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GEOLOGICAL SURVEY OF CANADA / COMMISSION GÉOLOGIQUE DU CANADA

DESCRIPTIVE NOTES

INTRODUCTION

This colour-coded surficial geology and sun-illuminated seafloor topography map, is part of a three-map series of The Gully, at a scale of 1:100 000. The series also includes a sun-illuminated seafloor topography map (Cameron and King, 2008b) and a colour-coded seafloor-slope analysis map (Cameron and King, 2008a). Multibeam sonar bathymetry, high-and medium-resolution seismic-reflection profiles, seabed samples, and seafloor photographic data were used in the completion of this map.

Glacial marine deposits and till are the dominant sediment types found on the flanks of The Gully. The till marks the maximum seaward extent of glaciers on the Atlantic Canadian continental shelf. This acoustically incoherent till has been scoured and pitted by icebergs at the seafloor on the outer flanks of The Gully. All glacial units on the flanks of The Gully are covered with sand and/or gravel lag deposits of varying thicknesses. Mapped units in the inner and outer parts of The Gully mostly consist of eroded proglacial and hemipelagic sediments on the canyon walls, with sand in the thalweg.

Figures 1–3 show deposits in the upper 10–50 m as interpreted from high- and mid-resolution deep-towed sparker and airgun seismic-reflection profiles. Such subsurface data are largely lacking, or of poor quality, in deeper areas of The Gully, mainly because surveys utilizing modern or present-day technologies have not been conducted.

MULTIBEAM BATHYMETRIC DATA COLLECTION

Multibeam sonar surveys were co-ordinated by the Geological Survey of Canada (Atlantic) in 1996, 1997, and 1998, and by the Canadian Hydrographic Service in 2000, within The Gully Marine Protected Area. Surveys were conducted in collaboration with several industry partners and Fisheries and Oceans Canada.

The surveys utilized Simrad EM1000 multibeam sonar with operational depths from 10 m to 4500 m. The system produces 135 beams over a maximum arc of 150°. During these surveys, the swath coverage was up to seven times the water depth, with survey speeds of 10–12 knots. A Differential Global Positioning System provided positioning accuracy of approximately 3 m.

GEOLOGICAL EVOLUTION

Introduction

The Gully is a large submarine canyon located between Sable Island Bank and Banquereau, on the eastern Scotian Shelf. The Gully formed over time by fluvial, glacial, and meltwater erosion (Fader et al., 1998), which periodically downcut into Tertiary and younger strata (Fig. 3). The gently seaward-dipping Tertiary mudstone and sandstone strata were deposited as part of the shelf-building process. In the outer canyon, deep erosion cuts through Miocene sediments, almost reaching Wyandot Formation chalks at the top of the Cretaceous.

Glacial geology

Tertiary bedrock strata are blanketed by a series of mid-to late-glacial and recent marine sequences (King, 2001). Geological reconstruction of older undifferentiated glacial deposits is difficult, because of multiple phases of excavation and infilling of large valleys (50–200 m deep) by subglacial meltwater.

Figures 1 and 2 show deposits from the penultimate and last glacial episodes that extended to the edge of the continental shelf. Indirect dating of these deposits, using morphostratigraphic, crosscutting and sea-level relations, and loose bracketing by ^{14}C dating (infinite and early postglacial ages) elsewhere in the region (King, 2001), suggest a Late Wisconsinan age. These deposits are interpreted as largely sandy till with iceberg-scoured upper surfaces; however, massive sand progradation elsewhere on Sable Island Bank may suggest an alternate proglacial origin. The extent and timing of bank-crossing glaciers remain uncertain.

There is little evidence, even in the subsurface, for widespread Late Wisconsinan till on the western flank of The Gully; however, low-relief moraines on the eastern flank confirm that glacial ice occupied most of The Gully. The moraines mark final glacial ice stillstand retreat positions. It is interpreted that Late Wisconsinan ice filled The Gully to at least the position of the outermost moraine, but did not overtop the western flank, leaving a limited ice-free area on the bank top. The glacial ice maximum reached the shelf-break, forming a contiguous blanket of till, but leaving little depositional record. The relations between till in The Gully and bank-top glaciogenic deposits are unclear.

Glaciomarine mud appears absent on the eastern flank of The Gully. Sparse and low-resolution data hamper differentiation between till and glaciomarine deposits. The glaciomarine deposits have not been cored in The Gully; however, deposits collected in cores from Brandal basin, to the west, consist of cohesive clayey silt and sandy silt with a sparse cold-water fauna. They were primarily deposited by quiescent plumes and ice rafting. This depositional phase was occasionally punctuated by higher energy events, likely accelerated currents, influenced locally by topographic features.

Canyon building

Renewed canyon building followed glacial retreat from The Gully, partially removing glacial and older sediments and accumulating canyon deposits. The canyon infill has a chaotic seismic signature and hummocky morphology, suggesting multiple failures (Fig. 3). Bracketing of this early canyon infill by glaciogenic deposits suggests a proximal glacial origin (Fig. 2, 3).

Renewed canyon building was concurrent with, and followed, by glaciomarine deposition (Fig. 2), largely as local basinal or canyon tributary infill. The proglacial marine muds partially infill the canyon flanks and heals some of the rough terrain (Fig. 1). This suggests a slowdown in canyon building, constraining the timing of maximum activity to a short period immediately following glacial retreat from The Gully.

Late glacial

An aggraded and prograded marine outwash apron was deposited along the southwestern flank of The Gully, after complete retreat of glacial ice. This apron is comprised of ice-distal silty sand rooted in a large sandy moraine crossing north-central Sable Island Bank. This moraine was formed during a late-glacial re-advance across nearby Brandal basin (King, 2001), but not into The Gully.

As ice retreated out of Brandal basin, largely removing the source of glaciomarine sediments, a significant erosional event occurred marked by a seabed unconformity across much of the western part of The Gully. While this represents the latest major geological event on the western flank, it was followed by local glaciogenic deposition much farther west in Brandal basin.

Recent deposits

Early postglacial age sand transport was active on the banks adjacent to The Gully. Three successive prograding sand sheets (Fig. 1, 2) on Sable Island Bank represent transport episodes with progressive postglacial sea-level rise, the latest probably reflecting modern conditions. As the sand sheets developed, they modified sand transport pathways into The Gully. The large, lowermost sheet obstructed sand supply to the northern flanking canyons, largely starving them while ensuring a sand supply to the southern canyons (Fader and King, 2003).

The presence of sand on the canyon floor suggests sediment transport to the canyon, despite average westward flow directions in the upper western part of The Gully. This sand is partially derived from these sand sheets, via the canyon thalwegs, as turbidity-current events; however, a major sand influx came from the floor of the upper reaches of The Gully. This sand likely came from Banquereau and sublittoral and erosional processes reworking glacial deposits on topographic highs in the upper part of The Gully and Brandal basin.

The general asymmetry of bedforms on the flanks of the upper part of The Gully indicates sediment transport directions. Transport directions are generally northwestward in the west and southward in the east. Well preserved and superimposed ripples on seabed photographs suggest periodically active bottom currents. Wave- and tidal-generated seabed stress models do not predict flows large enough to mobilize sand in the upper part of The Gully (C.G. Hannah, pers. comm., 2006). Ephemeral, tidally forced internal waves, or shelf-wide prolonged storm winds may have produced flows large enough to generate these bedforms.

A current-generated lag deposit is widespread within The Gully, but is generally too thin to be resolved on seismic profiles. An attempt has been made to map these lag deposits only where they are measured or inferred to be greater than 1 m thick. Grain size of this lag deposit ranges from sand-sized particles to boulders.

Conditions have never allowed significant deposition of Holocene mud, typical of other basins on the shelf. This is likely because of distance from source and continued high-energy levels from bottom currents.

GEOLOGICAL FEATURES

The glacial features in The Gully have been modified under the modern regime of oceanic currents, and sediment transport and deposition. In spite of this modification, a number of features remain prominent at the seafloor.

Moraines

A succession of curvilinear ridges, with the outermost over 30 m in height, occurs on the eastern flank of The Gully. Fader and King (2003) interpreted these ridges as recessional moraines, further suggesting they were evidence of glacial ice advance to the shelf edge. These features consist of gravel-lag-covered till (Fader and King, 2003). Similar moraines are not present on the western flank of The Gully and may have been covered by younger deposition. Lobate moraines up to 8 m in height occur in shallower northern areas of The Gully.

Scours, pits, and pockmarks

Iceberg scours and pits occur on both flanks of The Gully, near the shelf break. They were interpreted by Fader and King (2003) to have formed during Late Wisconsinan ice recession, in till. These scours can reach depths of 10 m.

Pockmarks have been identified in and around the iceberg scours and pits on the western flank of The Gully. These features have been interpreted by Fader and King (2003) as active gas-escape features. They can be over 2 m deep and several hundred metres in diameter.

Bedforms

Several sublittoral sandwave fields occur as elongated bodies parallel to the broad valleys on either side of the upper part of The Gully. These sandwaves are typically 2–4 m high, but can reach a maximum of 10 m. They have a typical wavelength of 100 m, with a maximum of 400 m. These transverse-flow bedforms occur in water depths ranging from 150 m to 310 m. They may be evidence of sand transport into The Gully.

Slumps

The upper part of The Gully is interpreted to have slump blocks, debris fields, headwall scarps, and sharp canyon edges associated with slumps. Slumping mechanisms and history of The Gully are not fully understood.

ACKNOWLEDGMENTS

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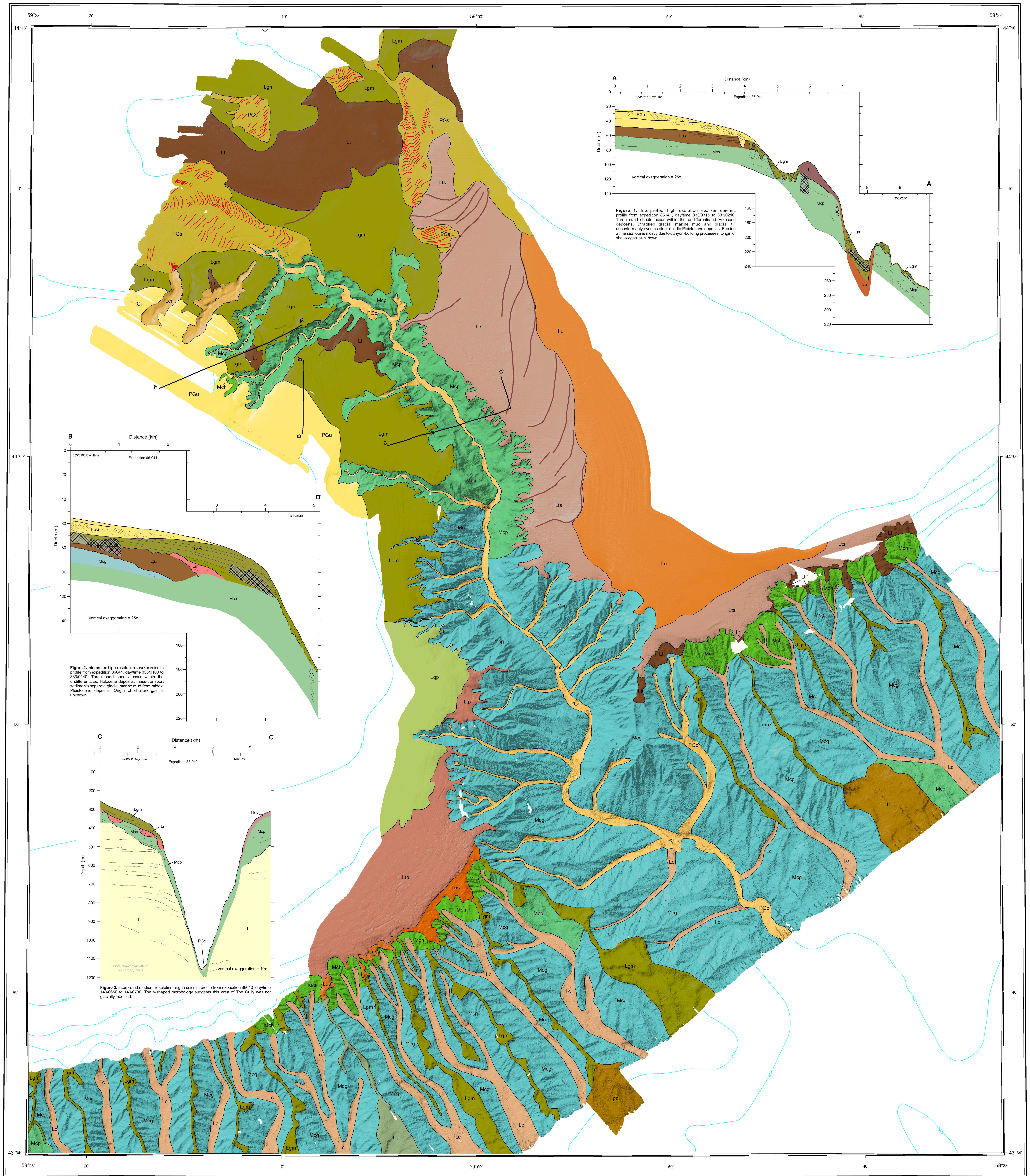


Figure 1. Interpreted high-resolution sparker seismic profile from expedition 86041, day/time 333/0315 to 333/0210. Three sand sheets occur within the undifferentiated Holocene deposits. Stratified glacial marine mud and glacial till unconformably overlies older middle Pleistocene deposits. Erosion at the seafloor is mostly due to canyon-building processes. Origin of shallow gas is unknown.

Figure 2. Interpreted high-resolution sparker seismic profile from expedition 86041, day/time 333/0100 to 333/0140. Three sand sheets occur within the undifferentiated Holocene deposits, mass-transport sediments separate glacial marine mud from middle Pleistocene deposits. Origin of shallow gas is unknown.

Figure 3. Interpreted medium-resolution airgun seismic profile from expedition 88010, day/time 149/0650 to 149/0730. The V-shaped morphology suggests this area of The Gully was not glacially modified.

LEGEND

QUATERNARY

POSTGLACIAL SEDIMENTS

Postglacial sediments occur as a sand and gravelly sand layered over glacial sediments on the upper slope and nearby bank tops, and as well sorted fine- to medium-grained sand in the heads and thalwegs of major canyons within The Gully.

PGu — ***Undifferentiated holocene deposits:*** *predominately sand or gravelly sand greater than 1 m thick. They usually occur on bank tops in water depths between 100 m and 300 m, and overlie glacial deposit. These storm-reworked deposits were deposited during late Pleistocene and early Holocene sea-level rise (Fig. 1, 2). These deposits are equivalent to Sable Island Sand and Gravel as defined by King and Fader (1986).*

PGc — ***Canyon floor deposits:*** *up to 1 m thick or more of fine- to medium-grained sand deposited by resuspension and advection from the shelf during storms and sandy turbidity flows. These deposits occur at the heads of most canyons and in the thalweg of major canyons (Fig. 3).*

PGs — ***Sublittoral sand deposits:*** *well sorted, silty or gravelly sand. They occur in water depths greater than 120 m and may have bedforms. These sand deposits have an acoustically reflective seabed and may reveal coherent internal reflectors. These time-trangressive deposits are interpreted to be late glacial and Holocene. They are partially equivalent to the Sambro Sand as defined by King and Fader (1986).*

LATE PLEISTOCENE GLACIAL DEPOSITS (MARINE ISOTOPIC STAGES 2 TO 4)

In the marine environment glacial sediments are derived from fallout from proglacial plumes, deposition from sediment flows due to glacial processes (hyperpycnal and turbidity flows), ice contact, and subsequent modification of these deposits (deformation and erosion) that occurred during glacial periods.

Lgm — ***Glacial marine mud or sandy mud:*** *a late Pleistocene marine silt deposited in a proglacial or subglacial environment, possibly with ice-rafted debris. These acoustically stratified silt units occur mostly on the northern and western flanks of The Gully and on intercanyon ridges. A thin veneer of gravel and/or sand lag, less than 1 m thick, may overlie these deposits (Fig. 1, 3). This deposit is partially equivalent to the Emerald Silt as defined by King and Fader (1986).*

Lgc — ***Glacial marine mud (complex near-surface erosion):*** *acoustically incoherent mud with sparse ice-rafted debris with highly irregular seafloor morphology, formed through the repeated failure and evacuation of proglacial mud and the development of linear and arcuate failure scarps at several stratigraphic levels. Glacial-marine mud occurs on intercanyon ridges in water depths greater than 1500 m and on Sable Island Bank (Fig. 2).*

Lgp — ***Glacial marine mud with pockmarks:*** *late Pleistocene marine silt deposited in a proglacial or subglacial environment, possibly with ice-rafted debris. These acoustically stratified silt units occur mostly on the northern and western flanks of The Gully. Pockmarks occur at the seabed and are fluid-escape features that have disrupted the sediments. A thin veneer of gravel and/or sand lag, less than 1 m thick, may overlie these deposits.*

Lgi — ***Glacial marine mud with interbedded sand and mud:*** *acoustically stratified mud with interbedded sand and mud layers and sparse ice-rafted debris, formed through deposition from meltwater plumes interspersed with deposition from turbidity currents. These marine muds occur on intercanyon ridges in water depths greater than 1500 m.*

Lm — ***Mass-transport deposits (undifferentiated):*** *acoustically incoherent, poorly sorted mud and sandy mud with irregular seafloor morphology, formed through the repeated failure of proglacial deposits. Denotes areas where seabed failure occurred frequently during the Pleistocene. These deposits occur on intercanyon ridges over a range of water depths (unit only appears on Fig. 2 and 3).*

Lc — ***Canyon and channel-fill deposits:*** *acoustically incoherent, mass- transport deposits, alternating with mud to gravelly-sandy mud, found in channels and canyon floors.*

Lcr — ***Canyon sand-fill deposit:*** *drifting sand from Sable Island Bank and Brandal basin partially infills side canyons on the upper western flank of The Gully. Downcanyon sediment transport is interpreted to be inactive. Bedrock outcrop and boulder and gravel lag occur in places.*

Lt — ***Till:*** *poorly sorted subglacial sediment with a stony fraction in a sand, silt, clay matrix, deposited at the seaward limit of glaciers. This acoustically incoherent till, with interbedded mud and sand, is mostly absent on the western flank of The Gully, likely because it is covered by glacial silt. Some of this till may be morainic in origin. A veneer of boulders, gravel, and/or sand lag, less than 1 m thick, overlies these deposits in places. This till is associated with last glacial ice in The Gully (Fig. 1, 3). This deposit may be equivalent to the Scotian Shelf Drift as defined by King and Fader (1986).*

Lts — ***Till with iceberg scours and pits:*** *poorly sorted subglacial deposit with a stony fraction in a sand, silt, and clay matrix, deposited at the seaward limit of glaciers. This acoustically incoherent ice-turbated glacial till, with interbedded mud and sand, has iceberg scours and pits present at the seafloor. A veneer of boulders, gravel, and/or sand lag, less than 1 m thick, overlies these deposits in places.*

Ltp — ***Till with iceberg scours, pits, and pockmarks:*** *poorly sorted subglacial deposit consisting of a stony fraction within a sand, silt, and clay matrix. This acoustically incoherent, ice-turbated glacial diamict has iceberg scours, pits, and pockmarks present at the seafloor. A veneer of gravel, boulders, and/or sand lag, less than 1 m thick, overlies these deposits in places.*

Lu — ***Undifferentiated glaciogenic deposits:*** *till or glacial marine deposit. A veneer of gravel, boulders, and/or sand lag, less than 1 m thick, overlies these deposits in places (Fig. 1).*

Lus — ***Undifferentiated glaciogenic with iceberg scours and pits:*** *interpreted from multibeam data only, may consist of till or glacial-marine deposit. Seabed is ice scoured and pitted. A veneer of gravel, boulders, and/or sand lag, less than 1 m thick, overlies these deposits in places.*

MIDDLE PLEISTOCENE AND OLDER DEPOSITS (PREMARINE ISOTOPIC STAGE 5)

Middle Pleistocene and older deposits outcrop on canyon walls and at canyon heads due to erosion.

Mcg — ***Canyon-wall deposits (gullied):*** *predominantly overconsolidated mud formed through the burial and diagenesis of proglacial and hemipelagic deposits and subsequent exposure through gully erosion of canyon walls. Associated with the penultimate glacial phase (Fig. 2, 3).*

Mcp — ***Canyon-wall deposits (planar or retrogressive):*** *may consist of undifferentiated glaciogenic and lowstand deposits or overconsolidated mud formed through the burial and diagenesis of proglacial and hemipelagic deposits. Subsequent exposure is through mass-transport erosion of canyon walls and by downcanyon erosive flows (Fig. 1, 2, 3).*

Mch — ***Canyon-head deposits:*** *predominantly overconsolidated mud, in places with lesser silt and sand, formed through the burial and diagenesis of proglacial and hemipelagic deposits and subsequent exposure through headward erosion of a canyon.*

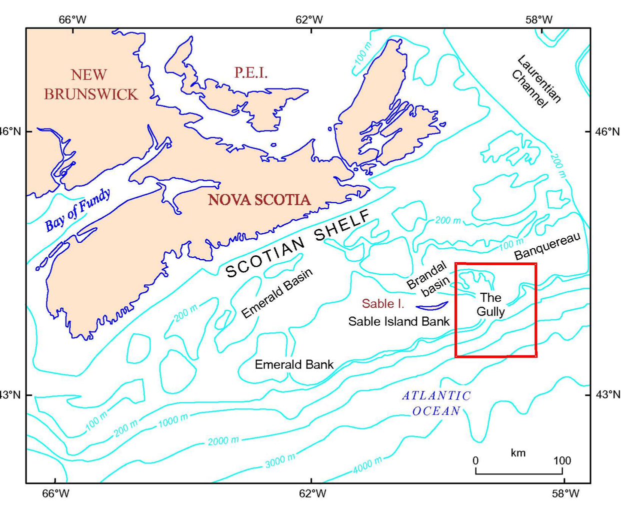
T — ***Tertiary bedrock:*** *consists of gently seaward-dipping mudstone and sandstone strata. May outcrop on canyon walls in The Gully (unit only appears on Fig. 3).*

Shallow gas masking or point sources (Fig. 1, and 2)

Moraine; late Pleistocene ice stillstand features on the eastern flank of The Gully.
Unrecognized on the western flank, likely because they are covered by proglacial silt. A veneer of gravel, boulders, and/or sand lag, less than 1 m thick, overlies these deposits in places

Sandwave crest lines; sublittoral sandwave fields with bedforms up to 10 m high.

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.



Copies of this map may be obtained
from the Geological Survey of Canada:
601 Booth Street, Ottawa, Ontario K1A 0E8
3303-33rd Street, N.W., Calgary, Alberta T2L 2A7
625 Robson Street, Vancouver, B.C. V6B 5J3
490, rue de la Couronne, Québec, Quebec G1K 9A9
1 Challenger Drive, P.O. Box 1006, Dartmouth, Nova Scotia B2Y 4A2

LOCATION MAP

MAP 2123A

SURFICIAL GEOLOGY AND SUN-ILLUMINATED SEAFLOOR TOPOGRAPHY

THE GULLY

SCOTIAN SHELF, OFFSHORE EASTERN CANADA

Scale 1:100 000/Échelle 1/100 000

kilometres 2 0 2 4 6 8 kilomètres

Authors: G.D.M. Cameron, E.L. King, and D.C. Campbell

Multibeam bathymetric data collected by M.Z. Li, and D.C. Campbell, Geological Survey of Canada (1996 – 1998); Canadian Hydrographic Services (2000) and C&C Technologies

Multibeam bathymetric data compiled by J. Strang, 2005

Digital cartography by G. Grant, GSC (Atlantic)

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

Universal Transverse Mercator Projection
North American Datum 1983

This map is not to be used for navigational purposes

Projection transverse universelle de Mercator
Système de référence géodésique nord-américain, 1983

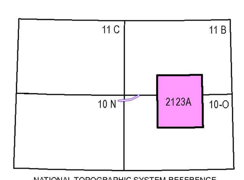
Cette carte ne doit pas être utilisée aux fins de navigation

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

Mean magnetic declination 2008, 18°55'W, decreasing 9.3' annually. Readings vary from 18°49'W in the SW corner to 19°01' in the NE corner of the map

Depth in metres below sea level

Published 2008



NATIONAL TOPOGRAPHIC SYSTEM REFERENCE

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2008: Surficial geology and sun-illuminated seafloor topography, The Gully, Scotian Shelf, offshore eastern Canada; Geological Survey of Canada, Map 2123A, scale 1:100 000.

Canada