DESCRIPTIVE NOTES

INTRODUCTION

The Bay of Fundy, located on the east coast of Canada between the provinces of Nova Scotia and New Brunswick (Fig. 1), is a macrotidal estuarine embayment (Amos et al., 1980) with the highest recorded tides in the world of 17 m (O'Reilly et al., 2005; Bishop, 2008). This map is one of a series of maps that show seafloor relief of the Bay of Fundy and topography of the surrounding areas in shaded-relief view (coded by colour) at a scale of 1:50 000. The maps are based on multibeam-sonar surveys completed between 1993 and 2009 to map 13 010 km² of the seafloor. Water-depth contours generated from the nultibeam-sonar data are shown (in white) on the colour-coded water-depth image at a depth interval of 20 m. Bathymetric contours (in blue) outside the multibeam survey area, presented at a depth interval of m, are from the Natural Resource Map series (Canadian Hydrographic Service, 1967, 1974a, b, c). he broad intertidal zone in the Bay of Fundy presented a particular surveying challenge to the collection of water-depth data. Historically, the intertidal zone was not surveyed due to the danger involved in operating vessels in coastal areas that dry between tides. As part of the multibeam-sonar mapping, the ntertidal zone was surveyed at high tide using shallow-draft survey vessels, thus overcoming operational challenges associated with deeper draft survey vessels. The complete Bay of Fundy seafloor relief map coverage is composed of seventeen adjacent map areas at a scale of 1:50 000 (Fig. 1). In total, fifty-one maps constitute the Bay of Fundy map suite (three

maps per map area: seafloor relief, backscatter strength, and surficial geology). MULTIBEAM BATHYMETRY DATA COLLECTION Multibeam-sonar water-depth data were collected by the Canadian Hydrographic Service, the Geological Survey of Canada, and the University of New Brunswick. The survey systems use a sonar

ourtney and Shaw, 2000). The width of seafloor imaged on each survey line was generally four times the water depth. Line spacing was about two to three times water depth to provide ensonification overlap between adjacent lines. The work employed a variety of survey vessels including: • the Canadian Coast Guard Ship (CCGS) Frederick G. Creed, a SWATH (Small Waterplane Area Twin Hull) vessel equipped with a Kongsberg EM1000 (prior to 2003) and a Kongsberg EM1002 (post-2003) multibeam-sonar bathymetric survey system with 111 beams operating at 95 kHz with the transducer mounted in the starboard pontoo

 the CCGS Matthew equipped with a Kongsberg EM710 multibeam-sonar bathymetric survey system with 200 or 400 beams operating at 70–90 kHz with the transducer mounted near the centre of the hydrographic survey launches Plover, Pipit, and Heron equipped with Kongsberg EM3000 (prior to 2005) and Kongsberg EM3002 (post-2005) multibeam-sonar bathymetric survey systems with 160 to

254 beams operating at 300 kHz. The Differential Global Positioning System was used for navigation and provided a positional accuracy of ±3 m. Survey speeds averaged 12 knots (22.2 km/h) on the CCGS Creed (and slower on the other survey vessels), resulting in an average data collection rate of about 2.5 km²/h in water depths of 35–70 m. The sound velocity in the ocean was measured during multibeam-sonar data collection and used to correct the effect of sonar-beam refraction. The 1992–2006 data were adjusted for tidal variation using tidal measurements and predictions from the Canadian Hydrographic Service. During the 2008 surveys, vessel elevations were also acquired using a combination of real-time kinematic GPS systems (Church et al., 2008) and hydrodynamic tidal models developed by the Canadian Hydrographic Service

BATHYMETRIC DATA DISPLAY

The multibeam-sonar bathymetric data are presented at 5 m per pixel horizontal resolution. The shadedrelief 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, bathymetric features are enhanced by strong illumination on the northwest-facing slopes and by shadows cast on the southeast-facing slopes. Superimposed on the shaded-relief 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. 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

BAY OF FUNDY GEOMORPHOLOGY

Minas Channel (Fig. 1). The floor of the bay, although hummocky in detail, presents a gently dipping profile along its axis from northeast to southwest. Grand Manan Island and its adjacent southeasteri shoals occupy nearly half the entrance to the bay, and divide it into two channels. Between Brier Island and Grand Manan Island lie several isolated depressions that together form Grand Manan Basin. The maximum water depth within these depressions is 233 m and the depth to the sill between Grand Manan Basin and the adjoining deeper parts of the Gulf of Maine is 160 m. The large tidal oscillations within this geomorphic setting are due to the near resonance between the principal lunar semidiurnal (M_2) component of the tide (representing 90% of the tidal energy) and the

natural period (about 13 hours) of the Bay of Fundy-Gulf of Maine system. Tidal current speeds are about 0.75–1 m/s over much of the outer and central portions of the bay, but are considerably higher within constricted channels and passages to the northeast (Greenberg, 1990).

Geomorphological features revealed through mapping of the Bay of Fundy seafloor reflect the geological history of the region. The Bay of Fundy is situated within the Carboniferous–Triassic lowland (Goldthwaite, 1924; Crosby, 1962; Williams et al., 1972) and is underlain by Triassic and Early Jurassic sandstone, shale, and basalt (Wade et al., 1996). Exposed bedrock has been modified by glacial erosion and exhibits a rugged surface. During the late Wisconsinan glacial maximum, culminating in the Gulf of Maine region at approximately 20 ka (20 000 BP), the Bay of Fundy was covered by a regional ice sheet that terminated to the south on the Scotian Slope (Schnitker et al., 2001; Hundert, 2003). The glacial maximum was followed by a multiphased retreat of the ice front. In the Gulf of Maine, ice-front retreat and glaciomarine deposition began as early as 18 ka. Grounded ice was absent from the Gulf of Maine and Bay of Fundy by approximately 14 ka (King and Fader, 1986; Schnitker et al., 2001; Shaw et al., 2006). The Bay of Fundy Moraines, drumlins, and megaflutes are topographically prominent. After grounded ice retreated from the area, icebergs scoured the seafloor in the waters east and south of Grand Manan Island. After deglaciation, relative sea level fell rapidly to a lowstand of about -30 m at ca. 7 ka (Amos and Zaitlin, 1985; Shaw et al., 2002) and then rose (Grant, 1970). From about 6.3 ka, tidal amplitude started to increase. This effect is continuing today (Godin, 1992). These high tides have resulted in large zones of erosion in areas with high current velocities such as Cape Split, Cape D'Or, and Cape Enrage (Fig. 1). Tidal eddies produced by headlands have created banner banks (Dyer and Huntley, 1999) on both sides of coastal promontories. Coastal erosion is up to 6 m/a in some areas (Amos et al., 1991). Sediment derived from this coastal erosion, coupled with sediment from seafloor erosion and sediment delivered by rivers, has contributed to the development of broad intertidal mud flats in the inner Bay of Fundy. The

Geomorphology of this map A series of detailed maps at a scale of 1:25 000 (Fig. 2–6) highlights Bay of Fundy geomorphological features. For each of these detailed maps, the colour-range values are hypsometrically optimized and differ from the 1:50 000 map sheet colour-range values. This map shows the bathymetry of the Bay of Fundy between Grand Manan Island and the approaches to Passamaquoddy Bay, encompassing the waters around Campobello Island (Fig. 1).
Grand Manan Basin lies to the east of Grand Manan Island. Water depths reach 160 m and the seabed is smooth and featureless. In contrast to this area of sediment accumulation, bedrock is exposed at the seafloor over much of Quoddy River between Campobello Island and Deer Island at the entrance to Passamaguoddy Bay. Off Indian Beach on northern Grand Manan Island is a sediment bank 1600 m long, with its long axis oriented southwest-northeast, 400 m wide, and up to 9 m thick (Fig. 2). Bedforms on the top of the bank have crests striking northwest and are 2–3 m in height with a wavelength of approximately 60 m. This banner bank (Dyer and Huntey, 1999) was formed by sediment transported and deposited under the

influence of currents in Grand Manan Channel. A moraine extends north from North Head on Grand Manan Island to The Wolves, unofficially named here the Owen moraine (Fig. 3). The moraine is lobate and convex to the east, indicating that it was formed by ice flowing east from Owen Basin. The moraine rises about 20 m above the adjacent seabed and its top displays iceberg pits. A pit is formed by a single, discrete impact of an iceberg keel into the seabed sediment (Fader and King, 1981). The high number of pits in the seabed around the rim of Owen Basin suggests that this area witnessed a substantial flux of icebergs during the retreat of the ice sheet. Southeast of The Wolves are two sedimentary bedform morphologies. A pattern of anastomosing bedform ridges strikes north-northeast (Fig. 4). These bedform ridges are 1 m or less in height with a wavelength of about 100 m. In contrast, nearby bedforms appear as discrete oval mounds about 2 m in height, with their major axes striking southwest (Fig. 5). Both of these bedform morphologies are likely created by sediment transport and deposition under the influence of complex current-flow patterns around The Wolves (Canadian Hydrographic Service, 1981; Greenberg, 1990). Off northern Campobello Island, strong currents flowing through Head Harbour Passage have

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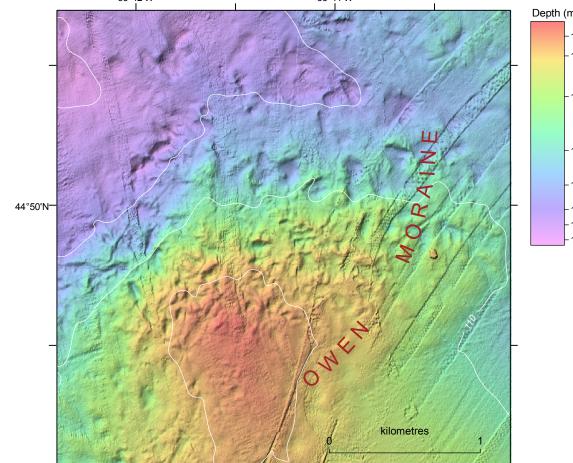
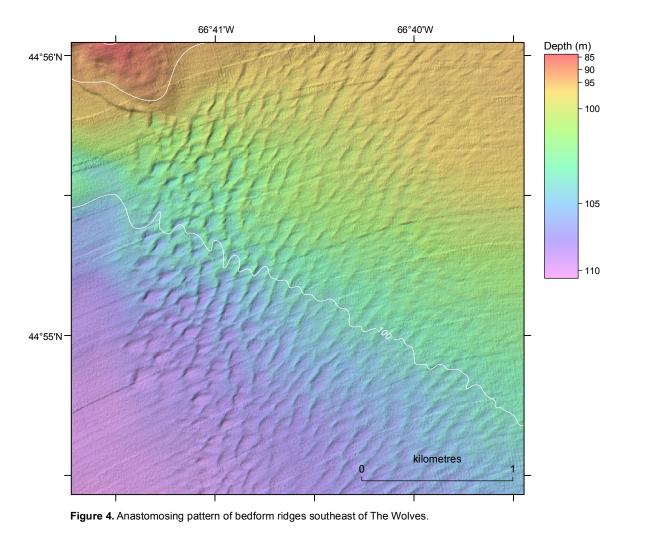
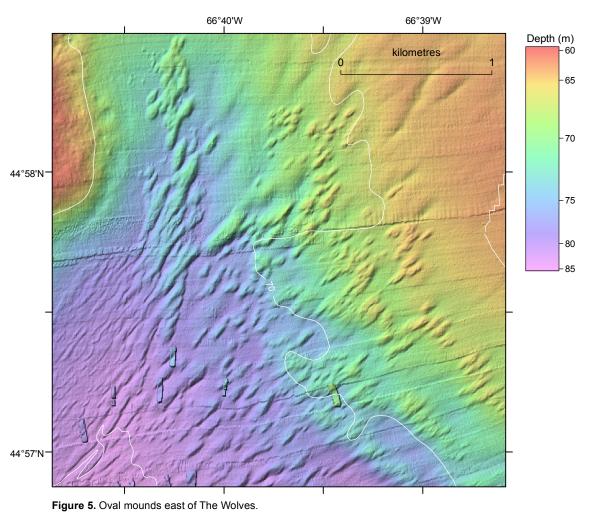
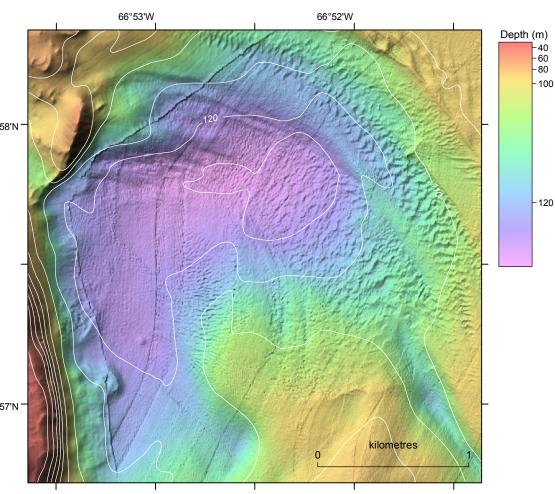


Figure 3. Iceberg pits on Owen moraine north of Grand Manan Island.







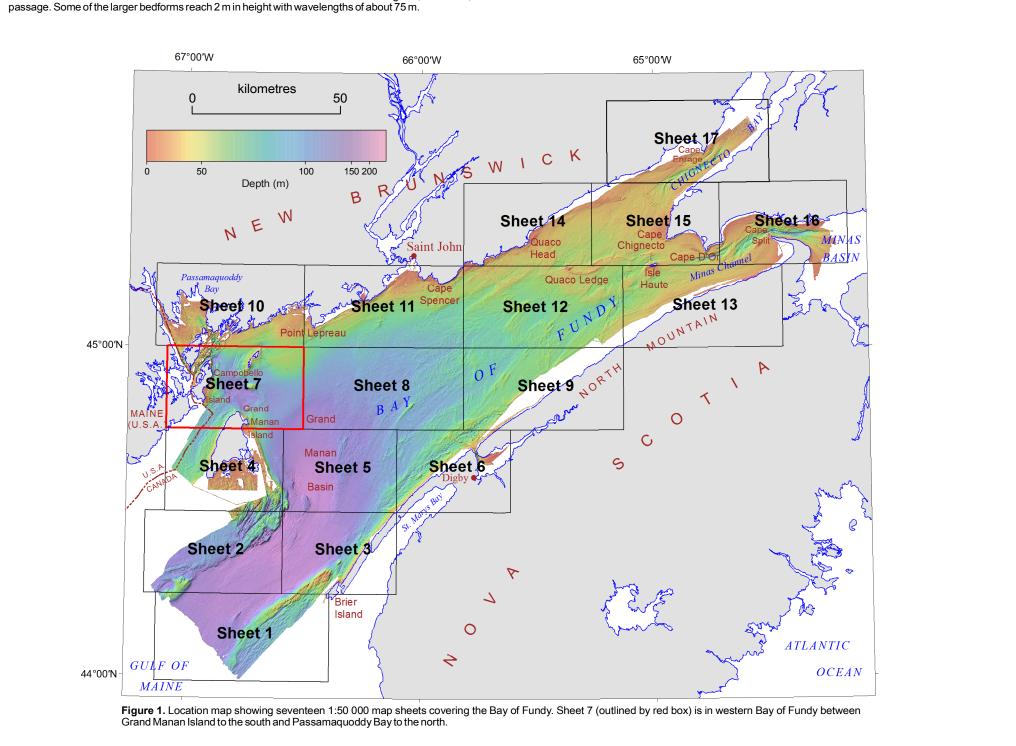


Figure 6. Scoured seabed with bedforms at the approaches to Head Harbour Passage

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