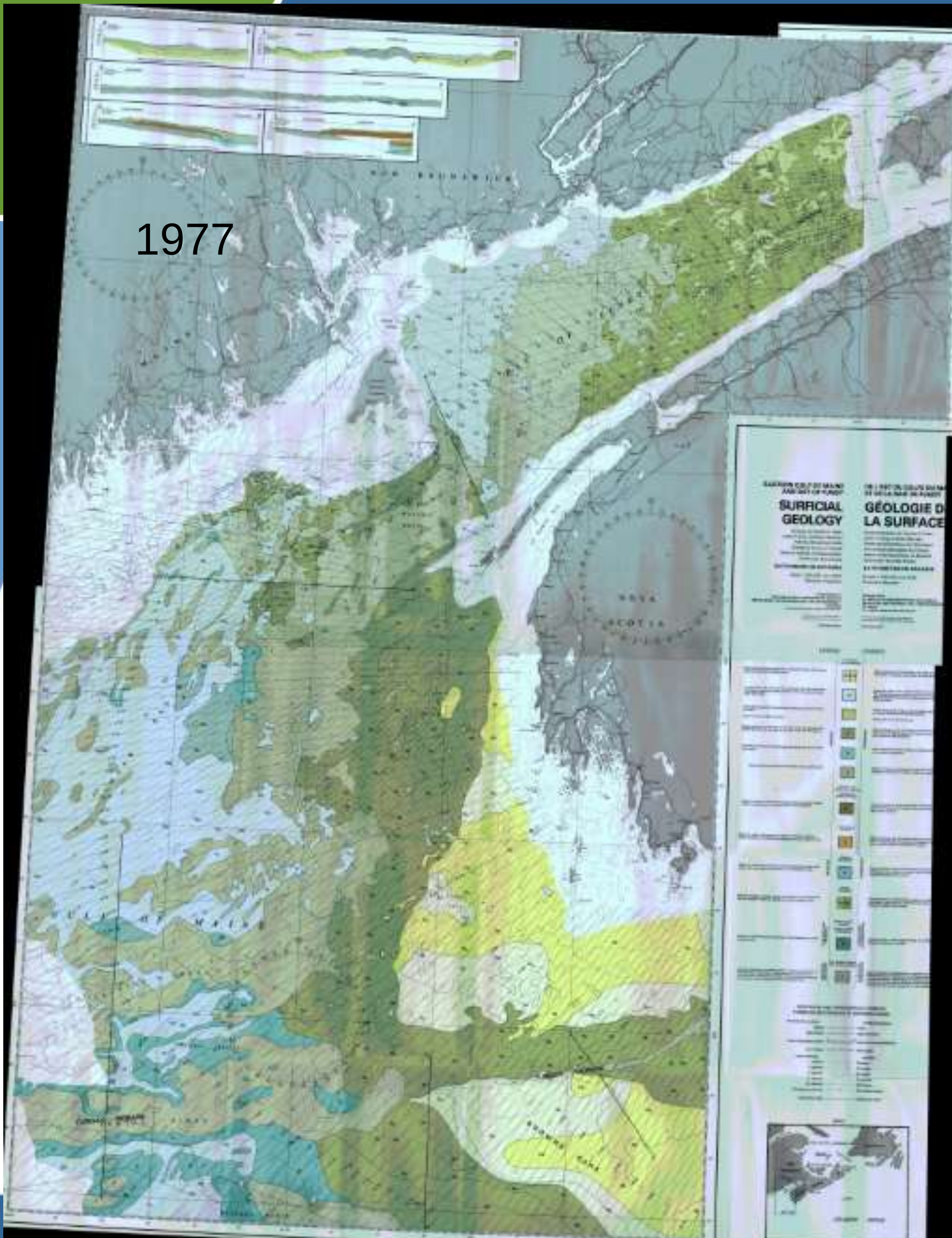
Mapping the Bay of Fundy

John Shaw & Brian J. Todd
Natural Resources Canada

- Surficial geology mapping in the 1970s
- Multibeam sonar mapping (early 2000s)
- The seascape map
- Conclusion



marine sciences paper 19
geological survey of canada paper 76-17

surficial geology of the eastern Gulf of Maine and Bay of Fundy

by Gordon B. Fader, Lewis H. King and Brian MacLean
geological survey of canada

Formation mapping

Strata consisting dominantly of a certain lithology…

- Scotian Shelf Drift *(deposited under glaciers or at glacier margin)*
- Emerald Silt *(derived from glacial meltwater plumes)*
- Sambro Sand
- LaHave Clay *(postglacial mud)*
- Sable Island sand and gravel *(postglacial, mobile)*

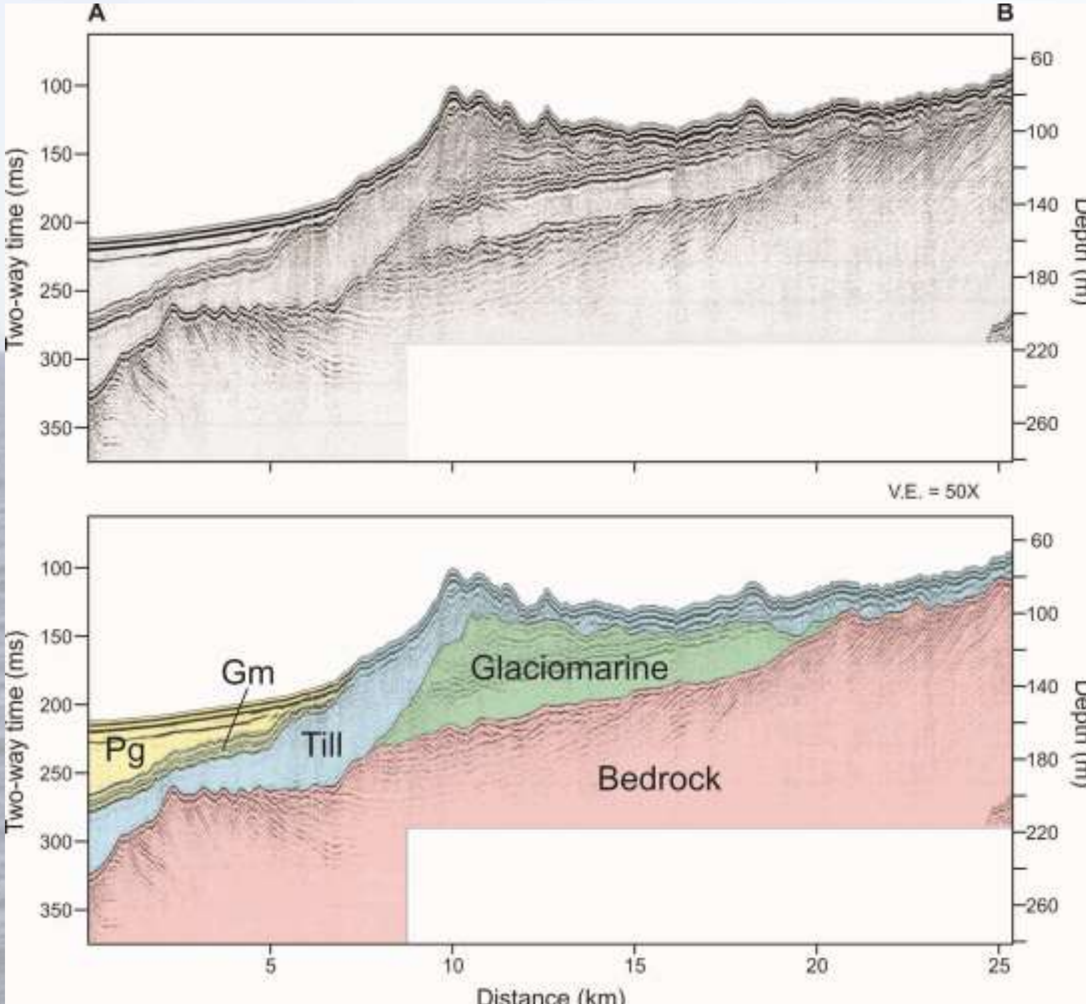
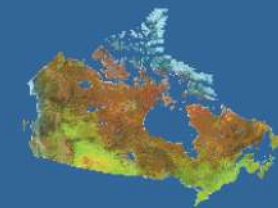
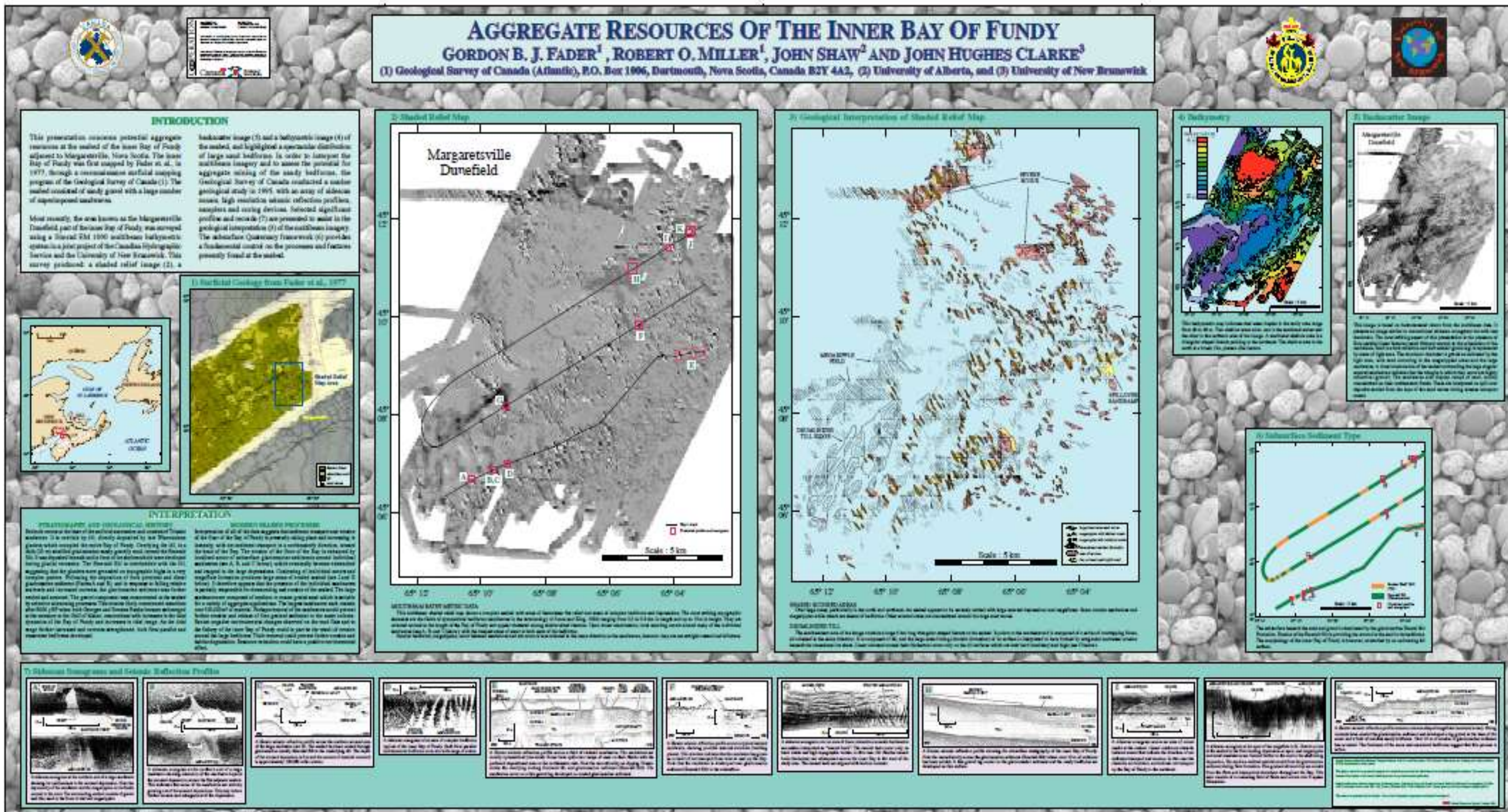


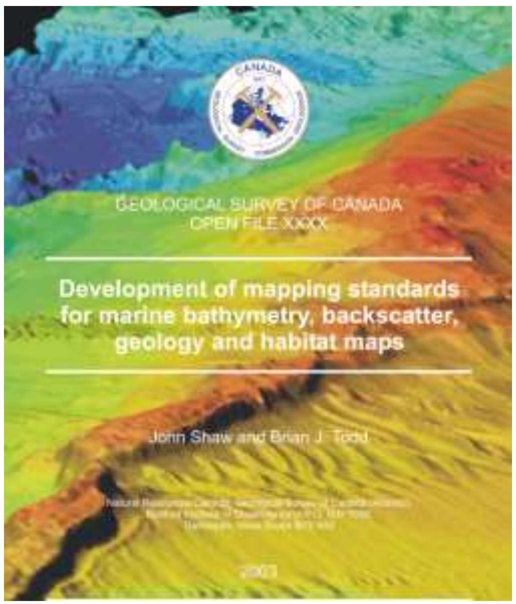
PLATE 1. Bottom photograph of the Scotian Shelf drift (map-unit 7). The glacial till consists of a mixture of angular fragments of pebble–boulder-sized material in a matrix of sand and mud. Numerous brachiopods (*Terebratulina septentrionalis*) can be seen in the upper half of the photograph as can several brittle starfish (Ophiuroidea). In the lower left corner a chiton (Polyplacophora) is on a large boulder and to its right is a small starfish (Asteroidea). The underwater current vane and compass indicate bottom current direction. Taken on Sewell Ridge at 42°49.5′N, 67°24′W at a depth of 194 m (106 fath).

Mid- 1990s: Advent of multibeam sonar mapping……….




AGGREGATE RESOURCES OF THE INNER BAY OF FUNDY
GORDON B. J. FADER[1], ROBERT O. MILLER[1], JOHN SHAW[2] AND JOHN HUGHES CLARKE[3]
(1) Geological Survey of Canada (Atlantic), P.O. Box 1006, Dartmouth, Nova Scotia, Canada B2Y 4A2, (2) University of Alberta, and (3) University of New Brunswick
INTRODUCTION
INTERPRETATION
Margaretsville Dunefield

Systematic mapping with multibeam sonar: Canada’s Oceans Action Plan



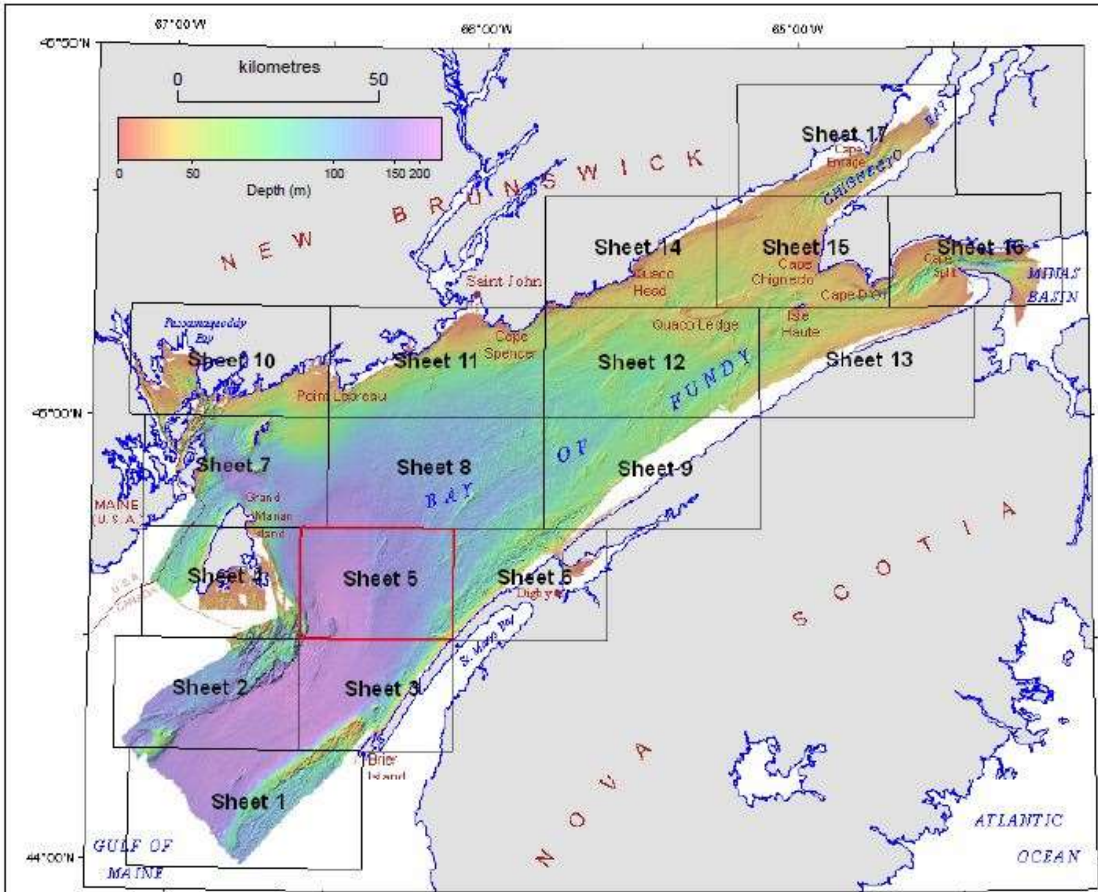
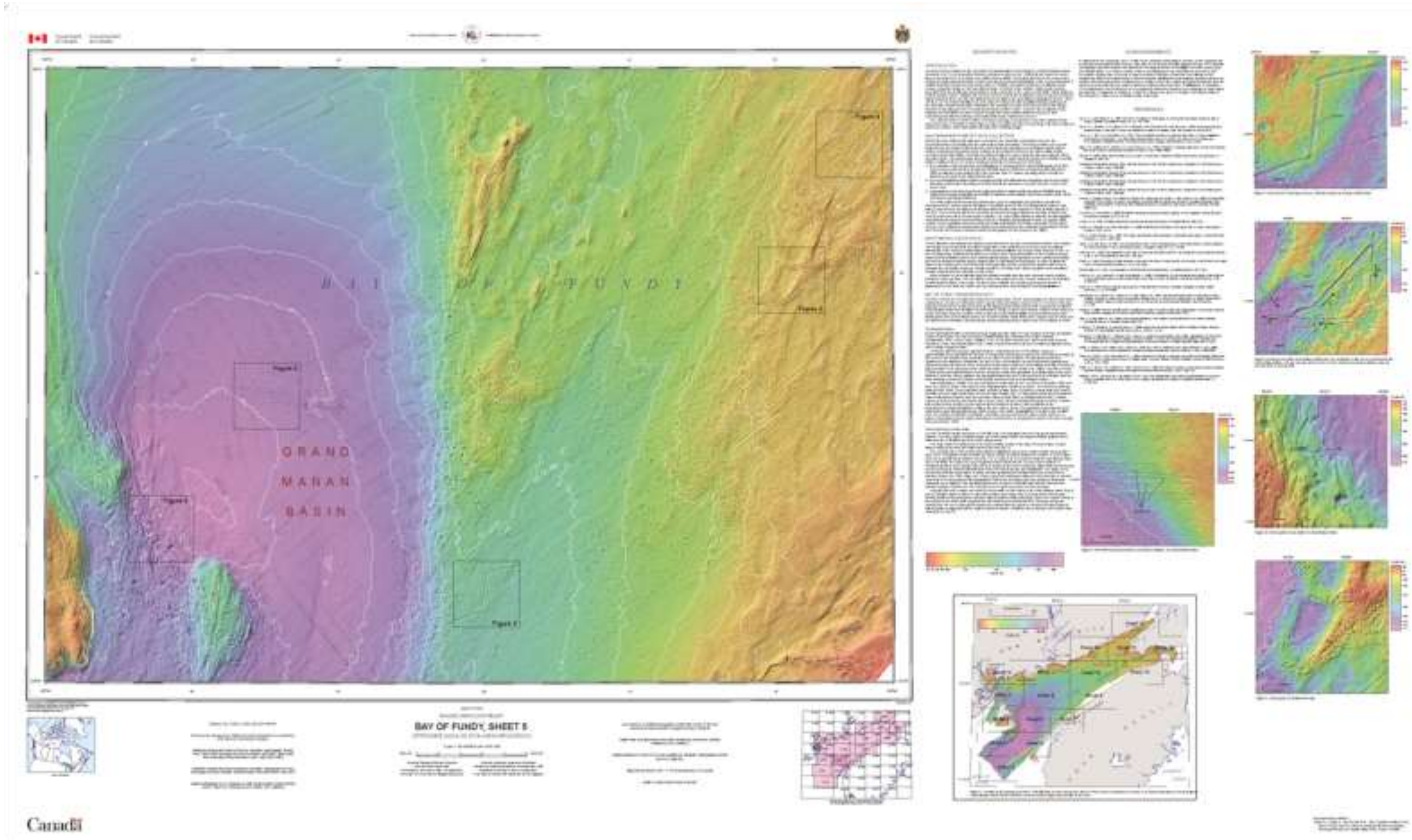
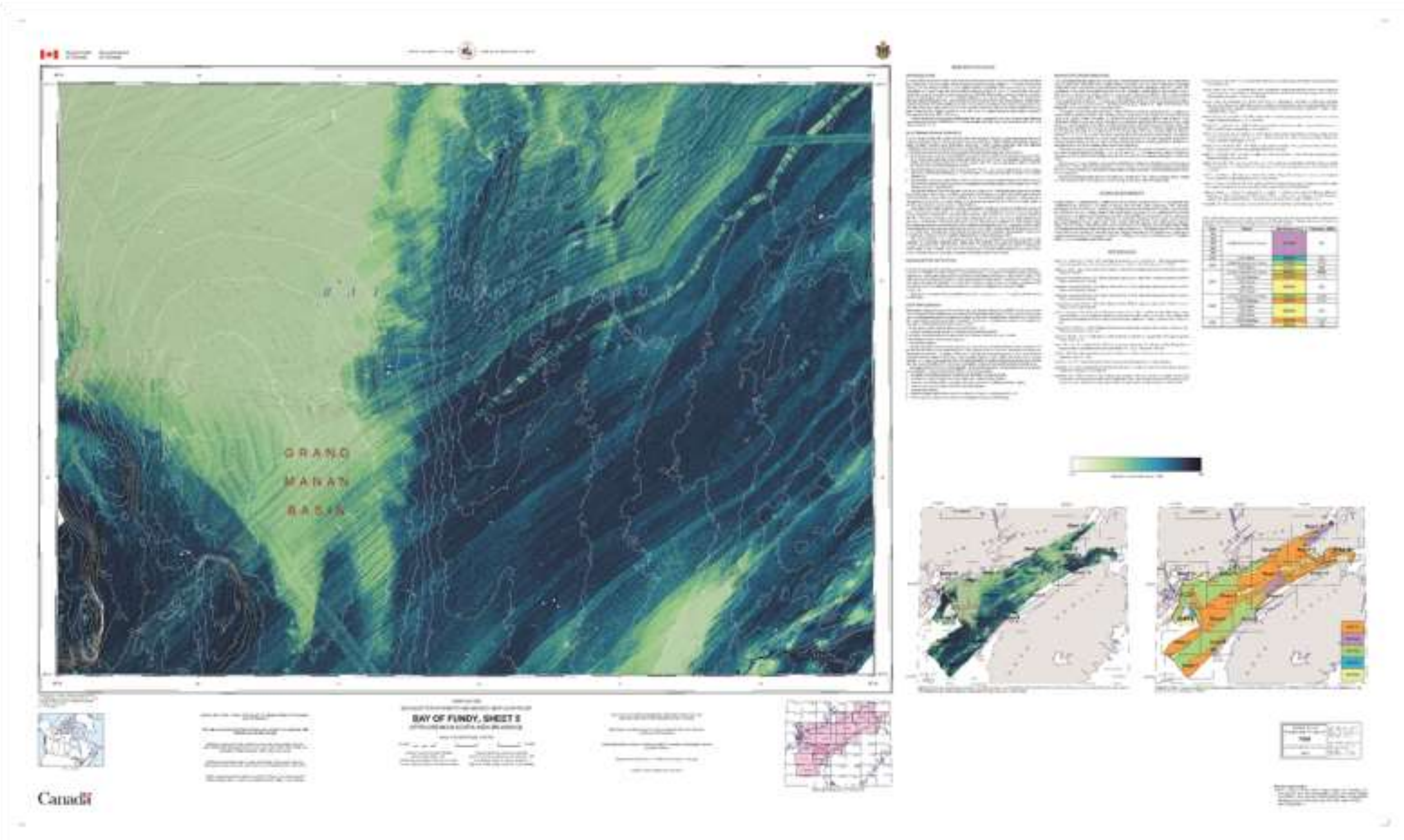


Figure 1. Location map showing seventeen 1:50 000 map sheets covering the Bay of Fundy. Sheet 5 (outlined by red box) is in southcentral Bay of Fundy between Grand Manan Island, New Brunswick, to the west and Digby, Nova Scotia, to the east.



Scale 1:50:00


GRAND
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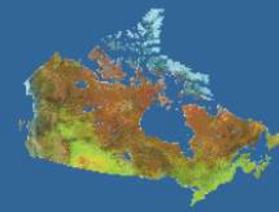
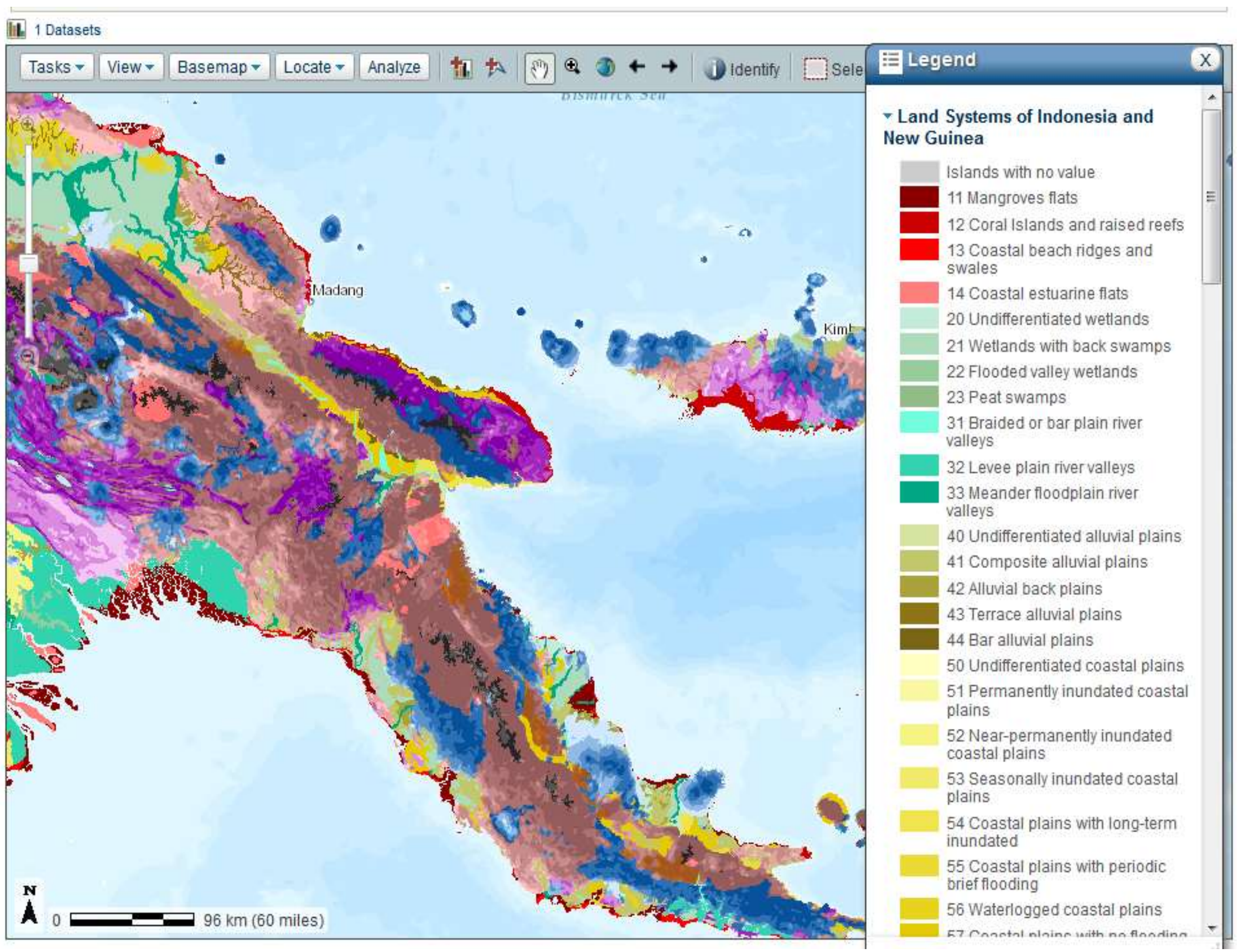
BASIN
BAY OF FUNDY, SHEET 5
Canada

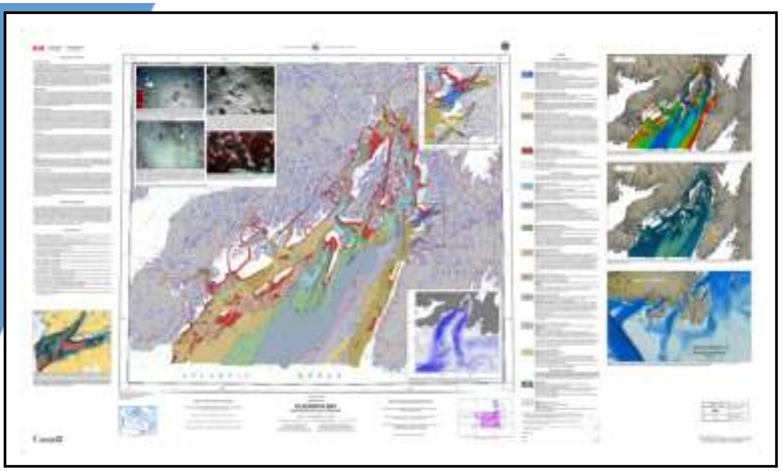
Land system mapping



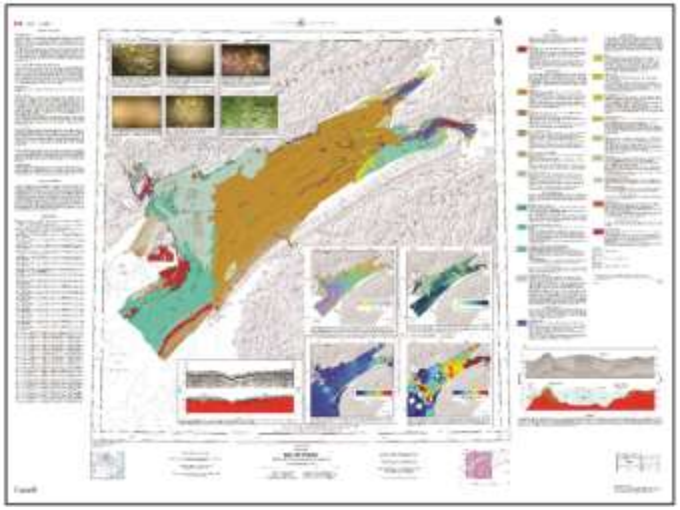
Areas with recurring patterns of landform, geology, and vegetation.



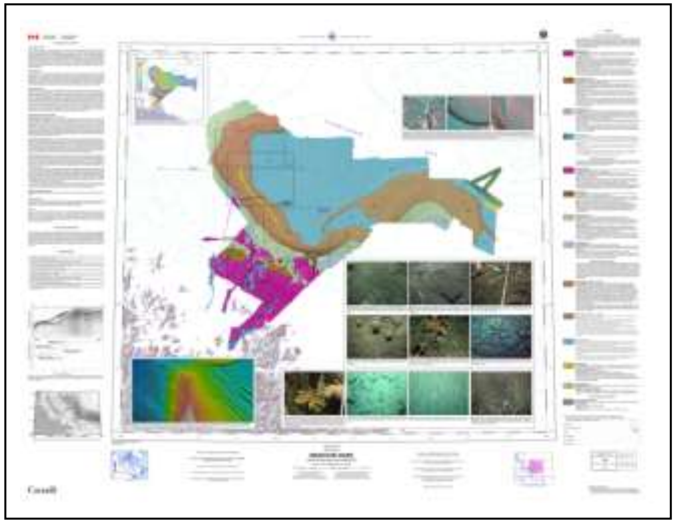
Seascapes: areas with recurring patterns of morphology, texture, and biota.



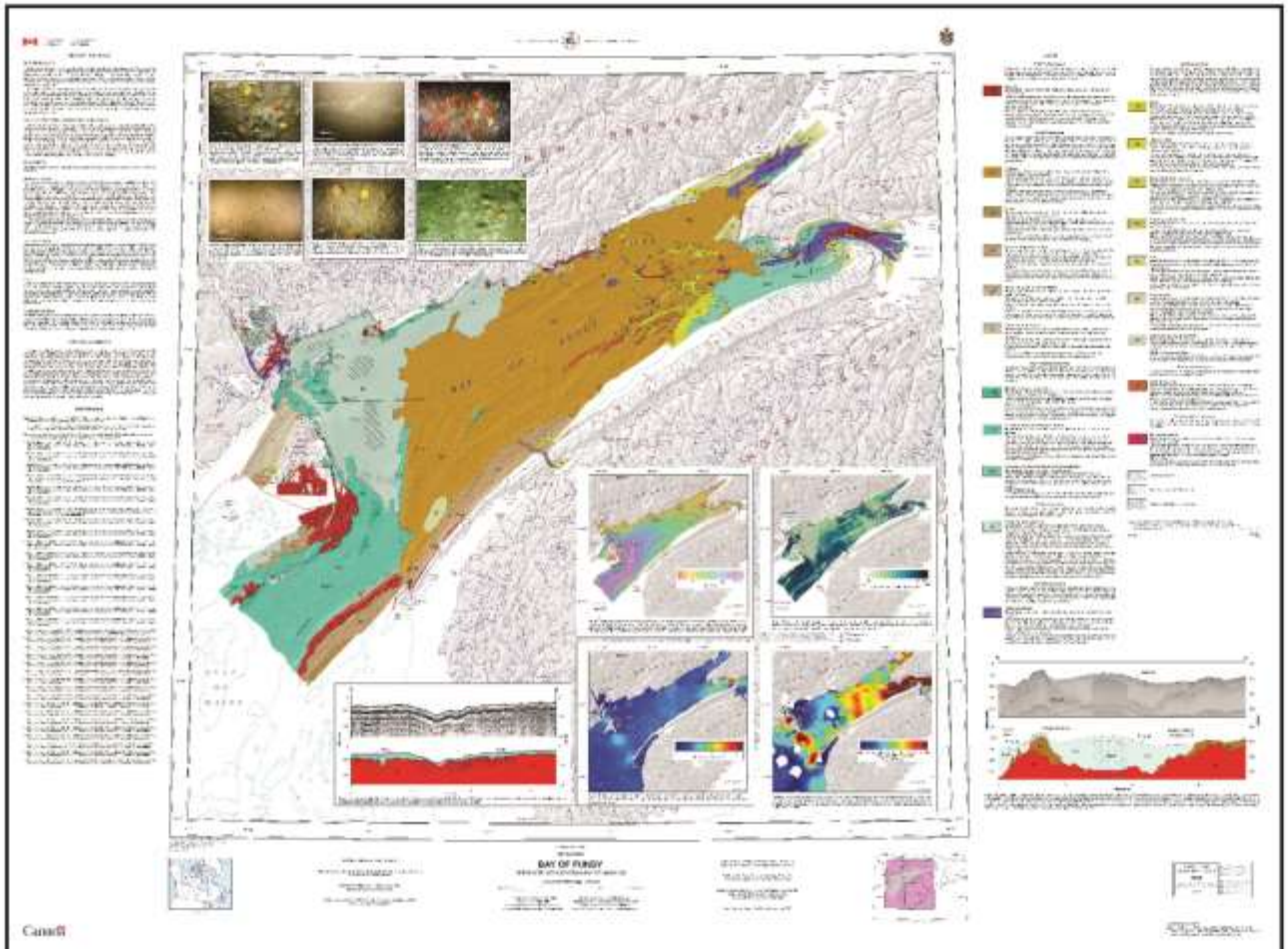
Placentia Bay

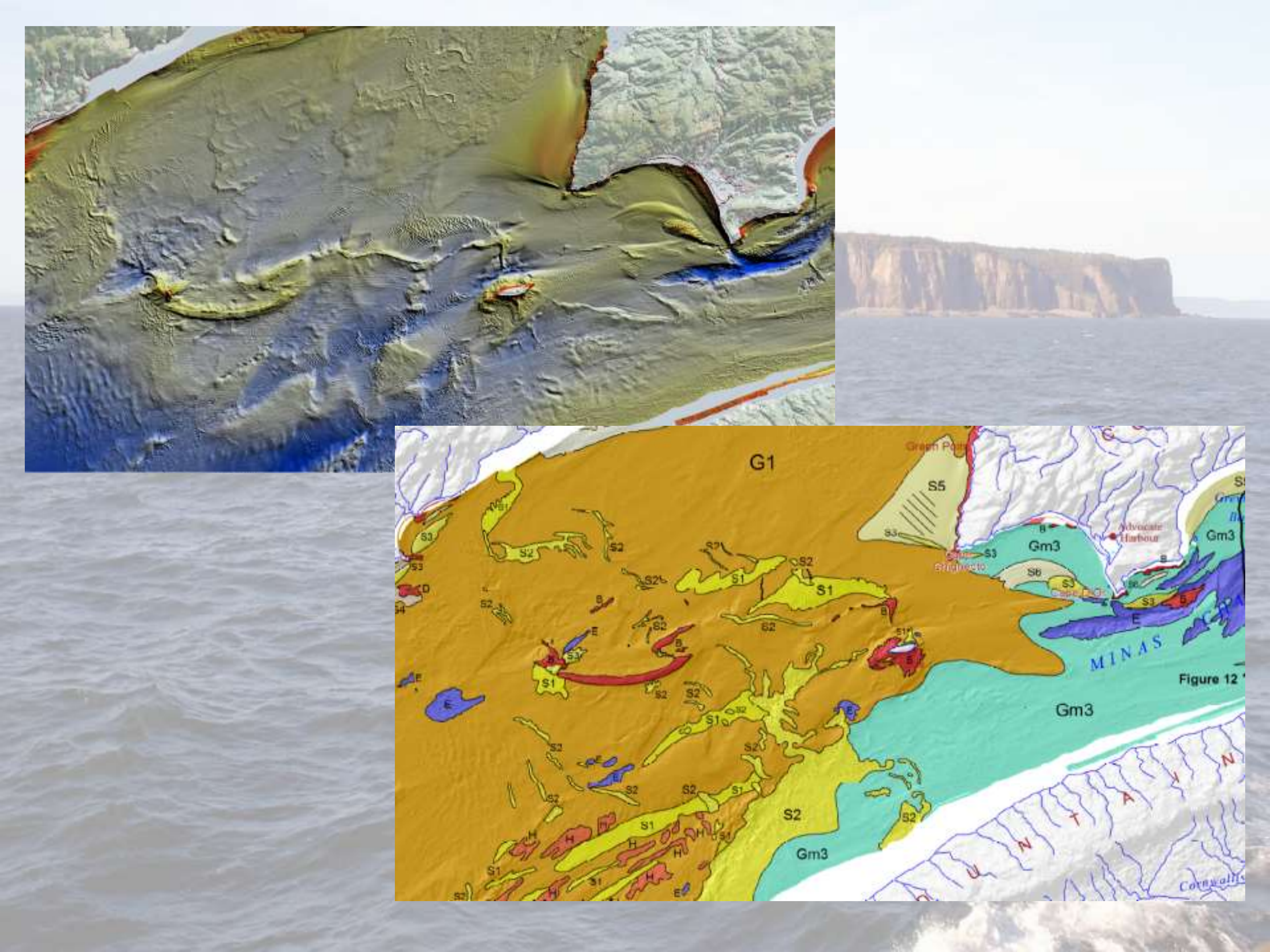


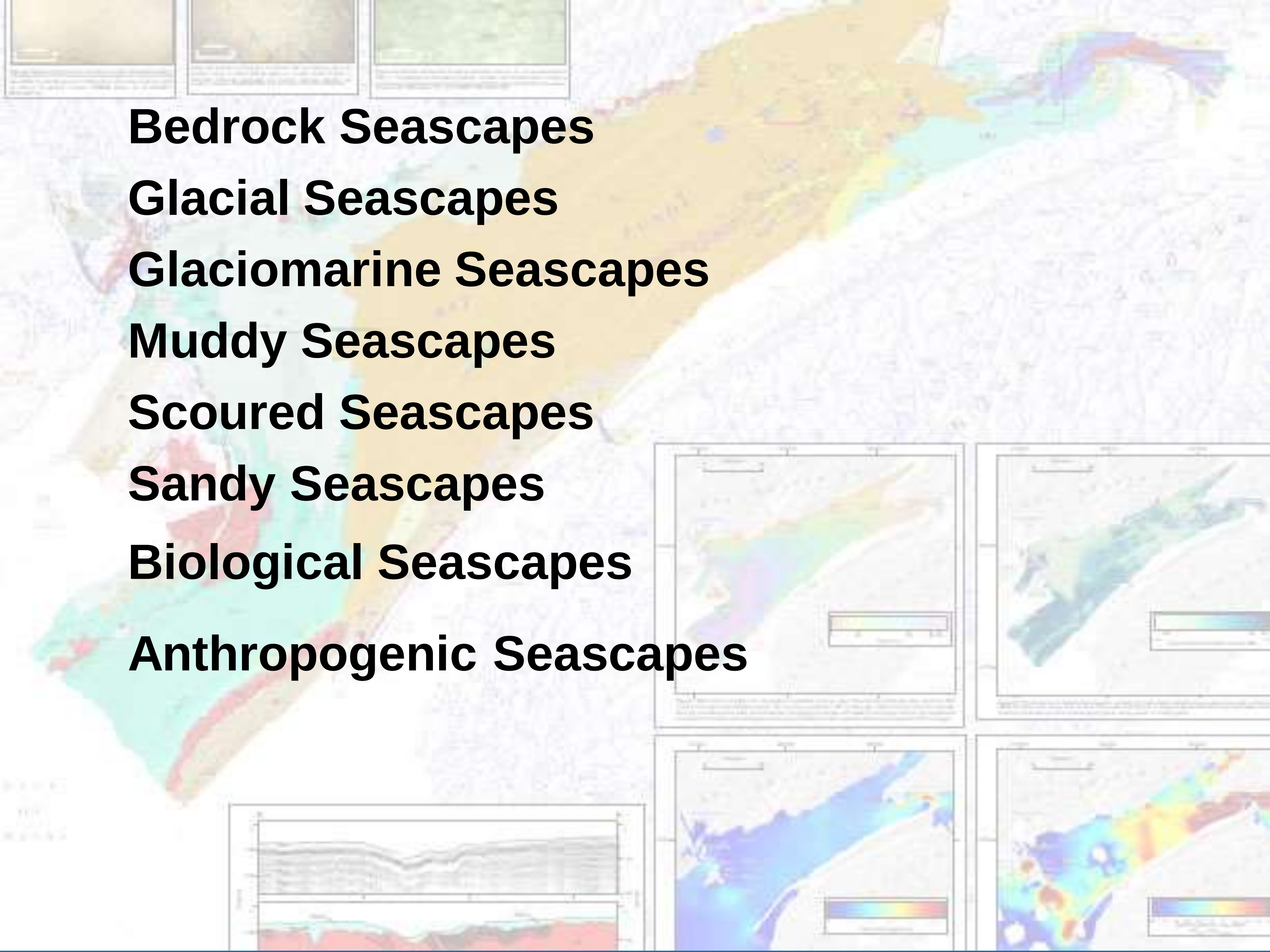
Bay of Fundy



Makkovik Bank




G1
S5
Gm3
Advocate Harbour
MINAS
Figure 12
Gm3
S2
Gm3
S1
S2
S3
E
H
Cornwallis



Bedrock Seascapes

Glacial Seascapes

Glaciomarine Seascapes

Muddy Seascapes

Scoured Seascapes

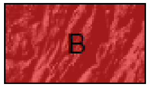
Sandy Seascapes

Biological Seascapes

Anthropogenic Seascapes

Bedrock Seascapes

Bedrock is exposed at or near the seafloor in several settings: 1) extensive areas off Passamaquoddy Bay and Grand Manan Island; 2) in coastal fringes; and 3) in scour troughs, where intense tidal currents have removed overlying sediments. Several lithologies are present, but are grouped together in this map.



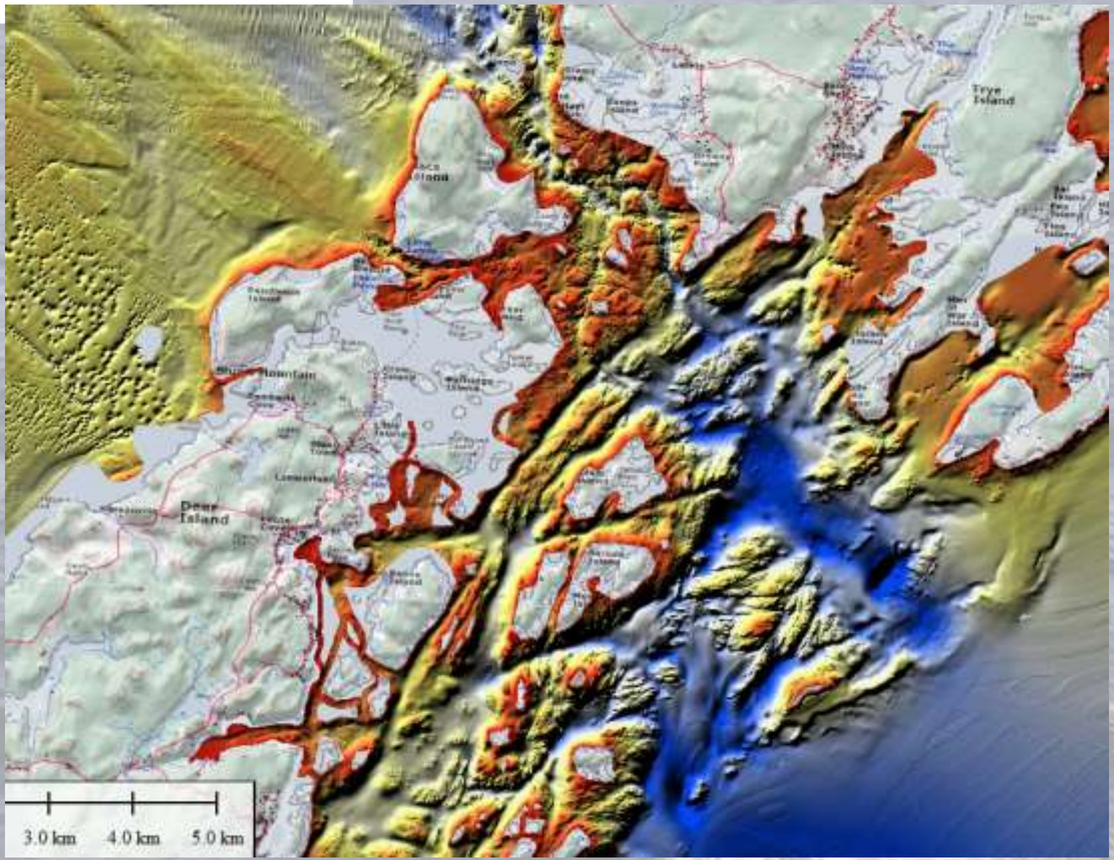
Bedrock

Morphology: Irregular terrain with knolls, and ridges up to 20 m high and tens of kilometres long.

Texture: Rock outcrops with veneers of gravel and sand; high backscatter strength. The gravel and sand may be mobilized by tidal currents, especially in scour troughs.

Biota: Attached fauna including coralline algae and algae in shallow areas, sponges, anemones.

Outcrops are rare, and bedrock commonly has a veneer of sand and gravel, with thicker sediments in pockets. Topography may be very irregular, with large areas of smooth sea floor between bedrock highs (e.g., off Passmaquoddy Bay). Most exposed rock is in shallow water, and the percentage cover of surficial sediments increases with depth.



Glacial Seascapes

Accumulations of sediment up to many tens of metres thick, organized into ridges and mounds of varying shapes and dimensions. Glacial seascapes formed under advancing glacial ice (parallel to ice-flow direction), at the margins of retreating ice (transverse to ice margins), or were created by meltwater under ice. They are generally composed of glacial diamict (stiff bouldery sandy mud), or sand and gravel. Reworking by tidal currents and waves has formed immobile surface lags of gravel. Commonly overlain by a thin (~5 m) drape of glaciomarine mud that has been winnowed to form a gravel veneer.

G1

Moraines
Morphology: Arcuate ridges of glacial diamict up to 8 m high and 10 kilometres long, separated by smooth seafloor.
Texture and mobility: Generally has a thin drape of glaciomarine mud that has been winnowed to form an immobile sandy gravel lag with high backscatter strength.
Biota: Attached fauna including sponges, anemones, Asteriidae (sea stars), and hydroids.
Moraines were deposited transverse to ice-flow directions during the retreat of glaciers from the bay c. 14,000 years ago. They consist of glacial diamict (bouldery gravel in a matrix of sandy mud). Moraines near Grand Manan have a thick cover of glaciomarine mud and are mapped as that unit.

G2

Eskers
Morphology: Curvilinear ridges up to 8 m high and tens of kilometres long that commonly occur as sets (beaded eskers).
Texture and mobility: Bouldery gravel, gravel, sandy gravel, all with high backscatter strength. The gravels are immobile but sand patches may be mobilized by tidal currents and by waves in shallow water.
Biota: Attached fauna including sponges, hydrozoans, anemones, with scallops in sandy areas.
Eskers were deposited by meltwater streams during deglaciation and are found off the south coast, located at gaps in North Mountain (e.g., at Digby).

G3

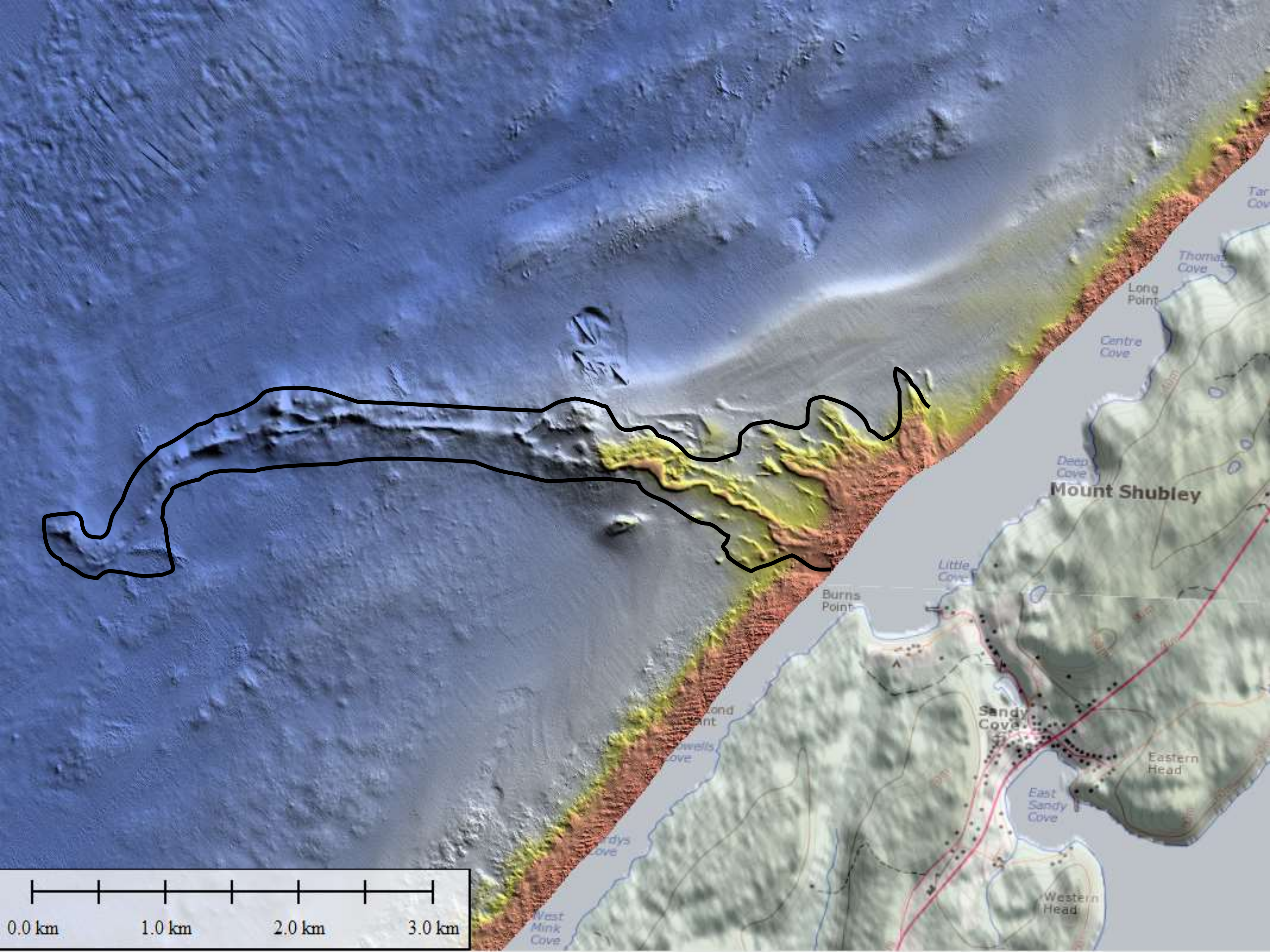
Drumlins, craig-and-tail ridges
Morphology: Rounded, smooth, elongate ridges up to tens of metres high and 7 km long. Crag-and-tail ridges comprise bedrock crags and glacial diamict tails.
Texture and mobility: Glacial diamict -(bouldery gravel in a matrix of sandy mud); immobile boulder gravel lags at the seafloor; high backscatter strength.
Biota: Attached fauna including sponges, anemones, Asteriidae (sea stars), and hydroids.
Eskers and crag-and-tail ridges were deposited under moving glaciers, parallel to the ice-flow. They may be many tens of metres thick and may be covered by a veneer of glaciomarine mud (which also has a surface lag veneer of sand or gravelly sand).

G4

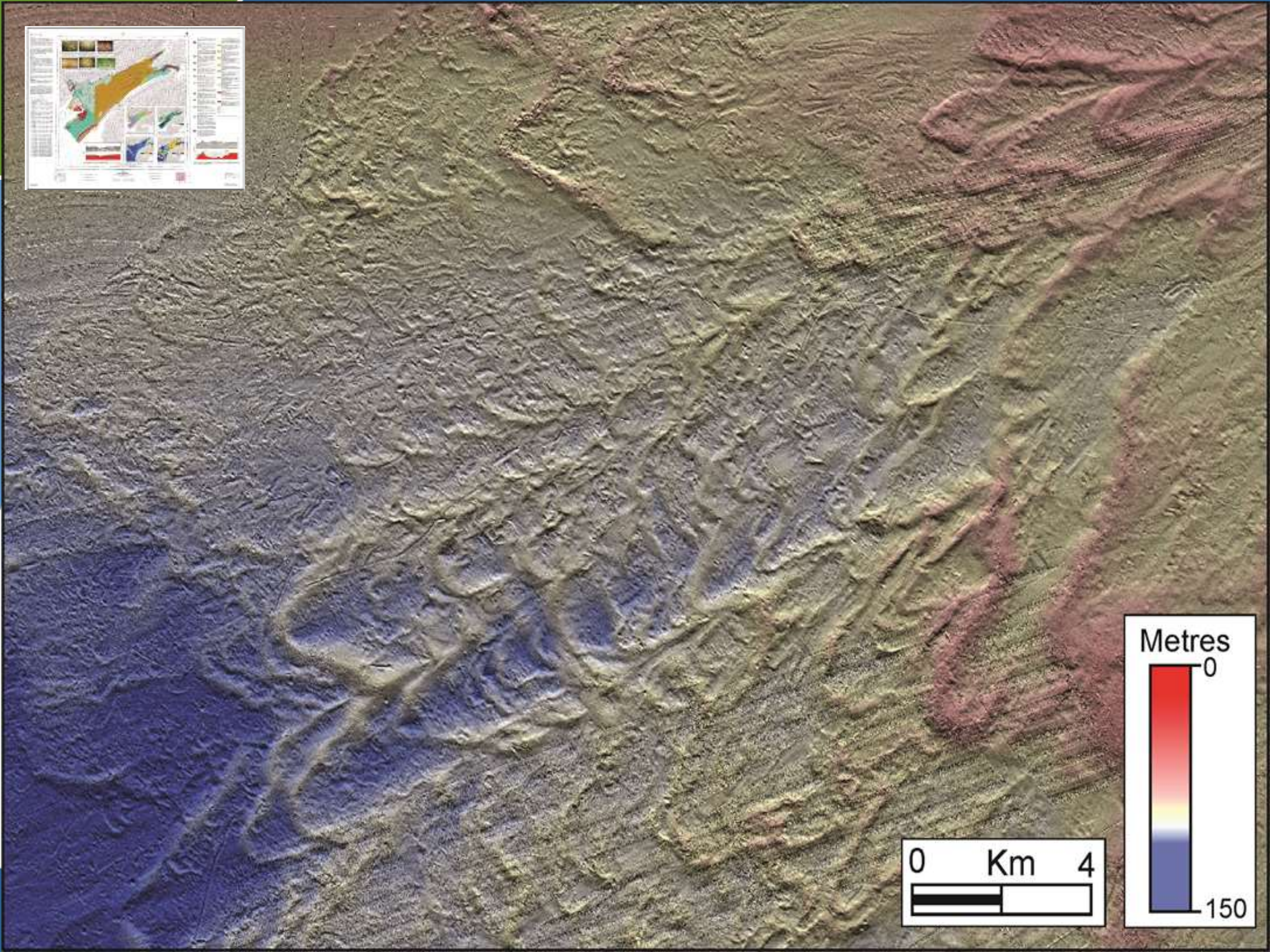
Mega scale glacial lineations (MSGL)
Morphology: Elongate ridges of glacial material up to tens of metres high and tens of kilometres long,
Texture and mobility: Composed of glacial diamict; surface lags of Immobile bouldery gravel; high backscatter strength.
Biota: Attached fauna including sponges, anemones, Asteriidae (sea stars), and hydroids.
MSGL were deposited under very fast-flowing glaciers (ice streams), parallel to ce-flow directions. They are commonly many tens of metres thick and may be draped by glaciomarine mud (which also has a surface lag veneer of sand or gravelly sand).

G5

Complex glaciated terrain
Morphology: Drumlins and MSGL, mainly oriented north-south, with numerous superimposed, east-west oriented small morainal ridges 1-2 m high (De Geer moraines)
Texture and mobility: The landforms consist of glacial diamict; immobile bouldery gravel at the sea floor; high backscatter strength..
Biota: Attached fauna including sponges, anemones, Asteriidae (sea stars), and hydroids.
Swarms of De Geer moraines created during retreat of the ice margins are superimposed on drumlins and MSGL formed during glacial advance.



Thomas Cove
Long Point
Centre Cove
Deep Cove
Mount Shubley
Little Cove
Burns Point
Sandy Cove
Eastern Head
East Sandy Cove
Western Head
West Mink Cove
0.0 km
1.0 km
2.0 km
3.0 km



Metres
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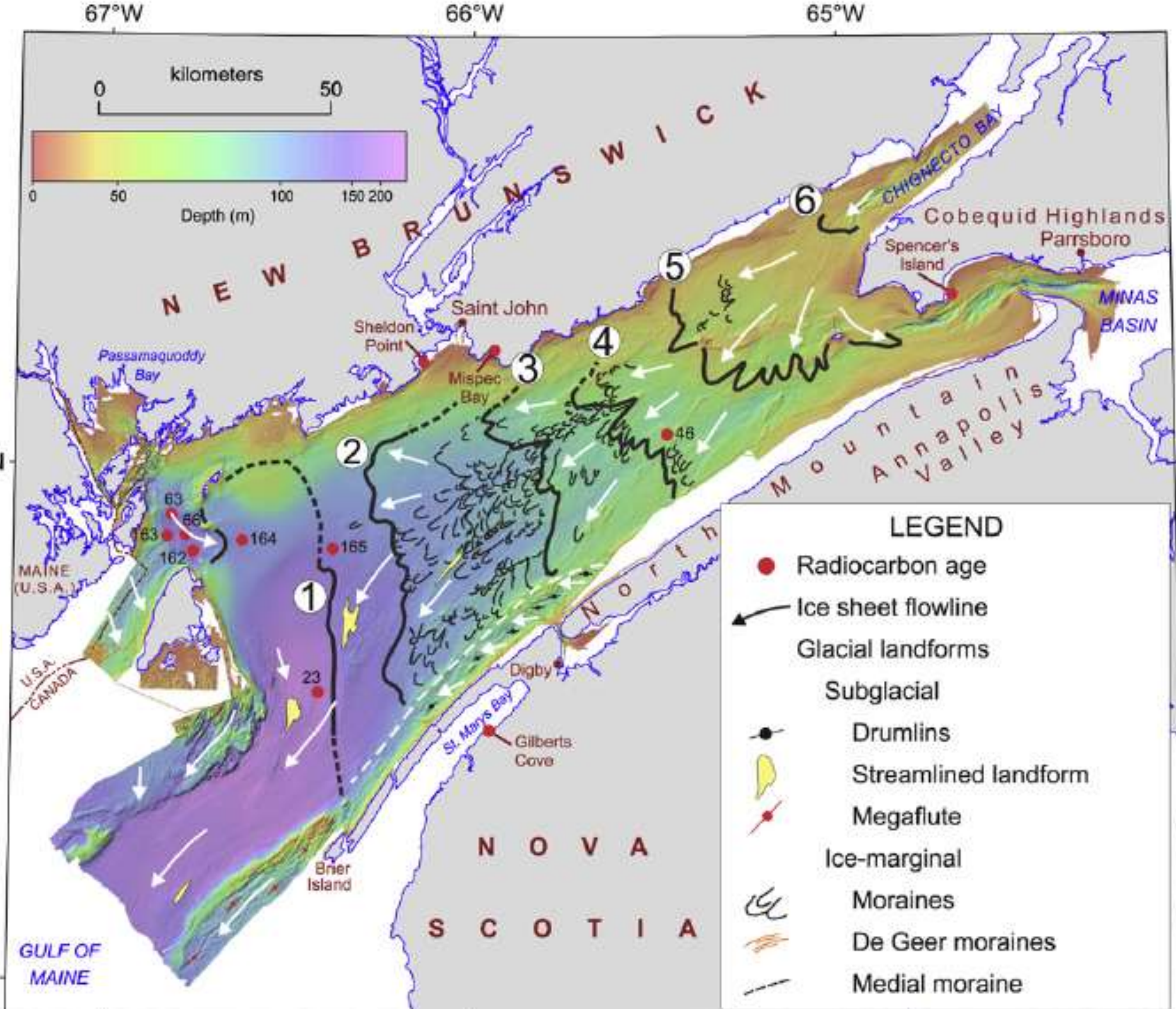

67°W
66°W
65°W
45°N
44°N
kilometers
0
50
0
50
100
150 200
Depth (m)
N E W B R U N S W I C K
CHIGNECTO BAY
Cobequid Highlands
Parrsboro
Spencer's Island
MINAS BASIN
Saint John
Sheldon Point
Mispec Bay
Passamaquoddy Bay
MAINE (U.S.A.)
U.S.A. CANADA
North Mountain
Annapolis Valley
Digby
St. Marys Bay
Gilberts Cove
Brier Island
N O V A
S C O T I A
GULF OF MAINE
1
2
3
4
5
6
63
66
163
162
164
165
23
46
LEGEND
Radiocarbon age
Ice sheet flowline
Glacial landforms
Subglacial
Drumlins
Streamlined landform
Megaflute
Ice-marginal
Moraines
De Geer moraines
Medial moraine

Glaciomarine seascapes

Acoustically stratified sheets of gravelly sandy mud derived from melting glaciers, draped over underlying terrains. Where exposed at seafloor these sediments have been winnowed by currents, with no subsequent deposition of postglacial mud or sand. Terrain may be imprinted by iceberg furrows and pits many kilometres long and up to 4 m deep.

Gm1

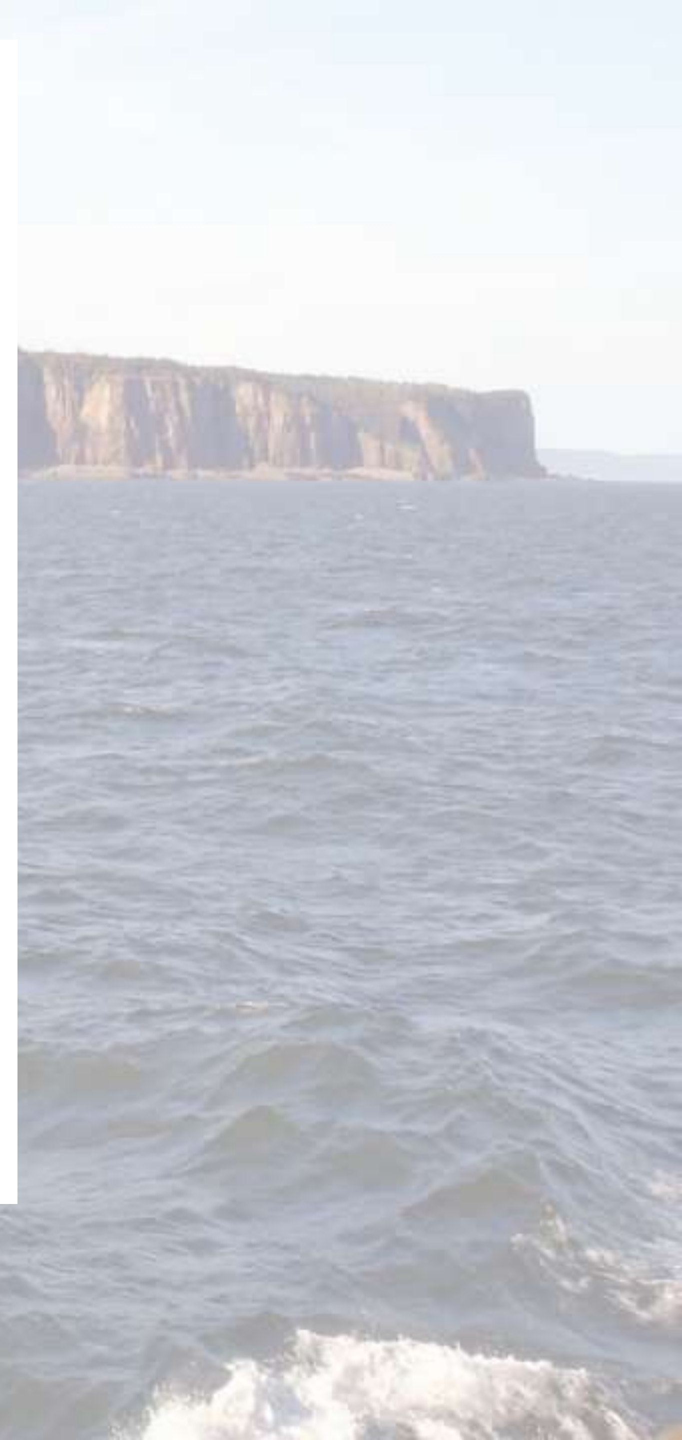
Mid Wisconsinan residual ridges
Morphology: Streamlined ridges up to 7 km long and 30 m above the surrounding seafloor; heavily furrowed by iceberg keels.
Texture and mobility: Acoustically stratified on seismic reflection records; surface lag of immobile muddy gravel; high backscatter strength.
Biota: Attached fauna.
Large residual ridges created when Late Wisconsinan ice advancing southwest out of the Bay of Fundy overran thick Mid-Wisconsinan glaciomarine deposits. One of the largest ridges is overlain by Late Wisconsinan morainal deposits and is not mapped under this unit. May be tens of metres thick in places.

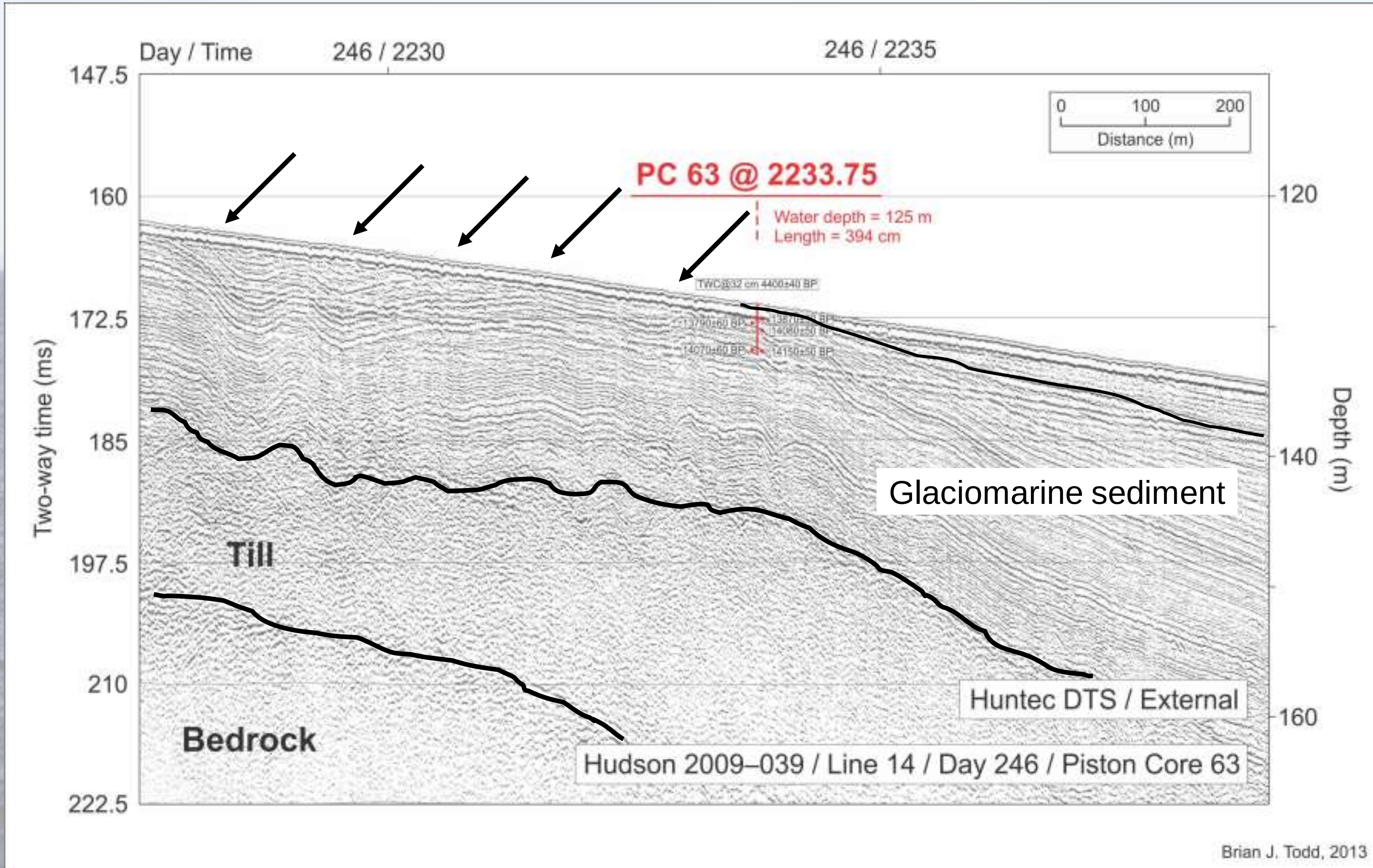
Gm2

Late Wisconsinan Glaciomarine sediments
Morphology: Generally smooth, low-relief seafloor imprinted by iceberg furrows and pits.
Texture and mobility: Acoustically stratified glaciomarine mud with dropstones, commonly 5 m thick except up to 20 m in the basin north of Grand Manan; an immobile veneer of muddy sandy gravel at the sea floor; high backscatter strength.
Biota: Bottom photographs show brittle stars (*Ophiopholis aculeata*), encrusting tunicates and sponges on gravel clasts, polychaete worms, anemones, brachiopods, sea urchins, and sea cucumbers.
The sea floor is a 14,000 year-old surface that was mapped by Fader et al. (1986) as the Emerald Silt Formation.

Gm3

Winnowed Late Wisconsinan Glaciomarine sediments
Morphology: Generally smooth, low-relief sea floor.
Texture and mobility: Acoustically stratified deposits of sandy mud with dropstones; veneer of boulder-cobble gravel at the sea floor; patches of sand in places; high backscatter strength; immobile except where it being eroded by scour troughs, as at Minas Passage, or where sand patches are activated by strong tidal currents.
Biota: Attached fauna.
This unit differs from the glaciomarine sediments of the outer bay in that iceberg furrows and pits have been effaced by strong tidal currents, giving a smooth sea floor.





Day / Time
246 / 2230
246 / 2235
147.5
160
172.5
185
197.5
210
222.5
Two-way time (ms)
120
140
160
Depth (m)
0
100
200
Distance (m)
PC 63 @ 2233.75
Water depth = 125 m
Length = 394 cm
TWC@32 cm 4400±40 BP
14070±60 BP
14150±50 BP
Glaciomarine sediment
Till
Bedrock
Huntec DTS / External
Hudson 2009–039 / Line 14 / Day 246 / Piston Core 63
Brian J. Todd, 2013

Muddy seascapes

Fine-grained sediment was deposited in postglacial time as a result of erosion of glacial sediments caused by changing sea levels and expanding tidal range. Equivalent to the La Have Clay formation of Fader et al. (1986).

M

Postglacial mud, sandy mud

Morphology: Generally a smooth, low-relief sea floor except where fields of pockmarks occur (mainly in Passmaquoddy Bay); also includes several areas of irregular seafloor morphology indicative of erosion.

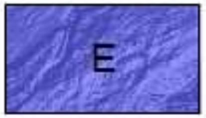
Texture and mobility: Mud and sandy mud with weak acoustic stratification except where the stratigraphy is masked by gas; up to 20 m-thick off Saint John; surface layer is active and compact substrate is immobile under present tidal conditions; surface may be heavily bioturbated; surface veneer of muddy sand in some areas; low backscatter strength;

Biota: Infauna of polychaete worms and amphipods; basket stars, sponges, anemones attached to scattered clasts, brittle stars, bivalves, and gastropods.

Radiocarbon dating shows that deposition of mud occurred primarily in the early postglacial period, before development of high tidal range, and that sedimentation rates have been low for the past 8000 years. Some areas have been winnowed, resulting in a 0.25 m veneer of muddy sand at the sea floor. Seabed photos in some stations show fresh seabed and current ripples. Sediment transport model using observed grain size predicts moderate to strong transport rates under peak tidal current conditions.

Scoured seascapes

Created by strong tidal flow, and erosion of glaciomarine and other sediments, giving surface lags. Occur on a range of scales, including the Minas Passage Scour Trough (170 m below sea level), the trough in Chignecto Bay (100 m); troughs in the central bay located near obstacles (e.g., Wolf Rock); troughs in narrow channels leading to coastal embayments (e.g., Digby Gut, Passmaquoddy Bay).



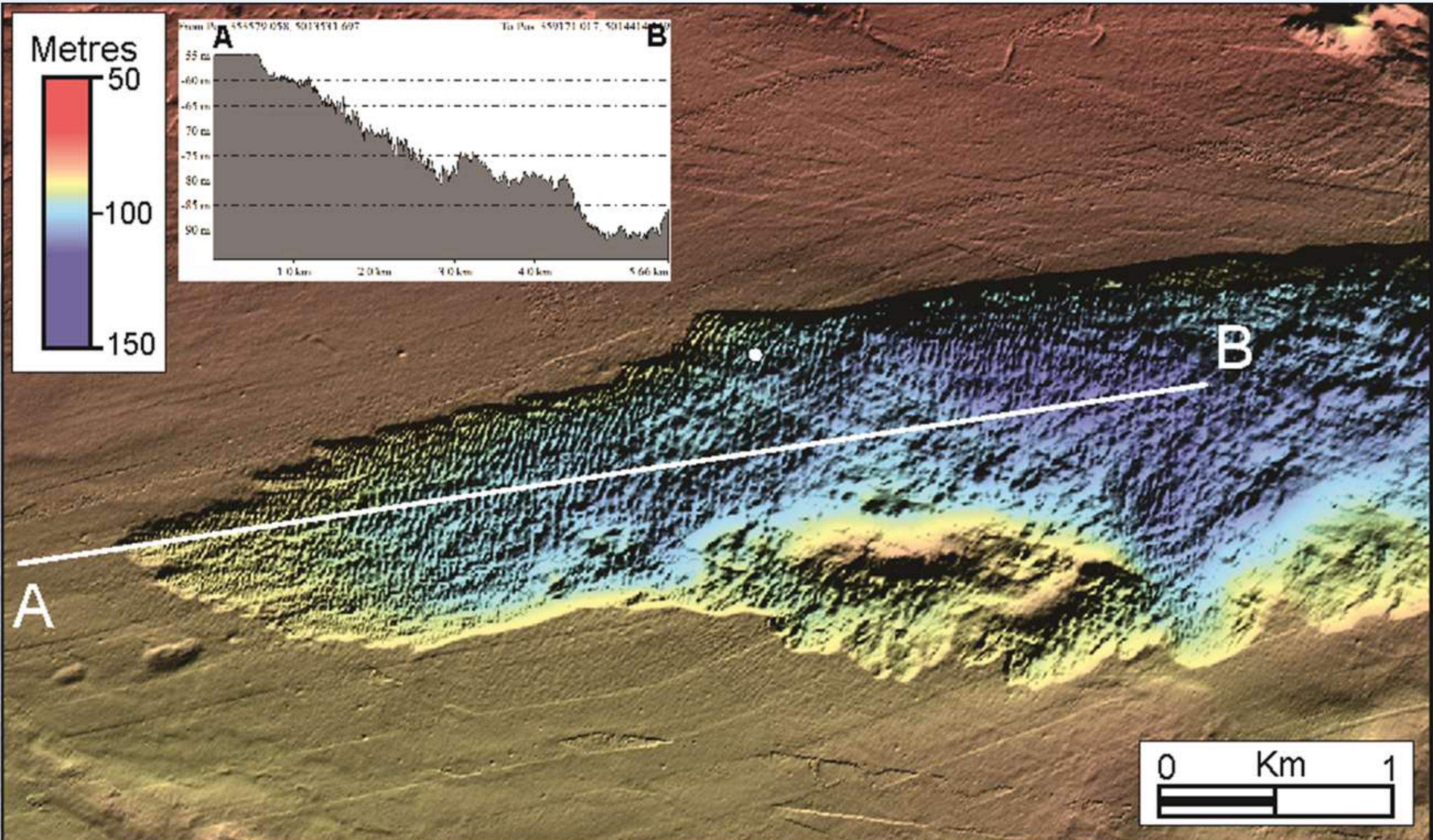
Tidal scour troughs

Morphology: Troughs incised into smooth sea floors; sharp boundaries; variable roughness.

Texture and mobility : Boulder-cobble gravel, sandy gravel, and bedrock occur at the sea floor; high backscatter. All sediments are mobile in these regions of strong tidal flow; glaciomarine sediments are experiencing active erosion.

Biota: Cobbles and boulders have encrusting sponges, anemones, bryozoans including *Flustra foilacea*, hydroids.

Areas within scour troughs where all unconsolidated sediment has been removed are classified as bedrock. Scour troughs may contain large bedforms which are not mapped separately, except for the gravel bank in Minas Passage


Metres
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Km
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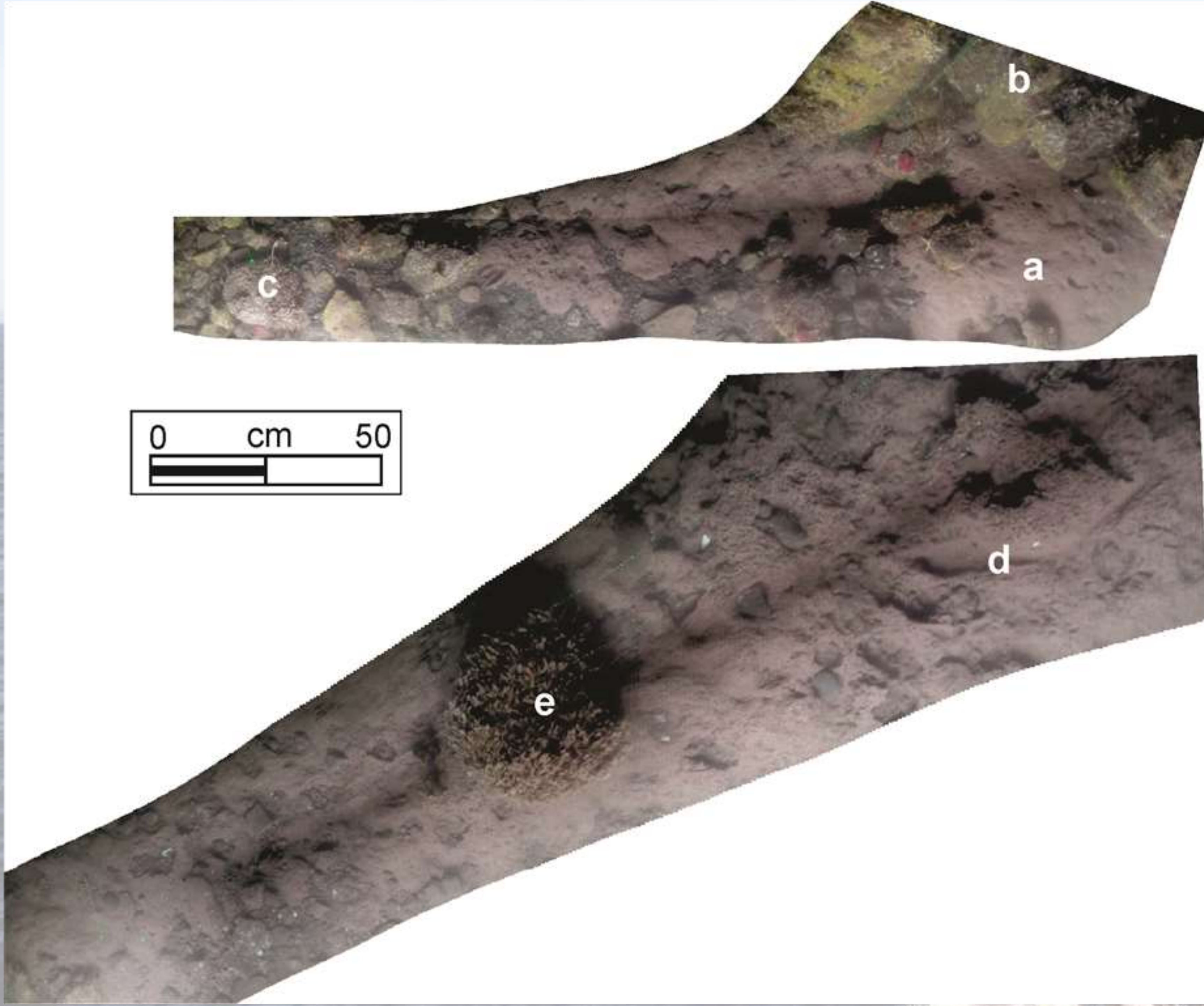

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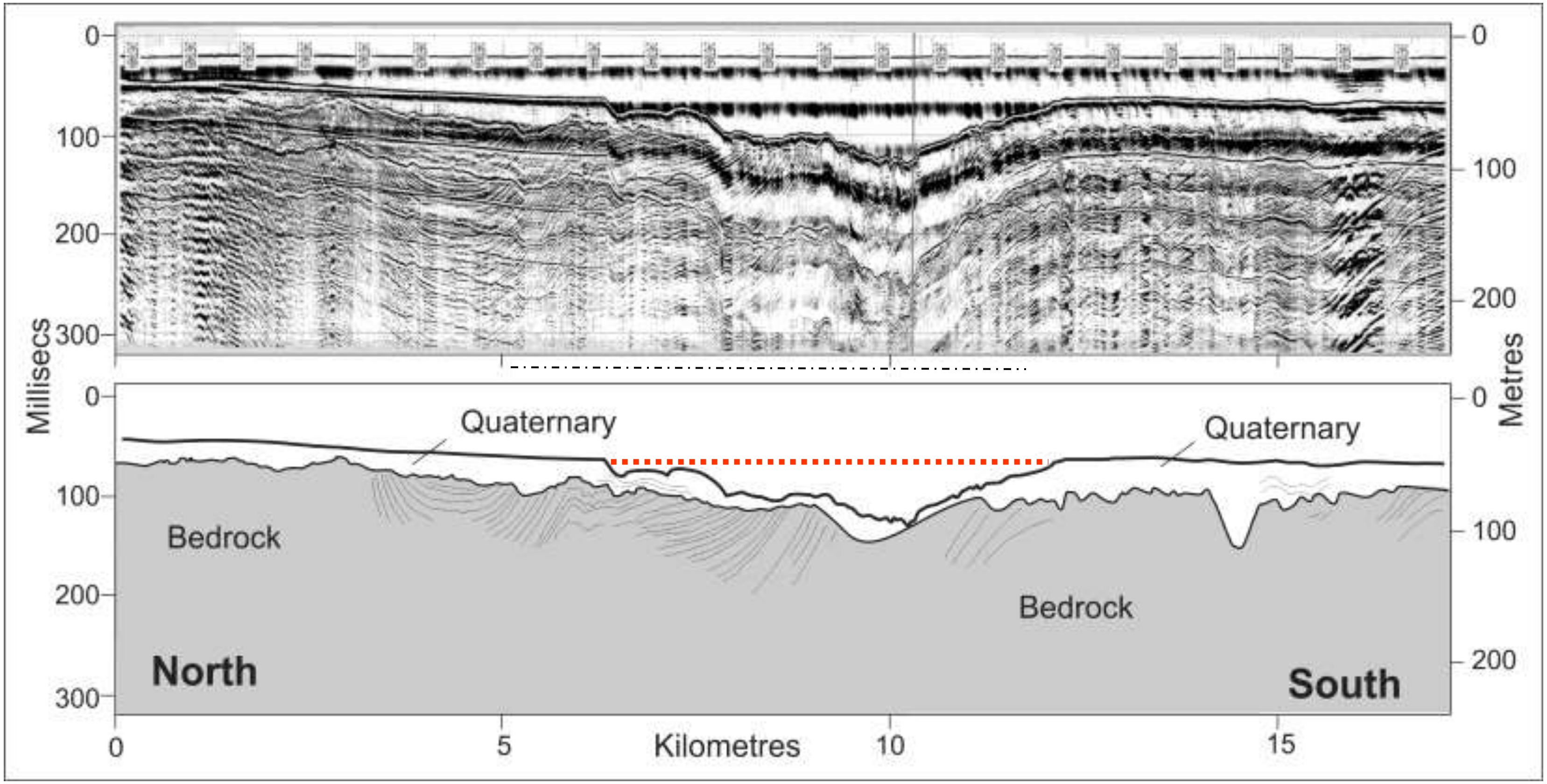

Millisecs
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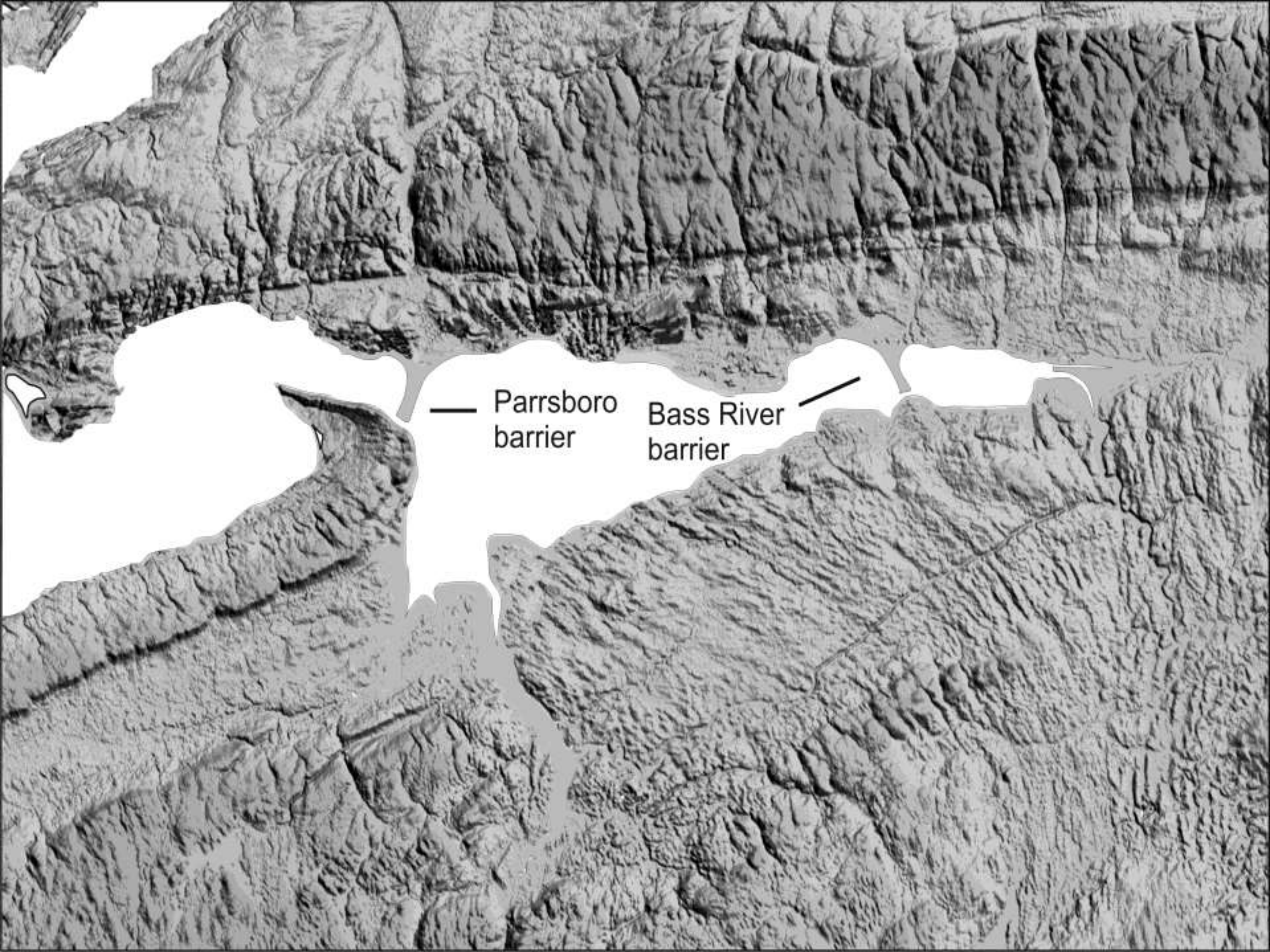

Parrsboro
barrier
Bass River
barrier

Sandy seascapes

In the postglacial period (after c. 14,000 radiocarbon years BP) glacial materials were reworked by waves and currents. About 9000 yrs BP, relative sea level dropped to ~-25 m, and large spits and spit platforms formed off the New Brunswick coast. With rising sea levels and expanding tidal amplitude, a range of sandy bedforms were created, oriented according to tidal current directions. Most mobile bedforms overlie a thin lag gravel developed on top of glaciomarine sediments. Because the sediment source is dominantly from the erosional channels in the upper bay and the sediment confinement by the overall net transport is to the top of the bay, most of the sandy seascapes occur in the upper Bay of Fundy.

S1

Dunes
Morphology: Flow-transverse ridges up to 10 m high and 4 km across, commonly with superimposed megaripples, organized into trains up to 20 km long.
Texture and mobility: Well-sorted medium sand with shell beds and gravel in troughs between bedforms; low backscatter strength; mobile under tidal currents.
Biota: Sand dollars, bivalves (e.g., *Clinocardium* sp.), gastropods, sand dollars, surf clams, starfish, scallops, anemones and sponges on shell beds, the bryozoan *Flustra foliacea* (hornwrack) on boulders and cobbles; some bottom images show presence of horse mussels *(Modiolus modiolus)*.
Derived from glacial materials reworked by strong tidal currents.

S2

Trapped dunes
Morphology: Solitary dunes can be up to 20 m high and 5 km long, commonly incised into otherwise flat sea floor; occurring as large fields or in long ribbons extending across the bay.
Texture and mobility: Well-sorted, mobile medium sand; may be mobile but movement can be oscillatory and hence low net migration; low backscatter strength.
Biota: Sand dollars, bivalves (e.g., *Clinocardium* sp.), gastropods, sand dollars, surf clams, starfish, scallops; anemones, and sponges on shell beds.
These dunes are generally considered as trapped because they have become incised into the underlying glaciomarine sediments.

S3

Banner Bank dune complexes
Morphology: Trains of dune ridges of varying size, up to 8 m high off Cape Split; organized into twin banks either side of headlands; a set also occurs either side of a rocky shoal (exposed at low tide) in the middle of the bay.
Texture and mobility: Well-sorted shelly medium to coarse sand, highly mobile; the banks themselves are fixed in position; low backscatter strength.
Biota: Sand dollars, bivalves (e.g., *Clinocardium sp.*), gastropods, sand dollars, surf clams, starfish, scallops; anemones and sponges on shell beds.
The banner banks form in tidal eddies either side of headlands. Sand probably cycles through the banks as individual bedforms migrate (e.g., the Scots Bay dune field off Cape Split.)

S4

Trapped gravel dune field
Morphology: Ridges of bouldery gravel up to 5 m high in a bank that is 20 m thick and 3.5 km long.
Texture and mobility: Well rounded boulder cobble gravel; high backscatter strength; boulders and cobbles are mobile under tidal currents.
Biota: No attached fauna; a few small starfish (*Asteriidae* sp.) noted on images.
This may considered one half of the banner bank complex at Cape Split, the other half being the Scots Bay dune field. This dune field is composed of coarse gravel, and has become trapped in the Minas Passage Scour Trough. Strong currents prevent growth of attached organisms.

S5

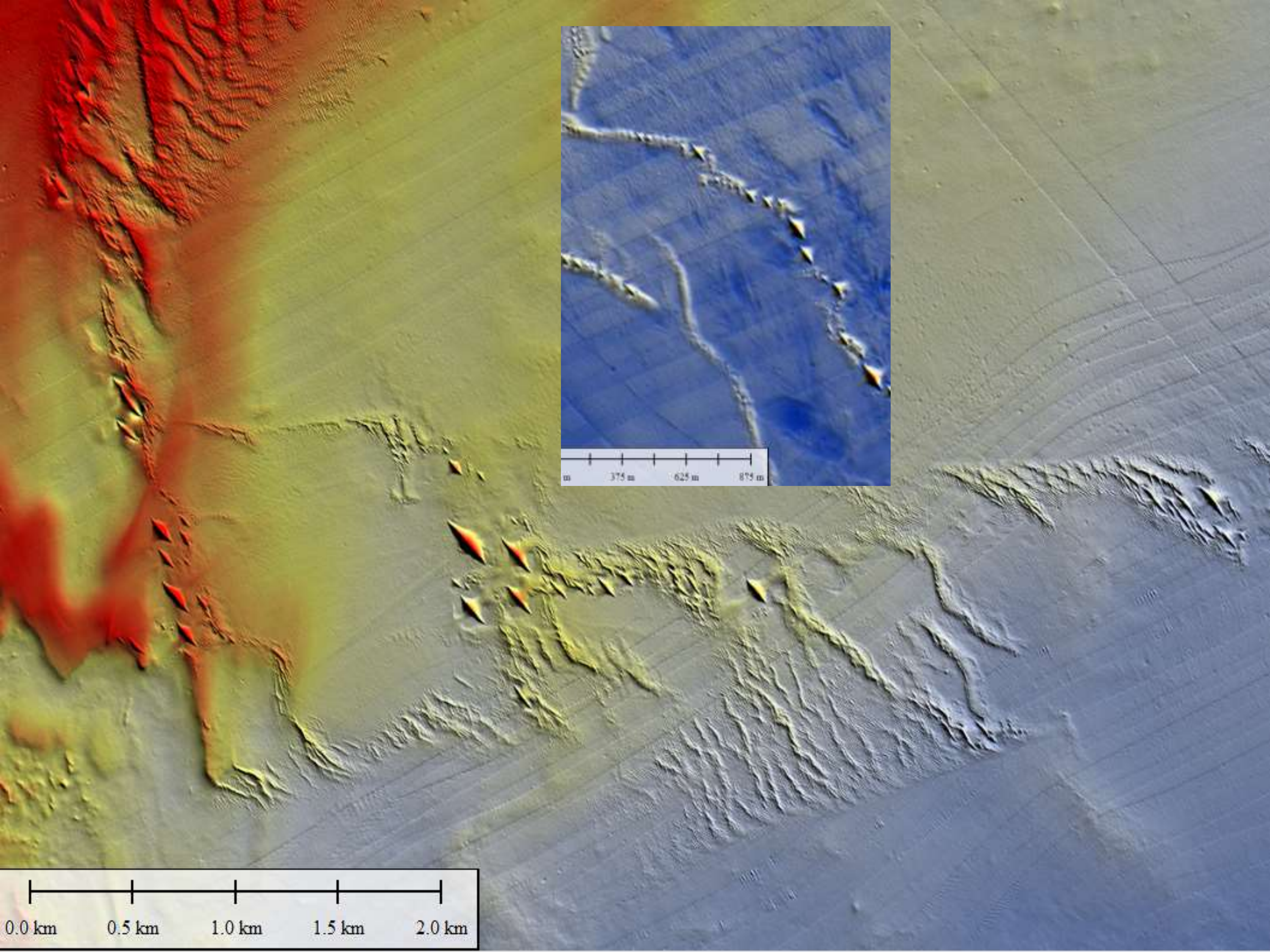
Sand
Morphology: Low-relief, gently banked deposits of sand up to 30 m thick; seaward-sloping prisms offshore from beaches; flood-tidal delta deposits; commonly without large bedforms.
Texture and mobility: Sand and muddy sand with low backscatter strength; mobile under tidal currents, and also wave action in shallow water.
Biota: Sand dollars, bivalves (e.g., *Clinocardium* sp.), gastropods, sand dollars, surf clams, starfish, scallops; anemones and sponges on shell beds.
Sand bodies that have accumulated in a series of large drifts (e.g., west of Cape Chignecto), or in other settings.

S6

Shadow banks
Morphology: Low-relief, gently banked deposits of sand up to 10 m thick, decorated by sand ribbons and barchan dunes up to 8 m high and 2 km across.
Texture and mobility: Well sorted medium sand with low backscatter strength; scattered cobbles and boulders, gravelly material in sand ribbon troughs; highly mobile under strong uni-directional tidal currents.
Biota: Sand dollars, bivalves (e.g., *Clinocardium* sp.), horse mussels, gastropods, sand dollars, surf clams, starfish, scallops; encrusting sponges and bryozoans on boulders and cobbles.
Sand bodies have accumulated adjacent to banner banks in areas of the seabed subject to uni-directional flow at all tidal stages.

S7

Submerged spit and spit platform
Morphology: Ridge with recurves, reaching 20 m above surrounding seabed.
Texture and mobility: Gravel with sand patches; mainly high backscatter strength; clinoform structure on acoustic records; gravel and sand are mobile under tidal currents.
Biota: Some attached fauna.
Sand and gravel spits and spit platforms accumulated with northeast-directed longshore drift when sea level was ~25 m lower than today in the early Holocene.


375 m
625 m
875 m
0.0 km
0.5 km
1.0 km
1.5 km
2.0 km

Biological seascapes

Areas of sea floor in which a particular biological community plays an especially strong role in determining morphology and texture.

H

Horse Mussel reefs
Morphology: Linear ridges up to 3 m high and 16 kilometres long; very straight.
Texture and mobility: Sand with accumulations of dead horse mussels; up to 4 m thick and located on top of glacial sediments; high backscatter strength.
Biota: Horse mussels (*Modiolus modiolus)* in association with the bryozoan *Flustra foliacea*; *Polymastia* sp. sponge gardens.
These mussel bed bioherms resemble bedforms, as they are primarily composed of sand. Formed by accumulation of horse mussel shells that interact with tidal currents, they are aligned along principal current directions.

Anthropogenic seascapes

Much of the seafloor has been impacted by fishing trawls, although strong currents soon efface the effects. The major anthropogenic effect is the marine disposal area off Saint John..

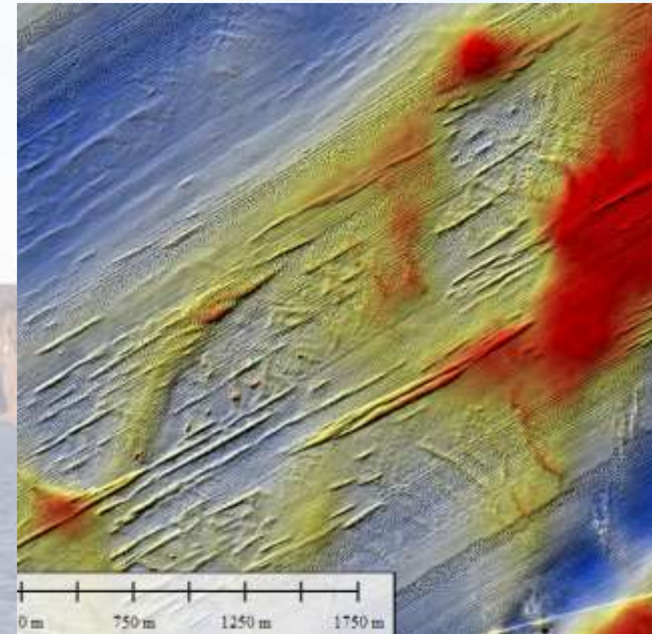
A

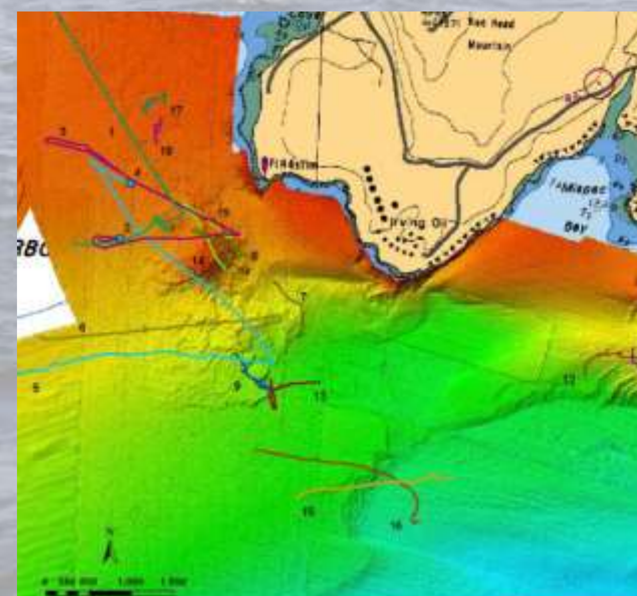
Marine disposal site
Morphology: Mounded deposits up to 10 metres thick off Saint John; slump apron extending to the south.
Texture and mobility: Mixture of mud, sand, gravel; high backscatter; material at the disposal site undergoes significant reworking by tidal currents and waves: 84% of the dumped material, mainly fine-grained sediments, is transported away from the disposal site and only 16%, mainly coarser material, remains.
Biota: Unknown.
Formed by repeated disposal of dredge spoil from Saint John harbour and described in a series of GSC reports commissioned by Environment Canada.

Pockmarked terrain

Gas masking on acoustic records

Irregular ridged terrain in mud areas






Maps available at GEOSCAN
The Future……

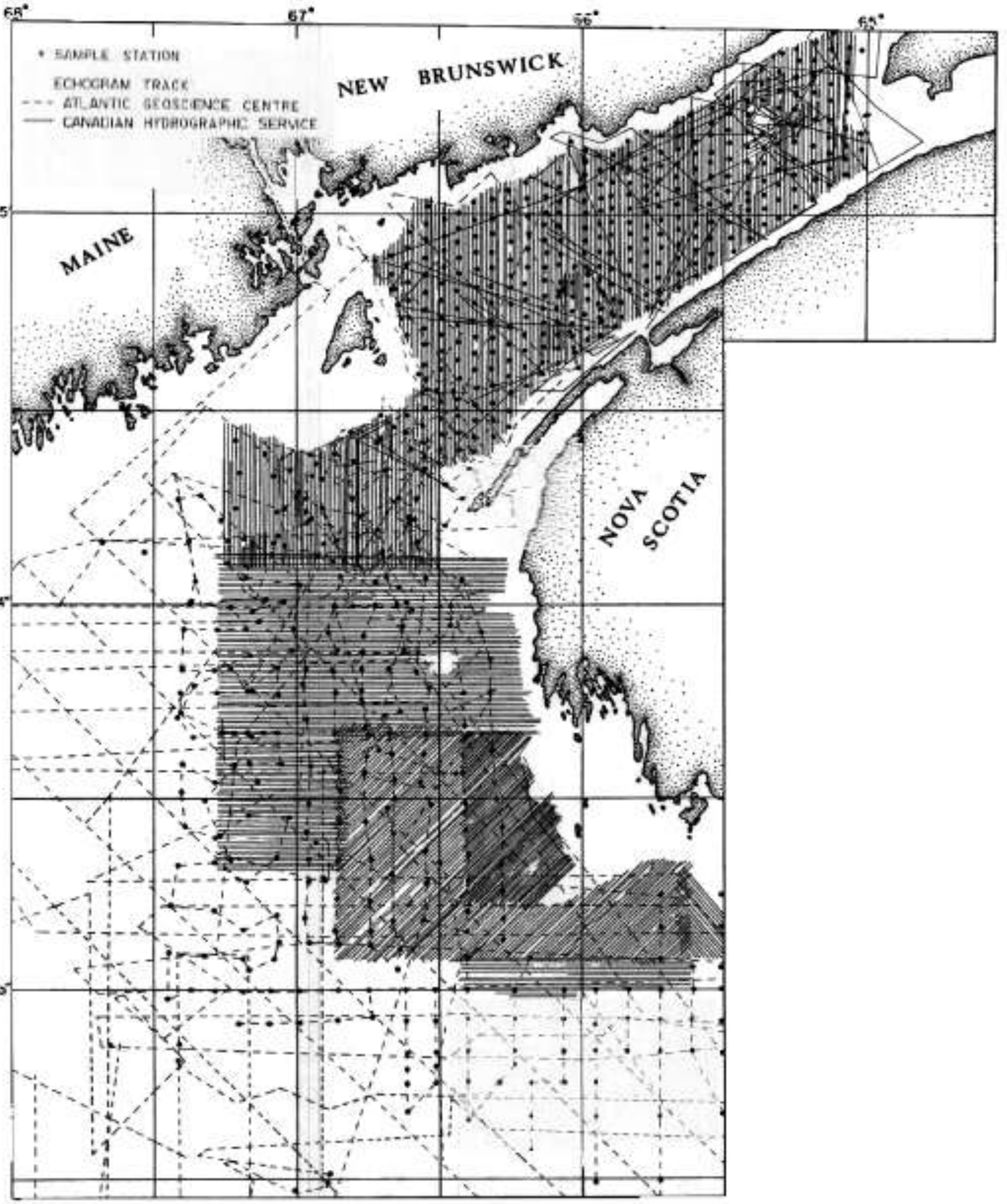


Fig. 1. Acoustic and bottom-sampling control across the eastern Gulf of Maine and Bay of Fundy map-area.

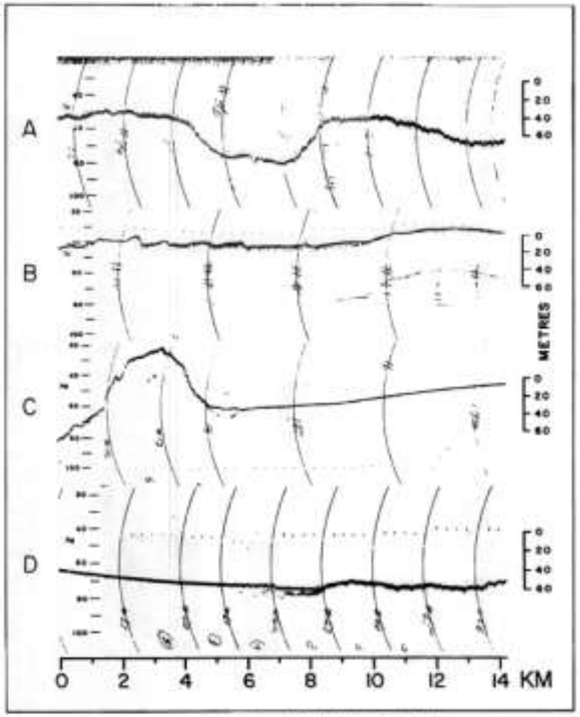
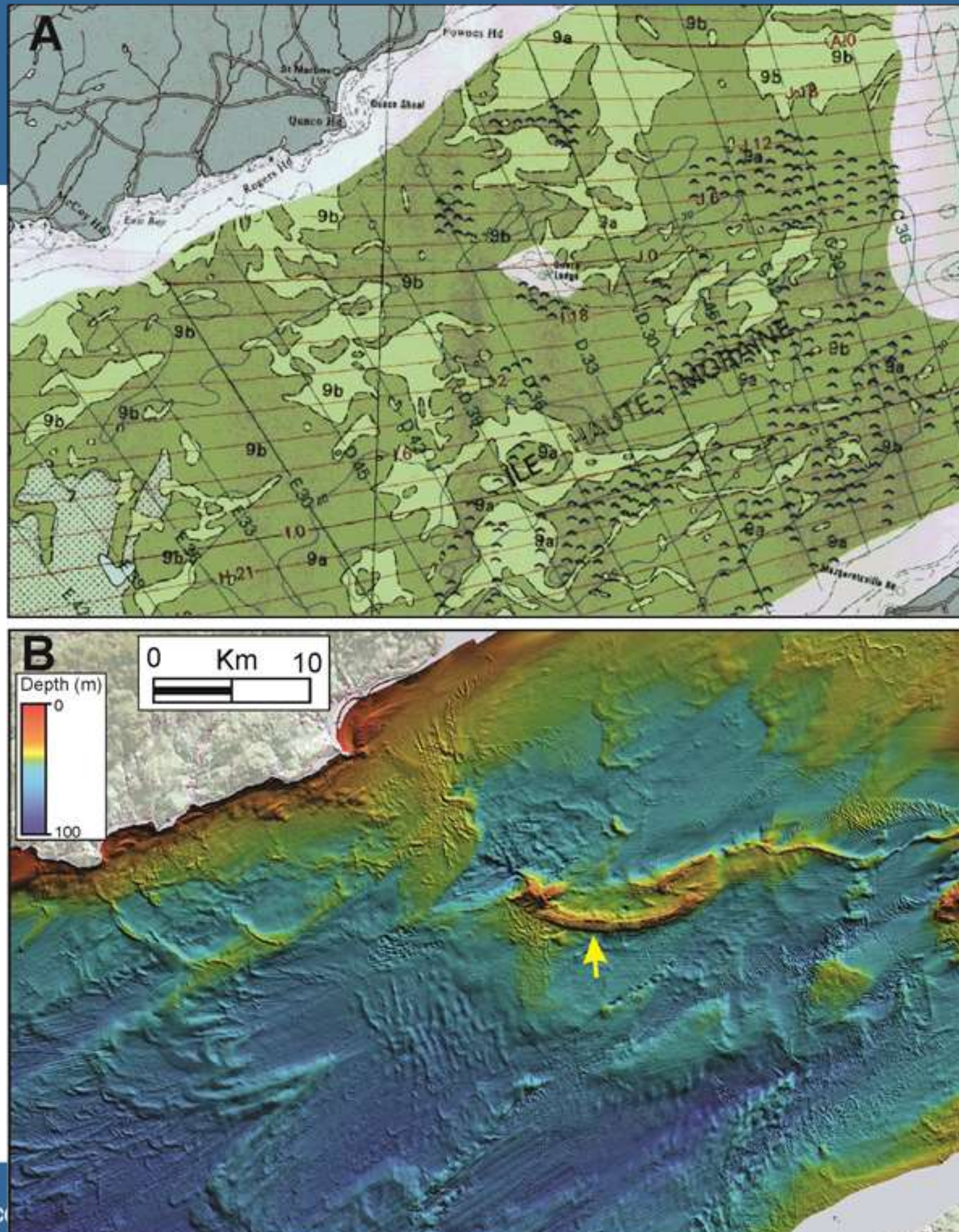


Fig. 7. Selected echogram profiles from the Gulf of Maine–Bay of Fundy map-area.


A
9a
9b
ILE HAUTE MORAINE
B
Depth (m)
0
100
0 Km 10