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Tectonic Stress and Earthquake Hazards

Jeanne L. Hardebeck[1] and Egill Hauksson
California Institute of Technology
([1]now at University of California, San Diego)

Progress Report

In 2000, we completed our project to constrain the orientation and magnitude of crustal stress in southern California. We have created a high spatial and temporal resolution model of stress orientation, inferred from earthquake focal mechanisms, covering 1981 to 1998. We also used observed rotations of the stress tensor associated with major earthquakes to constrain the magnitude of deviatoric stress at seismogenic depths. These results are detailed in a paper submitted to the Journal of Geophysical Research. Additionally, we have a paper in press for the Bulletin of the Seismological Society of America, in which we verify that the stress inversion technique obtains accurate results with appropriate error estimates.

We completed work on a high spatial resolution image of stress orientation in southern California (Figure 1.) Stress orientations were inferred from the focal mechanisms of small earthquakes, using the methodology developed by Michael (JGR 1984, 1987). Variable spatial resolution was used in order to achieve the finest possible resolution everywhere. The stress field appears to contain significant spatial hetereogenity, associated primarily with differences in faulting regime and with the occurrence of major earthquakes. Temporal changes are also observed, again associated with major earthquakes.

The temporal stress rotations caused by major earthquakes can be used to constrain the magnitude of the background deviatoric stress, as a stress rotation is controlled by the ratio of the stress change to the deviatoric stress level. There are clear stress rotations associated with the 1992 M7.3 Landers earthquake, as previously observed (Hauksson, BSSA 1994). Results from a simple model indicate low deviatoric stress, on the order of earthquake stress drop (Figure 2), which has important implications for fault mechanics, as it implies that faults in this region operate at low stress.

As all of our results depend on the inversion of earthquake focal mechanisms for stress, it is important to verify that the inversion methodology works correctly. We tested the technique of Michael (JGR 1984, 1987) on noisy synthetic data sets and found that the method does a good job of recovering the correct stress state, even for

very noisy data. We also found that in most cases the computed confidence regions are of the appropriate size, for example, the 68% confidence region contains the correct stress state for approximately 68% of the data sets.

Publications

Hardebeck, J. L. and E. Hauksson, The crustal stress field in southern California and its implications for fault mechanics, *J. Geophys. Res.*, in review.

Hardebeck, J. L. and E. Hauksson, Stress orientations obtained from earthquake focal mechanisms: What are appropriate uncertainty estimates?, *Bull. Seism. Soc. Am.*, in press, 2001.

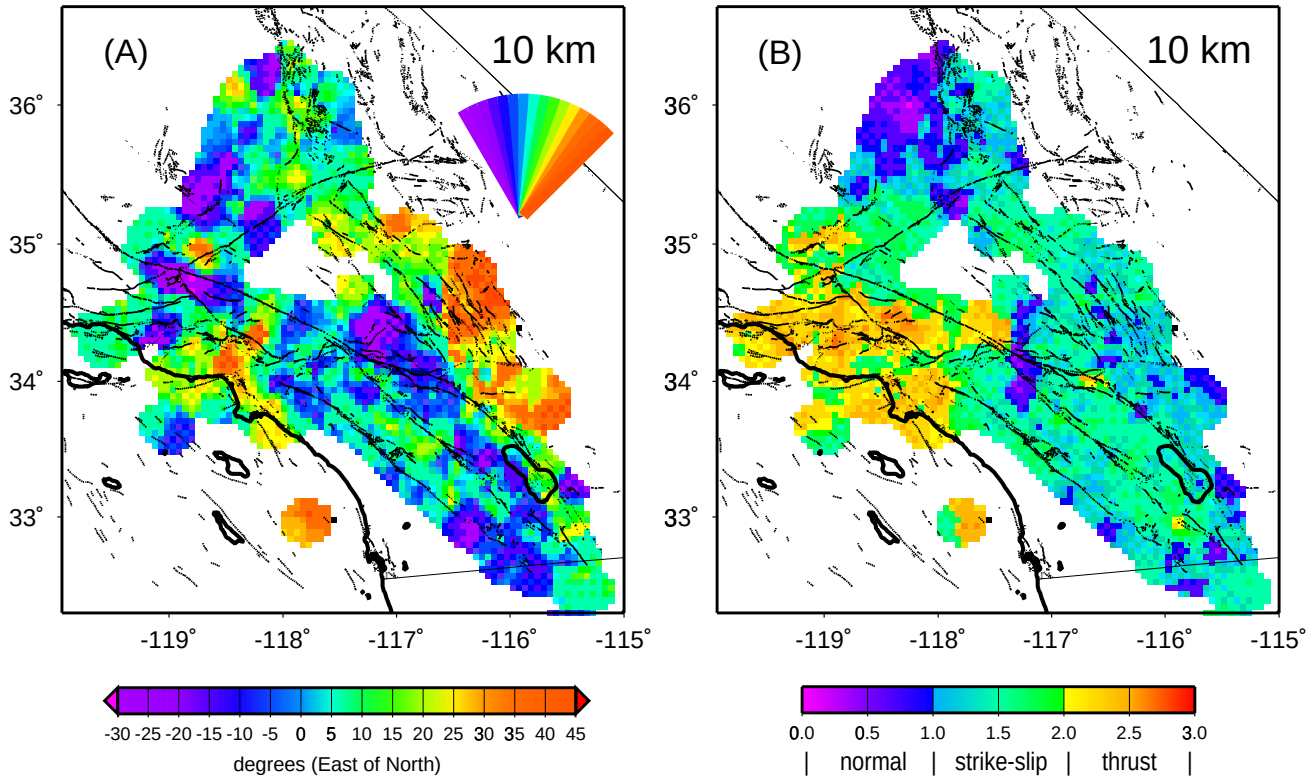

Figure 1: Stress orientations in southern California at 10 km depth. **(A)** Orientation of the maximum compressive stress axis. The color fan indicates the stress directions corresponding to each color. All orientations which are not different from N7E at the 95% confidence level are displayed as this 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.)

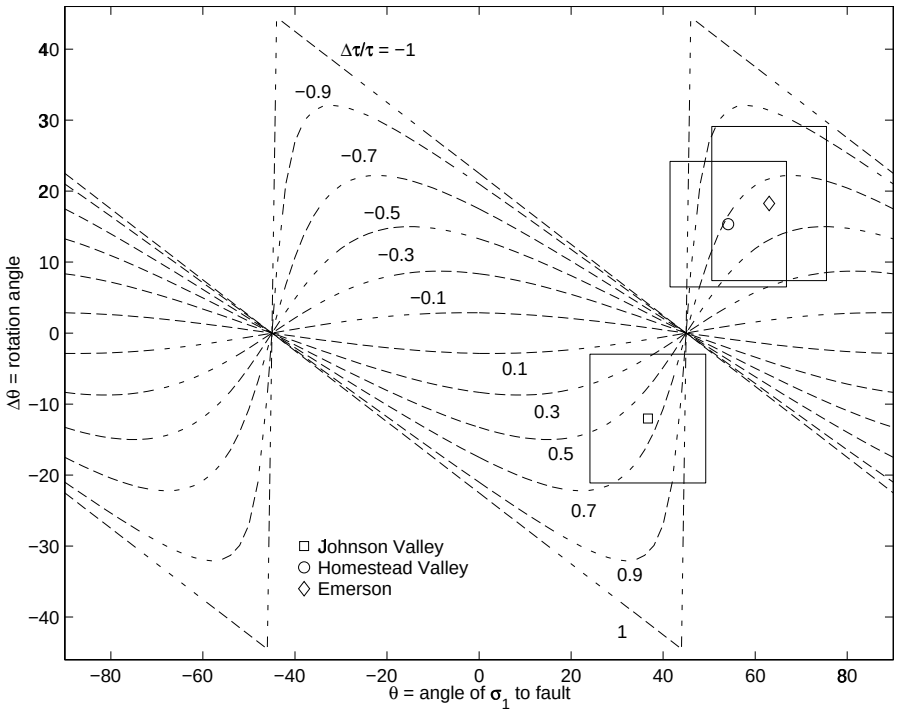

Figure 2: The rotation of the stress field due to an earthquake for a simple 2D model. The stress rotation, $\Delta\theta$, is shown versus the angle from the fault to the pre-earthquake σ_1 axis, θ, for various values of $\Delta\tau/\tau$, the ratio of the stress drop to the deviatoric stress magnitude. The observed θ and $\Delta\theta$ for three segments of the 1992 Landers earthquake are shown as symbols. Large squares are the 2σ confidence ranges of the stress orientations and fault strike.