Neogene-Quaternary Stratigraphic Responses in a Tectonically Driven Basin: Northern California Continental Shelf and Upper Slope

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LONG-TERM GOALS

This project is a component of ONR's STRATAFORM program, the goal of which is to link short-term (i.e., acting over hours to weeks) biological and physical processes affecting sedimentation ("event stratigraphy") to the sequence stratigraphy and facies architecture of the preserved record. STRATAFORM consists of three interrelated projects whose goals are to study: 1) shelf sediment dynamics and the development of lithostratigraphy, 2) slope geological processes and resultant geomorphology, and 3) stratigraphic sequences resulting from shelf and slope sedimentation. High-resolution multichannel seismic (MCS) data collection, described below, is part of the third project, but the data also form part of a multi-faceted approach that ties all three projects together.

OBJECTIVES

Specific objectives include: 1) origins of sequence stratigraphic architecture in an environment characterized by high rates of sediment supply and active tectonism, 2) tracking the history of northward sediment dispersal from the Eel River and identifying sediment transport pathways that existed during sea-level lowstands, 3) morphologies and evolution of slope canyons, and 4) history of the Humboldt Slide.

APPROACH

STRATAFORM participants are documenting the stratigraphy of the continental shelf and slope of the Eel River Basin, northern California margin, at a variety of spatial scales (lateral and vertical) and in three dimensions (3-D). The key to this entire effort is the collection of "nested" geophysical and geological data, through use of a variety of tools whose individual temporal and spatial scales overlap to form a wide-ranging continuum of measurements. High-resolution 2-D MCS profiles were collected from the outer shelf to slope, offshore Eel River Basin jointly by the University of Texas Institute for Geophysics (UTIG; P.I.s Fulthorpe and Austin) and Lamont-Doherty Earth Observatory (L-DEO; P.I. G.S. Mountain) in July - August 1996. The seismic system, developed and owned by L-DEO, included a 48-channel I.T.I. streamer and 45/45 cu. in. G.I. air gun. A backup Geco streamer was used for part of the survey. The survey was designed to image stratal geometries at a scale intermediate between those of the existing very-high-resolution (500-3500 Hz) Huntec deep-towed boomer seismic profiles and commercial MCS data, fulfilling the STRATAFORM goal of providing "nested" seismic coverage

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(several Huntec and commercial lines were duplicated). The seismic grid consists of 84 lines (~2200 km; Figure 1). Line spacings vary, but a spacing of 800 m was maintained, where possible, in both dip and strike directions. Such dense coverage was necessary to provide the 3-D stratigraphic perspective mandated by STRATAFORM. Vertical resolution is ~5m. Data processing is being shared by UTIG and L-DEO. The data are the focus of the Ph.D. research of University of Texas graduate student R.L. Burger (supervised by Fulthorpe and Austin).

WORK COMPLETED

UTIG has processed all but one of its 41 lines to the stage of post-stack migration. We have also received 11 processed profiles from L-DEO. Interpretation to date has focused on the shelf, analysis of slope profiles has begun.

RESULTS

Multiple, superimposed channel incisions have been identified and mapped near the mouth of the Eel River (southernmost part of the seismic grid) (Figure 2; Burger et al., 1999; Burger, et al., submitted). The channel systems were probably formed by fluvial processes when paleoshelves were subaerially exposed during successive relative sea-level lowstands. They converge on Eel Canyon and this evidence for southwesterly sediment transport at lowstand is in marked contrast with the primarily northward and northwestward transport during flood events under present highstand conditions (Cacchione et al., 1999). Furthermore, these interpretations show that Eel Canyon has been a long-lived conduit for lowstand sediment transport, since it has existed through multiple channel-incision/sea-level cycles (up to ~500 ky). The maximum depth of incision (up to ~250 m near Eel Canyon) suggests that the seaward ends of the systems may have been produced by submarine erosion, headward from Eel Canyon. Finally, channel orientations suggest a northerly source (Mad or Elk rivers, or local drainage from the offshore extension of the Table Bluff Anticline), rather than the Eel River. The deepest channelled horizon crosses the Table Bluff Anticline and channel offset indicates right-lateral displacement along faults associated with the anticline.

We have assigned tentative ages to two prominent seismic horizons (~0.5 and ~1.0 Ma) beneath the shelf by correlating the high-resolution MCS profiles with a seismic stratigraphic framework developed using the JEBCO and other low frequency MCS data. These are, in turn, tied to industry wells and dated outcrops onshore (Gulick and Meltzer, submitted; McCrory, 1995, 1996, in press). These age assignments are the best available pending long coring. They provide the approximate timing of the migration of shelf depocenters, as revealed by isopach maps, and of tectonic deformation. We are now confident that some surfaces can be correlated from shelf to slope through the zone of gas wipeout that lies beneath the outer shelf. This will allow assignment of approximate ages to seismic horizons beneath the Humboldt Slide, some of which may be past failure surfaces.

IMPACT/APPLICATION

The MCS data: 1) fill the gap in seismic resolution and depth of penetration between existing data sets to provide fully "nested" coverage, 2) link outer shelf and upper slope stratigraphic regimes, and 3) allow development of models that will determine the transfer functions between modern sedimentary processes and stratigraphic preservation.

TRANSITIONS

The MCS data have been used to select sites for long (up to 150 m) cores (STRATAFORM Deep Coring Workshop, October 1998). These cores will provide ground truth for nested MCS and shallow-penetration Huntec profiles.

RELATED PROJECTS

We have provided profiles to M. Field and G. Spinelli (USGS), for integration with Huntec profiles, and D. Orange and J. Yun (University of California, Santa Cruz), to augment their analyses of deep-penetration commercial MCS profiles. We expect interactions with stratigraphic modelers D. Swift and M. Steckler to increase as our interpretations become more complete.

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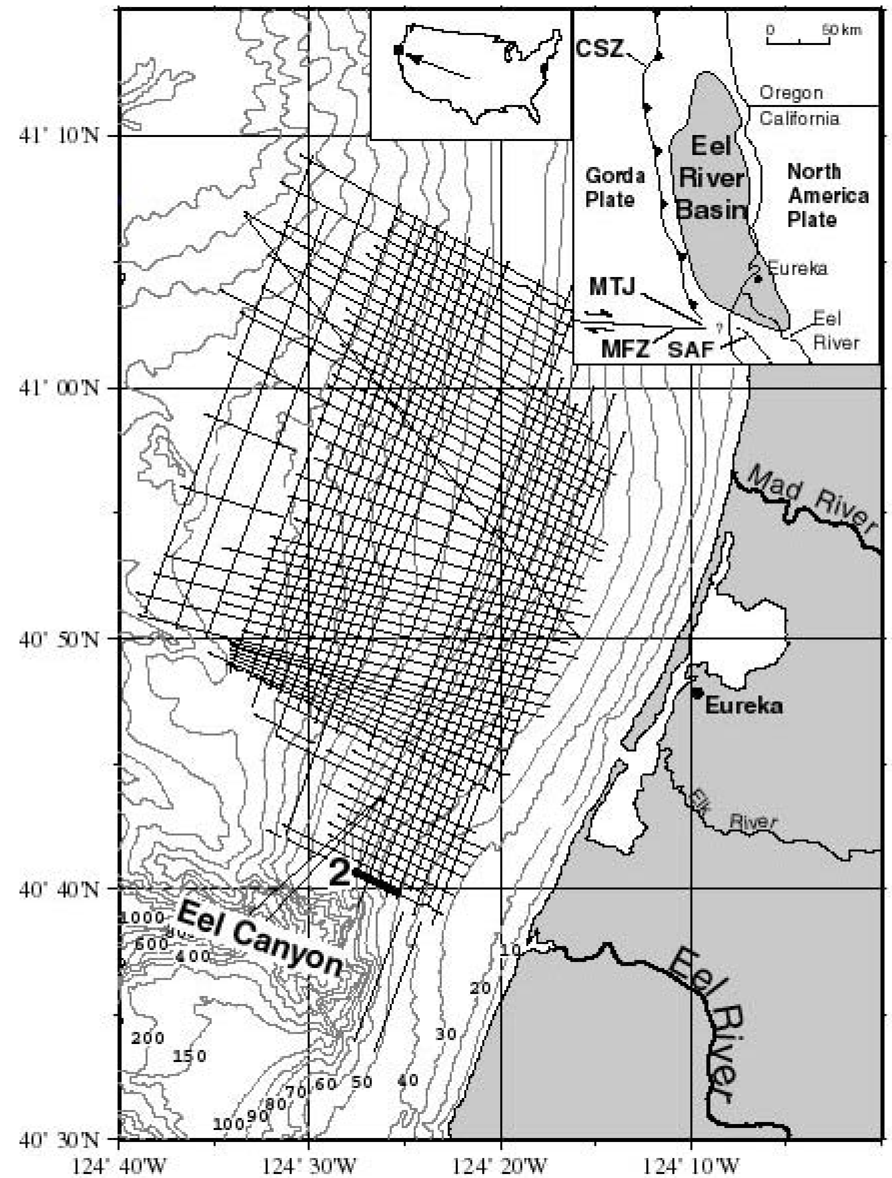

Figure 1. Eel River Basin, showing the 1996 high-resolution multichannel seismic survey. Both UTIG- and L-DEO-processed profiles are shown. Also shown are the Eel, Mad, and Elk rivers, Eel Canyon, major bounding structural features (inset), and location of Figure 2. Bathymetry in meters. MTJ = Mendocino Triple Junction; MFZ = Mendocino Fracture Zone; SAF = San Andreas Fault; CSZ = Cascadia Subduction Zone (inset adapted from Clarke, 1987).

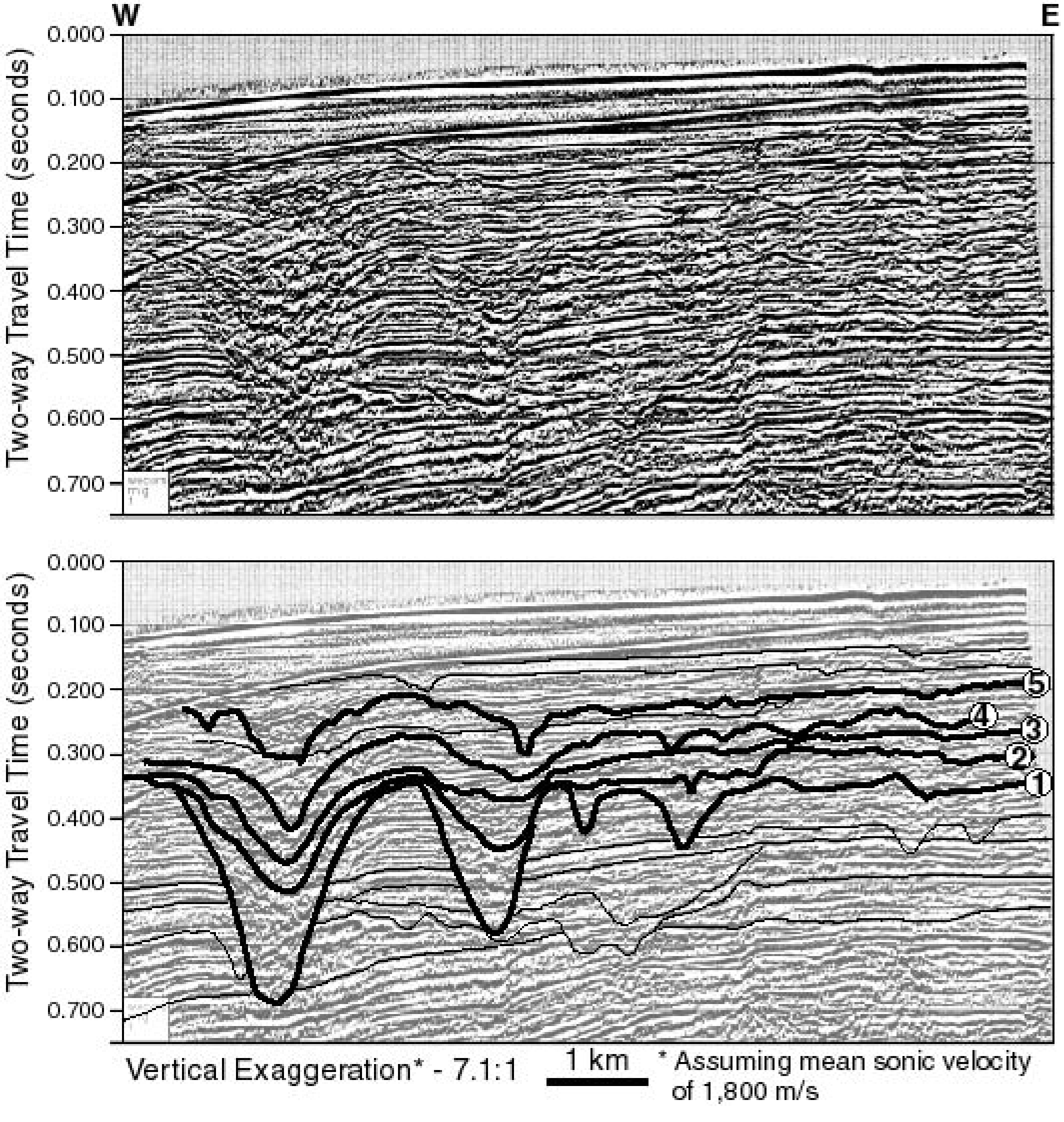

Figure 2. Interpreted and uninterpreted versions of seismic dip profile 1 (see Figure 1 for location), showing superimposed/stacked channels/incisions. Bold interpretations indicate the seismic surfaces characterized by channels that can be mapped between profiles. These channel systems converge on Eel Canyon. (From Burger et al., submitted.)