USE OF STOCHASTIC MODELING OF STRATIGRAPHIC RELATIONSHIPS IN HIGH RESOLUTION SEISMIC REFLECTION DATA FOR PREDICTION OF THE DISTRIBUTION OF ACOUSTIC PROPERTY VARIABILITY IN NEAR SURFACE SEDIMENTS ON THE EAST CHINA SEA CONTINENTAL MARGIN

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LONG-TERM GOALS

Our research group is collecting and analyzing various levels of high resolution seismic data and cores, for ground-truthing seismic facies, on continental margins with a spectrum of depositional boundary conditions. The long-term goal of this work is develop stochastic models of variation of geotechnical and seismic property distribution on margins subjected to a spectrum of depositional regimes. The importance of being able to produce these stochastic models is that it will provide a means of making predictions (with assignment of statistical risk) of the variation of geotechnical and seismic properties in areas where the only data that may exist for that margin at the time that a prediction is needed is information on physical oceanography or other gross descriptions of depositional conditions on the margin.

SCIENTIFIC OBJECTIVES

- Initially, collect high-resolution seismic data on margins with extreme depositional boundary conditions with objective of subjecting these data to sequence stratigraphic and seismic facies analyses to characterize the magnitude of the impact of variation in depositional regime on seismic facies distribution.
- Quantify the nature of horizontal and vertical seismic facies heterogeneity within a sequence stratigraphic context, develop stochastic models of seismic facies heterogeneity produced under depositional conditions described above
- Assess the impact of the depositional processes from margins with extremely different boundary conditions on stochastic models of vertical and horizontal distribution of seismic facies (and therefore geotechnical and acoustic properties)
- Determine the minimum data required to predict the distribution of attributes on margins with various depositional boundary conditions by conducting sensitivity tests on survey spacing and changes in mapped parameters.

APPROACH

University of Alabama Seismic Stratigraphy Group (UASSG) is researching the relationships between variations in sedimentary boundary conditions and the stratigraphy produced by these conditions. Limited work has been conducted on relating distribution of near-surface seismic facies and variability in depositional environment boundary conditions. The study area on the Western Pacific Continental Margin (WPCM) is a region with high sediment supply (4 times the amount of sediment per year as the Mississippi River) and large magnitude hydrodynamic sediment transport processes (tidal currents and large waves from typhoons and storms associated with the winter monsoon), so that there may be a high degree of correspondence between the sedimentary processes active on the margin and the preserved stratigraphy. In other words it may be a situation where the sedimentary processes and recent stratigraphy may be in dynamic equilibrium. This situation may be rare today

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and it may be an "End-Member", but understanding this system is essential to understanding systems where the record of sedimentation is much less complete. In fact this area contrasts quite distinctively with many other continental margins (such as offshore Alabama, offshore Eel River, California, or offshore New Jersey).

UASSG is simultaneously conducting an investigation of the 3-D variability of an area (the Alabama Shelf) with low sediment supply, microtidal conditions, and relatively infrequent storm events. Approximately 2,125 km of high-resolution (<1 m) Geopulse reflection seismic data were acquired within a 900 km^2 grid in an area that extends from • 5 km offshore of the Alabama coast to the upper continental slope. We are developing probability models of the distribution of seismic facies variability in this area and determining the minimum data density required to successfully make predictions of physical property distribution given the set of boundary conditions described above.

The approach for this project is to: (1) acquire data from environments with a history of extreme depositional boundary conditions, (2) conduct sequence stratigraphic analyses of these data to identify units deposited within the same interval of time, and (3) conduct quantitative seismic facies analyses on the data sets so that the variations in seismic facies within each time-slice can be tracked spatially and later subjected to Q-mode factor and binomial markov process analysis to identify non-random variations in seismic facies variability. This provides the stochastic model of spatial variability in acoustic property variability on the continental margin. We then test for sensitivity to survey spacing by under and over sampling isochron maps of seismic facies and thickness of systems tracts at various spacings, overlaying the maps, measuring deviations in orientation of features, and their spatial magnitude and conducting statistical tests to determine when the differences are significant. We are conducting similar analyses when comparing the near-surface sonar facies distributions of the “end-member” continental margins.

WORK COMPLETED

- Completed stratigraphic and statistical analyses of chirp sonar facies from the initial WPCM data set (which includes 3,428 km of chirp-sonar data) and on 28 sediment cores acquired from WPCM during cruise 331293. We are currently working on subsurface acoustic attribute analyses of chirp sonar data collected on cruise 331293 (reflection coefficients and attenuation coefficients) by working with Dr. Steven Schock of Florida Atlantic University on processing these chirp sonar data. These data will be compared to chirp sonar facies, core lithofacies, and a manuscript is being written and will be submitted for publication on process-response relationships among lithofacies, chirp sonar facies, acoustic attributes derived from the chirp sonar data and depositional processes in the WPCM study area. New chirp sonar data (2,824 km) collected in the WPCM study area during cruise 221196 and 6 new cores collected on cruise 221296 will be integrated into this analysis. Currently thirteen chirp sonar facies are identified and completion of cluster analysis indicates that there are 8 chirp sonar provinces in the study area. Thus far, 6 core provinces are identified in the 28 cores from WPCM margin. One result from analysis of data from the 331293 cruise is that we know that the chirp seismic facies are under sampled by the sediment cores. Both the chirp data and the sediment core data indicate that there are north-south gradients and east-west gradients in the distribution of facies related to proximity to sediment source and distribution of various hydrodynamic forcing mechanisms on the continental margin.
- Completed seismic stratigraphic and facies analysis of 2,825 km of Geopulse high resolution seismic reflection data acquired as part of the initial WPCM data set during cruise 331293 and are in the midst of completing statistical analyses of these results. A manuscript on the results of seismic stratigraphic and facies analysis of Geopulse data from initial WPCM data set (331293) was submitted to the Geological Society of America Bulletin (GSAB), come back from review, and is currently being revised for publication. New high resolution seismic reflection data (2,824 km) collected during cruise 221196 will be analyzed and integrated into statistical analyses for the stochastic model of the area. Examination of the new data provide evidence of a stratigraphic architecture in the study area that is not inconsistent with hypothesis presented in the GSAB manuscript. Statistical analysis that are required to complete our stochastic model of the area will be completed shortly and a manuscript will be submitted for publication in a refereed journal. These analyses will include the additional 2,824 km of high resolution seismic data acquired during cruise 221196 (total of 5,649 km of high resolution seismic data). To date, we clearly can identify distinctive sequence stratigraphic systems tracts for at least 2 sea level fluctuations on the initial WPCM

data set. Early highstand seismic facies are characterized by parallel, continuous, moderate to high amplitude, high to moderate frequency reflections, late Highstand seismic faces characterized by widespread, channel-form, low to high amplitude, low to moderate frequency reflectors, Lowstand seismic facies are similar to late highstand facies except they are confined to incised valleys, Transgressive facies range from sheet-like high amplitude, moderate frequency units to units that are similar to modern tidal ridges. Preliminary analysis of Geopulse seismic data collected during cruise 221196 (an additional 2,824 km bringing the total to 5,649 km in the ECS study area) does not provide evidence that is inconsistent with observations and analysis of data from cruise 331293. However, time constraints during cruise 221196 prevented acquisition of data from the outer continental shelf and upper continental slope in the study area, so our data set on the margin is still not complete. Preliminary comparison to offshore Alabama data indicates that the depositional boundary conditions have left a significant impact on seismic stratigraphy and facies distributions in these locales with quite different depositional boundary conditions.

- Completed seismic stratigraphic and facies analysis of Geopulse data from offshore Alabama margin and completed statistical analyses of results of this seismic stratigraphic and facies analysis of Geopulse data. Currently in the midst of writing up these results and have made several presentations of these results at a number of national level professional conferences. To date we clearly can identify distinctive sequence stratigraphic systems tracts for at least 2 sea level fluctuations on the Alabama margin and as mentioned above we observe that the near-surface facies distribution is quite different from WPCM.
- Completed sensitivity tests on impact of survey profile spacing on successful prediction of property distribution on WPCM. Have made 2 presentations of results of these analyses at national level professional conferences and are writing a manuscript on the results for submission to a refereed journal for publication. Next task is to integrate analyses from additional 2,824 km of high resolution seismic reflection data acquired during cruise 221196 into existing data set and conduct the sensitivity tests on a data set that is nearly twice as dense.
- Initiating sensitivity tests on impact of survey profile spacing on successful prediction of property distribution on Alabama continental margin. This area has very different depositional boundary conditions than those of WPCM and therefore provides a standard to which the ECS results can be compared.
- Initiating comparison of results of stochastic models from margins with extremely different boundary conditions to assess the impact of the processes on development of stratigraphic architecture and distribution of near-surface acoustic and geotechnical properties.
- Initiating processing, seismic stratigraphic, and facies analyses on approximately 5,024 km of high resolution seismic reflection data collected during cruises 221196 and 221296 in the Yellow Sea. Following completion of these analyses we will initiate stochastic modeling of acoustic property distribution in this depositional system. Analyses of relationship of facies distribution with variations in depositional boundary conditions (from published literature) will be conducted on the data as well. We will also start sensitivity tests on impact of survey profile spacing on successful prediction of property distribution on this portion of continental margin.
- Initiating processing, seismic stratigraphic, and facies analyses on approximately 5,024 km of chirp sonar data collected during cruises 221196 and 221296 in the Yellow Sea. Upon completion of these analyses sonar facies will be related to lithofacies and physical properties of cores were possible. Following completion of these analyses we will initiate stochastic modeling of acoustic property distribution in this depositional system. Analyses of relationship of facies distribution with variations in depositional boundary conditions (from published literature) will be conducted on the data as well. We will also start sensitivity tests on impact of survey profile spacing on successful prediction of property distribution on this portion of continental margin. Analyses of variation of sub-surface reflection coefficients, attenuation coefficients, and properties derived from acoustic impedance such as bulk density and velocity of intervals between reflections will be calculated on data that are representative of widely distributed and distinctive sonar facies.
- Completed x-radiography, lithologic description, geotechnical measurements (torvane shear strength tests and measurement of bulk density; sound velocity in cores has already been measured) and initiating grain size analyses of 16 cores collected during cruises 221296 in the Yellow Sea. Upon completion of these analyses of core lithofacies facies will be related to chirp sonar facies were possible. Following completion of these analyses we will initiate stochastic modeling of lithofacies distribution in this depositional system. Analyses of relationship of facies distribution with variations in depositional boundary conditions (from published literature) will be conducted on the data as well.

RESULTS

We have tracked the fluvial systems that have a tremendous impact on the WPCM pretty well, but our work tells us that the system is complex and we are picking up indications that the system had significant impact north and south of the survey area. Therefore, to produce a complete stochastic model we need to sample in these areas. However, it appears that the broad nature of the WPCM and its continental shelf/slope break depth (140-150 m), which exceeds the magnitude the last few major sea level falls, has resulted in a continental margins stratigraphy that is dominated by wide-spread lowstand braided fluvial complexes separated by thin transgressive units characterized by the presence of tidal ridge facies, and wide-spread highstand successions that are breached by the overlying lowstand sequences in many locations and consists of seismic facies that are primarily moderate to high frequency, moderate to high amplitude, sea floor parallel, and very laterally continuos reflections.

Stratigraphy on the WPCM is quite different than stratigraphy developed on continental margins with much lower sedimentation rates and less ability to disperse sediment. Data from the continental margin of the Gulf of Mexico consist of highstand deposits of wide lateral extend and relatively homogenous reflection character, lowstand incisions that are narrow (few km to 10 km) and shallow (10's m) and widely dispersed along the margin, and transgressive deposits consisting of thin (1-2 m) sheets of sand or mud. Significance of these results is that depositional boundary conditions do have a important impact on distribution of acoustic properties of continental margins and we are developing an understanding about how strongly coupled these process-response relationships are and a quantitative perspective on how they vary.

IMPACT/APPLICATIONS

The scientific impact of this work is that it quantifies relationships between depositional boundary conditions and near-surface seismic/geotechnical properties distribution on continental margins. This therefore leads to more reliable estimates of these properties in areas where it is either difficult to acquire such data, or it is necessary to design a survey that will quickly provide needed insight, with a given level of risk of a bad prediction. It also leads to more successful design of transmission loss surveys. This obviously has impact in areas such as oil and gas exploration and production, environmental waste containment, and of course defense related issues on continental margins.

TRANSITIONS

Understanding the process-response relationship between depositonal conditions and seismic facies distribuition leads to improved understanding the nature of the heterogenity of the distribuiton acoustic properties on a continental margin. The Naval Oceanographic Office has used the results of our analyses to design and conduct more successful transmission loss surveys on the WPCM.