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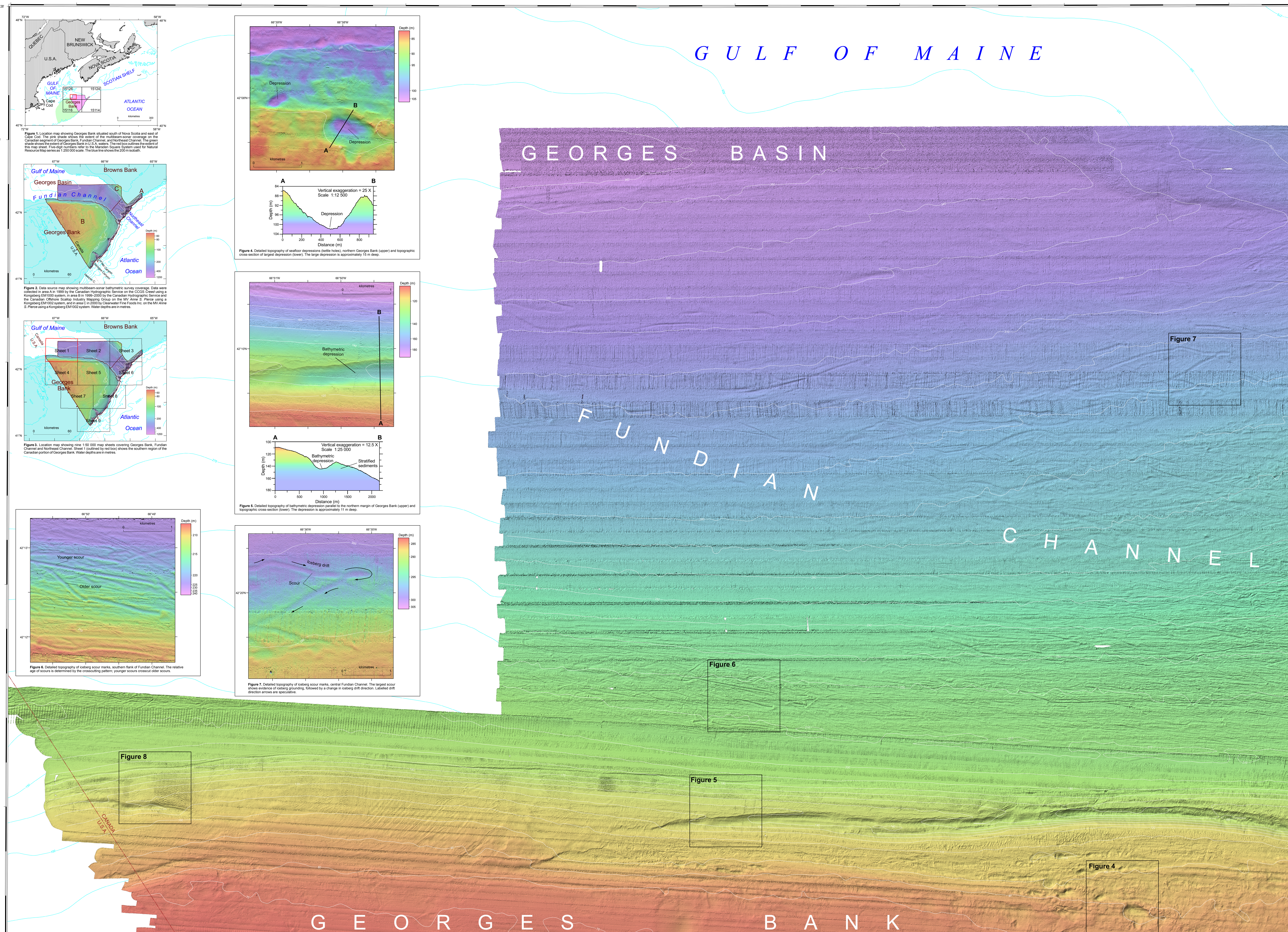


DESCRIPTIVE NOTES

INTRODUCTION

Georges Bank is a shallow submarine bank that lies south of Nova Scotia and east of Cape Cod, Massachusetts and bounds the seaward side of the Gulf of Maine (Fig. 1). Water depths on the bank range from less than 5 m to 200 m. The bank is approximately 280 km long and 150 km wide, and has an area of 42 000 km^2 in water depths less than 200 m. The Fundian Channel and Georges Basin bound Georges Bank to the north; Northeast Channel bounds the bank to the northeast and separates it from Browns Bank on the Scotian Shelf (Fig. 2). The international boundary between Canada and the United States transects Georges Bank, and the eastern part of the bank (~7500 km^2) lies in Canadian territory and is the subject of this map series (Fig. 3).

The bank waters are characterized by energetic tidal currents associated with the near resonance that exists between the principal lunar semidiurnal tidal component (M_2) of the tide that represents 90% of the bank's tidal energy and the natural oscillation period of approximately 13 hours of the Bay of Fundy–Gulf of Maine system (Brown and Moody, 1987; Greenberg, 1990). The major axis of the semidiurnal tidal current ellipse is oriented northwest-southeast across the bank, and the amplitude of this current near the seabed increases from less than 10 cm/s along the deeper southern flank to greater than 100 cm/s on the relatively shallow northern edge of the bank (Butman and Beardsley, 1987). On the shallowest portions of Georges Bank (<50 m), tidal currents are so strong that complete vertical mixing of the water column occurs throughout the year (Butman and Beardsley, 1987). These strong currents also form large sand bedforms (Jordan, 1962; Stewart and Jordan, 1964; Todd and Valentine, 2012) and continuously rework the surficial sediments, thereby removing most of the clay, silt, and fine-grained sand and leaving coarse-grained sand and gravel (Twichell et al., 1987; Butman, 1987).

This map is one of a series that show seafloor topography of the Canadian segment of Georges Bank, Fundian Channel, and Northeast Channel in shaded-relief view (depth coded by colour) at a scale of 1:50 000. This topographic map has a companion map of backscatter strength that shows the relative reflectivity of the seafloor substrates in response to sound waves (backscatter strength) that will be published separately (B.J. Todd, P.C. Valentine, and J. Shaw, work in progress, 2012). Together, the shaded seafloor topography and backscatter strength maps provide a basis for interpreting the origin of seafloor features and the nature of materials that form the seafloor. The maps are based on multibeam-sonar surveys conducted in 1999 and 2000 to map 11 965 km^2 of the seafloor (Fig. 3). On this map, water-depth contours were computer-generated from the multibeam-sonar data and are shown (in white) on the colour-coded water-depth image at a depth interval of 10 m for water depths less than 200 m and at an interval of 100 m for water depths greater than 200 m. Bathymetric contours (in blue) outside the multibeam survey area on this sheet, presented at a depth interval of 25 m, are from the Natural Resource Map series (Canadian Hydrographic Service, 1966, 1967, 1971, 1972); and bathymetric contours in Figures 1–3 are from the same sources.

The complete series of Georges Bank, Fundian Channel, and Northeast Channel seafloor topographic maps comprises nine adjacent map areas at a scale of 1:50 000 (Fig. 3). In total, eighteen maps constitute the Georges Bank, Fundian Channel, and Northeast Channel map suite (two maps showing seafloor topography and backscatter strength per map area).

MULTIBEAM-SONAR BATHYMETRY DATA COLLECTION

Multibeam-sonar water-depth data are the basis for the seafloor shaded topographic map. The data were collected as a collaborative effort between the Canadian Hydrographic Service (CHS), the Geological Survey of Canada (GSC), the Canadian Offshore Scallop Industry Mapping Group, and the Ocean Mapping Group of the University of New Brunswick. The survey systems use multiple sonar beams angled downward and outward (from a location on the ship's hull) to ensonify a narrow strip of seafloor across the ship's track. The travel times of the outgoing sound waves and returning echoes from the seafloor are used to calculate the water depths of the ensonified area (Courtney and Shaw, 2000). On Georges Bank, the width of the seafloor swath imaged along each survey line was two to five times the water depth; in the deeper water of Fundian Channel, the ensonification width increased to five to six times the water depth. Line spacing was approximately three to four times water depth to provide up to 100% ensonification overlap between adjacent lines. Areas shown in white within the surveyed areas are places where no multibeam data were collected. Surveys were conducted as follows:

- by the CHS in Northeast Channel in 1999 (area A, Fig. 2), using the Canadian Coast Guard Ship (CCGS) *Frederick G. Creed*, a SWATH (Small Waterplane Area Twin Hull) vessel equipped with a Kongsberg EM1000 multibeam-sonar bathymetric survey system with 60 beams operating at 95 kHz arrayed over an arc of 150° with the transducer mounted in the starboard pontoon,
- by the CHS and the Canadian Offshore Scallop Industry Mapping Group on Georges Bank in 1999 and 2000 (area B, Fig. 2), using the MV *Anne S. Pierce* equipped with a Kongsberg EM1002 multibeam-sonar bathymetric survey system with 111 beams operating at 95 kHz configurable over an arc of up to 150° with the transducer mounted on a ram extended beneath the hull, and
- by Clearwater Fine Foods, Inc. in Fundian Channel in 2000 (area C, Fig. 2), using the MV *Anne S. Pierce* equipped as described above.

The Global Positioning System (with differential corrections) was used for navigation and provided a positional accuracy of ±3 m. Survey speeds averaged 14 knots (26 km/h) on the CCGS *Creed* resulting in an average data collection rate of about 48 km^2/h in water depths of 250 m. Survey speeds averaged 6 knots (11 km/h) on the MV *Anne S. Pierce* resulting in an average data collection rate of about 6.6 km^2/h in water depths of 80 m. Sound velocity profiles were collected at regular intervals during multibeam-sonar bathymetric data collection and were used to correct the data for refraction of the sonar beams due to density stratification in the water column. The bathymetric data were adjusted for tidal variation using an innovative tidal model that was developed for the seafloor mapping project by the Ocean Sciences Division of Fisheries and Oceans Canada at the Bedford Institute of Oceanography. The bathymetric data were processed using software developed by the Ocean Mapping Group at the University of New Brunswick.

BATHYMETRIC DATA DISPLAY

The multibeam-sonar bathymetric data are presented at 5 m per pixel horizontal resolution on Georges Bank and 10 m per pixel horizontal resolution in Fundian Channel and Northeast Channel. The shaded-relief topographic image is presented with a vertical exaggeration of the bathymetry of 10 times and an artificial illumination of the relief by a virtual light source positioned 45° above the horizon at an azimuth of 315°. In the resulting image, topographic features are enhanced by strong illumination on the northwest-facing slopes and by shadows cast on the southeast-facing slopes. Superimposed on the topographic image are colours assigned to water depth, ranging from red (shallow) to violet (deep). In order to apply the widest colour range to the most frequently occurring water depths, hypsometric analysis was used to calculate the cumulative frequency of water depth. Each figure has a unique colour ramp, and the colour ramp for an inset map showing topographic detail may differ from the colour ramp used for the main map. The resulting colour ramp highlights subtle variations in water depth that would otherwise be obscured.

Some features in the multibeam data are artifacts of data collection and environmental conditions during the survey periods. The orientation of the survey track lines can, in some instances, be identified by faint parallel stripes in the image. Because these artifacts are usually regular and geometric in appearance on the map, the human eye can disregard them and distinguish real topographic features.

GEOMORPHOLOGY OF GEORGES BANK, FUNDIAN CHANNEL, AND NORTHEAST CHANNEL

Physiographic setting

Georges Bank flanks the seaward side of the Gulf of Maine and rises more than 300 m above the Gulf of Maine seafloor (Fig. 1, 2). Most of the Canadian portion of Georges Bank has water depths between 60 m and 90 m (Canadian Hydrographic Service, 1990, 1997; Valentine et al., 1992), but depths shallow to 42 m near 42°N, 67°W. The bank surface gradually deepens seaward and has an average slope of less than 0.05° (0.9 m/km). The 200 m isobath along the southeastern margin of Georges Bank approximates the continental shelf break (Fig. 1). Seaward, water depths increase down the continental slope, which has an average slope of 7° (123 m/km). The seaward margin of the bank in Canada is incised by a number of submarine canyons, the largest of which are Corsair and Georges canyons (Fig. 2).

Georges Bank is bounded to the north by the Fundian Channel which comprises Northeast Channel to the east and Georges Basin to the west (Fig. 2). Georges Basin is the deepest portion of the Gulf of Maine with a maximum depth of 377 m. The Fundian Channel north of Georges Bank is approximately 45 km wide and is bounded to the north by Browns Bank on the Scotian Shelf. The Fundian Channel narrows southeastward into Northeast Channel, which is approximately 28 km wide. The seaward sill depth in Northeast Channel is 232 m, and the channel mouth is incised by submarine canyons (Fig. 2).

Recent geological history

Seismic-reflection profiles show that beneath the surface of Georges Bank there is a prominent unconformity formed on late Cretaceous and Tertiary sedimentary rocks (King and MacLean, 1976; Lewis et al., 1980). The surficial sediment overlying the unconformity is glacial debris transported to Georges Bank and other Gulf of Maine banks during the late Pleistocene epoch from continental areas to the north (Shepard et al., 1934, Knott and Hoskins, 1968; Oldale and Uchupi, 1970; Schlee, 1973; Schlee and Pratt, 1970; Fader, 1984; Fader et al., 1988; Todd et al., 2007). During the postglacial Holocene epoch (~12 000 years before present), sea level rose from a low stand 120 m below the present sea level (Emery and Garrison, 1967; King and Fader, 1986), and the bank was submerged about 6000 BP (radiocarbon years) (Shaw et al., 2002). Georges Bank surficial sediments were reworked by marine processes during sea-level transgression and continue to be reworked under the modern oceanic regime (Twichell et al., 1987; Valentine et al., 1993).

The present morphology of the Gulf of Maine, Georges Bank, and the Fundian and Northeast channels mapped here displays the imprint of multiple glaciations during the Pleistocene epoch (~12 000 years ago to 2.5 million years ago). During the last glaciation of the Pleistocene, the Wisconsinan, the Laurentide Ice Sheet extended southeastward from central Canada across Maritime Canada and New England to the present northern margin of Georges Bank and the continental shelf edge off Nova Scotia and the Fundian and Northeast channels were a major outlet for glacial ice to the Atlantic Ocean (Shaw et al., 2006). Based on the mapping of glacial gravel collected from the seabed in the Gulf of Maine region, Schlee and Pratt (1970) reported that glacial ice lapped onto the northern margin of Georges Bank.

Geomorphology of Sheet 1

The northwest margin of the Canadian portion of Georges Bank, western Fundian Channel, and southern Georges Basin are shown on this map at a scale of 1:50 000. Inset maps at a scale of 1:25 000 (Fig. 4–8) highlight geomorphological features typical of the area. For each of these, the colour-range values are hypsometrically optimized and differ from the colour-range values of the 1:50 000 scale map sheet.

On the bank, at depths less than 70 m to approximately 80 m, the seafloor is relatively smooth and featureless. The lack of bedforms in this area, known for strong tidal currents, suggests that the seabed here is gravelly and that sand has been winnowed and transported downslope onto the bank margin.

In the southeastern part of the map sheet, in the 80–110 m depth interval, is a group of irregular depressions in the seafloor (Fig. 4). The largest depression is 1200 m across and approximately 15 m deep. These depressions are interpreted to represent kettle holes that formed when stagnant blocks of ice located in front of a melting glacial margin were partly buried by glacial outwash sediment and subsequently melted to leave depressions in the landscape.

Along the northern margin of Georges Bank in water depths from 120 m to 170 m, a curvilinear bathymetric depression, about 500 m wide, extends eastward from 66°52.5´W to 66°13.5´W (onto Sheet 2 of this map series, Todd et al., 2013), a distance of 59 km. This bathymetric depression (Fig. 5) marks the southern extent of northwest-dipping stratified sediments that may represent a grounding line wedge deposited from an ice sheet on the bank. In places, strong current action has winnowed fine-grained material and emphasized the edges of the sediment strata exposed at the seabed.

North of the relatively steep bank margin, the seafloor slopes gradually from 200 m to 360 m in Georges Basin and Fundian Channel. The seafloor here has been incised with an intersecting pattern of linear to curvilinear depressions, some over 5 km in length. The depressions, or scours, are interpreted to represent the ploughing of seabed sediment by the keels of icebergs calved from the front of a floating ice shelf during its retreat westward from the Fundian Channel into the Gulf of Maine during the deglaciation of the Laurentide Ice Sheet. The iceberg scour marks occur from approximately 200 m to 350 m water depth and are oriented generally west-east. Those in shallower water (Fig. 6) are numerous and relatively well defined. Many are approximately 1 m deep and 100 m wide, and the seafloor in places is completely scoured. In water deeper than 280 m (Fig. 7), scour marks are not as numerous, have a muted appearance, and are 1–2 m deep and generally wider (150 m or greater) than the scour marks in shallower water. As iceberg trajectory is dictated mainly by ocean-current direction (Todd et al., 1988; Bigg et al., 1996), these iceberg scour marks document a dominant west to east current flow direction in Fundian Channel during the last deglaciation.

Superimposed on seafloor features that have a glacial origin are postglacial sedimentary bedforms that occur intermittently in the 100–180 m depth interval. Crests of these bedforms form transverse to current flow with the steep slope facing downcurrent. The orientation of the features on the bank margin suggests they were formed by currents flowing to the north, downslope (Fig. 8).

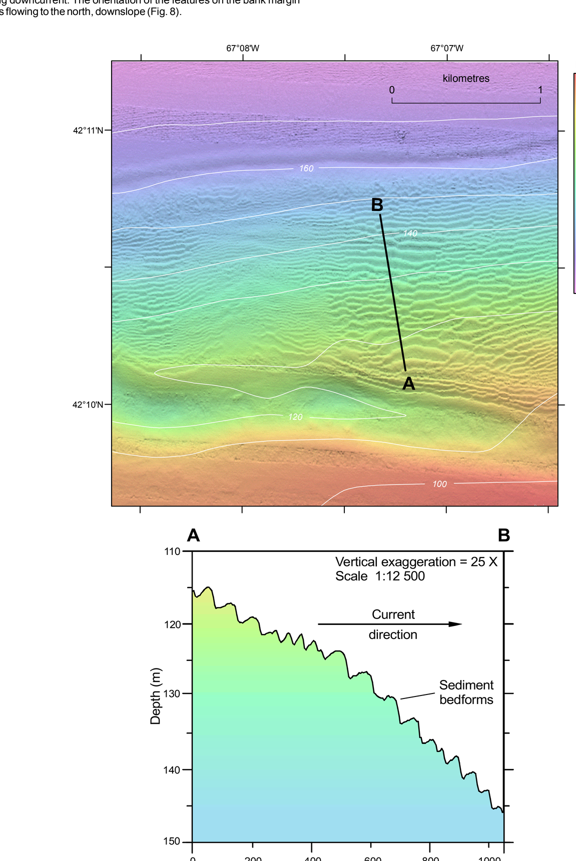
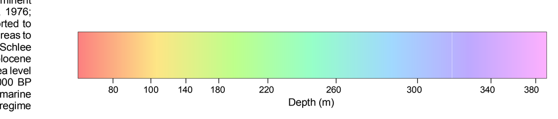


Figure 8. Detailed topography of flow-transverse sediment bedforms on the northern flank of Georges Bank (upper) and topographic cross-section (lower). The largest sand waves are about 3 m high and 90 m wide. Sandwave crests are oriented roughly east-west and their steep north-facing slopes suggest they were formed by currents flowing to the north, downslope.

ACKNOWLEDGEMENTS

REFERENCES



MAP 2191A

SHADED SEAFLOOR RELIEF

GEORGES BANK, FUNDIAN CHANNEL, AND NORTHEAST CHANNEL; SHEET 1

GULF OF MAINE

Scale 1:50 000/Échelle 1/50 000

kilometres 1 0 1 2 3 4 kilomètres

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

Authors: B.J. Todd[1], P.C. Valentine[2], and J. Shaw[1]
[1]Geological Survey of Canada
[2]U.S. Geological Survey

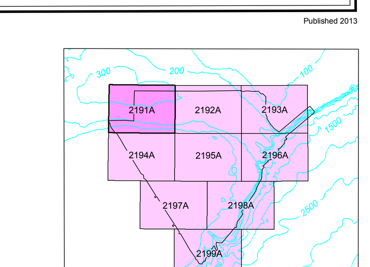
This map was produced by Natural Resources Canada in co-operation with Fisheries and Oceans Canada

Multibeam bathymetric data collected by Canadian Hydrographic Service, Canadian Offshore Scallop Industry Mapping Group, and Clearwater Fine Foods Inc.,1999–2000

Multibeam bathymetric data compiled by Canadian Hydrographic Service and Geological Survey of Canada, 1999–2007

Digital cartography by P. O'Regan, Data Dissemination Division (DDD) and S. Hayward, GSC (Atlantic)


LOCATION MAP



Recommended citation
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