GEOLOGICAL SURVEY OF CANADA Government Gouvernement of Canada du Canada DESCRIPTIVE NOTES JORDAN BASIN This map is part of a four-map series of German Bank, located on the Scotian Shelf offshore souther POSTGLACIAL SEDIMENTS Nova Scotia. It is the product of a 1997-2003 survey that used a multibeam-sonar system to m Postglacial sediments result from reworking by ocean processes of earlier 1866 km² of the seafloor. Other surveys collected geological and biological data for scientific glaciogenic sediments — principally till and glaciomarine silt — and from modern interpretation. This map shows the seafloor topography of German Bank in shaded-relief view with olour-coded surficial geological units at a scale of 1:50 000. Topographic contours generated from the sediment transport and deposition. Postglacial sediments are commonly denoted as multibeam data are shown (in white) on the surficial geology at a depth interval of 20 m. Bathymetric Sable Island Sand and Gravel. contours (in blue) outside the multibeam survey area, presented at a depth interval of 10 m, are fror Natural Resource Map series (Canadian Hydrographic Service, 1967, 1971a, b, 1972). Map 2 Postglacial sand and gravel: well sorted sand, grading to rounded and Todd, 2007b) shows colour-coded seafloor topography in shaded-relief view. Map 2106A (Todd, 2007a) PG subrounded gravel, with characteristic parallel to subparallel, low-amplitude shows coloured backscatter strength in shaded relief view. Map 2109A (Todd et al., in press) shows reflections. Sand bodies have a mounded form and reach up to 20 m thick. seafloor topography in shaded-relief view with colour-coded benthic habitat zonation. The complete German Bank map suite includes three adjoining map areas at a scale of 1:50 000 that GLACIAL SEDIMENTS comprise 5321 km² of seafloor surveyed with a multibeam-sonar system. In total, twelve maps constitute the German Bank map suite (three map sheets each on four themes: topography, backscatter strength, Ice-distal glaciomarine sediments result from fallout of sediment from glacial meltwater plumes and ice-rafted debris. On the Scotian Shelf these fine-grained surficial geology, and benthic habitat). sediments mainly occur in basins as draped deposits outcropping at the seabed, but GEOLOGICAL HISTORY occur on some banks as well. Glaciomarine sediments are commonly denoted as The Scotian Shelf is a formerly glaciated continental margin characterized by a topographically rugged Ice-contact sediments were deposited directly by and underneath the ice sheet inner shelf. The inner shelf area constituting German Bank is dominated by outcropping bedrock primarily resulting in till that has an acoustically incoherent signature on seismic-Carboniferous granitoid plutons (Drapeau and King, 1972; King and MacLean, 1976; Pe-Piper and reflection profiles. Ice-contact sediments are ascribed to the Scotian Shelf Drift. This Loncarevic, 1989; Pe-Piper and Jansa, 1999; McCall, 2002). Bedrock has been modified by glacial till was deposited directly by ice on bedrock during the Wisconsinan stage of the erosion and is separated from the discontinuous and thin overlying unconsolidated Quaternary Vertical exaggeration: 20X sediments by a rugged erosional surface At the glacial maximum of the Late Wisconsinan substage of the Quaternary period, culminating in Ice-distal glaciomarine silt: poorly sorted clayey and sandy silt with some gravel. Figure 2. Cross-section C-D of northern German Bank. Although the top of acoustic basement (bedrock) is mostly obscured, ice-contact sediments (unit Ic1) are assumed to be thin. The central portion of the cross-section shows a field of drumlins the Gulf of Maine region at approximately 20 000 BP (radiocarbon years before present, 20 ka), German This unit exhibits a characteristic parallel to subparallel seismic-reflection 20-30 m in height with glaciomarine sediment (unit Gm) deposited between the drumlins. Thin (<10 m) postglacial sand and gravel (unit PG) is deposited by the action of currents. Depth scale was calculated using a water velocity of 1500 m/s. Bank was covered by a regional ice sheet that terminated to the south on the Scotian Slope (Schnitker et al., 2001; Dyke et al., 2002; Hundert, 2003; Stea, 2004). The glacial maximum was followed by a configuration; the reflectors conformably drape the irregular top of the underlying kilometres ice-contact sediment (unit lc1) and bedrock. In places it is interbedded with the multiphased retreat of the ice front and the incursion of marine waters into the Gulf of Maine and onto German Bank. Ice-front retreat and glaciomarine deposition began as early as 18 ka with grounded ice underlying ice-contact sediment (unit lc1). absent from the Gulf of Maine by approximately 14 ka (King and Fader, 1986; Schnitker et al., 2001). Ice-contact sediments (till): unsorted, unstratified, and unconsolidated drift with The landforms and deposits of the German Bank seafloor provide evidence of the pattern of Late Vertical exaggeration: 20X Wisconsinan glacial-dynamic events in the Gulf of Maine offshore southern Nova Scotia. Interpretation of lc2 // characteristic transparent seismic-reflection configuration, consisting of a the regional glaciation history of German Bank is primarily based on major glacial landforms (Todd et al., heterogeneous mixture of clay, sand, gravel, and boulders varying in size and Figure 1. Cross-section A-B of northern German Bank. In Jordan Basin to the west, ice-contact sediments (till, units Ic1 and Ic2) up to 50 m thick overlie Tertiary and Triassic Jurassic bedrock, which is incised in places by channels up to 75 m deep, possibly 007). Glacial landforms occurring in the study area were formed below the ice sheet (drumlins and shape. The till occurs on the eastern flank of Jordan Basin, reaching 60 m in formed by subglacial erosion. To the east on German Bank, pre-Triassic bedrock is overlain by thin (<20 m) ice-contact sediments (unit Ic1). Basins are draped with glaciomarine silt (unit Gm). Depth scale was calculated using a water velocity of 1500 m/s. megaflutes) and at its margins (regional scale moraines >10 km long and De Geer moraines <10 km thickness. The till is absent from the eastern portion of the map area. A surficial gravel lag commonly overlies these sediments. GEOSCIENTIFIC DATA Ice-contact sediments (till): unsorted, unconsolidated drift with characteristic In order to provide groundtruth for the multibeam data, and to complement the historical geoscientific chaotic seismic-reflection configuration, with evidence of internal reflections information in the area, high-resolution geophysical profiles were collected over German Bank in 2000, 2002, and 2003 (Fig. 5; Todd et al. (2001a, b, 2003, 2004)). The systems deployed included a Huntec Deep Tow Seismic (DTS) boomer, a single-channel sleeve-gun seismic-reflection system, and a Simrad MS902 sidescan sonar (120 kHz) and 220 kHz). The geophysical survival investigated 177 suggesting stacked tills, probably consisting of a heterogeneous mixture of clay, sand, gravel, and boulders varying in size and shape. The till occurs across the map region and is thickest on the eastern flank of Jordan Basin where it is commonly MS992 sidescan sonar (120 kHz and 330 kHz). The geophysical surveys investigated different seafloor types and features identified using the multibeam-bathymetric and backscatter data (Todd, 2007a, b). In 20 m to 40 m thick, buried beneath unstratified ice-contact sediment (unit lc2). Elsewhere, the outcropping till typically displays an array of glacial landforms total, 1208 km of geophysical profiles were used in the interpretation of the German Bank surficial including moraines, drumlins, and megaflutes. Using an 0.75 m³ Institutt for Kontinentalsokkel-undersøkelser (IKU) grab, 38 seafloor sediment samples were collected at strategic sites interpreted from geophysical profiles (see Fig. 5, data source map). The sites were chosen to collect seafloor-sediment samples representative of broad areas sharir Bedrock is exposed on much of German Bank and mainly consists of Cambrosimilar geomorphology (based on Map 2107A, Todd (2007b)) and acoustic backscatter response (based on Map 2106A, Todd (2007a)). In regions of soft sediment, the grab sampler was able to penetrate the Ordovician metasedimentary rocks (Meguma Group) intruded by Late Devonian granitoid plutons. Bedrock is separated from overlying unconsolidated Quaternary seafloor to a depth of 0.5 m and, when recovered, preserve the integrity of layering within the surficial sediments. Grain-size descriptions based on the samples adhere to the Wentworth size class scheme for sediments by a rugged erosional surface. clastic sediments (Wentworth, 1922). With locations chosen from the multibeam-bathymetric data and the geophysical profiles, 40 seafloor TERTIARY AND LATE CRETACEOUS PALEOGENE AND NEOGENE; excluding Pleistocene photographic sites were occupied using Campod, an instrumented tripod equipped with oblique- and downward-oriented video and still cameras (Gordon et al., 2007). Campod was deployed while the ship slowly drifted across sites of geological (or biological) interest and was repeatedly landed on the seabed to obtain still photographs, thereby collecting transects of high-resolution imagery. Transect duration was BANQUEREAU FORMATION (cross-section only): shale, sandstone, siltstone, 30 minutes with transect lengths ranging up to 1000 m, depending on the current speed. About 10 s images were acquired per transect. The still photographic images represent a seafloor area of 0.96 m<sup>2</sup>. MIDDLE TRIASSIC-EARLY JURASSIC SURFICIAL GEOLOGY FUNDY GROUP Syvitski (1991) showed that a complete deglacial sequence consists of some or all of the following: icecontact sediments, ice-proximal sediments, ice-distal sediments, paraglacial coastal sediments, and postglacial sediments. The Quaternary stratigraphy of German Bank described here follows this T-Js

Unditterentiated to see 2.2. conglomerate, and shale. Undifferentiated (cross-section only): acoustic basement; sandstone, siltstone, deglacial sequence scheme. Earlier interpretations of surficial geological formations on German Bank were based on a regional understanding of the Gulf of Maine and Scotian Shelf (Drapeau and King, 1972) Fader et al., 1977, 2004). The formation names corresponding to the deglacial sequence names are noted here and in the legend. SOUTH MOUNTAIN BATHOLITH AND MEGUMA TERRANE PLUTONS Regional geological cross-sections (Fig. 1, 2) illustrate the stratigraphic relationships of the deglacial Acoustic basement: undifferentiated Late Devonian granitoid suites cutting the Cambro-Ordovician Meguma Group. **GLACIAL SEDIMENTS** CAMBRO-ORDOVICIAN Ice-contact till (units Ic1 and Ic2), equivalent to Scotian Shelf Drift (Fig. 3; Drapeau and King (1972); MEGUMA GROUP Fader et al. (1977)), is widespread on German Bank. On the eastern flank of Jordan Basin, unit Ic2 is exposed on the seafloor and overlies unit Ic1 (Fig. 1). Unit Ic2 pinches out to the east. In places, a gravel C-OM Acoustic basement: metasedimentary rocks, Cambrian quartzite, greywacke, and lag developed from the till (both units Ic1 and Ic2), which was reworked during transgression of sea level across the Scotian Shelf after about 18 ka (Drapeau and King, 1972; Fader et al., 1977; Fader, 1989). In grab samples, seafloor photographs, and sidescan-sonar records, the gravel lag exhibits a range of grain ize from pebbles (2-64 mm) to cobbles (>64-256 mm) to boulders (>256 mm). PRECAMBRIAN TO MISSISSIPPIAN Glacial landforms of ice-contact sediment (unit lc1, till) are widespread on German Bank. These pP Undifferentiated (cross-section only): acoustic basement; comprises instrusive, volcanic, and metasedimentary rocks. Unit determined as pre-Pennsylvanian by landforms are well preserved and conspicuous despite having been subjected to modification during sealevel transgression and during the modern regime of oceanic currents and associated sediment transport King and MacLean (1976). Subglacial landforms are accumulations of sediment formed below active ice and are aligned either longitudinal or transverse to ice-flow direction (Menzies and Rose, 1989). Longitudinal forms are streamlined features divided into flutings, megaflutings, and drumlins (prominent on German Bank) and Tusket Island Geological contact (map unit boundaries are interpreted from multibeam sonar mega-scale glacial lineations (Clark, 1993). bathymetry and geophysical seismic-profile data and are inferred contacts that The geomorphology of northern German Bank is characterized by oval mounds with long axes oriented northwest-southeast (Fig. 2; Map 2107A, Todd (2007b)). The mounds are typically 500–800 m in length and 100–300 m in width with elevations 10–15 m above the surrounding seafloor. Seismicmay be gradational or conceptual in nature) . . . . . . . reflection profiles reveal that the mounds are constructed of acoustically incoherent sediment, interpreted as till, with intermound areas deeply draped by stratified sediment characterized by continuous, coherent reflections, and interpreted as glaciomarine sand and silt (Fig. 2). The true height of the partly buried mounds is 20–30 m. The mounds are interpreted to be drumlins with their long axes parallel to the direction of ice flow. Drumlins on German Bank do not display the typical drumlin morphology of unequivocal stoss (steep, blunt) and lee (gentle, pointed) sides, as defined by Menzies (1979), that would provide further evidence of ice-flow direction; however, the long axis orientation of the drumlins is consistent with an ice-flow direction from northwest to southeast. The drumlins on northern German Bank sometimes have medial ridges, measuring 3–6 m in height and 30–70 m in width, oriented roughly parallel to the drumlin long axis. Farther south at 43°32.5′N, 66°25.0′W, megaflutes are interspersed with drumlins. The distinction between drumlins and megaflutes is based on length, I; width, w; and elongation ratio, E; of the bedform (Rose, 1987): E = I/w. With an increasing elongation ratio, drumlins grade into megaflutes. The average elongation ratio for drumlins on northern German Bank is about three. In comparison, some markedly elongated features are up to 1200 m in length with widths of approximately 100 m, giving an elongation ratio of twelve. There is no clear spatial segregation of drumlins and megaflutes. De Geer moraines are small, transverse moraines formed at or close to the grounding lines of waterterminating glaciers (Benn and Evans, 1998). De Geer moraines are the most ubiquitous glacial landforms on German Bank (Fig. 4). Drumlinized terrain on northern German Bank exhibits west-east De Geer moraines with crest lines striking normal or oblique to the drumlin long axes. Cobbles and oulders were observed and recovered from De Geer moraines. Troughs between moraines are smoothsurfaced, as observed in multibeam imagery, and are composed of sand and pebble gravel. Glaciomarine silt (unit Gm) is equivalent to Emerald Silt (Fig. 1, Drapeau and King (1972); Fader et al. (1977)) and is exposed at the seabed in small basins across German Bank. POSTGLACIAL SEDIMENTS Postglacial sediments (unit PG) are derived from current and wave reworking of glaciogenic deposits and are equivalent to Sable Island Sand and Gravel (Fig. 3; Drapeau and King, 1972; Fader et al., 1977). The morphology and extent of postglacial sediments are interpreted from the topographic map (Map 2107A, Todd (2007b)) and the backscatter strength map (Map 2106A, Todd (2007a)), on which the low backscatter strength areas are interpreted as predominantly sand with minor gravel; seafloor sediment samples and sidescan sonograms confirm this interpretation (Todd et al., 2001a, b, 2003, 2004). In the shallow (~50 m), eastern region of German Bank, sand occurs in elongated deposits oriented southeast-northwest with the current flow direction. Although typically a few metres thick, these deposits reach 17 m thick in places. In deeper water (>100 m) on western German Bank, sand is deposited in broad sheets up Postglacial deposits adjacent to expanses of outcropping bedrock, for example at 43°24.4′N, 66°20.7′W, display a high backscatter strength (Map 2106A, Todd (2007a)) resulting from pebbles and Sambro Sand cobbles at the seabed surface. Winnowing of finer grained sediment by currents produced this lag deposit, effectively armouring the underlying postglacial material against erosion. ACKNOWLEDGMENTS line shows outline of area mapped using multibeam sonar. Black line outlines extent of 2000-047, 2002-026, 2003-054) and during 2000 on the MV Anne S. Pierce. P.C. Valentine (United States Geological Survey), O. Longva (Geological Survey of Norway), J. Shaw (Geological Survey of Canada), and C. McCall (St. Mary's University) collaborated at sea and in the elucidation of the deglacial history of German Bank. Multibeam sonar data were collected and processed by the Canadian Hydrographic Service. Geographical Information Systems and cartographic support was provided by S.E. Hayward, W.A. Rainey, S. Hynes, and P. O'Regan. The author thanks J. Shaw and P.C. 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 Sun-illuminated seafloor topography, German Bank, Scotian Shelf, offshore Nova Scotia; Geological Survey of Canada, Map 2107A, scale 1:50 000. Todd, B.J., Asprey, K.W., Atkinson, A.S., Blasco, R., Fromm, S., Girouard, P.R., Kostylev, V.E., Longva, O., Lynds, T., Rainey, W.A., Spencer, P.L., Uyesugi, M.S., and Valentine, P.C.
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kilometres 1 0 1 2 3 4 kilomètres

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Système de référence géodésique nord-américain, 1983

Universal Transverse Mercator Projection

North American Datum 1983

Geological compilation by B.J. Todd, S.E. Hayward, W.A. Rainey, and R.O. Miller, 2001–2008

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

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

Magnetic declination 2009, 17°23'W, decreasing 6.0' annually

Depth in metres below mean sea level

Elevations in metres above mean sea level

Canada

Sheet 1 of 3, surficial geology and sun-illuminated seafloor topography (north area)

Recommended citation:

Todd, B.J.

2009: Surficial geology and sun-illuminated seafloor topography, German Bank,
Scotian Shelf, offshore Nova Scotia; Geological Survey of Canada, Map