Forward Modeling of Stratigraphic Sequences at Continental Margins

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LONG TERM GOAL

The goal of the Stratigraphy project of the STRATAFORM program is *to understand the creation of the preserved stratigraphic record on continental shelves and slopes as the product ofphysical processes acting with spatial and temporal heterogeneities. I* am using numerical models to provide insight into the fon-nation and preservation of stratigraphic sequences at margins. My goal is to obtain a quantitative understanding of the interactions of environmental parameters and their influence on stratal architecture and facies distribution. I wish to be able decipher the stratigraphy on margins to read the geologic record of the past and predict future stratigraphy.

OBJECTIVES

I wish to understand how sea level and other factors control the formation of the stratigraphic record at margins. The stratigraphy at margins is packaged into unconforrnity-bound sequences whose form and lithology record the active processes at the margin. The influences of individual processes that create these sequences are only partly understood. My aim is to quantitatively determine the system response of margins to different forcing functions sufficiently to be able to both predict stratigraphy and invert observed sequence architecture for geologic history.

APPROACH

I am using numerical models as a tool to provide insight into the formation and preservation of stratigraphic sequences at continental margins. In conjunction with others, I have constructed an interactive computer model of stratigraphic sequences at continental margins, and am applying these models to the STRATAFORM field areas. The work is proceeding along three lines:

(1) Development of 2-D models focused on combining parameterizations of the dynamic sedimentologic and morphologic processes that control sediment deposition and erosion within a framework that accounts for geologic processes that effect accommodation.
(2) Numerical experimentation with the model to deten-nine the stratigraphic consequences of the processes and parameter interactions. Examination of margin data to calibrate the model.
(3) Analysis of the geologic record sedimentary and geomorphologic processes in NJ and CA. A particular focus is backstripping to reconstruct the margin development. The modeling of the two margins provides constraints for unraveling the control of sequence development.

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WORK COMPLETED

The interactive X-Window graphical user interface for the stratigraphic modeling software continues to be updated according to the requirements of the research. These allow more complex manipulation of input and output. The algorithms for calculating the stratigraphy have been improved for faster, more accurate and more stable computations. A 21/2-D functionality has been added to include affects of along-strike variations in the model. We have performed sensitivity further experiments to investigate the model response. Forward model runs aimed at simulating the New Jersey and Eel River margins are underway. Comparisons of the simulations to observed seismic and well data is also underway.

Preparations are underway to convert the sequence stratigraphic interpretation for the entire Ewing 9009 multichannel data set for New Jersey margin to a digital format. Completion of this task will

enable the mapping of sequence geometies and examination of along-strike variability to proceed more easily. In the future, the entire multichannel seismic data set for New Jersey will be added

RESULTS

Experiments indicate that the shoreface and clinofonn rollover do not respond similarly to sea level. Clinoform progradation commonly begins during the transgression. This behavior has not been previously recognized. Such differences in response of the clinoform, imaged by seismic data, and the shoreface, mapped from outcrop and well logs, need to be integrated into sequence methods. Whether shoreface strata grade into underlying strata or are erosionally juxtaposed can vary with. subtle difference in model conditions. This feature should not be used to identify sequence boundaries.

Backstripping of the NJ margin has yielded an improved geologic history of the margin. In the Eocene, the NJ margin was a carbonate ramp dipping at ~1:300. The shelf edge lay at >500 m water depth. Enhanced terrigenous sediment supply starting in the Oligocene caused progradation of clinoforms across the margin creating a new shallower shelf. The clinofon-n rollovers appear to represent a new shelf edge. During the early to middle Miocene the shoreline lay ~50 km landward of the clinoform rollovers. The reconstructions also image the progradation of the new shelf edge past the relict shelf edge. This appears to coincide with the initiation of greater mass flow deposits on the slope and rise. The clinofortn heights and slope increases as they prograde across the seawarddipping ramp. This is in agreement with predictions of advection-diffusion models of clinoform formation.

Numerical experiments for NJ have been undertaken with initial conditions corresponding to the Eocene ramp margin. This resulted in clinoforms that steepened as they prograded into deeper water, consistent with observations and the backstripping. Simulations contrast the conditions and sequence architecture for early and late Miocene sequences. The early Miocene sequences could be simulated with a moderate amplitude sea level cycle that resulted in progradational sequences with little aggradation. The clinoform rollovers remained ~50 seaward of the shoreface. The late Miocene simulations with large sea level fluctuations predicted extensive transgressive deposits and the fon-nation of oblique, truncated clinoforms during sea level fall. The shoreline position fluctuated widely. While erosion truncated much of these deposits, limited shore and non-marine strata are preserved close to the clinoform rollover. These results are very similar to findings of recent ODP Leg 174A drilling. The modeling and drilling results conflict with existing models of sequence development at margins. I am analyzing when the standard conceptual model can be applied and when it fails.

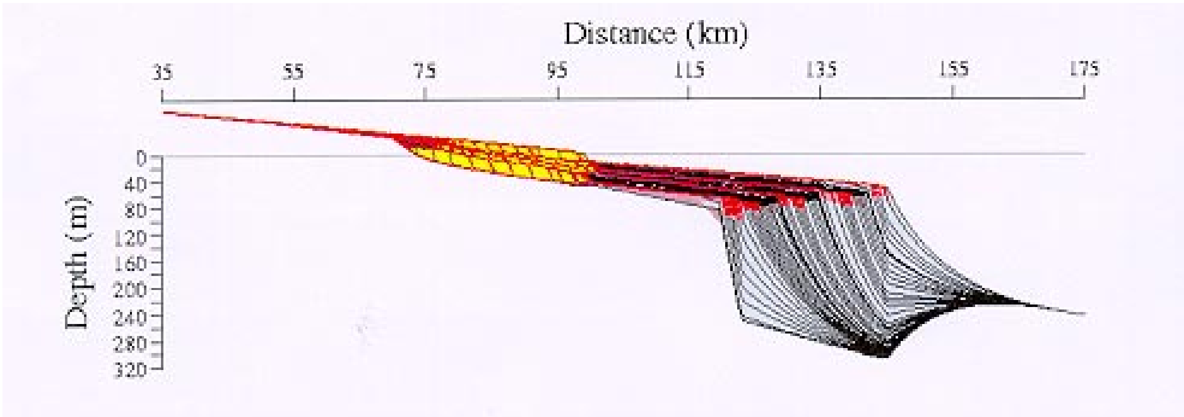

Figure 1. Simulation of early Miocene sequences. The model used initial topography estimated from the backstripping reconstructions and 25-m amplitude sea level fluctuations. Stacked shoreface deposits are located at km 70-100, while the clinofon-n rollovers prograde from km 120 to 145. Topsets are thin and contain prominent erosion surfaces.

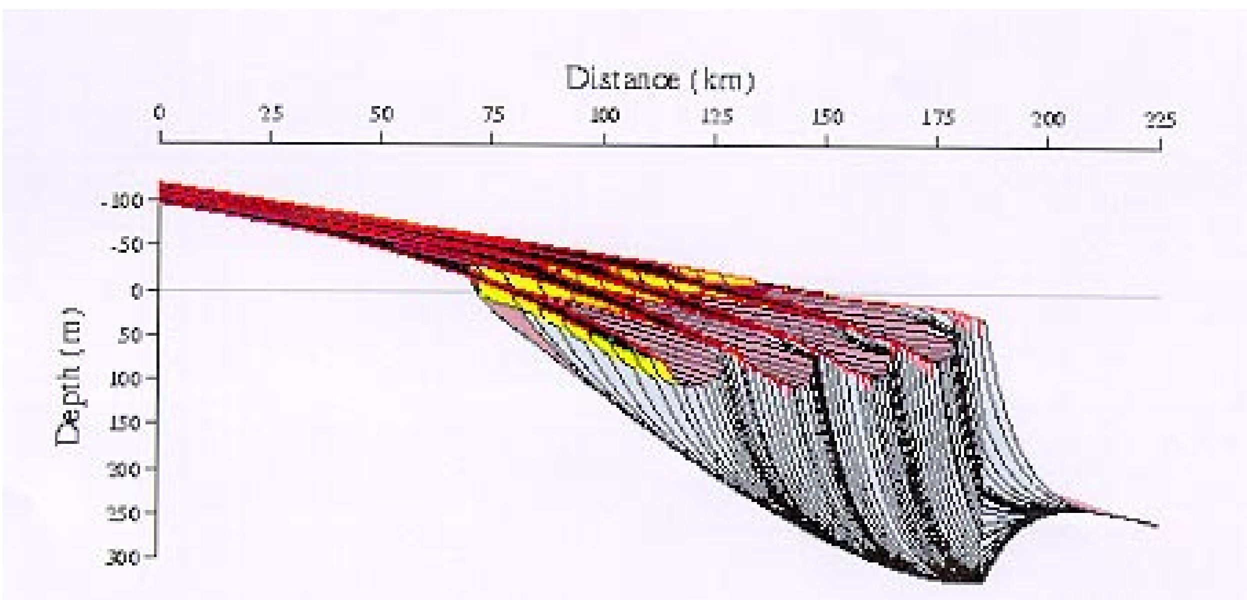

Figure 2. Preliminary simulation of late Miocene sequences. The model used an initial ramp morphology and 80-m amplitude sea level fluctuations. The thick topset strata are dominantly transgressive deposits separated by erosion surfaces overlain be thick shore and nonmarine deposits. Highstand deposits are oblique and truncated by erosion surfaces.

Initial models of the Eel River shelf predict a complex pattern of erosion surfaces separating packages of regressive shorefaces interfingering with trangressive or minor lowstand to wedges near the shelf edge. These strata are covered by a relatively thick Holocene transgressive sheet. Earlier trangressive sheets were almost entirely eroded during subsequent sea level falls. The changing shape of the shelf profile during sea level fluctuations greatly influences preservation. The model can now take into account along-strike variations in tectonic subsidence and the alterations to the sediment loading they cause. This was required because of the short spacing between synclines and anticlines on the margin. This has enable better match to the observations.

IMPACT/APPLICATIONS

Sequence stratigraphic models will have to be revised to deal with differences between sequence architecture as imaged by clinoform geometry and facies patterns as mapped by shoreface stacking patterns. Implications of the presence of sharp-based shorefaces for sequence interpretation need revision. In general, modeling and detailed field studies are raising questions about the simplifying assumptions that allowed sequence stratigraphic theory to initially develop.

The changes in continental margin morphology and sediment supply seen at NJ appear to be I widespread and apply to numerous other margins. They are hypothesized as being related to the climatic changes of the Cenozoic. I conclude that widespread changes in morphology and sediment supply at margins during the Tertiary are related to global climate. This will enable better prediction of the stratigraphy at other margins.

TRANSITIONS

Software is being used at Old Dominion University and the University of Edinburgh/Imperial College for both STRATAFORM and other sequence stratigraphic investigations. The code has been sent to the University of Virginia. I will be distributing software more widely. Reconstructions were used for predicting strata for ODP Leg 174A.

RELATED PROJECTS

I have developed a parameterized model for estimating flexural rigidity. This model is being used for rigidity estimates in my backstripping calculations and forward modeling.

Reconstructions of West African margins indicate strong similarities with the NJ margin. Other margin also show similar sequence architectures. I conclude that widespread changes in morphology and sediment supply at continental margins occurred during the Tertiary and they are related to global climatic change.

I have started to use the forward model to investigate the sequence architecture in rift basins. Initial experiments suggest that changes in sea level, rather than in sediment supply or tectonics are responsible for the fine-scale cyclicity in preserved strata.

PUBLICATIONS

Carey, J S, Steckler, M S, Swift, D J, Reed, C W, Niedoroda, A W, Field, M E, Accounting for 3-D effects in a 2-D model: a comparison of simulation results to Holocene stratigraphy of the Eel Margin, Northern California, AGU Fall Meeting, EOS, Dec. 1998.

Carey, J.S., D.J.P. Swift, M.S. Steckler, C. Reed and A. Niedoroda, 1998. High resolution sequence stratigraphic modeling: 2. The influence of sedimentation processes, in J. Harbaugh, L. Watney, G. Rankey, R. Slingerland, R. Goldstein and E. Franseen (eds.) Numerical Experiments in Stratigraphy, SEPM Memoir 63, in press.

Gupta, S, Steckler, M S, Constructing shore-zone sequence architecture in foreland basins: Insights from field studies and numerical modeling, AGU Fall Meeting, EOS, Dec. 1998.

Pirmez, C., L.F. Pratson, M.S. Steckler, 1998. Clinoform development by advection-diffusion of suspended sediment: Modeling and comparison to natural systems, J. Geophys. Res, 103, 24141-24157.

Reed, C.W., A.W. Niedoroda, D.J.P. Swift, Y. Zhang, J. Carey, and M.S. Steckler, Coastal evolution: Modeling fabric and form at successive spatial scales, Proceed. Intem. Conference on Coastal Research through Large Scale Experiments, submitted.

Steckler, M S, Gupta, S, 1998. Numerical modeling of delta stacking patterns in extensional settings, AAPG Hedberg Conference, Integrated Structural and Sequence Stratigraphic Analysis in Rift Settings, Cairo, Egypt, October 20-22, 1998.

Steckler, M.S., G.S. Mountain, K.G. Miller and N. Christie-Blick, 1998. Reconstruction of Tertiary clinoform progadation on the New Jersey passive margin by 2-D backstripping, Marine Geology, in press.

Steckler, M.S., C.W. Reed, D.J.P. Swift, and A.W. Niederoda, 1998. High resolution sequence stratigraphic modeling: 1. The interplay of sedimentation, erosion and subsidence, in J. Harbaugh, L. Watney, G. Rankey, R. Slingerland, R. Goldstein and E. Franseen (eds.) Numerical Experiments in Stratigraphy, SEPM Memoir 63, in press.

Steckler, M S, Mountain, G S, Chrisitie-Blick, N, Miller, K G, Controls of the architecture of prograding sequences on the New Jersey continental margin: Results from numerical modeling, AGU Fall Meeting, EOS, Dec. 1998.

Swift, D J, Fan, S, Carey, J S, Parsons, S B, Niedoroda, A W, Reed, C W, Steckler, M, Zhang, Y, Modeling sedimentary facies: Preliminary steps, AGU Fall Meeting, EOS, Dec. 1998-