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DESCRIPTIVE NOTES

INTRODUCTION

The traditional product of seabed mapping on Canadian continental shelves was the surficial geology map depicting Quaternary sediment formations (e.g., Fader et al., 1982). With the advent of multibeam sonar, three principal types of 1:50,000 scale maps were produced, viz. 1) shaded seafloor relief; 2) backscatter strength; and 3) surficial geology. Geologists have long been aware of the links between surficial geology and benthic communities (Maritime Testing, 1985), and the recent increasing awareness by biologists (Todd et al., 2007) has led to multiple approaches to visualizing the links on maps. This map is merely one approach among many. It is based on systematic multibeam sonar mapping by the Geological Survey of Canada (GSC) and Canadian Hydrographic Service (CHS), supported by seismic data, sidescan sonograms, bottom photographs, video, submersible observations, and grab samples.

SEASCAPES

Our definition of a 'seascape' is based on the Australian Land-System approach, developed to manage agricultural land. To adequately understand the land and its use and management it was thought necessary to understand the relationships between soils and the soil parent materials, climate, and topography. Land-systems are "areas, or groups of areas, throughout which there is a recurring pattern of topography, soils, and vegetation" (Christian and Stewart, 1953; Commonwealth Scientific and Industrial Research Organization, 1967). By analogy, our seascape definition is as follows: *Seascapes are underwater landscapes characterized by unique combinations of geomorphology, texture, and biota.*

MAKKOVIK BANK

Makkovik Bank consists of gently dipping Cenozoic rocks separated from largely igneous rocks of the Makkovik Province (Wardle et al., 1997) by the Labrador Trough (see Fig. 1). The Labrador Current travels south in this region, but a clockwise gyre is evident in the mean circulation pattern at Makkovik Bank, at all depths down to the sea floor (Fig. 2). The bank top has low relief, is deepest in the west (130 m), and gradually deepens eastwards. It is fringed by a steep escarpment in the west; gentler slopes extend towards Makkovik and Hamilton Saddles, to the north and south respectively. A prism of stacked tills on the western side of the bank attains a maximum thickness of 130 m. The tills have been compacted, for they form several minor escarpments and a major escarpment that is 30 m high. The region has been highly impacted by iceberg furrows and pits. The density of furrows and pits on the sea floor varies, as does the ratio between these two. Parts of the multiple tills have almost no iceberg furrows or pits, perhaps indicating a resistant substrate, or influence of some other factor. Figure 3 is a transect illustrating varying degrees of iceberg impacted on terrain.

MAKKOVIK BANK SEASCAPES

We classify the seascapes into four broad areas:

Makkovik Province Seascapes occur west of the Labrador Trough, adjacent to the mainland. Bedrock Terrain consists of crystalline basement rocks of the Makkovik Province (Wardle et al., 1997). It has irregular relief that ranges up to 25 m. Bedrock exposures are rare, and a veneer of Quaternary sediments is more typical at the seafloor. A small area mapped as bedrock terrain in the extreme southwest is mantled by De Geer moraines (not shown). The Grounding Line Wedge located on the flanks of the Labrador Trough consists of till heavily imprinted by iceberg furrows. It was formed by grounded ice emanating from the mainland. Areas of Glaciomarine Mud comprise gravelly sandy silty clay deposited by meltwater plumes and imprinted by iceberg furrows. Due to winnowing, texture at the seafloor is muddy angular gravel. Postglacial Mud (low backscatter) occupies depression in the seafloor, and is imprinted by recent iceberg scouring.

Labrador Trough Seascapes occupy relatively deep water (>130 m) between Makkovik Bank and the shallower basement topography to the southwest, and also the saddle between Makkovik and Harrison Banks. Bedrock Terrain is morphologically similar to that of the Makkovik Province seascape but is muted due to a thick drape of glaciomarine mud (Fig. 1). Fluted Terrain was created by moulding of till by ice originating on the mainland and flowing towards the east. Glaciomarine Mud consists of gravelly sandy mud deposited by meltwater plumes and draped over pre-existing terrain. Relief is low, the seabed has been heavily furrowed by icebergs, and the unit has high backscatter indicative of a gravel texture at the seafloor. Postglacial mud up to 25-m thick occupies basins, and has low backscatter.

Makkovik Bank Seascapes occupy the gently-sloping top and more steeply-sloping flanks of Makkovik Bank. The western, northern and southern flanks of the bank are mapped as the Bank Margin Moraines-Lower Till seascape unit. Multiple layers of compact till form steep escarpments up to 30 m-high with slopes up to 15 degrees. Iceberg furrowing is evident, although less so above -120 m, and indeed the moraine surface seems smooth above this depth. The Upper Till is located at the north and south flanks of the bank, has more subdued relief, is marked by iceberg furrows, and is younger (Josenhans and Zevenhuizen, 1989).

The Bank Top Terrain has low relief, low to intermediate backscatter, sandy gravel textures at the sea floor, and is heavily imprinted by iceberg furrows. A cover of Quaternary sediment thin enough to allow Cenozoic bedrock structure to be evident at the seafloor is incised by 10 m-deep channels of unknown origin. Some are gently arcuate whilst others are arrayed in a splayed form. Perhaps they were created by water under grounded ice, and were excavated along weaknesses in the underlying bedrock. Possibly analogous channels on offshore banks have been mapped off northern Labrador by Fillion and Harmes (1982). Another anomaly in this seascape is the presence of 5 or 6 narrow morainal ridges up to 3 m high, and suggestive of glacier retreat towards the east.

A strip of Sand Waves runs along the west side of the bank in depths of 105–115 m. Finally, in the extreme east, in relatively deep water (220–240 m), is the Outer Bank Sand seascape. The low-backscatter sand is organized into barchan dunes indicative of a current from the northwest.

Continental Slope Seascapes

The Upper Continental Slope seascape consists of a network of deep dendritic channels in depths below 500 m.

BACKSCATTER

A backscatter mosaic was used to classify the region into seascape units. Figure 4 illustrates some of the variability in the region. Sands and muds have low backscatter while all other terrains (bedrock, till, glaciomarine mud) are characterized by harder, more reflective substrates.

BIOTA

Coarse substrates predominate in the map area, but at varying depths, with varying wave and current influence, so the biota seems to vary also. In some areas boulder-cobble-pebble seafloor show brittlestars and soft corals attached to clasts (Figs. 5, 6) but elsewhere a greater diversity is apparent (Figs. 7, 9). Crinoids and basket stars occur in quite large numbers in some areas, but it is difficult to generalize on their overall distribution based on the small number of photographs. Figure 8 is probably typical of areas of postglacial mud.

ACKNOWLEDGMENTS

The map is based on multibeam sonar data collected by the Canadian Hydrographic Service on vessels of the Canadian Coastguard. The multibeam data were collected as part of a research collaboration between the Geological Survey of Canada and C-CORE; under which several petroleum exploration companies kindly provided financial support and access to data. Groundtruthing data were collected by GSC staff also on board Canadian Coastguard vessels. Multibeam and backscatter data were processed by Tekmap Consulting. Geographic Information System work and data processing was provided by S. Hayward. Cartographic support was provided by P. O'Regan and the Open File was reviewed by G. Cameron.

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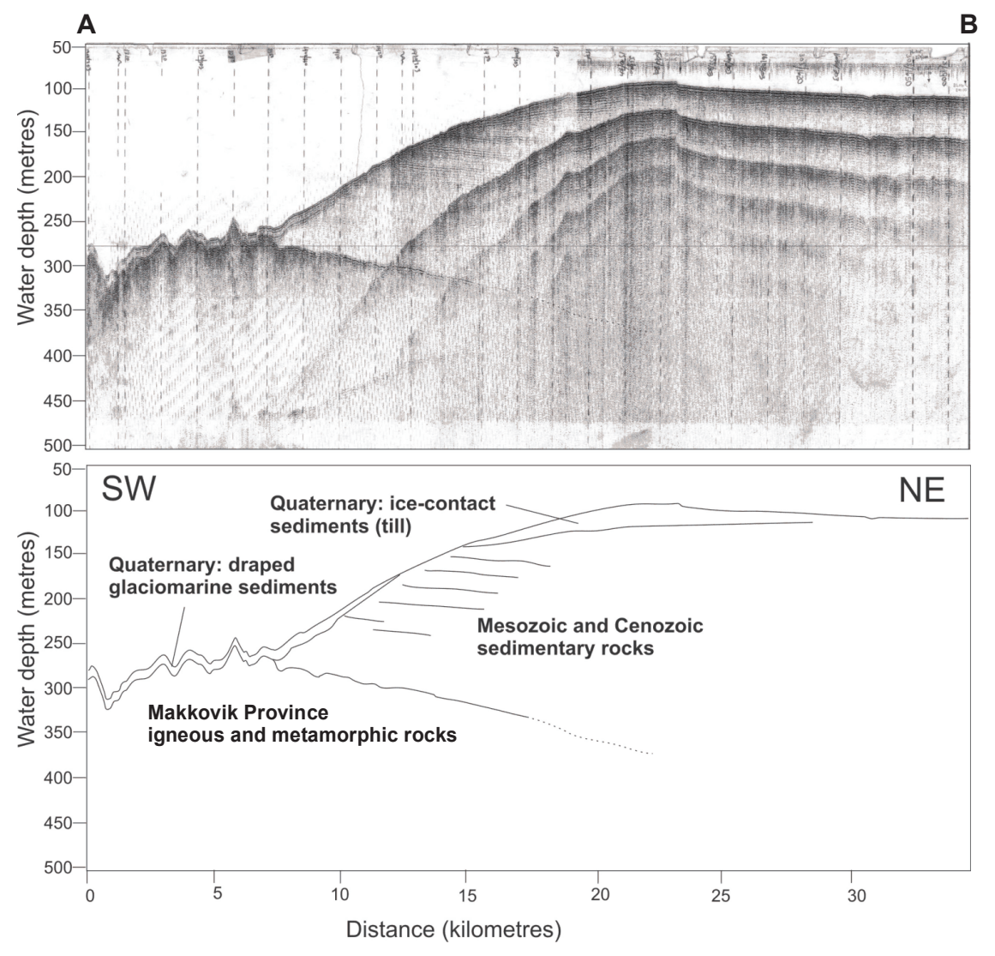

Figure 1: Airgun seismic reflection record extending from the deep water of the Labrador Trough onto the bank. Bedrock has an apparent dip to the east. A prism of till is thickest on the west side of the bank and thins eastwards.

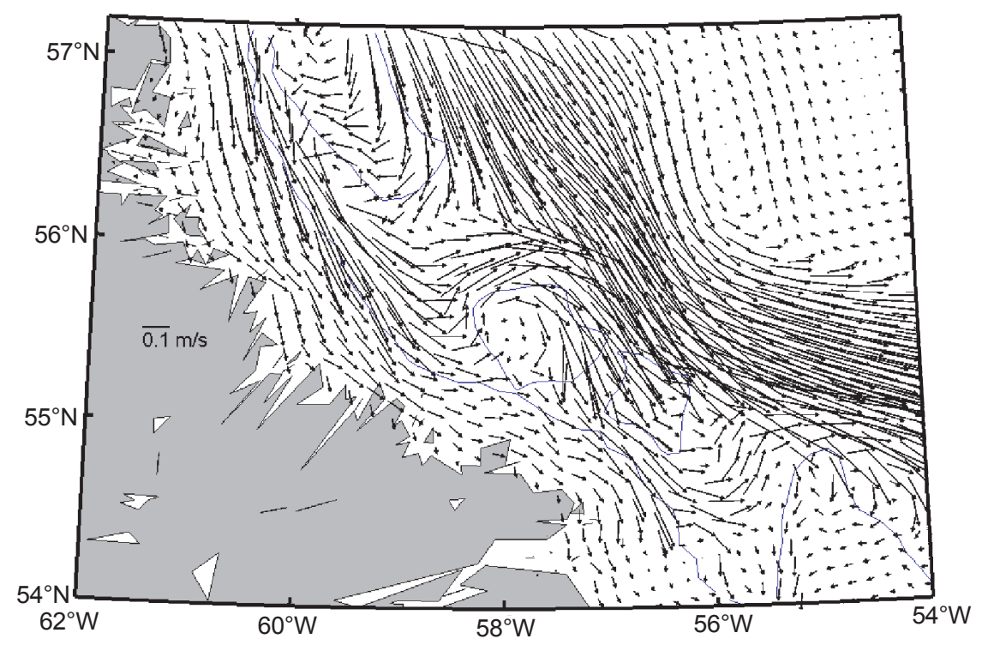

Figure 2: Mean annual current velocity at 100 m depth. Courtesy of C. Hanna, DFO, Halifax.

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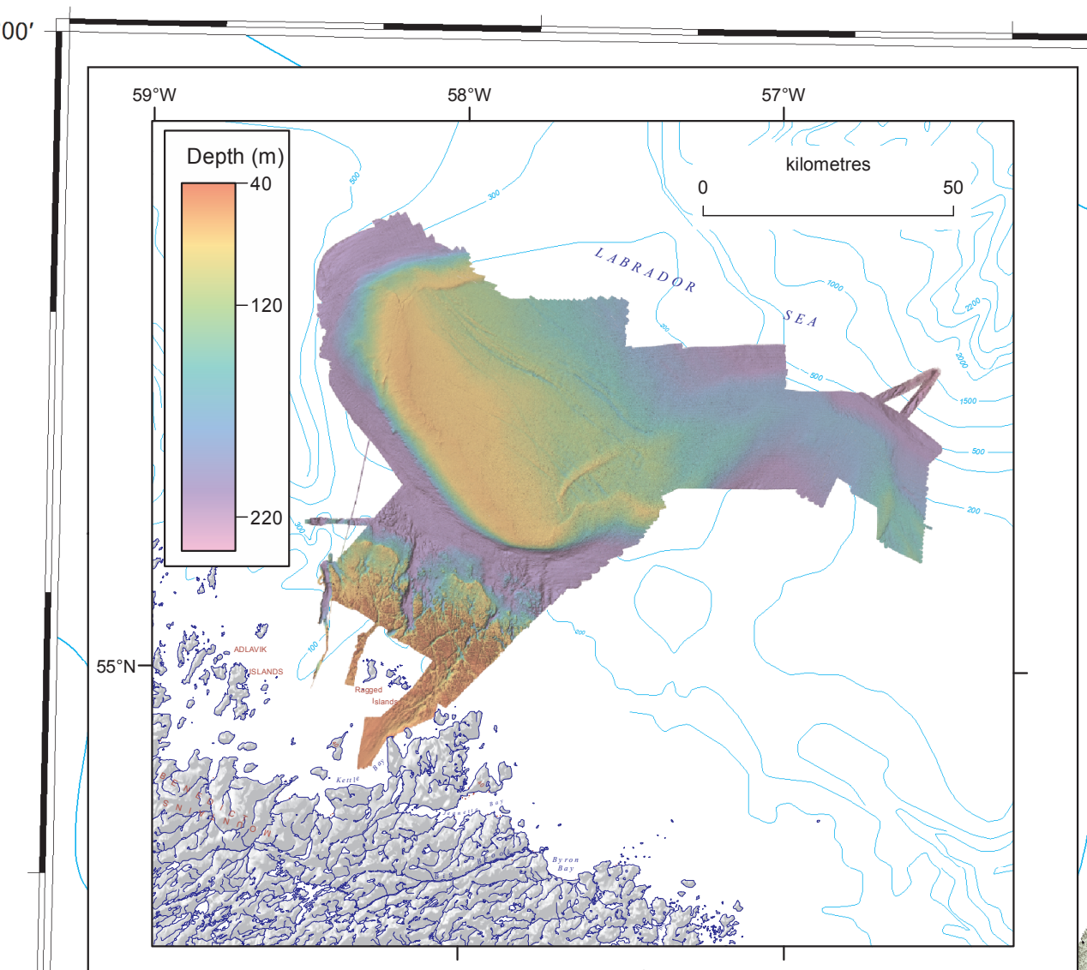
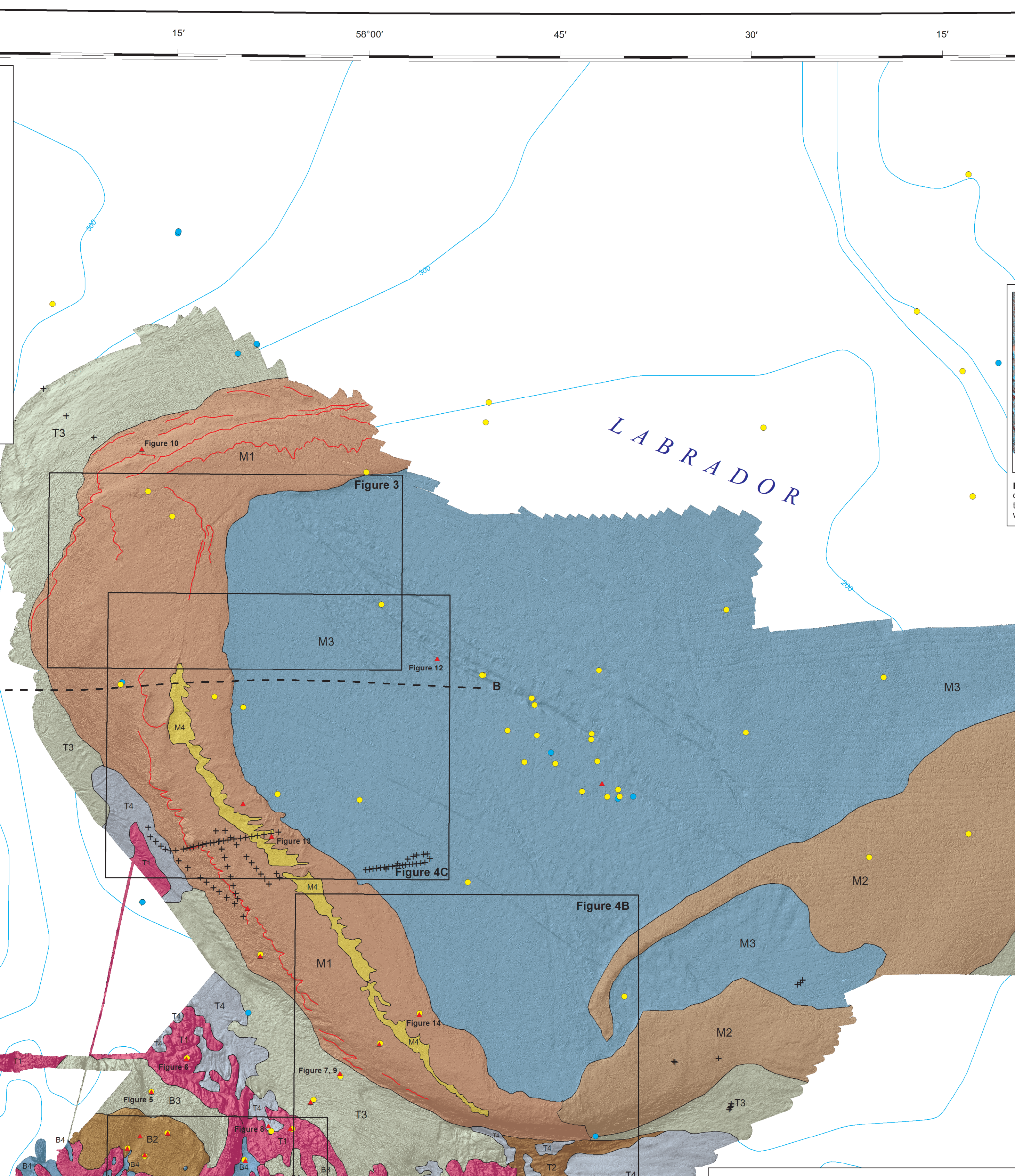


Figure 15. Map showing the multibeam coverage of Makkovik Bank.



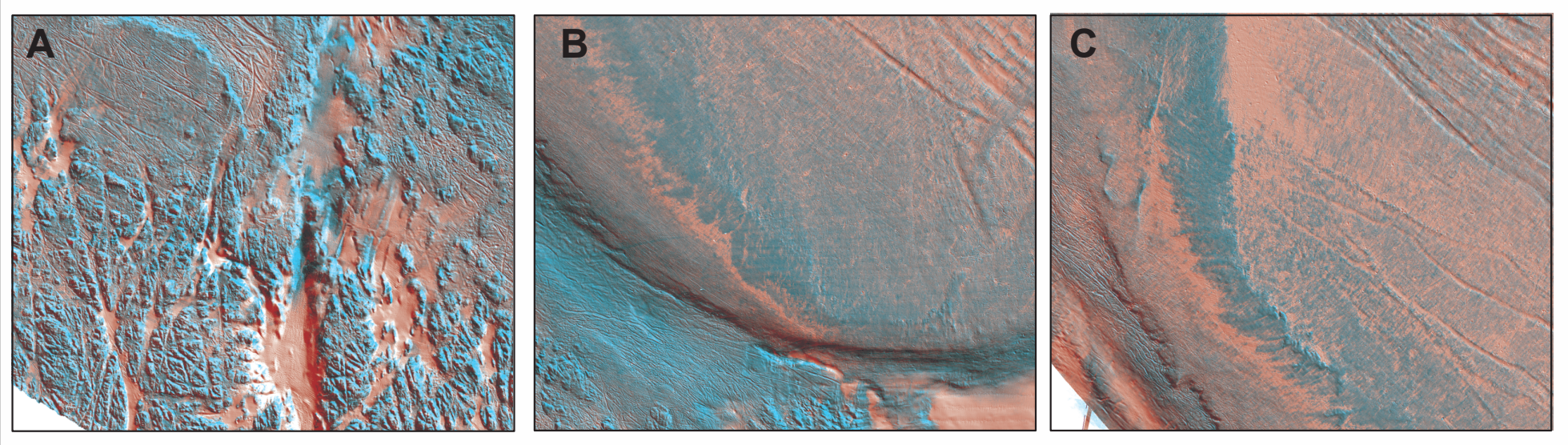


Figure 4: Three images of Makkovik Bank, with backscatter draped over the terrain. Low backscatter has a pink colour, and high backscatter is gray. **A**: postglacial mud fills depressions between basement rock. The grounding line wedge at upper left has high backscatter. **B**: The ice-turbated glaciomrine mud in the deep trough has high backscatter. On the bank top the band of low backscatter stretching to the NW shows the location of sandy bedforms. **C**: Again on the bank top, the bedform zone is at the left, contr asting strongly with the high backscatter of the till ridge. The extensive areas of low backscatter east of the ridge indicate the presence of mobile sand.

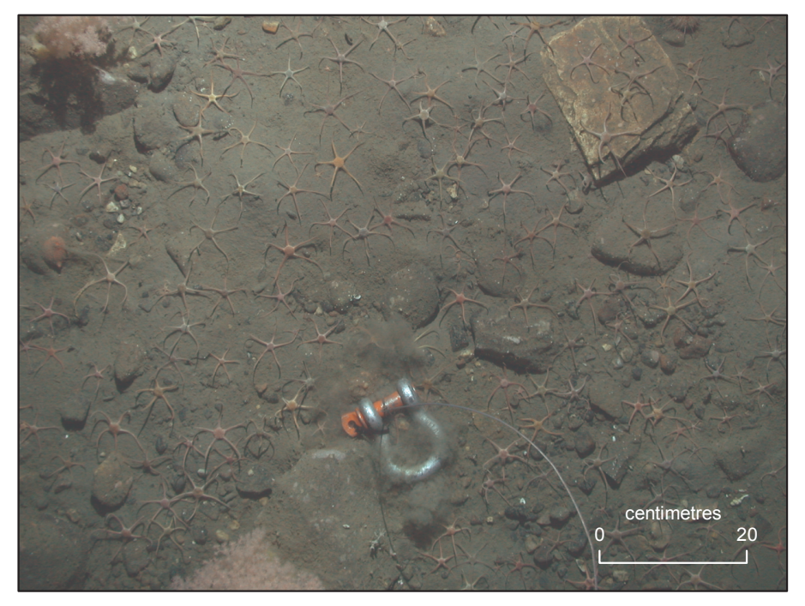


Figure 5: Seafloor photograph 2006040-031, photo 1, located within unit B3 at a depth of 216 m, showing sub-angular and sub-rounded cobbles and pebbles on a sandy mud seafloor with numerous brittlestars and some soft coral attached to clasts.

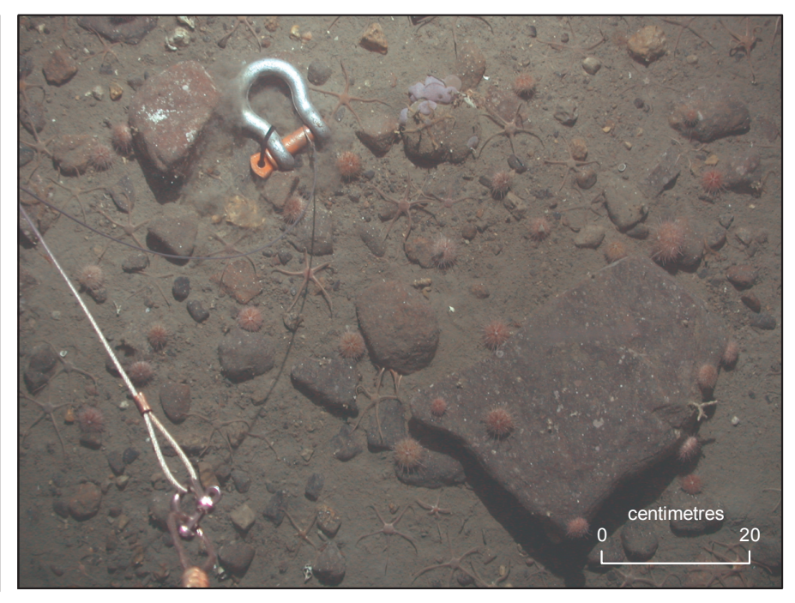


Figure 6: Seafloor photograph 2006040-033, photo 1, located within unit T1 at a depth of 265 m, showing sub-angular and sub-rounded boulders, cobbles and pebbles on a sandy mud seafloor; fauna includes sea urchins, brittle stars, sponges, soft corals.

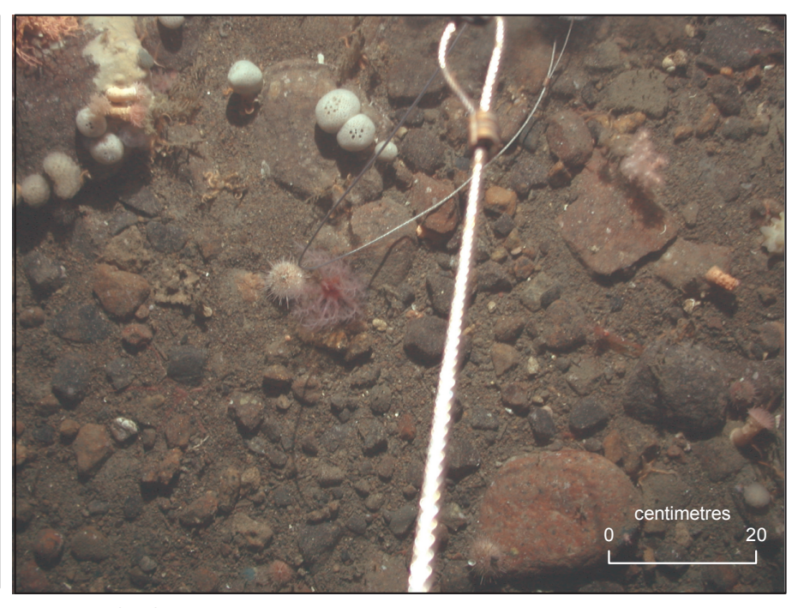


Figure 7: Seafloor photograph 2006040-012, photo 1, located within unit T3 at a depth of 284 m, showing a boulder gravel seafloor, with sponges, soft corals, anemones, and perhaps a basket star..

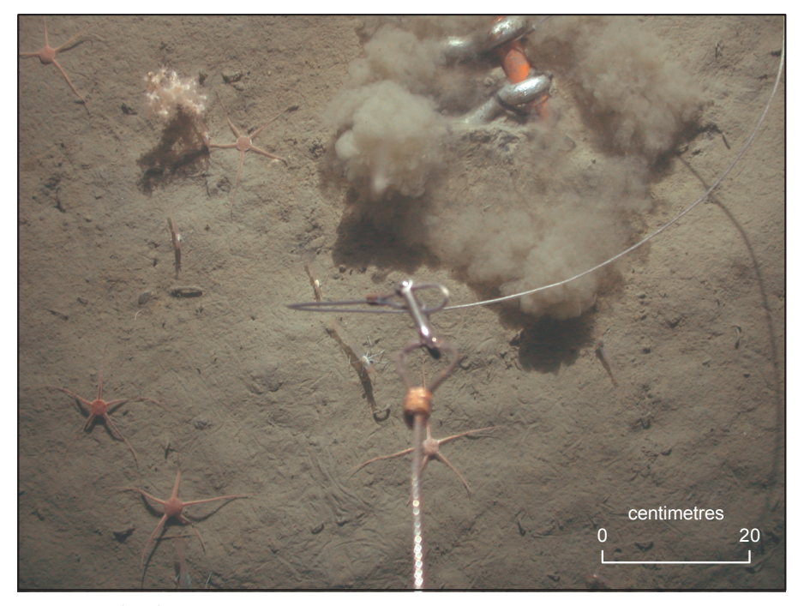


Figure 8: Seafloor photograph 2006040-018, photo 2, located within unit T4 at a depth of 292 m, showing a muddy seafloor, with burrows, animal tracks, and brittlestars.

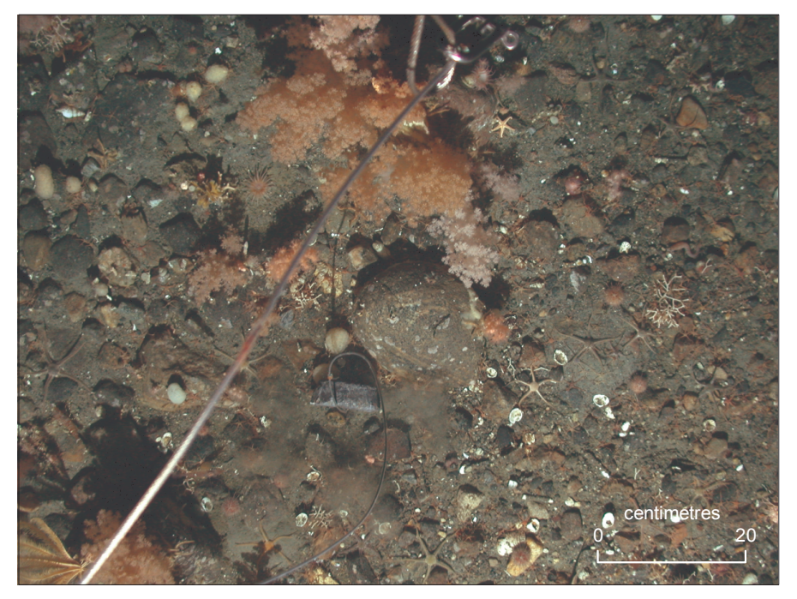


Figure 9: Seafloor photograph 2006040-012, photo 3, located within unit M1 at a depth of 139 m, showing a boulder gravel seafloor, with soft corals, sponges, gastropods, crinoids, sea urchins.

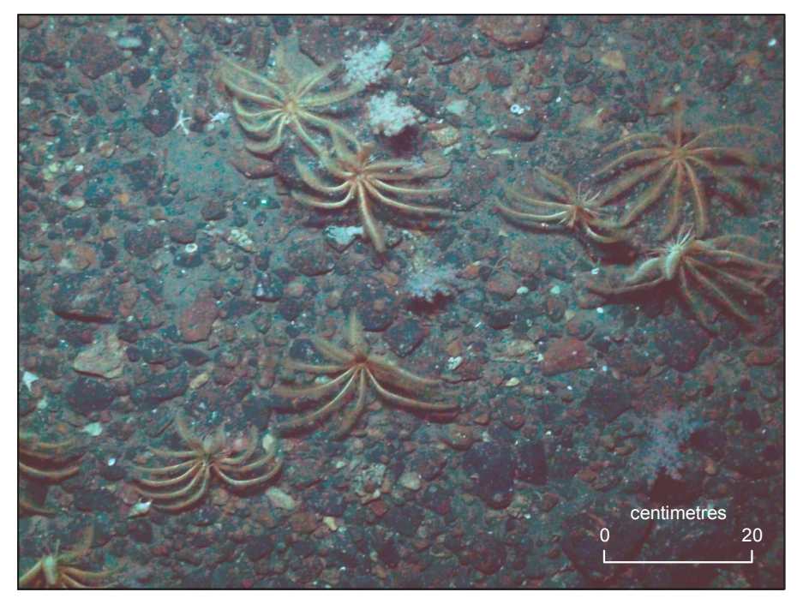


Figure 10: Seafloor photograph 2010034-003, photo 4, located within unit M1 at a depth of 207 m, showing the gravel pavement typical of unit M1, and also large numbers of crinoids.

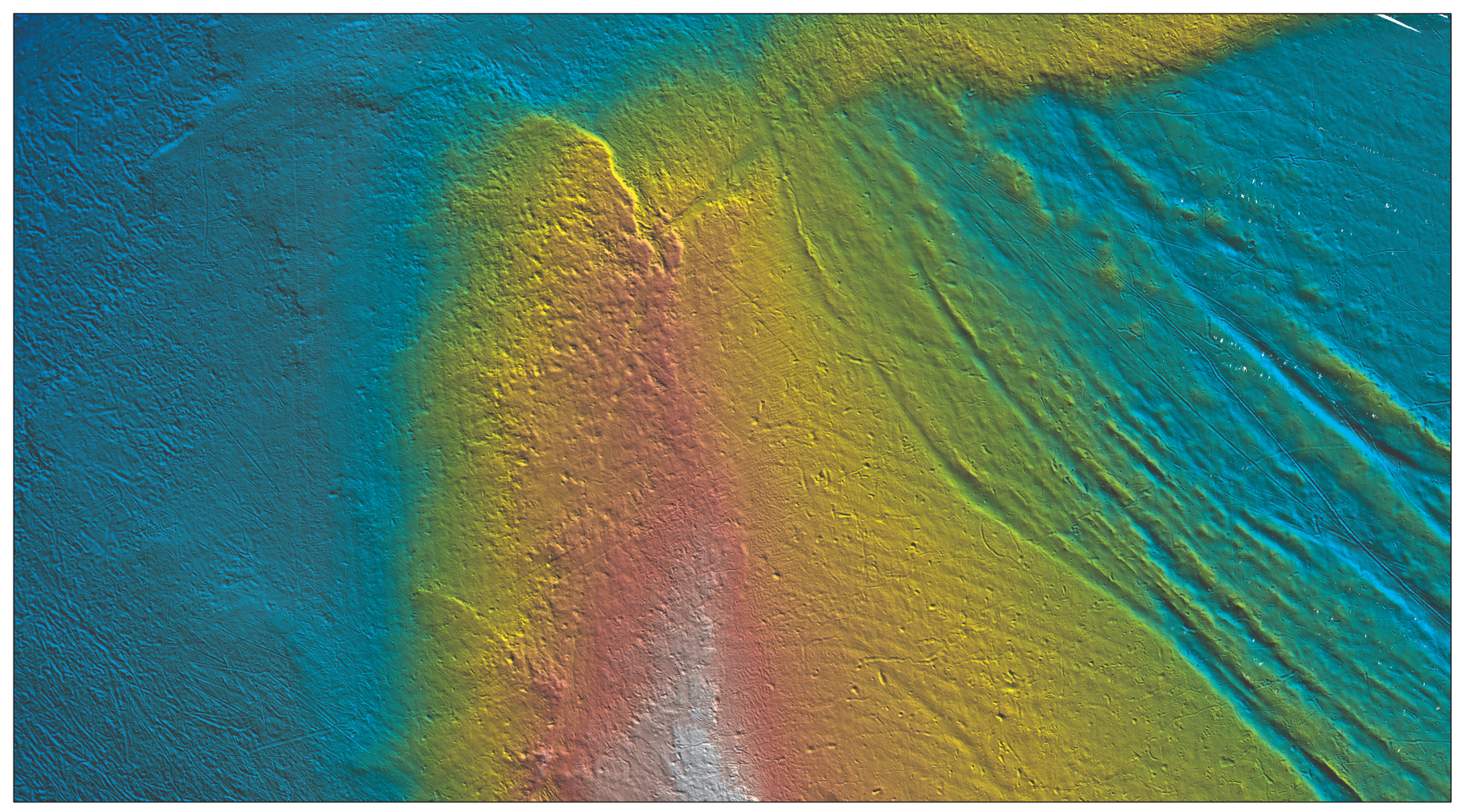


Figure 3. Multibeam image showing part of Makkovik Bank. In the deep trough (left) iceberg furrowing has been intense, and many furrows are wide and deep. Much of the morainal area at the shallow west side of the bank has a smoother appearance. Iceberg pits and furrows also are present east of the moraine. The bank-top terrain on the eastern half of the image shows parallel ridges and channels whose genesis is unclear.

Figure 11: Seafloor photograph from 2005033B-048, photo 1, located within unit M2 at a depth of 170 m, showing basket stars (Gorgonocephalus sp. at extreme right and left, and a crinoid (*Heliometra glacialis*) at centre for the field of view. Other photographs from this series show that the seafloor is highly variable, and the fauna includes anemones, sea urchins, sponges, soft corals. Areas of more extensive sand have an infauna.

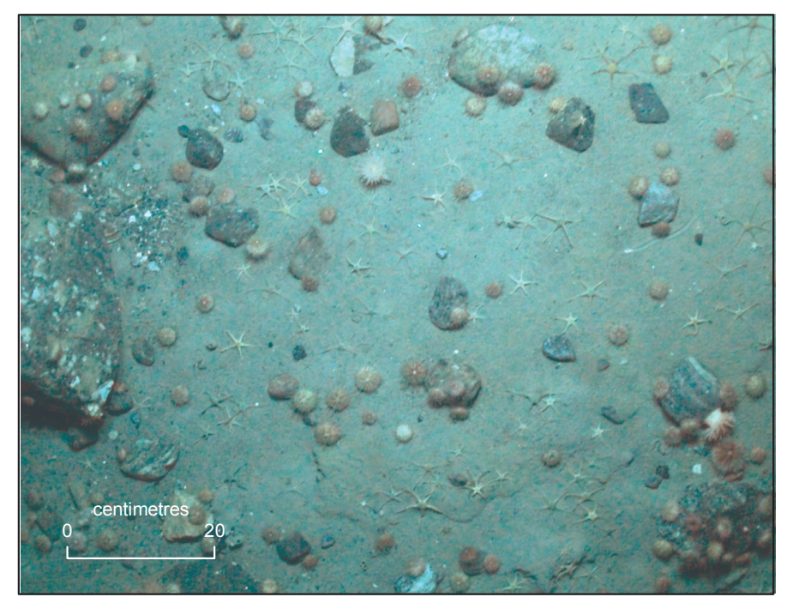


Figure 12: Unit M3, seafloor photograph from 2010034-006, photo 21, depth 132 m. Sandy sea floor with burrows, brittlestars, sea urchins, anemones on clasts.

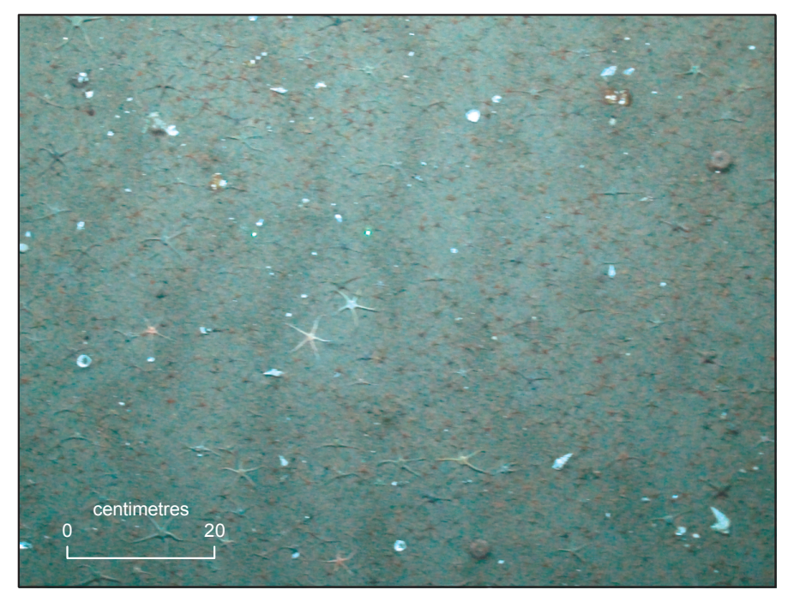


Figure 13: Unit M4, seafloor photograph from 2010034-001, photo 75, depth 103 m. Sandy sea floor with ripples, scattered shell hash, brittle stars, sea urchins.

Figure 14: Seafloor photograph 20060400-008, photo 2, located within unit M1 at a depth of 99 m, and showing the seabed covered with polychaete worms of the family Onuphidae. These site also has burrowing cucumbers and some quahhaugs (siphons protruding from sediment).

LEGEND

Makkovik Province Seascapes

In the southwest of the map area crystalline basement rocks have irregular relief, ranging up to 25 m. Quaternary sediments form a veneer except where more extensive areas of postglacial mud occupy depressions (Unit B2), at a grounding line wedge (Unit B3), and where the bedrock terrain is mantled by thick glaciomarine mud (B4). Except for the postglacial mud (Unit B2) backscatter is high due to the presence of gravel and exposed rock at the seafloor.

B1 **Bedrock terrain**
Morphology: Ridges, knolls, and ledges, with relief up to 25 m and at depths usually shallower than 130 m; irregular flat-floored depressions oriented along structural elements.
Texture: Bedrock with veneers of sandy muddy gravel; thicker deposits of postglacial and glaciomarine mud in depressions; high backscatter except in muddy depressions; on geophysical records this unit forms acoustic basement.
Biota: There are no photographs of this seascape but probably the bedrock and boulder gravel surfaces host sponges, anemones, and soft corals. The extensive muddy depressions have infauna.
The rock types are unknown but are most likely similar to the granites and graniodiorites onshore (Wardle et al., 1997). In the extreme southwest of the coverage, just southwest of Cape Harrison, scattered bedrock knolls penetrate a cover of fluted till with (barely discernable) de Geer moraines superimposed.

B2 **Grounding-line wedge**
Morphology: Terraces with gentle relief and steep northeast-facing slopes, 30 m high; heavily imprinting by iceberg furrows.
Texture: Glacial diamict (till) comprising boulders and angular gravel in a matrix of sandy silty clay; surficial lag veneer of gravel with scattered boulders; high backscatter; low backscatter in partly-infilled iceberg furrows; acoustically incoherent on geophysical records.
Biota: Three sets of photographs show brittlestars, gastropods, brittlestars, with occasional soft coral on clasts. The fourth photograph set, from an area of low backscatter in an iceberg furrow, shows sandy mud with numerous burrows and animal tracks.
This unit was formed under ice grounded on the west flank of the Labrador Trough, following retreat of the ice margin from farther offshore. It is the equivalent of till elsewhere on the Labrador Shelf (Moran, 1989). If equivalent to the Labrador Shelf upper till (most likely) it is normally-consolidated); if equivalent to the lower till it is over-consolidated).

B3 **Glaciomarine mud**
Morphology: Low, undulating relief; heavy imprinting by iceberg furrows and pits.
Texture: Sandy gravelly mud draped over overlying basement rocks; variable relief; surficial lag of sandy muddy gravel; photographs show pebbles and cobbles and rare boulders embedded in sandy mud; high backscatter; strong coherent, parallel, internal reflections that mimic underlying terrain.
Biota: Photographs at one site show brittlestars, sea urchins, gastropods, some soft corals, sponges on cobbles; patches of sandy mud in iceberg furrows and pits likely have infauna.
This unit, equivalent to the Qeovik Silt (Josenhans et al., 1986) was deposited as a drape over underlying glaciogenic sediments by meltwater plumes from retreating glacier ice. Moran (1989) describes the Qeovik Silt as being normally consolidated with low shear strength.

B4 **Postglacial mud**
Morphology: Relatively large areas of flat-to gently-sloping sea floor occupying depressions within the bedrock terrain; some imprinting by recent iceberg grounding.
Texture: Silty mud in a basin-fill style, with variable thickness up to 10 m, overlying glaciomarine mud; low backscatter; on geophysical records this unit is acoustically transparent.
Biota: No bottom photographs available, but photographs at site 2006040-027 (from a muddy part of seascape B2) may be typical: muddy seafloor, animal tracks, numerous burrows.
This mud is derived through reworking of glaciogenic sediments in postglacial time. It is the equivalent of the Maqqauk Clay Formation of Josenhans et al. (1986). Moran (1989) denotes this unit as having low shear strength.

Labrador Trough Seascapes

These terrains occur in relatively deep water (>130 m) between Makkovik Bank and the shallower and more rugged basement topography to the southwest, and also in the saddle between Makkovik and Harrison Banks.

T1 **Bedrock terrain**
Morphology: Ridges, knolls, and ledges, with relief up to 20 m; generally draped by at least several metres of glaciomarine mud.
Texture: Winnowed veneers of sandy muddy gravel; thicker deposits of glaciomarine mud in depressions; high backscatter; on geophysical records this unit forms acoustic basement.
Biota: Photographs (2006040-033) show sub-angular and sub-rounded boulders, cobbles and pebbles on a sandy mud seafloor; fauna includes sea urchins, brittle stars, sponges, soft corals; attached fauna on pebbles and cobbles.
This type of bedrock terrain has some similarities with B1, but postglacial mud does not fill structural depressions. The rock types are unknown but are most likely similar to those onshore nearby (Wardle et al., 1997), i.e., granites and graniodiorites.

T2 **Fluted terrain**
Morphology: Glacial lineations (crag-and-tail) developed in the lee of basement highs; ridges up to 10 m high and 500 m long.
Texture: Glacial diamict (till) comprising boulders and angular gravel in a matrix of sandy silty clay; overlain by glaciomarine mud; surficial lag veneer of muddy gravel; high backscatter; acoustically incoherent on geophysical records.
Biota: No photographs available, but texture and fauna may be similar to T1.
This unit was formed under ice moving rapidly seaward via the saddle between Makkovik and Harrison Banks. It is the equivalent of till elsewhere on the Labrador Shelf (Josenhans et al., 1986). If equivalent to the Labrador Shelf upper till (Moran,1989) it is normally-consolidated); if equivalent to the lower till it is over-consolidated).

T3 **Glaciomarine mud**
Morphology: Low relief; heavy imprinting by iceberg furrows and pits.
Texture: A surficial lag of gravel overlies sandy gravelly mud up to 70 m thick draped over overlying basement rocks; variable relief; surficial lag of sandy muddy gravel; high backscatter; strong coherent, parallel, internal reflections that mimic underlying terrain.
Biota: Bottom photos at 2006040-014 show pavement of sub-angular to sub-rounded boulders, cobbles and pebbles with sandy mud in interstices; brittlestars and sea urchins; however, one photograph at 2006040-012 shows a richer fauna, with sponges (attached to cobbles), anemones, soft corals.
This unit, equivalent to the Qeovik Silt (Josenhans et al., 1986) was deposited as a drape over underlying glaciogenic sediments by meltwater plumes from retreating glacier ice. Moran (1989) describes the Qeovik Silt as being normally consolidated with low shear strength.

T4 **Postglacial mud**
Morphology: Very gently sloping seafloor with little relief.
Texture: Silty mud in a basin-fill style, with variable thickness up to 25 m, overlying glaciomarine mud; low backscatter; on geophysical records this unit is acoustically transparent.
Biota: No photographs available, but burrowing organism are probable..
This mud is derived through reworking of glaciogenic sediments in postglacial time. It is the equivalent of the Maqqak Clay Formation of Josenhans et al. (1986). Moran (1989) denotes this unit as having low shear strength.

Makkovik Bank Seascapes

The gently-sloping top and steeply-sloping flanks of Makkovik Bank are subdivided into a series of terrains based on morphology, seafloor texture, and biology. The western, northern and southern flanks of the bank are occupied by multiple layers of till, some of which appear to be compacted and form escarpments.The bank top has a cover of Quaternary sediment thin enough to allow Cenozoic bedrock structure to be evident at the seafloor. The bank top is incised by channels of unknown origin, and also long narrow moraines. Much of the bank is iceberg turbated, but there are variations in the intensity and style. High-resolution seismic reflection systems are unable to resolve the stratigraphy.

M1 **Bank margin moraines - lower till**
Morphology: Ridges of till along the west side of the bank; a series of minor escarpments along the northwest flank, and a 20-m-high escarpment along the southwest side; density of iceberg impact features is depth dependent: highly iceberg-furrowed below 150 m depth, and relatively smooth seafloor above 150 m (the majority of the unit), except for iceberg pits; large areas shallower than 100 m.
Texture: Multiple tills forming a wedge up to 90 m thick, thinning to the east; glacial diamict (till) comprising boulders and angular gravel in a matrix of sandy silty clay; surficial lag veneer of muddy gravel; high backscatter; acoustically incoherent on low-frequency geophysical records; lower layers especially may be compacted.
Biota: Seafloor photographs at site 2006040-010 show a pavement of gravel, some sand in interstices, and a rich fauna including crinoids, soft corals, sponges, anemones, brittlestars.
Comments: Airgun seismic reflection data show this unit as a wedge plastered onto the west flank of Makkovik Bank; higher frequency seismic reflection systems do not penetrate. These deposits are likely equivalent to the lower till of Josenhans and Zevenhuizen (1989).

M2 **Bank margin moraines - upper till**
Morphology: Broad, low-relief ridges of till along the north and south flanks of the bank in water depths of 130-200 m.
Texture: Boulders and angular gravel in a matrix of sandy silty clay; surficial lag veneer of gravel with high backscatter; patches of sandy seafloor with low backscatter; acoustically incoherent on geophysical records.
Biota: Variable biota. In high backscatter areas (sandy boulder gravel) the rich fauna includes sponges, soft corals, basket stars, anemones; in low backscatter areas (sand with some gravel) an infauna is present.
Comment: airgun seismic reflection data show this unit as a wedge plastered onto the north and south flanks of Makkovik Bank; higher frequency seismic reflection systems do not penetrate; equivalent to the upper till of Josenhans and Zevenhuizen (1989).

M3 **Bank-top terrain**
Morphology: Low-relief plateau incised by channels up to 10 m deep; several narrow, arcuate moraines up to 2 m high; possible bedrock structure evident in places (strike-parallel ridges); iceberg furrows and pits.
Texture: Veneer of sand with bedforms, sandy gravel, or gravelly sand; high and low backscatter depending on grainsize. Sandy sediment infills iceberg furrows.
Biota: Photographs at sample site 2010034-006 show brittlestars and sea urchins; burrows, attached fauna where gravel is exposed includes sponges, soft corals, anemones.
Acoustic stratigraphy is unhelpful, but generally Quaternary sediments are 20-50 m thick, but perhaps thinner in places where bedrock ridges are apparent on multibeam sonar imagery. Sea-floor texture is patchy.

M4 **Sand waves**
Morphology: Broad, curving ridges 1-1.5 m high, typical wavelengths 70 m, in a 1.2 km-wide zone, at depths of 105-115 m; orientation changes from southwest in the south to northwest in the north.
Texture: Rippled sand; low backscatter.
Biota: Brittlestars and sea urchins are evident on photographs.
Elongate strip along west flank of the morainal ridge; submersible observations indicate the presence of active megaripples; the varying orientation of the sand waves may relate to orientation of a circulation gyre around Makkovik Bank revealed by oceanographic modeling.

M5 **Outer bank sand**
Morphology: Sheets of sand in the southeast, including 1.5 m-high barchan dunes.
Texture: Sand; low backscatter.
Biota: No information available.
Occurs in relatively deep (220-240 m) water; orientation of barchan-like ridges suggests northwest to southeast current, in agreement with oceanographic models.

Continental slope seascapes

S1 **Upper continental slope**
Morphology: Steeply sloping, dendritic network of >200 m deep canyons begins at ~600 m depth.
Texture: Uncertain- high backscatter.
Biota: unknown.
Steeply sloping upper continental shelf -only one small area mapped.

Geological contact (map unit boundaries are interpreted from multibeam sonar bathymetry and geophysical seismic profile data and are inferred contacts that may be gradational or conceptual in nature) . . . . ∼
Escarpment . . . . ∼
Cross-section (Figure 1) . . . . — — — —
Photos . . . . Figure 7 ▲
Grab samples . . . . ●
Core samples . . . . ●
Other samples . . . . +

doi:10.4095/292138

LOCATION MAP

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This map was produced by Natural Resources Canada in co-operation with Fisheries and Oceans Canada

Geology by J. Shaw, Geological Survey of Canada, 2010

Geologic compilation by J. Shaw, Geological Survey of Canada, 2010

Digital cartography by P. O'Regan, Data Dissemination Division (DDD); and S. Hayward, GSC (Atlantic)

OPEN FILE 7005

SEASCAPES

MAKKOVIK BANK

NEWFOUNDLAND AND LABRADOR

Scale 1:1 250 00 000/Échelle 1/1 250 000

kilometres 40 0 40 80 120 kilomètres

Universal Transverse Mercator Projection	Projection transverse universelle de Mercator
North American Datum 1983	Système de référence géodésiquenord-américain, 1983
© Her Majesty the Queen in Right of Canada, 2013	© Sa Majesté la Reine du chef du Canada, 2013
This map is not to be used for navigational purposes	Cette carte ne doit pas être utilisée aux fins de navigation

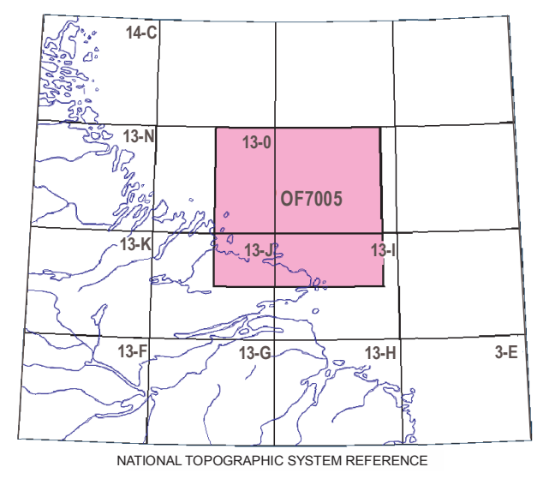
Any revisions or additional information known to the user would be welcomed by the Geological Survey of Canada

Digital base map (land area) from data compiled by Natural Resources Canada, modified by GSC (Atlantic)

Digital bathymetric contours in metres supplied by the Canadian Hydrographic Service and GSC (Atlantic)

Mean magnetic declination 2013, 23°02'W, decreasing 15' annually. Readings vary from 22°30'W in the SE corner to 23°34'W in the NW corner of the map

Depth in metres below mean sea level



NATIONAL TOPOGRAPHIC SYSTEM REFERENCE

OPEN FILE
DOSSIER PUBLIC
7005
GEOLOGICAL SURVEY OF CANADA
COMMISSION GÉOLOGIQUE DU CANADA
2013

Recommended citation
Shaw J., Courtney, R.C. and Sonnichsen, G.V., 2013. Seascapes, Makkovik Bank, Newfoundland and Labrador; Geological Survey of Canada, Open File 7005, scale 1:250 000. doi:10.4095/292138

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