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Acoustic Backscatter Mapping in Stellwagen Bank National Marine Sanctuary

OS22A-11

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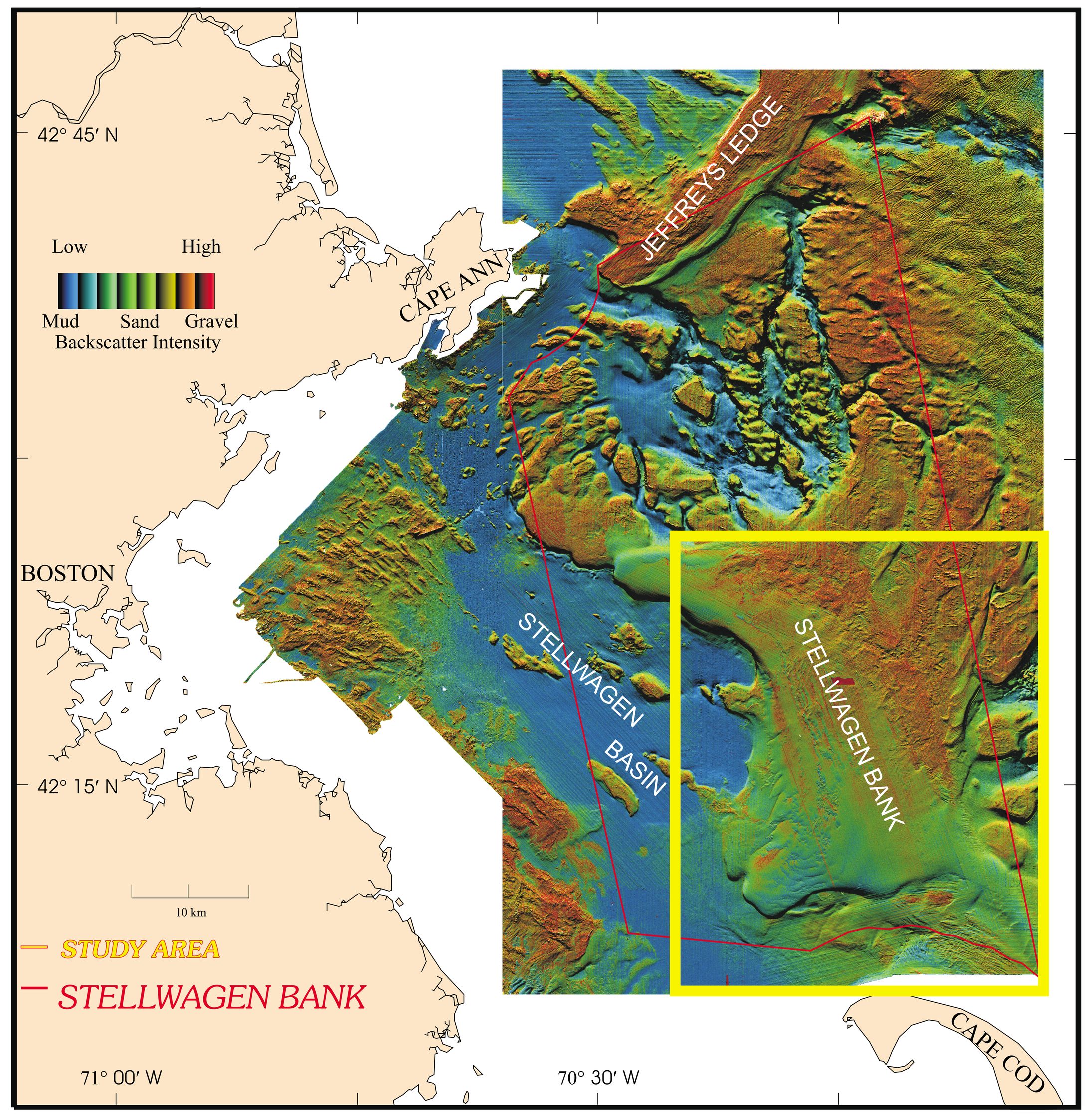
Introduction

Backscatter data from a Kongsberg Simrad EM1000 multibeam sounder have been compared with grain size information in the Stellwagen Bank National Marine Sanctuary (SBNMS) to determine the extent of quantitative relationships between these two for the purposes of classifying sediment in areas lacking bottom sampling. The SBNMS region covers approximately 3800 square km (1100 square nm) lying approximately 25 nm off the coast of Boston, Massachusetts. The SBNMS Mapping Project database includes continuous multibeam backscatter and bathymetric coverages (average resolution ~10 m) and extensive ground truth information (1318 bottom samples, video camera coverage, submersible dives, etc.). Stellwagen Bank is host to a wide range of sediment types (boulders to clayey silt) and thus provides an excellent natural laboratory to investigate the relationship between grain size and backscatter strength (BS).

The Stellwagen Bank NMS Region



Sun-illuminated map of Stellwagen Bank National Marine Sanctuary and Massachusetts Bay with backscatter intensity draped over the topography. Red indicates high-backscatter material including coarse sand, gravel, and rock; green indicates sand; blue indicates mud. Within each backscatter color interval, the intensity varies from dark to light depending on the sun illumination. The image illustrates the wide variety of sedimentary environments in this region of the coastal ocean. The transitions between sediment types are often very sharp. Topographic features observed here were formed for the most part by glacial processes. Glacial ice containing rock debris moved across the region, sculpting its surface and depositing sediment to form basins, knolls, banks, and other features. Later, many of the smaller features were formed during a final period of ice stagnation and melting. Today, the sea floor is mainly modified by storm currents and waves from the northeast. These currents erode sand and mud from the shallow banks and transport them into the basins. Stellwagen Bank and Jeffreys Ledge are shallow banks (20-40 m water depth) covered with sand and gravel. Stellwagen Basin (80-100 m) is floored with mud. In deeper water (85-140 m) in the northeastern part of the image, a fine hummocky pattern on the sea floor was created by gouges (5-10 m deep and up to 120 m wide) caused by icebergs that grounded in the muddy sand at the close of the last period of glaciation. The yellow box shows the location of the study area.

Methods

Data Collection

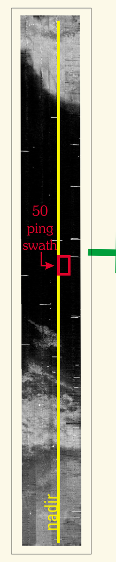
Multibeam Data

- Survey using the *Frederick G. Creed, a* SWATH (small waterplane twin hull) vessel between the fall of 1994 and the fall of 1996
- Continuous bottom coverage using the Kongsberg Simrad EM 1000 multibeam sounder (95 kHz); Data collection at 15 knots in water depths between 5 m and 200 m
- EM 1000 has 60 aimed beams set at intervals of 2.5 degrees that insonify an area 7x the water depth with a horizontal resolution here averaging about 10 m
- Data processing using SWATHED, a suite of software developed by the Ocean Mapping Group of the University of New Brunswick

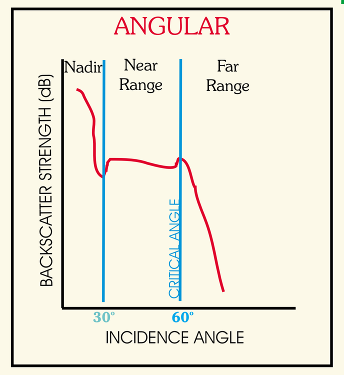
Sediment Data

- Samples collected using a modified Van Veen sampler which measures an area of 0.1 meters square by 6 in deep sampling bucket. See map below for location of sediment samples.
- The top 2 cm of sediment are collected and characterized by wet sieve, settling tube, and Coulter Counter analyses.

Angular Response Analysis



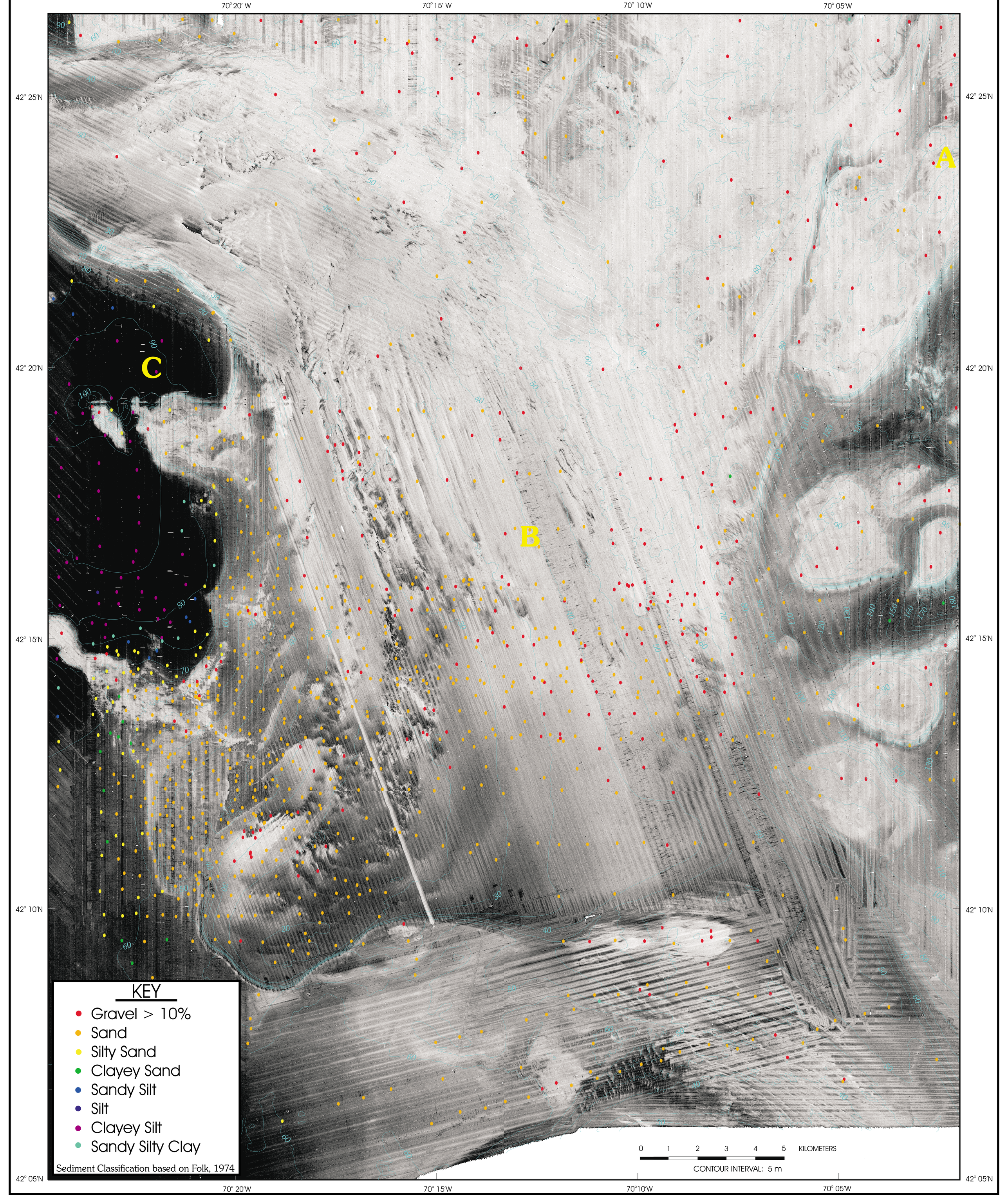
An average angular response curve is generated for every 50 ping swath. The backscatter response received by each of the 60 beams is plotted against the angle of incidence of the pulse to the sea floor.



An area of gravel pavement is selected and an angular response curve is generated for each cruise. Due to the nature of true gravel pavement, volume scattering will be limited and a Lambertian curve should result. This curve is used to normalize the rest of the data set for that cruise. The data is tested for sediment boundaries. If a swath crosses an apparent boundary it is discarded.

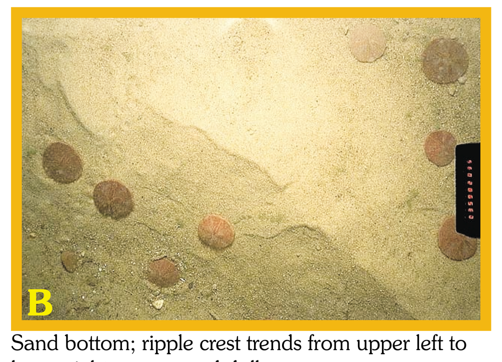
Once normalized the angular response for a chosen angle of incidence may be plotted against sediment parameters to determine a correlation.

Backscatter and Sediment Samples

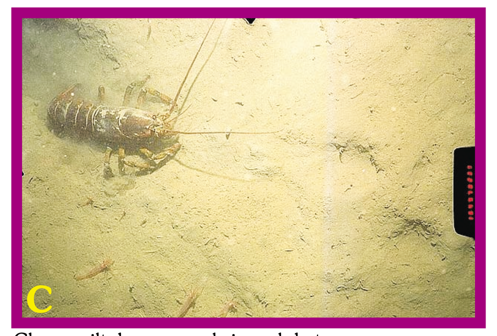


Bottom Photos

Gravel bottom; some shell fragments; cerianthid anemone
Percent Gravel: 73.7 % Percent Sand: 21.9 %
Percent Silt: 2.44 % Percent Clay: 1.97 %
Mean Grain Size: -1.34 phi
Standard Deviation: 2.81



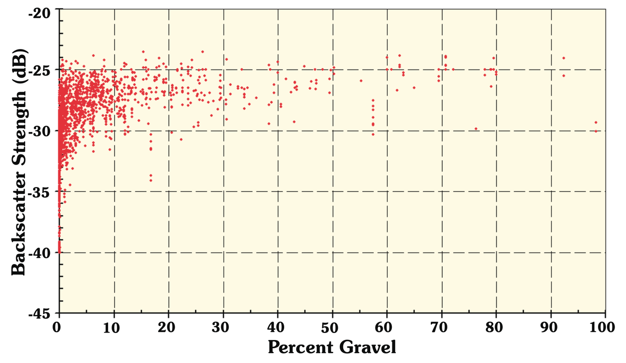
Sand bottom; ripple crest trends from upper left to lower right; many sand dollars
Percent Gravel: 1.01 % Percent Sand: 98.8 %
Percent Silt: 0.07 % Percent Clay: 0.06 %
Mean Grain Size: 0.54 phi
Standard Deviation: 0.7



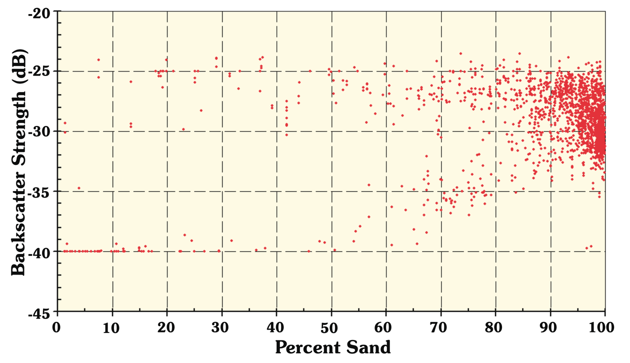
Clayey silt; burrows; shrimp; lobster
Percent Gravel: 0.00 % Percent Sand: 11.1 %
Percent Silt: 67.9 % Percent Clay: 20.9 %
Mean Grain Size: 6.33 phi
Standard Deviation: 1.91

Grain Size and Backscatter Strength

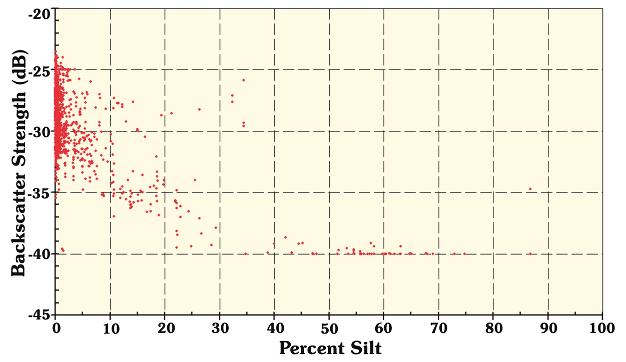
Percent Gravel vs. Backscatter Strength



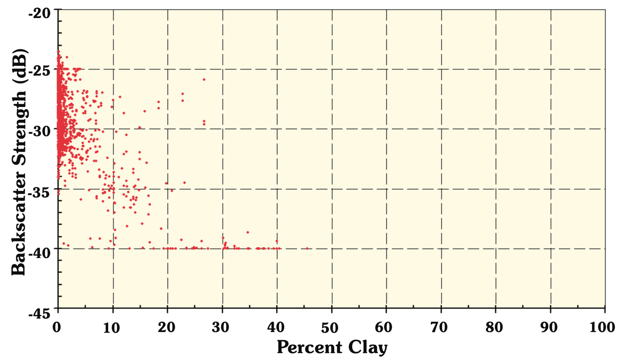
Percent Sand vs. Backscatter Strength



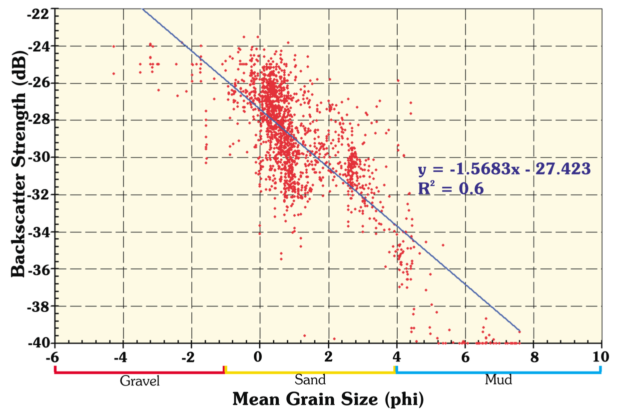
Percent Silt vs. Backscatter Strength



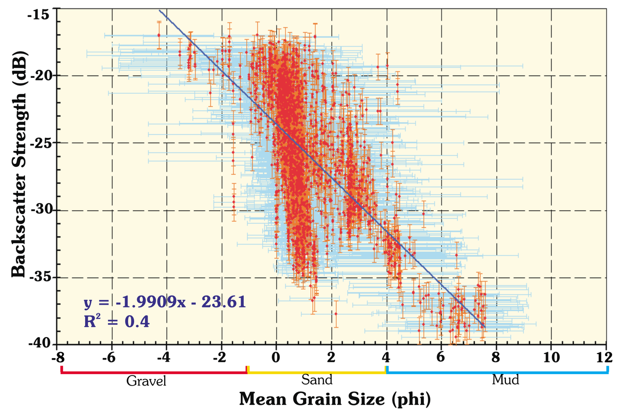
Percent Clay vs. Backscatter Strength



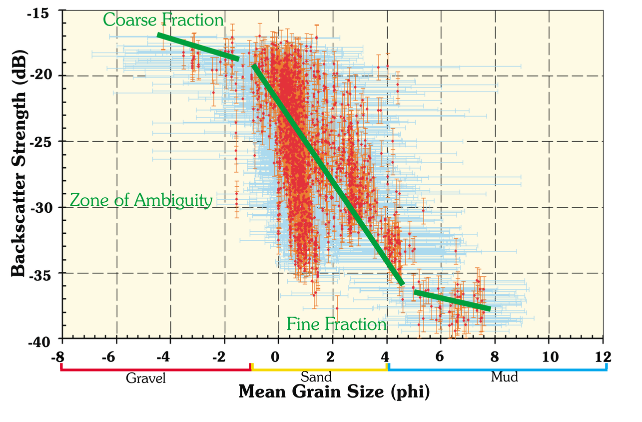
Mean Grain Size vs. Backscatter Strength



Mean Grain Size vs. Backscatter Strength for the 50° - 55° Range of Angle of Incidence



Mean Grain Size vs. Backscatter Strength for the 50° - 55° Range of Angle of Incidence



Results

- As expected gravel has high backscatter strength and silt has low backscatter strength.
- Using this method, we may isolate 2 trends separated by a zone of ambiguity; one in the coarse (gravel) fraction and another in the fine (mud) fraction.
- Most scattering appears to be in the -2 phi to 5 phi range, or sandy materials. This is probably due to the wide variety of bedform features associated with sandy sea floor environments.
- On the basis of backscatter alone, it is difficult to separate sand from gravel without ground truth data.