

PRF# 56969-DNI8

Project title: Characterizing Basin Structure With Dense Passive Arrays

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Understanding the evolution and structure of sedimentary basins is fundamental to the knowledge of petroleum systems, as hydrocarbon reserves are located in different types of basins around the world. High-resolution seismic imaging of sedimentary basins constrains basin development and architecture, but traditionally involves manmade sources and dense instrument arrays at high logistical and monetary costs. In this project, we utilized recent advances in instrument technology and data analysis to explore basin structure in central New Mexico by recording distant earthquakes and the ambient noise field with densely-

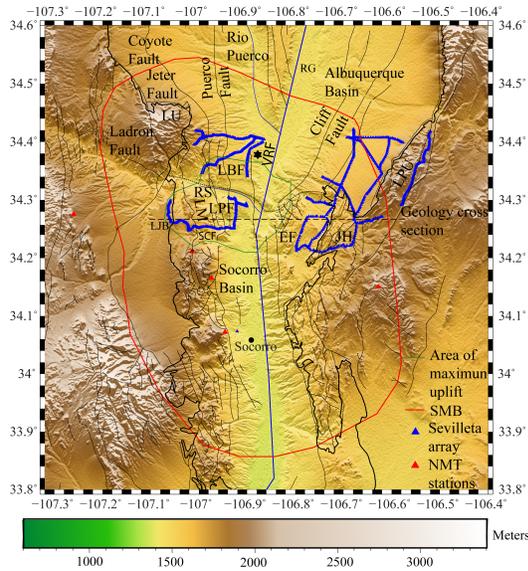


Figure 1: Map of the study area. The red outline is the estimated lateral extent of the Socorro magma body. Black lines are faults. Blue lines show Sevilleleta Array.

Ambient Noise Tomography

For this portion of the study, we characterized the basin and upper crustal velocity structure of the southern part of the Albuquerque Basin using ambient noise seismic data collected by the Sevilleleta Array. We developed Rayleigh wave phase velocity maps from 3 s to 8 s period via a damped least squares inversion, using $0.02^\circ \times 0.02^\circ$ (~2.2 km x 2.2 km) grid elements (Figure 2). Rayleigh wave phase velocity maps at 3 and 4 s periods show a broad low velocity anomaly (~3-7%) in the north-central part of the array where the Rio Puerco River merges with the Rio Grande. The phase velocity maps at 5, 6 and 7 s period show a broad low velocity (~4-7%) area in the western part of the Sevilleleta array, roughly coinciding with the area of maximum uplift associated with the Socorro Magma Body. At 7 s period, local mountain ranges in the eastern part of the Sevilleleta array are associated with lower velocities (2-6%), whereas positive velocity anomalies (2-5%) coincide with the rift axis at 5, 6 and 7 s periods.

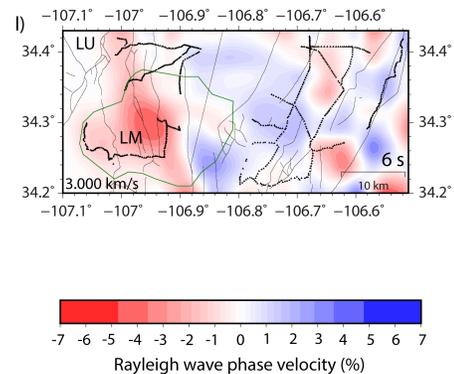


Figure 2. Rayleigh wave phase velocity map at 6 s period.

A 3-D S-wave velocity model obtained through inverting the Rayleigh wave velocity maps shows strong correlation with known geo-tectonic features, such as basin bounding faults, uplift of Socorro magma body and thick syn-rift sediments (Figure 3). Our S-wave results agree well previous active-source

spaced, continuously recording seismometers. Data acquisition with dense passive seismic arrays is quickly taking over in industrial surveys and has thus far been exploited in few academic surveys. The Sevilleleta Array (Figure 1) in central New Mexico is an early example of academic datasets using this model of data acquisition. The 801-node Sevilleleta Array was deployed for 14 days in February, 2015, within a ~50 km x ~30 km section of the southern Albuquerque Basin. Use of ambient noise and virtual source processing methods and innovative array designs facilitated by the advent of small, portable, cable-less seismometers are inevitable directions for future growth in academic seismology with particular applications to basin characterization and imaging. The PRF-DNI supported one Masters student and one postdoctoral fellow at the University of New Mexico. Work from this grant thus far has contributed to four conference abstracts, two peer-reviewed articles, a Masters thesis and one manuscript in preparation. The work from this project has motivated multiple successful proposals using similar techniques to NSF and DOE and has greatly accelerated my grant success.

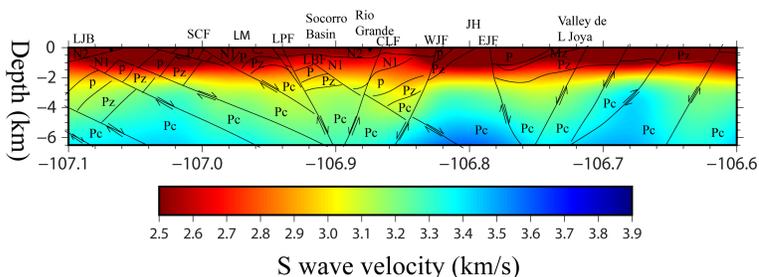


Figure 3. Cross-sectional profile taken from 3D S-wave velocity structure with previously mapped and interpreted faults.

seismic imaging and geologic interpretation. Our results suggest that the upper crustal velocity structure of the south-central Rio Grande Rift is largely controlled by Neogene syn-rift sedimentation patterns

and long-lived low angle normal faulting. Large-N seismic arrays can be effectively employed to constrain the shallow structure within and surrounding sedimentary basins in a cost-effective manner, complementing active source and other seismic and electromagnetic methods.

Teleseismic Virtual Source Reflection Processing

For the next part of the study, we used teleseismic earthquakes recorded by the Sevilleta Array to interrogate the seismic wave field in the middle Rio Grande Rift. Multiple arrivals were detected across the array. The most dominant signals across the dataset were steeply east-dipping arrivals in the western half of the array on the rift perpendicular ATT, Popotosa and Alamillo profiles (Figure 4). We created synthetic seismograms using a 2-D finite difference elastic wave propagation algorithm. Simple homogenous velocity layers were created, testing a variety of basin-bounding fault dips and impedance contrasts between the basin and the crust. The resulting synthetics for each model display a high amplitude, dipping arrival similar to the dipping arrivals that dominate the Alamillo, ATT, and Popotosa lines. These arrivals are present regardless of the prescribed dip on the basin-bounding structure. Also, the moveout of the arrival remains constant regardless of the dip of the structure. We suggest that these arrivals represent P-to-Rg converted phases originating from high impedance contrast across the basin-bounding Loma Pelada fault, which separates Quaternary alluvium deposits to the east from Tertiary basement rocks to the west. Three of the lines in the Sevilleta array cross this fault, and three lines sit within the sedimentary basin immediately east of the fault, allowing for different perspectives of the Rayleigh wave. The increased spatial density of stations in the Sevilleta array compared to prior studies in the region is conducive to detecting this phase that may be present in other datasets, but not detectable because of lack of station density. It's important to note that the P-Rg conversion swamps shallow signals from the basin and faults, so workers using large-N arrays for structural imaging should be aware of the possibility that this arrival is clouding their signal.

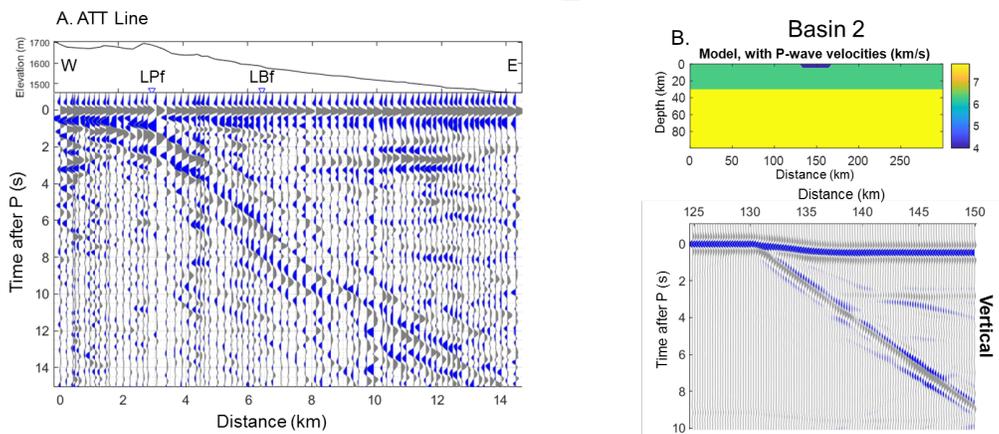


Figure 4. A) Teleseismic virtual source profile from the ATT line in the western portion of the array. B) Two-dimensional model (top) and synthetic signal (bottom).