GEOLOGICAL HISTORY The Scotian Shelf is a formerly glaciated continental margin characterized by a topographically rugged inner shelf. The inner shelf area constituting German Bank is dominated by outcropping bedrock Carboniferous granitoid plutons (Drapeau and King, 1972; King and MacLean, 1976; Pe-Piper and Loncarevic, 1989; Pe-Piper and Jansa, 1999; McCall, 2002). Bedrock has been modified by glacial erosion and is separated from the discontinuous and thin overlying unconsolidated Quaternary sediments by a rugged erosional surface. At the glacial maximum of the Late Wisconsinan substage of the Quaternary period, culminating in the Gulf of Maine region at approximately 20 000 BP (radiocarbon years before present, 20 ka), German 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). The glacial maximum was followed by a 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 absent from the Gulf of Maine by approximately 14 ka (King and Fader, 1986; Schnitker et al., 2001). The landforms and deposits of the German Bank seafloor provide evidence of the pattern of Late Wisconsinan glacial-dynamic events in the Gulf of Maine offshore southern Nova Scotia. Interpretation of the regional glaciation history of German Bank is primarily based on major glacial landforms (Todd et al., 2007). Glacial landforms occurring in the study area were formed below the ice sheet (drumlins and

megaflutes) and at its margins (regional scale moraines >10 km long and De Geer moraines <10 km GEOSCIENTIFIC DATA In order to provide groundtruth for the multibeam data, and to complement the historical geoscientific information in the area, high-resolution geophysical profiles were collected over German Bank in 2000, 2002, and 2003 (Fig. 4; 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 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 total, 948 km of geophysical profiles were used in the interpretation of the German Bank surficial geology. Using an 0.75 m³ Institutt for Kontinentalsokkel-undersøkelser (IKU) grab, 25 seafloor sediment samples were collected at strategic sites interpreted from geophysical profiles (Fig. 4). The sites were chosen to collect seafloor-sediment samples representative of broad areas sharing similar 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 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 clastic With locations chosen from the multibeam-bathymetric data and the geophysical profiles, 24 seafloor photographic sites were occupied using Campod, an instrumented tripod equipped with oblique- and

30 minutes with transect lengths ranging up to 1000 m, depending on the current speed. About 10 still images were acquired per transect. The still photographic images represent a seafloor area of 0.96 m<sup>2</sup>. SURFICIALGEOLOGY 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 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 The regional geological cross-section (Fig. 1) illustrates the stratigraphic relationships of the deglacial sequence discussed below.

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

**GLACIAL SEDIMENTS** lce-contact till (units lc1 and lc2, till), equivalent to Scotian Shelf Drift (Fig. 2; Drapeau and King (1972); Fader et al. (1977)), is widespread on German Bank. On the eastern flank of Jordan Basin, unit lc2 is exposed on the seafloor and pinches out to the east. In places, a gravel lag developed from the till (both units lc1 and lc2) 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 size from pebbles (2–64 mm) to cobbles (>64–256 mm) to boulders (>256 mm). Glacial landforms of ice-contact sediment (unit lc1, till) are widespread on German Bank. These landforms are well preserved and conspicuous despite having been subjected to modification during sea-level transgression and during the modern regime of oceanic currents and associated sediment transport Former ice-sheet margins on German Bank are demarcated by regional (i.e. >10 km in length) moraines formed by deposition of sediment at the leading edge of the active ice sheet. The regional moraines on German Bank are recessional (Benn and Evans, 1998), formed during overall glacial retreat even though they were deposited during minor readvances or stitlands. The maximum seaward limit of the Late Wisconsinan ice-sheet advance on the southern Scotian Shelf reached the Scotian Shelf edge, 100 km to the southeast (Schnitker et al., 2001; Dyke et al., 2002; Hundert, 2003; Stea, 2004). Four regional moraines (RM) are identified on southwestern German Bank (Fig. 3). Morphologically, these moraines are composed of 25–40 km long curved segments concave to the northwest. RM 1 is the longest regional moraine and can be traced along segments for approximately 105 km from the southwestern to the eastern part of German Bank. The regional moraines are roughly parallel, have a regional southwest-northeast orientation, and traverse a wide range of water depths. For example, the western end of RM 2 is at a depth of 160 m and rises to 57 m on central German Bank. Sections of some regional moraines rise to 34 m at the eastern edge of the German Bank map area. Regional moraines display variable heights and widths and both dimensions are consistently larger than De Geer moraine dimensions (discussed in the following section). True moraine heights may be appreciably greater than apparent heights. For example, RM 2 rises 10 m above the surrounding

seafloor; however, including the portion of the moraine buried under the flanking glaciomarine sediment, the true height of this moraine is 40 m, four times the apparent height. The exposed moraine width at the seafloor is about 400 m whereas the width at the buried moraine base is approximately 600 m.

At a large scale in plan view, these moraines display a complex geomorphology composed of a suite of curvilinear elements. For example, a continuous, curvilinear, narrow ridge about 50 m wide sharply demarcates the southeastern flank of RM 2 (43°9.9′N, 66°21.5′W). To the northwest of this flank, the moraine is composed of short (tens to hundreds of metres), discontinuous, curvilinear narrow ridges. The orientation of these short ridges, although variable, is southwest-northeast on average. The multitude of curvilinear elements is interpreted to reflect processes occurring at the ice front during moraine De Geer moraines are small, but numerous, transverse moraines formed at or close to the grounding lines of water-terminating glaciers (Benn and Evans, 1998). De Geer moraines are the most ubiquitous glacial landforms on German Bank (Fig. 3). glacial landforms on German Bank (Fig. 3).

Topographic highs on southern German Bank are mantled by swarms of De Geer moraines. Most of these moraines display a simple or curved crest line in planform, but in some areas the crests are complex with bifurcating crest lines and (or) short, en echelon crest segments. The orientation of the moraine crests is generally west-southwest–east-northeast. Individual moraine crests can be traced horizontally from short segments of 2 km up to almost 10 km. The longer moraine crests are formed of multiple curved sections 2–5 km in length with the crests convex toward the southeast. Individual moraines traverse bathymetric ranges of up to 25 m. In the seabed lows between the topographic highs, the De Geer moraines are subdued in relief or are absent, resulting from partial to complete burial by the De Geer moraines are subdued in relief or are absent, resulting from partial to complete burial by sediment transported from glacial fronts and/or reworked during sea-level transgression of German Bank. The horizontal distance between moraines, normal to strike, is variable. In some areas, well defined parallel moraines have a roughly regular spacing of approximately 150 m to 200 m. In other areas, subparallel ridges are as closely spaced as 30 m to 50 m. The De Geer moraines vary in height and width. Moraines displaying a subtle appearance on the map (e.g. 43°6.7′N, 66°17.7′W) are approximately 1.5 m high and 40 m wide. The more prominent De Geer moraines (e.g. 43°5.0′N, 66°12.0′W) are approximately 5–8 m high and 100–130 m wide.

Glaciomarine silt (unit Gm) is equivalent to the Emerald Silt (Drapeau and King, 1972; Fader et al., 1977) and is present on the surface and in the subsurface on the eastern flank of Jordan Basinand 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 the Sable Island Sand and Gravel (Fig. 2; 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

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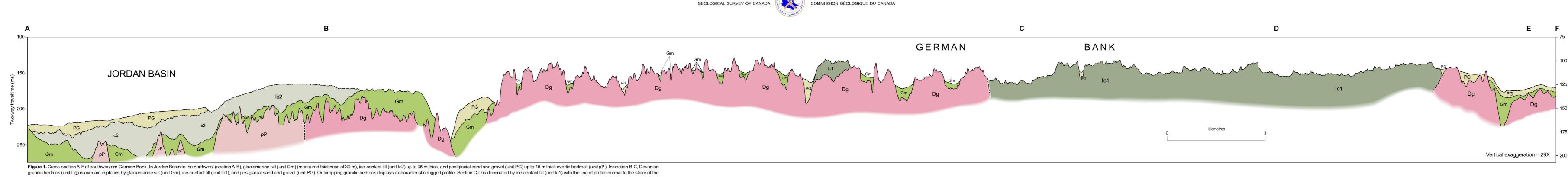
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moraine crests. East of point D, the line of profile is almost parallel to the strike of the moraine crests. At the eastern end of the cross-section near section E-F, Devonian granitic bedrock (unit Dg) is overlain by glaciomarine silt (unit Gm) and postglacial sand and gravel (unit PG). M A I N E66°51' Copies of this map may be obtained from the Geological Survey of Canada: 615 Booth Street, Ottawa, Ontario K1A 0E9 625 Robson Street, Vancouver, British Columbia V6B 5J3 490, rue de la Couronne, Québec, Quebec G1K 9A9 1 Challenger Drive, P.O. Box 1006, Dartmouth, Nova Scotia B2Y 4A2 MAP 2148A SURFICIAL GEOLOGY AND SUN-ILLUMINATED SEAFLOOR TOPOGRAPHY Author: B.J. Todd **GERMAN BANK** Any revisions or additional information known to the user would be welcomed by the Geological Survey of Canada SCOTIAN SHELF This map was produced by Natural Resources Canada in co-operation with Fisheries and Digital bathymetric contours in metres supplied by the Canadian Oceans Canada OFFSHORE NOVA SCOTIA Hydrographic Service and GSC (Atlantic)

Scale 1:50 000/Échelle 1/50 000

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This map is not to be used for navigational purposes Cette carte ne doit pas être utilisée aux fins de navigation

Système de référence géodésique nord-américain, 1983

Universal Transverse Mercator Projection North American Datum 1983

Magnetic declination 2009, 17°15' W, decreasing 5.8' annually

Depth in metres below mean sea level

Geology by B.J. Todd, 2006–2008

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)

POSTGLACIAL SEDIMENTS Postglacial sediments result from reworking by ocean processes of earlier glaciogenic sediments — principally till and glaciomarine silt — and from modern sediment transport and deposition. Postglacial sediments are commonly denoted as Sable Island Sand and Gravel. Postglacial sand and gravel: well sorted sand, grading to rounded and PG subrounded gravel, with characteristic parallel to subparallel, low-amplitude reflections. Sand bodies have a mounded form and reach up to 20 m thick. GLACIAL SEDIMENTS Ice-distal glaciomarine sediments result from fallout of sediment from glacial meltwater plumes and ice-rafted debris. On the Scotian Shelf these fine-grained sediments mainly occur in basins as draped deposits outcropping at the seabed, but occur on some banks as well. Glaciomarine sediments are commonly denoted as Ice-contact sediments were deposited directly by and underneath the ice sheet primarily resulting in till that has an acoustically incoherent signature on seismicreflection profiles. Ice-contact sediments are ascribed to the Scotian Shelf Drift. This till was deposited directly by ice on bedrock during the Wisconsinan stage of the Pleistocene Epoch. Ice-distal glaciomarine silt: poorly sorted clayey and sandy silt with some gravel.

This unit exhibits a characteristic parallel to subparallel seismic-reflection configuration; the reflectors conformably drape the irregular top of the underlying ice-contact sediment (unit lc1) and bedrock. In places it is interbedded with the underlying ice-contact sediment (unit lc1). Ice-contact sediments (till): unsorted, unstratified, and unconsolidated drift with characteristic transparent seismic-reflection configuration, consisting of a heterogeneous mixture of clay, sand, gravel, and boulders varying in size and shape. The till occurs on the eastern flank of Jordan Basin, reaching 60 m in thickness. The till is absent from the eastern portion of the map area. A surficial

gravel lag commonly overlies these sediments. Ice-contact sediments (till): unsorted, unconsolidated drift with characteristic chaotic seismic-reflection configuration, with evidence of internal reflections 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 20 m to 40 m thick, buried beneath unstratified ice-contact sediment (unit Ic2). Elsewhere, the outcropping till typically displays an array of glacial landforms including moraines, drumlins, and megaflutes.

Bedrock is exposed on much of German Bank and mainly consists of Cambro-Ordovician metasedimentary rocks (Meguma Group) intruded by Late Devonian granitoid plutons. Bedrock is separated from overlying unconsolidated Quaternary sediments by a rugged erosional surface.

SOUTH MOUNTAIN BATHOLITH AND MEGUMA TERRANE PLUTONS

Acoustic basement: undifferentiated Late Devonian granitoid suites cutting the Cambro-Ordovician Meguma Group. CAMBRO-ORDOVICIAN MEGUMA GROUP Acoustic basement: metasedimentary rocks, Cambrian quartzite, greywacke and

PRECAMBRIAN TO MISSISSIPPIAN Undifferentiated: acoustic basement; comprises instrusive, volcanic, and

metasedimentary rocks. Unit determined as pre-Pennsylvanian by King and MacLean (1976). Geological contact (map unit boundaries are interpreted from multibeam sonar

bathymetry and geophysical seismic-profile data and are inferred contacts that 

Sable Island Sand and Gravel Sambro Sand Emerald Silt Scotian Shelf Drift geological formations on the Scotian Shelf and in the Gulf of Maine based on premultibeam- sonar survey data (Drapeau and King, 1972; Fader et al., 1977, 2004). Red

line shows outline of area mapped using multibeam sonar. Black line outlines extent of map

**Figure 3.** Areas of regional moraines 1–4 (labelled circles) and crest lines of De Geer moraines on German Bank. Extent of map sheet is outlined in red.

Figure 4. Data source map showing the distribution of geophysical tracklines (seismicreflection profiles, sidescan-sonar sonograms) and seafloor-sediment samples and photographs. Extent of map sheet is outlined in red.

> Figure 5. Location map shows extent of map sheet in red. The pink shadowing shows the extent of the multibeam sonar coverage. Five-digit numbers refer to Marsden Square System used for Natural Resource Map series at 1:250 000 scale. Blue line shows 200 m isobath.

Sheet 2 of 3, surficial geology and sun-illuminated seafloor topography (southwest area) Recommended citation: 2009: Surficial geology and sun-illuminated seafloor topography, German Bank, Scotian Shelf, offshore Nova Scotia; Geological Survey of Canada, Map 2148A, scale 1:50 000.