Sediment Transport by Mud Flows and Turbidity Currents in Continental Margins

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LONG-TERM GOAL

Our long-term scientific goal is to develop sound theoretical models for submarine sediment movement that can be used to predict the initiation, spatial development, and time duration of mud flows and turbidity currents. Of particular interest are the characteristics of the sedimentary deposits that these flows generate as well as their capability to develop submarine channels and gullies via bed scour in continental margins.

OBJECTIVES

The main objectives are: 1) to study the effect of sediment discharge, sediment size and density, and bottom slope on the evolution of three-dimensional mud flows and turbidity currents "representative" of those expected to occur on continental shelves and slopes, 2) to study the nature of the sediment deposits generated by three-dimensional turbidity currents and mud flows and 3) to develop a sediment erosion function for the submarine environment.

APPROACH

Large-scale laboratory experiments have been used to observe the behavior of three-dimensional turbidity currents and mud flows. Sediment erosion by swift, unsteady flows has also been the subject of several laboratory experiments with the help of a special purpose facility. All the laboratory observations have been used to test and improve physically-based predictive models of turbidity currents and mud flows developed in collaboration with STRATAFORM researchers Lincoln Pratson, James Syvitski, Gary Parker, and Jasim Imran.

WORK COMPLETED

An analytical model previously developed for laminar, non-hydroplaning mud flows resulting from submarine slides, was generalized to handle muds having different rheological properties. Now the model can be used to predict the movement of Bingham as well as Herschel-Bulkley muds . Small-scale experiments were conducted to test the model predictions. A number of rheological tests were done to test the properties of the artificial muds used in the experiments.

A unique set of experiments on sediment entrainment into suspension by unsteady flows was also completed. Two sediment particle sizes, having diameters of 0.1 and 0.5 mm respectively, were used

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in the tests. A sediment entrainment function was formulated with the help of these observations and dimensional analysis. An algorithm was developed to implement the entrainment function into STRATAFORM sediment transport models.

RESULTS

The Herschel-Bulkley model can predict the asymptotic runout characteristics of submarine, non-hydroplaning mudflows. For given initial conditions, the model can predict the variation of mudflow frontal velocity, thickness, and time location as a function of distance from the sediment source. Numerical experiments indicate that the run-out distance of mudflows depends strongly on the rheology of the mud, and this is supported by the laboratory observations.

Sediment concentration measurements taken as a function of time during an unsteady flow experiment are shown in Figure 1. Notice how the concentration decreases with distance above the bed. Such measurements were then used to test and improve the sediment entrainment function developed by Garcia and Parker (1991, 1993) for open-channel flows and turbidity currents (Figure 2)

IMPACT/APPLICATIONS

The analytical solution obtained for mud flows provides a tool for both learning about the behavior of flows that can rarely be observed directly, and predicting the run-out distance of mud flows generated by submarine slope failures. The model is particularly suitable for application to the muddy sediments found in the shelf just off the EEl River mouth, for they have been found to have the rheologic behavior of a Herschel-Bulkley fluid (Locat 1997).

The observations made during the sediment entrainment experiments have indicated the entrainment function of Garcia and Parker (1991) can be used to estimate sediment erosion by unsteady submarine flows, provided that a correction is made to account for the time history of the flow. Such relation can be readily incorporated into all the STRATAFORM models that need to determine sediment entrainment rates for varying flow conditions.

TRANSITIONS AND RELATED PROJECTS

This effort aims at providing STRATAFORM researchers with direct observations of mud flows and turbidity currents, with an emphasis on the sedimentological implications of such flows, so that predictive models can be tested and verified. More precisely, the work of J. Syvitski on hyperpycnal flows, G. Parker on debris flows, L. Pratson on slope failures and slides, H. Lee and J. Locat on slope stability, and M. Field, J. Gardner, and D. Prior on characteristics of deposits, will benefit from the laboratory experiments being conducted as part of this research. The sediment entrainment function will also be very useful to all the STRAFORM modelers interested in quantifying erosion rates.

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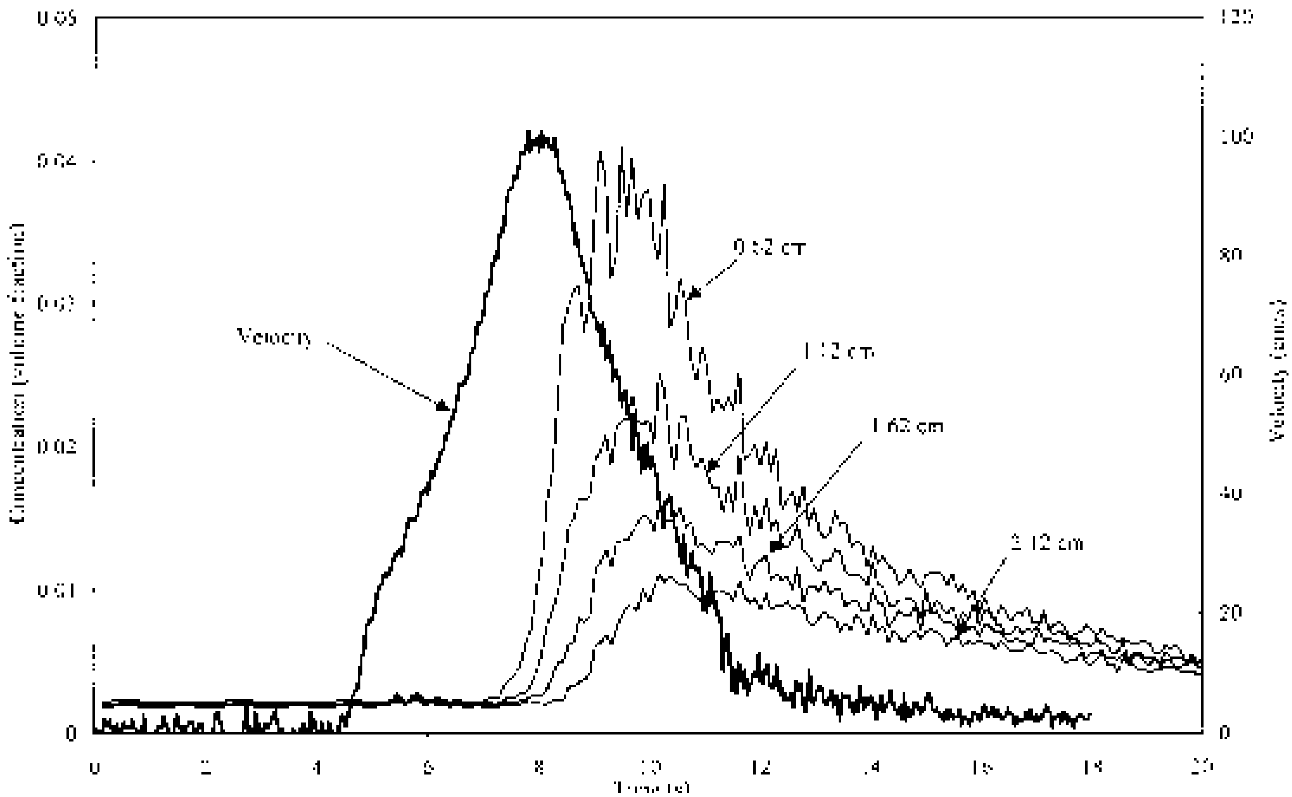

Figure 1: Time series of centerline velocity and concentration at various elevations for an unsteady velocity pulse. 0.1 mm sand.

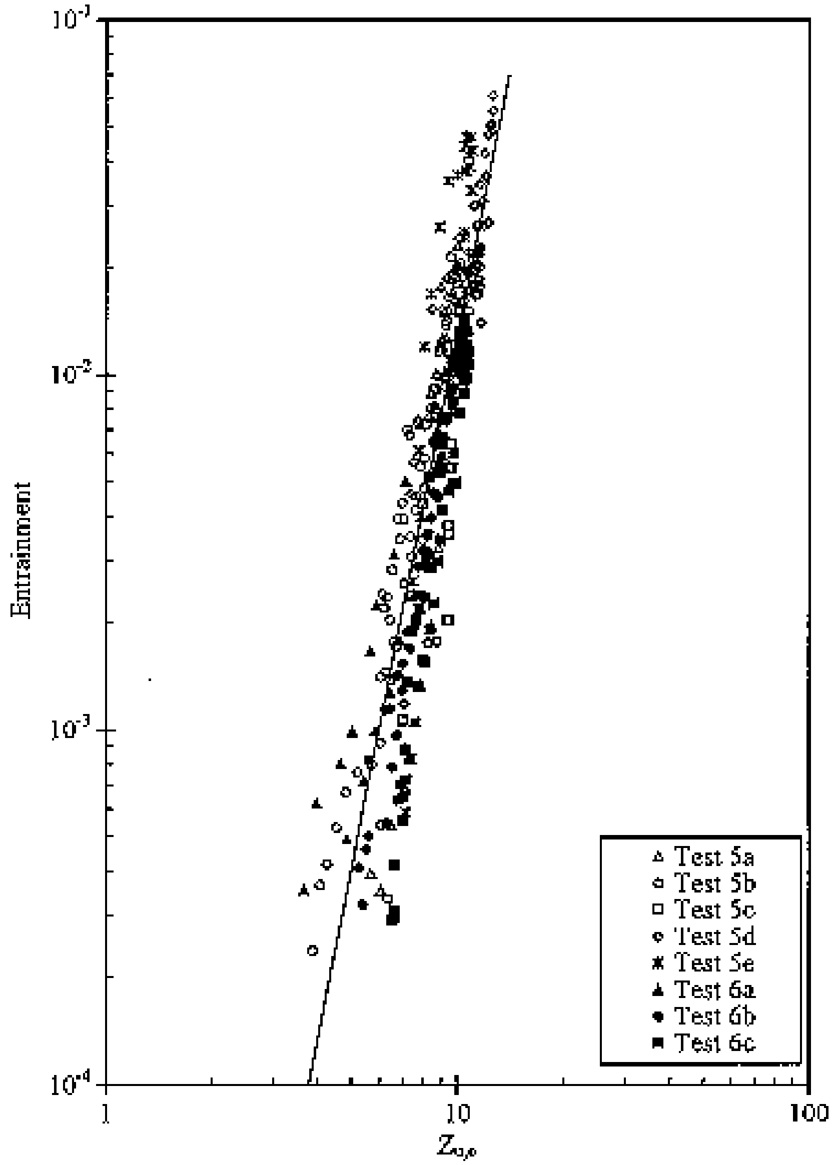

Figure 2: Measured entrainment as a function of the corrected value of Z_u; shown with the Garcia-Parker entrainment relation