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3-D Velocity Models and Focal Mechanisms

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INVESTIGATIONS

This project involves several complementary aspects of investigating 3-D velocity structure and seismicity in southern California. First, we have inverted for new 3-D Vp and Vp/Vs regional models. This project is near completion and a manuscript is being prepared for JGR. Second, we have relocated the 1981 to present seismicity and determined first motion focal mechanisms. This project is near completion and the 3-D catalog and focal mechanisms will be provided to SCEC Data Center in early spring. Third, we have begun investigating two different aspects of depth of seismicity in southern California. One project involves comparing depths determined from arrival times and waveforms, while the second project involves a detailed analysis of maximum depth of earthquakes in southern California. We summarize below the highlights of these two projects.

3-D Vp and Vp/Vs Velocity Models

New three-dimensional V_P and V_P/V_S models are determined using P and S travel times from local earthquakes. These models confirm existing tectonic interpretations and provide new insights into configuration of the geological structures along the Pacific North America plate boundary in southern California. The models that extend from the US Mexico border in the south to the Coast Ranges and Sierra Nevada in the north, have 15 km horizontal grid spacing and an average vertical grid spacing of 4 km, down to 22 km depth. The V_P models have two characteristics that we trace across southern California. The first is the shape of the near-surface gradient that in most cases exists from the surface to 6 or 8 km depth and in rare cases extends down to 15 km depth. The second is the shape of the Conrad discontinuity at approximately 16 km depth. To illustrate how these characteristics vary across southern California we show maps of interpolated velocity variations and velocity depth profiles for the average velocities within individual regional blocks (Figure 1). Average crustal velocities (V_P and V_P/V_S) are observed within the Mojave, southern Sierra Nevada, Coast Ranges west of the San Andreas fault, and the eastern Peninsular Ranges. Several major mountain ranges such as the San Gabriel's, Tehachapi's, Santa Monica's, and west Peninsular ranges show unique velocity profiles. In contrast larger variations in the velocity depth profiles, with low V_P and high V_P/V_S, are observed within and beneath the major basins, such as the Ventura, Santa Barbara Channel, Los Angeles, Great Valley, Coachella Valley, Imperial Valley, and Borrego Valley. The Continental Borderland has average V_P except for high V_P/V_S in the shallow layers, extending from the surface to 6 to 8 km depth. The heterogeneity of the crustal structure as imaged in both the V_P and V_P/V_S models is larger within the Pacific plate than the North America plate reflecting regional asymmetric variations in the crustal composition and the past tectonic processes. Similarly, the spatial distribution of the seismicity reflects shallower seismicity within the North America plate and more complex three dimensional distribution within the Pacific plate. The change in depth of seismicity is appears to coincide with the major northwest striking strike-slip faults such as the San Andreas, San Jacinto, and Elsinore faults. The most complex three-dimensional seismicity distributions within the Pacific Plate are in areas of known thrust faulting.

Depth of Seismicity Before and after the 1992 Mw7.3 Landers Earthquake

The lithological and tectonic complexity of the southern California crust is reflected in the significant variations in style, maximum depth, and depth distribution of seismicity across the region. Seismic hazard analysis is a challenge in not only identifying all potential seismic sources (visible or buried), but also in estimating the thickness of the seismogenic crust and the maximum depth of rupture during moderate to large earthquakes. In the Phase II report (1995), the Working Group on California Earthquake Probabilities assumed a value of 11 km for the thickness of the brittle crust in their calculation of seismic moment rate, because that value results in an acceptable predicted total seismic moment rate. However, local hazard calculations could be incorrect as the moment rate depends linearly on the assumed thickness of the seismogenic crust. We seek to provide a quantitative constraint for the maximum rupture depth by answering the following question: Does background seismicity provide a good estimate of the maximum depth of rupture during a moderate to large earthquake?

In our preliminary analysis of the maximum depth of seismicity we have considered the maximum depth of earthquakes, which we have defined as the 95% depth. The 95% depth is the depth above which 95% of all earthquakes in a bin occur. When calculating the 95% depth, rounding occurs in calculating 95% of the earthquakes in a bin. As a result, the depth may be representative of anywhere from 90.9% to 100% of the earthquakes in a bin (e.g., a bin with 10 earthquakes chooses the 10th and deepest earthquake, but a bin with 11 earthquakes will choose the 10th earthquake which is 90.9%). An overview of maximum depths for seismicity in southern California is shown in Figure 2.

Regional approach

In a study done more than a decade ago, Sanders (1990) noted that the major strike slip fault zones have predominantly deep earthquakes, while the surrounding crustal blocks had predominately shallow seismicity. The maximum depth of 22 km for seismicity in the San Andreas and San Jacinto fault zones was 5 km greater than in the surrounding crustal blocks (Sanders, 1990). The distribution of the earthquakes was also markedly different with most of the seismicity along the strike slip systems located 11-18 km, while most of the earthquakes in the surrounding crustal blocks was located from 1-6 km (Sanders, 1990). A more detailed analysis by Nazareth and Hauksson (1998), with much smaller block sizes (0.1 degree on a side) shows that the maximum depth of seismicity can vary significantly within fault zones and crustal blocks. Much of southern California has a maximum depth of seismicity between 10-15 km. Deeper seismicity is found in the southwest San Joquin valley, Banning Pass-San Gorgonio region, San Jacinto Mountains, between the central San Jacinto and Elsinore fault zones, and in the Ventura Basin. Seismicity is predominantly shallow in the southern Salton Sea and Brawley Seismic Zone, the central western Mojave Desert, and parts of the western Transverse Ranges. Most of the active part of the Eastern California Shear Zone lies in the intermediate depth category (10-15 km max depth).

Local approach

As part of a feasibility study we have used the three mainshock planes from Wald and Heaton (1994) to project the seismicity from 5 km on either side of the faults (Figure 3). For the Landers/Johnson Valley fault segment, the mean of the difference between the 95% depth after and before, for 1 km strike parallel bins, was 2.7 km. The mean difference for the Homestead Valley segment was 4.2 km, and for the Camp Rock/Emerson segment, it was 7.8 km. When qualitatively comparing the pre-seismicity 95% depth to the maximum depth of major regions of slip, they are mostly similar for the Landers/Johnson Valley and Camp Rock/Emerson segments, while under-predicting the major slip in the central portion of the Homestead Valley segment by a few km.

Our preliminary results indicate that the southern part of the Landers rupture is deeper by a few km than the northern part. In a pre to post comparison of 0.01 x 0.01 degree bins (126 with data both before and after), 77% of the bins had a deeper 95% depth after the mainshock (mean difference = 5.6 km), with 23% a shallower 95% depth post mainshock (mean difference = -2.8 km). The mean difference in post and pre-event 95% depths is 3.7 km. We plan to evaluate this comparison in a much more quantitative way as part of our proposed work for FY99.

Publications

Nazareth, J. and E. Hauksson, Preliminary Evaluation of the Maximum Depth of Earthquakes in Southern California (abstract), Eos, Trans. 79, 561, 1998.

Nazareth, J. and E. Hauksson, A Preliminary Evaluation of the Maximum Depth of Earthquakes in Southern California, (abstract), SCEC Annual Meeting, Palm Springs, CA, October 17-20, 1998.

DiLuccio, F., L. Jones, L. Zhu, and E. Hauksson, Comparison of Waveform Inversions and Arrival Time Techniques to Resolve Earthquake Depths and Focal Mechanisms in Southern California (abstract), Eos, Trans. 79, 603, 1998.

Unruh, J., E. Hauksson, F. Monastero, and M. Hasting, Seismogenic Deformation in the Coso Range, East-Central California: NW Dextral Shear Along the Eastern Margin of the Sierra Nevada Microplate (abstract), Eos, Trans. 79, 564, 1998.

DiLuccio, F. L. Jones, L. Zhu, E. Hauksson, Comparison of Waveform Inversions and Arrival Time Techniques to Resolve Earthquake Depths in Southern California, (abstract), SCEC Annual Meeting, Palm Springs, CA, October 17-20, 1998.

Hauksson, E. Preliminary Crustal Depth Profiles of Poisson's Ratio for Geological Terranes in Southern California: Contribution to the 2nd Generation SCEC 3-D Velocity Model, (abstract), SCEC Annual Meeting, Palm Springs, CA, October 17-20, 1998.

Hauksson, E., J. Hardebeck, L. Zhu, F.C. Monastero, M. Hasting, J. R. Unruh, Seismotectonics of the Indian Wells Valley and Coso Range, Southern California: Tomographic V_p and V_p/V_s Velocity Models, the 1981-1998 Seismicity; and Stress From Focal Mechanisms (abstract), Eos, Trans. 79, 565, 1998.

Figure Captions

Figure 1. Summary of the 3-D velocity model for southern California.

Figure 2. Preliminary map of 95% maximum depth of seismicity in southern California.

Figure 3. Comparison of the depth extent of the Wald and Heaton (1994) slip model and the seismicity that occurred the decade before the Landers mainshock.

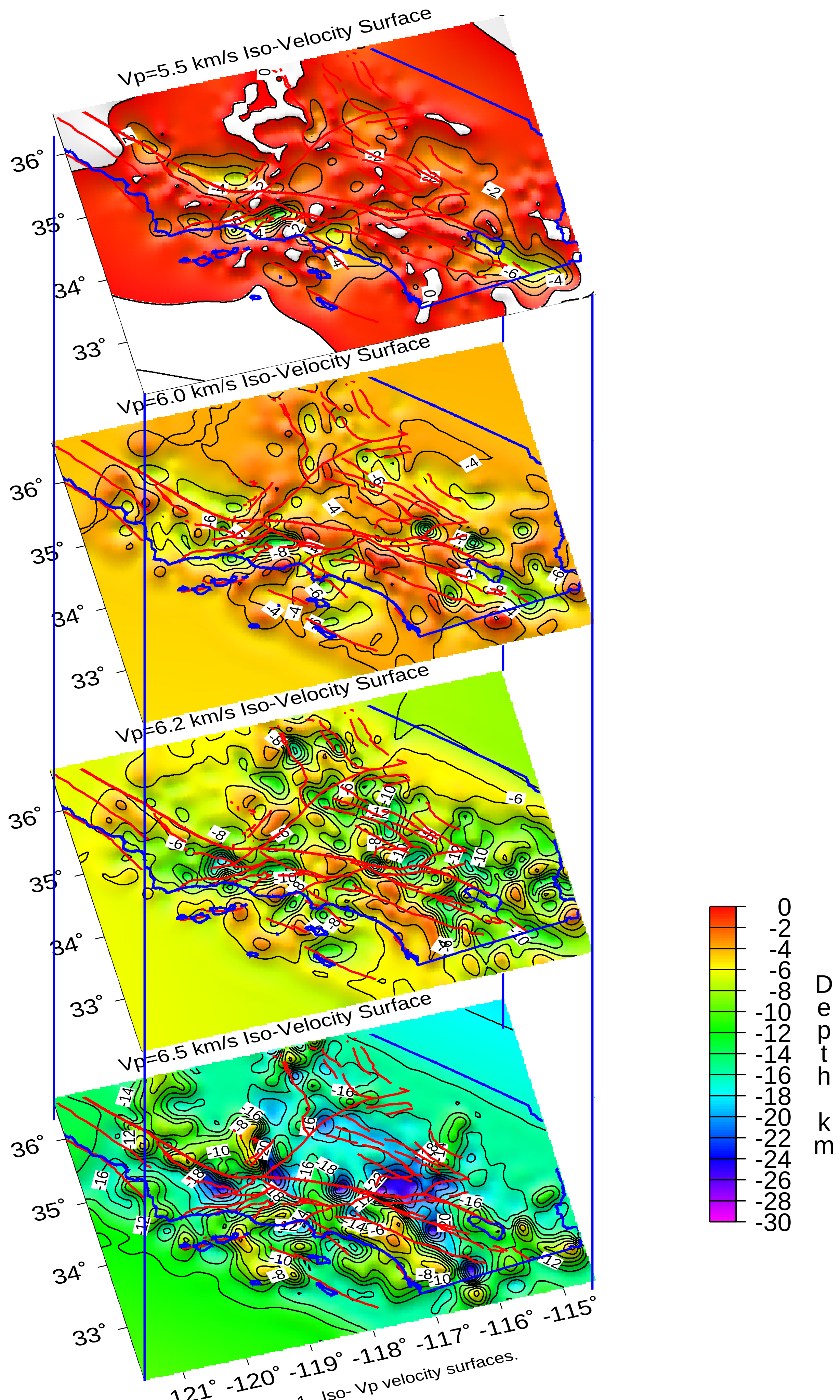


Fig. 1. Iso- Vp velocity surfaces.

All Bins

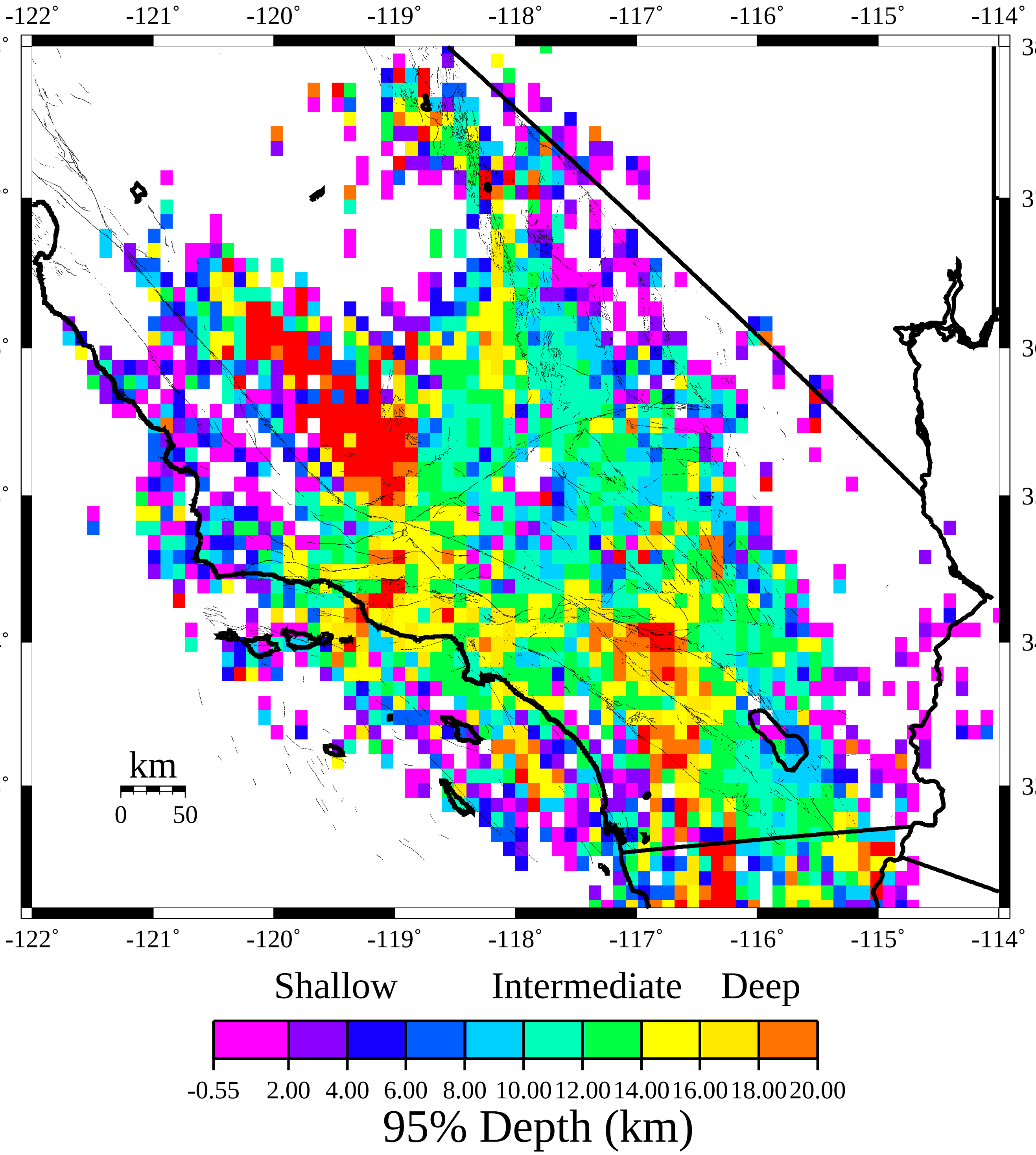
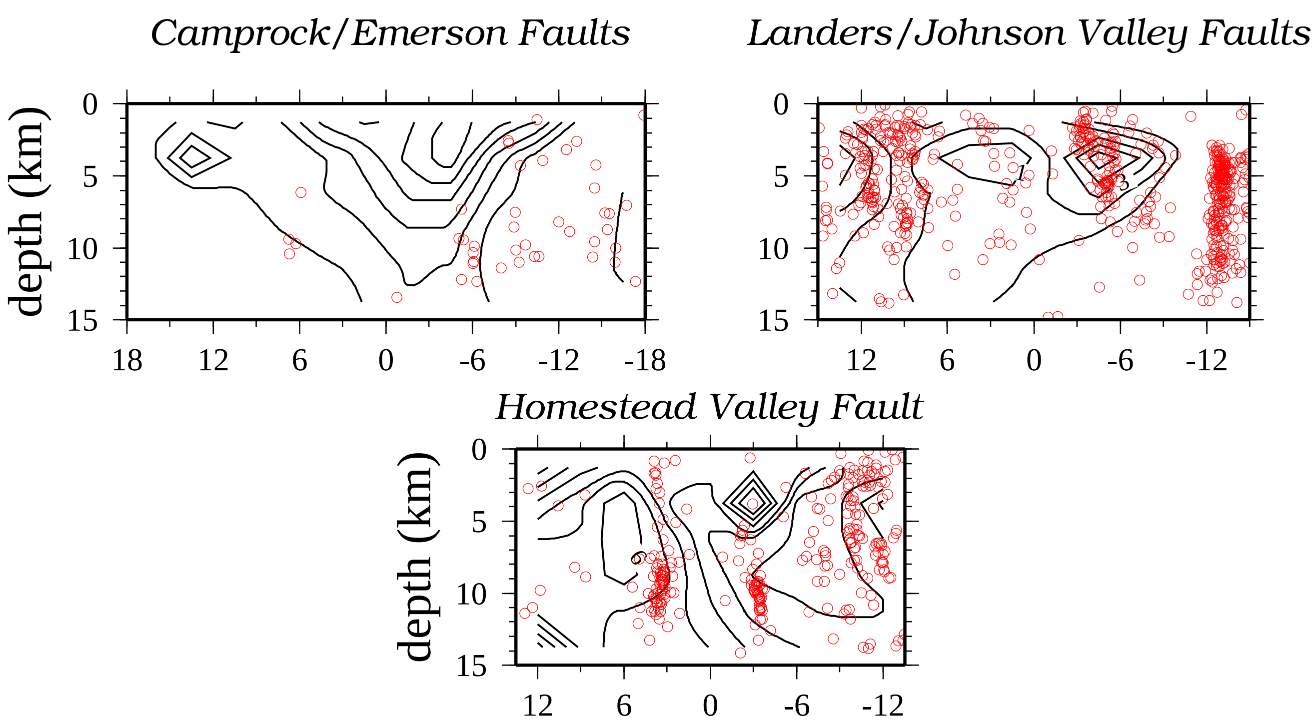


Figure 2

Pre-Landers Seismicity (1981-1992)



* *Mainshock Slip Model from Wald & Heaton, 1994*

Figure 3