Seascapes of St. Anns Bank
and adjoining area off Cape Breton, Nova Scotia
Bedrock Geology and Seabed Texture

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

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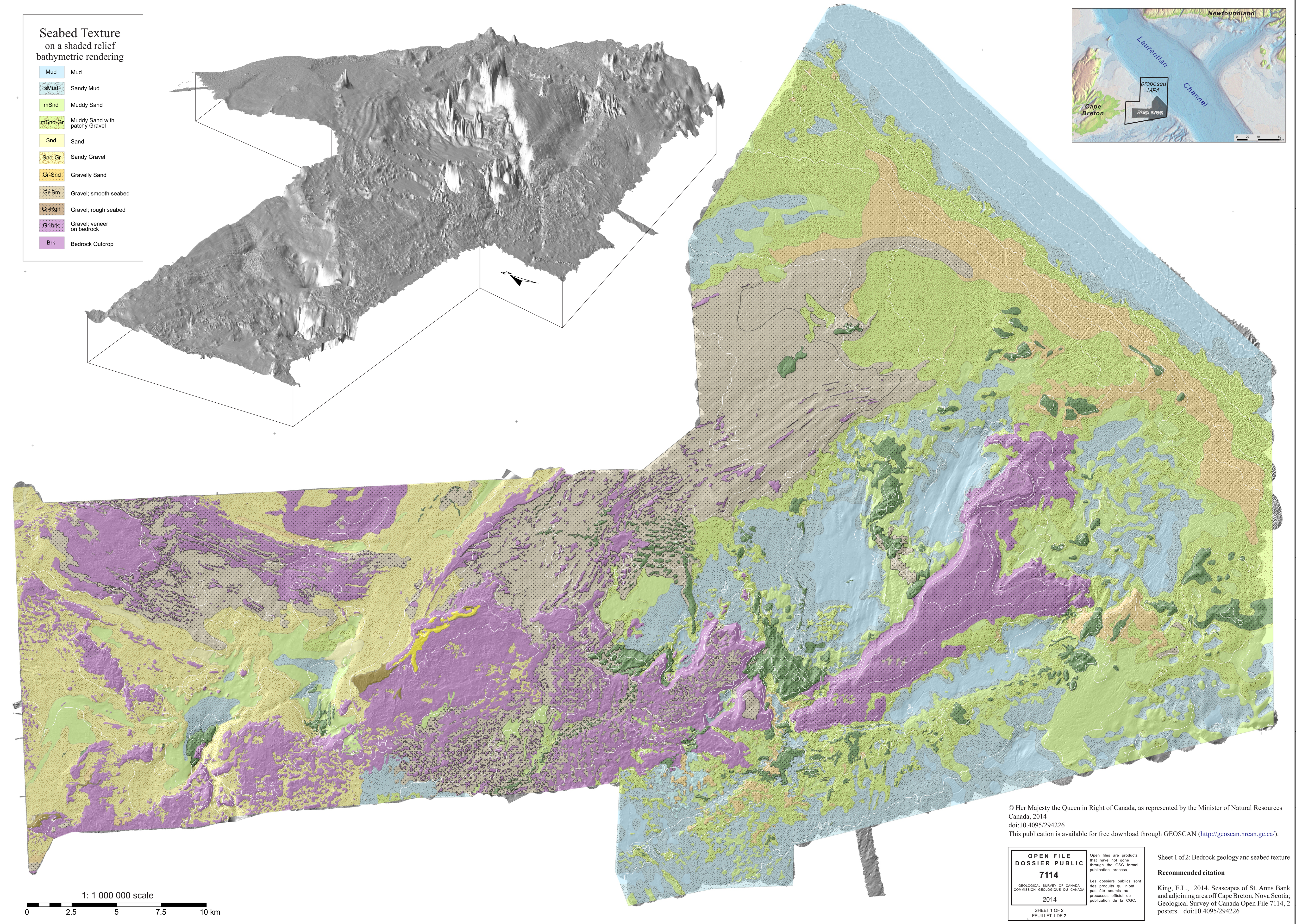

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SEABED TEXTURE LEGEND

Overview

The seascape is strongly governed by bedrock type and the glacial and post-glacial processes imprinted on this seascape. The higher and rougher elements stem from crystalline or metamorphic bedrock and the flatter banks have underlying Carboniferous age strata or, to the east, thick till. A strong erosional and depositional imprint from the last glaciation more directly affected the texture of the seabed. Gravel-rich glacial deposits dominate on highs and banks while muds dominate the basins and intermediate facies flank the basins.

Following glacial retreat the sea incurred and a lowest relative sea-level stood 50 to 70 m below present, subaerially exposing much of the western part of the bank, subjecting all of the western map area to wavebase action. As sea-level rose, and transgressed this landscape, the coastal and wave-base energy formed gravel lags. Its intensity diminished with time but onset of the Nova Scotia Current maintained local current influence on the seabed. In this context, the general seabed incline from shallow in the east to deeper in the west imparts a relative abundance of bedrock, gravelly and sandy texture in the west.

Muds following glacial retreat

A facies shift from soft mud to muddy sand occurs from deepest basin to flank, generally reflecting depositional energy levels. This process would have been most active with the low-stand and diminished with time. However, seabed currents maintain non-deposition of mud and locally attain strengths able to move sand in traction.

Mud	***Mud;** low acoustic backscatter, acoustically transparent (in profile), smooth surface except locally where scoured by paleo-icebergs. Soft and cohesive but locally with a sandy lag on its surface. Confined to basinal areas in water depths greater than 150 m; up to several metres thick. Derived mainly from early post-glacial coastal (glacial age low-stand) reworking of glacial sediments with the fine (mud) component transported to adjacent low-energy basins. Boundary with sandy mud or muddy sand map units is transitional. Locally sculpted by topographically steered currents which have reduced or enhanced mud deposition resulting in broad troughs, especially along the base of steep slopes. Broad linear troughs in the central basins may conform to an underlying glacial fluting fabric or reflect currents sweeping the basin in the same direction.*
sMud	***Sandy Mud;** similar to Map Unit "Mud" but with slightly higher acoustic backscatter attributed to a higher sand content; little or no gravel. Boundary with "Mud" or "Muddy Sand" units is transitional. Eroded into current-parallel troughs or ribbons in the westernmost basin.*
mSnd	***Muddy Sand;** similar to Map Unit "Sandy Mud" but with a higher higher acoustic backscatter attributed to greater sand content; little or no gravel. Boundary with Map Units "Sandy Mud" or "Muddy Sand with patchy Gravel" units is transitional.*
mSnd-Gr	***Muddy Sand with Patchy Gravel;** Identical to Sandy Mud unit but thinner deposits such that underlying gravel is locally exposed in patches, generally on slight elevations. Patches can be large, commonly associated with exposed paleo-iceberg scour berms or small sediment-draped glacial moraines or drumlins; generally transitional to the Gr-Gl gravel unit with proportion of gravel increasing toward this contact.*

Sand and Gravel from lower paleo sea-level

Beach ridges and washover sheets; 2 to 3 m high, sharp crested ridges or scarps on sediment sheets lying between 55 and 25 m below sea-level. The setting is generally on the northern edge of bedrock paleo-shoals presenting abrupt shallowing that would have experienced high energy breakers. Other evidence of low-stand includes the common washing of bedrock paleo-shoals of their sediment cover shallower than 50 m with adjacent sub-littoral mantling, and the preservation of small moraines and drumlinoid forms only deeper than 40 m (typically 60-70 m).

Gr-LS	***Gravel; paleo-Sea-Level;** small ridges of gravel interpreted as beach ridges; commonly associated with gravelly or sandy washover sheets or sandy back basin fill.*
Snd-LS	***Sand; paleo-Sea-Level;** sand sheets associated with littoral processes at time of lower sea level. Washover sheets or sandy back basin fill. Post depositional current reworking is likely.*

Sand and Gravel derived from Glacial deposits

Glacimarine muds in the basins and till on the basin flanks were reworked at the seabed, leaving gravels and sands while the mud component settled in the lower energy basins (see above).

Snd	***Sand;** Sand with little mud component; local patchy gravel between sand crests; sorted by current action; local bedforms showing current direction*
Snd-Gr	***Sand and Gravel;** Generally undifferentiated in terms of relative percent of sand versus gravel but with relatively high acoustic backscatter. Sand content is inferred from general seabed smoothness but locally with subdued relief (sediment cover) from underlying bedrock. Locally modifed into fields of current-transverse sand waves or long, curvilinear and sub-parallel, bifurcating troughs oriented along current direction. Minor erosion is inferred from this process and results in sorting of fine gravel and sand at a small scale, e.g. coarse troughs and finer crests. Differs from Muddy Sand with Patchy Gravel unit in that little mud is inferred and the boundary transitions between the sand and gravel components are more subtle.*
Gr-Snd	***Gravel with limited sand:** Gravel on top of a till sheet or patchy till with sand patches. Larger and more continuous sand patches in the troughs of relict iceberg scours. Differs from Gr-Glf by its generally smoother surface and its greater sand component.*

Gravel derived from Glacial Deposits

Gravelly surface on glacial landforms including blanket till, irregular moraines, and mid-size to small fields and complexes of ribbed moraine and drumlinoid forms. Glacial deposits were reworked by iceberg scouring and wave action with the low-stand and transgresssion.

Gr-Gls	***Gravel on smooth topography;** thin deposit on relatively smooth bedrock; local sand inferred; commonly in small topographically flat areas surrounded by bedrock- or till-cored ridges but also includes gravel on thick iceberg scoured till; Differentiated from Map Unit "Gr-Brk" mainly by lower seabed roughness; can include rare small till or bedrock outcrops.*
Gr-Glf	***Gravel on glacial landforms;** thin gravel lag deposit on till and glacimarine diamict. All size ranges of gravel including locally abundant cobbles and boulders and some sand inferred; commonly across relict iceberg-scoured till blanket and mid and large-scale topographically elevated glacial landforms. Differentiated from Map Unit "Gr-Gls" mainly by lower seabed roughness and greater thickness of underlying glacial deposit; May include areas with small bedrock outcrops and gravel-covered bedrock where its differentiation from glacial deposit is not readily discernable.*

Bedrock Outcrop and Gravel cover on Bedrock

Bedrock, eroded during glaciation, was left bare or locally washed of all its sediment cover during the subsequent 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.

Gr-brk	***Gravel veneer on Bedrock.** Differs from Map Unit "Gr-Glf" by its elevated roughness due to common outcrops but locally includes small glacial deposits on bedrock.*
Brk	***Bedrock Outcrop;** generally a topographic high with considerably greater local relief than in surrounding sediment; bare rock or scattered gravel up to boulder size; local sand patches. Bedrock comprises two general types. The crystalline and metasedimentary rock types (preCambrian) present greater jointing development and relief than the sedimentary, locally with steep cliffs (See Bedrock Theme Box). The sedimentary rocks (Carboniferous) commonly exhibit bedding-related parallel ridge/valley topography.*

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. 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. 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. Backscatter strength is a proxy for seabed texture yet there is no simple relationship between backscatter strength and surficial sediment type. The samples and photography are integrated with a conceptual, interpretive model of past and present seabed processes to generate a representation of seabed geology. This map protrays the texture of the seabed in several classes, not strictly related to the sequence and timing of events or processes and their transitions, However, a link between the texture and its genesis is meant to add a dimension of enhansed understanding of the seabed. A separate map derivative emphasizes the Quaternary geology, more closely relating seascapes with sediment genesis (companion poster).

SUMMARY

St. Anns Bank has a diversity of seascapes strongly controlled by bedrock: a ridge and bedrock scarp of early Cretaceous flow basalts and basic intrusives contrast with Carboniferous folded strata in the north.

The 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.

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

Past and present seabed currents flowed S and SW and attest to the influence of the proto and present Nova Scotia Current.

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.

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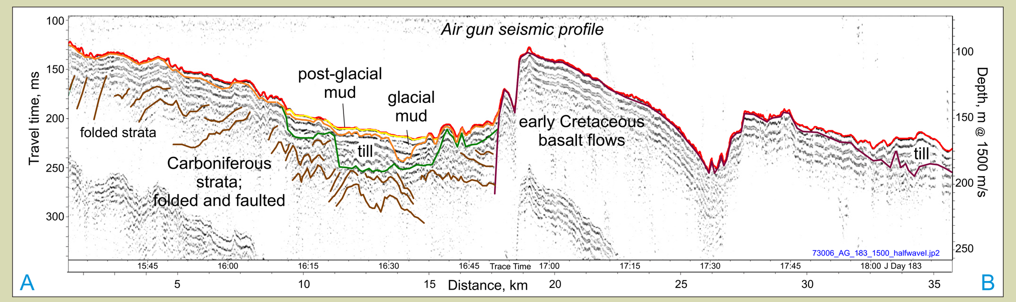
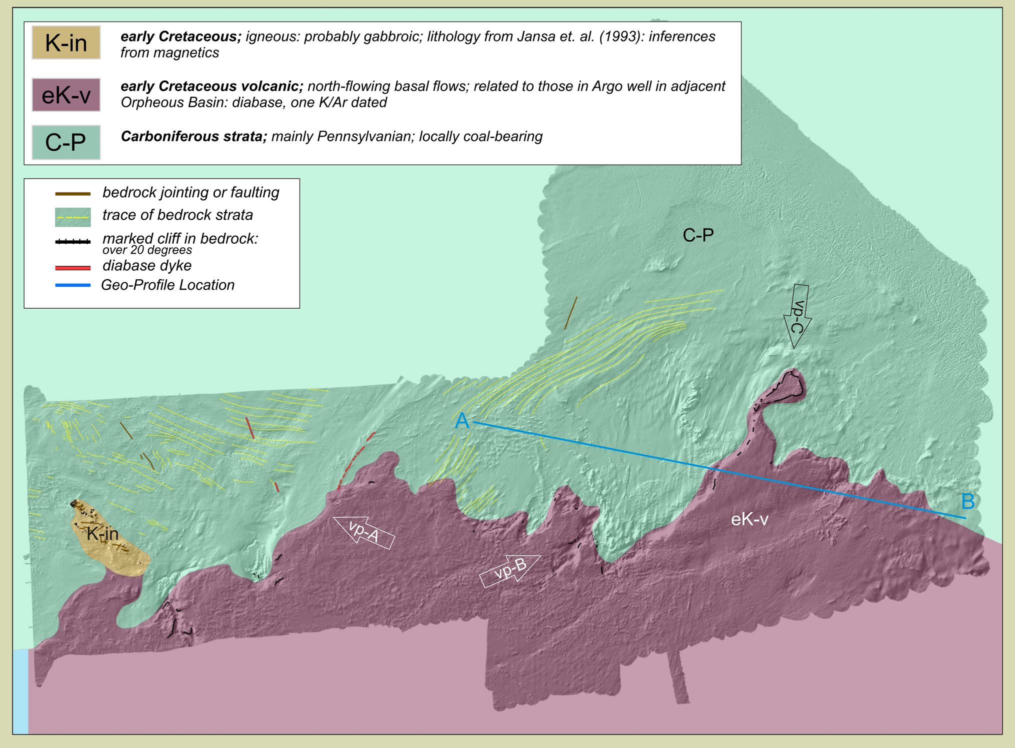
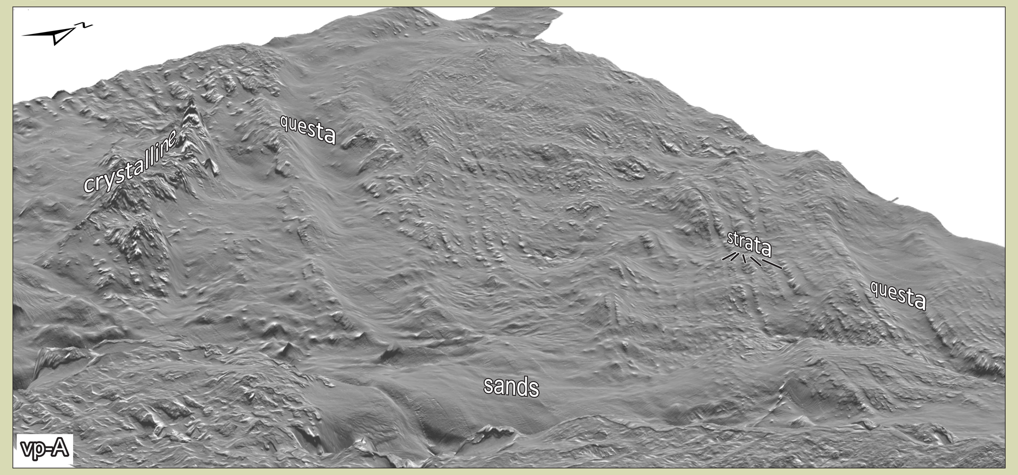
BEDROCK FEATURES

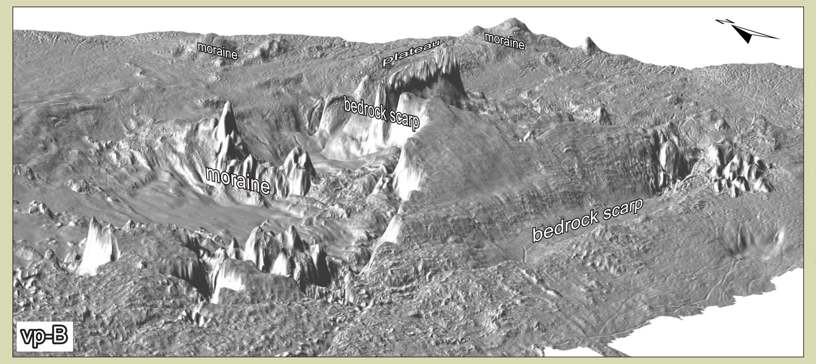




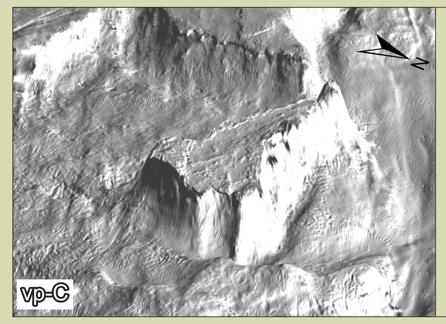
Bedrock sub-crop distribution: A large questa-like form dominates the terrain in the map area and represents acoustic basement. Steepest cliffs are demarcated, some associated with glacial erosion but some more likely related to faults and joints. This basement is part of the Burin High, marking the divide between the Sydney Basin and Laurentian sub-basins. The outcrop yielded two short drill cores comprising diabase (Jansa et al. 1993) of Early Carboniferous age (DeLabio et al., 1980). Their tabular and terraced morphology, an E-W oriented linear magnetic anomaly to the south (Jansa et al., 1993) and the nearby occurrence of basaltic flows flooring the Orpheus Graben to the south (Wade and MacLean, 1990; Bowman et al. 2012) supports the interpretation that these represent basalt flows. They cover about 40 000 km^2 at or near the seabed and this size may be doubled in if the subcropping magnetic anomaly is interpreted as a feeder dyke. These intruded into folded and lightly faulted Carboniferous strata. The enechelon structure near point "A" (blue) on the profile represents a discontinuity in the Carboniferous strata interpreted as a fault-line and a protruding ridge is likely a basic dyke. Alternatively, the ridge is morainal but apparent cross-cutting may be superimposed moraines. Steep and high cliffs are marked in red. The hollow arrows with "VP-x" designations, above, refer to oblique viewplanes in the 3-D seabed representations below.

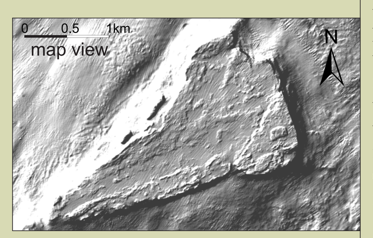


Seascape of viewplane A: This view emphasizes the control of topography and sediment depocentres by the bedrock and subcrop. The hard crystalline outcrop is likely preCambrian or Cretaceous age intrusives and contrasts with the ridges and valleys of the north-dipping Carboniferous strata. These are coal-bearing rocks similar to those mined at Sydney, NS. A veneer of sands and gravels drapes the lows at the scale of both the strata and the questas. In the foreground, thicker sand flanking the basin are driven by currents.



Seascape along viewplane B: This shows the cliffs of the basement rocks along on the south flank of a basin. The smoother elevations in the background are irregular moraines. The highest (central) plateau is shown in the adjacent box.

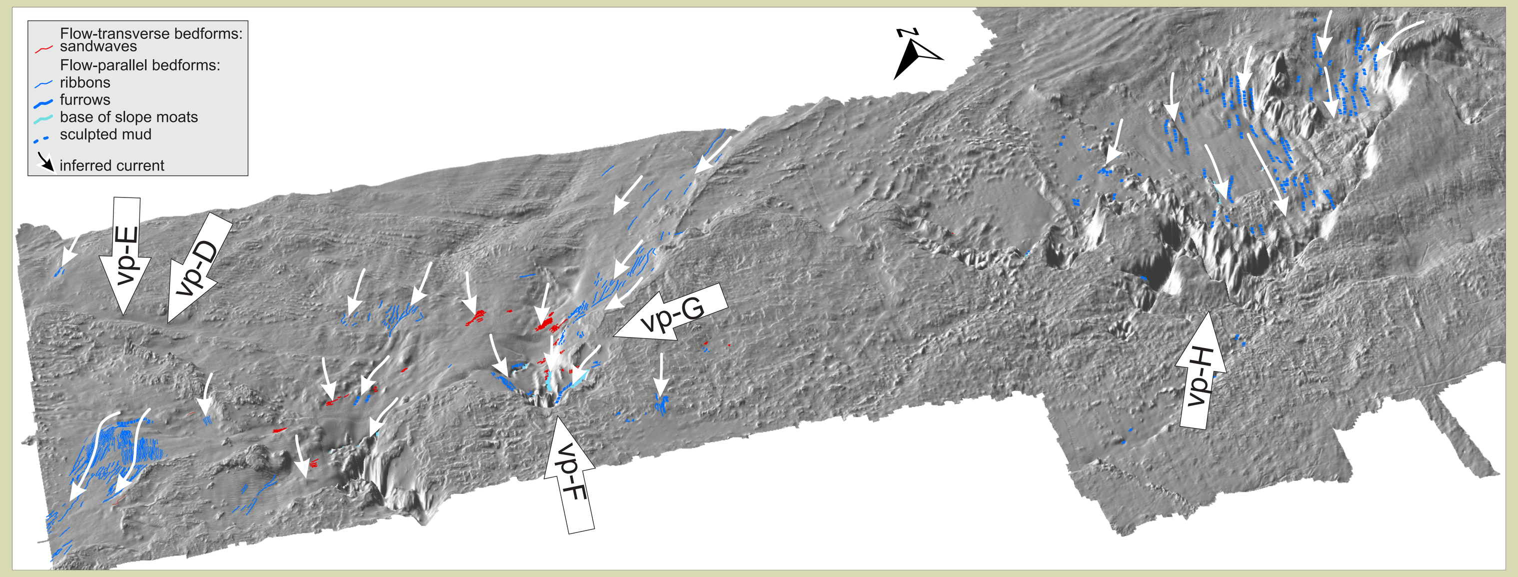




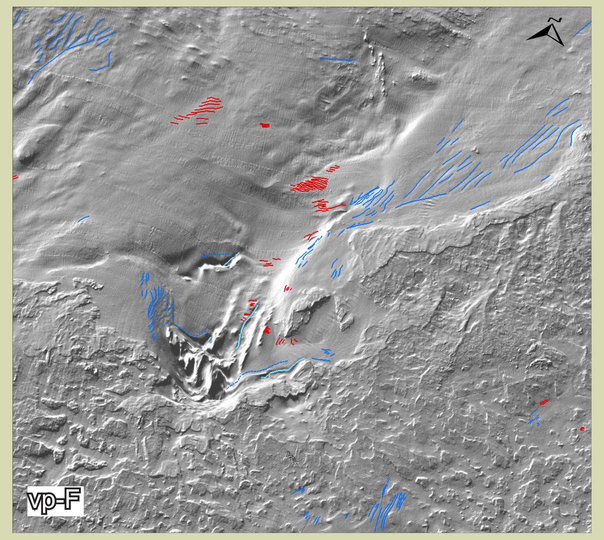
Viewplane C: This tabular topographic high comprises basic volcanics as identified from drill core. The tabular morphology on this and on the plateau in the background (left) suggest basalt flow sheets.

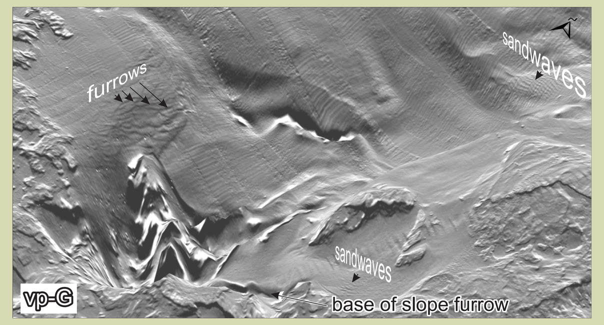
SEABED CURRENT FEATURES

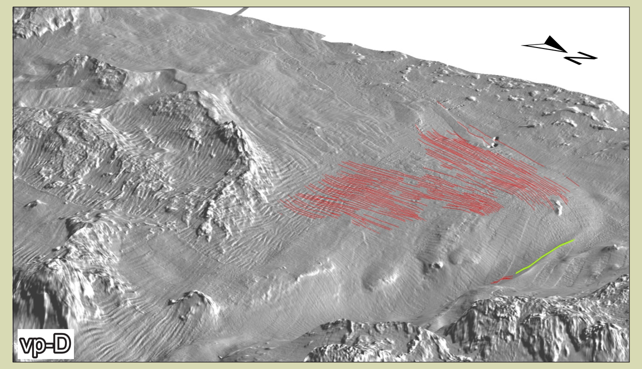
Seabed current-related features and inferred present day bottom current pattern on a 3-D seabed rendering. A variety of bedforms indicate local, topographically-steered bottom current directions but the general trend follows the Nova Scotia Current direction. The hollow arrows with "VP-x" designations refer to additional oblique 3-D viewplane renderings highlighting more details. As post-glacial sea-level rose there must have been an interplay of sea-level related processes on the seabed with the erosional or non-depositional effect of the proto- Nova Scotia Current as it evolved and changed strength. This evolution may be superimposed in the seabed bedforms and difficult to distinguish chronologically; it may be recorded in sediment facies differences in the basinal sediment column.



Sandwave fields (above and below) flanking this basin have slightly different orientations suggesting local steering of the currents. The sand and muddy sand are also broadly sculpted, mostly at the base of local bedrock-controlled slopes. Various bedforms with a curvilinear furrow character do not readily fit classification schemes. The context indicates lineations are flow-parallel and they are simply termed furrows here.

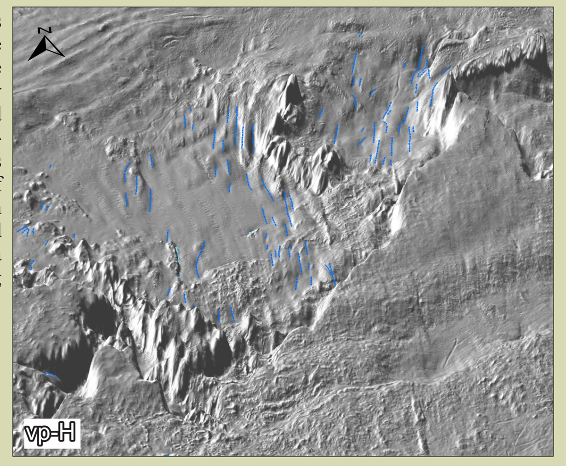




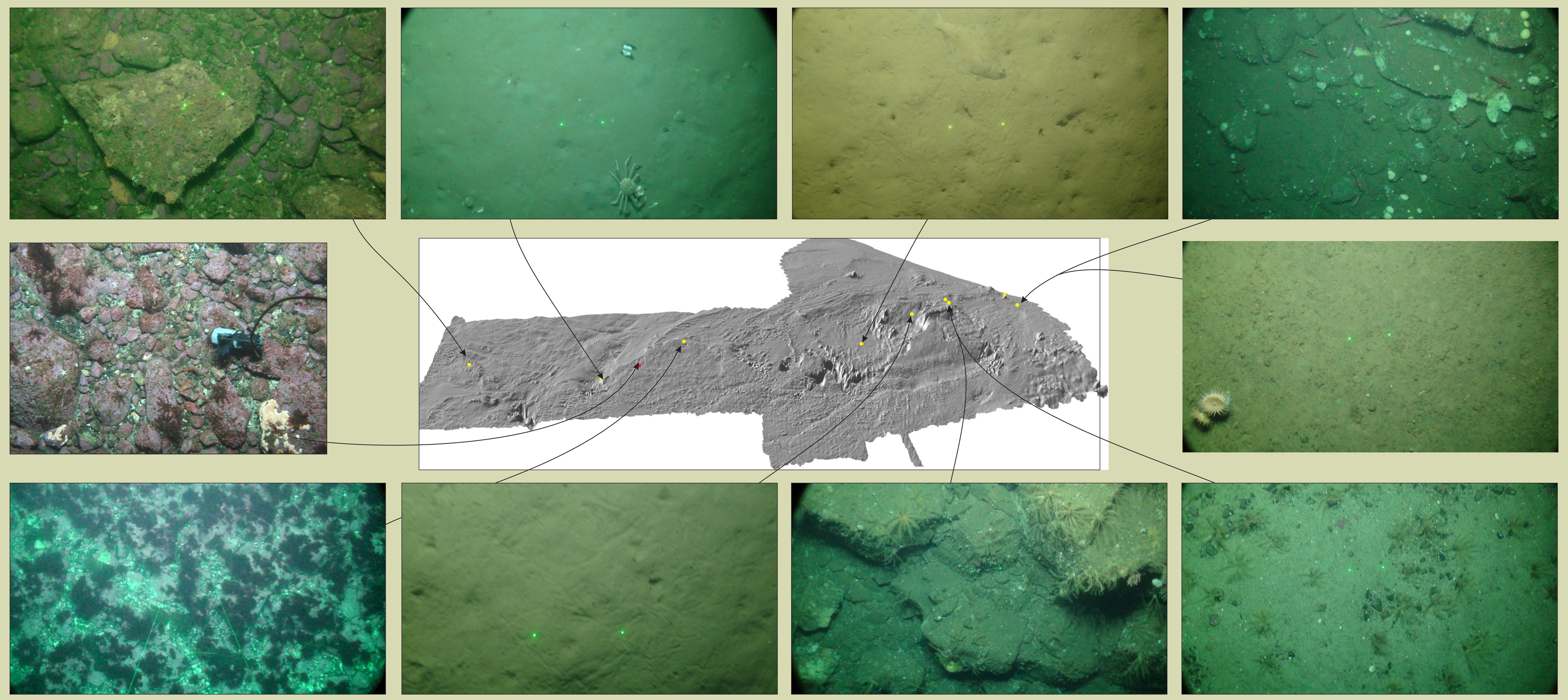


Ribbon and furrows in muddy sand, Viewplane D , left and Viewplane E, right. These have decimetre relief and probably coarser material in the troughs. Downstream (southward), they evolve into broader bedforms with more sand and gravel. These may be related to an acceleration of the currents as they pass over the basin flank. Without the context of the smaler ribbon-like furrows, the broader examples might be wrongly interpreted as flow transverse bedforms.

Broad current furrows in muds reflect the bottom currents. The linear features may have been generated through relative non-deposition of the muds across flanks of drumlinoid features in the basins, maintained by a proto- Nova Scotia Current during sea-level rise.



SEABED PHOTOGRAPHS



Seabed photographs showing the variety of textures across the map area.