Using High-Resolution Stratigraphy for Understanding Continental Slope Sedimentary Processes: Integrating Results from the STRATAFORM Project

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LONG-TERM GOALS

Over centuries to millennia, sediment discharge, climate, and sea-level all change significantly, affecting the preserved record of sedimentary processes in the margin and the dominant processes responsible for acoustic stratigraphy observed in seismic profiles. The long-term goal of this project is to determine the sedimentary processes that develop acoustic stratigraphy and the characteristic signatures of these processes. In support of this overarching goal, the focus of the present project is on detailed study of core properties with the goal of discerning the signatures of processes both that act to emplace and to destroy strata. Detailed observations are necessary because muddy sediments, such as those that compose the study area, dominantly exhibit fine-scale variability in sedimentary structure and sediment texture.

SCIENTIFIC OBJECTIVES

The focus of this one year project was to look in detail at the preserved stratigraphic record in Eel margin deposits and to focus on the biological and physical processes that work to modify these deposits. Through documentation of the detailed character of sedimentary process signatures, we gain a better understanding of the relative importance of different processes on millennial timescales on the continental slope and how these processes are recorded in the sedimentary strata of continental margins.

The specific objectives of this effort are:

- to document sedimentary structure on several scales in slope deposits and relate these structures to processes of emplacement.
- to synthesize the rates of sediment accumulation on 1000-yr timescales.
- to determine the response of slope sediments to changing sea-level by integrating textural and age data.
- to quantify the rates and signatures of biological activity in the seabed.
- continue the planning and preparation for long-coring in STRATAFORM

APPROACH

Sediment cores (0.5-7 m in length) have been collected previously on numerous STRATAFORM cruises to investigate processes that dominate on 1000 year time-scales. From this sample set, cores were selected that were representative of the depositional environments found in slope, canyon and deep water regions on the Eel margin. Examination of sedimentary structures in long cores and on a variety of scales is being used to provide a more thorough understanding of those processes that leave their signature in the geologic record and the processes that destroy stratification. Claudia Venherm works as my lab technician, carrying out x-radiography, textural analyses and preparing material for carbon dating. Joe Lambrix is an intern from Savannah State University who worked on the microstratigraphic analyses. Courtney Reich worked as a technician to identify biological organisms and analyze biological distribution data. ^{14}C ages were determined at the AMS facility in Woods Hole, MA. Assessing the deep coring capabilities of various platforms in support of the STRATAFORM deep coring initiative continues through field tests and meetings with platform operators.

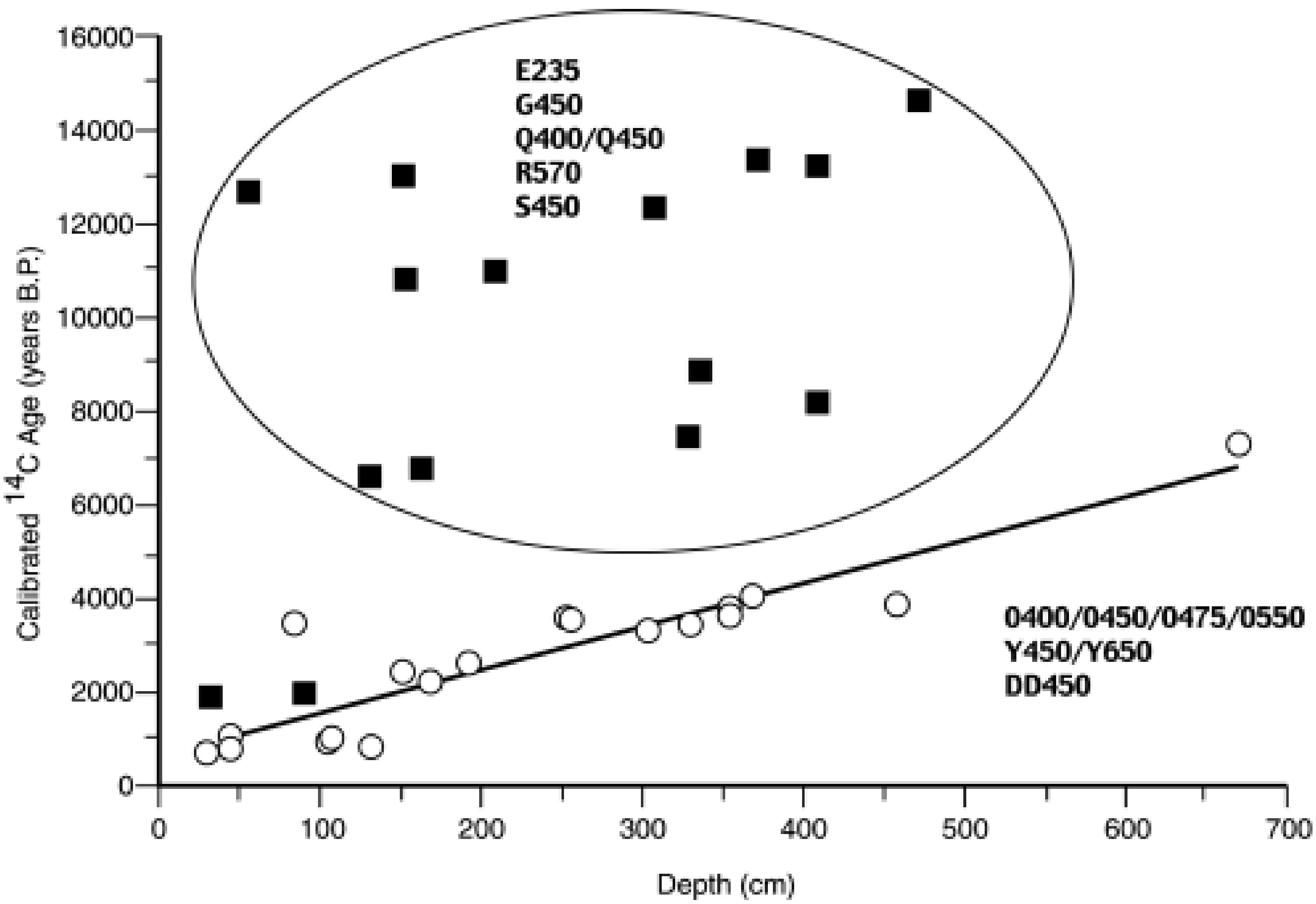
WORK COMPLETED

No cruises were conducted this year. Laboratory analyses were carried out on existing core and biological material. All 20 of the long piston cores collected from the Eel slope and lower margin during this project have been further analyzed and subsampled. X-radiographs were produced from split sections of each core. Additional ^{14}C samples were collected from selected cores and submitted for analysis to provide age constraint on changes in textural parameters and long-term accumulation rates. Long cores are stored at the USGS in Menlo Park and their facilities were used for subsampling.

Activities completed during the past year are listed below. We examined 149 x-radiographs from box and kasten cores and 212 x-radiographs of piston cores to facilitate our selection of cores for thin section analysis. Based on these data, we produced 87 thin sections from 29 individual cores for microstratigraphic analysis. A total of 27 additional samples were submitted for ^{14}C dating this past year and integration of these data has been an ongoing task as the results are returned from the WHOI AMS lab. The AMS dating technique is being used, necessitating the time-consuming task of picking over 1000 forams from each sample interval. The small amount of material available from many STRATAFORM cores and the need for special handling at the AMS facility for the small samples has extended the turnaround time for many of the samples to more than 4 months. A total of 21 long cores (1.5-7 m in length) have been examined for texture and 14 cores have been dated with between 1 and 8 ^{14}C ages. Previously, biological specimens from 4 cores collected from 150 m, 300 m, 450 m and 600 m water depths were preserved . At the time of collection, cores were sectioned into intervals at 0-2 cm , 2-5 cm, 5-10 cm and >10 cm. This year, the organisms were identified and their distributions were examined statistically. Biological mixing rates were determined on each of the cores to relate to the biological distributions.

RESULTS

Only four ^{14}C dates from long cores on the slope are still in queue to be analyzed at the Woods Hole AMS facility. These dates will be combined with 49 dates produced over the past few years, which provide rates in the range of 20-330 cm/10^3y, to constrain the rates of sediment accumulation on 1000-y timescales. These rates are typically lower by a factor of 2-10 than those measured on 100-y timescales, as is frequently observed when these two timescales are compared, because the long-term rates incorporate more small erosional or hiatal events within their time frame of reference. Using all the existing ^{14}C data, it is possible to determine a general rate of long-term accumulation in the study region. The figure below shows the distribution of age versus depth in the piston cores (pelagic forams, wood and shell material only). The dates fall into two general groups. The filled squares (circled) are from cores located on or near uplifted structural features (i.e., Little Salmon Fault, Table Bluff anticline), where long-term accumulation should be hindered by tectonism. The open circles are located in tectonically stable areas or in synclines where the record of sediment input should be well-preserved. A regression through the data representing undisturbed areas indicates that the average accumulation rate on millennial timescales has been ~100 cm/10^3y, in good agreement with previous work on the California margin.



When sediment texture in long cores is combined with stratigraphic age control, the influence of changes in sea level on sediment delivery to the margin can be discerned. Cores from north of the Little Salmon anticline and within the Humboldt slide contain sediments extending back to 7 Ky, and exhibit millennial accumulation rates that are within a factor of two of modern rates. Cores from the Humboldt Slide show a textural fining trend beginning 3-4 Ky BP, probably representing the initiation of sediment delivery processes similar to those at present (i.e., shelf fluid mud buildup and flow seaward). Cores from regions with structural complexity exhibit higher rates in the past. Rates decreased between approximately 6-8 Ky BP and may represent the rapid recession of the shoreline as sea level rose above the shelf edge.

Observation of sedimentary structure on x-radiographic and thin-section scale demonstrates the relative importance of bioturbation and sediment accumulation in creating the stratigraphic record on the margin. Approximately 60% of the stratigraphic column exhibits mottled sedimentary structure with laminated and homogenous sedimentary structure each making up ~20% of the remainder. These observations highlight the importance of biological mixing in the seabed on the continental slope and suggest that most slope deposits will be non-fissile mudrocks in the geologic record. The laminated structures, where present, give useful information concerning mechanisms of emplacement. In the Eel Canyon, laminae consist of medium silt beds with erosional bases alternating with finer silts and clays, reflecting downcanyon flows of silty material. Although ^{210}Pb analyses have not yet documented modern sediment transport and accumulation at the mouth of the Eel Canyon, a core analyzed this year from the mouth of the Trinidad Canyon shows modern rates of ~0.5 cm/y, suggesting that downcanyon flows are common, at least in that system. On the Humboldt slide and on the open slope, bases of beds are similarly erosional, but the units themselves are graded, typically showing a transition from very fine sand/coarse silt at the base into concentrations of woody fragments mixed with mud ultimately into muds, suggesting that turbid flows are reaching the slope in this region. Compositional observations document that woody material is present in all sediments from the margin and gets finer with radial distance from the river mouth, suggesting that a source for biogenic gas exists throughout the margin but is concentrated nearer the river.

Biological data document that the diversity, evenness and species richness are moderately high, indicating a healthy biological community. Most of the organisms found were living in the upper 5 cm of the sediment. Statistical testing of organism distributions between the 4 intervals examined bear out this observation and suggest that the upper 5 cm of the seabed is actively mixed, whereas those regions below 5 cm are more slowly mixed, if at all. Mixing rates determined for the cores range from 3-32 cm^2/y, with the highest rates being observed on the shelf edge, where the sea mouse, Chloeia pinnata, dominated the assemblage. Polychaetes were common in all cores and intervals. A number of size-selective deposit feeders were also identified, explaining the fining in surface texture commonly observed on the slope in detailed grain-size analyses.

Long coring is moving forward on two separate fronts. In the past year, I have participated in meetings with the French to coordinate STRATAFORM's use of the Marion Dufresne II in the Eel margin study area, and have been part of the planning for development of a heave compensation system (HCS) on the GLAD800 drilling system for use in the NJ study area. I will attend a test on the RV KNORR to evaluate the GLAD800 HCS in November 2001.

IMPACT/APPLICATIONS

Physical and time stratigraphy in long cores suggests that stratigraphic development on the Eel slope dominantly reflects changes in sea level. As is commonly expected, slope areas proximal to the river mouth have experienced dramatic decreases in sediment accumulation rate and in coarse sediment supply as sea level has risen, reflecting retreat of the sediment source. In areas distal from the sediment source, fine-grained sediments, which become finer from depth towards the present seafloor, again representing a retreat of sediment source, have continued to accumulate over the past ~4,000 years at rates that do not change as dramatically between transitional to modern sea level conditions. Proximal regions are much more sensitive and responsive to small fluctuations in sea-level than are distal regions and should be targeted when interpreting the stratigraphic record of sea level change.

However, even when targeting such regions in accretionary systems, the dominant signature will be one of biological activity which will obscure the various signatures of sediment supply.

TRANSITIONS

High-resolution age control (on 1000-y timescales) and stratigraphic interpretations in long cores are being used by geophysical groups to ground-truth their data. Shelf researchers are using my slope data to complement their data to gain a margin-wide perspective on the redistribution of fluvial material on longer time scales. Knowledge of the capabilities of the GLAD800 and the Marion Dufresne II will be used by the STRATAFORM community to further develop the plans for deep coring within the program. Biological community and mixing rate data will be useful as a comparison to shelf biological researchers.

RELATED PROJECTS

C. Sommerfield (Univ. of Delaware) and I are cooperating closely to quantify long-term sediment accumulation rates and integrate shelf and slope data for the margin. H. Lee (USGS) and I continue to collaborate on the relationship between sedimentary processes and geotechnical properties The high-resolution time stratigraphy and sediment textural observations are critical ground-truth for M. Field’s (USGS) acoustic stratigraphy determined from geophysical data. Field and I are planning a meeting to identify important reflectors in seismic profiles to target for deep coring and further sedimentological analyses. Information concerning the rates and patterns of sediment transport to and within the slope region are important as input to Pratson’s (UNC) modeling efforts. Austin (UTIG), Mountain (LDEO) and I are working together to advance deep coring in the NJ STRATAFORM area. Wheatcroft (OSU) is quantifying biological parameters for the Eel shelf.