RCL	The 2002 Gulf of California Seismic Experiment	
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In studying continental rifting, basic questions persist about the symmetry (pure shear) or asymmetry (simple shear) of extension; the roles of lower crustal flow, magmatism, and sedimentation in evolving rift architecture; and the sensitivity of rift evolution to variations in key parameters such as lithospheric strength and temperature, strain rate, and crustal thickness. The Gulf of California is an excellent location to study rifting processes because the ongoing rifting there is young (beginning 12Ma); the 'mode' of rifting varies along its length - narrow and abrupt in the S., wide and diffuse in the N.; and a large team of scientists at CICESE can provide substantial expertise derived from many years spent actively studying the rift.

An NSF MARGINS funded crustal-scale, active-source seismic experiment was conducted in the Gulf of California (Fall 2002), with the aim of imaging crustal structure across conjugate margins of major basins throughout the Gulf. Goals were to determine modes of extension, the influence of sedimentation and magmatism on breakup, and other features leading to better understanding of the rifting process:

- R/V Maurice Ewing provided the acoustic source and acquired MCS data using a 6km streamer.
- R/V New Horizon deployed 206 OBSs.
- MCS and OBS data were acquired along 3 flow line transects across Guaymas Basin, Alarcon Basin, and between Puerto Vallarta and Cabo San Lucas. A fourth 2-part 'coast-perpendicular' transect extended from the Pacific margin across the Baja Peninsula through Bahia de la Paz and across the margin S. of Mazatlan up into the Mexican mainland Sierras. Offshore shots were recorded by OBSs and onshore seismometers (to ~100km inland) at 10-15km spacings.

The logistical and technical program was extremely successful. Highlights and initial results include:

- A record 206 OBS and 90 RefTek deployments, combined MCS/wide-angle profiles, and MCS transects (Fig. 1) achieved near 100% data recovery, at extremely good quality. This success demonstrates the capabilities of the new active-source OBS fleet and the feasibility of conducting onshore/offshore experiments of this scale.
- Initial results suggest markedly amagmatic Alarcon Basin rifting (Fig. 2). Clues to the lithospheric strength here are provided by identification and characterization of failed rifting events (one had been previously speculated by P. Lonsdale and others). Apparent ~symmetry of the Alarcon rift is unexpected for such an amagmatic rift. Questions remain to be addressed through the detailed crustal images resulting from wide-angle data analysis.

- Very preliminary results of Guaymas MCS and wide-angle data suggest a robustly magmatic asymmetric rift (Fig. 3). Apparent spreading center emplacement of new igneous crust (most of the offshore crust) is asymmetric in style, and the spreading center is offset from the geographic center of the basin. The asymmetry may be imposed tectonically, or by deeper mantle circulation. Mantle upwelling, at larger scales than tectonic processes, may be focused at the center of the basin, providing an asymmetric magma supply to the rift.
- A very exciting find is that the rifted margin at the eastern end of the Cabo San Lucas/Puerto Vallarta transect (see Fig. 1) has already transformed into a convergent margin. In the classic Wilson-cycle paradigm for continent-ocean interactions, old oceanic lithosphere eventually initiates subduction along previously rifted continental margins. In contrast to the usual ~200Myr required, the mid-American trench has taken advantage of the weak margin lithosphere and propagated northward. This discovery provides a rare opportunity to study the earliest stages of continental lithosphere evolution under the influence of subduction processes.

We are extremely pleased with the success of the fall 2002 experiment. We have barely scratched the surface of what the data have to tell us about continental rifting processes. Moreover, these data will provide the framework for subsequent geologic studies that aim to fully delineate the extensional history of the region, as well as geophysical studies such as the Ritsema and recently funded Garherty/Collins passive seismic experiments, which together will delineate the deeper mantle component of this dynamic system.

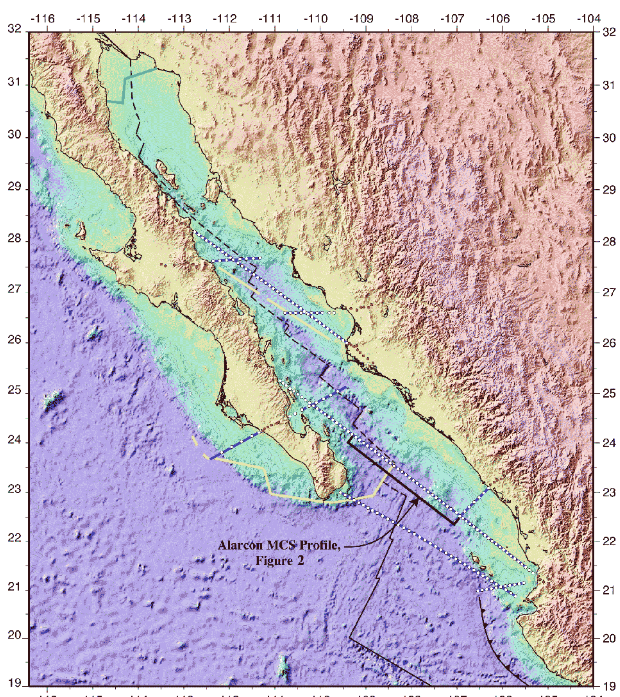

Figure 1. Distribution of combined MCS/wide-angle profiles (blue), OBS locations (white), MCS transects (yellow), and onshore RefTek seismometers (red). There were 206 OBS deployments and 90 Reftek deployments. Location of the Alarcon MCS data shown in Figure 2 is indicated. The Guaymas velocity model shown in Figure 3 extends from coast-to-coast along the main transect.

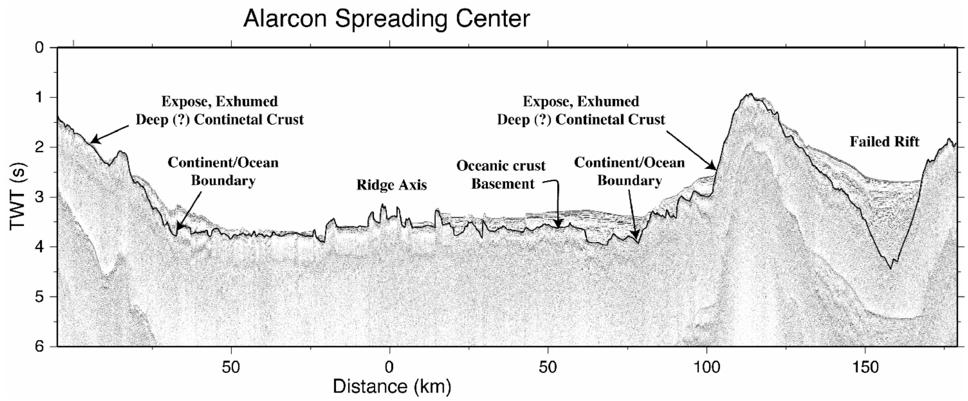

Figure 2. Alarcon Basin MCS profile surrounding the spreading center (see Fig. 1 for location). A prominent failed rift is seen to the east. From the apparent depth to 'basement', crustal rifting was probably complete here, but seafloor spreading began in another location. Extension in this basin involved the disassembly of the continental crust into a number of large rotated blocks with nearly complete extension between several of them. The nature of the surface at the base of these rotated blocks is not yet clear, but it should become apparent when wide angle data have been analyzed. OBS instrument spacing along this line is ~11km.

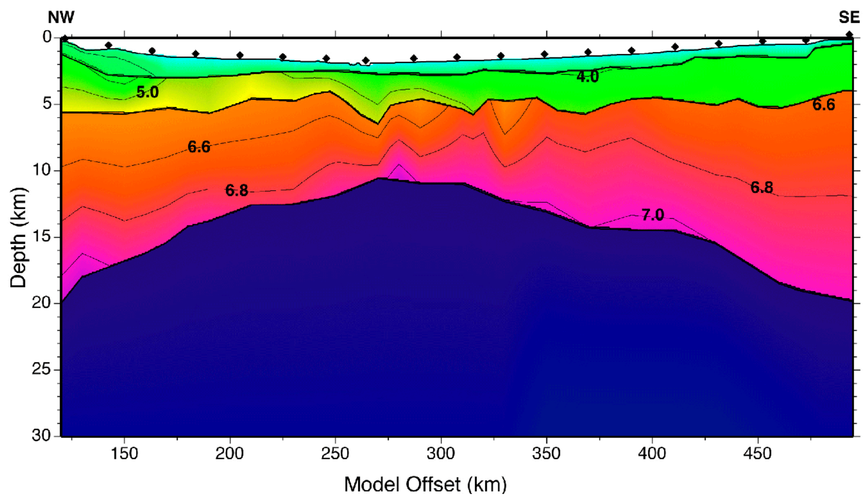

Figure 3. Guaymas Basin transect velocity model (kms^{-1}) based on preliminary crude analyses of only half of the offshore, and none of the onshore instruments. Shown are sediments (lt. blue); a mix of sills and sediments equivalent to oceanic 'Layer 2' (green-yellow); and plutonic igneous crust probably formed at the Guaymas spreading center (orange-magenta). Asymmetry is manifest in several ways. Plutonic crust velocities to the east are higher (more mafic) and have lower velocity gradients than those to the west. 'Layer 2' has substantially higher velocities to the west, reaching 6kms^{-1} near km 225. The rift axis is displaced ~25km from the basin center, and the top of the plutonic crust is characterized by a very large, low angle, east dipping surface that, since it is at the plate boundary, is very likely a fault. It may be that melt rises near the center of the basin (km 300) and builds crust to the east, mostly via underplating of more residual magmas, while more evolved magmas are transported up and westward, perhaps aided by tectonism, building the crust to the west and emplacing more magmas into 'Layer 2'. If this speculation is valid, then crustal formation in Guaymas Basin proceeds through a tectono-magmatic asymmetry which has not previously been envisioned.