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Seascapes of St. Anns Bank

and adjoining area off Cape Breton, Nova Scotia

Quaternary Geology

Edward L. (Ned) King, Geological Survey of Canada, eking@nrcan.gc.ca

Natural Resources Canada, GSC-Atlantic, 1 Challenger Dr. P.O. Box 1006, Dartmouth, NS, B2Y 4A2

Canada

INTRODUCTION

St. Anns Bank and the adjoining area of the Laurentian Channel present a diverse habitat on the Scotian Shelf due largely to a combination of seabed terrains and local ocean circulation pattern. Seascapes include expanses with rugged bedrock outcrops and broad glacially carved channels and basins superimposed with a more subdued relief of glacial till, locally thick and with diverse attributes. Different bedrock types exert a strong control on the seabed morphology and texture and superimposed on this are glacial erosion and deposition features.

Glacial flow patterns can be inferred from fluting, smoothed drumlinized hills, patterned morainic ridges of various scales and paleo-iceberg scour marks. Despite this record, reconstruction of glacial ice directions and retreat pattern is tentative. Primary questions remain unconfirmed such as the relation to the Laurentian Channel ice stream, existence of an offshore ice cap and onshore-directed late glacial movement.

Several sub-basins are largely mud-filled, generally ringed with more sandy and gravelly deposits where the older glacial deposits protrude from below the sand and mud cover. The effects of a post-glacial lower sea-level are preserved in now-drowned coastal deposits. This developed broad gravelly plains, bedrock washed clean of most sediments and muddy basins which were the sinks for this washing process. The muds are locally punctuated by conical depressions, pockmarks, eroded with the escape from below of natural gas from the bedrock and sediments.

This diverse seascape is swept by the nutrient-rich Nova Scotia Coastal Current producing a diverse pelagic and benthic life. These environmental parameters facilitate evaluation of the area for habitat protection with a new Marine Protected Area.

DATASET AND MAPPING PROCEDURES

Seabed morphology and sonar backscatter strength derived from multibeam bathymetric data and a digital elevation model are supplemented with sediment samples, seabed photography and limited seismic reflection profiling as the basic dataset for seabed mapping. This map protrays the surficial geology of the seabed in several classes aiming to elucidate the depositional processes and environnments through the last glaciation and post-glacial time. A companion poster and map presents the bedrock distribution and a more textural classification of the seabed.

CONCLUSIONS

St. Anns Bank has a diversity of seascapes strongly controlled by bedrock morphology but with glacial deposits thinning from east to west and a record of lower paleo-sea-level.

Glacial imprint is dominated by thick tills in the east but thin cover in the central and west with fluting, moraines and drumlinized forms at different orientations. The flow patterns are tentatively correlated to the Late Wisconsinan maximum Escuminac Phase and the later Chignecto Phases of Stea et al. (1998) but there is no clear evidence for a strong northerly component matching their intervening Scotian Phase.

Deglaciation and subsequent sea-level low-stand at somewhere between 50 and 70m below present contributed to muddy infill in several sub-basins under a variable influence of wave and current processes. This produced a variety of seabed textural facies dominated by gravel and cobbles in shallow water transitioning to sandier and then muddier in the basins.

A late phase of iceberg scouring attests to existence of the proto-Nova Scotia Current while there were still marine-ending ice sheets supplying icebergs to the Gulf of St. Lawrence.

GLACIAL FEATURES AND THEIR SIGNIFICANCE

Glacially-related features shown in the maps and 3-D views include fluting, possible sub-glacial fluvial tunnel valleys, till sheets, large moraines and irregular till mounds, drumlins and drumlinized moraines, and subtle ribbed moraine fields including some with drumlinization. A variety of ice flow directional changes have been proposed from onshore observations, including an offshore ice cap or divide and landward flow (cf. Grant, 1989 and Stea et al. 1998; Scotian Phase, Shaw et al. 2006, 14 ka phase). New morphological data in this area had the potential to address these claims but lack of a clear superposition history and variety of inferred flow directions still precludes a clear glacial-deglacial pattern reconstruction. This arises partly because many of the glacial forms are not well developed morphologically and introduce uncertainty in their classification.

A SW-directed phase of Laurentide ice is represented by the fluting across Carboniferous strata in the NW and basement rocks in the SE (Fig. 1), and by the larger drumlins (Fig. 2 and map below). It is presumed to represent an early flow phase because much smaller scale landforms with evidence of different directions (Fig. 3) would not have survived such rigorous bedrock erosion. Note that these flutes parallel ice movement inferred by Shaw et al. (2006) but they suggested northeastward flow, that is *opposite* to that suggested here. The larger of the morainal deposits located in the southeast and south-central part of the map may be associated with the SW or SSW flow but the morphology of other large till-covered hills here confirm little about glacial flow patterns. This flow is compatible with the Escuminac Phase of Stea et al. (1998).

A phase of eastward sub-glacial flow which cut deep tunnel valleys in the Mesozoic/Cenozoic sequence towards the Laurentian Channel in the Misaine Bank area suggests an ice cap or divide in the mid-shelf area south of the map area. However, similar relations are not recognized here. Numerous re-entrants along the north edge of the main bedrock scarp include one (the westernmost) which has an anastomizing fluvial pattern. They are too deep, at greater than 140 m, to have formed fluvially during the glacial low-stand and are thought to have formed as tunnel valleys, nucleating on the bedrock "dam" the scarp created and driving a divergent water flow southwards (Fig. 4). In this light, the other re-entrants might also be sub-glacial fluvially cut but all are S or SW-directed.

The SSW flow pattern probably evolved toward the SE according to clusters of mid-size to small moraines in the central, south-east and south central map area. This would suggest a more Cape Breton-situated ice divide, compatible with the Chignecto Phase of Stea et al. (1998). Some of the moraine complex traces conform to large bedrock scarps, suggesting its control on the ice margin pattern under a deglaciation phase when a thinner ice profile was more influenced by topography at the sole.

The smallest ribbed moraine fields are assumed to represent the latest ice flow pattern but even these show conflicting orientations. Many have drumlinized tails and miniature drumlin fields cover much of the smooth bedrock surface (Fig. 4). Nevertheless, a dominance of late flow features toward the SW is indicated. Perhaps local late fluctuations and flow direction changes are superimposed.

In the Laurentian Channel, the ice-scoured till blanket comprises multiple tills related to successive ice stream depositional phases directed along the channel axis (King 2012). Latest-stage flow and stillstand phases farther up-ice, include a very late Cape Breton highland-originating flows entering easterly into the Laurentian Channel, as recognized by Josenhans and Lehman (1999).

In summary, the early SW flow direction corresponds to general patterns previously inferred (c.f. Stea et al. 1998) with minor deviation, likely the result of the Laurentian Channel derived ice-stream "spilling" over its flank. Alternatively they resulted from NE-flowing ice north of an offshore ice divide but this is difficult to reconcile with the preservation of small-scale glacial landforms. Rather, a scenario is favoured whereby the active Laurentian Channel ice stream fed a SW flow which evolved with ice sheet thinning and a shift of the ice divide toward Cape Breton, into SE-directed flow and retreat to the mainland.

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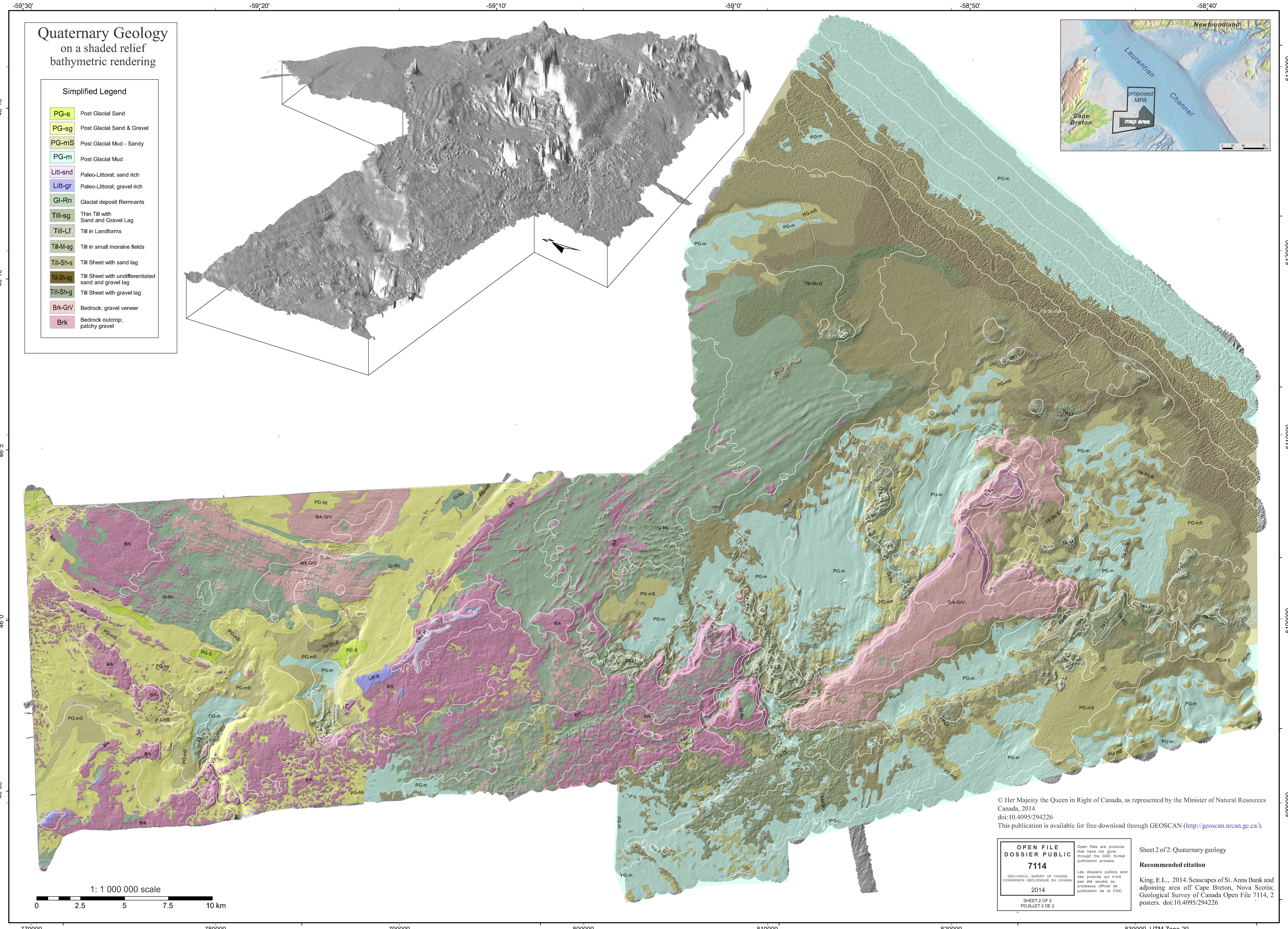

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SEABED QUATERNARY GEOLOGY LEGEND

Post-Glacial Deposits from Lower Sea-Level

Gravel ridges and sand sheets interpreted as remnants of coastal processes from a post-glacial low-stand below 50 m and subsequent transgression and drowning of the bank. Veneers of sand and gravel reworked from glacial deposits while mud component was transported to basins.

- PG-s — ***Post Glacial Sand :*** *Sand with little or no gravel; local bedforms, some with gravel in troughs; Low to mid acoustic backscatter strength; transitional boundary with adjacent map units; probably lag over glacimarine and/or post-glacial mud*
- PG-sg — ***Post Glacial Sand and Gravel:*** *patches or mix of Sand and Gravel; relatively smooth seabed with mid to high acoustic backscatter; locally with subdued relief of underlying bedrock; gravel patches locally large on iceberg scour berms in till or small sediment-draped glacial moraines or drumlins; locally modifed into bedform fields under current influence*
- PG-mS — ***Post Glacial Mud - Sandy:*** *Sandy Mud with little or no gravel; boundary with mud or sandy units is transitional; backscatter higher than adjacent mud; eroded into current-parallel troughs or ribbons in the westernmost basin*
- PG-m — ***Post Glacial Mud:*** *Soft Mud; smooth surface except locally where scoured by paleo-icebergs; occurs in basinal areas >150 m water depth; locally current sculpted; low acoustic backscatter*
- Litt-snd — ***Paleo-Littoral; sand rich:*** *sandy washover sheets or back-basin fill. Post depositional current reworking is likely.*
- Litt-gr — ***Paleo-Littoral; gravel rich:*** *Gravel ridge or sheet near paleo low-stand of sea level; beach ridges up to 2 m high and wash-over deposits*

Glacial Deposit Remnants

Till and possibly pro-glacimarine sediments in thin sheets. Smoother seabed than till sheets and landforms. Generally over lower-lying areas of bedrock; thickness of at least one and locally up to several metres as inferred from morphology. Upper surface modified/washed mainly during lower-sea-level.

- Gl-Rn — ***Glacial deposit Remnants:*** *small drumlin fields, irregular moraines and moraine clusters*
- Till-sg — ***Thin Till with Sand and Gravel Lag:*** *similar to Till-Sh-SG but thin (one to a few metres) and more modified by low-stand processes; similar to PG-SG*

Till in Glacial Landforms

Till sculpted into drumlins, moraines and hummocky terrain. Most moraines and drumlins are not well formed or continuous as to readily infer ice movement direction; this is complicated by a superpostion and modification of some landforms with an evolution of ice directions.

- Till-Lf — ***Till in Landforms:*** *small drumlin fields, irregular moraines and moraine clusters*
- Till-M-sg — ***Till in small moraine fields:*** *mid to very small ribbed moraine in irregular patterns; generally one to two metre height and 10s to 100s m length; drumlinoid modification of some examples.*

Till Sheet

Ground moraine in a blanket of several to tens of metres thickness, generally heavily iceberg scoured surface. Two to three successive sheets on the flank of the Laurentian Channel, deposited mostly under the last glacial maximum and general deglaciation. Lag is low-stand-derived or from current washing and as such equivalent to PG-sg but only centimetres or decimetres thick such that the sub-glacial deposit is emphasized in the map.

- Till-Sh-s — ***Till Sheet with sand lag:*** *patchy sand and gravel on till surface; Larger and more continuous sand patches in the troughs of relict iceberg scours.*
- Till-Sh-sg — ***Till Sheet with undifferentiated sand and gravel lag:*** *locally abundant cobbles and boulders on iceberg scour berms and local highs and sand patches common in scour troughs and lows*
- Till-Sh-g — ***Till Sheet with gravel lag:*** *locally abundant cobbles and boulders and some sand inferred*

Bedrock outcrop and Gravel cover on Bedrock

Bedrock, eroded during glaciation, was left bare or locally washed of all its sediment cover during sea-level low-stand and rise. Commonly the residual was deposited locally in the joints, swales and mini-basins adjacent topographic highs. This produced a gravel lag across bedrock and any erosion-protected glacial deposits.

- Brk-GrV — ***Bedrock: gravel veneer:*** *Gravel up to boulder size over bedrock; locally includes small glacial deposits and sand on bedrock; small outcrops common*
- Brk — ***Bedrock outcrop; patchy gravel:*** *bare rock or scattered gravel up to boulder size; tabular morphology on volcanics; local sand patches*

ACKNOWLEDGMENTS

Collection of the multibeam sonar data was made possible by the contributions of the captain and crew of the hydrographic survey ship CCGS Matthew and launches Plover and Pipit. M. Lamplugh (Hydrographer-in-Charge) and staff from the Canadian Hydrographic Service-Atlantic (CHS-Atl) carried out the data collection and processing of the multibeam data. C. Brown, DFO Ecosystem Research Division, oversaw the backscatter data processing and provided rationale for choosing the ten seabed still and video photography stations, obtained from the CCGS Matthew with instrument operation by P. Pledge, GSC-A. Prior to any multibeam sonar data collection the CCGS Hudson obtained two video stations with instrument assistance from A. Robertson, GSC-A. J. Ford, DFO, kindly organized and supplied the multibeam and photography data.

Geologic data interpretation and subsequent mapping was carried out under the auspices of the Geological Survey of Canada- Atlantic (GSC-A). This interpretation contributes to Fisheries and Oceans Canada (DFO) initiatives to establish Marine Protected Areas by the Oceans and Coastal Management Division.

The geologic maps are based on preliminary processing of bathymetry and backscatter strength images. Backscatter data from the launch survey was not available at time of mapping so textural mapping in that area was based mostly on extrapolations of seabed morphology/backscatter relations. Future bathymetric surveying will cover more of the Area Of Interest (AOI). Legacy sample and limited seismic data, collected by GSC-A from the 1970s and 80s contributed to geologic understanding. G. Cameron, GSC-A, first suggested the dyke interpretation and D. Piper provided background and significance of the volcanics. The author benefitted from seabed geology mapping experience at the Norwegian Geological Survey in support of the MAREANO habitat mapping of the continental shelf.

GLACIAL FEATURES

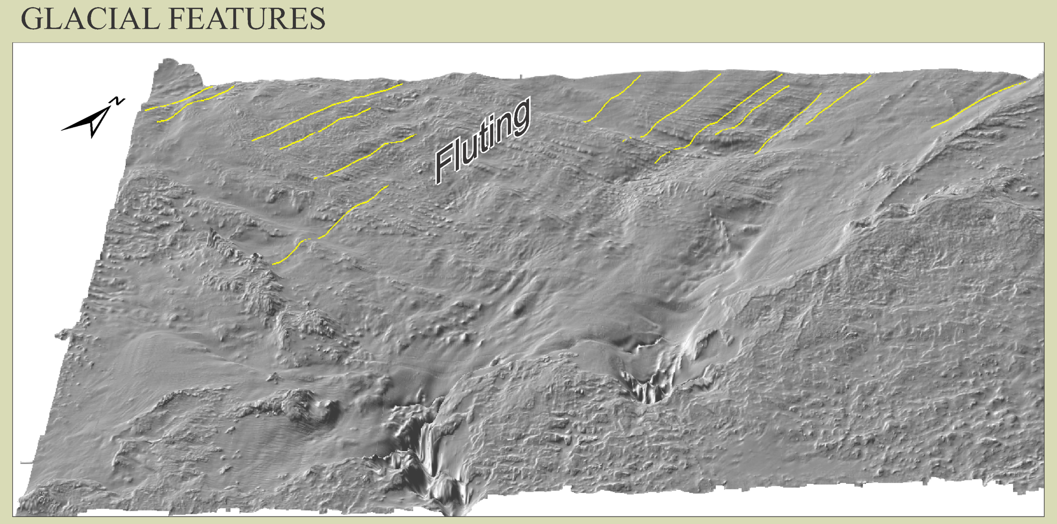

Figure 1. Seascape of NNE-looking Viewplane A showing glacial mega-fluting in a SSE-NNW orientation. While there are no strong indicators of flow direction, it is thought to represent the main Laurentide ice flow during the last glacial maximum.

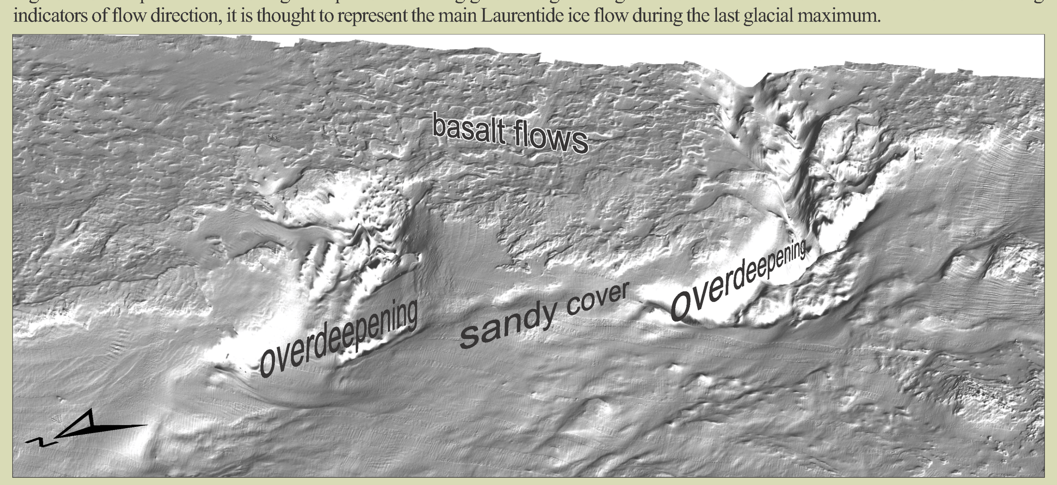

Figure 4. South-looking Viewplane E showing two small overdeepened basins cut into hard bedrock. An anastomosing and distributary pattern developed in the example to the right while three or four channels feed that on the left. They are interpreted as the termination of tunnel valleys from an ice sheet abutting the bedrock scarp, flowing southward (toward background).

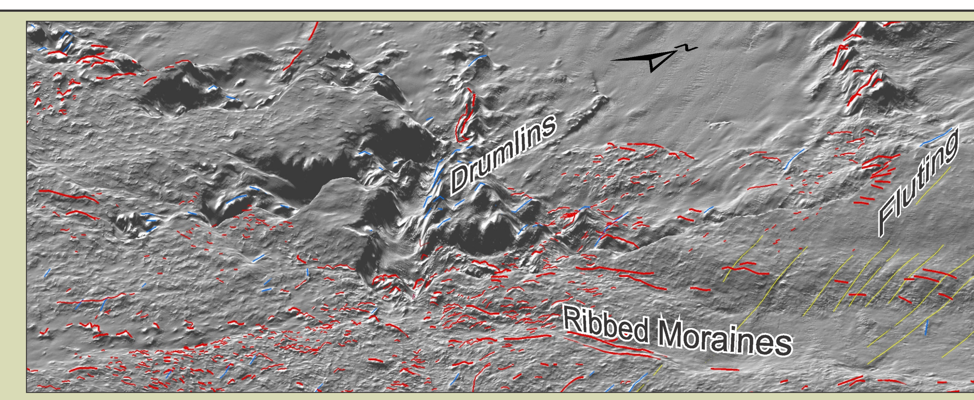

Figure 2. Seascape of viewplane B showing glacial features along the south flank of the main basin. Drumlinized forms and fluting are sub-parallel. The larger, irregular ridge, upper right, is likely a moraine. Mid and small scale ridges in the foreground are likely deglaciation moraines.

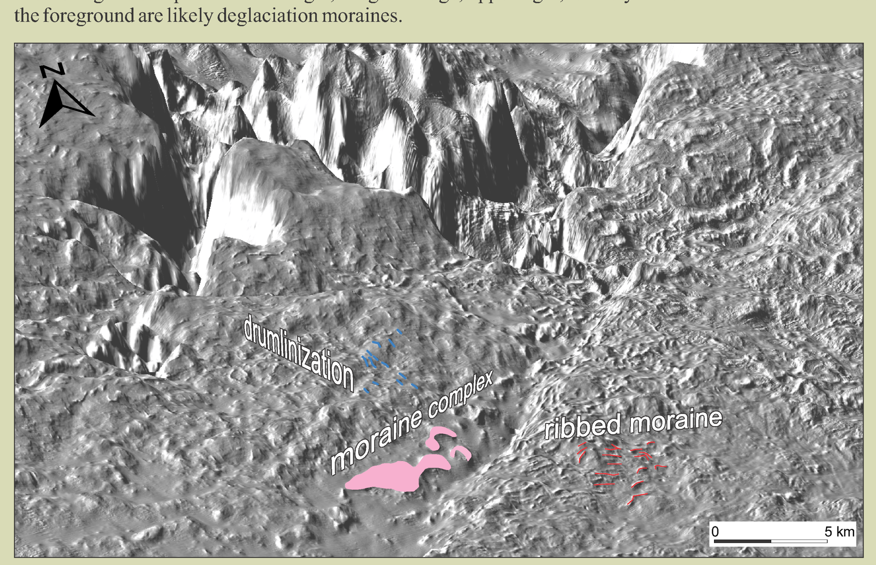

Figure 3. NW-looking Viewplane C showing a delicate pattern of glacial ridges on a bedrock surface. Those in the foreground are curvilinear but have a general E-W orientation and contrast with the even smaller ridges in the mid-ground, the majority of which are straight and with a N-S orientation. In the intervening bedrock trough a series of mid-scale moraines surrounded by mud marks a former ice margin. Selected examples highlighted with coloured lines.

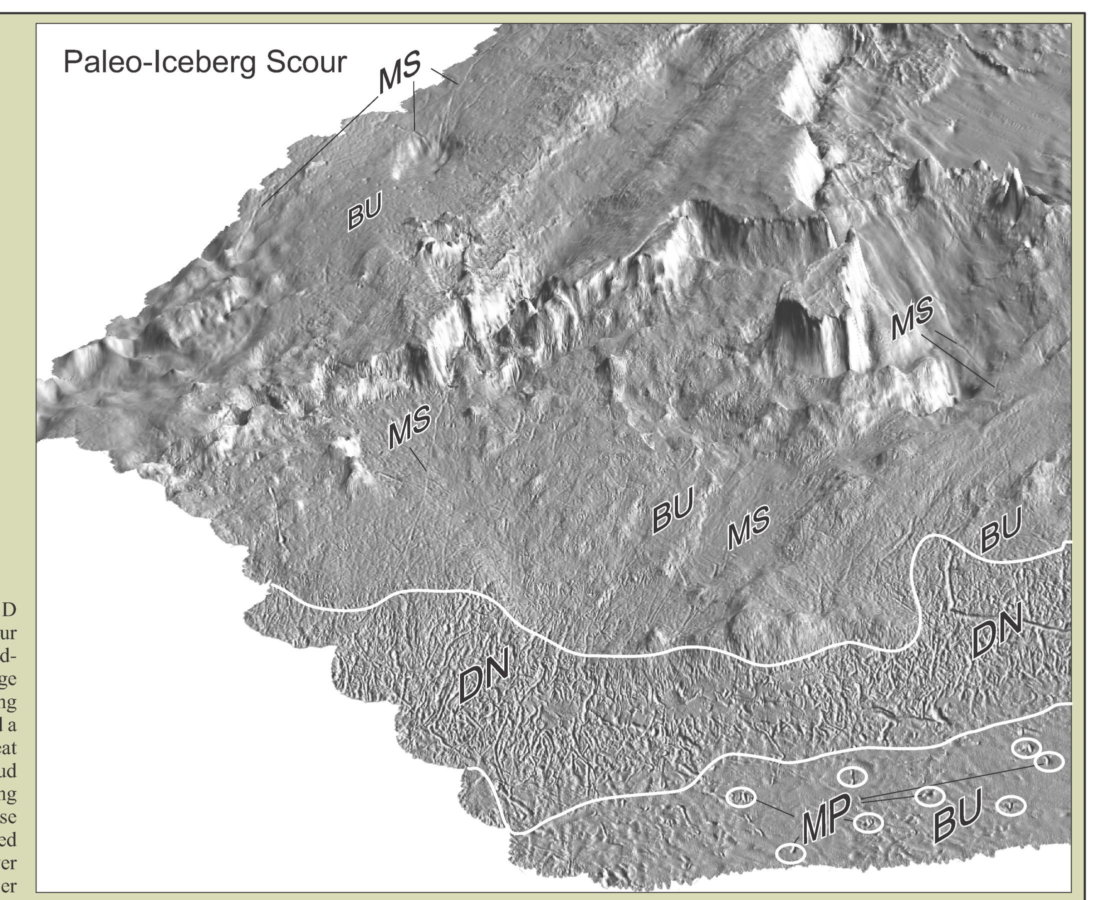

Figure 5. Seascape of viewplane D showing variations in iceberg scour expression. These partly reflect end-members in a continuum in scour age populations. The sediments infilling the till surface and the basins record a time span from earliest glacier retreat to latest (significant) basinal mud deposition. The dense cross-cutting scour network on the till (DN, dense network) is successively more buried by sand (BU, buried) in the shallower water depths, and mud in the deeper settings. This, as noted elsewhere, is related to post-glacial water depth increases following the low-stand and evolving oceanographic current processes. Yet the basins also have long scours (MS, mud scours) cut into the sandy and muddy post-glacial deposits. These are much fewer, more continuous, have a strong SW oriented trend, and traverse across a large range in water depths, reaching 175 m at the deepest. Similarly, large iceberg pits cut the post-glacial age muds flanking the Laurentian Channel (MP, mud pits), clearly post-dating those scours buried by the muds. The SW directionality of the mud-cutting scours follows the pattern of ocean currents as inferred from younger and present-day sedimentary bedforms (see accompanying poster). These observations suggest that the *early* scouring was from calving bergs as the Laurentian Channel ice stream collapsed, driving them into relatively hard tills in relatively shallow water. Later but diminished iceberg scouring frequency is recorded when sea-level rose and deposited basinal muds which were, in turn, iceberg scoured. These were driven by the early Nova Scotia Current. By this time calving would be occurring only much further up the ice system, possibly from late glacial ice streaming from embayments such as the Cape Breton Trough or St. George's Bay or even farther shores of the Gulf of St. Lawrence, ceasing only when the Laurentide ice terminated on land.

GLACIAL FEATURES