

**DISCUSSION**  
**Introduction**

The Stellwagen Bank National Marine Sanctuary Mapping Project is a cooperative effort of the U.S. Geological Survey and the National Oceanic and Atmospheric Administration, with support from the University of New Brunswick and the Canadian Hydrographic Service. The multibeam echo sounder survey was conducted on four cruises over a two-year period from the fall of 1994 to the fall of 1996. This map shows one of a series of 18 quadrangle maps (see location map) in which sea floor depth information is depicted in sun-illuminated (or shaded relief) view at a scale of 1:25,000, with topographic contours superimposed in blue. The image shown here uses a sun elevation angle of 45 degrees above the horizon from an azimuth of 150 degrees and a vertical exaggeration of four times. In effect, topographic relief is enhanced by halving the sun illuminates the sea floor from a position 10 degrees west of north, so that shadows are cast on the southern flanks of seabed features. Some features in the images are artifacts of data collection. They are especially noticeable where the seabed is smooth, and they include small highs and lows and unnatural-looking features and patterns that are oriented parallel or perpendicular to survey tracklines. For a depiction of the topographic contours alone, and for an explanation of survey and topographic data processing methods, see the companion map by Valentine and others (1997). Topographic contour maps of all 18 quadrangles in the map series are available on a CD-ROM in EPS, PLT, Arc export, and PDF file formats (Valentine and others, 1998). Blank areas represent places where no data exist.

**Regional seabed features**

The major topographic features depicted in the map series were formed by glacial processes. In broad terms, these features are interpreted here to represent a geologic history that developed in several stages. Ice containing rock debris moved across the region, sculpting its surface and depositing sediment to form the large banks, ridges, and valleys. Many other features observed here represent the latter stages of deglaciation. They are the result of processes at work when much of the area was covered by stationary retreating ice, and when at the same time small valley glaciers and ice falls were active in and near areas of high topographic relief. The sea invaded the region formerly occupied by ice, and seabed features were partly eroded and some new sedimentary deposits were formed. Today, the sea floor is modified mainly by strong southwesterly flowing bottom currents, caused by storm winds from the northeast. These currents erode sediments from the shallow banks and transport them into the basins. With time, the banks affected by these currents become cuspate,

as sand and mud are removed and gravel remains, and the western flanks of the banks, as well as adjacent basins, are built up by deposits of mud and sand.

**Quadrangle 14 features**

The sea floor in Quadrangle 14 is topographically variable and includes banks, shallow and deep basins, and valleys. The southeastern part of a shallow bank (Jefferys Ledge) is located in the far northeastern part of the quadrangle. The seabed of this bank at water depths of 35 to 50 m is gravel and includes boulder piles and ridges and a large depression (42° 38.3' N, 70° 24.6' W) that possibly marks the former location of a mass of melting glacial ice. Sand and shell deposits cap the flank of the bank from a depth of 50 m to its base at 65 to 70 m, where an adjacent deposit of sand, west of about 70° 23' N, extends southward (42° 38.3' N, 70° 24.4' W). A broad bank that dominates much of the western part of the quadrangle slopes gently south and east from Jefferys Ledge through water depths of 75 to 90 m. It is bounded on the south and east by valleys and basins that range in depth from 115 to 165 m. This seabed in the northern part of the broad bank is relatively smooth with some low hills; it is covered with gravel, including patches of cobbles and boulders, that is also partly covered by a veneer of sand. Long, narrow grooves in the seabed that typically are 100 to 150 m wide, less than 5 m deep, and up to 4 km long are interpreted to be marks made by the jagged bottoms of icebergs that gouged the seabed by grounding here during the late stages of the last glaciation. These grooves are shallower and less pronounced than similar features that occur in Quadrangles 15 and 16 (Valentine and others, 2001a), possibly because they have been partly filled with sand transported from Jefferys Ledge to the northwest. The southern part of the broad bank exhibits low, rounded hills and shallow, smooth-floored valleys and basins. The hills are covered with gravel, including boulder piles, and the gravel is covered in places by a thin veneer of sand that is most extensive on the hilltops. The floors of the shallow valleys and basins (42° 31.9' N, 70° 20.1' W; 42° 36.2' N, 70° 22.7' W; and 42° 36' N, 70° 20.25' W) are covered with sand and muddy sand.

A wide, deep glaciated basin extends from the northern edge of the quadrangle to its center, where it divides into two basins that extend southward around a large, elongated bank. The basin floor, which ranges in depth from 115 to 185 m, are muddy sediment, except for some areas where sand has been transported into the basin from neighboring banks. Hummocky, lobe-shaped depositional features extend into the basins (42° 34.6' N, 70° 19.5' W) and southward from the southwestern edge of the broad bank on the western edge of the quadrangle (42° 35.7' N, 70° 24.5' W). They are interpreted to have been formed by glacial debris (now covered with muddy sand) that was deposited by ice falls that flowed from the surfaces of the

banks and ridges. Irregular lumps on the basin floor (42° 34.6' N, 70° 15.65' W) possibly represent piles of rock debris (now partly covered with mud) that were deposited from glacial ice that occupied the basin. The large bank (centered at 42° 38' N, 70° 21.5' W) has a relief of 55 to 125 m, and its surface is covered with sand and gravel, including boulder piles and ridges. Some of the boulder ridges resemble ridges of sand and gravel deposited by running water in channels within stationary glacial ice. Other ridges are located along the upper edges of small glaciated valleys (42° 32.75' N, 70° 16.6' W) and are interpreted to be lateral moraines (deposits of rock debris piled up at the edges of moving ice). East of the central basin, the quadrangle is characterized by low hills and shallow valleys, similar to features that occur in the adjacent Quadrangle 15 to the east. The low hills are covered with gravel, including boulder piles and ridges. The gravel is covered in places by a thin veneer of sand that is more extensive on the hilltops than on the hilltops. In the northeastern part of the quadrangle, the seabed displays iceberg scars similar to those described above in the western part of the quadrangle. In the southwestern part of the quadrangle (south of the broad bank), hills, complex ridges, and shallow and deep valleys and basins (as deep as 140–150 m) display a range of sediment types. Generally, the hills are covered with gravel including some boulder piles and ridges, the shallow valleys and depressions (42° 34.1' N, 70° 20.4' W) are sandy, and the deep valleys and basins (42° 34' N, 70° 23' W) are muddy sand and mud.

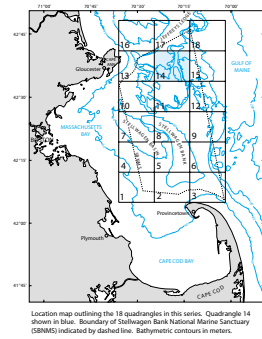
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## SUN-ILLUMINATED SEA FLOOR TOPOGRAPHY OF QUADRANGLE 14 IN THE STELLWAGEN BANK NATIONAL MARINE SANCTUARY OFF BOSTON, MASSACHUSETTS

By

Page C. Valentine, Tanya S. Unger, and Jessica L. Baker

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