Passive Source Seismic Study of Rupturing Continental Lithosphere in the Salton Trough

Introduction

We propose a study of the upper mantle under the Salton Trough in southern California through analysis of shear wave splitting from teleseismic data. The main questions we wish to answer are: (1) what is the main direction of anisotropy in the mantle under the Salton Trough? (2) what is the lateral and vertical extent of the anisotropy in and beyond the rift margins? and (3) what is the source of the observed anisotropy?

Anisotropy in the upper mantle is a long-range order in material that causes seismic waves to travel at different speeds in different directions (as opposed to isotropic media, in which waves travel at the same speed in all directions). Anisotropy is primarily caused by the strain-induced preferred orientations of the minerals that compose the mantle, as well as by aligned fluid-filled fractures or cracks. Last year, Simon Klemperer and his team placed 40 broadband seismometers across the Salton Trough to gather particle displacement data, which, when analyzed, will provide velocity data that we will use to characterize the anisotropy of the upper mantle.

Geologic Background

The Salton Trough is an active rift between the North American plate and Pacific plate. It is both the landward extension of the Gulf of California as well as the southernmost part of the San Andreas Fault System. The Salton Trough is an important part of the San Andreas Fault System, as it is where the majority of plate boundary strain is transferred northward to the San Andreas and San Jacinto faults. The trough was likely created by tensional and strike-slip movements connected to the opening of the Gulf of California as Baja California was moved from the North American plate to the Pacific plate. Olivine, a highly anisotropic mineral, is the most common mineral in the upper mantle beneath the Salton Trough, resulting in anisotropy that can be measured through shear wave splitting. However, the complex tectonic setting of the Salton Trough makes the mantle anisotropy difficult to predict: the trough transitions from a strike-slip boundary to a divergent boundary as well as from continental rifting to oceanic spreading. These two transitions suggest two different primary directions for mantle anisotropy, but the results of this study will hopefully shed light on the interplay between these different influences on anisotropy.

Shear Wave Splitting Background

To analyze the data collected by Simon Klemperer’s instruments, I will look at the splitting of shear waves as they enter a portion of the mantle. When a shear wave enters an anisotropic medium, it splits into two separate polarized shear waves, which travel at different speeds. The faster shear wave moves parallel to the cracks in the medium and the other shear wave oftentimes propagates orthogonal to the first. The difference in speed occurs because the speed of a shear wave depends on the density of the medium – in a dense medium, the grains are closer together and energy can be transferred more rapidly, whereas in a less dense medium, the energy has a larger gap to travel between grains. The portion of the shear wave that is polarized parallel to the cracks in medium will travel faster because of the tightly packed grains, while the wave polarized perpendicular to the cracks will travel slower. By studying the polarization of the fast wave and the time delay between the two waves, one can characterize the anisotropy of a medium. We will primarily use SKS waves for this analysis. SKS waves begin as S-waves as they travel into the earth, but are converted to P-waves as they pass through the outer core, and then convert back to S-waves as they return to the mantle. The advantage of using SKS waves is that it ensures no contribution from the source-side of the path due to the P-wave to S-wave conversion at the Core-Mantle Boundary. Also, the waves ascend nearly vertically through the mantle and sample upper mantle anisotropy at near-normal incidence, which makes the results easier to interpret.

Method

To do this analysis, I will use SplitLab, an open source Matlab code. The program looks at particle displacement data and provides the time delay (δt) and the polarization direction (Φ) of the fast component of the shear wave. Splitlab works by using three different methods and performs grid searches for the values of Φ and δt that best reverse the splitting of the shear wave. Using SplitLab will allow me to find Φ and δt for each station and create a map showing the anisotropy of the upper mantle. I plan to do this analysis twice, first assuming one layer of anisotropy and then assuming two layers. After mapping the anisotropy I will interpret the results geologically to create a model of what is happening in the upper mantle.

References

Elders, W.A., Rex, R.W., Robinson, P.T., Biehler, S. & Meidav, T. Crustal Spreading in Southern California: The Imperial Valley and the Gulf of California formed by the rifting apart of a continental plate. *Science* **178**, 15-24 (1972).

Liu, H., Davis, P.M. & Gao, S. SKS splitting beneath southern California. *Geophys. Res. Lett.* **22**, 767-770 (1995).

Savage, M.K. Seismic anisotropy and mantle deformation: What have we learned from shear wave splitting? *Rev. Geophys.* **37**, 65-106 (1999).

Silver, P.G. & Chan, W.W. Shear Wave Splitting and Subcontinental Mantle Deformation. *J. Geophys. Res.* **96**, 16429-16454 (1991).

Vinnik, L.P., Makeyeva, L.I., Milev, A. & Usenko, A.Y. Global patterns of azimuthal anisotropy and deformations in the continental mantle. *Geophysical Journal International* **111**, 433-447 (1992).

Wolfe, C.J. & Solomon, S.C. Shear-Wave Splitting and Implications for Mantle Flow Beneath the MELT Region of the East Pacific Rise. *Science* **280**, 1230-1232 (1998).

Wüstefeld, Andreas, Götz Bokelmann, Christophe Zaroli, and Guilhem Barruol. SplitLab: A shear-wave splitting environment in Matlab. *Computers and Geosciences* **34.** 515-528 (2008)

Work Plan

Week 1

- Drive to Nevada and pick up equipment
- Learn about instruments and field work
- Take preliminary look at data

Week 2-3

- Learn to search earthquake catalogs for appropriate events,
- Learn to download data from IRIS DMC
- Learn to use SplitLab

Weeks 4-5

- Basic processing of data in SplitLab assuming a single layer of anisotropy

Weeks 6-7

- Building catalog and improving azimuthal distribution
- Processing data in SplitLab assuming 2 layers of anisotropy

Week 8

- Interpreting the data and geologic processes involved

Week 9

- Drive to Salton Trough and pick up equipment
- Learn about geology of the area.

Week 10: Prepare posters for SURPS and AGU

Budget

$5600 – Stipend for 40 hrs/wk for 10 weeks at $14/hr

$400 – Shared motel and food for 14 days in the field