HIGH-RESOLUTION GEOLOGIC MAPPING OF THE INNER CONTINENTAL SHELF: NAHANT TO GLOUCESTER, MASSACHUSETTS

U.S. Geological Survey Open-File Report 2005-1293

Map Sheet 3: Backscatter intensity of seafloor (grayscale)

Introduction

A series of five map sheets shows the seafloor topography and geology of the inner continental shelf between Nahant and Gloucester, Massachusetts including Salem Sound and parts of western Massachusetts Bay. This map (sheet 3) shows acoustic backscatter intensity in grayscale, derived from sidescan sonar imagery, with selected topographic contours overprinted in blue. Sheet 1 shows shaded-relief topography in color, sheet 2 shows shaded-relief topography in grayscale, sheet 4 shows shaded-relief topography colored by backscatter intensity, and sheet 5 shows seafloor geology. These maps are produced as part of a cooperative effort by the U.S. Geological Survey (USGS) and the Massachusetts Office of Coastal Zone Management (CZM) to systematically map the seafloor geology offshore of Massachusetts. This map sheet is accompanied by a more extensive report on DVD-ROM that presents a description of the data collection, processing, and analysis procedures used to create these maps. The DVD-ROM also includes copies of all data layers in GIS format, and the original data used to validate the geologic interpretations.

The geophysical data presented in these five maps were collected on two research cruises conducted in September-October 2003 and April-May 2004. The intensity of acoustic backscatter is represented by 256 shades of gray, ranging from lighter shades (high backscatter values) to darker shades (low backscatter values). Accurate interpretation of substrate properties from backscatter data requires validation by direct sampling, bottom photography and video. High values, depicted by lighter shades, suggest that the seafloor in those areas is covered with coarse sand, gravel, cobbles, boulders and rock. Moderate values indicate sand or muddy sand. Low values, depicted by darker shades, indicate sandy mud or mud. Relief on the seafloor also influences the intensity of reflected sound waves. For example, a sloping surface that faces the sound source (sonar) will produce higher backscatter values than a surface that slopes away from the source.

Some features in the image are artifacts of data collection and environmental conditions. They include unnatural-looking stripes oriented parallel to survey tracklines, which were run northeast-southwest in the map area. These evenly spaced stripes are produced by strong acoustic echoes that occur at the "nadir" directly beneath the sonar. Slight mismatches in the grayscale tones are also artifacts of data processing. These occur where the substrate in one swath is very different from the swath next to it, which makes it difficult to match the grayscale tone along the entire length of those lines. Areas that could not be surveyed because they were too shallow (typically less than 5 m deep) are shown in light gray. The small gray strips and slivers that occur in several parts of the image are areas of no data, or gaps where adjacent swaths did not overlap.

Additional data are included on this map to show the regional topography in areas adjacent to the new survey. To the southeast, offshore of the new survey, seafloor topography in shaded-relief view is shown at a resolution of 6 m/pixel based on data presented by Butman and others (2004). To the northwest, inshore of the new survey, seafloor topography in shaded-relief view is shown at a resolution of 30 m/pixel from the NOAA/NOS estuarine bathymetry database (NOAA, 1998). The onshore topography is from the Massachusetts Geographic Information System (MassGIS, 2005) displayed at a resolution of 25m/pixel.

Data and Methods

Mapping of the seafloor was carried out in the nearshore region between the 5 and 40 meter isobaths. Approximately 134 km^2 of the inner shelf were mapped using interferometric sonar (seafloor topography), sidescan sonar (backscatter intensity), and chirp seismic-reflection profiling (sediment thickness). The three mapping systems were simultaneously deployed from the RV *Rafael,* a 25-ft research vessel outfitted for mapping in shallow water.

The acoustic backscatter data, shown on this map, were collected with an Edgetech DF-1000 sidescan sonar that operates at dual frequencies of 100 and 500 kHz. The system has two transducers that collect backscatter data in a continuous swath on either side of the vessel. Sidescan sonar provides wider, more efficient coverage of the seafloor relative to swath bathymetric sonars. With line spacing set at 100 m to maximize the bathymetric systems, adjacent swaths of sidescan-sonar data completely overlapped each other, providing > 100% coverage of the seafloor. Sidescan-sonar data were processed for beam angle and slant range correction using LINUX-based Xsonar/Showimage as described in Danforth (1997). Raw image files of each trackline were mosaicked using PCI Geomatics GPC works (PCI Geomatica ver 8.2). The 100- kHz data were used for the final mosaic, which is presented here with a pixel size of 1 meter.

Navigation for the survey vessel and all data collection used Real-Time Kinematic Global Positioning System (RTK-GPS) from a base station established by USGS near the Eastern Point Lighthouse in Gloucester. All survey data were collected in Universal Transverse Mercator (UTM) coordinate system, Zone 19 using the WGS84 Geodetic Model. Tidal offsets were calculated using the RTK-GPS elevations and applied to soundings data during post processing. Tidal datum was recorded as Mean Sea Level (MSL) and was later reduced to Mean Lower Low Water (MLLW) by subtracting 1.4 meters.

Samples of the surficial sediments and bottom photographs were used to validate interpretations of the remotely-sensed depth and backscatter data. Bottom samples and/or photographs of the seafloor were obtained at 100 stations on a cruise conducted in

May 2004 immediately following geophysical data acquisition. Stations were selected to sample areas of differing characteristics, based on a qualitative examination of the backscatter and topographic data. At each station, the survey vessel deployed a USGS Sea Bed Observation and Sampling System (SEABOSS; Valentine and others, 2000) and drifted over the seafloor. Continuous video and still photographs were recorded along the drift track. At each station about 5 minutes of video and 5 bottom photographs were obtained. Sediment samples were collected at 56 of the 100 stations where the bottom was not covered with boulders, rock, or ledge. Sediment grabs were later analyzed for grain size using the methods outlined in Poppe and others (2000).

Features

Maps depicting topography and surficial materials on the inner continental shelf play an important role in understanding the region's geologic history and the ongoing processes that have shaped the seafloor. Igneous and metamorphic rocks spanning millions of years of Earth history control the overall geometry of the coast and inner continental shelf (Zen et al., 1983). Erosion resistant intrusive rocks form rugged coastal headlands and some of the submarine shoals. Glaciation and relative sea-level change are the most important processes to act on the region, and have produced a heterogeneous mix of bottom types on the inner continental shelf.

Rock outcrops and coarse-grained glacial sediment form the rugged, irregular topography that characterizes the seafloor in much of the study area. Deposits of glacial till and outwash partially mantle the rocks with a wide range of particle sizes from fine-grained mud to large boulders. Glaciers produced a prominent series of boulder-covered ridges or moraines southeast of Marblehead Neck, in shallow water just outside the entrance to Salem Sound. These relic features are arcuate and convex seaward in planform, with each moraine marking a former position of the ice-sheet margin as it progressively retreated across the region at the end of the last Ice Age. Sandy sediment fills several small, closed depressions in the vicinity of the moraines, which probably represent kettles that formed in glacial drift and have been modified by erosion. An elongate valley with rocky walls extends offshore from Salem Sound, passing between Little Misery and Bakers Islands. The valley exhibits a pattern of tributaries and a main channel that were probably eroded by the ancestral Danvers River when relative sea level was lower than today.

No major rivers presently deliver significant amounts of sediment to the area, so reworking of existing deposits has largely determined the observed distribution of bottom sediment. Modern processes interact with bedrock and glacial deposits to create the sandy beaches and other coastal landforms extant along the present shoreline. Sandy sediment, derived from reworked glacial sediment, has also accumulated on the surface of broad, gently sloping areas of seafloor in Nahant Bay in the southwestern part of the map, and offshore of Manchester in the northeastern part of the map. Thick deposits of muddy sediment primarily occur in Salem Sound, where islands and shoals at the estuary mouth provide shelter from large waves out of the northeast and create a depositional environment. More details on the geologic framework and evolution of the region are found in the report that accompanies this map.

The narrow trough or furrow-like feature crossing Salem Sound was created by construction of a high-pressure pipeline that carries natural gas from Canada to the Boston area. The 30-inch diameter steel pipe is buried below the seafloor. It passes east of Childrens Island and out into deeper water, turning southwest towards Boston.

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