Supplement Material

**The 2012 Brawley Swarm Triggered by Injection-Induced Aseismic Slip**

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**Supplement table and figure captions**

**Table S1.** Focal mechanism of 19 out of 22 large (M>3.5) events in the 2012 Brawley swarm

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **ID** | **Lat.** | **Lon.** | **Depth(km)** | **Mw** | **strike/dip/rake(°)** |
| **15198929** | 33.0128 | -115.5480 | 5.4 | 3.67 | 53/80/-25 |
| **15199577** | 33.0172 | -115.5482 | 5.2 | 3.86 | 55/84/-9 |
| **15199593** | 33.0182 | -115.5420 | 4.2 | 4.42 | 56/82/-14 |
| **15199681** | 33.0172 | -115.5537 | 5.5 | 5.28 | 48/82/4 |
| **15199689** | 33.0173 | -115.5480 | 3.7 | 4.71 | 251/81/7 |
| **15199721** | 32.9867 | -115.5970 | 3.7 | 4.19 | 228/77/-5 |
| **15199865** | 33.0207 | -115.5370 | 4.7 | 3.44 | 60/90/-18 |
| **15200001** | 33.0103 | -115.5570 | 3.9 | 3.28 | 41/84/12 |
| **15200401** | 33.0185 | -115.5403 | 4.5 | 5.37 | 58/90/-14 |
| **15200489** | 33.0352 | -115.5280 | 3.5 | 3.87 | 47/52/-43 |
| **15200513** | 32.9813 | -115.5980 | 5.0 | 3.68 | 50/90/25 |
| **15200593** | 32.9957 | -115.5780 | 2.9 | 3.30 | 40/80/16 |
| **15200601** | 33.0268 | -115.5250 | 4.4 | 3.45 | 46/90/-12 |
| **15201297** | 32.9903 | -115.5810 | 3.7 | 3.88 | 231/78/-8 |
| **15201537** | 33.0300 | -115.5297 | 2.0 | 4.35 | 44/52/-79 |
| **15202921** | 33.0212 | -115.5195 | 2.0 | 4.70 | 29/45/-77 |
| **15204369** | 33.0063 | -115.5580 | 3.4 | 3.47 | 41/80/1 |
| **15204969** | 33.0018 | -115.5600 | 3.0 | 4.03 | 59/79/-8 |
| **15205377** | 32.9740 | -115.6030 | 3.6 | 3.21 | 36/90/6 |

**Figure S1. Sensitivity test for attenuation.** We used the relationships Qs = 50\*Vs and Qp = 2\*Qs to take into account the strong attenuation in the basin. The green’s functions were computed and filtered to the same frequency ranges as we used in inversion (0.02-0.1Hz) for the two velocity models. They are the original model (black, used in the paper) and a similar model with attenuation factors of P and S waves half of the original one (red). The phases and amplitudes for these two models are almost identical (in view of the differences between the synthetics and the observations).

**Figure S2.** **Depth sensitivity of waveform fits for the Mw4.7 normal earthquake.** The upper panel shows three component synthetics (red) generated by assuming various centroid depths, using the mechanism obtained by long period waveform inversion is Fig. S1. The data (black) is shown at the bottom. All the waveforms are plotted in a normalized way, and note the development of surface-waves and surface reflection phase when the centroid depth is as shallow as 2km. The tangential component has worse waveform fits because of the nodal direction. A schematic ray path plot is shown in the lower panel, highlighting the surface reflection phase as observed clearly in the radial component.

**Figure S3.** **UAVSAR guided field observations.** Field observations (a-d) are shown for different locations along the 3.5km rupture trace that is well recorded by the UAVSAR data (lower left). The rupture trace was mapped in the field using GPS. Slip values at various locations are also shown in the lower right. Although post-earthquake UAVSAR data were acquired in Sept. 2012, processing was not performed until May 2013. The initial results indicated a phase break located north of Brawley and east of the New River, in an area where no surface break had been previously noticed([Hauksson et al., 2013](#_ENREF_1)). Upon ­field inspection on May 22, 2013, the surface rupture was found and mapped along most of its ~3.5 km total length, using a hand-held GPS receiver. From the Best Road crossing at the north end to a geothermal injection pipeline crossing near the South end, the rupture was mapped and photographed, also on May 24, 2013. Subsequently, the zone was flown over by Donnellan and Treiman in order to assess whether or not any of the features seen along the surface breaks appeared to be consistent with any non-tectonic origin, such as ground failures related to liquefaction. That assessment identi­fied one area in the south that was thought to be a possible liquefaction-related feature, but it had already been studied on the ground and showed no evidence of ejected sand; it was simply an area of ponded irrigation water that had killed the crop in an area that had dropped along the surface rupture. The dead vegetation had appeared, from the air, to possibly be a sand blow, but it was not. Field investigation therefore confirmed the observed fault offsets to be of tectonic origin.

**Figure S4. Static offsets predicted by the M5+ SS events.** The deformation field in the LOS (line-of-sight) of the UAVSAR data (Fig. 1c) is computed by using the slip models of two M5+ SS events. The same color scale in Fig. 4f for the miss fit plot is used here. The map view of fault planes for the M4.7 normal event (red) and the SS events (black) are shown as rectangles with upper bound shown as heavy lines. The red star indicates the epicenter of the normal earthquake. Note that the amplitude of static offsets is similar as that in the misfit plot of Fig. 4f which is much smaller than the signal from the normal event.

**Figure S5.** **Checkerboard tests.** Checkerboard-like slip distribution (a, left) and risetime (a, right) are used to generate the synthetic data and then inverted with static only (b), seismic only (c) and jointly (d). The slip distributions are shown in the left column and risetimes are shown in the right column. Note the improvement of the resolution when both data sets are used.

**Figure S6.** **Waveform sensitivity to the rupture velocity for the Mw4.7 normal earthquake.** The waveform misfit as a function of the rupture velocity is plotted in the upper panel. The corresponding waveform fits for three rupture speeds (marked as arrows) are shown in the lower panels. Some components in the data are highlighted by the ellipses. Note that when rupture speed is larger than the preferred value (1.75km/s), the trade-off between risetime and rupture speed starts to kick in and reflected as smoother curve in the error-vr plot. This kind of trade-off is commonly observed in other studies([Wei et al., 2013](#_ENREF_2)).

**Figure S7. Contribution to Coulomb stress change of coseismic slip and aseismic slip on the normal fault.** (a) Contribution from aseismic slip, the white star indicates the hypocenter of the Mw4.7 normal earthquake which is determined by fitting the geometry of the fault (see supplement text for more details) (b) Contribution from coseismic slip of M5+ SS events. The white star indicates the hypocenter and the green circles are the intersection points between the known wells and normal fault.

**Reference**

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