

Statistical Characterization of Bathymetry and Stratigraphy on Continental Margins

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Award Number: N00014-95-1-0067

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LONG-TERM GOALS

- Enable realistic acoustic modeling in the continental shelf environment given limited geological and geophysical data.

OBJECTIVES

- Formulate statistical models of shelf and slope bathymetric roughness and for stratigraphic architecture.
- Develop methodology for interpolation of sparsely sampled bathymetric and stratigraphic data.
- Ground-truth swath sonar data to enable prediction of geotechnical properties of surface sediments.

APPROACH

The focus of this past year's STRATAFORM efforts have been aimed at ground-truthing the swath sonar data from the New Jersey natural laboratory. In a joint effort with JOI (part of a site survey augmentation for Mid-Atlantic Transect proposed drilling sites), a series of ~300 grab samples were collected within the STRATAFORM swath survey area in water depths ranging from 20 m to 70 m (Figure 1). Other participants in this effort included Hilary Olson and James Austin, both from UTIG. Sediment samples were analyzed for grain size distribution, and will be the focus of a micropalaeontological study by Olson. A two-phase sampling strategy was used. Over areas that exhibited rapid variations (~100 m) in acoustic backscatter, which included bedforms such as ribbons and dunes, a series of samples were collected at a station spacing of ~50 m. Over larger-scale bedforms, predominantly sand ridge morphology, stations were spaced several hundred meters apart, but three samples were collected at each station to reduce variability.

The purpose of the sediment grab sampling and grain-size analysis was to establish a correlation, if possible, between grain-size distribution and backscatter intensity. Sediment grabs were collected from the seafloor using a van Veen sampler. Sample sizes of ~100-300 g were retained for analysis; each sample was washed, dried, weighed and sieved through a series of mesh sizes ranging from 4 mm to 0.0625 mm, each sequential mesh size reduced by a factor of two from the previous. Finally, each sieved portion was weighed and divided by the total weight for computation of weight percent. Typically grain-size distributions approximate a log normal distribution (Pettijohn et al. 1987). Hence, following standard practices, sieve sizes were converted to ϕ units (Pettijohn et al. 1987) using the

Report Documentation Page

Form Approved
OMB No. 0704-0188

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1. REPORT DATE 30 SEP 1999		2. REPORT TYPE		3. DATES COVERED 00-00-1999 to 00-00-1999	
4. TITLE AND SUBTITLE Statistical Characterization of Bathymetry and Stratigraphy on Continental Margins				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of of Texas at Austin, Institute for Geophysics (UTIG,4412 Spicewood Springs Road, Bldg. 600, Austin, TX, 78759				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT unclassified	b ABSTRACT unclassified	c THIS PAGE unclassified			

equation $\phi_s = -\log_2[\text{sieve size, mm}]$, and, for the purpose of computing the mean grain size, the weight percent for each sieved portion is centered at $\phi_s - 1/2$.

WORK COMPLETED

Structural interpretation and statistical analysis of the STRATAFORM northern California and New Jersey margin swath mapping surveys were covered in the PI's 1995 and 1996 progress reports. Results from the northern California survey were presented in Goff et al. (1996) and Goff et al. (1999). Results from the New Jersey shelf survey are presented in Goff et al. (in press.). The PI's 1998 progress report described collaborative work with Dr. N. Driscoll of Woods Hole Oceanographic Institution on an analysis of the statistical character of canyon systems on the New Jersey and Virginia continental slopes. This work was presented at AGU (Goff and Driscoll, 1997) and is the subject of both a submitted manuscript (Driscoll et al., submitted) a manuscript in preparation.

In collaboration with Dr. J. Jennings at the University of Texas Bureau of Economic Geology, a study has been completed which optimizes the Fourier methods of unconditional and conditional simulations (Goff and Jennings, 1999). This study was described in the PI's 1997 progress report. Computer code has been developed for generating Fourier conditional simulations of two dimensional fields with arbitrary conditioning criteria, using and combination of anisotropic Gaussian and von Kármán model as a basis. This code is available for distribution from the PI. A working stratigraphic simulation algorithm (SimStrat), described in the PI's 1998 progress report, has been completed both for two- and three dimensions. This work is presented in Goff (in press).

The primary task accomplished over the past year has been the collection and analysis of the sediment grab samples within the STRATAFORM New Jersey swath map region. The cruise was very successful and the grain size analysis is complete. This work is the subject of a manuscript submitted to *Geo-Marine Letters*.

RESULTS

In a comparison of 95 kHz sidescan data and grain size distribution from samples on the primarily siliciclastic New Jersey shelf, we have been able to establish, under certain conditions, an unprecedented degree of correlation between backscatter strength and mean grain size (Figure 2). However, the correlability of backscatter and mean grain size cannot be established everywhere in our survey area, particularly in the deeper waters seaward of the mid-shelf shore (Figures 1, 3). We find that our ability to correlate backscatter and mean grain size is strongly dependent on the shape of the grain size distribution; in particular, a unimodal distribution with small variance (well sorted) is required. Addition of just a few extra weight percent of the larger grain sizes (> 4 mm), which in our samples typically consists of shell hash, can throw off the correlation (Figure 4). Backscatter is most sensitive to the proportion of the larger grain sizes. We could, theoretically, establish a good correlation between backscatter intensity and the weight percent of the largest grain sizes. However, it is almost impossible to obtain a representative weight percent measurement of the largest grain sizes from a single sample, which might only include a few shell pieces for the sample sizes we employed. Only by averaging the results from a number of such samples can the proportion of the larger grain sizes be accurately measured. Nevertheless our result do clearly indicate that the grain size distribution, though not necessarily just the mean, is the primary determinant of backscatter intensity in this sandy sediment seafloor environment.

Our grain size analysis also supports several of the conclusions of Goff et al. (1999) based on inference of the bathymetry and backscatter data in this region. In particular: (1) the smaller scaled, ~N-S oriented features on the inner shelf are transverse-to-flow dunes responding to an onshore directed flow as evidenced by the consistently larger grain sizes on the seaward slopes; (2) the surfaces of mid shelf ridges are winnowed of fines, which could armor them against modern reworking, (3) the presence of greater portions of shell hash on the mid shelf implies that those surficial sediments are older and more stable than inner shelf sediments; and (4) in the absence of any significant modern deposition, the presence of muddy sediment in the mid shelf ribbon-floored swales confirms that erosion into lower sedimentary strata is taking place at the edges of these swales, undercutting the coarse-grained mid shelf sand ridges.

IMPACT/APPLICATIONS

Our efforts at ground-truthing the sidescan backscatter and bathymetry data will help us to infer geotechnical properties of surficial sediments over a broad region. Knowledge of the near-surface sediment properties is essential for attempts to model forward-propagating acoustic energy because most all of the wavefield/seafloor interactions occur below the critical angle. The surficial sediments will thus largely determine whether reverberated energy is derived from surface roughness or from subsurface heterogeneities.

TRANSITIONS

It is expected that the software and expertise developed under this grant will be utilized by acoustic modelers in the newly-formed ONR Geoclutter program.

RELATED PROJECTS

In collaboration with J. Austin (UTIG) and N. Makris (MIT) I have begun work on the ONR Geoclutter program, which is described in a separate progress report.

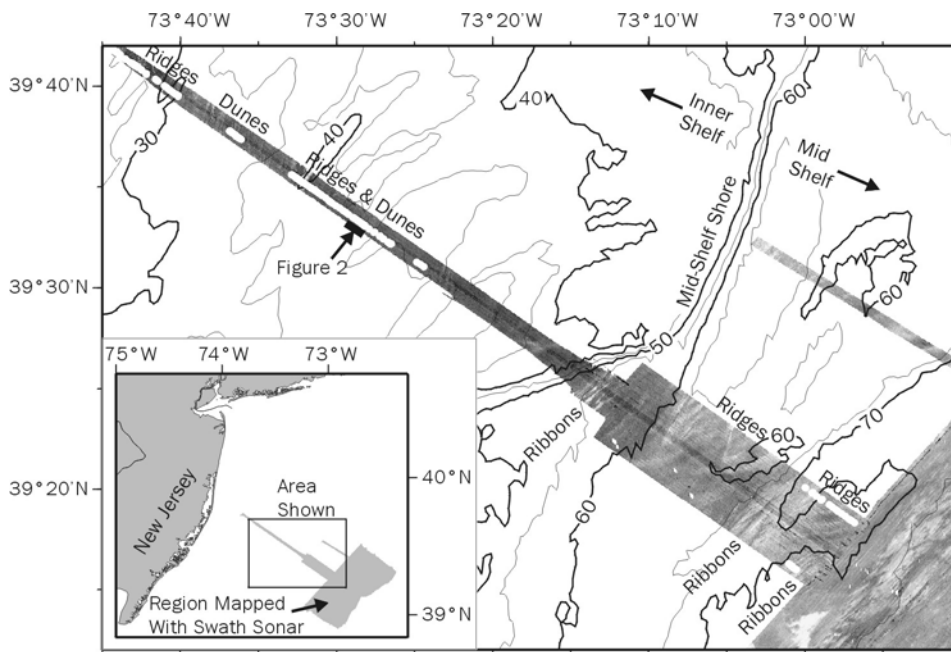


Figure 1 Sidescan backscatter data from the 1996 Simrad EM1000 swath survey, with regional bathymetry contours in meters. Lighter shades indicate higher backscatter values. Regional bathymetry is derived from the NOAA compilation of hydrographic survey data. White dots indicate locations of 1998 sediment grab samples. The mid shelf shore is the probable location of a stillstand during the latest sea-level rise. It also demarcates important changes in seabed morphology and properties, including a ~6 db change in the overall brightness of the backscatter.

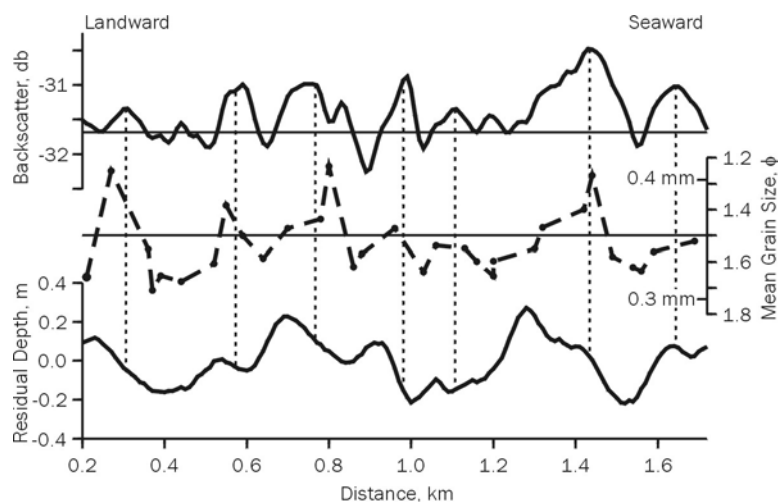


Figure 2 Coincident backscatter, mean grain size, and residual bathymetric depth over a series of small submarine dunes on the inner shelf. Location is given in Fig. 1. The backscatter profile was generated by averaging the data 150 m along the dune orientation, and then 80 m in the track orientation, to enhance dune-related structures and suppress data noise. Residual depth profile was generated by removing a best-fitting linear trend from a ~2 km segment. Vertical dashed lines indicate the correspondence of high backscatter and larger mean grain sizes with the seaward facing dune slopes.

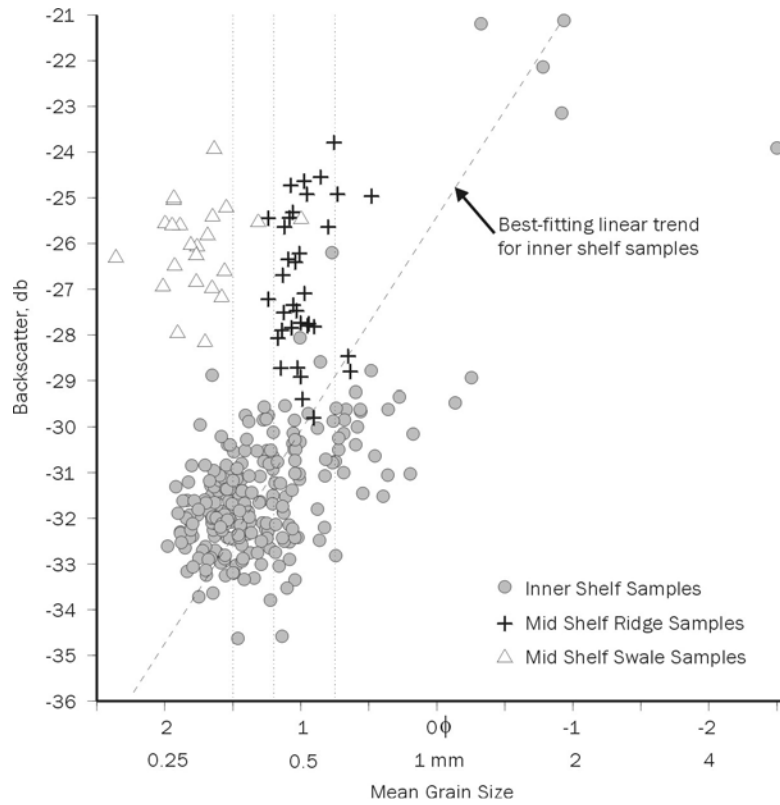


Figure 3. Mean grain size from the individual grab samples (see Figure 1 for location), plotted versus backscatter values averaged within 15 m by 15 m areas centered at the sample location. Vertical dashed lines mark sectors used in Figure 4 for calculating composite grain-size distributions.

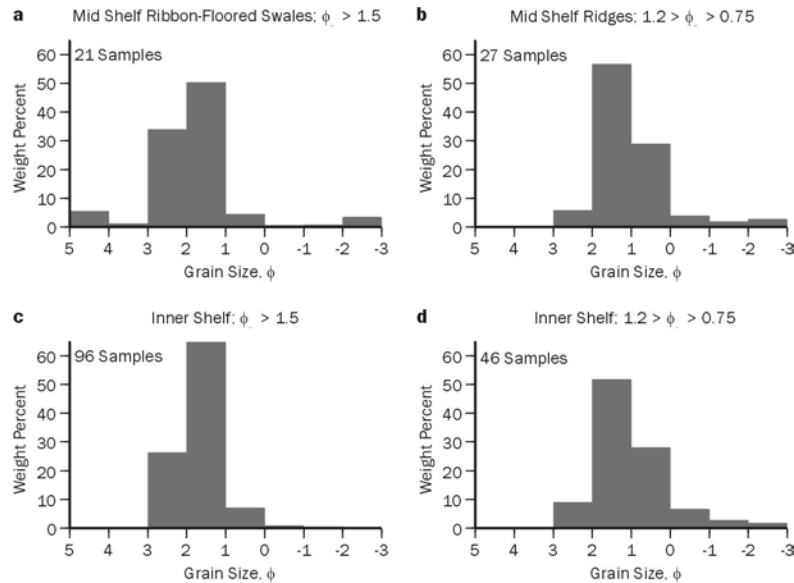


Figure 4. Composite grain-size histogram distributions for four populations of samples as indicated (see also Figure 3). Backscatter differences among the populations are evidently controlled by the small percentage of the largest grain sizes.

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