Statistical Characterization of Bathymetry and Stratigraphy on Continental Margins

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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 statistical characterization of shallow sediment variability within the N. California natural laboratory. Data examined were collected during the "Correlation Length Experiment," a STRATAFORM-sponsored box coring effort off Eureka, California in the summer of 1997, conducted with the express purpose of characterizing the lateral variability of near-surface shelf sediments over scales from meters to kilometers. Understanding such variability is critical for constraining models of sediment deposition, reworking and preservation. Coring focused on two sites, K60 and S60, separated by ~15 km along the 60 m isobath (Figure 1). The sites are near the sand/mud transition, although K60 is sandier owing to its proximity to the Eel River mouth. Both dip and strike lines were collected with sample interval that increased with distance from each site (minimum interval < 10 m, maximum ~1 km). The strike lines merge along the 60 m isobath. 137 cores were collected with penetration depths typically ranging between 20 cm and 40 cm. Physical parameters examined included density, porosity, and grain size, which were measured to at least 1 cm depth accuracy within each core. Variograms were computed for the full strike line, for both strike and dip directions at each site, and for depth at each site.

Key partners in this effort are Rob Wheatcroft (porosity and x-radiographs), Don Swift (grain size analysis), Dave Drake (grain size analysis) and Homa Lee (GRAPE core logs).

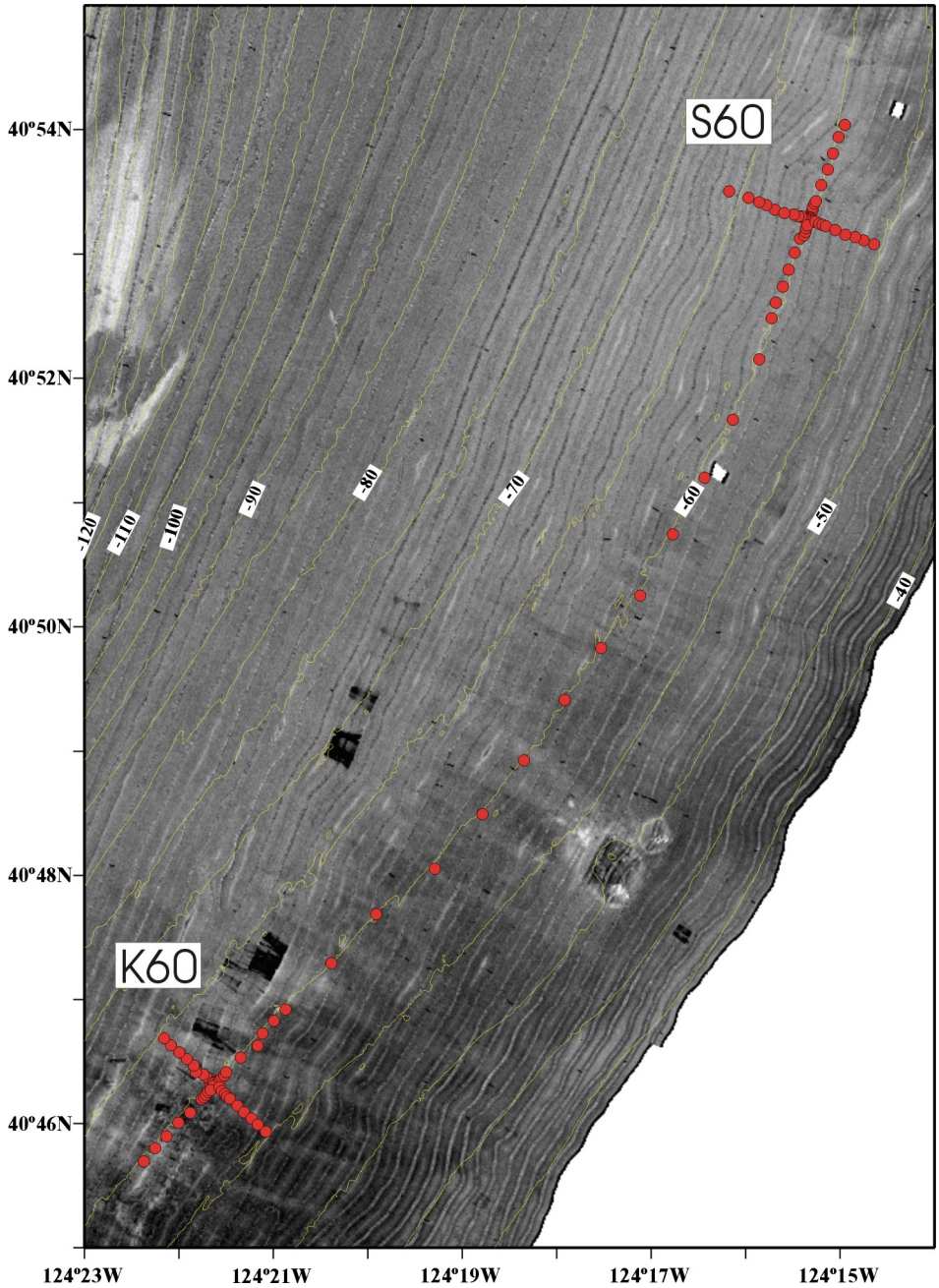

Figure 1. Location of "Correlation Length Scale" cores overlain on sidescan backscatter in the N. California STRATAFORM natural laboratory.

WORK COMPLETED

Density, porosity and grain size data from the CLS experiment have been analyzed for estimation of spatial statistical properties at scales ranging from centimeters (within cores) to kilometers).

RESULTS

Figure 2 displays the density logs collected with the densely sampled "crosshair" cores at sites K60 and S60; the crosshair samples are all located within about 50 m from each other at the intersection of the N-S and E-W sample lines. These plots visually demonstrate the extent to which these nearby cores exhibit coherent, or not, downhole density structure. Here is one of many pieces of evidence that S60 and K60 are radically different from each other: the K60 cores exhibit considerable density variability, but completely incoherent from one core to the next, whereas the S60 cores exhibit variation, particularly in the upper 20 cm, that is very coherent from core to core (i.e., layering), and is evidently related to preservation of the 1995 flood layer. Note that there is also considerable incoherent variation in the S60 cores that can be considered as superposed on the coherent variations. These density log observations are consistent with visual observations of x-radiographs at these sites.

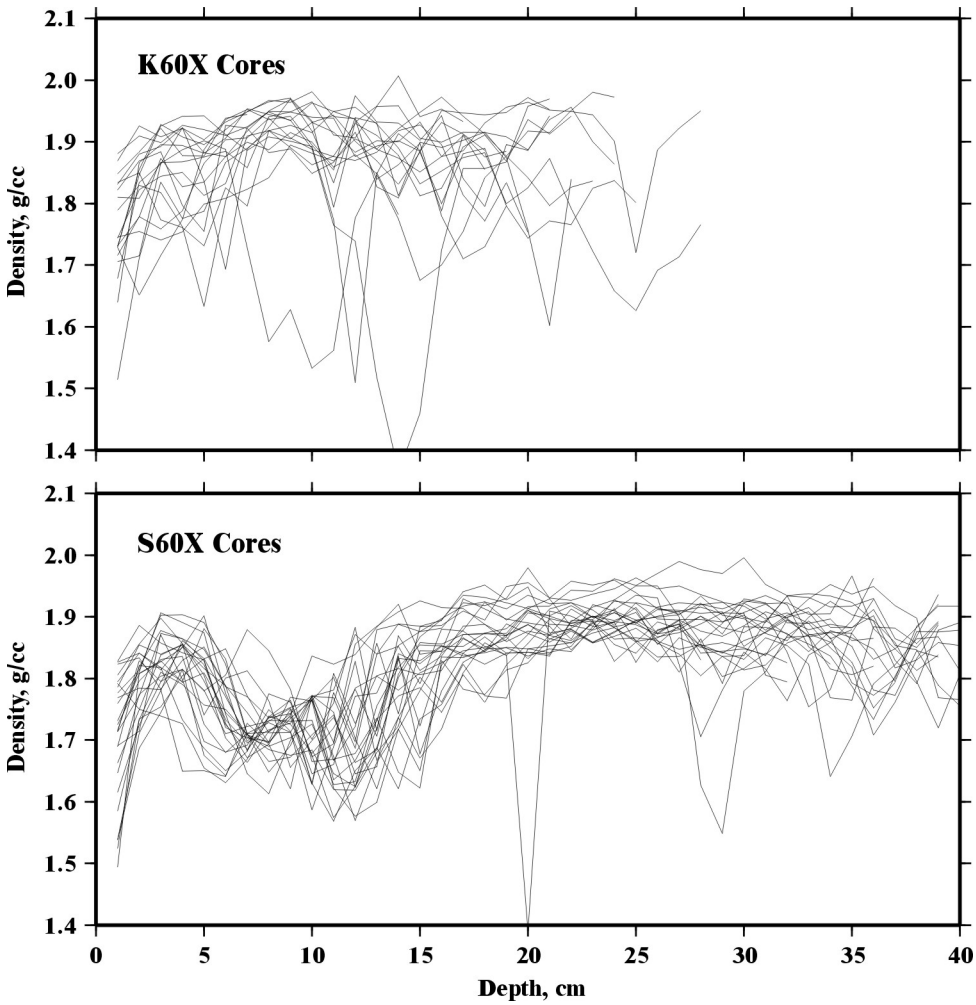

Figure 2. Density cores at the cross-hair locations (all are located within ~50 of each other) at sites K60 and S60.

Figure 3 shows down-hole, N-S and cross-hair sample semi-variograms, displayed at the same vertical scale but with quite different horizontal scales as indicated. The K60 variograms are the simplest to interpret. Note first that neither the semi-variogram for the K60 North-South line nor the K60 crosshair samples exhibits any structure – i.e., neither approaches zero at zero lag. Instead, they are, taking into consideration their rather erratic variability, roughly constant as a function of lag – the sign of a white noise process (contrast this behavior with the downhole variogram, which has a structure/correlation length of ~5 cm). Furthermore, note that this level of variance is comparable to the total variability exhibited within each core, as evidenced by where the downhole semi-variogram "sills" out. The interpretation here is that horizontal density variability at and about K60 is completely incoherent at anything larger than a few meters scale (the smallest scale measured). Furthermore, the similar degree of variability observed horizontally as observed downhole strongly suggests that these are determined by the same process.

The S60 variograms indicate more structure, both vertically and horizontally. Note first that two down hole semi-variograms have been computed. The full-length semi-variograms at S60 are dominated by the coherent structure noted above. The variance here is very large – larger than exhibited on the horizontal semi-variograms. To get an estimate of the incoherent structure, a second downhole semi-variogram was computed from data confined to depths >20 cm. As with K60, the semi-variogram of the cross-hair samples is essentially flat over all lags – and here we note an excellent correspondence with the level of incoherent variability exhibited downhole. Thus, as before, we see that horizontal density variability at these small scales is incoherent and determined by the downhole incoherent variability. However, when at the larger lags along the North-South line, a clear structure/correlation length of ~0.5 km is observed. Note here that, at the smallest resolvable lag larger than 0, the North-South S60 variogram is at a value identical to that of the crosshair semi-variogram – the incoherent variability is a base level of white noise.

IMPACT/APPLICATIONS

Sediment variability differs markedly between the two sites. At K60, no coherent bedding is seen; the cores are fully uncorrelated at the smallest scales examined (a few meters), and horizontal variability up to ~8 km scale is equal to the variability seen within cores. At S60, by contrast, there is considerable structure both down hole and laterally. Coherent bedding is observed at S60 related to the preservation of the 1995 flood deposit. Laterally, a correlatable structure is seen with a characteristic scale of ~500 m. The source of this structure is not yet determined. It is suggested that the high variability at the shortest observed scales at K60 is a result of more intense bedform reworking of the seabed in the sandier environment.

TRANSITIONS

It is expected that the results obtained will have important implications for modeling efforts aimed both at understanding deposition and preservation of shelf sediments and for understanding the interaction of acoustic signals with the sea floor.

RELATED PROJECTS

This work is closely related to a number of STRATAFORM projects focused on the Northern California natural laboratory.

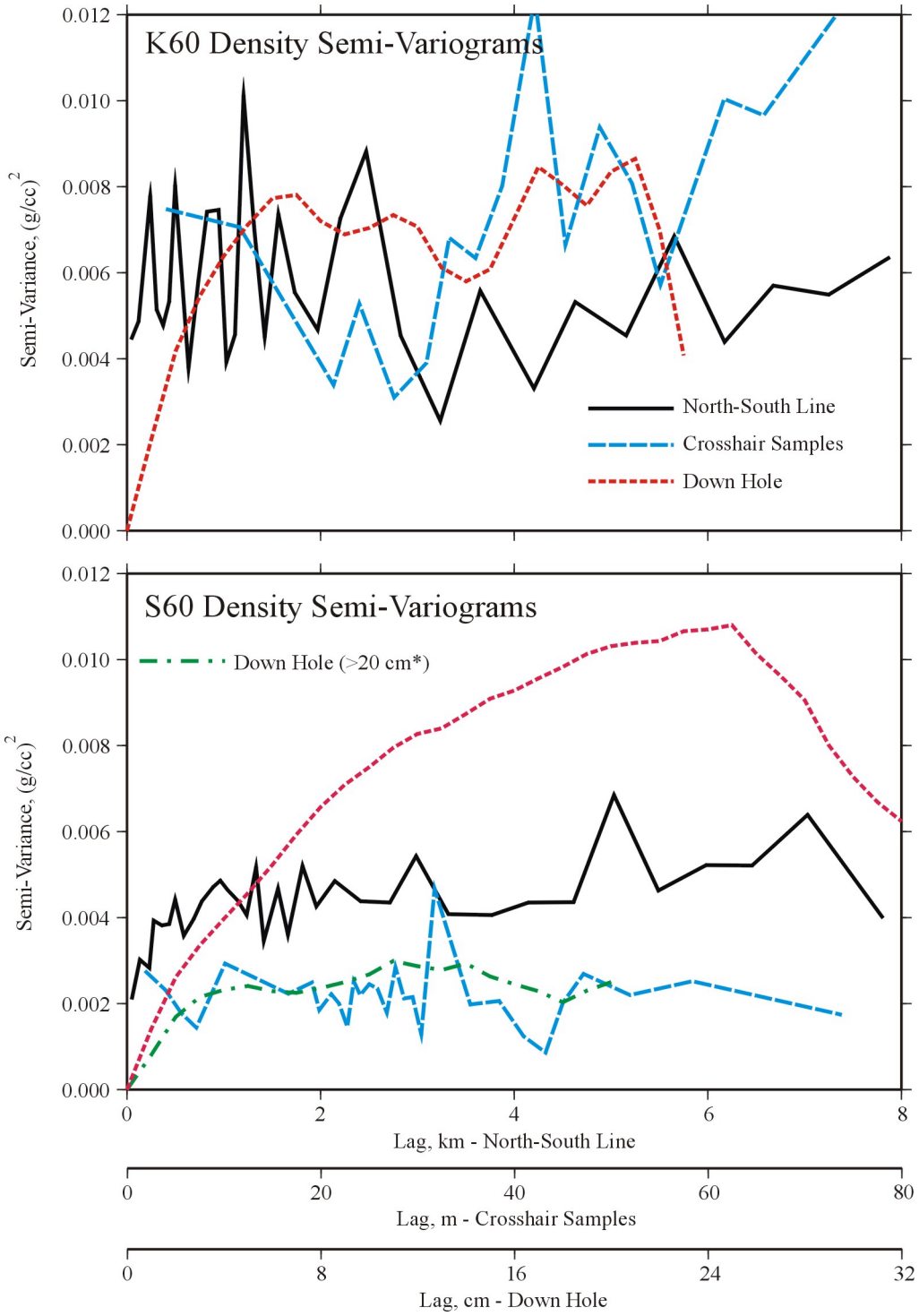

Figure 3. Down hole, cross-hair and North-South density semi-variograms at the S60 and K60 sites. A separate downhole semi-variogram restricted to depths >20 cm was computed at S60 to extract the incoherent component variability where otherwise the core is dominated by coherent layering associated with preservation of the 1995 flood deposit.