

RCL	Collaborative Research: Upper-Mantle Structure Beneath the Gulf of California	
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We are funded to carry out a passive seismic experiment to evaluate the degree to which mantle processes control lithospheric rupture and the initiation of seafloor spreading in the Gulf of California (GoC). We will deploy, for 15 months, 18 wide-band ocean bottom seismographs (OBS) in the GoC. The data from these stations (Fig. 1), in conjunction with observations from the MARGINS-funded NARS-Baja experiment, will be used to image mantle structure beneath the Gulf and the surrounding region. We will specifically address two questions that are important for achieving the goals of the Rifting Continental Lithosphere science plan:

- **Is the upper-mantle directly underlying GoC extension anomalously hot?** This question is critical to understanding the magmatic budget of GoC extension, and the role of this magmatism on strain localization and partitioning. The GoC lies on a broad region of very low seismic velocities (Fig. 2), implying that temperatures in the upper mantle are elevated. Volcanism associated with rifting, however, appears to be quite modest in the region compared to many rifted margins. The OBS deployment will allow us to image structure directly beneath the Gulf and its margins, better constraining thermal processes in the region.
- **To what extent do North-South variations in extensional style correlate with upper-mantle velocity variations?** Addressing this question will allow us to evaluate the importance of mantle state in controlling or modulating rift extension. Despite nearly constant total extension all along the rift axis over the past 5 Ma, the style of extension changes dramatically from continental extension in the north, to sea-floor spreading in the south. Mantle thermal and rheological properties probably modulate this process. The OBS deployment will allow us to image along-axis variations in mantle structure, placing better constraints on the impact of this structure on rifting.

If data quality is high, as expected, we will also address:

- ***Is the GoC rifting predominantly passive (driven by far-field tensional stresses), or is it driven by buoyant upwelling beneath the Gulf?*** Strikingly, the GoC sits exactly at the intersection between apparently upper-mantle uplift- and flow- modulated B&R continental extension (e.g. Jones et al., 1996; Sheehan and Savage, 2000); and entirely passive EPR oceanic extension (e.g. Forsyth et al, 1998; Wolfe and Solomon, 1998). So, is GoC extension an on-shore continuation of EPR spreading, or is there a, B&R-like, buoyant character as well? Estimates of radial seismic anisotropy (e.g. Gaherty, 2001) are probably needed to answer this question, and that hinges on recording intermediate-period tangential-component data.

The deployment builds upon the NARS-Baja backbone, placing 6 OBS at ~100-150 km spacing down the southern Gulf axis. In addition, two 6-station subarrays span the Guaymas and Alarcon spreading centers, providing the means to image the mantle beneath two of the crustal transects shot by the Lizarralde et al. active-source experiment. We will measure Rayleigh-wave velocities, P and S delay times, and attenuation structure in order to provide estimates of mantle temperature variations. We will map mantle flow patterns by measuring the magnitude and orientation of azimuthal anisotropy using SKS and $SKKS$ phases and inter-station Rayleigh wave dispersion. Azimuthal anisotropy will be further constrained by Pn and Sn travel times from regional events. We will use receiver functions to map the depth to both mantle transition zone and shallow mantle discontinuities, thereby providing additional constraints on thermal, compositional and mechanical structure. If useable Love waves are recorded, we will constrain radial anisotropy, which could place important constraints on local mantle buoyancy.

Broader Impacts: A full-time graduate student will be supported on this project, which will form the primary content of the student's thesis. The project also has strong international collaboration. The improved locations of seismicity within the Gulf will lead to better assessment of the natural hazards environment of the Gulf of California. Following OBSIP guidelines, the unique ocean-bottom seismic data collected in this experiment will be available to any interested investigator 2 years following instrument recovery through the IRIS DMC. Finally, the project closely builds on previously funded MARGINS experiments, furthering the return on the investment made in those programs.

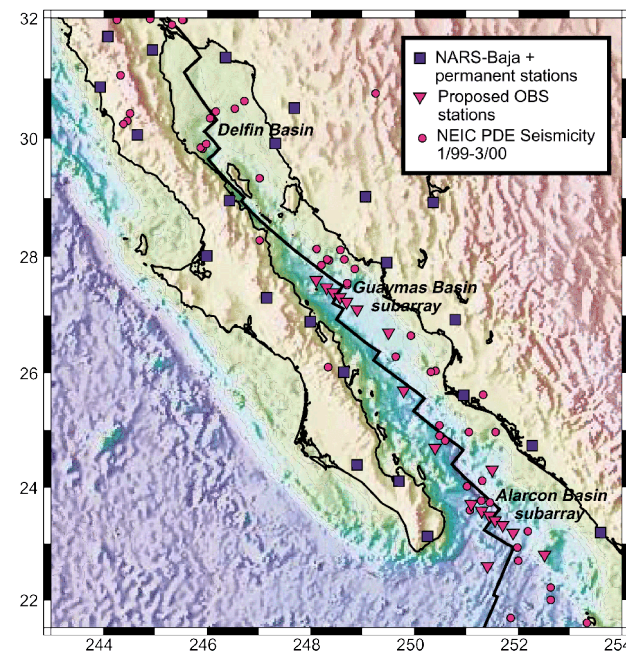


Fig. 1. Topographic map of the Gulf of California (GoC) region. Blue squares represent locations of the NARS-Baja deployment, plus permanent broadband stations of the CICESE and UNAM regional networks (J. Ritsema, personal communication). Red triangles depict planned locations for the OBS deployment that we are proposing, with the two six-station subarrays labeled. Magenta circles are NEIC seismicity from a representative 15-month period, with Richter magnitudes ranging from 3.2 to 5.6.

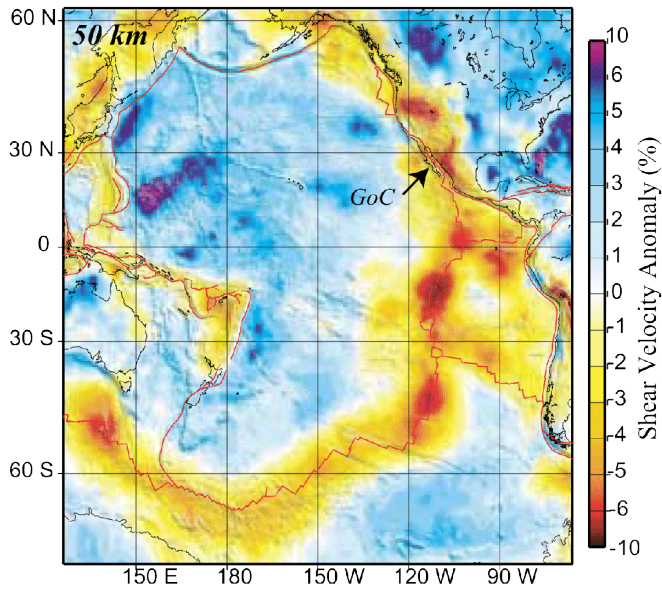


Fig. 2. Shear velocity anomaly at 50- km depth relative to PREM, from a recent global model of Ritzwoller et al. (2002). At this depth, the Gulf of California (GoC) sits on a distinct velocity low that is matched or exceeded only in regions of hotspot volcanism (e.g. Yellowstone, Galapagos) and/or super-fast spreading on the EPR. This implies that GoC extension may be driven or facilitated by anomalously hot or wet underlying mantle, at odds with its non-volcanic nature. However, the spatial resolution of this model is of order 1000 km and greater, which is too large to discern whether the regional upper mantle anomaly is characteristic of the Gulf as well.

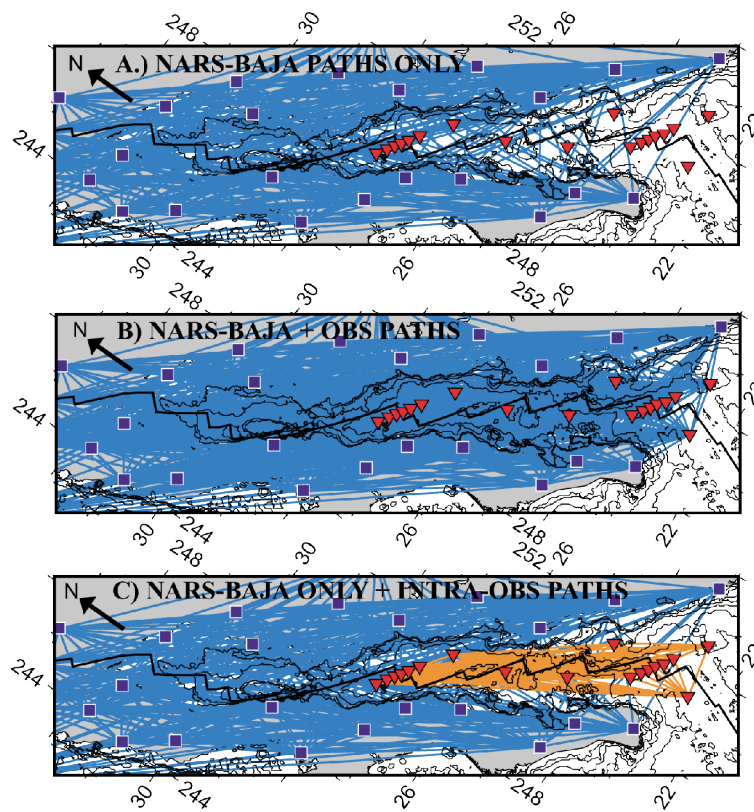


Fig. 3. Expected surface-wave path coverage (colored lines) for different array subsets over representative periods from the Harvard CMT catalog. (A) NARS-Baja array only. Events are $M_w \geq 6$ within 100° distance over a 5-year period. Coverage is poor in the southern third of the Gulf. (B) NARS-Baja plus the proposed OBS complement. Events are $M_w \geq 6.5$ within 100° distance over a 15-mo period. Spatial coverage of the Gulf is much more complete. (C) Orange lines show subset of raypaths from panel B that are restricted within the OBS array, and thus sample the actively extending Gulf with minimal interaction with the surrounding margin. In all cases, a station-station path is selected if the source-receiver azimuth to the two stations is within 1° . For these deployments and earthquake distributions, nearly all station-station paths are sampled by at least one earthquake.