2003 SCEC Workshop Report

Developing a Coordinated, Integrated Approach for a Continental Dynamics Study of the California Borderland

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The California Continental Borderland offshore of southern California is one of the most active continental margins of the late Cenozoic in the world. The region experienced significant elements of Paleogene subduction and Neogene extension, in addition to accommodating major strike-slip components associated with the evolving Pacific-North American (NAM) transform system. The Borderland was the locus of Pacific-NAM plate motion in southern California for about 70% of its tectonic history (from ~19 Ma to ~6 Ma), and recent GPS and VLBI data suggest that as much as 20% of the current plate boundary motion may still be located offshore. This has resulted in both mature and relatively young fault structures offshore that pose a serious but as yet unresolved seismic and possible tsunami hazard to large coastal populations of southern California. Thus, understanding the tectonic evolution of the plate boundary and the current tectonic architecture of the San Andreas fault system, as well as the tectonic history and seismic hazards of southern California necessarily requires a fundamental understanding of the offshore California Borderland.

In recognition of the importance and significance of the offshore Continental Borderland, SCEC recently created the SCEC Borderland Working Group. Its purpose is to initiate, foster, and coordinate activities in the California Borderland relevant to SCEC's mission of understanding the tectonic evolution, earthquake dynamics and seismic hazards of southern California. Because SCEC itself has limited resources to conduct offshore research, a 2-day workshop was held to develop integrated, multi-disciplinary studies of the offshore Borderland for possible submission to appropriate NSF programs. The workshop was held on June 26-27, 2003 at the SCEC office on the USC campus in Los Angeles. There were 16 attendees (see list below). Talks were given on: 1) Regional tectonic models for Borderland evolution, rifting and rotation (Nicholson); 2) Influence of slab gaps on Inner Borderland structure (Okaya on behalf of Uri Ten Brink); 3) Models for Outer Borderland structure and evolution derived from seismic and gravity data (Miller); 4) The nature of oblique rifting and possible seafloor spreading in South San Clemente Basin (Legg); 5) Possible interactions between the Continental Borderland and the rotating Western Transverse Ranges province (Sorlien); 6) Constraints on plate motions and California margin evolution from marine magnetic data and regional volcanism (Wilson); 7) Lessons learned on Southern California crust and upper mantle structure from passive deployments (Davis); and 8) Distribution of existing industry seismic data sets in the offshore Continental Borderland (Piper).

A wide range of various science issues and tectonic problems were discussed, with specific emphasis on those questions of global significance that could best be addressed in the offshore Borderland, or with onshore-offshore experiments This included those issues that could best utilize the extensive grids of existing industry seismic reflection data that may soon become available (see Borderland Working Group report). It was clear from these discussions that the Borderland does indeed represent an ideal natural laboratory to study many types of fundamental processes. Most of these are related to the general question of: *How does an oblique continental transform system initiate and evolve?* Four major science issues were identified:

- What happens when a spreading ridge obliquely subducts and initiates forearc rifting? Why is the Borderland offshore Southern California different from Northern California? Multiple regional transects at Viscaino, San Quintin and the US-Mexico border could elucidate the differences between where the spreading ridge did not subduct and the margin is unrifted *versus* where the ridge did subduct and the margin did rift, thus allowing a systematic evaluation of this evolutionary process.
- How is mantle flow distributed along a continental transform boundary? Is plate boundary shear distributed or discrete, and are there differences in how the lower crust and upper mantle behave? Models for plate boundary shear make different predictions for slip rates on large plate boundary faults that are testable. The largest discrepancy between the flow models is for faults at the edges of the plate boundary system, like the offshore San Clemente fault in the California Borderland. This issue gets at fundamental problems of estimating offshore fault slip rates, anisotropy in the crust and upper mantle, hazards, and developing new techniques for marine paleoseismology.
- What drives large-scale rotation of the western Transverse Ranges? Is it driven from below by basal tractions or from the sides? Based on geologic and geophysical evidence, the western Transverse Ranges province (which includes the Northern Channel Islands) has rotated by more than 90° clockwise since 19 Ma and, based on geodetic data, this rotation continues today. This rotation accompanied oblique rifting of the Inner Continental Borderland. This problem gets at issues of timing of Borderland deformation, rates of rotation, coupling, mantle flow (anisotropy), remnant fragments of subducted oceanic lithosphere, and how the southern boundary of the rotating western Transverse Ranges province interacts with the northern boundary of the non-rotating Outer Borderland.
- How does oblique continental rifting initiate and develop? Did continental rifting in the inner Borderland progress to seafloor spreading? How do high- and low-angle faults interact to accommodate oblique finite strain? These questions are fundamental to understanding the tectonic evolution and seismic hazards of Southern California as many of the currently active fault systems originated under this process of oblique continental rifting. Preliminary evidence suggests that South San Clemente basin underwent oblique rifting since its inception and may have reach the stage of incipient seafloor-spreading.

There are—of course—distinct advantages to working in the Continental Borderland, not the least of which is that much of it is underwater. This means that it is generally an area of ***deposition***, not erosion, so much of the deformation is preserved and a detailed syntectonic stratigraphic record is available to assess dates and rates of active faulting and fold growth. Because it is underwater, less expensive, high-resolution marine geophysical techniques can be used to image and evaluate this structure, stratigraphy, and tectonic geomorphology. Moreover, many of the most important scientific issues regarding active faults ***onshore*** in southern California also have analogs ***offshore*** in the Borderland where they are more easily imaged and evaluated in 3D. This includes such processes as strain partitioning, the interaction between faults of different orientation, and fault reactivation under different stress or strain regimes. And finally, the potential availability of extensive grids of existing (previously proprietary) high-quality industry seismic reflection data can provide substantial 2D (and 3D) subsurface imaging capability in many areas.

Discussion of the various data resources needed to investigate these important tectonic issues suggested a multiphase approach to studies of the offshore Borderland:

Phase I - *Archiving and analysis of existing offshore industry data,* including the extensive grids of high-quality 2D and 3D multichannel seismic reflection data (MCS), well and gravity data;
Phase II – *Comprehensive coverage of multibeam bathymetry and compilation of seafloor and sub-seafloor geology*, including data sets at the USGS, MMS and from industry, and filling in data gaps in existing multibeam coverage;
Phase III - *High-resolution stratigraphic, petrologic, petrophysical, and geochronological studies*, to provide a necessary framework for assessing rates, dates, lithology, material properties, and a basis for conducting marine paleoseismological studies;
Phase IV – *Passive long-term GPS and seismic monitoring,* including ocean-bottom seismometer (OBS) deployments and seafloor observatories (such as the Gumbi-moor OBS, marine strainmeters, etc.); and
Phase V – *Active-source imaging and refraction studies,* including deep-penetration MCS, and wide-angle reflection and refraction to resolve crust and upper mantle velocity and anisotropy.
These five phases are not necessarily sequential as several of these are already on-going.

As a result of this workshop and other on-going collaborations within SCEC, at least four major science proposals were submitted to NSF to investigate important, interesting problems in the offshore Continental Borderland. These include: 1) a passive long-term OBS deployment to investigate the transition from oceanic to continental lithosphere (UCLA, Caltech, UCSB, Scripps); 2) a high-resolution study of late-Quaternary transform tectonics in thinned submerged continental crust (UCSB, LDEO); 3) a high-resolution stratigraphic study of late-Quaternary climate and deformation in the Santa Barbara Channel (UCSB, USGS); and 4) an initial analysis of some of the existing, high-quality industry MCS data to look at issues of plate boundary evolution and the interaction of high- and low-angle faults to accommodate oblique plate boundary strain (UCSB, USGS). A major component of the last proposal involved matching support for an on-going USGS effort to transcribe, transfer and archive existing industry MCS data into a digital, on-line, useable community research tool. If funded, these proposed studies would augment existing, on-going projects funded by NOAA, USGS and other agencies, and provide an important framework for understanding the structure, tectonic evolution, and seismic hazard of this active region.

List of Workshop Attendees

Shirley Baher (USGS)
Paul Davis (UCLA)
Gary Fuis (USGS)
Mark Legg (Legg Geophysical)
Drew Mayerson (MMS)
Kate Miller (UTEP)
Craig Nicholson (UCSB)
Bill Normark (USGS)
David Okaya (USC)
Ken Piper (MMS)
Tom Rockwell (SDSU)
Daniel Scheirer (USGS)
Chris Sorlien (UCSB)
Joann Stock (Caltech)
Doug Wilson (UCSB)
Victor Wong (CICESE)