Recognition of Diagnostic Acoustic Signatures in Shelf and Slope Deposits: The STRATAFORM California Site

Michael E. Field
U. S. Geological Survey
University of California, Santa Cruz, CA 95064
ph: (831) 459-3428, fax: (831) 459-2336, mfield@usgs.gov

James V. Gardner
U. S. Geological Survey
345 Middlefield Rd, Menlo Park, CA 94025
ph: (650) 329-5469, fax: (650) 329-5411, jvgardner@usgs.gov

David B. Prior
Department of Oceanography
Texas A & M University, College Station, TX 77843
ph: (409) 845-3651, fax: (409) 845-0056, prior@ocean.tamu.edu

Glenn Spinelli
Dept of Earth Sciences
University of California, Santa Cruz, CA 95064
ph: (831) 459-3431, fax: (831) 459-4882, gspinelli@usgs.gov

Award # N00014-99007

LONG-TERM GOALS

One of the major goals of the STRATAFORM Project is to gain a better understanding of how strata form and how they combine to form characteristic stratigraphic sequences, such as drapes, aprons, wedges, sigmoids, and other characteristic geometries. An essential part of this understanding is the analysis and interpretation of surface features and deposits in the upper 50 m of the shelf and slope to provide information on the mechanism of sediment transport and deposition. Interpreting the signatures of various processes in surface and near-surface deposits provides a critical link between knowledge gained from measuring physical processes that are dominant over time spans from the duration of a single event to several years, and those inferred from seismic-reflection data that may represent 10^2 to 10^4 years. Towards these ends, we have been testing some of the concepts of sequence stratigraphy.

OBJECTIVES

Our objectives are to identify the types of sediment signatures that occur in high-resolution seismic-reflection and sidescan-sonar records from the California continental margin, correlate them with the causative process (flood sedimentation, turbidity flow, slow hemipelagic drape, slope currents, etc.) that formed the deposits, and identify the relative abundance and significance of slope- and shelf- sediment signatures. These signatures can then be correlated with results from other STRATAFORM investigations and major patterns can be related to fluctuating sediment sources, sea levels, and climate.

Our specific objectives for FY2000 included the following:

- Complete and submit a manuscript on continuity, extent, vertical history, and overall significance of gullies on the slope.
- Expand studies of instability mechanisms to other margins to address the critical factors that cause some seafloor areas to remain stable and others to undergo failure.
- Begin preparation of a manuscript to interpret the styles of sedimentation and the amount of sediment deposited during the last transgression and present-day highstand of sea level.
- Present findings at international and national meetings and workshops on slope gully systems, slope sediment-gravity deposits, reflector geometry, and inferred sediment processes.

Sediment is deposited on shelves and slopes in distinctive packages or sequences that bear similarities at many sites around the world. The exact processes that form these sequences are not well understood. The STRATAFORM project seeks to integrate studies of sediment transport with observations of sediment deposition and with computer models to develop a better understanding of how sediment sequences originate on continental margins.

APPROACH

Our study contributes as an integral part of STRATAFORM, specifically the investigation of small-scale topography on the shelf and slope. We have employed high-resolution seismic-reflection data and side scan sonar to document the presence and distinctive characteristics of marine sediment-gravity deposits and record the diagnostic geometric patterns of shallow subsurface strata on the shelf and slope.

WORK COMPLETED

Our studies of key scientific issues in the STRATAFORM area have been based on analyses of high-resolution acoustic profiles and sidescan data from two major research cruises using the Huntec DTS System and a Datasonics SIS-1000. Our research focus has been directed toward the following science topics, all of them key to addressing the over-arching goals of the project and the STRATAFORM Program:

- The California shelf is underlain at shallow depths by a major unconformity which appears to represent a significant hiatus in sediment accumulation.
- The Humboldt Slide Zone is a complex feature formed principally by limited-movement shear of sediment at depth. Late stage sediment failures and flows appear to cap the structure.
- The stratigraphy of the shelf and upper slope consists of a lowstand surface of erosion overlain by transgressive surface of erosion followed upwards by transgressive and high-stand deposits.
- Gullies are a major slope feature on the Eel river slope and on many slopes world-wide. We have found that the gullies initially formed *prior* to the last lowstand of sea level. Since that time they have gone through several periods of growth and infill. At present they show little evidence of being active and appear to be infilling.

- Uplift on an upper slope anticline concurrent with deposition has resulted in a ridge and swale terrain. Strata composing the ridges and underlying the swales are truncated and locally tilted, and are thought to result from a complex interplay of sedimentation and tectonic uplift.

RESULTS

We have examined a series of sub-parallel, downslope-trending gullies on the northern California continental slope on high-resolution seismic reflection profiles. The gullies are typically 100 m wide, and exhibit 1 to 3 m of relief. They extend for 10 to 15 km down the slope and merge into larger channels which feed the Trinity Canyon. The high-resolution seismic reflection profiles image the upper 50 m of sediment, approximately. In the lower half of the 50 m stratigraphic section, the gullies increase in both relief and number up section, to maxima at a surface 5 to 10 m below the last glacial maximum lowstand surface. Gully relief increased as interfluves aggraded more rapidly than thalwegs; erosion is not evident in the gully thalwegs. As the gullies increased in relief, their heads extended upslope toward the shelfbreak. Prior to the last glacial maximum, approximately 10 km of non-gullied upper slope and shelf stretched between the heads of the gullies and the paleo-shoreline. Following the last glacial maximum the gullies head approximately 30 km from the shoreline and potential sediment sources.

Gully growth occurred when the gully heads were in relatively shallow water (~200 m paleo-water depth) and were closest to potential sediment sources. We suggest that prior to the last glacial maximum, the Mad River, then within 10 km of the gully heads, supplied sediment to the upper slope which fed downslope eroding sediment flows. These flows removed sediment from nearly parallel gullies at a rate slightly slower than sediment accumulation from the Eel River, 40 km to the south. The process or processes responsible for gully growth and maintenance prior to the last glacial maximum effectively ceased following the lowstand, when sea level rose and gully heads lay in deeper water (~300 m water depth), farther from potential sediment sources. During sea level highstand, the Mad River is separated from the gully heads by a 30 km wide shelf and no longer feeds sediment flows down the gullies, which fill with sediment from the distal Eel River. Approximately one-half of the sub-surface gullies have no expression on the seafloor, as they have completely filled with sediment following the last glacial maximum lowstand of sea level.

IMPACT/APPLICATIONS

Gullies are common on many continental slopes around the world, and we believe that our recent findings may have application for understanding their role in sediment transport and evolution of slopes. The process or processes responsible for gully growth and maintenance prior to the last glacial maximum lowstand of sea level effectively ceased following the lowstand, when the gullies head in deeper water (~300 m water depth) and lie farther from potential sediment sources. Gully growth occurred when the gully heads were in relatively shallow water (~200 m paleo water depth) and were closest to potential sediment sources.

Our findings are significant to sequence stratigraphic models in two ways. First, the presence of relatively thick transgressive deposits adjacent to small coastal drainage basins indicates that sequence stratigraphic concepts operate differently on the narrow, high-relief, high-sediment load areas characteristic of Pacific-style margins where base levels rapidly adjust to sea level shifts. Changes in base level seem to be quickly accommodated, although sedimentation remains more-or-less continuous, with only subtle changes associated with shifts in sea level. Second, accommodation space varies along margins as well as across margins. On margins affected by local or regional tectonics, the processes of uplift and downwarp locally create and destroy space as rapidly as do shifts in sea level. Fold axes on the northern California shelf and slope strike normal to sub-parallel to the coastline, thus continuing uplift and downwarp along these axes destroys and creates accomodation space, respectively. The result is a shelf-slope depositional unit that is discontinuous and of variable thickness.

TRANSITIONS

Our results are being used directly by other ONR investigators in the STRATFORM Project for multiple purposes. These include: calibrating numerical models of sequence stratigraphy, comparing analyses of short-term rates of sediment accumulation, analyzing geologic structures and fluid escape features, and interpreting and comparing high resolution acoustic data with the shallow part of MCS profiles.

RELATED PROJECTS

Our studies of late Quaternary stratigraphy and sedimentation on the Eel shelf and slope are integrated with colleagues:

- Providing stratigraphic control for comparison of multiple seismic reflection data sources (C. Moore, University of California, Santa Cruz)
- Developing computer simulations of the Eel River continental margin (J. Syvitski, U Colorado; D. Swift, Old Dominion U.; and M. Steckler, Lamont Doherty Earth Obs);
- Measuring sediment accumulation rates for comparison with our maps of sediment sequences (C. Nittrouer, U. Washington; and C. Alexander, Skidaway Inst. Ocean)
- Analysing deep structure and stratigraphy in the Eel River basin to provide an integrated interpretation (C. Fulthorpe and J.Austin, U. Texas; and D. Orange, UC Santa Cruz).

PUBLICATIONS

Field, M., Berne, S., Colella, A., Nittrouer, C., and Trincardi, F., 1999, EOS

Field, M. E., Gardner, J. G. Prior, D. B., 1999, Geometry and significance of stacked gullies on the northern California slope. *MARINE GEOLOGY,* v. 154 p. 271-286.

Field, M., Berne, S., Colella, A., Nittrouer, C., and Trincardi, F., 1998, Editors, STRATCON '98: Strata and Sequences on Shelves and Slopes. Program and Abstract Volume,SEPM Research conference, Sicily IT, Sept, 1998. Society of Sedimentary Geology, Tulsa, OK.

Friedlander, A., Boehlert, G. W., Field, M. E., Mason, J. E., Gardner, J. V., and Dartnell, Peter, 1999, Sidescan sonar mapping of benthic trawl marks on the shelf and slope off Eureka, CA. JOURNAL OF FISHERIES, v. 97, p 786-801.

Gardner, Prior, D B., Field, M. E., 1999, Humboldt Slide- A large shear-dominated retrogressive slope failure. *MARINE GEOLOGY. ,* v. 154, p. 323-338.

Prior, D. B., and Hooper, J. R., in press, Seafloor engineering geomorphology: Some recent achievements and future directions. *JOURNAL OF GEOMORPHOLOGY*

Prior, D.B, van der Spek, A.J. F., Tutton, M. A., Buleka, J., Abrahams, J., Kuna, G., van der Valk, L., Woods, M., and Dennis, A.in press, High energy transport processes--from the coast to deep water--Huon Gulf, Papua New Guinea, special volume of MARINE GEOLOGY

Spinelli and Field, M. E., in press, Geomorphic evolution of continental slope gullies on the northern California margin. JOURNAL OF SEDIMENTARY RESEARCH

Storlazzi and Field M. E., in press, Sediment distribution and transport along a rocky, embayed coast: Monterey Peninsula and Carmel Bay, California. MARINE GEOLOGY

Yun, J. W., Orange, D. L., Field, M .E., 1999, Gas distribution off shore northern California and its link to submarine morphology. *MARINE GEOLOGY,* v. 154, p. 357-368.