MECHANICS OF PORE FLUID TRIGGERING IN THE LANDERS AFTERSHOCK SEQUENCE

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Over the past year we have performed large-scale cross correlation and relocation of the Joshua Tree-Landers-Big Bear earthquake sequence. We relocated over 49,000 earthquakes using ~18,000,000 relative *P* and *S* wave arrival time measurements. The focus of the proposal, and of this report is on the large extensional fault jog between the Johnson Valley and Homestead Valley faults that rupture during the 1992 Landers earthquake. This work comprised the bulk of Eva Zanzerkia's Ph.D. thesis and a number of highlights were presented in a talk at the 2003 SCEC annual meeting. The primary motivation for this research was the evidence, in the form of protracted aftershocks, for pore-fluid triggering.

Earthquake Relocation

The first part of the proposed research was to perform cross correlation of *P* and *S* waves for earthquakes withing the fault jog. We did this using data from the SCEDC following *Schaff et al.* [2004]. Using these relative arrival time data, we relocated the seismicity using the double-difference method [*Waldhauser and* Ellsworth, 2000]. The precise earthquake locations allowed us to discern subfaults within the fault jog that many of the aftershocks occurred on. Figure 1 shows the three principal subfaults we resolved within the fault jog.

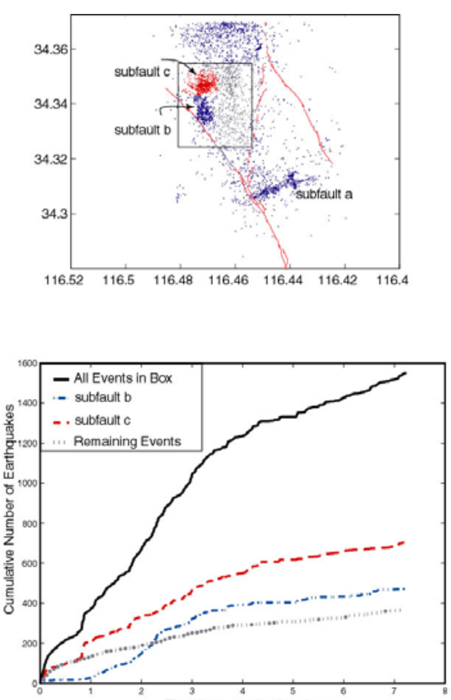


Figure 1. Map view of aftershocks in the vicinity of the fault jog after relocation. We found that for aftershocks within the fault jog, only those occuring on subfaults were protracted (red and blue dashed curves). The remainder show normal Omori decay (gray curve). This suggests that fault-zone porosity plays an important role in the triggering mechanism. The geometry of the relocated seismicity in subfaults A, B, and C were found to be consistent with the focal mechanisms. By determining both the mechanism and the geometry of the subfaults we can resolve the usual fault-plane vs. auxilliary-plane ambiguity, which is extremely useful for the poro-elastic stress change calculations used to test pore-fluid triggering.

Test of Poro-Elastic Triggering

Rather than model the time evolution of the stress change from undrained to drained conditions, we calculate the mainshock induced stress change in the undrained and drained conditions using Poisson's ratio of 0.27 and 0.35 respectively [*Peltzer et al.,* 1998]. The net (long-term) fluid modulated change is then the difference between these two stress states. If protracted aftershocks are to be explained by this mechanism, then they must occur in regions where the transition from undrained to drained conditions favors failure. Figure 2 shows that this is the case for subfault A.

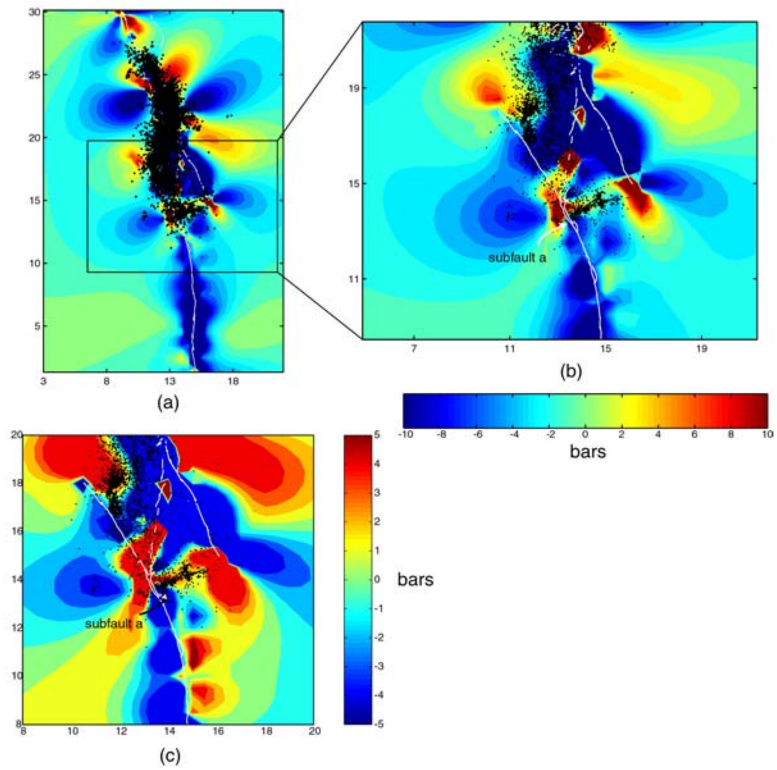
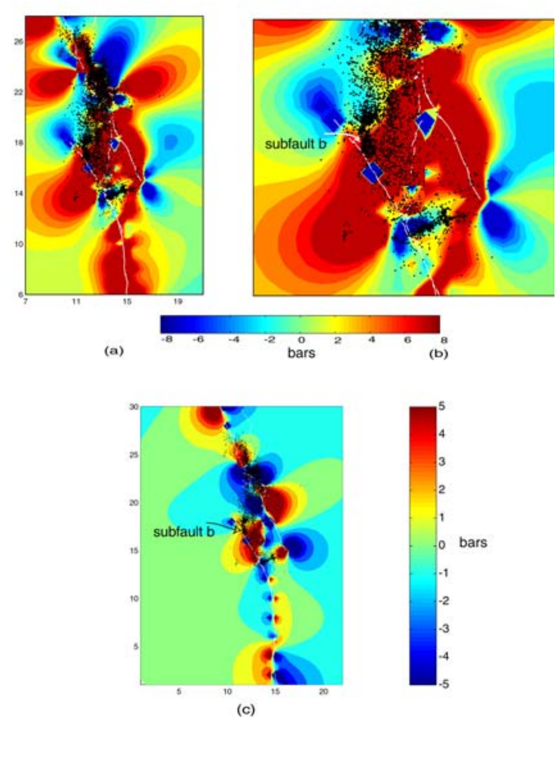


Figure 2. Poro-elastic stress change calculation for subfault A. (a) stress change calculated at all points, but relevant to the Coulomb stress that would be resolved on the (non-optimally oriented) subfault A. (b) close up of the same calculation, but for the drained state. (c) difference between the two calculations. Red represents an increase in stress that favors failure on subfault A. It is this difference that can drive protracted aftershocks and the results are consistent with our hypothesis, i.e., the poro-elastic stress change favors protracted aftershocks on subfault A.

Figure 3. Same as Figure 2: (a) undrained stress change, (b) drained stress change, (c) difference, but in this case calculated assuming the geometry of subfault B. Subfault B is also moved towards failure during the transistion from undrained to drained conditions, consistent with the pore-fluid triggering hypothesis.



Stress Change from Seismicity

We also solved for the time rate of change of stress during the Landers aftershock sequence using changes in the seismicity rate as data, following *Dieterich et al.* [2000]. This technique had been applied to volcanoes before, but not to aftershock sequences, which allowed us to determine the time rate of change of Coulomb stress, which we took to represent pore pressure variations within the jog. Figure 4 shows our results for the Landers sequence over the period 1993-1997.

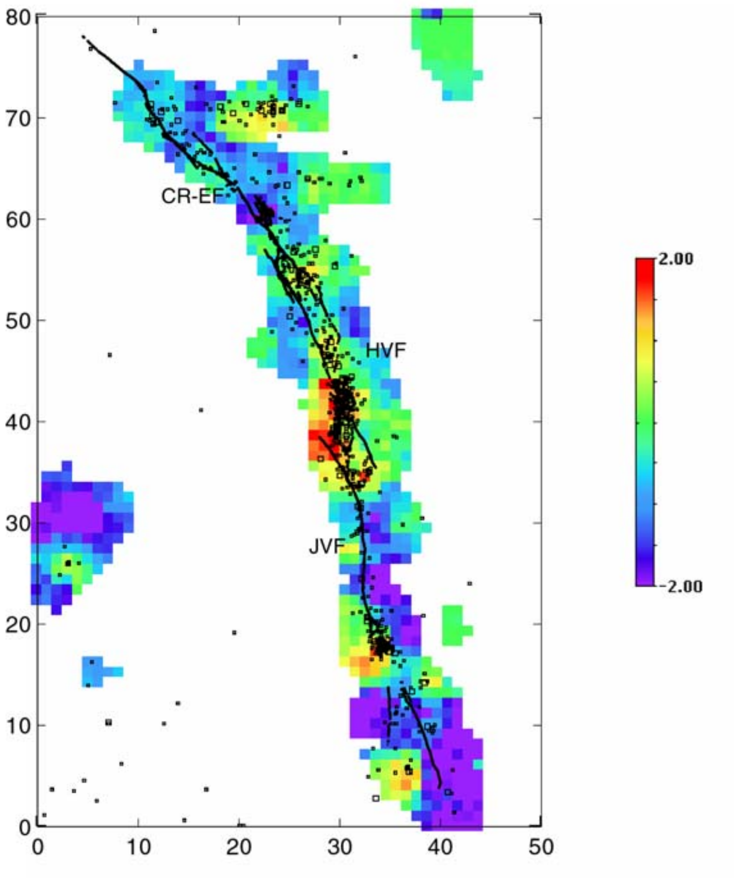


Figure 4. Stress change along the Landers mainshock rupture between 1993 and 1997, averaging over 0.5 year time intervals. Black lines denote the Landers surface rupture. Red areas show an increase in stress over the time period. The Johnson Valley-Homestead Valley fault jog, which was the focus of our study, shows a clear increase in stress. Most other areas do not. The maximum amplitude of the stress change in the jog, assuming As as determined by *Gross and Kisslinger* [1997] is in the range of 0.1-1.2 MPa.

Figure 5 shows the temporal variation of the estimated Coulomb stress at a number of points in and near the fault jog. Not surprisingly, all regions show a large stress change coincident with the 1992 Landers mainshock. There is a great deal of variation over short temporal scales following that, but the overall trend is clear Seismicity on subfaults within the jog shows a post-seismic increase in stress, whereas seismicity on subfaults outside the jog do not. There is the suggestion of a response to the nearby Hector Mine earthquake for panel (a), but it does not show up at the other locations.

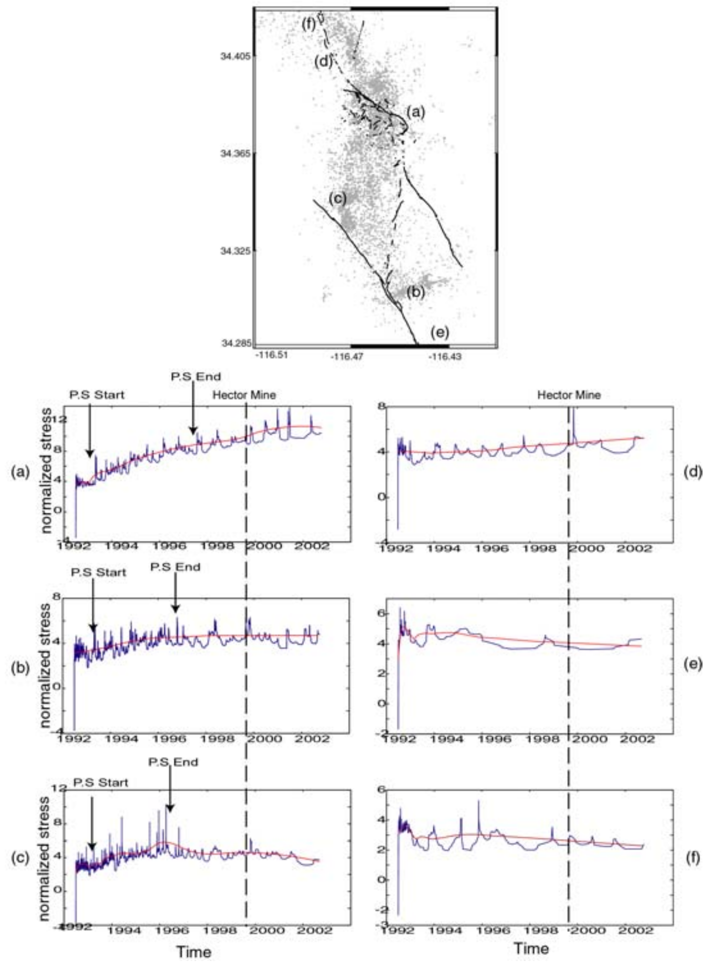


Figure 5. Map view of the Johnson-Valley-Homestead Valley fault jog and relocated Landers aftershocks. Letters indicate regions of the nodes where stress histories are calculated from the seismicity rate following *Dieterich et al.* [2000]. Stress vs. time for these nodes are shown in panels a-f. Panels a-c (inside the jog) show a gradual increase in stress following the Landers mainshock, but panels d-f (outside the jog) do not.

References

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