Analysis of the Causes and Consequences of
Submarine Slope Failure

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LONG-TERM GOAL

The long-term goal of this project is to provide information that can aid in predicting submarine slope failures and their impact on continental margin morphology and stratigraphy.

OBJECTIVES

The project objectives are to: (i) characterize how the response of pore pressures to sedimentation and erosion may destabilize submarine slopes; (ii) constrain the impact of individual turbidity currents on seafloor evolution; and (iii) develop a technique for correlating stratigraphy in strata that may be complicated by a history of slope failure.

APPROACH

The link between sedimentation/erosion, pore pressure evolution and slope stability is being explored using analytical and numerical modeling. This modeling is being done in collaboration with Ulisses Mello of IBM's T.J. Watson Research Center, who is an expert in hydrologic and structural simulations. Numerical modeling is also being used to simulate the effect of turbidity current erosion and deposition on seafloor evolution. Equations are being contributed to this modeling by Jasim Imran of the University of South Carolina, as well as STRATAFORM researchers Gary Parker, James Syvitski and Marcelo Garcia. Finally, the correlation technique is being developed in collaboration with Doug Martinson of Lamont-Doherty Earth Observatory, who is an expert in geostatistics. The technique extracts all possible correlations between any two down-core measurements of stratigraphy (e.g., lithology, physical properties or log response) based on variations in the amplitude of the measurements.

WORK COMPLETED

In terms of the slope stability analysis, a new analytical model has been developed that defines the state of stress in a simple infinite slope in two dimensions rather than just one (Mello and Pratson, in press). The model, which accounts for the both sediment cohesion and constant pore pressure, forms the

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theoretical foundation for more complicated modeling of stress changes due to spatially-varying pore pressures.

Two other new models have also been developed. One is a numerical model that simulates turbidity current erosion, transport and deposition of sediments along a seafloor profile (Fig. 1) (Pratson et al., in review). The other is a numerical model that simulates the movement of turbidity currents in two dimensions over bathymetric grids.

The correlation algorithm is largely completed. Some additional refinements need to be done to improve its performance, but the algorithm has produced good results in tests using synthetic geologic data. It is now ready to be exercised on real down-core measurements.

RESULTS

The most significant results from the project during FY98 stem from the 2-D slope stability model and 1-D turbidity current model. The stresses in a simple infinite slope predicted by the 2-D slope stability model can be used to explain why many submarine slides exhibit both extensional failure along a relatively steeply dipping headwall and compressional failure along a low angle basal shear plane (Mello and Pratson, in press). The model also predicts that such slides can occur at lower pore pressures and along lower-angle basal shear planes than those predicted by the more often used 1-D infinite slope analysis.

The 1-D turbidity current model has been compared to a similar model for debris flows and the comparison predicts that the two types of flows should have very different impacts on the evolution of continental slope morphology and stratigraphy (Pratson et al., in review). Among the most significant of these is that debris flows should lead to the aggradation and progradation of a continental slope, while turbidity currents should in general lead to continental slope degradation (Fig. 2).

IMPACT/APPLICATIONS

The 2-D slope stability model provides a basis for understanding the geometry and movement of many submarine slides, including that interpreted by Gardner et al. (in press) for the Humboldt slide in the Northern California STRATAFORM study area. Also, being analytical, the model can be applied using a hand-held calculator, significantly enhancing its use in assessing regional slope stability. The 1-D turbidity current model predicts that a trough should occur at the base of continental slopes predominantly traversed by turbidity currents. This result appears to explain the existence of such a trough at the base of the continental slope in the New Jersey STRATAFORM study area (Farre and Ryan, 1987), as well as along other continental slopes worldwide (R. Sarg, pers. comm.).

TRANSITIONS

The 1-D turbidity current model has been incorporated into the 2-D basin evolution model, SEDFLUX, which is being developed by James Syvitski and other STRATAFORM researchers at INSTAAR at the University of Colorado. Requests for the model have also been made by scientists from Mobil, Texaco and Exxon.

RELATED PROJECTS

A collaboration with Gary Parker and Chris Paola has been started to model basin evolution in a large experimental tank at the St. Anthony Falls Laboratory of the University of Minnesota. The experimental stratigraphy formed in the tank will provide a realistic test bed for calibrating the accuracy of the correlation algorithm.

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FY98 PUBLICATIONS

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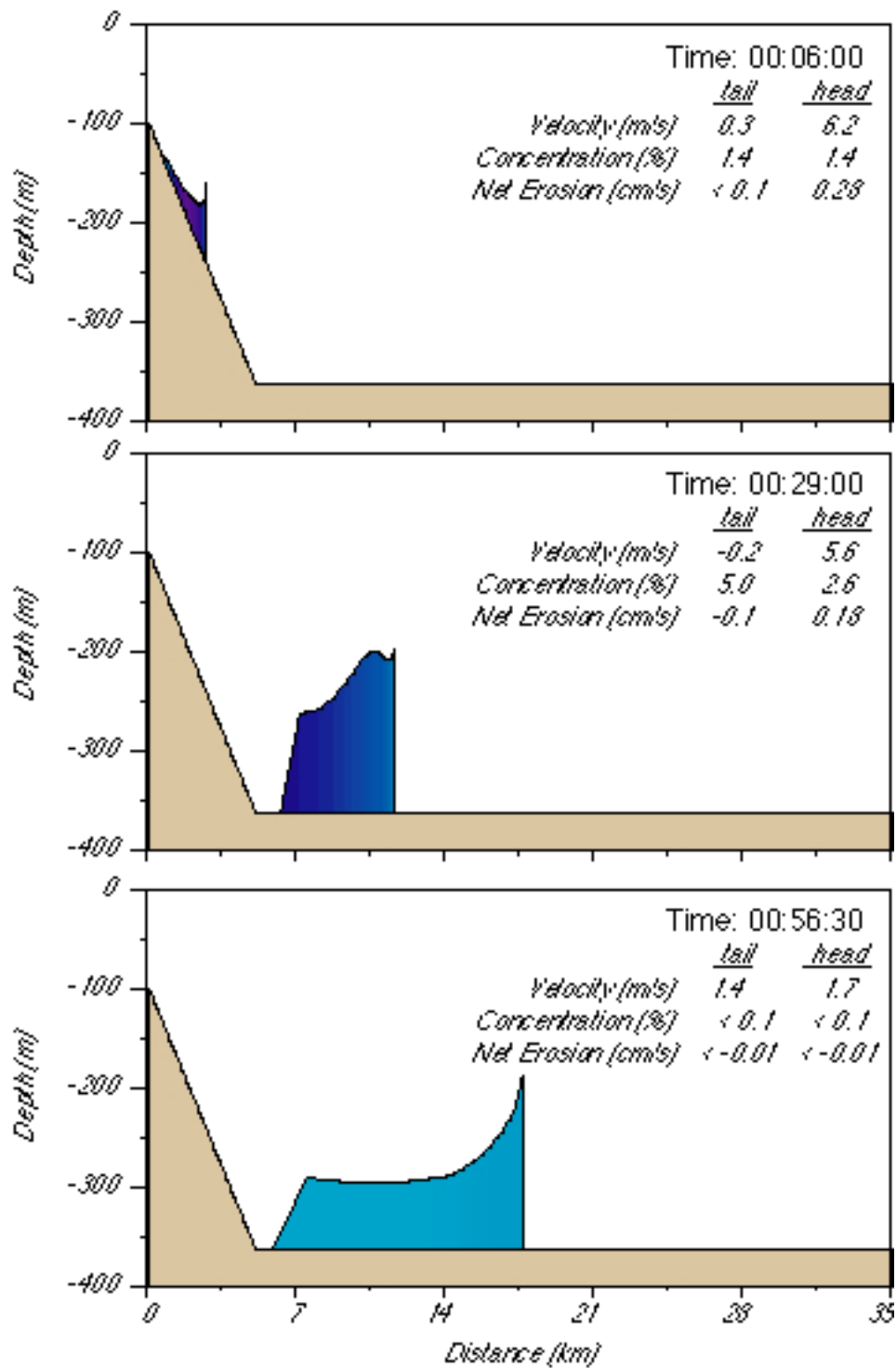
Figure 1. Panels from top to bottom illustrate the evolution of a turbidity current as simulated by the 1-D turbidity current model. Varying shades of blue reflect changes in bulk sediment concentration along the current, which in this model run range from ~7% (purple in top panel) to less 0.01% (light blue in bottom panel). Flow height is exaggerated five times relative to the water depth (vertical axis).
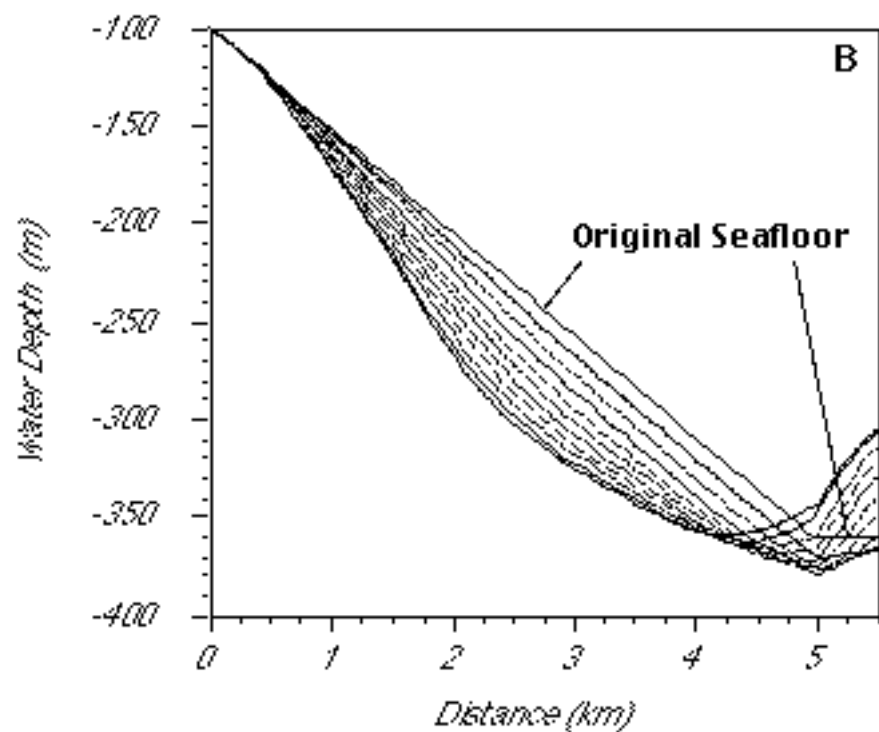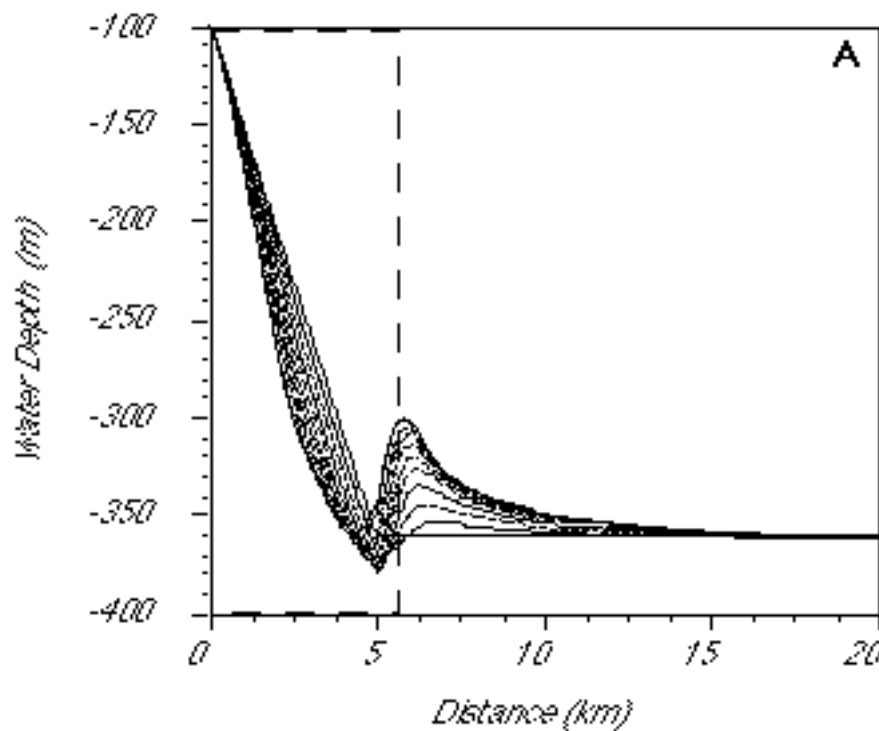
Figure 2. The impact of multiple turbidity currents on seafloor morphology and stratigraphy as simulated by the 1-D turbidity current model. The original seafloor is the simple slope and basin floor geometry shown in Figure 1. Additional lines are profiles of the seafloor after every 10 turbidity currents. A. Erosion of the slope and upbuilding of the basin floor over the course of 100 simulated turbidity currents. B. Blow up of the slope – basin floor transition highlighting slope erosion and base-of-slope deposition. Note the trough formed at the base of the slope.