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 km² 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 km²) lies in Canadian territory and is the subject of this map series (Fig. 3). 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

The bank waters are characterized by energetic tidal currents associated with the near resonance 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 multibeamsonar surveys conducted in 1999 and 2000 to map 11 965 km² of the seafloor (Fig. 3). On this map, waterdepth 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 km²/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 km²/h in water depths of 80 m. Sound velocity profiles were collected at regular intervals during multibeamsonar 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

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 shadedrelief 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 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

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 7 The west-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 sheet. The most prominent features on this map sheet are extensive fields of flow-transverse sediment bedforms. They exhibit a range of sizes and morphologies that vary with water depth and presumably are directly related to the strength of current flow at the seabed. Crest lines are oriented northeast-southwest, normal to the dominant current flow, which is generally to the southeast. In the northwestern portion of the map area (70 m to ~80 m water depth), sediment bedforms range in height from a few decimetres to over 10 m. Some are single-crested (Fig. 4), some display a simple to complex anastomosing crest pattern (Fig. 4, 5), and some, more rarely, display a barchan-like, crescent-shaped morphology (Fig. 6). In the central portion of the map area (80 m to 90 m water depth), parallel, relatively straight bedform crests are very long and narrow with heights of approximately 1.5 m and wavelengths of approximately 100 m (Fig. 7). In the southeastern portion of the map area (90 m to <100 m water depth), 'horsetail' patterns of sediment bedforms occur. The crests these bedforms are subparallel, curvilinear, converge to the northeast, and have heights of less than 1 m (Fig. 8). In the southern portion of the map area are several very shallow seabed depressions, enclosed by the 100 m isobath, in an almost flat seabed surface. The largest depressions exhibit a rough seabed characterized by possible iceberg pits that appear to be partially buried by sediment (Fig. 9). A small portion of the head of Corsair Canyon is present in the southeastern corner of the map area.

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AND NORTHEAST CHANNEL; SHEET 7 **GULF OF MAINE**

Scale 1:50 000/Échelle 1/50 000 Universal Transverse Mercator Projection Projection transverse universelle de Mercator North American Datum 1983 Système de référence géodésique nord-américain, 1983 © Her Majesty the Queen in Right of Canada 2012 © Sa Majesté la Reine du chef du Canada 2012 This map is not to be used for navigational purposes Cette carte ne doit pas être utilisée aux fins de navigation Digital bathymetric contours in metres supplied by Geological Survey of Canada Magnetic declination 2013, 16°22'W, decreasing 5.4' annually

Some geographical names subject to revision Depth in metres below mean sea level