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Variations in tremor activity and implications for lower crustal deformation along the central San Andreas Fault, California

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Tremor activity patterns can serve to illuminate spatially variable properties and deformation styles of the deep fault. Toward this goal, we first separate tremor into more tractable individual events, called low-frequency earthquakes (LFEs). We then divide the LFEs into 88 families (groups of similar events) distributed along 150 km of the central San Andreas Fault, beneath creeping, transitional, and locked sections of the upper crustal fault (Fig. 1).

For maximum accuracy, we locate these tremor families using a 3D velocity model and seismogram stacks of up to 400 events. These stacks reveal clear P and S body waves, even on analog surface stations, which tightly constrain event hypocenters. Depths are mostly between 18 and 28 km, in the lower crust, and below the maximum depth of regular earthquakes. Tremor epicenters are concentrated within 3 km of the surface trace, implying a nearly vertical fault. Combined with observations of tremor migration [Shelly, 2010], this suggests that the San Andreas Fault remains a localized, through-going structure at least to the base of the crust in this area.

Using these 88 event families as waveform templates, we scan 9 years of continuous seismic data. We detect more than 550,000 events (LFEs) since mid-2001; typically multiple bursts per day. We find considerable variation in properties among families, including amplitudes, recurrence intervals, responses to the nearby M 6.0 Parkfield and M 6.5 San Simeon earthquakes, and sensitivity to small stresses imparted by the tides and by waves of regional and teleseismic earthquakes. These properties tend to show systematic variation with location, providing hints of lower-crustal heterogeneity. For example, maximum tremor amplitudes vary along the fault by at least a factor of 7, with by far the strongest sources along a 25 km section of the fault southeast of Parkfield (Fig. 1). In addition, shallower sources (i.e. < 23 km depth) have more concentrated (larger, but less frequent) bursts of activity compared to deeper sources, perhaps signaling changing fault strength with depth.

References

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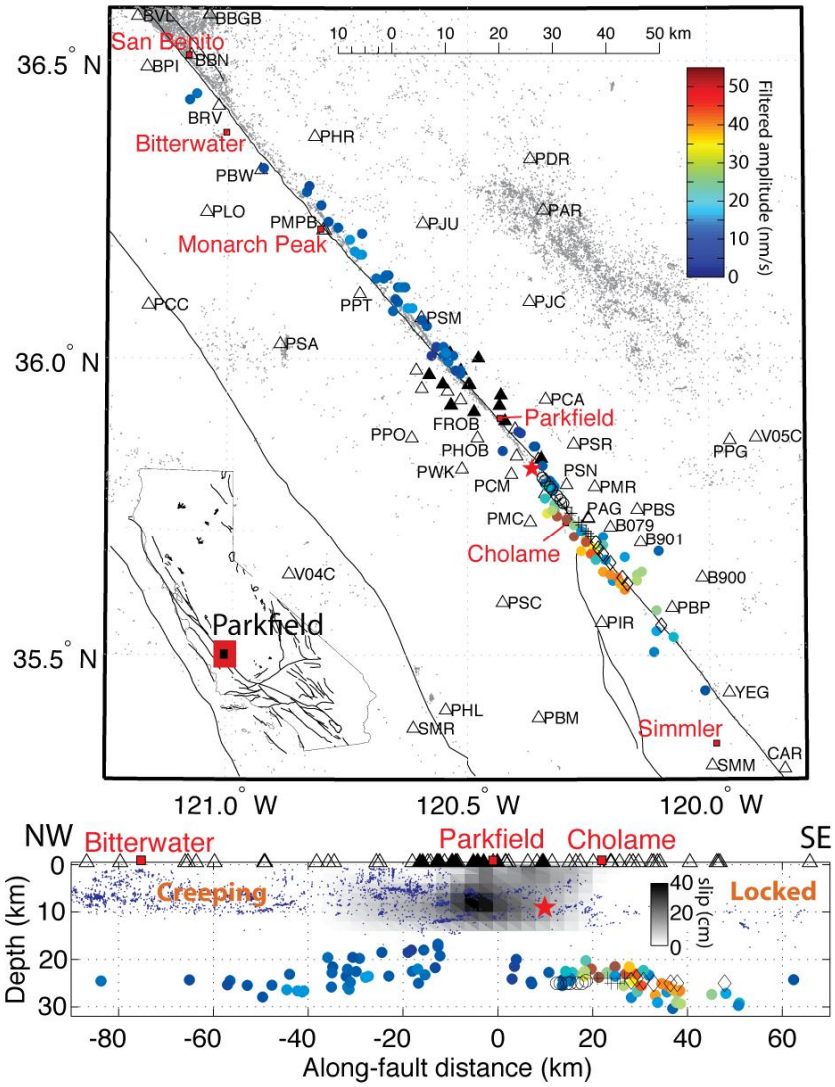

Figure 1. Map and cross-section of tremor family locations and amplitude potential. Top panel shows map view of tremor locations (colored circles) and seismic stations used for event location (triangles). Filled triangles are HRSN borehole stations used for event detection. Open circles, plusses, and diamonds show interpreted tremor family locations from *Shelly* [2010] for reference. Gray dots show relocated upper crustal microseismicity from 1984-2003 [*Waldhauser and Schaff*, 2008]. Red star indicates hypocenter of 2004 M 6 earthquake. Bottom panel shows along-fault cross-section. Microseismicity within 5 km of the fault trace is in blue. Other symbols are the same as in map view. Gray shading shows the coseismic and first 230 days of postseismic slip from the 2004 earthquake [*Murray and Langbein*, 2006]. Figure from *Shelly and Hardebeck* [2010].