Modeling Sedimentary Deposits on the Continental Margin

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LONG TERM GOAL

The long-term goal of my research group is to construct mathematical descriptions of the processes that form sedimentary deposits at all spatial scales on continental margins, from storm beds to the deposits of 100,000 yr sea level cycles, and to conduct numerical experiments leading to the prediction of the sedimentary fabric (structure and stratification pattern) of the resulting deposits. We are undertaking this work in collaboration with our subcontractors, Alan Niedoroda and Chris Reed, at URL Greiner, Tallahassee.

OBJECTIVES

A first objective is to investigate the fabric (pattern) of seabed stratification on continental margins at small time and space scales (1 cm-50 cm depth into the seabed; 1 hr-3 yr sedimentary record). To this end, we are testing the hypothesis that on muddy shelves such as the northern California shelf, Holocene event stratigraphy consists of the deposits of high-concentration storm regimes associated with river floods, alternating with deposits of low-concentration storm regimes.

At intermediate spatial scales (1 -20 m depth into the seabed; 1-1,000 yrs), we are testing a second hypothesis. The hypothesis states that facies assemblages are stacked on, or are capped by, erosional bounding surfaces (source diastems,) in patterns reflecting fluid power gradients in the parent dispersal system; and that these patterns are responses to progressive sorting and stratal condensation mechanisms.

At large time and space scales (1 -1,000 m depth into the seabed; 100-2.5 million yrs) we are testing a third hypothesis. The hypothesis states that that depositional sequences can be explained in terms of shifts in the equilibrium configuration of shelf surface in response to changes in sea level, the rate and character of sediment input, and the hydrodynamic climate.

APPROACH

We are testing the short-term sedimentation ("flood" bed) hypothesis by driving event bed simulation directly from time series of bottom velocity and concentration measurements, and by comparing these hindcasts with observations. The hypothesis is being tested by simulation of the 1995-1997 stratigraphy of the Eel River sector of the northern California shelf, as revealed in time series obtained from STRATAFORM tripods.

We are testing the hypothesis for intermediate scale sedimentation (Facies assemblage hypothesis) by linking deterministic algorithms for boundary layer sedimentation (EVENT) with a probabilistic algorithm for stratal succession (FACIES; Zhang et al., 1997, 2000).

In order to test the hypothesis for long term sedimentation (equilibrium margin hypothesis) We have combined the morphodynamical model for continental margin evolution developed by URS Greiner (1995) with Mike Steckler's (1993) geodynamical model, leading to a combined stratigraphic model (SEQUENCE).

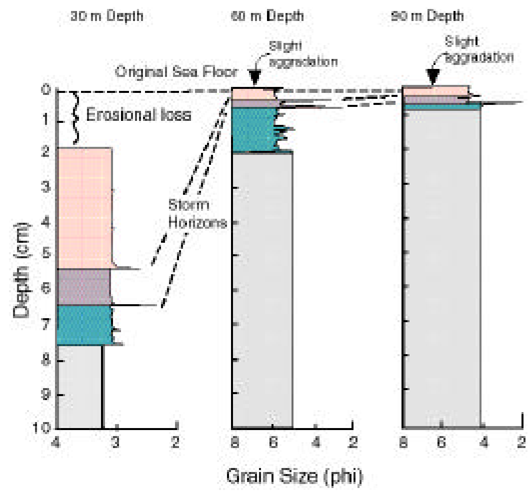

Fig. 1. Simulation by EVENT illustrating the relationship between depositional regime and bed architecture on the Northern California Shelf.

WORK COMPLETED

We (Alan Niedoroda and Chris Reed, URS Greiner) have developed a 1-d model of sediment resuspension by waves and Currents (RESUSPEND). We (Chris Reed, URS Greiner) have developed a 2-D version (SLICE) that evaluates cross-shelf sediment transport in response to waves, tides and wind-driven currents. We (Shejun Fan, ODU) have developed a modified I-D version of RESUSPEND, in order to explore the behavior of high concentration regimes (ULTRASUSPEND). We (Yong Zhang and Shejun Fan) have developed a two- dimensional variant of RESUSPEND and have fitted it with a probabilistic description of the wave climate, so sediment facies may be simulated (FACIES). We (Alan Niedoroda and Chris Reed, URS Greiner Woodward Clyde) have merged the morphodynamic and geodynamic models to form SEQUENCE. We (Chris Reed) have developed SLICE, a two-dimensional circulation model for the continental margin in order to calibrate SEQUENCE.

RESULTS

Simulations using EVENT and RESUSPEND show that short lived, coast-hugging, surface flood plumes, forming over the inner shelf of northern California during winter storms, leave behind them slowly consolidating, high-concentration, near-bottom suspensions (fluid mud). Transport occurs by offshore bottom flows or as near bottom suspensions (remobilized fluid muds), responding to their own excess density. In this manner, high-energy winter re-sedimentation events, occurring within days or weeks of the flood, rework mud-rich material. Later spring and summer resuspension episodes involved higher levels of critical bed-shear stress, and a reduced supply of fine sediment. The resulting storm beds (Fig. 1) are thin and sand rich, partly as a consequence of *in situ* winnowing, and partly as a consequence of advection of sand from the further inshore (Fan et al., in press).

Simulations using FACIES (Fig. 2) predict the development the three basic facies of a high sediment-input shelf; an Amalgamated Sand Facies in the nearshore sector, an Interbedded Sand and Mud Facies on the inner shelf, and a Laminated or Bioturbated Mud Facies on the outer shelf.

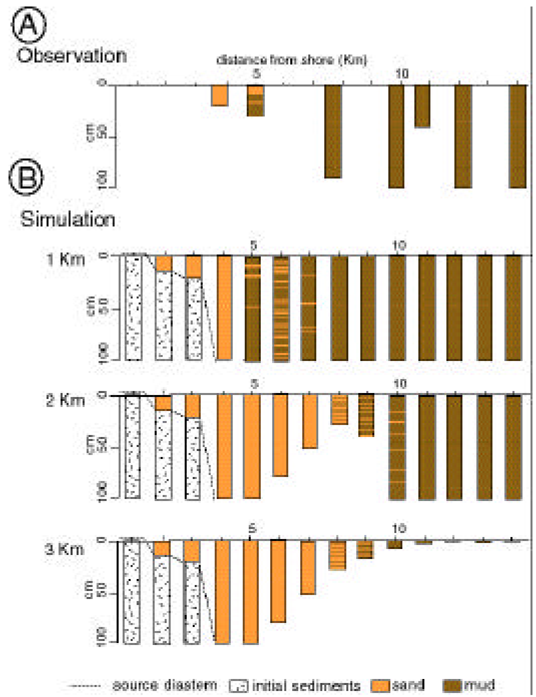

Fig. 2. Simulation by FACIES of the event stratigraphic section on the Northern California Shelf. A: Observations near the "S" sampling line of the STRATAFORM project, collected by Borgeld (1985). B: Simulations of Event stratigraphy displaced, 1, 2, and 3 km north from the Eel River mouth.

Simulations using SEQUENCE portray the Quaternary deposits of the Northern California continental margin as a series of high frequency depositional sequences, in which the high stand systems tracts have been largely replaced by unconformable surfaces (Fig 3). As a consequence of ongoing tectonic activity, sedimentation is largely confined to the subsiding areas between rising anticlinal folds. The sequences are attempts by the Continental margin dispersal system to "restore" the equilibrium shelf configuration during a sea level oscillation.

IMPACT AND APPLICATIONS

EVENT will predict the geotechnical and acoustic properties of first meter of the sea floor. FACIES will predict the geotechnical and acoustic properties of first 10 meters of the sea floor. SEQUENCE will predict seafloor structure at depths up to several kilometers, for foundation studies and petroleum exploration.

TRANSITIONS

We are, in structural terms, the most "downstream" component of STRATAFORM in the sense that we use the results of other STRATAFORM groups as constraining data. The process has feedbacks; our modeling results have lead to changes in the approach of our observationist colleagues (Mike Field's seismic work, USGS, Menlo Park, and Neal Driscoll's seismic work, WHOI). The larger oceanographic community outside of STRATAFORM is also a consumer of our products. We are presently exchanging code with Peter Cowell, University of Sidney, Australia, and other members of the PACE group (Predicting Aggregate Coastal Evolution) funded by the European Economic Community.

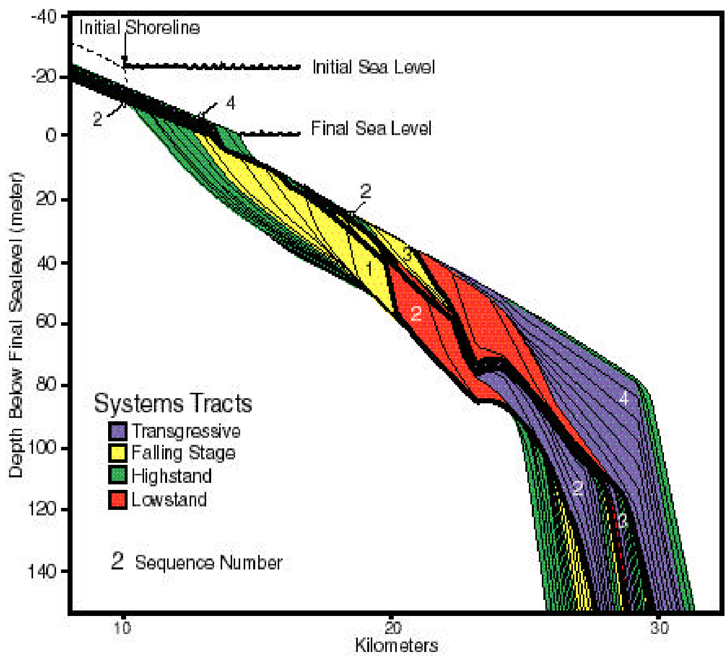

Fig. 3. Simulation of the deposits of a 125 K sea level oscillation on the Eel Sector on the northern California Shelf.

RELATED PROJECTS

We are calibrating the models against dynamical data sets collected by STRATFORM investigators (Cacchione, Sternberg, and Wright). We are validating the models by comparison with the sea floor observations of other STRATAFORM investigators (Drake, Wheatcroft, Borgeld, Bentley, Traykovski, and Nittrouer).

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