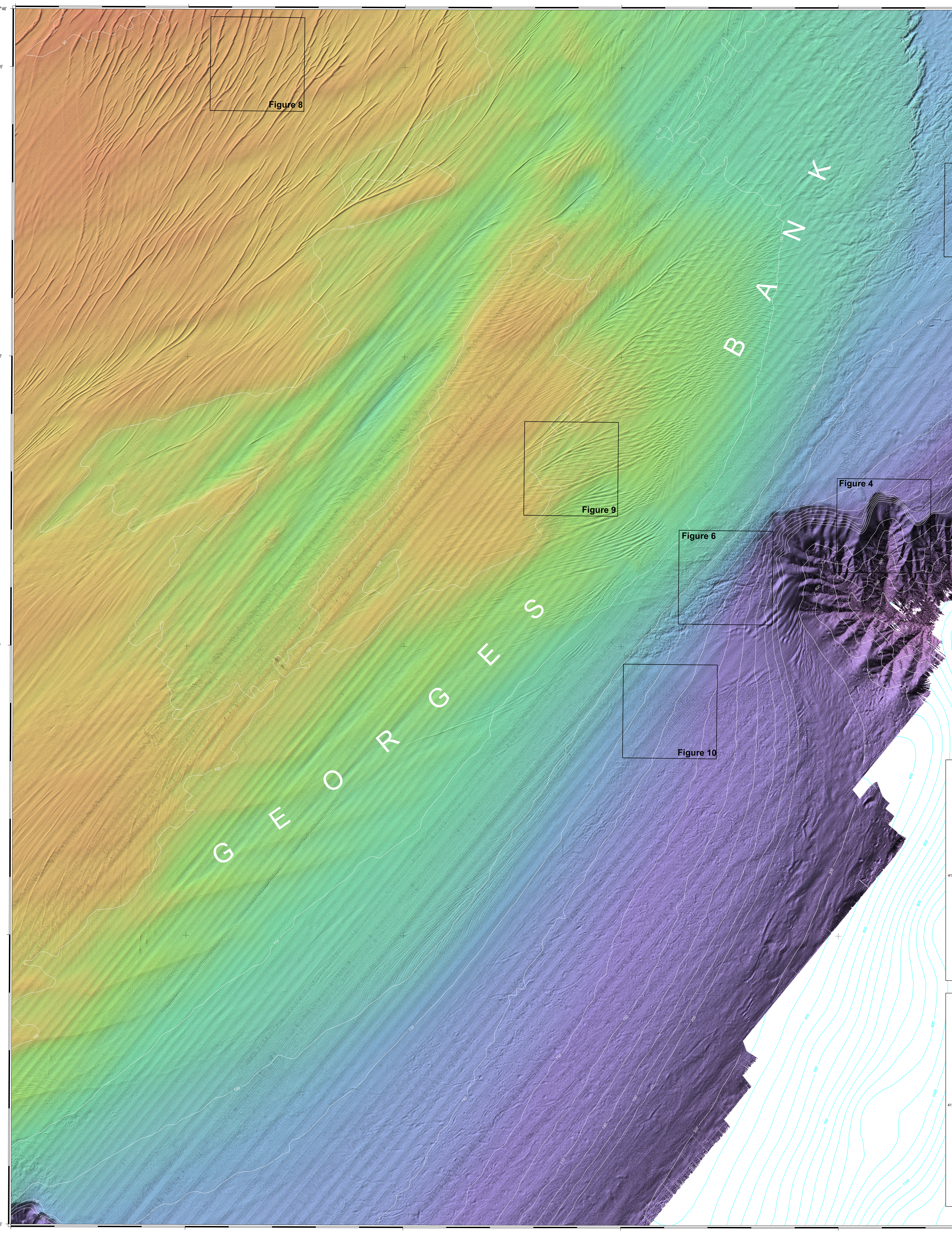
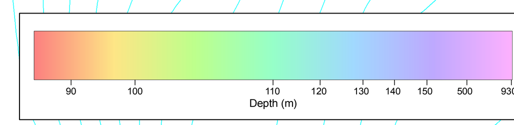
Government of Canada / Gouvernement du Canada

GEOLOGICAL SURVEY OF CANADA / COMMISSION GÉOLOGIQUE DU CANADA





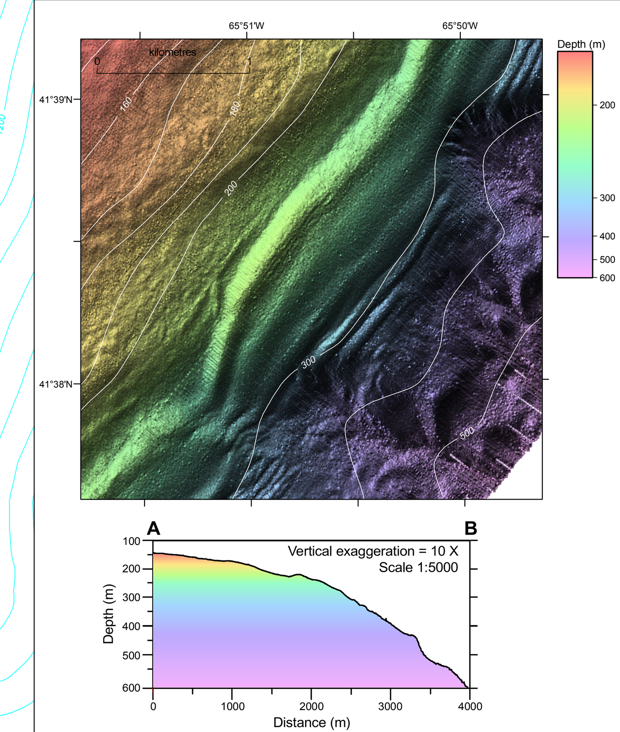


Figure 5. Detailed topography of sediment slumps on the continental shelf of Georges Bank (upper) and topographic cross-section (lower).

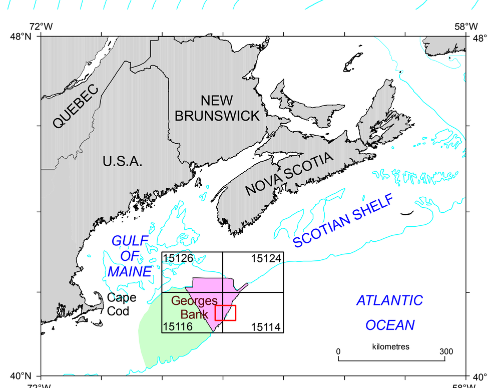


Figure 1. Location map showing Georges Bank situated south of Nova Scotia and east of Cape Cod. The pink shade shows the extent of the multibeam-sonar coverage on the Canadian segment of Georges Bank, Fundian Channel, and Northeast Channel. The green shade shows the extent of Georges Bank in U.S.A. waters. The red box outlines the extent of this map sheet. Five-digit numbers refer to the Marsden Square System used for Natural Resource Map series at 1:250 000 scale. The blue line shows the 200 m isobath.

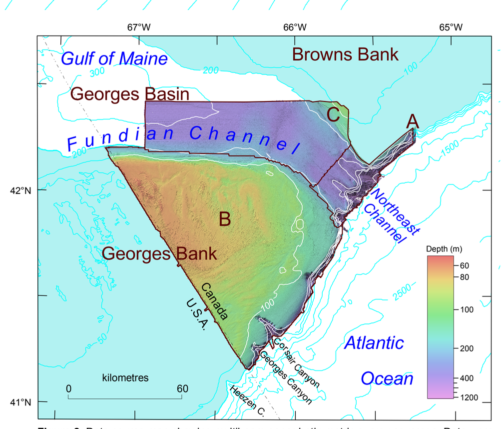


Figure 2. Data source map showing multibeam-sonar bathymetric survey coverage. Data were collected in area A in 1999 by the Canadian Hydrographic Service on the CCGS Creed using a Kongsberg EM1000 system, in area B in 1999–2000 by the Canadian Hydrographic Service and the Canadian Offshore Scallop Industry Mapping Group on the MV Anne S. Pierce using a Kongsberg EM1002 system, and in area C in 2000 by Clearwater Fine Foods Inc. on the MV Anne S. Pierce using a Kongsberg EM1002 system. Water depths are in metres.

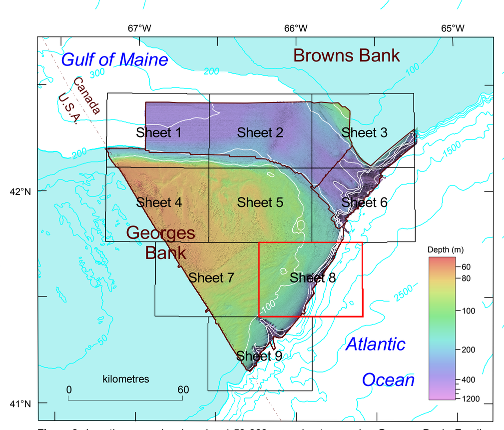


Figure 3. Location map showing nine 1:50 000 map sheets covering Georges Bank, Fundian Channel and Northeast Channel. Sheet 8 (outlined by red box) shows the southern region of the Canadian portion of Georges Bank. Water depths are in metres.

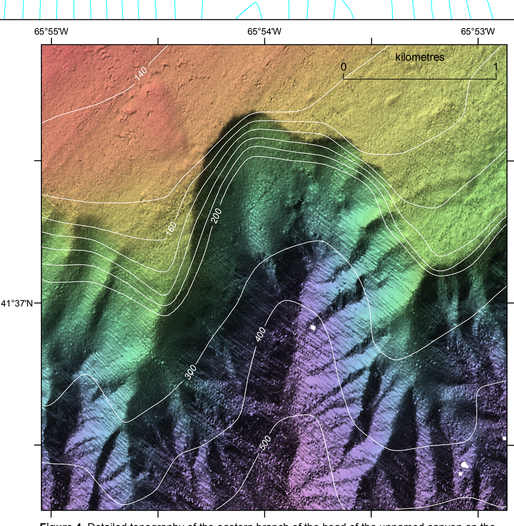


Figure 4. Detailed topography of the eastern branch of the head of the unnamed canyon on the southeastern margin of Georges Bank. This part of the canyon incises Georges Bank to a water depth of about 150 m.

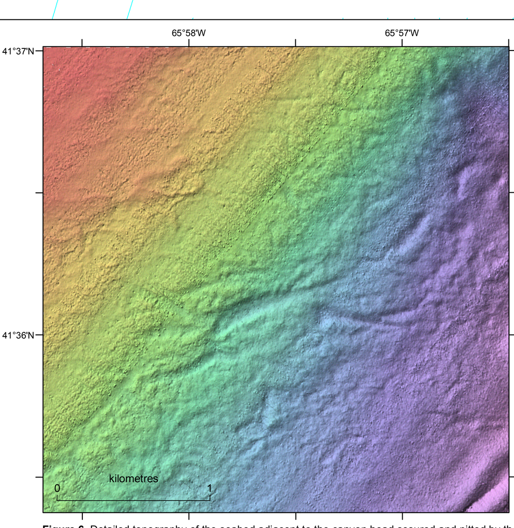


Figure 6. Detailed topography of the seabed adjacent to the canyon head scoured and pitted by the grounding of iceberg keels.

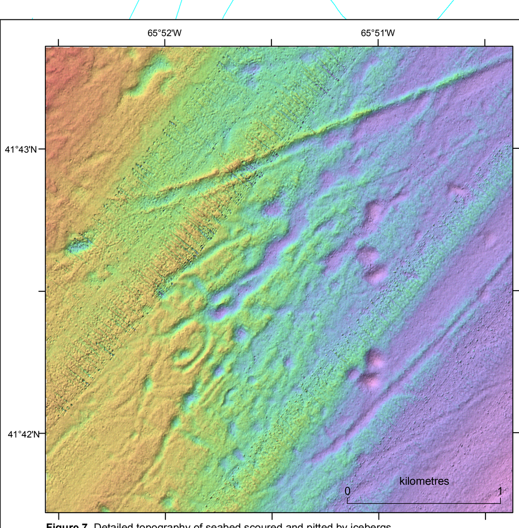


Figure 7. Detailed topography of seabed scoured and pitted by icebergs.

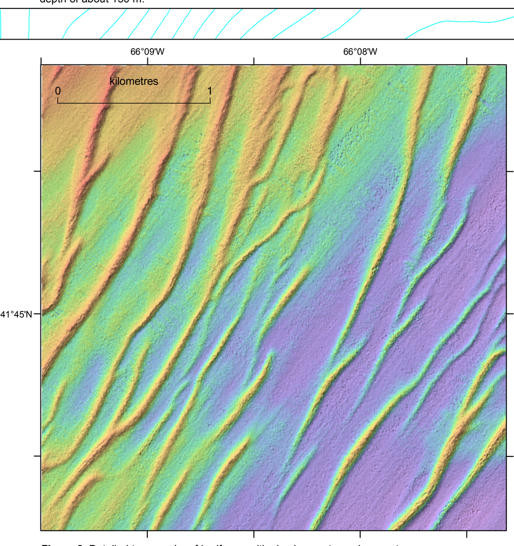


Figure 8. Detailed topography of bedforms with simple anastomosing crests.

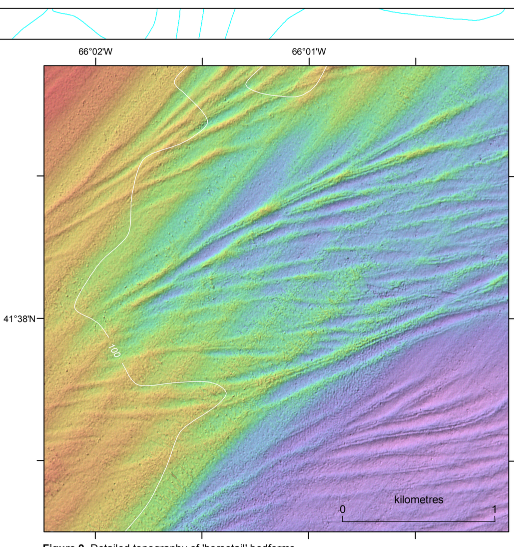


Figure 9. Detailed topography of 'horsetail' bedforms.

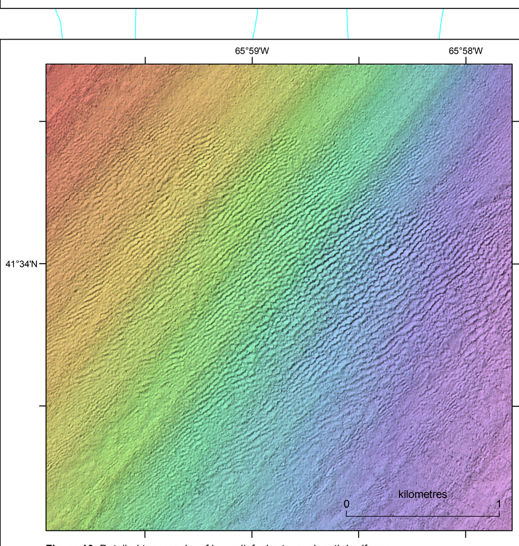


Figure 10. Detailed topography of low-relief, short-wavelength bedforms.

LOCATION MAP

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)

MAP 2198A

SHADED SEAFLOOR RELIEF

GEORGES BANK, FUNDIAN CHANNEL, AND NORTHEAST CHANNEL; SHEET 8

GULF OF MAINE

Scale 1:50 000/Échelle 1/50 000

Universal Transverse Mercator Projection
North American Datum 1983
© Her Majesty the Queen in Right of Canada 2013
This map is not to be used for navigational purposes

Projection transverse universelle de Mercator
Système de référence géodésique nord-américain, 1983
© Sa Majesté la Reine du chef du Canada 2013
Cette carte ne doit pas être utilisée aux fins de navigation

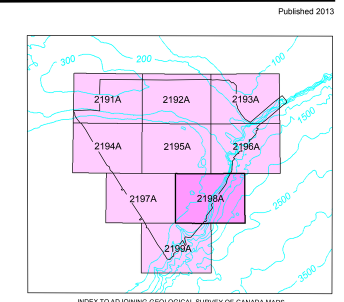
Any revisions or additional information known to the user would be welcomed by the Geological Survey of Canada

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

Magnetic declination 2013, 16°33'W, decreasing 5.7' annually

Some geographical names subject to revision

Depth in metres below mean sea level



INDEX TO ADJOINING GEOLOGICAL SURVEY OF CANADA MAPS

Published 2013

Canada

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 8

The east-central region of the Canadian portion of Georges Bank is shown on this map at a scale of 1:50 000. Inset maps at a scale of 1:25 000 (Fig. 4–9) highlight geomorphological features typical of the region. For each of these detailed maps, the colour-range values are hypsometrically optimized and differ from the colour-range values of the 1:50 000 scale map.

A prominent feature on this map is the head of an unnamed submarine canyon that incises the continental shelf and slope of Georges Bank. The canyon head extends to the 130 m isobath on the shelf, and water depths in the canyon reach more than 700 m in the mapped region. The walls of the canyon are incised by gullies with interposed ridges (Fig. 4).

Along the bank margin northeast of the canyon to 41°41´N, subparallel rounded ridges up to 6 m high are present below the shelf break in the 200–300 m depth interval (Fig. 5). These features are interpreted to represent the early stages of sediment slumping. Similar features are present in the southwestern part of the canyon head.

The Georges Bank seafloor both south and north of the canyon has been incised with linear to curvilinear depressions and circular to oval pits (Fig. 6, 7). The depressions, or scours, and pits are interpreted as evidence of the dragging of the keels of icebergs on the seabed. Most of the scour marks have a muted appearance, whereas a few of the longest scours (3–8 km) show a well defined morphology (Fig. 7). The scours are oriented generally northeast-southwest. As iceberg trajectory is dictated mainly by ocean current direction (Todd et al., 1988; Bigg et al., 1996), a northeast to southwest current direction is inferred for the continental margin of Georges Bank during the last deglaciation. These icebergs may have calved from the front of the floating ice shelf in the Gulf of Maine and drifted out Northeast Channel and thence southwestward along Georges Bank.

North of the submarine canyon, iceberg keel marks are present in the 110 m to 160 m depth interval. North of 41º43´N, terminations of scour marks are associated with an irregular scarp-like linear feature of low relief at 120 m water depth that may delineate the position of a Wisconsinan glacial or postglacial shoreline. This feature extends northward into Sheet 5 of this map series (Todd et al., 2013a). South of the canyon, iceberg scour marks are present in the 130 m to more than 300 m depth interval.

A large area of this map, in the 90–110 m depth interval, dips very slightly seaward and is covered with sediment bedforms. In the northwest portion of the map at depths from 90 m to 100 m, sediment bedforms with well defined crestlines form a simple anastomosing pattern in plan view with an overall northeast–southwest orientation, normal to the direction of dominant residual current flow, which is generally to the southeast. These bedforms range in height from a few decimetres to over 10 m (Fig. 8). At somewhat deeper depths to 110 m, bedforms are smaller and form 'horsetail' patterns of subparallel curvilinear crestlines that converge to the northeast and have heights of less than 1 m (Fig. 9). A small isolated field of low-relief, short-wavelength bedforms is present southwest of the canyon head on the outer part of the bank (Fig. 10).

A small portion of the head of Corsair Canyon is present in the southwestern corner of the map. *See* Sheet 9 of this map series for a map of the canyon (Todd et al., 2013b).

ACKNOWLEDGMENTS

K. Paul of the Canadian Hydrographic Service (CHS) organized the multibeam-sonar bathymetric survey of the Northeast Channel. M. Lamplugh and G. Costello (CHS) organized the multibeam-sonar bathymetric survey of Georges Bank in co-operation with the Canadian Offshore Scallop Association Industry Mapping Group. D. Beaver of the Geological Survey of Canada (GSC) participated in the Fundian Channel multibeam-sonar survey undertaken by Clearwater Fine Foods Inc. The Georges Bank and Fundian Channel maps are based on multibeam-sonar data used in agreement with the Canadian Offshore Scallop Association Industry Mapping Group and Clearwater Fine Foods Inc. Multibeam-sonar data were processed by CHS and GSC. The authors thank the master and crew of the CCGS *Frederick G. Creed* and of the MV *Anne S. Pierce* for their efforts at sea. Geographical Information Systems and cartographic support was provided by P. O'Regan (Data Dissemination Division, Natural Resources Canada), S.E. Hayward, E. Patton, W.A. Rainey, and S. Hynes (GSC). Scientific reviews of the map were undertaken by G.D.M. Cameron (GSC), and L.J. Poppe and K.M. Scanlon (both U.S. Geological Survey). Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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