

## Progress Report:

The goal of this project is to constrain the orientation and magnitude of crustal stress in southern California. We are in the process of creating a high spatial and temporal resolution model of stress orientation, inferred from earthquake focal mechanisms, covering 1981 to the present. We are also using observed rotations of the stress field associated with major earthquakes to constrain the magnitude of deviatoric stress at seismogenic depths. The results will provide important observational evidence for understanding stress evolution, fault mechanics, and earthquake-stress interaction.

In 1999, we created a high spatial resolution image of stress orientation in southern California (Fig. 1). Stress orientations were inferred from the focal mechanisms of small earthquakes using the methodology developed by Michael (1984, 1987.) Variable spatial resolution is used in order to achieve the finest possible resolution everywhere. Inversions are performed at points on a 5 km spaced grid, using all earthquakes within 5 km of the point if there are at least 50 such events, or the 50 closest events if there are not.

Fig. 1A demonstrates that the stress field in southern California is highly complex. The orientation of the maximum horizontal stress averages N6E, but locally varies from N30W to N45E. Some of the stress orientation complexity is related to differences between the major geologic provinces, for example the N20-45E orientations in the Eastern California Shear Zone (ECSZ.)

The stress state over much of the region corresponds to strike-slip faulting, but thrust and normal faulting regimes are also observed (Fig. 1B.) For instance, the Los Angeles Basin area exhibits a combination of strike-slip and thrust regimes. The Transverse Ranges also exhibit two distinct stress regimes, with thrust faulting dominant to the west of Cajon Pass, and strike-slip to the east. This implies that little convergence is taking place across the San Bernardino segment of the San Andreas Fault, perhaps due to transfer of slip to the San Jacinto Fault and the ECSZ.

We began study of the temporal evolution of the stress field by determining stress orientations before and after the 1992 Landers and 1994 Northridge earthquakes. There are very clear stress rotations associated with both mainshocks (Fig. 2.) Stress rotations have previously been observed for these events (Hauksson, 1994; Zhao et al., 1997), but the high resolution image reveals more spatial complexity in the rotations. Additionally, the observed stress rotations can be used to constrain the deviatoric stress magnitude, because a stress rotation is controlled by the ratio of the stress change to the background deviatoric stress level (Sonder, 1990.) Preliminary results indicate low deviatoric stress at seismogenic depths, on the order of 10-100 bars, as opposed to the order kilobars predicted by laboratory friction. If correct, this has important implications for fault strength.

In 1999, we also published in *Science* the results of work done in 1998, studying the orientation of stress along the San Andreas Fault (Hardebeck and Hauksson, 1999.) We observed that while the maximum horizontal stress makes a high angle to the San Andreas in the far field, near the fault it rotates to a lower angle. This is clearly an important observation for understanding the mechanics of the San Andreas because it indicates that the fault is not weak relative to its immediate surroundings. However, it may still be weak in an absolute sense if its surroundings are at a low level of deviatoric stress, as suggested by our preliminary stress magnitude estimates.

## References:

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- Hauksson, E., State of stress from focal mechanisms before and after the 1992 Landers earthquake sequence, *Bull. Seism. Soc. Am.* 84, 917-934, 1994.
- Michael, A. J., Determination of stress from slip data: Faults and Folds, *J. Geophys. Res.* 89, 11517-11526, 1984.
- Michael, A. J., Use of focal mechanisms to determine stress: A control study, *J. Geophys. Res.* 92, 357-368, 1987.
- Sonder, L. J., Effects of Density Contrasts on the Orientation of Stresses in the Lithosphere: Relation to Principal Stress Directions in the Transverse Ranges, California, *Tectonics* 9, 761-771, 1990.
- Zhao, D., H. Kanamori, and D. Wiens, State of stress before and after the 1994 Northridge earthquake, *Geophys. Res. Lett.* 24, 519-522, 1997.

## Figure Captions:

Figure 1. Stress orientations in southern California at 10 km depth. (A) Orientation of the maximum horizontal compressive stress. The color fan indicates the stress direction corresponding to each color. All orientations which are not different from N6E at the 95% confidence level are displayed as this average value. (B) Faulting style as inferred from stress orientations. Purple: normal (maximum stress vertical.) Green: strike-slip (intermediate stress vertical.) Orange: thrust (minimum stress vertical.)

Figure 2. Maximum horizontal stress direction at 10 km depth (A) before and (B) after the 1994 Northridge earthquake. The projection of the mainshock fault plane is shown as a black rectangle. The color fan indicates the stress direction corresponding to each color.

Figure 1

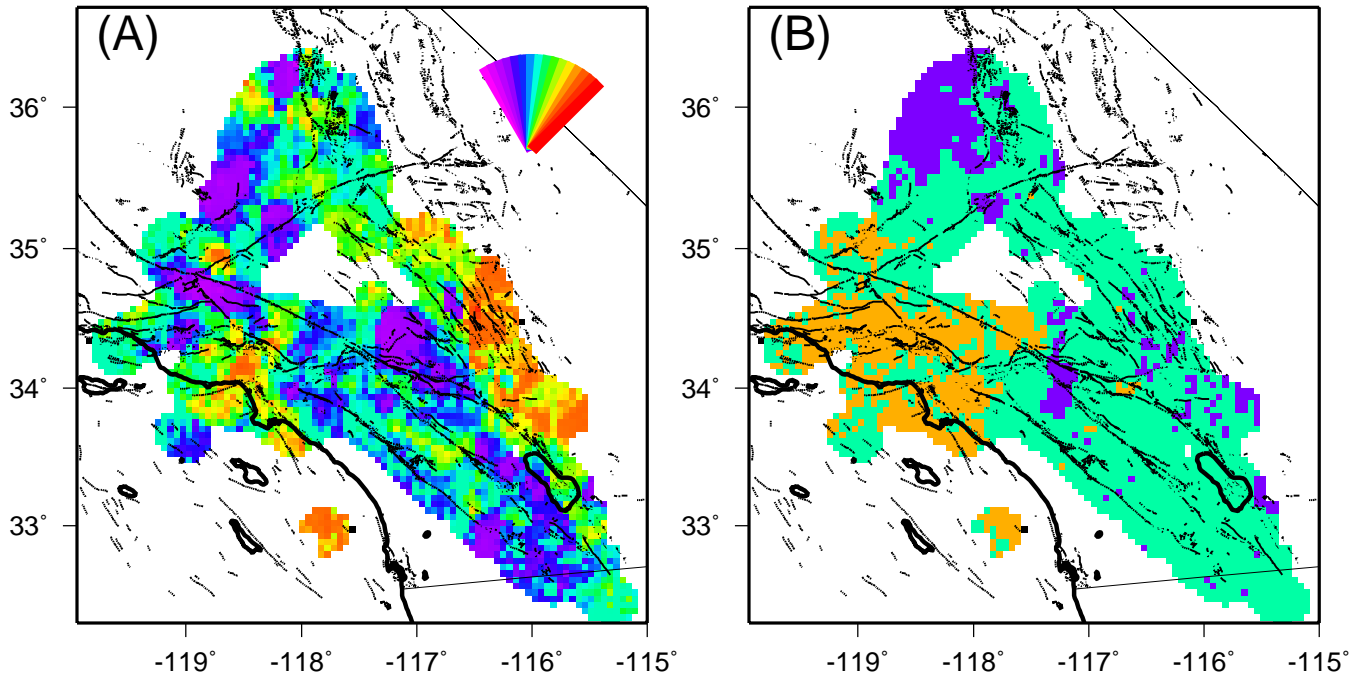


Figure 2

