High-Resolution Geologic Mapping of the Inner Continental Shelf: Cape Ann to Salisbury Beach, Massachusetts

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Map Sheet 4 : Shaded-relief topography of the seafloor (colored by backscatter intensity.)

Introduction

A series of five map sheets shows the seafloor topography and geology of the inner continental shelf between Cape Ann and Salisbury Beach, Massachusetts. This map (sheet 4) shows seafloor topography in shaded-relief view, and colored by backscatter intensity, with selected bathymetric contours overprinted in black. Sheet 1 shows shaded-relief topography in color, sheet 2 shows shaded-relief topography in grayscale, sheet 3 shows acoustic backscatter intensity, and sheet 5 shows seafloor geology. These maps were 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 available on the Internet and a DVD-ROM that presents a full description of the data-collection, processing, and analysis procedures used to create the maps. The report also includes copies of selected data layers in a Geographic Information System (GIS).

The intensity of acoustic backscatter shown on this map is represented by a spectrum colors, ranging from orange (high-backscatter values) to blue (low-backscatter values). High-backscatter values indicate that the seafloor is generally composed of coarse sand, gravel, cobbles, boulders, and rock. In contrast, moderate- to low-backscatter values indicate a bottom composed of finer grained mixtures of sand and mud. Accurate interpretation of substrate properties from acoustic backscatter data requires validation by sediment sampling, bottom photography, and video. The shaded-relief image was created by vertically exaggerating the bathymetry five times and then artificially illuminating the relief by a light source positioned 335° above the horizon from an azimuth of 45°. Bathymetric contours are shown at 10-m intervals and, for clarity, have been simplified or omitted in areas of complex topography.

Additional data are included on this map to show the regional topography in areas adjacent to the area of the new survey. To the north and west, seafloor topography in shaded-relief view is shown at a reduced resolution of 90 m/pixel from the data published by the National Geophysical Data Center (NGDC) Coastal Relief Model (Divins and Metzger, 2007). Hillshaded bathymetry to the east and southeast from Butman and others (2007) is displayed at a resolution of 10 m/pixel. Onshore topography displayed at a resolution of 5 m/pixel is from the Massachusetts Geographic Information System (MassGIS, 2005). Some features in the image are artifacts of data collection and environmental conditions. They include small highs and lows and unnatural-looking patterns oriented parallel or perpendicular to survey tracklines, which were oriented northwest-southeast in the map area.

Data and Methods

Approximately 325 km^2 of the inner shelf in water depths of 2–92 m were mapped on two separate cruises in 2004 and 2005. Several different geophysical systems were used, including multibeam echosounders and interferometric sonars (bathymetry), sidescan and multibeam sonars (acoustic backscatter intensity), and chirp seismic-reflection profilers (subsurface stratigraphy and structure).

In deeper offshore areas, bathymetric data on this map were collected by a Reson 8101 multibeam echo sounder (MBES) operating at a frequency of 240 kHz (SAIC, 2004). The system has a 101-beam transducer that collects depth data in a continuous swath on either side of the vessel. Adjacent swaths were overlapped to achieve 100 percent coverage of the seafloor. Depth data were processed with SABER software developed by Science Applications International Corporation (SAIC). The bathymetric data have a vertical resolution of approximately 0.5 percent of water depth and a grid cell size of 5 m. Tidal offsets, calculated by using a discrete tidal-zoning model and observations from National Oceanic and Atmospheric Administration (NOAA) Tidal Station #8418150 at Portland, Maine (NOS CO-OPS, 2005), were used to reference the soundings to the local mean lower low water datum.

In shallower nearshore areas, bathymetric data were collected by a SEA SwathPlus 2000 series interferometric sonar that operates at a frequency of 234 kHz. The system has two transducers that collect depth data in a continuous swath on either side of the vessel. Adjacent swaths were overlapped to obtain 100 percent coverage of the seafloor. Data were processed and gridded with the CARIS Hydrographic Information Processing System (HIPS ver. 6.1). Minor gaps were filled by creating a Triangulated Irregular Network (TIN). The bathymetric data have a vertical resolution of approximately 1 percent of water depth and a grid cell size of 5 m. Navigation was provided by a Real-Time Kinematic Global Positioning System (RTK-GPS) from a base station established onshore. Tidal offsets were calculated by using RTK-GPS orthometric elevations (GEOID 03, NAVD88) and were applied to soundings during post processing. Soundings were referenced to local mean lower low water using an ellipsoid to chart datum offsets obtained from NOAA Tidal Station #8440452 located at the Parker River National Wildlife Refuge.

Bottom photography and sediment sampling at 87 stations were used to validate interpretations of the remotely-sensed geophysical data. A SEABed Observation and Sampling System (SEABOSS; Valentine and others, 2000) recorded continuous video and still photographs along drift tracks that typically lasted 5–15 minutes at each station. Sediment samples were collected at locations where the bottom was not covered with boulders or ledge and analyzed for grain size by the methods outlined in Poppe and others (2005).

Features

Maps depicting topography and surficial materials on the inner continental shelf play an important role in representing the geologic history of the region and the 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 and others, 1983). Erosion-resistant granitic rocks form rugged headlands and submarine shoals that define the northern and southern margins of the study area. Glaciation and relative sea-level change are the most important processes to have acted on the region and have produced a heterogeneous mix of bottom types on the inner continental shelf. Late Pleistocene glaciers reached their maximum extent south of Cape Cod about 21,000 years before present (yrs B.P.) and retreated northward as the climate warmed. The retreating ice margin passed the present coast of Cape Ann about 14,500 yrs B.P. (Kaye and Barghoorn, 1964). The glaciers smoothly eroded the underlying bedrock and largely buried it with bouldery till and muddy glacial-marine sediment (Stone and others, 2006). Thick deposits of coarser grained fluvial, deltaic, and littoral sediment accumulated above the glacial deposits and masked the underlying topography beneath a generally smooth, seaward-dipping seafloor. These younger sediment accumulations represent the variety of different environments that existed on the inner shelf after the end of the last Ice Age.

Large excursions in relative sea level, primarily caused by a combination of global climate change and local isostatic effects, have driven profound changes in the position of the coastline and strongly influenced the geologic evolution of the region. Relative sea level fell from a highstand of +33 m at 14,500 yrs B.P. to a lowstand of about -50 m at 12,000 yrs B.P. (Stone and Peper, 1982; Oldale and others, 1993). As isostatic rebound decreased, relative sea level rose at different rates to the present elevation. The ongoing Holocene transgression (i.e. landward migration of the coast) has reworked a wide expanse of the inner shelf, and eroded a prominent unconformity overlain by relatively thin, discontinuous deposits of mobile sand. Large mounds of boulder-sized clasts represent the remnants of ice-contact deposits such as drumlins and moraines, which have been eroded by marine and terrestrial processes. In water depths greater than about 50 m, below the sea-level lowstand, the generally smooth seafloor is dominated by fine-grained marine mud interrupted by a few widely separated outcrops of ledge and boulders. Scoured moats around these deep-water outcrops indicate persistent erosion by bottom currents.

The Merrimack River, which drains a large area of Massachusetts and New Hampshire, enters the Gulf of Maine just north of Cape Ann. Sediment supplied by the river and derived from erosion of coastal and inner-shelf deposits has built the longest chain of sandy barriers in the Gulf of Maine (FitzGerald and others, 1994). The barrier islands and spits are pinned to bedrock or glacial promontories along the coast and stretch approximately 30 km from Ipswich Bay to the New Hampshire border.

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