RCL	NARS-Baja: A Five-Year Deployment of Broadband Seismic Instruments Around the Gulf of California	
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NARS-Baja fills a gap in broadband station coverage in California and southern Mexico. Combined, NARS-Baja, and stations from the Berkeley Digital Seismic Network (BDSN), TriNet (Caltech), and the UNAM Array in southern Mexico provide extensive coverage of the entire North American Plate Boundary. NARS-Baja will provide an important seismic data set for RCL research:

NARS-Baja will operate for at least five years to ensure that a large database of waveform data will be collected, and that NARS-Baja will operate in conjunction with the planned OBS experiment in the Gulf of California (Gaherty and Collins, PIs), and the deployment of EarthSCOPE/U.S. Array in the western U.S.

NARS-Baja data will be available from IRIS and the SCEDC Data Centers immediately after the data have been collected and checked. Thus, the data will be immediately available to any interested researcher.

There are only a few constraints on the role of the mantle in the heterogeneous deformation processes that may be central in the formation of the Gulf of California rift. While recent seismic studies indicate a stark contrast in the thickness of the lithosphere across the eastern Mohave shear zone [Melbourne and Helmberger, 2000], and the presence of deep-seated low velocity structures in parts of the Basin-and-Range [e.g., Song *et al*., 2003], there are no models that provide a regional perspective of structural heterogeneity. Global seismic models indicate that seismic velocities in the uppermost mantle beneath the East-Pacific Rise, Gulf of California, and the western U.S. are anomalously low [e.g., Grand and Helmberger, 1984; Su *et al*.,1994; Ritsema *et al*., 1999; Megnin and Romanowicz, 2000]. However, the intrinsic 1000-km scale lateral resolution of velocity variations is not sufficiently high to determine whether structural heterogeneity in the mantle is the underlying cause of the systematic variation in deformation style in western North America (e.g., rapid sea-floor spreading along the EPR, oblique rifting in the Gulf of California, and Basin-and-Range extension in the western U.S.).

We will invoke a number of tomographic and forward modeling studies that utilize not only data from the NARS-Baja network, but also permanent network stations in southern Mexico (operated by UNAM) and California (TriNet and the Berkeley Digital Seismic Network), to attain models of crust and mantle across the entire North American Plate Boundary region that will have an order of magnitude higher resolution that models derived from global network data (e.g., Fig. 2). When the opportunity arises, we will also make use of the forthcoming EarthScope – U.S. Array, planned to begin its march across the U.S. in the western states in the next few years.

The distribution of NARS-Baja seismic stations on both sides of the Gulf of California rift (Fig. 1) is ideal for studying seismicity and earthquake faulting processes. The systematic location of earthquakes allows us to identify active faults in the Gulf of California region. Focal mechanisms are pivotal for confirming the direction of plate motion and likely orientation of transform faults.

On average, for each year, the NOAA/PDE catalog contains epicentral information for six southern and central (22°N – 28°N) Gulf of California earthquakes with a magnitude larger than 4.5. However, only 14 central and southern Gulf of California earthquakes larger than Mw 3 are reported in this bulletin, even though, based on empirical relationships, we should expect that at least 60 such earthquakes occur each year. The number of Gulf of California earthquakes smaller than Mw 4 in global catalogs is artificially low because small earthquakes are poorly recorded by distant (>1000 km) seismic instruments. Locating small earthquakes is important for identifying active tectonic structures that may not be easily identified from bathymetric and seismic reflection profiles in regions with thick sediment cover of the basement rock. We will use NARS-Baja recordings to detect and locate small earthquakes throughout the Gulf of California region. Based on our experience with the TriNet network in southern California [Kanamori *et al*., 1997], we anticipate that we will be able to record Mw 3.5 earthquakes well above the background ground-motion noise-level at at least 5 stations. These events can be located with a 15-km precision, whilst relative locations of earthquakes in the northern Gulf of California region, where the density of seismic stations is highest, can be estimated as accurately as within a few kilometers through cluster analysis [e.g., Richards-Dinger and Shearer, 2000].

Recently, Lewis *et al*. [2001] applied this technique to data from an east-west profile of seismic stations that were deployed in northern Baja California. They showed the gradual thickening of the crust from 15 km beneath the Gulf of California to ~40 km depth beneath the western part of the Peninsular Ranges. With NARS-Baja data, one can constrain the Moho depth at each NARS-Baja station in Baja-California and Sonora with comparable vertical accuracy. Recently Patricia Persaud [Persaud *et al*., 2003; AGU Fall Meeting abstract] computed receiver functions with the NARS-Baja recorded so far (Figure 3). Her study indicates that crustal thinning towards the coast occurs along the entire length of the Baja peninsula, and that the crust beneath the Sonora side of the Gulf of California is as thick as that beneath the Baja-California peninsula. These crustal thickness estimates will get more precise, since more recordings (especially for the recently deployed Sonora stations) are currently being archived.

Seismic waves that reflect off discontinuities in the crust and mantle arrive within several minutes after the main P arrival (Fig. 4). These signals (also called P coda) provide excellent constraints on the depth of the Moho-discontinuity (the interface between the crust and the mantle) and discontinuities in the mantle. Receiver functions feature large-amplitude P-to-S converted phases that have encountered seismic discontinuities at depths of 410 km and 660 km [Fig. 4; e.g., Vinnik *et al*., 1983; Gurrola and Minster, 1998]. These discontinuities are due to the olivine-to-spinel transition and the spinel-to-perovskite transition, respectively. Receiver-function analysis is a useful technique for imaging seismic reflectors in the crust and mantle [e.g., Owens *et al*., 1984]. It is especially effective for constraining the depth of the crust-mantle transition, where the material contrast is large. Receiver functions can also be used to image reflectors deeper in the mantle. Precise depth estimates of these discontinuities can be obtained from the arrival of converted phases. Variation in the depth of the 410-km and the 660-km discontinuities is an excellent indicator of thermal anomalies in the mantle transition zone because the depths at which the mineralogical phase transitions occur depend on pressure and temperature.

Figure 4 shows that the Gulf of California uppermost mantle may contain additional reflectors. In receiver functions for station NE76, in particular, there are high-amplitude arrivals near 20 and 25 s after the direct P phase. While we must fully investigate how significant multiple crustal phases affect the receiver function, it is possible that some of these signals are due to the presence of the Farallon slab in the mantle. We can distinguish crustal multiples from deeper mantle reflections by measuring the slowness of the high amplitude arrivals with high precision (via slant stacking). The relatively large aperture of the NARS-Baja will facilitate this.

Figures, figure captions, and narrative kindly provided by J. Ritsema (March, 2004)

Figures and Captions

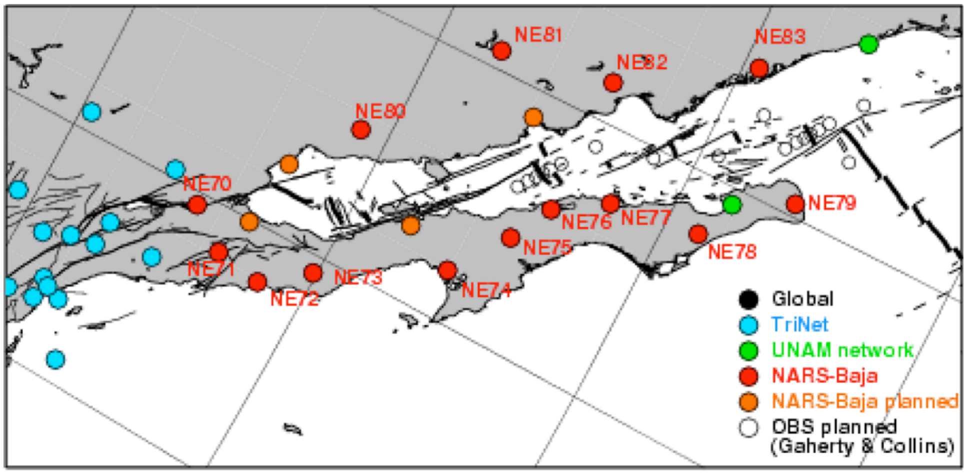

Figure 1: Map of the NARS-Baja seismic network.

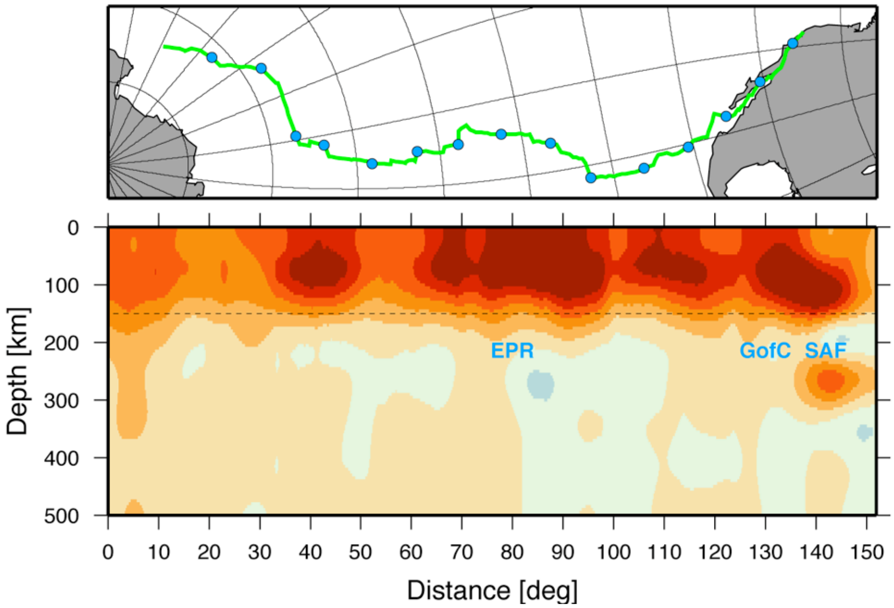

Figure 2: Shear velocity perturbation from PREM in the mantle according to global model S20RTS beneath the East Pacific Rise (EPR), the Gulf of California rift (GofC), and the San Andreas Fault (SAF). The cross-section follows the green line shown in the map. While the model indicates that the uppermost velocities are anomalously low in the uppermost mantle of western North America, its inherent 1000-km (~10 deg) lateral resolution is too poor to elucidate changes in mantle structure that can be related to variable deformation processes.

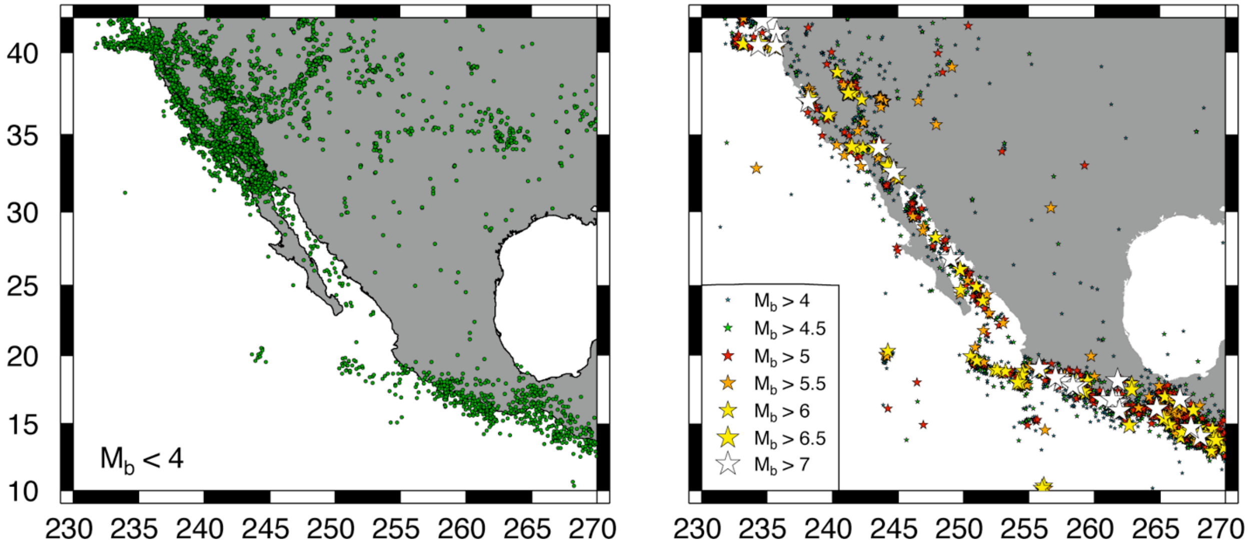

Figure 3: Epicenters of earthquakes between 1978 and 1999 from the NOAA/PDE bulletins of earthquake locations. Shown on the left are earthquakes smaller than Mw 4. Shown on the right are earthquakes larger than Mw 4. The low number of moderate-size earthquakes in the Gulf of California region is likely due to the lack of seismic instruments in this region.

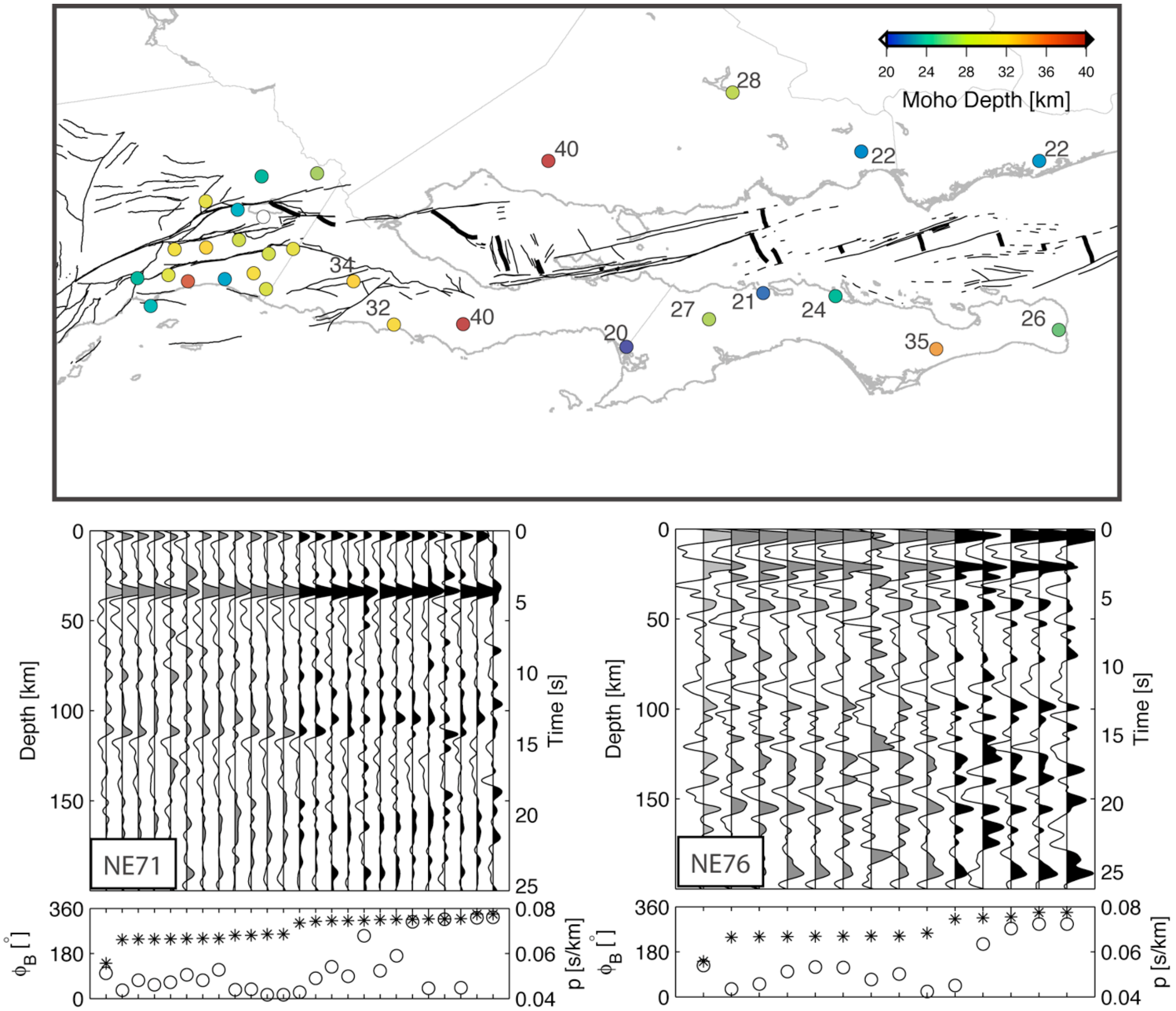

Figure 4: (Top) Crustal thickness estimates at each of the NARS-Baja stations inferred from receiver function analysis [Persaud *et al*., 2003]. (Bottom) Receiver functions at stations NE71 (~34km thick crust) and NE76 (~21km thick crust) demonstrating that the difference in crustal thickness at these stations can readily be inferred from the travel times of the high-amplitude P-to-S signal that arrives within 5-s after the main P pulse. The receiver functions clearly demonstrate that the mantle beneath these stations has a different reflectivity. (Courtesy of P. Persaud, Caltech.)

Publications and Presentations

Trampert, J., Paulssen, H., van Wettum, A., Ritsema, J., Clayton, R., Castro, R., Rebollar, C., and Perez-Vertti, A., 2003, NARS-Baja: monitoring the Gulf of California, Mexico, EOS, Vol. 84, No. 4, , p. 29, 32.

Persaud, P., Perez-Campos, X., and Clayton, R.W., 2003, The Telltale Moho and Novel Views of the Crust and Upper Mantle in the Gulf of California. EOS-AGU Fall Meeting abstract