Open File 3741

THE MORPHOLOGY OF THE EASTERN SCOTIAN SHELF

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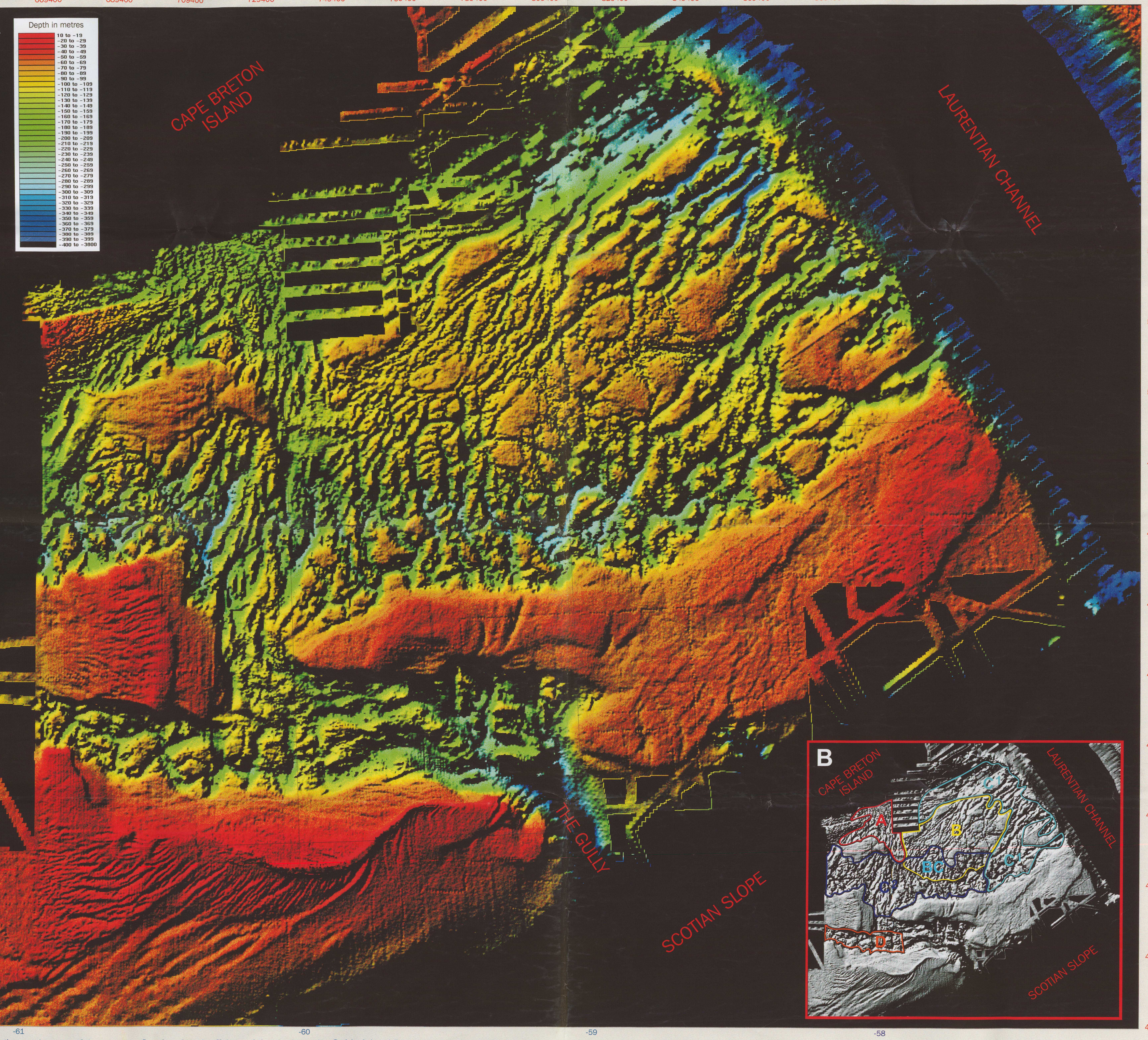
INTRODUCTION

The distinct morphology of the eastern Scotian Shelf, offshore southeast Atlantic Canada, presents both a difficult terrain for engineering activities such as pipeline and telecommunication route selection, as well as a highly variable seabed habitat for fisheries resource assessment and management. The origin of the rough and irregular morphology has been the subject of debate for a considerable time. This poster summarizes M.Sc. thesis research by the senior author on the origin of the morphology of the eastern Scotian Shelf.

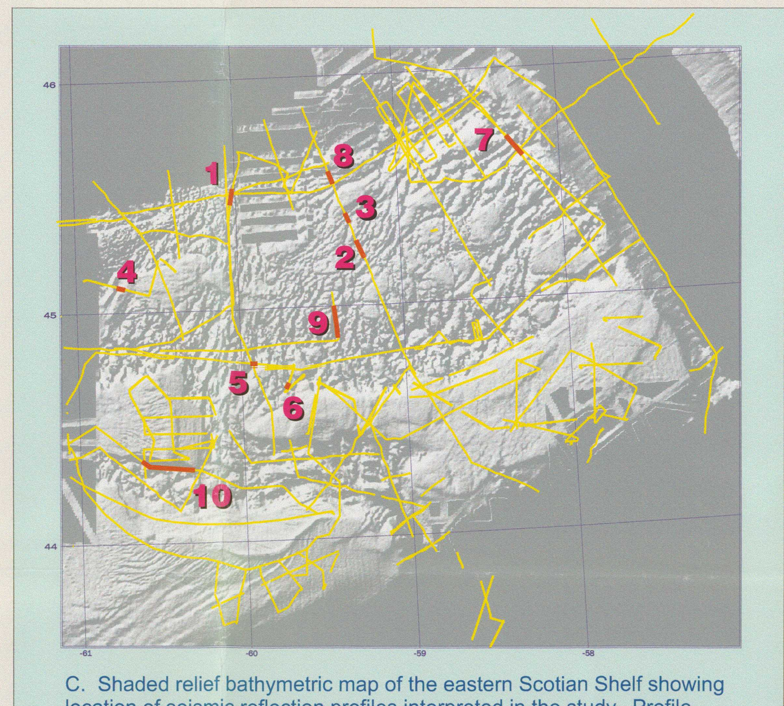
EASTERN SCOTIAN SHELF BATHYMETRIC IMAGE

The image below (A) shows the morphology of the eastern Scotian Shelf and was produced by manipulating bathymetric data with a GIS software package called GRASS (public domain software developed by the U.S. Army Corps of Engineers). The depth soundings were collected via echosounders from the CSS Baffin, between the years of 1979 and 1990 (Loncarevic et. al., 1992). These data were processed into digital format by the Canadian Hydrographic Service (CHS), each point consisting of x, y, and z (easting, northing, and depth) coordinates. The image is termed a digital elevation model (DEM), created by importing the digital data set of depth soundings into GRASS and further processing it through an imaging package written by R.C. Courtney of the Geological Survey of Canada (Atlantic). The data set was gridded to 250 m x 250 m using a program which applies a tension and spline method to generate an interpolated surface (Ocean Mapping On-line help). The gridded data set was then assigned a colour range chosen to maximize the resolution of features between 20 m and 400 m below sea level. Finally, the colour image was combined with a shaded relief image (shadowgram) vertically exaggerated 100x, with an illumination source set at an inclination of 25° and an azimuth of 320° (from the northwest).

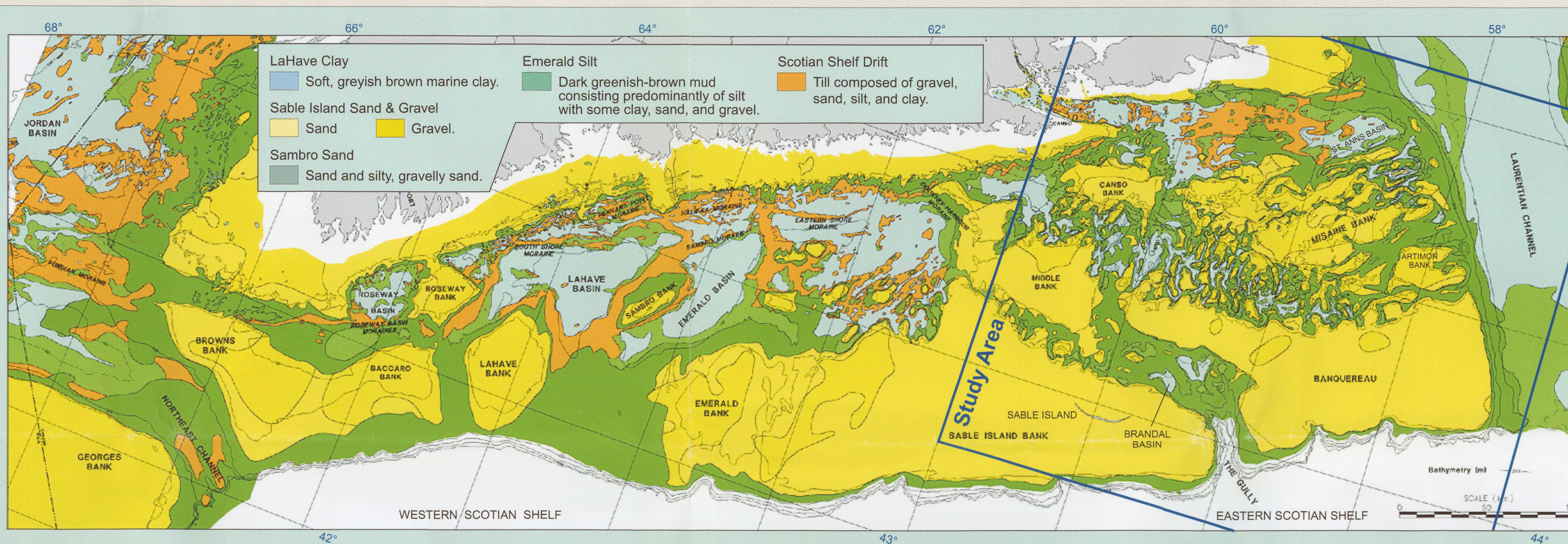


A. Bathymetric map of the eastern Scotian Shelf, offshore Atlantic Canada. Sable Island Bank lies southwest of the Gully, and Banquereau occurs to the northeast.

B. A zone classification of exposed incisions.



C. Shaded relief bathymetric map of the eastern Scotian Shelf showing location of seismic reflection profiles interpreted in the study. Profile locations 1-10 below are indicated.



D. Surficial Geology map of the Scotian Shelf showing study area

CLASSIFICATION OF THE EXPOSED INCISIONS OF THE EASTERN SCOTIAN SHELF

Based on interpretations of over 6035 km of high-resolution marine seismic reflection data (Huntec DTS, airgun, sleeve gun, and sparker systems, C), areas of incisions have been classed into four primary zones from the inner shelf to the outer shelf; Zone A, Zone B, Zone C (consisting of Subzone C^1 and Subzone C^2), and Zone D (B).

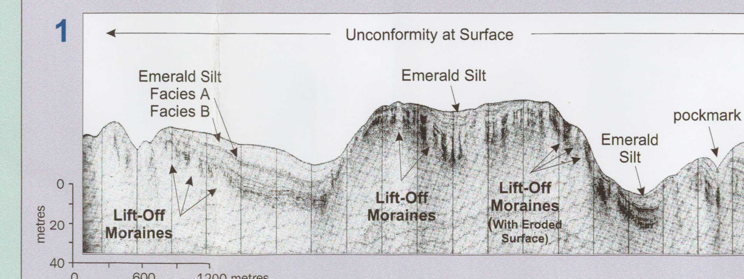
Zone A incisions occur in the inner shelf region, and are a combination of incompletely filled older incisions (Pleistocene and/or Tertiary?), and surface expression of late incision into less resistant glaciomarine sediments (1). Zone A incisions cut into both outcropping acoustic basement of the Appalachian Region, and thin Tertiary and/or Cretaceous bedrock. Incisions in southern Zone A are larger than those to the north, and reach depths of 120 m and widths of 1 km. There appears to be an acoustically incoherent fill at the base of some of these incisions, overlain by glaciomarine deposits. In northwest Zone A, a series of incisions <60 m deep and <1 km wide appears to be filled with stratified deposits, some displaying a clinoform character.

Zone B (Misaine Bank) is underlain by few buried incisions, while the surface is heavily dissected by a complex system of exposed and partially infilled incisions ranging in depth from <10 m to 100 m (2). Zone B incisions are relatively shallow when compared with the incisions of other zones. Some buried Tertiary valleys with superimposed Pleistocene incisions occur (3). High resolution Huntec DTS data is lacking in this zone, therefore, the incisions' fill remains largely unknown. A recent sidescan sonar survey revealed that the sea bed is characterized by gravel deposits, and sand which is largely concentrated in incision depressions.

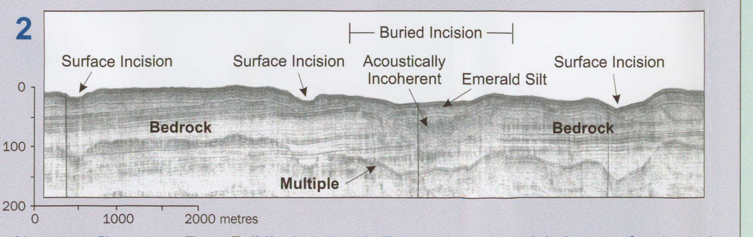
Zone C, consisting of **Subzone C^1** and **Subzone C^2**, contains a series of deep incisions, some of which reach in excess of 400 m below sea-level. Some incisions are completely buried, however, the majority are only partially filled. The incisions east and north of Misaine Bank (Subzone C^1) are oriented northeast-southwest, similar to the smaller incisions on the surface of Misaine Bank (Zone B). Those to the south (Subzone C^2), have a north to south orientation (slightly skewed to the south-east or south-west) and appear to cross-cut the southern edge of the northeast-southwest trending Misaine Bank (Zone B) incision system (area marked BC). Unlike the northeast-southwest oriented Subzone C^1 incisions, Subzone C^2 incisions are more linear in character and do not appear to have distributary/tributary extensions. At least the uppermost sediments of the majority of Zone C incisions are filled with depositional sequences typical of the Scotian Shelf basins to the west (incoherent acoustic unit (Scotian Shelf Drift, including lift-off moraines); stratified acoustic units (ice proximal and ice distal glaciomarine deposits of Emerald Silt Facies A and B); transparent acoustic unit (Holocene mud deposits of LaHave Clay, see King and Fader, 1986; 4, 5)). Incision fill at depth is also highly variable, including both complex stratified sequences and acoustically incoherent sequences (6, 7, 8). Only one long profile of the incisions in this zone exists, and it displays a fjord-like character, including basins and sills (9).

Zone D (Brandal Basin) incisions are similar in width, depth, and fill, to Zone C incisions. Zone D has an acoustically incoherent unit (till) which blankets much of the area, including the near surface of buried incisions, and interfluves (10). Some incisions in Zone D contain basal stratified units, while others contain basal acoustically incoherent units.

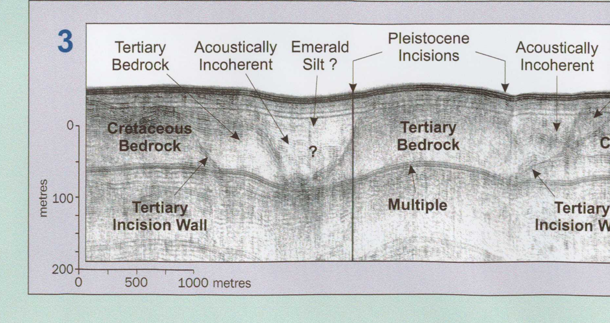
Sable Island Bank, Banquereau, Middle Bank, Canso Bank, and Artimon Bank are underlain by networks of buried incisions, however, their relationship to the exposed incisions adjacent to the banks is uncertain as data are sparse and seismic penetration and high resolution through the hard surface sands and gravels (Sable Island Sand and Gravel) is poor. Therefore, it remains unknown if Zone A, Zone C, and Zone D incisions extend beneath the adjacent banks, though limited data indicates some may.



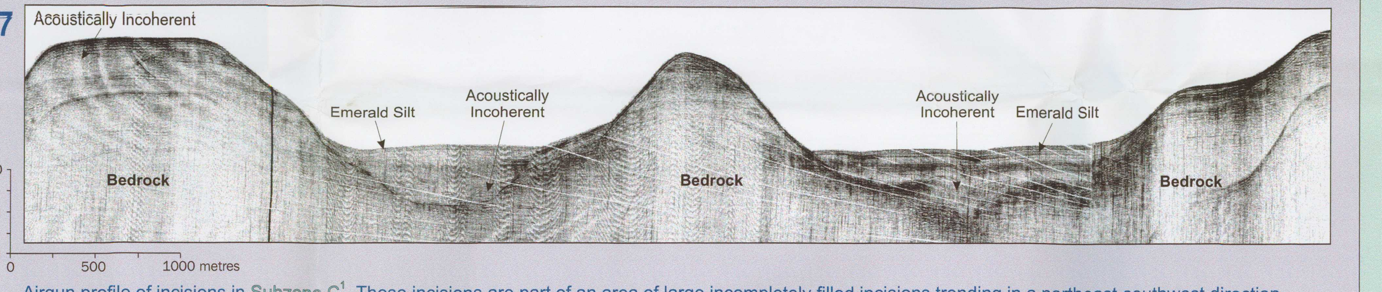
Huntec DTS profile across terrain in Zone A, south of Cape Breton Island. Note how the regional unconformity preferentially eroded into softer glaciomarine sediments (Emerald Silt), while the overall topography reflects the presence of a more resistant undulating basal surface developed on bedrock overlain by Scotian Shelf Drift with superimposed lift-off moraines.



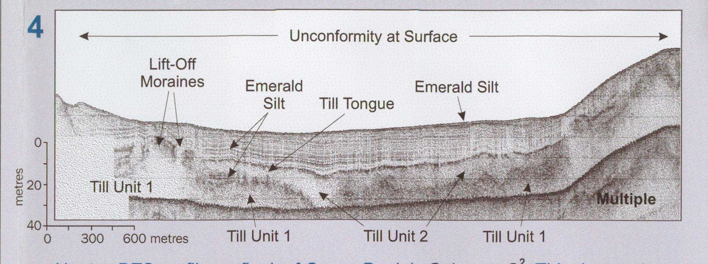
Airgun profile across Zone B (Misaine Bank). This zone is underlain by very few buried incisions. The surface is dissected by shallow incisions (<100 m deep); some of which are partially infilled with Quaternary sediments. Bedrock is close to the seabed.



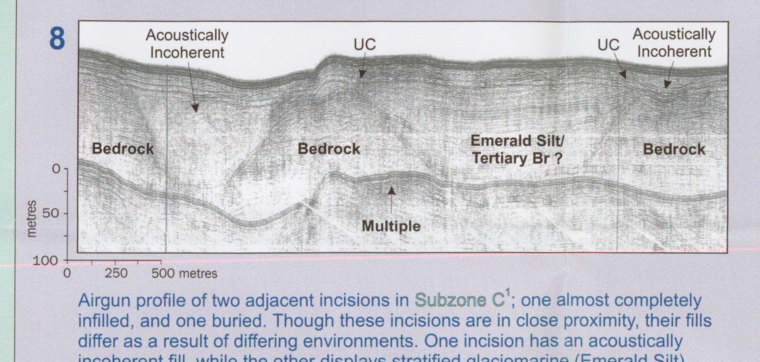
Airgun profile showing two generations of buried incisions in Zone B (this is the only large buried incision in this area observed from available seismic data). There are two Pleistocene incisions cut into Tertiary bedrock, which infills an incision cut into Cretaceous bedrock. This profile is an example of what buried incisions look like under the other banks of the eastern Scotian Shelf.



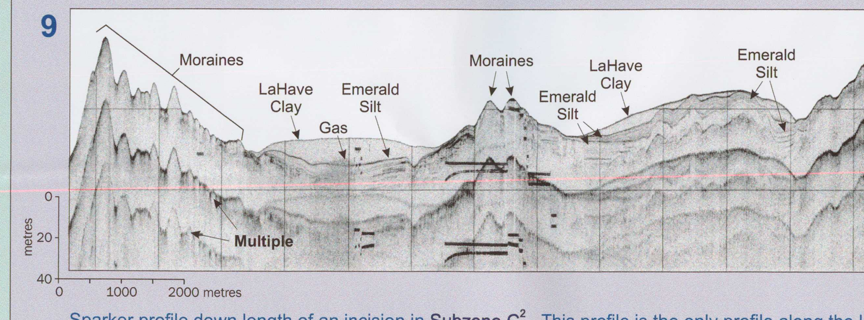
Airgun profile of incisions in Subzone C^1. These incisions are part of an area of large incompletely filled incisions trending in a northeast-southwest direction. These incisions show a u-shape profile in cross-section. The stratigraphic infill sequence consists of a basal incoherent unit (till) overlain by thick Emerald Silt (glaciomarine) sequences.



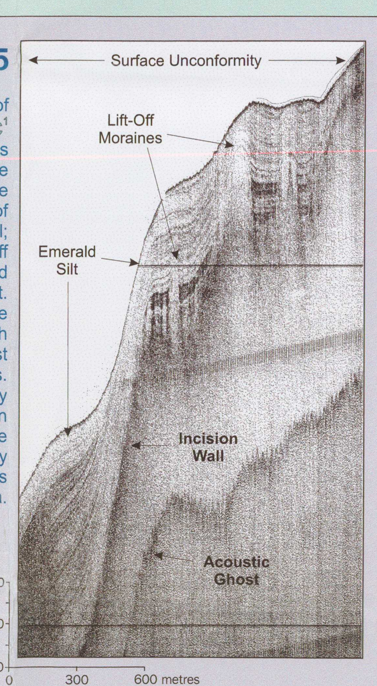
Huntec DTS profile on flank of Canso Bank in Subzone C^2. This depression off Canso Bank contains a till tongue stratigraphy which is representative of a fluctuating, partially floating ice margin.



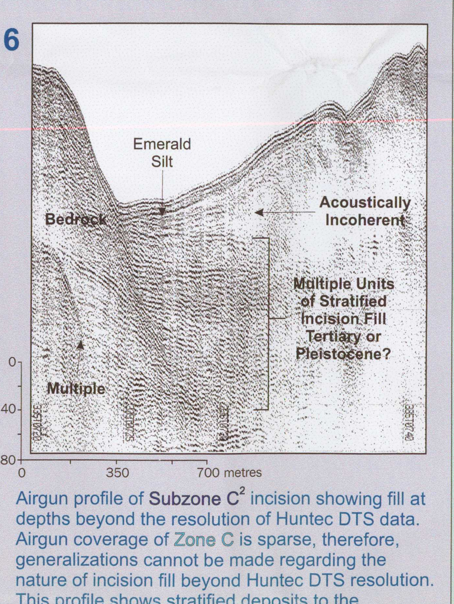
Airgun profile of two adjacent incisions in Subzone C^1; one almost completely infilled, and one buried. Though these incisions are in close proximity, their fills differ as a result of differing environments. One incision has an acoustically incoherent fill, while the other displays stratified glaciomarine (Emerald Silt) deposits. UC marks the surface of an unconformity which can be followed over the surface of the incision filled with stratified sediments indicating it may be of an older generation than the incision with acoustically incoherent fill. It is unclear if the stratified fill is Tertiary of Pleistocene (Emerald Silt).



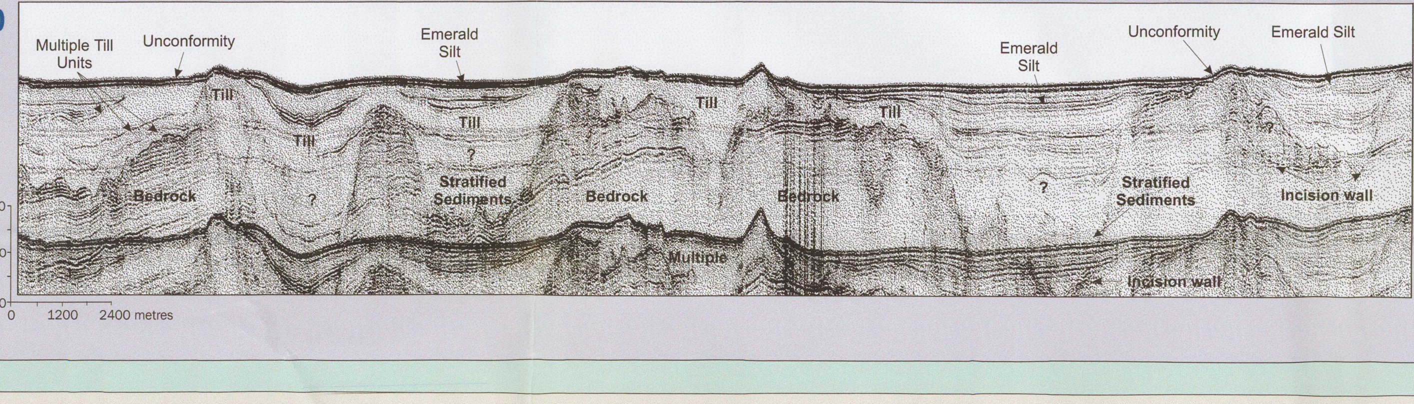
Sparker profile down length of an incision in Subzone C^2. This profile is the only profile along the length of an incision and displays a morphology reminiscent of a fjord (i.e. sills and basins along the length).



Huntec DTS profile of a Subzone C^1 incision flank. This high resolution profile shows near surface sediments typical of Zone C incision fill: glacial drift and lift-off moraines capped with Emerald Silt. These deposits are generally much thicker in the lowest part of the incisions. Ponded LaHave Clay deposits are often found as a surface unit, however, they do not occur in this area.



Airgun profile of Subzone C^2 incision showing fill at depths beyond the resolution of Huntec DTS data. Airgun coverage of Zone C is sparse, therefore, generalizations cannot be made regarding the nature of incision fill beyond Huntec DTS resolution. This profile shows stratified deposits to the maximum depth of resolution and resembles the lowest portion of incision fill of the buried incisions in Brandal Basin, profile 10. This contrasts with basal fill in airgun profile 7, which shows an acoustically incoherent basal unit overlain by stratified glaciomarine deposits (Emerald Silt).



Airgun profile across Zone D (Brandal Basin) incisions. This profile shows an extensive system of buried incisions and an acoustically incoherent seismic unit (till) which blankets the area. These incisions display ice recessional deposits towards their surface and basal stratified units. The buried incisions along this profile are good examples of buried incisions under the Bank areas. Note that the positive relief feature at the seabed are largely till mounds deposited on bedrock highs. Therefore, to some degree, the seabed morphology mimics the morphology of the buried bedrock surface.

THE MORPHOLOGICAL DISCUSSION

The eastern Scotian Shelf (A) is morphologically distinct when compared with the western Scotian Shelf (D). It appears to be extensively dissected by networks of buried and exposed incisions of varying widths and depths. This is in contrast to the western Scotian Shelf, which exhibits broad open basins between shallow banks (D). The origin of this distinct morphology is cause for much debate: Were the incisions formed by water or by ice? In a sub-aerial or subglacial environment; what are the relative ages of the incisions and their associated processes of formation? Some buried incisions appear to be filled with Tertiary sediments and are, therefore, likely representative of fluvial valleys formed as part of a Tertiary age drainage system that flowed across the Scotian Shelf. However, many incisions present at the surface (A), in addition to others buried beneath the eastern Scotian Shelf banks, are cut into Cretaceous, Tertiary, and Quaternary sediments and are partially-to-completely filled with Quaternary sediments. All of the eastern Scotian Shelf incisions are located below maximum estimates of Late Wisconsinan glacial low sea-level stand (-110 m to -120 m, Fader, 1989). This suggests that during the Pleistocene phase of incision, erosion took place in a subglacial environment.

It has been proposed that portions of the buried eastern Scotian Shelf incision networks were formed by catastrophic outbursts of subglacial meltwater (Boyd et. al., 1988; Sable Island Bank), while others have proposed that they were excavated by ice in a similar manner to which fjords are excavated (Amos and Knoll, 1987; Banquereau). It has also been suggested that the exposed incisions crossing Misaine Bank, and on the north and south flanks, were formed as a result of development of an ice divide across Misaine Bank (Stea, 1995).

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CONCLUSIONS

Conclusions regarding the origin of the morphology of the eastern Scotian Shelf are based on observation (seismic stratigraphy and bathymetry), a comparison to observed modern glacial processes, and theory (see Sankeralli, 1998, and references therein).

Zone A incisions in B, on the inner Scotian Shelf off Cape Breton Island, may have been affected by local glacial advance and retreat phases, and associated glaciofluvial activity which did not affect the middle and outer shelf areas, in addition to more extensive shelf-wide glaciations. The incisions may reflect fluvial development extending as far back as the Mesozoic over the acoustic basement, in addition to Cretaceous and Tertiary fluvial activity. Ice streaming was likely important, particularly where Zone A merges into Subzone C^2.

Zone B incisions may be older than Zone C incisions (based on cross-cutting relationships; area BC). It is unknown how much of this morphology is inherited from pre-glacial fluvial development, though evidence of Tertiary fluvial evolution does exist. This morphology may be representative of a distributed subglacial drainage system modifying a pre-glacial fluvial morphology.

Zone C and Zone D incisions are best explained by an ice streaming model. Modern ice streams and outlet glaciers (eg. West Antarctic ice streams and the Antarctic Peninsula) possess similar subglacial morphologies. Modern ice streams are non-uniform through space and time, and this can account for differences in incision fill and morphology. Different ice margin configurations can account for differences in the orientation of the incisions, and multiple ice-flow phases of differing orientations have been mapped on land (Stea, 1995). Lithostratigraphy and biostratigraphy (Amos and Knoll, 1987; Amos and Miller, 1990) suggests open marine and ice shelf conditions from the Mid-Wisconsinan to the Holocene, with no evidence of input from sudden discharges of large quantities of freshwater. Large inputs of ice from ice streams were likely necessary to support a temperate ice shelf in a relatively open marine environment such as the Scotian Shelf.

From this regional analysis, we interpret that the morphology of the eastern Scotian Shelf is probably not the result of one formational event, or of synchronous formation. Rather, it is more likely the result of multiple glaciations and ice sheet configurations which modified an ancient fluvial landscape by both ice and meltwater. The dominant incision fill comprising at least the upper sediments appears to be Late Wisconsinan recessional deposits. This indicates that Late Wisconsinan ice was both extensive across the eastern Scotian Shelf, and likely occupied at least the upper portions of the eastern Scotian Shelf incisions during ice advance and retreat.

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Further information about the poster may be obtained from the Geological Survey of Canada (Atlantic), Bedford Institute of Oceanography, PO Box 1006, Dartmouth, Nova Scotia B2Y 4A2. Phone: (902) 426-2159, Fax: (902) 426-4104. Job reference number is LS1491p.

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