Introduction

Until recently, active fault zones were thought to deform via seismic slip during earthquakes in the upper, brittle portion of the crust, and by steady, aseismic shear below. However, in the past decade, this view has been shaken by seismological observations of seismic tremor deep in the roots of active fault zones. First recognized on subduction zones in Japan and the Pacific Northwest, tremor has also been found to be very active on a short section of the San Andreas Fault to the southeast of one of the most densely monitored fault segments in the world, near Parkfield, CA (Nadeau and Dolenc, 2005). This deep (~20-30 km) zone of activity is located right below the nucleation zone of the great 1857 Fort Tejon earthquake, estimated to be an M~7.9 event. Thus, learning more about the temporally and spatially complex faulting processes in this zone may help us better understand the conditions that lead to such large ruptures.

The Project Plan and Implementation

The tremor source region is southeast of existing seismic networks around Parkfield, along the San Andreas Fault. We are adding eight seismic stations—the TremorScope (TS) network—in this area to complement existing instrumentation.

Now, all sites for the TS network have been permitted and all four surface stations have been installed, two in this past year. Figure 2.26.1 shows the installation of the seismometer vault at station TRAM, just above the centroid of the tremor sources. Surface installations have a broadband seismometer, an accelerometer and a digitizer. Station TRAM will also host one of the four boreholes. The borehole sites, with a hole about 300 m deep, will have an accelerometer at the surface. Seismometers, accelerometers and geophones will be installed at the bottom of these boreholes, where the levels of environmental and human-induced noise are much lower than at the surface, so the weak tremor signals will be more easily detected and analyzed. We defined the specifications for the boreholes, including target depth and casing options. In late-June, we hosted a pre-bid walk-through for prospective drilling companies to introduce them to the drilling sites in preparation for their bids. Downhole will be a three-component set of gimballed, 2 Hz geophones. Three boreholes will also be equipped with a Guralp downhole sensor package, consisting of a three-component broadband seismometer, a three-component accelerometer and a digitizer. At all locations, data will be logged onsite and forwarded to Berkeley for real-time processing. The data will be used in real-time earthquake monitoring (see Operational Section 3.1) as well as for tremor studies. Data are now being archived and analyzed from the four surface stations.

Figure 2.26.2 shows non-volcanic tremor in the Parkfield region on May 8th, 2013. This type of tremor is hard to detect at just one station because it has a low diffuse signal that lasts for minutes. The TS network is located very near the source of these tremors and we can clearly pick up the signal on multiple stations (THIS, TRAM, TSCN) and confirm that this is indeed tremor. In contrast, station RAMR is located about 50 km away from the source region and no identifiable tremor signal is visible.

Results

Figure 2.26.3 depicts a map of the Parkfield, California area. The stars are locations of tremor bursts occurring 90 days prior to June 9th, 2013. Red stars are the five most recent tremor bursts. The solid and dotted lines in both panels represent the locked and creeping portions of the San Andreas Fault, respect-
Figure 2.6.3: Map showing the 90 days of tremor prior to June 9th, 2013.

The white triangles are sensitive borehole stations of the High Resolution Seismic Network (HRSN) used in the detections, and the Tremorscope stations are shown as blue triangles. The towns of Parkfield and Cholame are the labeled squares. The bottom panel shows the locations of the tremor episodes in depth section along the fault. The pink horizontal line represents the Moho in the area. To look at the most recent tremor, go to http://seismo.berkeley.edu/research/recent_tremor.html

**Perspectives**

Data from the TremorScope project will improve earthquake tremor monitoring in the region south of Parkfield. Insights from the project will also contribute to an understanding of tremor and slip in other regions of the world where such phenomena have been observed, but are not nearly as accessible. Should a great San Andreas earthquake occur during this experiment, the network would also provide unprecedented and exciting insights into the seismic rupture process. In addition, the BSL received the go-ahead from the university to submit a “major research initiative”, or MRI, proposal to the National Science Foundation for tracking fault processes on the deep San Andreas with a high-sensitivity seismic array of borehole stations. This project would use the TremorScope instrumentation as leverage to increase and improve seismic monitoring throughout the area and improve our understanding of the transition in fault behavior between the locked San Andreas Fault in the Fort Tejon/Carizo Plains segment and the creeping section to the northwest of Parkfield.

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**References**