located in a deep trough in the outer bay. The maximum thickness is 74 m. They consist of stratified glacial marine and postglacial hemipelagic sediments (Units 3 and 4 - see below), largely ponded, but in places draped over ridges.

Away from the trough, sediment thickness is typically less than 2 m, with extensive areas of bedrock exposed on the seabed. However, isolated pockets of unit 4 sediments (postglacial sand and gravel) occur offshore from Devil's Cove, Deer Cove, Coachman's Harbour and Marble Cove.

Seismo-stratigraphy

A number of seismo-stratigraphic units are recognized within the Quaternary sediments depicted on the enclosure. Syvitski and Praeg (1989) define seismo-stratigraphic units as "successive intervals that can be recognized and traced on the basis of distinctive acoustic attributes, bedding styles, and/or unit geometry. Acoustic attributes are the presence and strength

of coherent reflectors (stratification) and incoherent backscatter (tone).....Bedding styles refer to the internal acoustic stratification in relation to the bounding surfaces of the unit. Unit geometry is the nature of the upper reflector and its relation to the basal reflector, and the relation of the unit as a whole to basal topography" (p. 294). (More properly, "reflectors" should be used to refer to reflecting geological horizons; these reflecting horizons appear as "reflections" on seismic records).

Four units are identified and interpreted in Baie Verte. A Seistec seismic reflection profile illustrating these units is shown on Figure 2. The units are as follows:

Unit 1: Bedrock

The bedrock surface appears as a high-intensity reflection on the seismic reflection profiles. Where bedrock is overlain by Quaternary sediments, the bedrock surface is not always apparent on Seistec profiles, but it marked by high-intensity reflections on bubble pulser profiles. Small bedrock exposures occur at several places in the inner bay, but bedrock exposures are extensive in the outer bay, where most of the seabed is either devoid of Quaternary sediment, or has a thin (<1 m) veneer.

Unit 2: Glacial diamict

This unit consists of incoherent reflections. It has a slight positive relief in some places, but more generally fills depressions in the bedrock surface. Near-seabed exposures have a dark tone or mottled dark and light tone on sidescan sonograms, indicating either a muddy gravel or gravel sediment on the seabed. This is confirmed by grab samples. Where postglacial cover is thin or absent boulders are present on top of this unit. It is interpreted as an ice-contact sediment, or glacial diamict.

Unit 2 is confined largely to the inner bay. The major ocurrences are: (1) a deposit which infills bedrock depressions and extends across the bay, from just north of Duck Island to Green Cove. It is typically more than 15 m thick, with a maximum thickness of 24 m. The sidescan sonar was not towed deep enough to determine the seabed character in this area; (2) a second deposit which extends across the bay from Shark Point to Pumbly Point. It is only 1 m thick close to Pumbly Point but has a maximum thickness of 17 m in the middle of the bay; (3) a third deposit which extends WNW from Pine Cove,with a thickness of about 11 m. Glacial diamict deposits extend from here towards the head of the bay, along the west coast. They are usually less than 5 -m thick, and, where they are not mantled by postglacial mud, are strewn with boulders.

Unit 3: Stratified glacial marine sediment

Unit 3 contains moderate to high intensity continuous coherent reflections which are conformable with the underlying terrain. Some differences exist between occurences in the outer and the inner bay. The thickest occurrences are in the outer bay, in the deep trough, where unit 3

sedments overlie bedrock and are up to 70 m thick. In the outer bay two sub-facies are identified: (1) a stratigraphically-lower facies with moderate to high intensity, continuous, coherent reflections, highly conformable to the underlying substrate; and (2) an upper facies with weaker reflections which decrease in intensity upwards, so that the acoustic character approaches that of acoustic unit 3.

A third sub-facies of unit 3 occurs in the inner bay, in areas where where sediments with unit 3 acoustic characteristics overlie bedrock or unit 2 (glacial diamict). While reflections are highly conformable in places, they are often less well-defined, more irregular, and not as continuous. Often they pass laterally into sediments with incoherent reflections.

Three gravity cores (samples 133-135) are believed to have intersected unit 3 sediments in the inner bay. They contained grayish clay or silty clay with grit and angular pebbles, sometimes concentrated in bands. Unit 3 is interpreted as a glacial marine mud.

Age of glacial marine deposits

No datable material was found in the glacial marine sediments from the three cores. However, Macoma calcarea fragments from the top of the glacial marine sediments in core 90-035-183 from the Sunday Cove Island area, at the mouth of Halls Bay (SHAW, BEAVER and WILE, 1990) are dated at 11,600±80 BP (TO-2395). This is an AMS date, corrected for a 410 yr reservoir effect. The core was taken in a water depth of 178 m; the sample was 0.38 m from the top of the core. For comparison, three AMS dates on glacial marine deposits off the east coast of the Baie Verte Peninsula (core 90-013-064, SHAW and WILE, 1990) range from 11.5 to 13.0 ka BP.

Unit 4: postglacial mud and sand

Unit 4 is the uppermost seismo-stratigraphic unit. In the inner bay it occurs in shallow basins overlying glacial marine sediments of unit 3, or, more commonly, as a thin surficial veneer over unit 3 or unit 2 deposits. The maximum thickness of unit 4 in the inner bay is 11 m. In contrast to the dark textured tone of unit 3 sediments on sidescan sonograms, and their roughness on the seabed, unit 4 has a light tone and a smooth surface, except where disturbed by anchor drag marks. Where unit 4 sediments infill small depressions between outcrops of unit 3, as in many parts of the inner bay, the seabed has a patchy light/dark tone on sidescan sonograms.

Analyses of grab samples and seabed photographs confirm that in the inner bay unit 4 consists of mud or sandy mud, with variable amounts of (ice-rafted) pebbles. In the limited area where the mud is more than 5 m thick (close to Baie Verte settlement), shallow gas is interpreted from seismic profiles, and is the only such occurrence in the region. The postglacial age of the basin muds in the inner bay is confirmed by an AMS date from core 90-035-134 (Appendix 1). Gastropods from a depth of 12 cm are dated at 5,510±60 BP (date includes a 410 yr correction for the reservoir effect).

In the outer bay thick, stratified Quaternary deposits occur in the central trough, but it is uncertain how much of these are postglacial in age. Away from the trough, the surficial sediment cover is very thin, typically 0.5 to 2 m, but isolated bodies of thicker postglacial sediment occur in areas of shallower water close to the coast, at Coachman's harbour, Devil's Cove, Deer Cove and Marble Cove. These are described in the following section.

ENCLOSURE 4: THICKNESS OF POSTGLACIAL SEDIMENTS

Enclosure 4 shows the thickness of postglacial sediments. The extensive deposits of the inner bay are ponded mud which is thickest in the deepest areas. As noted above, in the outer bay the problem of determining the postglacial /glacial marine boundary on the seismic reflection records introduces some error in the estimate of postglacial thickness in the deep trough. Grab samples indicate that the seabed consists of mud.

The maximum thicknesses of the sediment bodies on shallow shelves in the outer bay are more than 5 m in Coachman's Harbour, more than 10 m in Deer Cove and Marble Cove, and exceed 20 m in Devil's Cove. These sediments are coarser-grained than the postglacial sediment in the deeper water and, since they may be potential sources of placer gold, they are discussed in greater detail below.

Coachman's Harbour

In Coachman's Harbour, at the north side of the entrance to Baie Verte, postglacial sediment infills depressions between bedrock knolls and ridges in water depths between 18 and 58 m. The sandy seabed is gently shelving, with little relief. The protruding bedrock is highly irregular, and is often masked by a thin gravelly veneer. The sediment is acoustically transparent on seismic reflection profiles and on 12 kHz sounder records. Thickness is highly variable; the maximum is 7 m with an average of 4 m. The sediment bodies extend over an area of approximately 0.75 x 1.75 km.

Four grab samples and corresponding seabed photographs provide evidence on the nature of these sediment bodies. Samples 93 (29 m), 95 (18 m) and 97 (27 m) consist of well-sorted medium sand. Photo 94 was obscured by seaweed, but photo 96 shows a sandy bottom with numerous sand dollars (Echinarachnius parma). Photograph 98, showing coarse angular gravel with sand, does not represent the seabed at sample site 97 - the vessel must have drifted over a rocky area. Sample 99 (57 m) was coarse, shelly sand with some gravel - photograph 100 shows coarse gravel.

Deer Cove

Sand and gravel is trapped in several pockets close to the coast which occupy an area 1.0 x

0.75 km in extent, and are bounded to seaward by a bedrock ridge which drops off steeply into the deep trough of the outer bay. Water depths on this narrow shelf range from 17-30 m. The sediment pockets are up to 18 m deep. Is is difficult to determine how much of the material in the pockets is an underlying glacial diamict, and how much is postglacial is age.

Navicula grab samples 103 (35 m), 105 (41 m), 107 (46 m), 109 (51 m) and 111 (47 m) consist of shelly, sandy gravel or gravelly sand. The gravel is generally coated with the encrusting alga Lithothamnion sp. Seabed photograph 104 shows a gravelly bottom; photographs 106, 108, 110, and 112 show sandy seabeds with some gravel, shell debris, and sand dollars (Echinarachnius parma). All five photographs show dead capelin littering the bottom.

The seabed has a patchy appearence, caused by the presence of both sand and gravel. Iceberg pits and scours are common, and a veneer of gravel appears to infill depressions between bedrock knolls in more elevated areas.

Note: although the enclosures show the locations of the seabed samples to the east of the survey tracks, it is believed that the track locations are probably shown too far west (because of errors in plotting), and that the samples were collected along the tracks.

Gold occurrences at Deer Cove

The gold-hosting deposits of postglacial sand and gravel at Deer Cove (Emory-Moore, 1991) are of limited extent. All five samples collected during cruise Navicula 90-035 had anomalous levels of gold in the mud fraction (up to 859 ppb); four out of five contained particulate gold in the sand fraction (up to 7.6 ppb).

Devil's Cove

The sidescan sonograms show a small area of fine-grained sediment, with moderate-light tone, between bedrock highs in Devil's Cove, at the mouth of Baie Verte. This pocket of sediment is located within a bedrock cleft and has a maximum thickness of 22 m. The width of the deposit is about 100 m. Elsewhere in this area, a thin (<0.5 m) discontinuous veneer of what appears to be gravel overlies bedrock. Grab sample 101 (Navicula, 90-035) consists of only a few cobbles encrusted with Lithothamnion sp. and the seabed photograph shows a bouldery bottom.

It is unclear from the seismic data whether or not all of this isolated sediment deposit is postglacial sand and gravel. As at Deer Cove it is possible that a surficial veneer of postglacial sediment overlies glacial diamict. However, since this is an area of high wave energy, it is equally likely that the sediment in the pocket may be entirely sand and gravel which has been transported across the seabed by wave action and trapped in the bedrock hollow. The landward extent of the deposit is uncertain.

Marble Cove

Postglacial sediments up to a maximum thickness of 10 m cover an area measuring

approximately 1.5 x 0.5 km in water depths shallower than 50 m. Navicula samples indicate the seabed comprises pebbly fine sand (119 and 121), fine sand (123), and pebbly medium sand (125). Away from bedrock exposures the seabed generally has a dark tone on sonograms. Seabed features include gravel ripples and iceberg scours and pits. Photographs in this area (120, 122, 124, and 126) show various seabed sediment textures, including sandy bottoms with sea urchins, gastropods and sand dollars. In gravelly areas pebbles, cobbles, and boulders are coated with Lithothamnion sp. Samples 121 and 125 contained anomalous (up to 86 ppb) gold amounts in mud (Emory-Moore, 1991), and sample 121 contained particulate gold.

ENCLOSURE 5: INTERPRETATION OF SIDESCAN SONAR DATA

This enclosure shows a classification of seabed features and types which are recognizable on sidescan sonograms. The coverage is not complete - in areas which were condsidered too deep and rugged and the sidescan fish was not lowered sufficiently close to the seabed to produce an image on the recorder. Three types of bottom are distinguished on the sonograms:

1) Bedrock

Bedrock is easily recognized by its strongly reflecting surfaces, acoustically shadowed areas, and patterns of joints and fissures. The most extensive occurrences are in the outer bay, where it is the dominant seabed type. Had the fish been lowered sufficiently to give full coverage of the seabed it would have indicated numerous bedrock outcrops in the deep area for which data is not available, except in the deepest areas, where stratified sediments attain considerable thickness (see below). The limited sidescan sonar data collected during Hudson 90-013 show that bedrock outcrops extend out beyond the bay onto the inner shelf.

In the inner bay, bedrock occurrences are less widespread. They occur mainly in the vicinity of Duck Island, in the narrows east of Big Head, along the south coast south of Pine Cove, and in a few small patches at the head of the bay.

2) Light-toned areas (fine grained sediments)

Areas of low acoustic reflectivity and uniform light tone on the sonograms are interpreted as occurrences of fine-grained sediment - sand or mud with little or no gravel. Light-toned areas occur throughout the inner bay, and are most extensive in basins. The largest area is located between Pine Cove and Apsey Cove, with a second zone occurring from seaward of Sandy Point to the head of the bay. In the inner bay, these light-toned areas are indicative of mud or sandy mud at the seabed.

In the outer bay the chief occurrences of light-toned areas on sidescan sonograms are shallow coastal embayments at Coachman's Harbour, Deer Cove and Devil's Cove - sediments in these

areas are sandy rather than muddy.

3) Dark-toned areas (gravel, muddy gravel, gravelly mud)

Areas of higher acoustic reflectivity and darker tone are interpreted as gravel, muddy gravel, and gravelly mud. They are scattered throughout the outer bay and generally occupy all areas where bedrock does not occur at the seabed, with the exception of the light-toned (sandy) areas at Coachman's Harbour, Deer Cove and Devil's Cove. In the inner bay, dark-toned areas are extensive, generally occurring on bathymetric highs, away from the muddy basins.

A zone of 'reniform' texture on the sonograms occurs along both sides of the inner bay, in depths ranging from 18-60 m, but averaging 30 m. This texture appears to represent lobate features, with less than 1 m of relief, and with steep seaward slopes. These lobes occur typically on slopes of 5 degrees. The provisional interpretation is that they are creep or slump phenomena.

Scattered small point sources of higher reflectivity on the seabed in parts of the dark-toned areas are interpreted as boulders. The principal occurrences are along the west side of the inner bay, and in a zone extending across the narrows from Shark Point to Pumbly Point (boulders occur at the coast at the latter location). The presence of boulders is interpreted as indicating near-seabed occurrences of glacial diamict (seismo-stratigraphic unit 2).

Seabed features

Seabed features interpreted from sidescan sonograms include the following:

Linear anchor-drag marks

Elongate grooves on the seabed, sometimes straight, mostly curving, up to 400 m in length, and averaging 1-2 m wide, are interpreted as anchor-drag marks. Some are kinked in places, sometimes with terminal kinks. Others display sharp changes in direction, often more than 90 degrees, and sometimes more than 180 degrees. The flanks of the drag marks appear as raised ridges or berms, and the central parts are depressed below the surrounding seabed, usually less than 1 m. In places, the ridges appear to consist of reflective, coarser material, possibly muddy gravel, with mud infilling the central troughs. The features are most common in the vicinity of Baie Verte Harbour, where the seabed is highly disturbed by a dense concentration of intersecting drag marks. Lesser occurrences exist in Upper Duck Island Cove, adjacent to the wharf at Advocate Mines, and in Green Cove.

Plumose-like anchor-drag marks

Features which consist of straight or slightly curved lineations, similar in width to those described above, but with plumose-like fans of grooves on the seabed at one end of the feature, are

interpreted as having been formed on the seabed by ships' chains and anchors. Both these, and the linear anchor-drag marks, were probably formed by the relatively large coastal tankers which once docked at Baie Verte. Marks on the seabed at Upper Duck Island Cove were probably generated by vessels loading asbestos.

Iceberg scours

These consist of two types: linear furrows, and pits. They occur close to the coasts of the inner bay at depths ranging from 17 to 46 m, at an average depth of 33 m. Pits are believed to have been formed by grounded icebergs, and average 5-10 m diameter. Furrows, formed by the movement of grounded icebergs, are typically up to 60 m long and 2-5 m wide. Some features are intermediate between the two types, and record both the movement and grounding of bergs.

Wreck

The possible remains of a 15 m vessel appear to lie on the seabed south of the Government Wharf in a water depth of approximately 15 m.

SUMMARY AND CONCLUSIONS

Baie Verte contains four seismo-stratigraphic units: 1) bedrock, most extensive in the outer bay; 2) glacial diamict, which is thickest in several bodies transverse to the inner bay; 3) glacial marine sediments, thickest in a deep trough in the outer bay; 4) postglacial sediments - mud in the inner bay and the deep trough of the outer bay, and sand and gravel in shallow, exposed settings in the outer bay.

The bay was surveyed because it was believed that the presence of numerous gold deposits onshore (Dubé, 1990) increased the potential for gold placers offshore. The analysis of samples collected on Navicula cruise 90-035 (EMORY-MOORE, 1991) indeed shows that gold is present in the area. Gold was found to be present in the fines of 17 samples out of 19 analyzed. Visible gold grains were found in the sand-sized component of 9 samples out of 35 examined.

The data suggest that processes capable of winnowing gold bearing glacial deposits only operate on the small, exposed embayments of the outer bay, and that coarse sediments, sand and gravel, are confined to those areas. While the gold quantities discovered hitherto are small, there remains a possibility that higher concentrations exist slightly below the surface (Emory-Moore, 1991).

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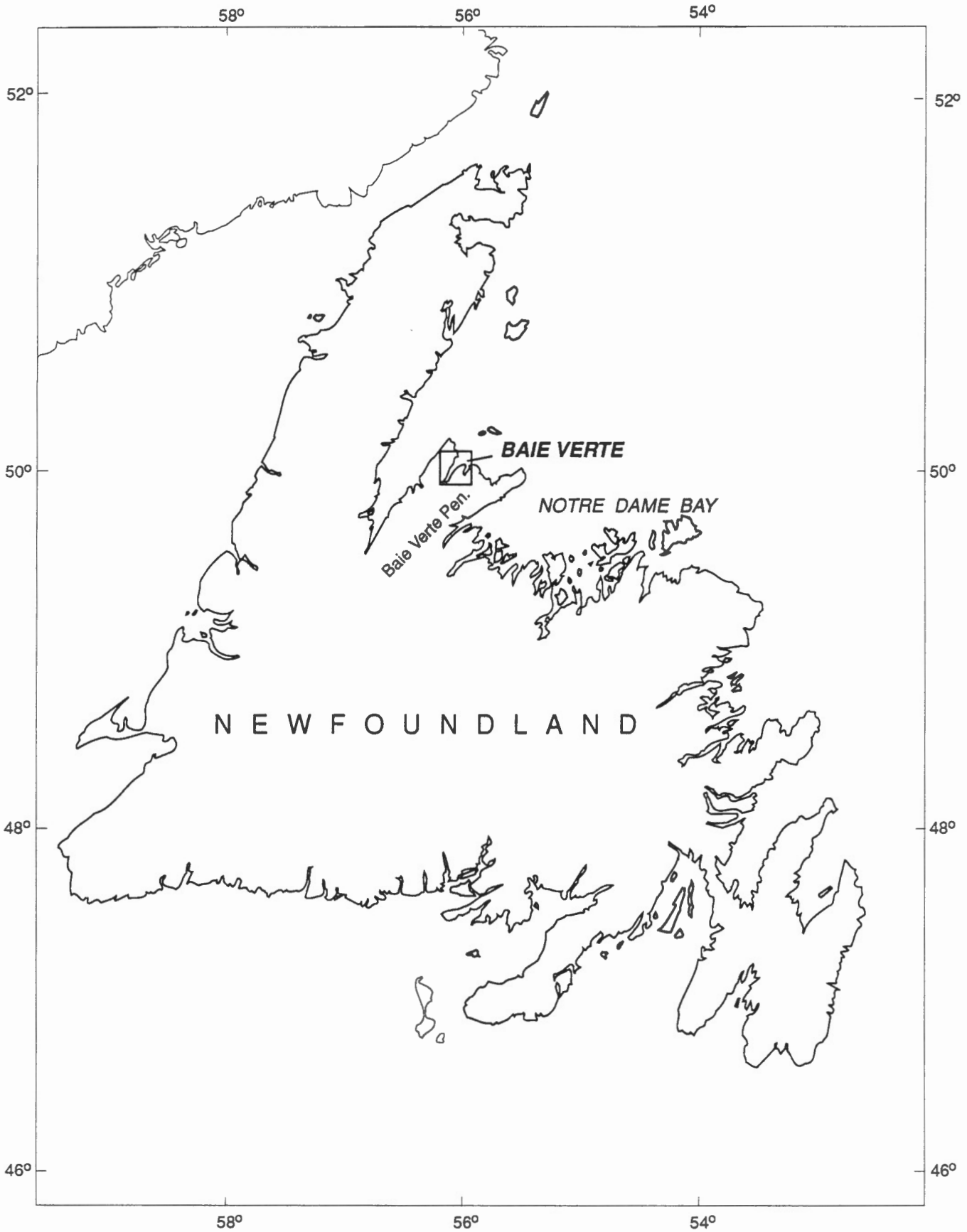


Figure 1: The location of Baie Verte. The rectangle denotes the area covered by the enclosures.

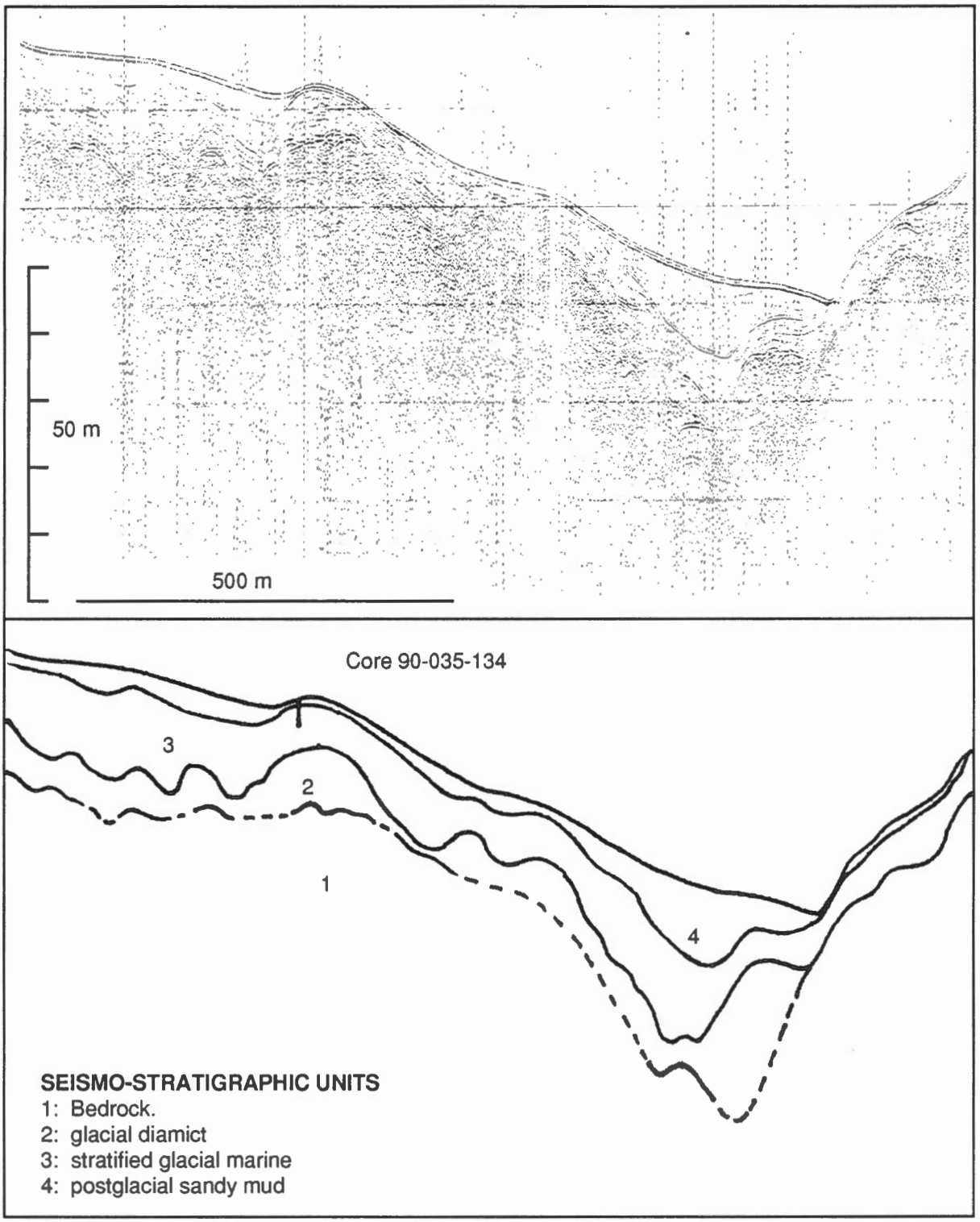
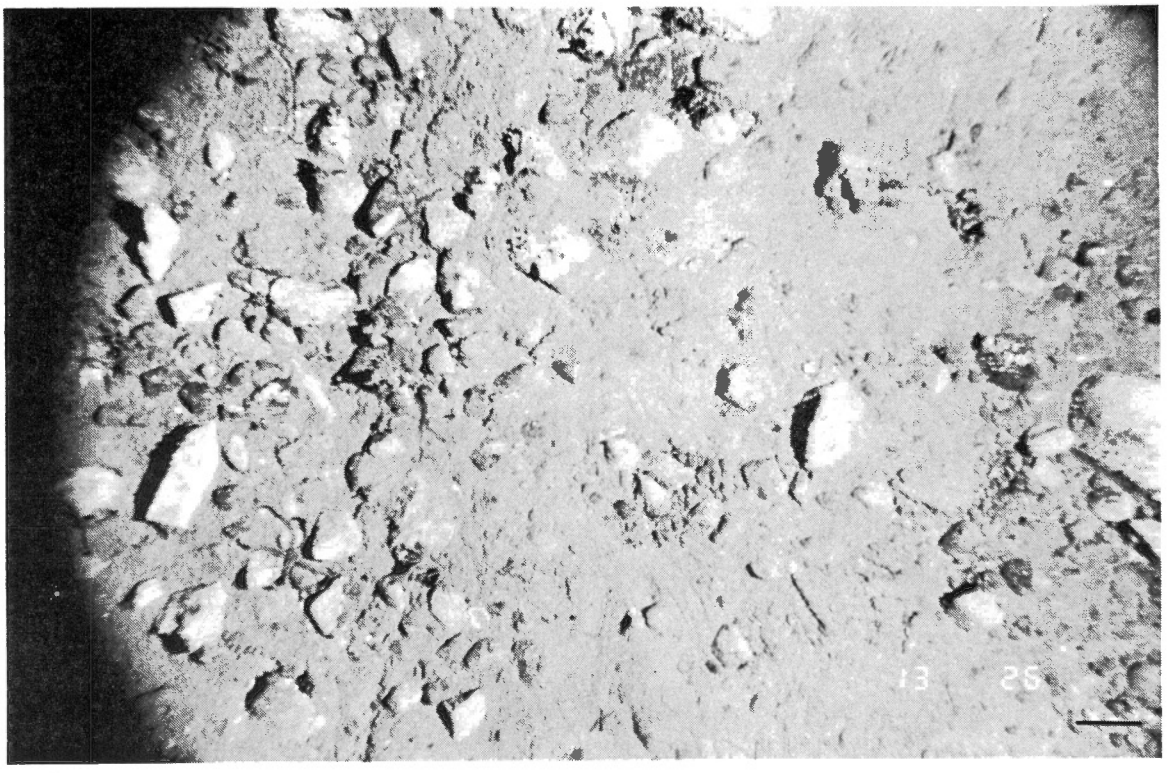


Figure 2: Seistec record from inner Baie Verte showing seismo-stratigraphic units one to four and the location of core 90-035-134.

APPENDIX 1: SEABED PHOTOGRAPHS
Cruise Navicula 90-035

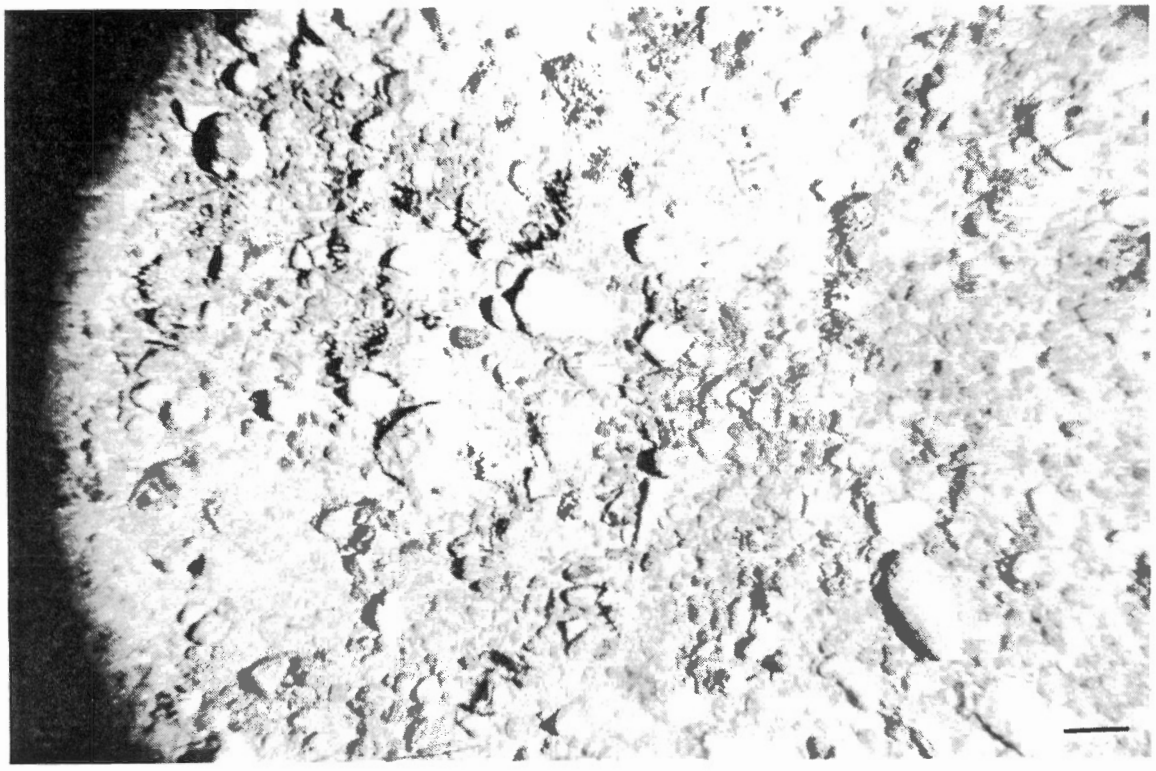
Note: add 3 m to water depths to compensate for depth of sounder below water level. The scale bar on the photographs represents 10 cm.

062 Baie Verte, 67 m. The bottom in this photograph consists of fine-grained sediment, probably sand or muddy sand, with scattered gravel in the pebble to small cobble size range. There is considerable evidence of biological activity: 8 brittlestars, pelecypod valves, shell debris, a tube worm, siphons of a pelecypod, and an active burrow pit occur on the seabed.



064 Baie Verte, 45 m. Subangular to subrounded gravel, in the very coarse pebble to coarse cobble size range, is strewn across a sandy bottom with tracks. The encrusting alga Lithothamnion is evident on some clasts. At least four brittlestars are seen, plus several tube-building polychaetes (family Eunicidae), a few partly buried pelecypod valves, an anemone, and a scaphapod making a track.

066 Baie Verte, 68 m. The bottom is characterized by small-scale roughness, possibly with a layer of flocculated material. The grab sample from this vicinity (065) comprised gravelly mud. If gravel clasts are present, they are buried.



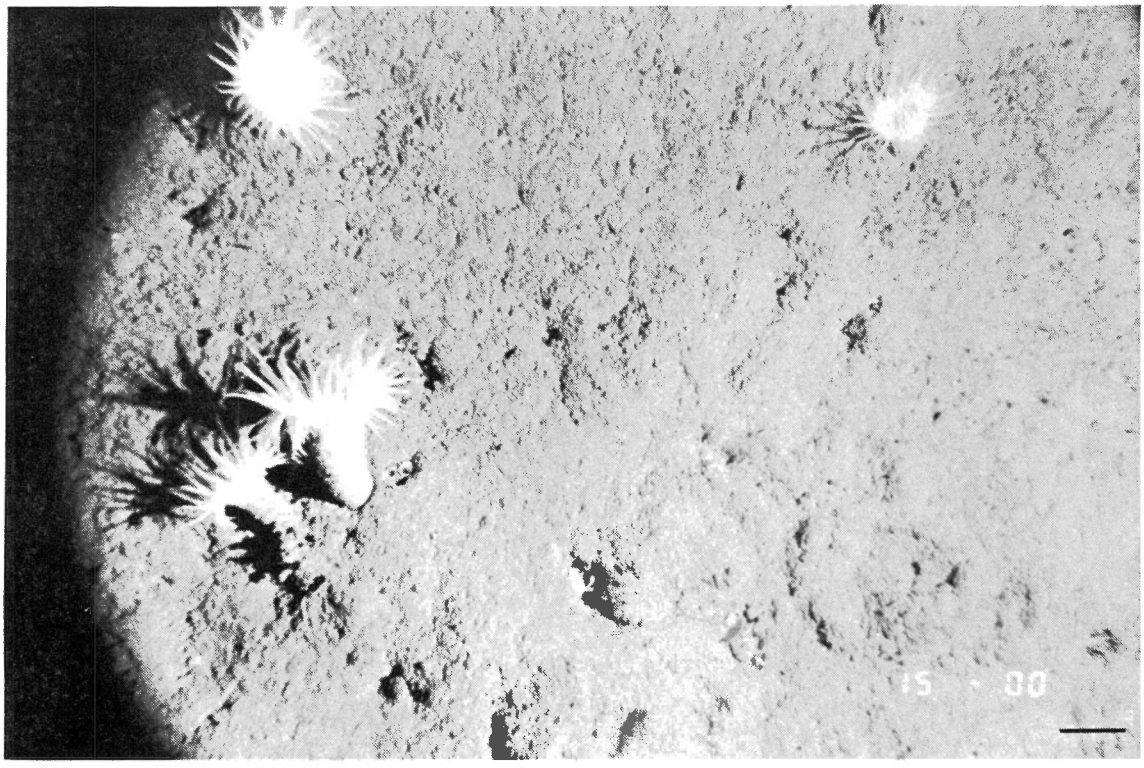
068 Baie Verte, 42 m. This photograph shows numerous clasts of gravel in the coarse pebble - large cobble size range, with sand or muddy sand visible in the interstices. Some clasts are coated with coralline alga (Lithothamnion sp.). A large numbers of brittlestars can be seen, with tentacles protruding between clasts.

070 Baie Verte, 16 m. In this photograph much of the bottom is obscured by seaweed fronds. Subangular gravel, chiefly small cobbles and very coarse pebbles, lies on a fine-grained bottom. One sea urchin is visible in the right central area of the image.

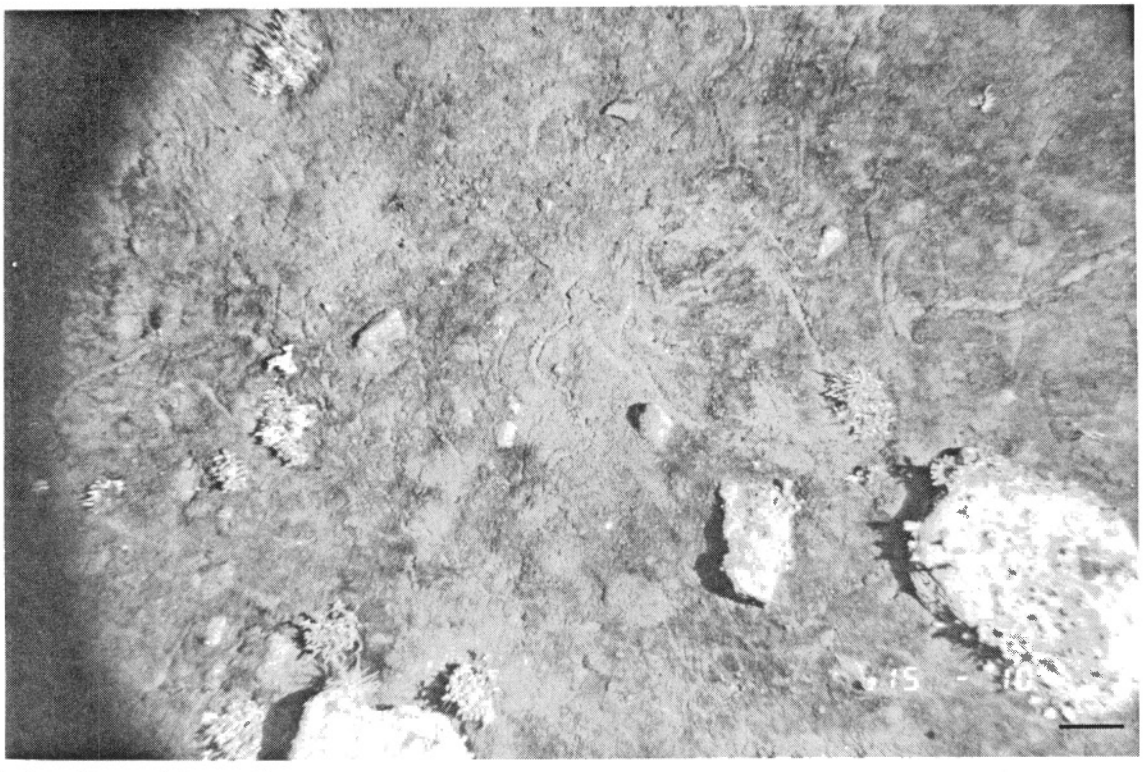
072 Baie Verte, 59 m. In this photograph, rounded and subrounded gravel clasts, up to small boulder size, lie on a fine-grained bottom which the grab sample suggests is sandy mud. The clasts are partly buried. A small amount of Lithothamnion sp. is evident on several. One anemone and one brittlestar can be seen.

074 Baie Verte, 46 m. The grab sample confirms that the sediment is sandy mud. The seabed shows small-scale roughness and a few faint tracks left by unidentified organisms.

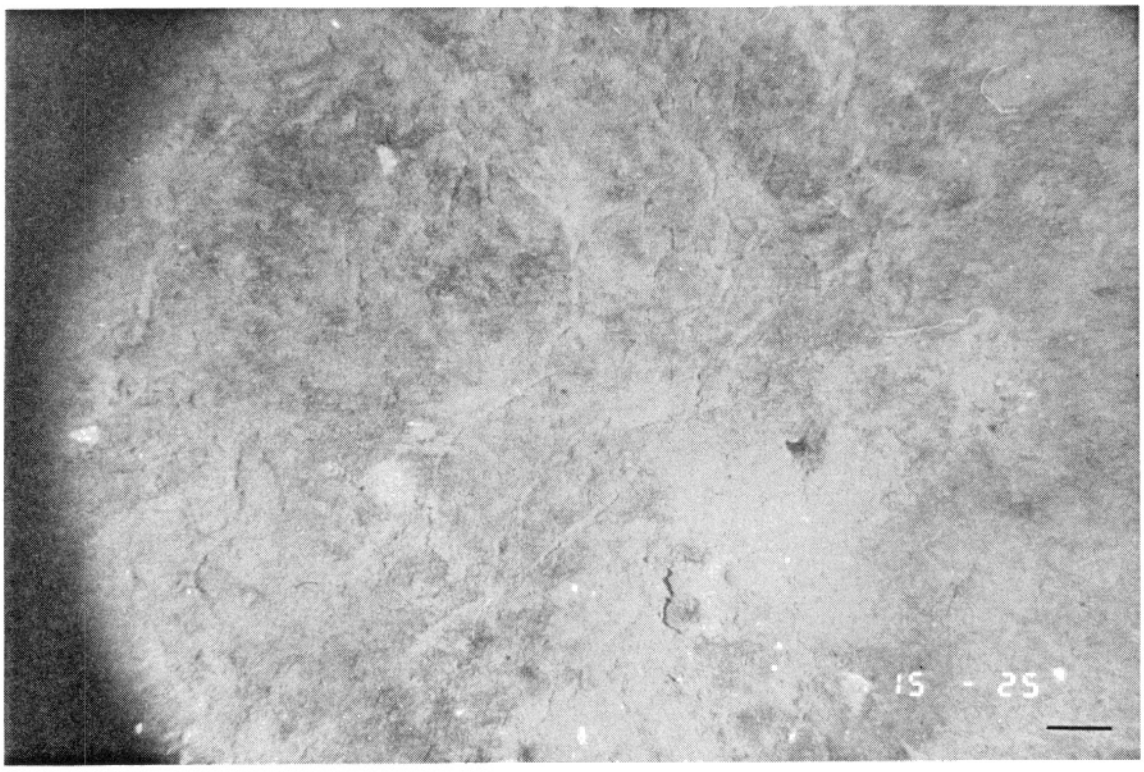
076 Baie Verte, 36 m. In this image gravel clasts up to small boulder size lie partly buried on a muddy substrate. Some Lithothamnion sp. is evident on the gravel. Several brittlestars and a dead fish (capelin) lie on the bottom. Faint tracks made by unidentified organisms are evident.



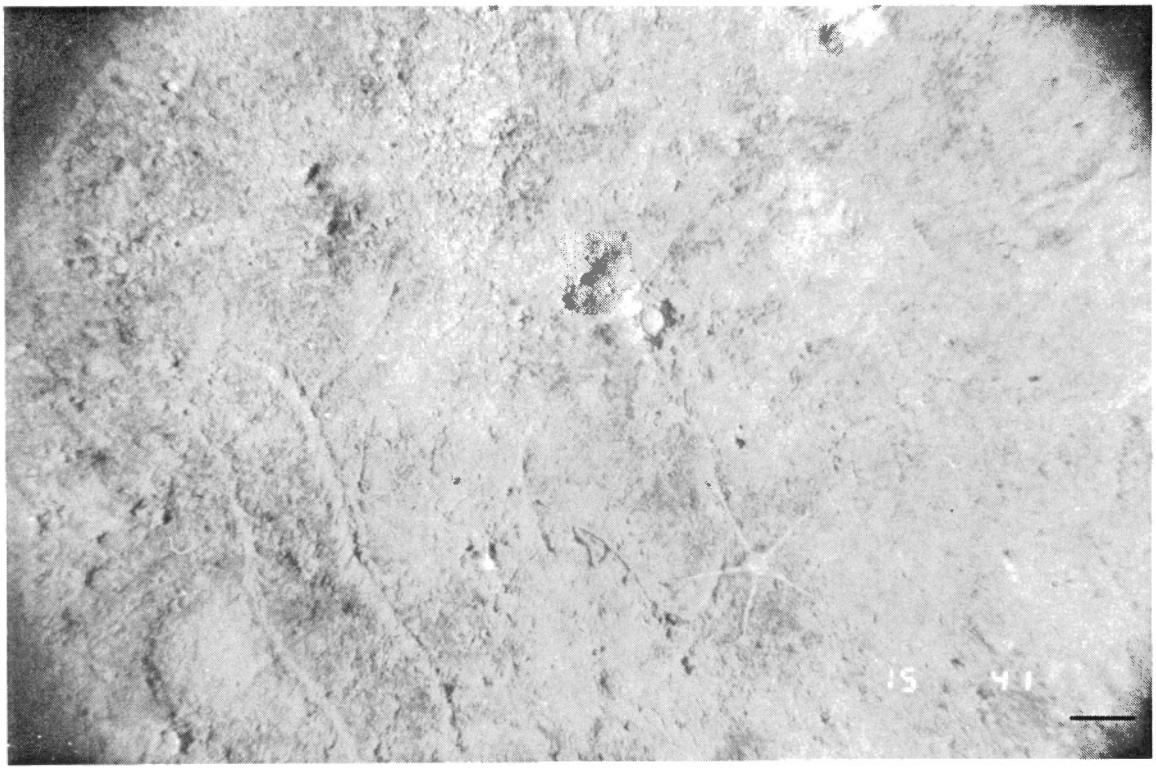
078 Baie Verte, 56 m. The muddy bottom in this image has a rough texture, with faint tracks in places. The most conspicuous objects are four burrowing anemones and the siphons of a buried pelecypod.



080 Baie Verte, 31 m. Numerous sinuous trails appear on the fine-grained (probably sandy) bottom in this photograph. Scattered pebbles and cobbles up to medium boulder size are heavily encrusted with Lithothamnion. sp. Some gravel clasts are partly or wholly buried in the sediment.

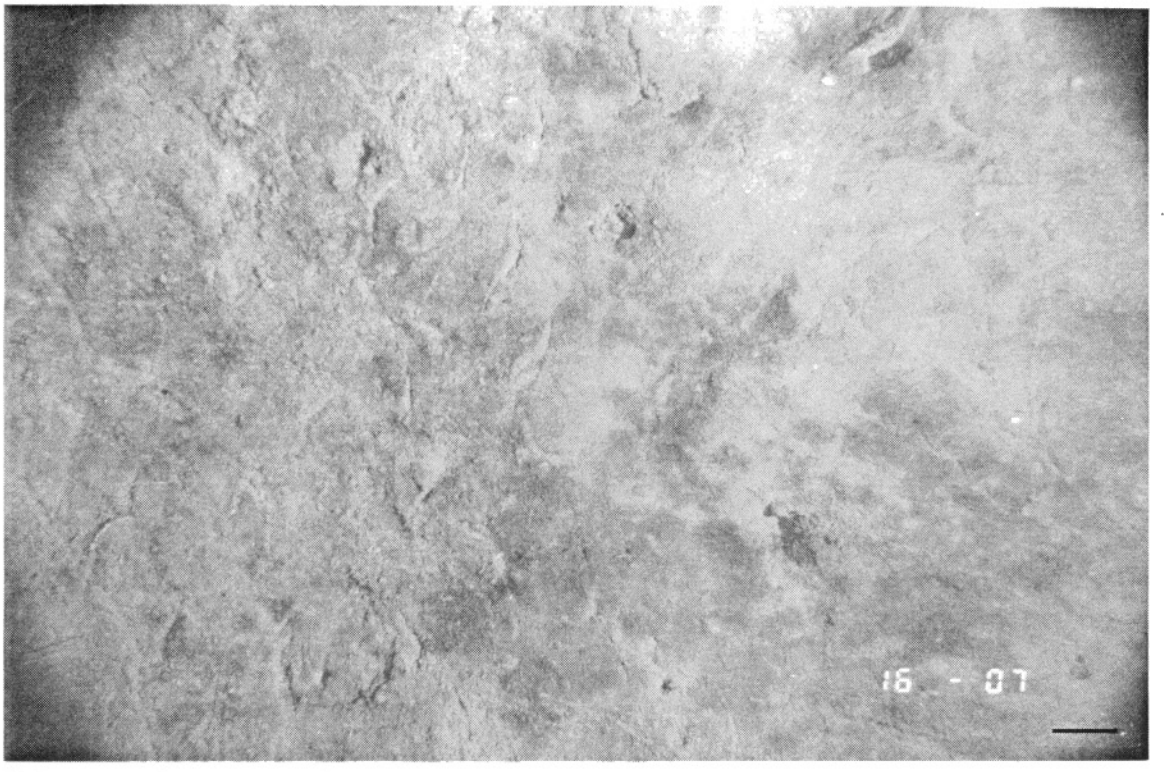


082 Baie Verte, 24 m. Here a fine grained (probably muddy) bottom is covered with a network of tracks. Several large burrows are evident.

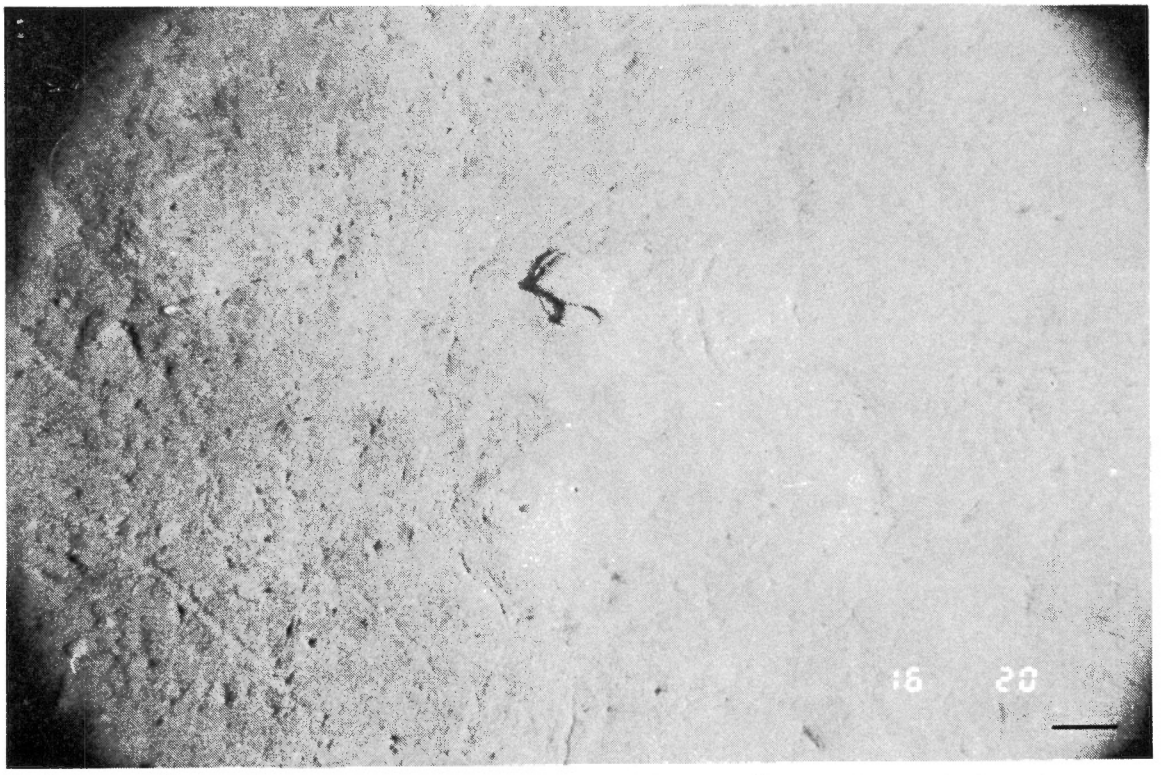


084 Baie Verte, 33 m. The rough, muddy bottom here is heavily disturbed by the activity of both infauna and epifauna, resulting in several pits and numerous tracks. Two prominant tracks are parallel to one another (left of centre). A single brittlestar is present.

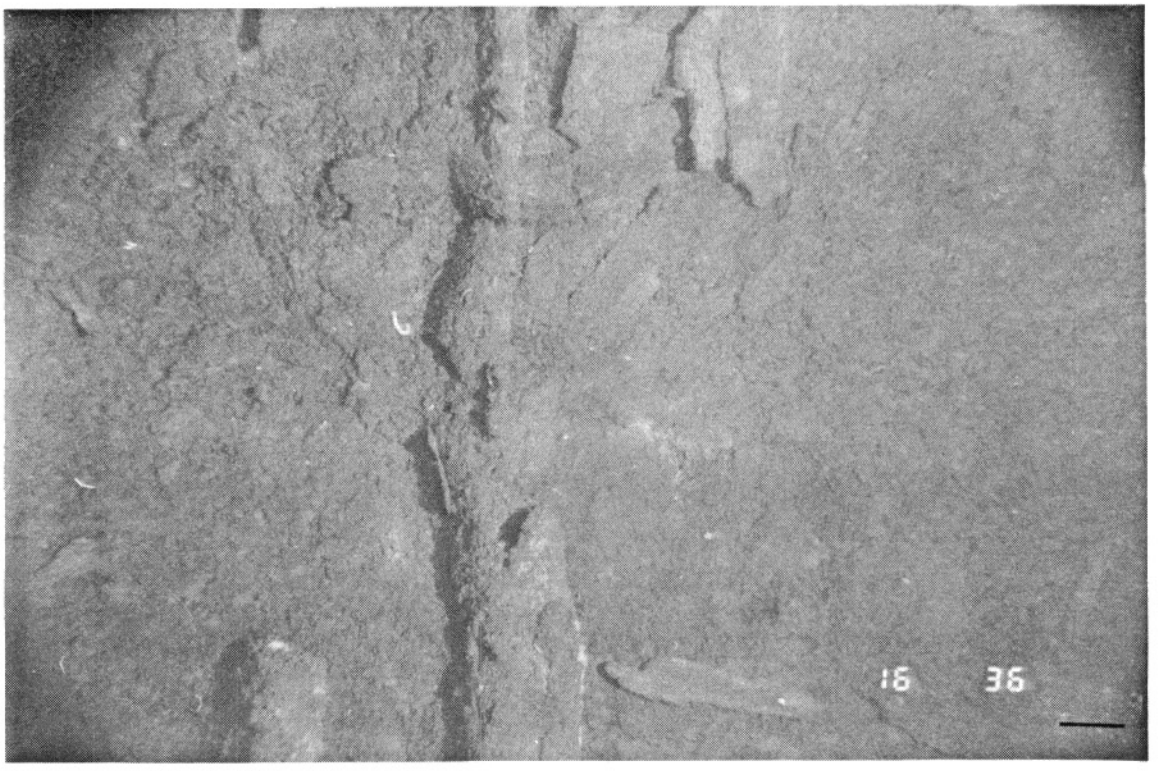
086 Baie Verte, 18 m. The seabed in this photograph consists of subangular to subrounded gravel clasts, mainly coarse pebbles but including a medium-sized boulder, sitting on a fine-grained bottom, possibly sand or muddy sand. The gravel is heavily encrusted with Lithothamnion sp.



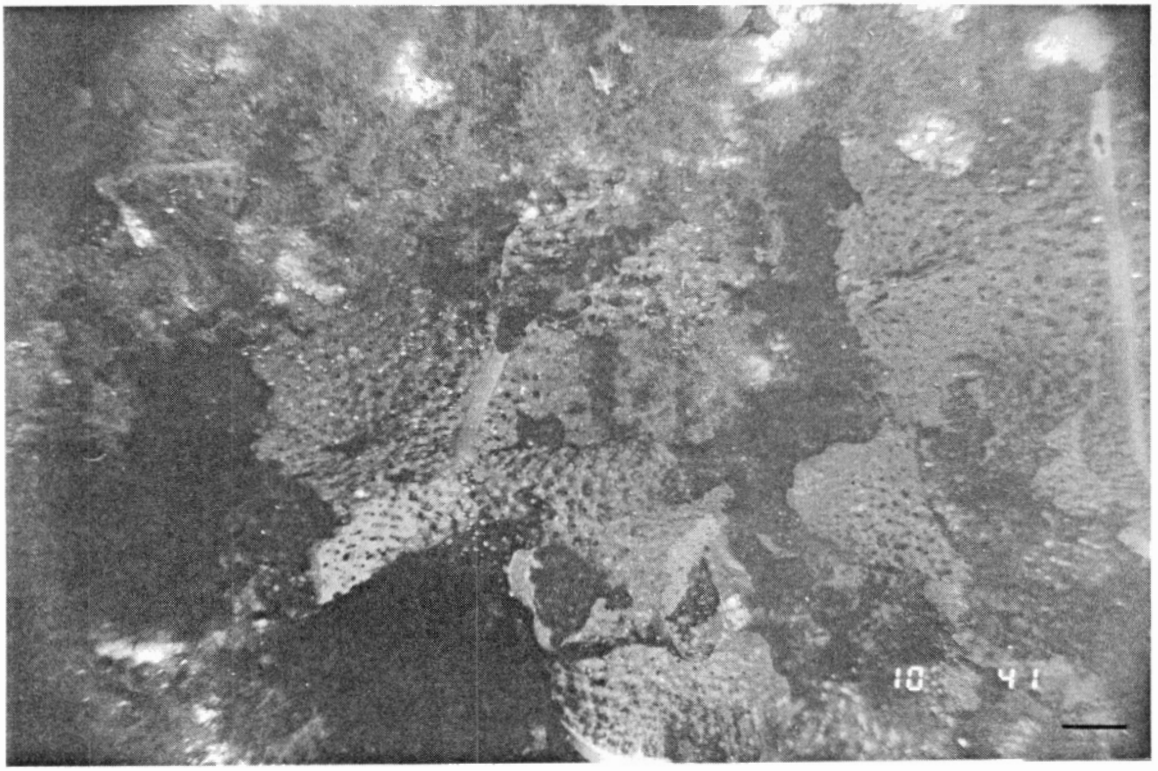
088 Baie Verte, 28 m. The muddy bottom here is heavily marked by trails. Several pits are also visible.



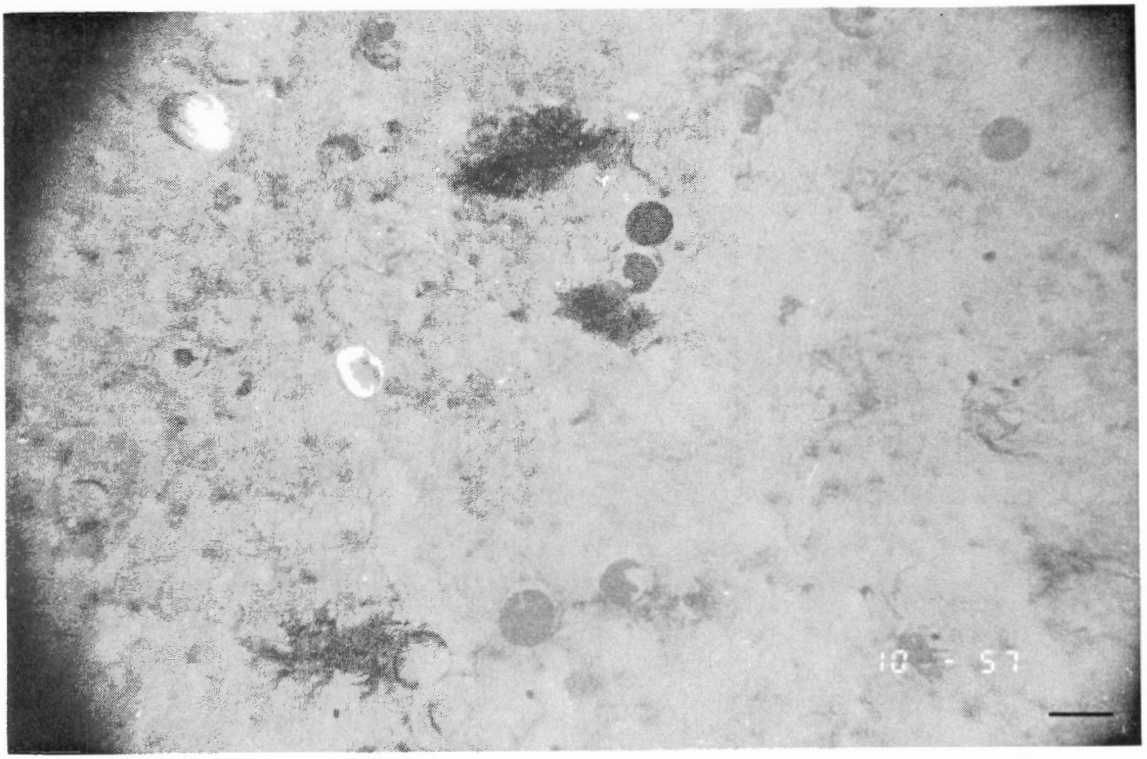
090 Baie Verte, 32 m. The grab sample from this area consistsed of black mud. The bottom has numerous small pits and is marked by many trails.



092 Baie Verte, 12 m. This photograph was taken close to the public wharf in Baie Verte. A grab sample in the vicinity was a foul smelling mixture of black mud and wood fragments. The photograph shows numerous wood fragments and bark on a fine-grained bottom. One small starfish is present.



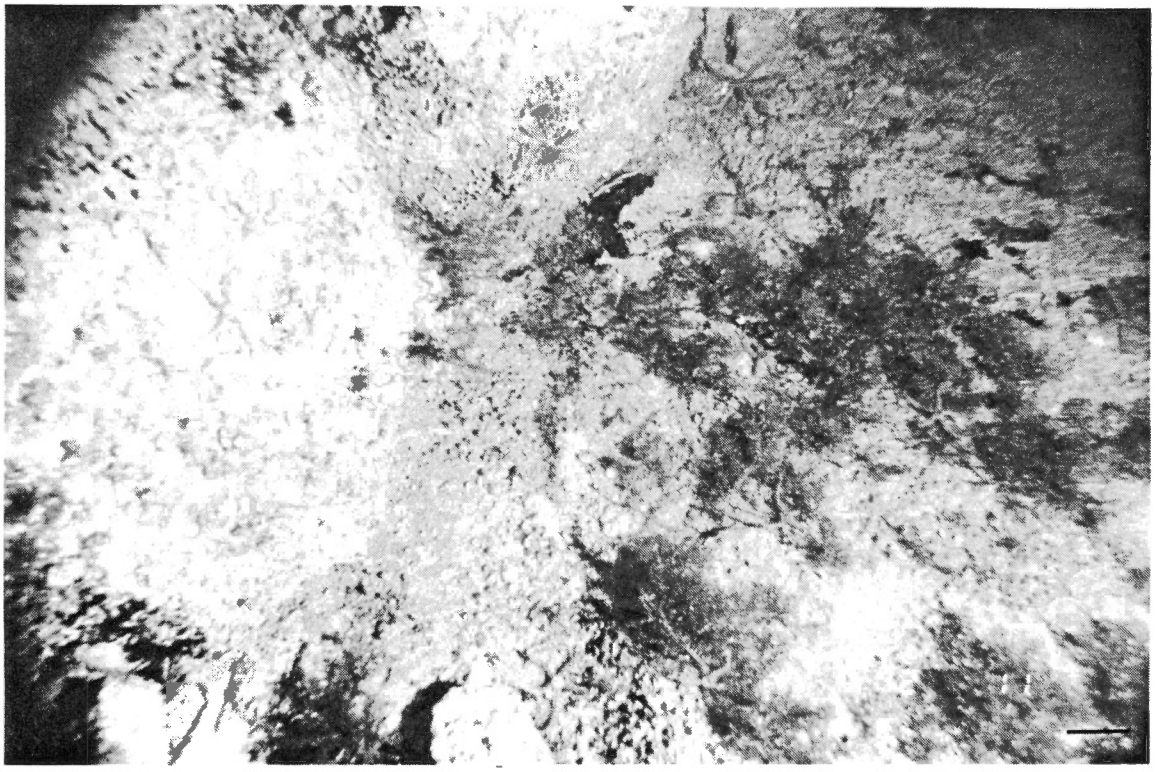
094 Baie Verte, 30 m. The sediment in this photograph is obscured by seaweed. The grab sample consisted of medium to fine grained sand with sand dollars (Echinarachnius).



096 Baie Verte, 19 m. Numerous sand dollars (Echinarachnius) are located on a sandy bottom in this photograph. Many are partly or completely covered by sand. Half of a bivalve shell (Mya truncata) is partly sand-filled. A large living gastropod is visible (Lunatia sp.) , and faint tracks are apparent in places.

098 Baie Verte, 47 m. The seafloor has a cover of poorly sorted, subangular gravel, ranging from fine pebbles to large cobbles, with sand visible in interstices. Some of the gravel has a light encrustation of coralline algae (Lithothamnion sp.) Also present are shells and shell fragments, a dead fish (capelin - top), and a small crab.

100 Baie Verte, 45 m. This photograph shows coarse gravel, much of it boulder-sized. and sub-angular to sub-rounded in form. The gravel is encrusted with Lithothamnion sp. The remains of a dead fish (capelin) are visible at the top right.



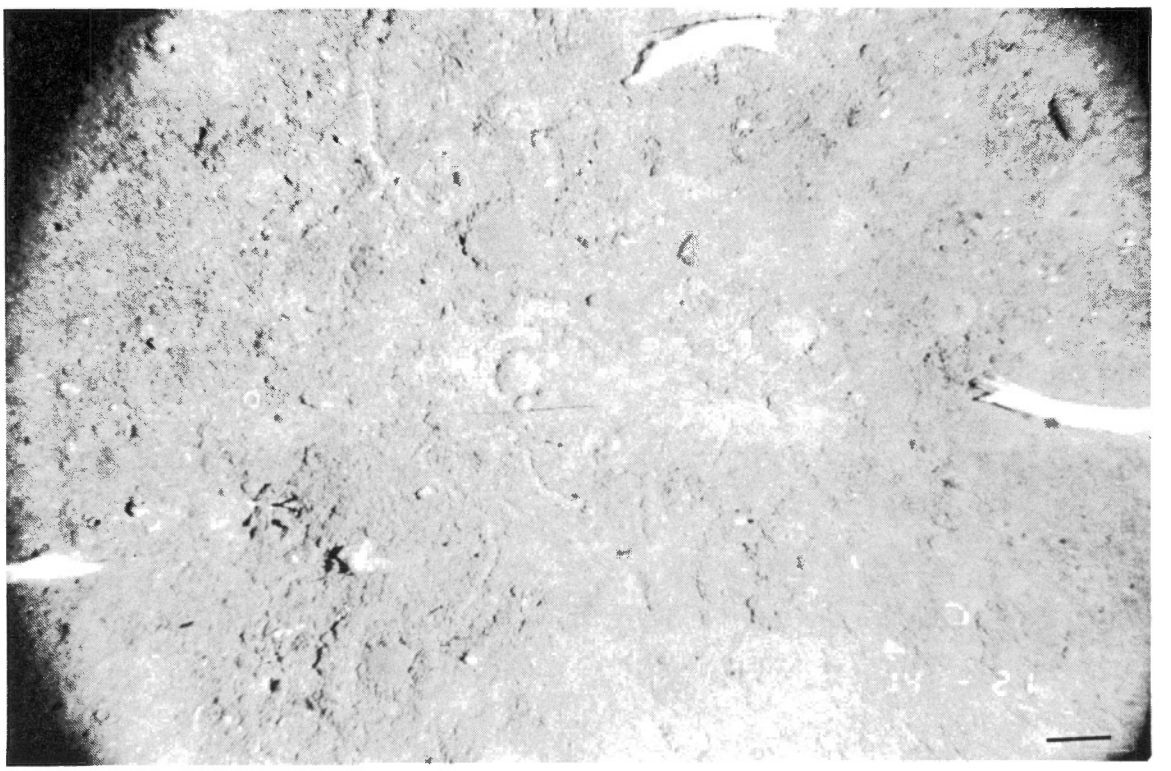
102 Baie Verte, 39 m. In this vicinity the van Veen sampler returned from the bottom several times with the jaws partly or completely open, suggesting a hard bottom. Several very large boulders are evident in this photograph, heavily encrusted with Lithothamnion sp. Patches of seaweed are present and numerous brittlestars are seen.

104 Baie Verte, 43 m. This sandy bottom is littered with subangular to subrounded gravel, ranging in size from medium pebbles to small cobbles, and numerous shells and shell debris. Seaweed is present, probably attached. A dead fish (capelin) is visible.

106 Baie Verte, 44 m. The bottom in this photograph consists of sand. Five dead capelin can be seen, as well as numerous sand dollars, a sea urchin, five anemones, shells and shell fragments, tracks, and a subrounded large cobble.

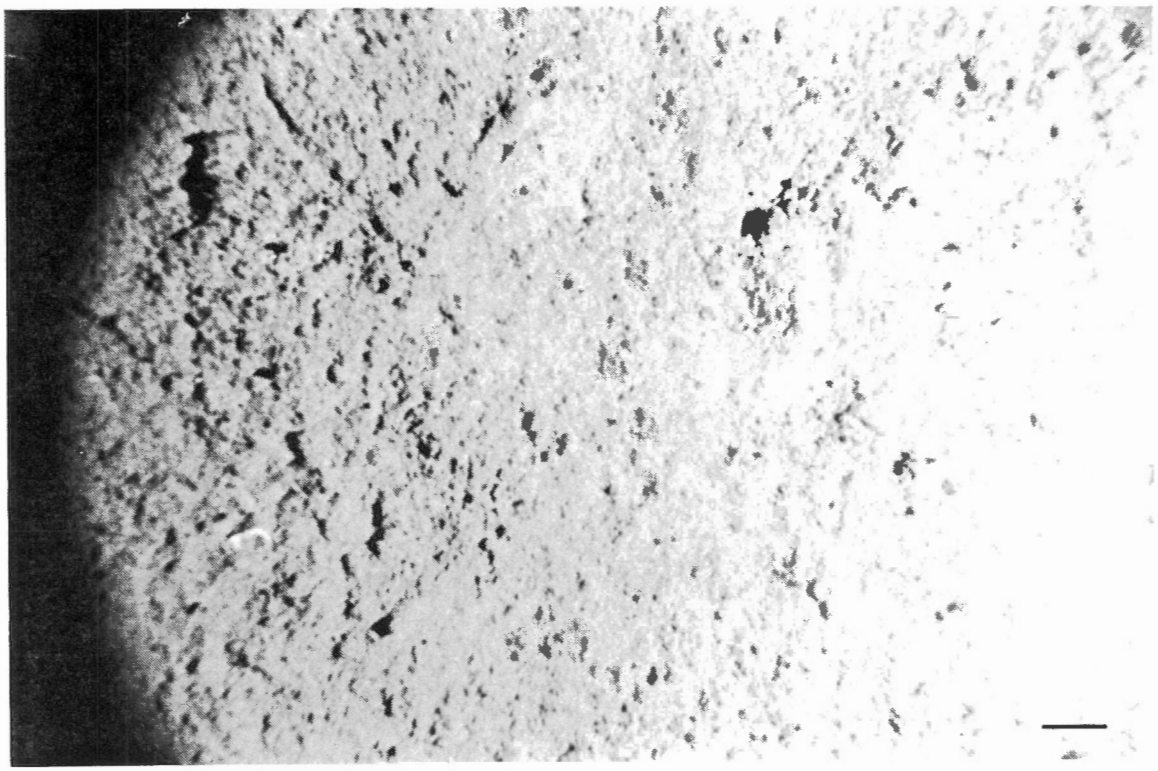
108 Baie Verte, 48 m. Dead capelin litter a sandy bottom in this photograph. Also present are some small cobbles coated with coralline algae, tracks, shells and shell debris, including a valve of Astarte sp., and a piece of seaweed.

110 Baie Verte, 53 m. Four small crabs appear on a rough-textured sandy bottom, close to a dead capelin. Small amounts of fine shell debris may be present. Grab samples indicate that the bottom is shelly sand.



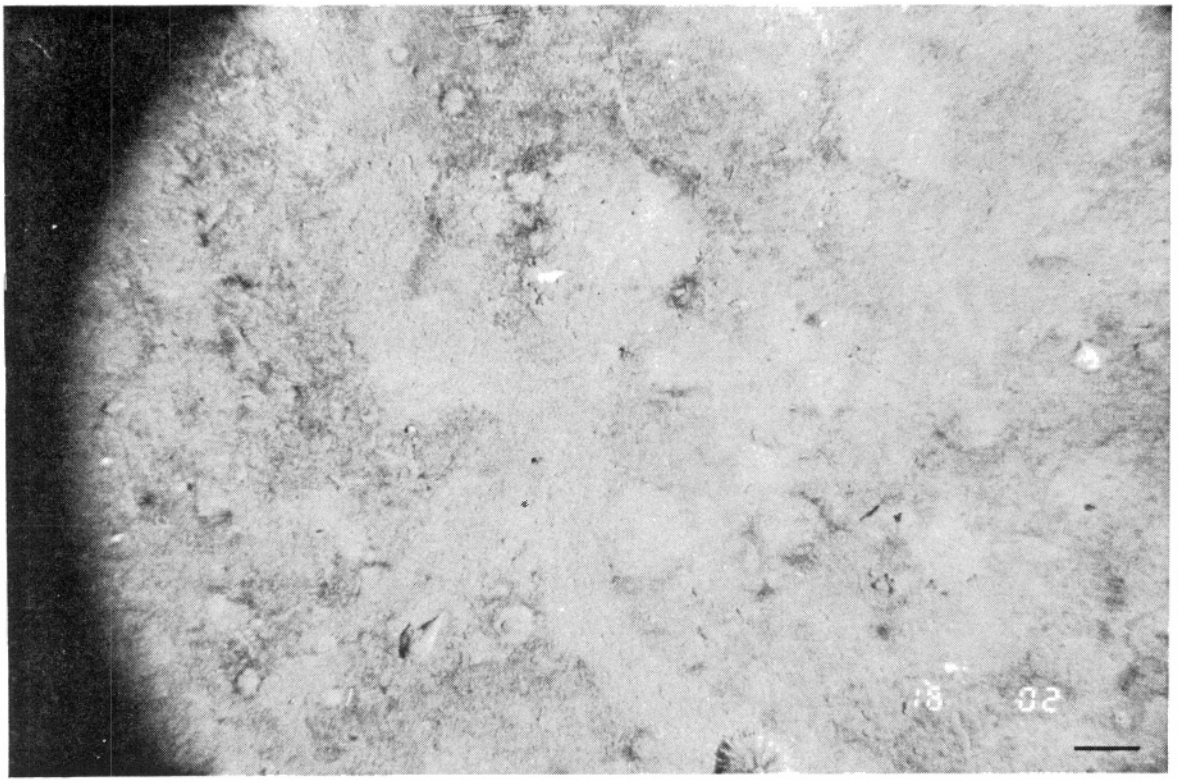
112 Baie Verte, 46 m. The sandy bottom in this photograph is marked by numerous tracks. Several sand dollars, partly or wholly buried, are visible, as are three dead capelin, shells and shell fragments, and a gastropod (Aporrhais occidentalis).

114 Baie Verte, 74 m. Seven dead capelin appear in this field of view. The bottom consists largely of very coarse pebbles, many coated with coralline algae (Lithothamnion sp.). The material in the interstices is probably sand. Some of the gravel is sand-covered.



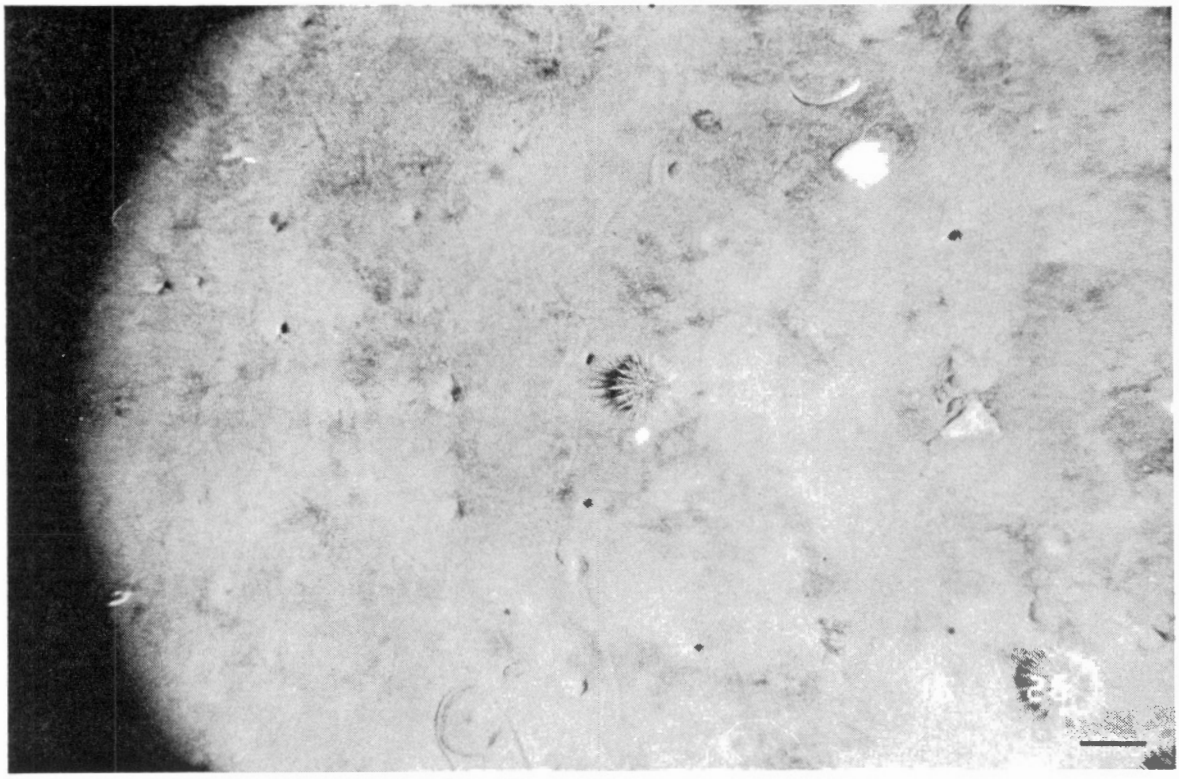
116 Baie Verte, 90 m. The bottom sediment here consists of sandy mud. The surface has a rough texture. One partly-buried shell is visible. The grab sample consisted of gravelly mud.

118 Baie Verte, 56 m. The sediment in this photograph consists of muddy sand. The gravel which is visible is mainly in the very coarse pebble size range. Also seen are numerous brittlestars, shells and shell debris, anemones, and a crab (at the left, on the edge of the field of view).

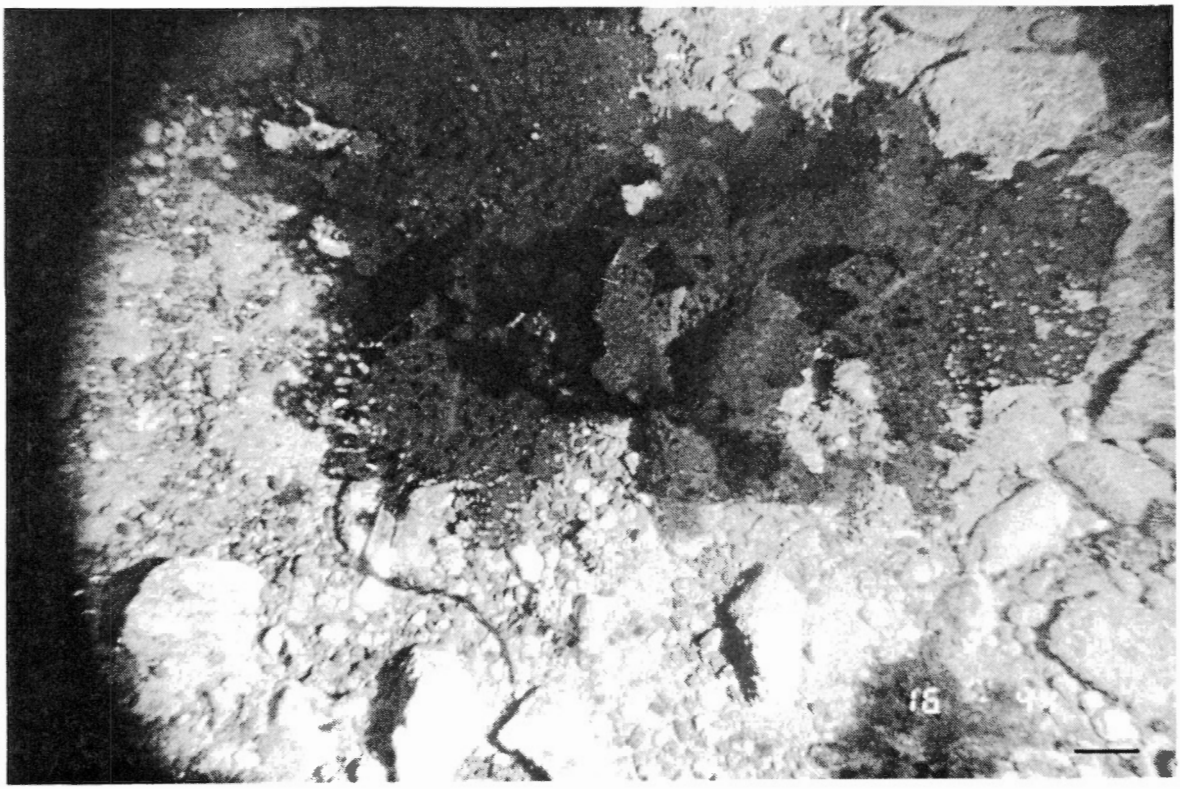


120 Baie Verte, 34 m. This sandy bottom has a mottled appearance. A sea urchin has left a wide track across the field of view. Other tracks are visible, including that made by a gastropod (Aporrhais occidentalis). Another gastropod is partly buried.

122 Baie Verte, 31 m. This photograph shows a closely-packed pavement of very coarse pebbles and small cobbles, with sand visible between the clasts. The gravel is subangular to subrounded, coated with coralline algae (Lithothamnion sp.) in most cases, and several clasts appear to have seaweed attached.

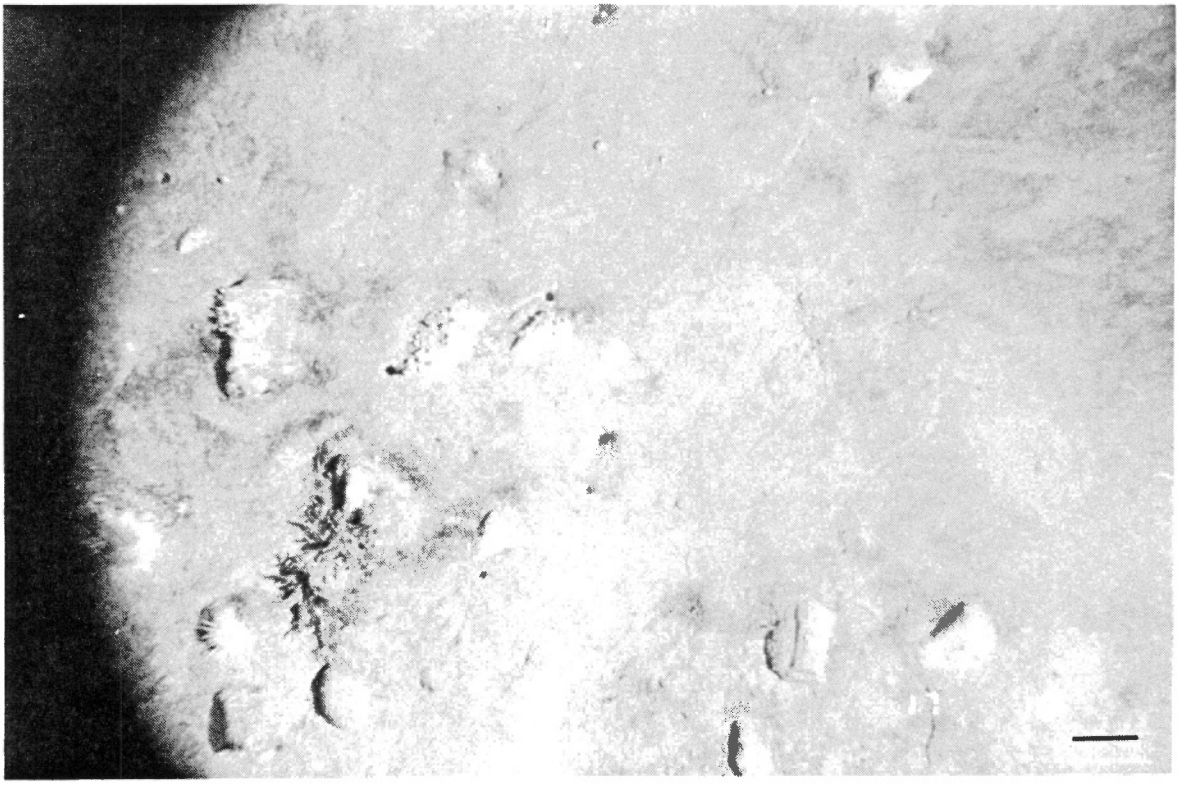


124 Baie Verte, 21 m. This sandy bottom shows much biological activity. Within the field of view are two sea urchins, a sand dollar which has made a well-defined track (with two outer berms), numerous mounds with pits, tracks, and several partly buried dead bivalves.

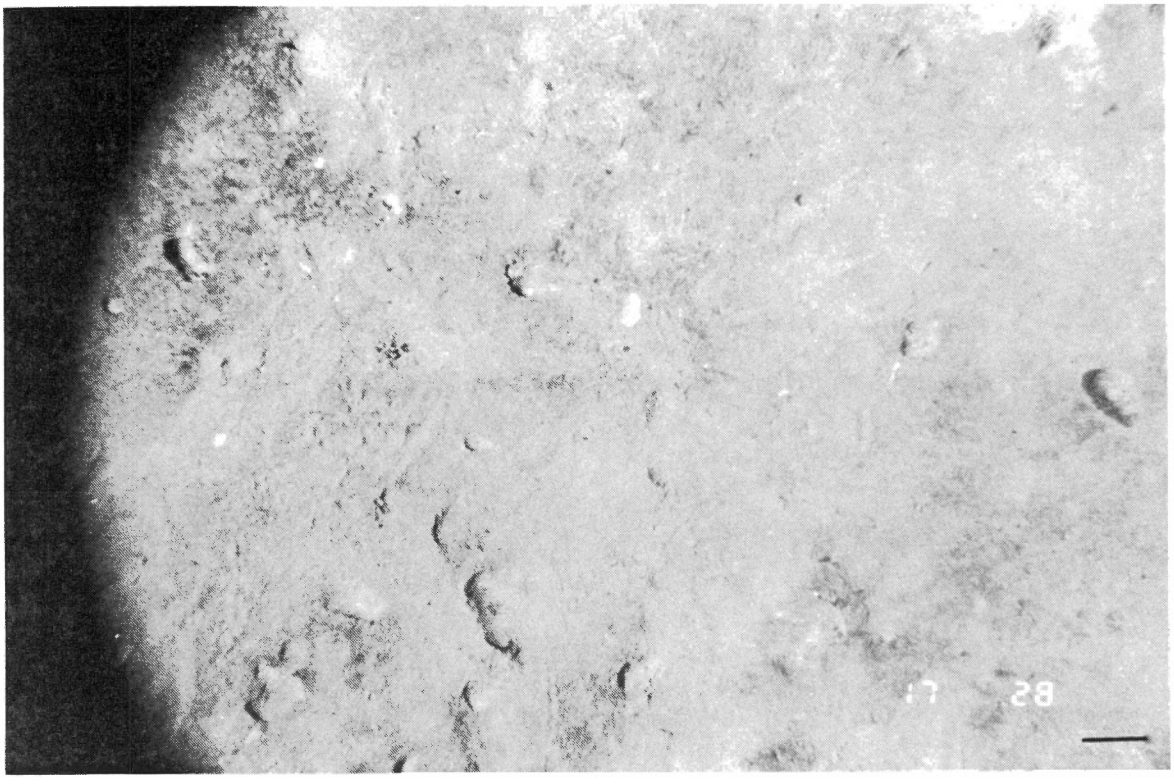


126 Baie Verte, 22 m. Seaweed obscures one third of the field of view in this photograph. Bottom sediment is gravel, subangular to sub rounded, ranging in size from small boulders to fine pebbles. Lithothamnion sp. is attached to some clasts and encrusts several pelecypod valves. Sand is visible in the interstices.

128 Baie Verte, 44 m. The bottom sediment in this view consists of sand with a scattering of coarse pebbles. The bottom is littered with shells, shell fragments, and tube-building polychaetes (probably of the family Eunicidae). Faint tracks are evident, and the view includes four sea urchins and one starfish.



130 Baie Verte, 32 m. The seabed is predominantly fine-grained. Grab sampling suggests it consists of muddy, fine sand. Gravel clasts, subrounded or rounded, and with sizes in the small to large cobble range, lie partly buried in the sand. Some have an encrustation of Lithothamnion sp. Faint tracks are visible, in addition to two sea urchins and a partly buried sand dollar (Echinarachnius parma).



132 Baie Verte 32 m. Gravel clasts in the medium pebble to small cobble size range, rounded to subrounded, lie partly buried on a sandy bottom with faint tracks, an anemone, one gastropod (Aporrhais occidentalis), and tube worms.

APPENDIX 2: CORE DATA

Core 90-035-133

Depth (cm)	Description
0-12.0	Dark olive gray sandy mud with angular gravel. 60 x 40 x 30 mm clast on surface. 45 x 30 x 20 mm clast at 2 cm.
12.0-38.5	Gray clay with grit and angular gravel. Shell fragments at 17 cm. 50 x 40 x 30 mm clast at 19 cm.

Note: The seismo-stratigraphic units here have thicknesses as following: Unit 4 (postglacial) 0.6 m; Unit 3 (stratified glacial marine) 0.8 m; Unit 2 (glacial diamict) 4.6 m. It is probable that the top 12 cm of the core, consisting of olive mud, is postglacial in age.

Core 90-035-134

Depth (cm)	Description
0-10.0	Dark olive gray silty mud with pebbles and some fine sand. A few shell fragments. Sharp lower boundary.
10.0-31.0	Gray clay containing grit and a few angular pebbles, inc. 80 x 50 x 40 mm clast at 25 cm. Two gastropods at 12 cm (Tachyrhynchus erosus).
31.0-38.0	Dark gray clay. A few small shell fragments. Diffuse upper and lower boundaries. Scattered grit and a few angular pebbles.
38.0-58.0	Light gray clay with grit and angular pebbles, inc. 40 x 30 x 20 mm clast at 40 cm.
58.0-86.0	Light gray clay with grit and pebbles, and some darker (bioturbation) mottles, esp. in the 60-70 cm interval. Upper and lower boundaries diffuse.
86.0-107.0	Gray clay. Vertically-aligned light olive gray mottle, possibly post-recovery alteration.

Note: Thicknesses based on acoustic records are: 0.35 m Unit 4 (postglacial); 3.65 m Unit 3 (stratified glacial marine); 3.0 m Unit 2 (glacial diamict). The upper 10 cm is believed to postglacial, and the remainder of the core consists of stratified glacial marine sediments (unit 3).

Core 90-035-135

Depth (cm)	Description
0-2.0	Black sandy mud.
2.0-17.0	Dark olive gray sandy mud with grit and pebbles. Sharp lower boundary.
17.0-30.0	Olive gray clay with dark gray mottles. Diffuse lower boundary, pebble layer at base of unit.
30.0-60.0	Gray silty clay containing grit and angular pebbles. One valve of Portlandia arctica at 33 cm.
60.0-87.0	Light gray clay with grit and angular pebbles. 30 x 30 x 20 mm clast at 81 cm.

Note: Based on acoustic data, thicknesses here are: 0.35 m Unit 4 (postglacial); 4.65 m Unit 3 (glacial marine); 2.0 m Unit 2 (glacial diamict).