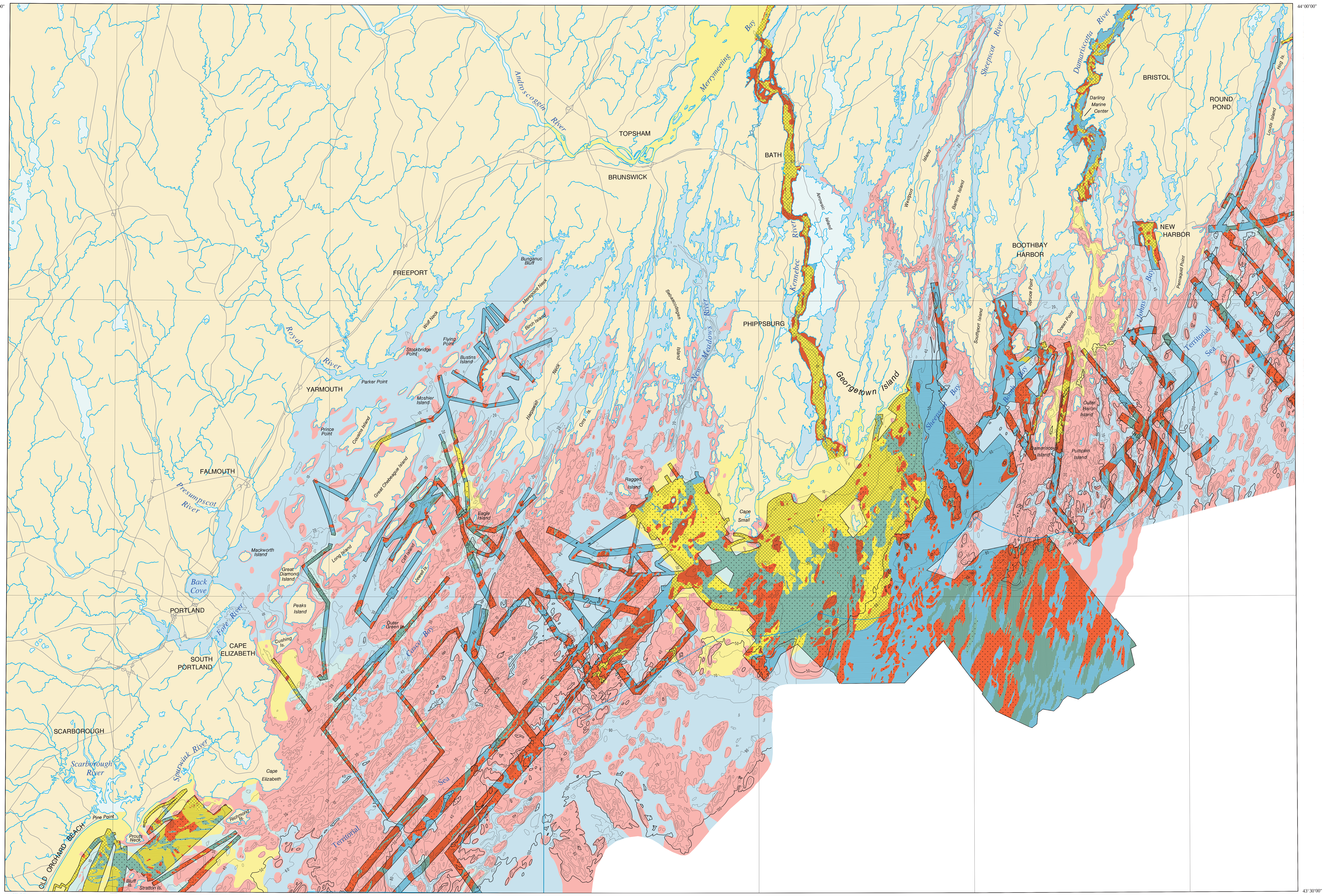
Surficial Geology of the Maine Inner Continental Shelf



Map Projection: Universal Transverse Mercator, Zone 19
1927 North American Datum

Map Scale 1:100,000

National Geodetic Vertical Datum of 1929
Contour Interval 10 Meters

Cape Elizabeth to Pemaquid Point, Maine

Walter A. Barnhardt
Daniel F. Belknap
Alice R. Kelley
UNIVERSITY OF MAINE
Department of Geological Sciences
Orono, Maine 04469-5711

Joseph T. Kelley
Stephen M. Dickson
DEPARTMENT OF CONSERVATION
Maine Geological Survey
22 State House Station
Augusta, Maine 04333-0022

Published by:
DEPARTMENT OF CONSERVATION
Maine Geological Survey
Robert G. Marvinney, State Geologist

GEOLOGIC MAP NO. 96-9
1996

Funding for the preparation and publication of this map was provided by the Regional Marine Research Program (RMRP #NA46RM0451)

Digital cartographic production and design by:
Bennett J. Wilson, Jr.
Robert D. Tucker

INTRODUCTION

SURFICIAL GEOLOGY

Introduction

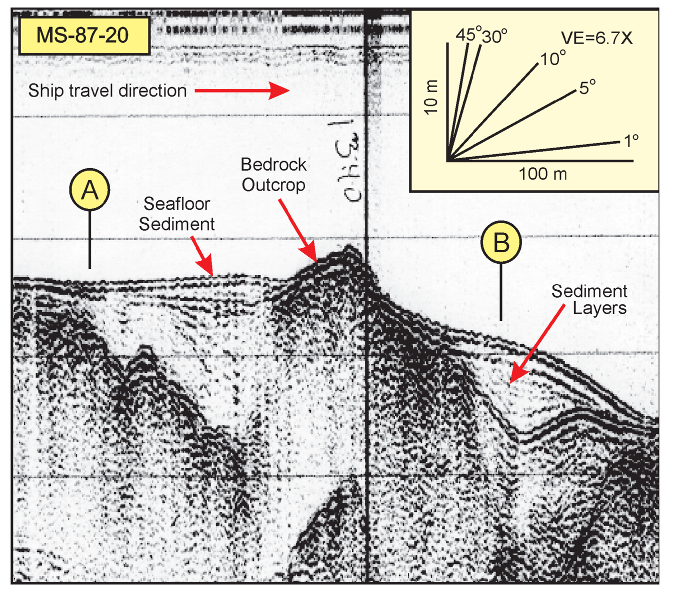
The surficial materials of the inner continental shelf of the northwestern Gulf of Maine are the most complex of any place along the Atlantic continental margin of the United States. Igneous, metamorphic, and sedimentary rocks spanning hundreds of millions of years of earth history form the regional basement. Glacial deposits, containing all clast sizes from boulders to mud, partially mantle the rocks. These materials, in turn, have been reworked by coastal processes during extreme fluctuations of sea level over the past few thousand years to create better-sorted modern deposits (**5**). Biological processes, including shell formation, bioturbation, and organic matter cycling have also altered the sediment composition and left geological imprints on the seafloor (**7, 8**). In addition to the surficial geology of this map, the geomorphology of the seafloor has also been mapped. The *Physiographic Map of the Maine Inner Continental Shelf* (**9**) shows the geomorphology of the offshore region covered by this series of surficial geologic maps in a single, smaller scale map.

Rocky Areas

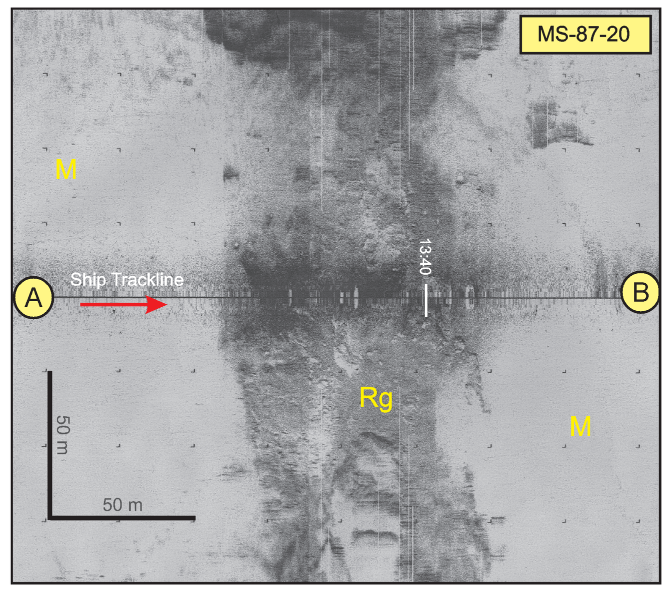
Rocky seabed occupies approximately 41% of the inner continental shelf and is the most abundant seafloor type in this map series. Where little data exist and the seafloor relief is very irregular, a rocky bottom was inferred. By this inference, large areas of rocky bottom were mapped off extreme southern Maine, Penobscot Bay, and Petit Manan Point. Large areas of rock also occur surrounding the many granitic islands in Blue Hill and Frenchman Bays. Elongate, submerged rock ridges follow the linear trend of the Casco Bay peninsulas. Although common as nearshore shoals in water less than 10 m (33 ft) deep, large outcrops of rock are relatively rare in deep offshore basins.

The bedrock geology was not determined, but side-scan sonar images clearly depict parallel fractures and elongate outcrop patterns common in layered metamorphic rocks as well as more rounded bodies of rock often associated with plutonic (granitic) igneous rocks (**10**). In shallow water, rock outcrops are usually covered with algae (seaweed) and encrusting organisms. Below water depths of a few tens of meters (the photic zone), encrusting organisms and organic mats often cover bedrock outcrops. "Rock greater than mud" (**Rm**; for an explanation of abbreviations see **Interpretation of Side-Scan Sonar Images**) is most common in deep offshore basins where outcrops project up through the mud that mantles the seafloor. **Rm** also occurs as small areas seaward of tidal flats in nearshore basins. "Rock greater than sand" (**Rs**) exists only in a few locations offshore of beaches.

Areas adjacent to rock outcrops are commonly covered with shells of dead organisms. Formerly attached to the rock surface, these shelly remains are mixed with angular rock fragments that have fallen off the outcrop (**8**). Bedrock fractures and troughs also have a similar mixture of shell and rock clasts. For this reason, extensive, "pure" rock outcrops were infrequently mapped. Instead, fractured bedrock and small bodies of rock were most often mapped as "rock greater than gravel" (**Rg**) or "gravel greater than rock" (**Gr**), two of the most common seafloor types observed.



Seismic Reflection Profile. The image above is a portion of an ORE seismic reflection profile from Muscongus Bay and shows a cross-section (side view) of the seafloor. The seafloor surface shape is analagous to a fathometer profile. A vertical exaggeration (VE) of 6.7 makes all slopes appear steeper than they really are. The subsurface reflectors are from sediment layers and buried bedrock surfaces. Positions A and B correspond to the same locations in both figures. A time mark is shown by the vertical line at 13:40.



Side-Scan Sonar Profile

METHODS

Navigation and Map Compilation

Navigation fixes in the outer estuaries and offshore areas were made at 2 to 5 minute intervals with LORAN-C, which provided an accuracy of ± 100 m (330 feet). In the upper reaches of the estuaries, radar and line-of-sight observations on buoys and landmarks provided navigational accuracy that varied from less than ± 10 m (33 feet) to around ± 200 m (660 feet). Recent work used the global positioning satellite system (GPS) for navigation and was accurate to ± 10 m (33 feet). All navigation was converted to Universal Transverse Mercator projection and plotted with a geographic information system (GIS).

Surficial geologic maps were prepared in six steps: (1) use a GIS to plot the geophysical tracklines, bottom sample locations, and bathymetry on large-scale maps, (2) interpret sonar records and geology based on other geophysical data and samples, (3) digitize the drafted interpretation into a GIS, (4) compile and edit the digital data to generate map polygons, (5) check the mapped geology, and (6) assemble the final product including geology, bathymetry, geographic names, and roads. The shoreline and roads are from the U.S. Geological Survey's 1:100,000 Digital Line Graph files.

Bathymetry

Bathymetry was digitized at a 10 m contour interval from preliminary National Ocean Service (NOS) Bathymetric and Fishing Maps at a 1:100,000 scale. The NOS bathymetric maps provide a 2 m contour interval in many locations that is too complex for inclusion on this map. Difficulty in interpretation of positive and negative changes in bathymetry on the poorly labeled NOS maps created many possible errors, especially in areas where accompanying geophysical data were lacking. For this reason, these maps should not be used for navigation. More detailed and accurate NOS conventional nautical charts should be used for navigation.

Bottom Samples

Between 1984 and 1991, 1,303 bottom sample stations were occupied (see the **Features and Data Source Map** for locations in this region). Two attempts were made at each station where the sampler initially returned empty, after which the site was considered a rock bottom. A Smith-McIntyre stainless steel grab sampler was used that nominally collected up to 0.016 m^3 (0.5 ft^3) of sediment. Southwest of Cape Small, samples were generally collected in a grid pattern with a 2 kilometer (1 nautical mile) distance between sample sites. Focus was placed on the large sandy embayments off Wells, Saco, and the Kennebec River mouth, as well as on muddy Casco Bay. Relatively few bottom samples were gathered off rocky areas such as Kennebunk or Kittery. Geophysical tracklines were later run over the sample stations to permit extrapolation of the bottom sediment data. North and east of Cape Small, geophysical data were generally gathered before bottom samples. This resulted in a need for fewer samples, and so fewer stations were occupied. Following collection, samples were stored in a freezer in the sedimentology laboratory at the University of Maine. Depending on the level of funding or specific needs of a particular project, samples were analyzed for grain size, organic carbon and nitrogen, carbonate content and/or heavy minerals (see Table 1 of **Reference 1**).

Side-Scan Sonar Profiles

Analog side-scan sonar records along 3358 km (1800 nmi) of the seafloor were gathered with an EG&G Model SMS 260 slant-range corrected sonar operating with a Model 272-T towfish at a nominal frequency of 105 kHz. The device was most often run at a 100 m (330 ft) range for each channel (200 m wide swath beneath the research vessel), although ranges from 25 to 300 m (80 to 1000 ft) were occasionally employed. The swaths of directly imaged and interpreted seafloor areas are depicted in brighter colors on the map. See the **Surficial Geology Legend** in the lower left corner of the map and the **Interpretation of Side-Scan Sonar Images** for further details.

Seismic Reflection Profiles

Seismic reflection profiles were gathered along 5011 km (2700 nmi) of tracklines, often in conjunction with side-scan sonar data (see simultaneous seismic and side-scan images above). A Raytheon RTT 1000a 3.5/7.0 kHz unit with a 200 kHz fathometer trace was used mainly in relatively shallow water (0 to 50 m; < 165 ft) over muddy bottoms. An ORE Geopulse "boomer" (0.5 to 200 kHz) seismic system was most effective in deeper water (15 to 150 m; 50 to 500 ft) over thicker deposits of sandy or gravelly sediment. Although seismic reflection profiles are most useful in constructing the geological history of an area, the bathymetry and stratigraphic context they provide, along with the strength of the surface return, also help identify the seafloor type (**6**). When used in conjunction with the side-scan sonar data, both the age and nature of the surficial sediment are easily interpreted.

Gravelly Areas

Sandy Areas

Muddy Areas

Surficial Geology Legend

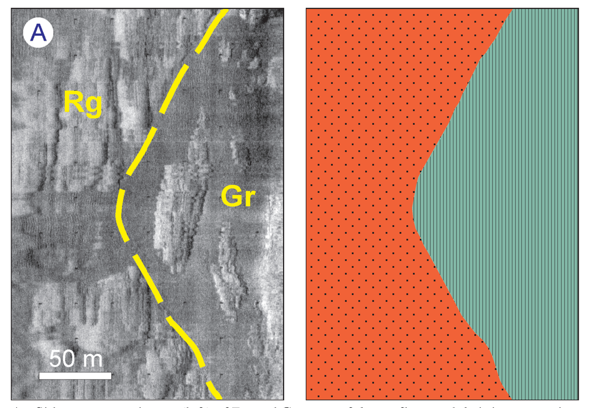
ROCKY

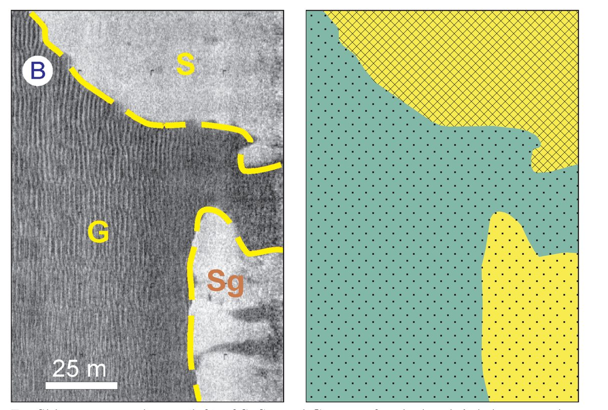
GRAVELLY

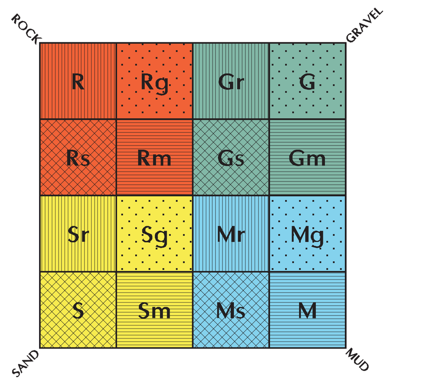
SANDY

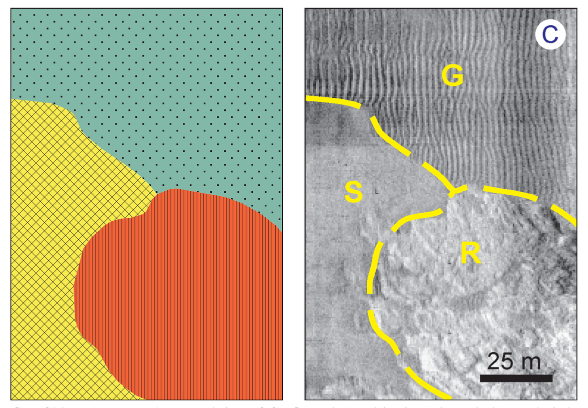
MUDDY

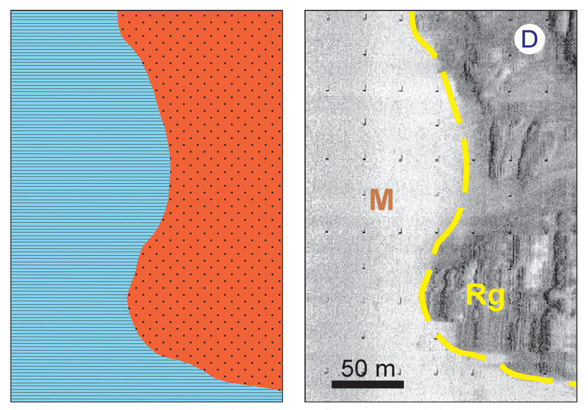
Interpretation of Side-Scan Sonar Images



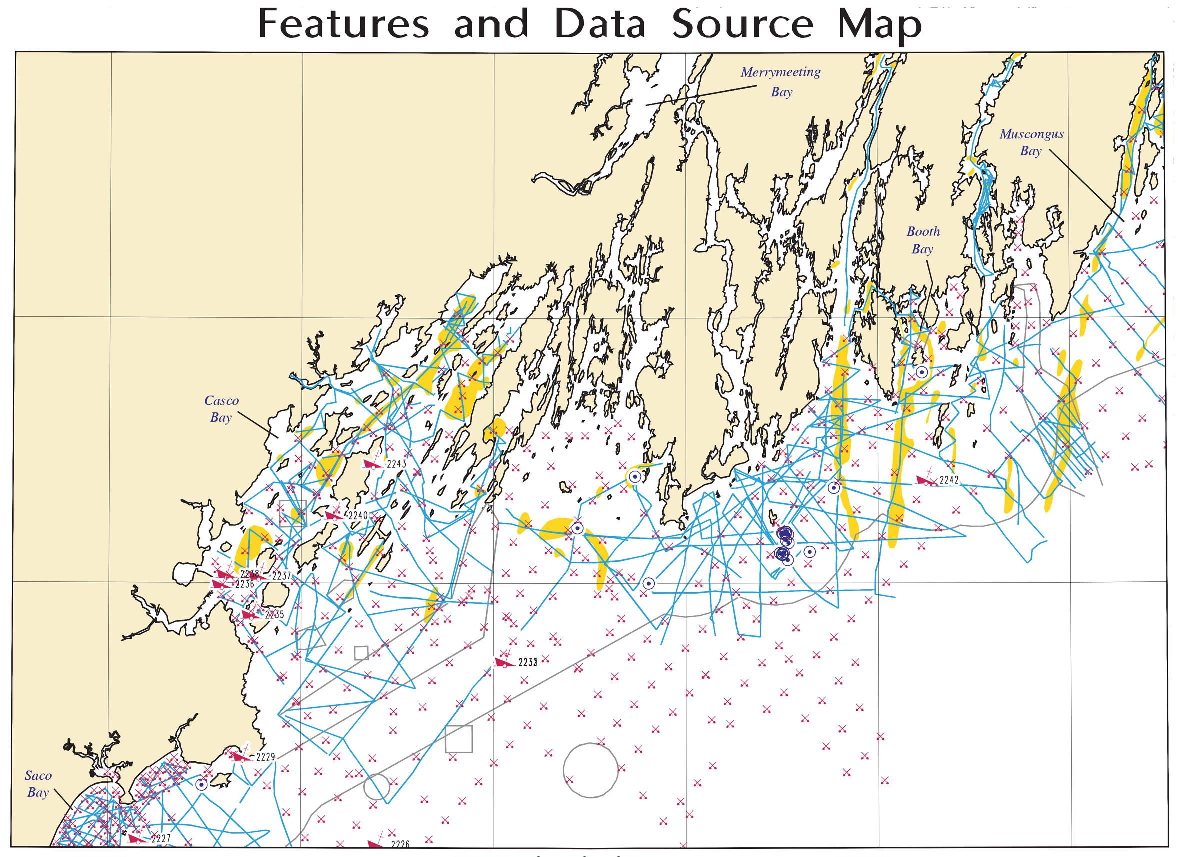


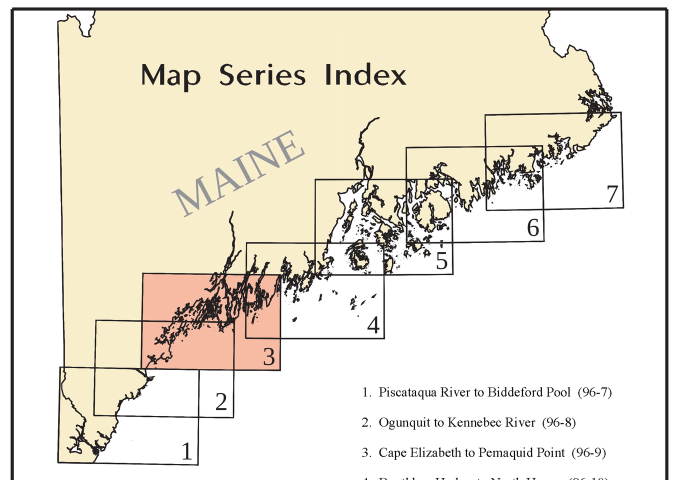






Features and Data Source Map





1. Piscataqua River to Biddeford Pool (96-7)
2. Ogunquit to Kennebec River (96-8)
3. Cape Elizabeth to Pemaquid Point (96-9)
4. Boothbay Harbor to North Haven (96-10)
5. Rockland to Bar Harbor (96-11)
6. Mt. Desert Island to Jonesport (96-12)
7. Petit Manan Pt. to West Quoddy Head (96-13)

Not to be Used for Navigation

REFERENCES CITED

(1) Kelley, J. T., Barnhardt, W. A., Belknap, D. F., Dickson, S. M., and Kelley, A. R., 1996, The seafloor revealed: the geology of the northwestern Gulf of Maine inner continental shelf: Maine Geological Survey, Open-File Report 96-6, 55p.

ACKNOWLEDGEMENTS