22 Repeating Earthquakes and Inferred Deep Slip on the Calaveras Fault

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Introduction

The Calaveras fault in the Eastern San Francisco Bay Area lies near major urban areas in the San Francisco Bay region, including San Jose, Fremont, and the cities of the San Ramon Valley corridor, and it has the potential to cause significant loss of life and property damage. Since 1850, there have been 13 earthquakes of $M_w > 5$ or greater on or near the Calaveras fault. Monitoring of the fault with GPS, creepmeter, gravity, magnetic and seismic data suggests a connection to the Hayward fault with active creep along much of the fault trace. Investigation of the distribution of seismicity along the fault reveals that in regions where $M_w > 5$ earthquakes occur, little seismicity above $M_L 1.4$ is found and that pre-mainshock and aftershock microseismicity patterns are similar (Oppenheimer et al., 1990). This spatial and temporal variability in creep and seismic behavior of the fault suggest that the situation at depth is significantly more complicated than a single locked/creeping region, leading to a time-dependent hazard for the Bay Area.

Geodetic measurements of surface deformation provide information about the nature of elastic strain accumulation near seismogenic faults, their locking depth and slip rates, and variations of those parameters in space and time due to time-dependent processes. However, the inference of these properties on fault zones at depth requires various modeling assumptions that are sometimes not well constrained. A primary objective of this project is to help addresses the seismic potential and natural hazard presented by the Calaveras fault in the Eastern San Francisco Bay Area by providing additional constraints on the spatial and temporal distribution of inferred deep fault slip using repeating earthquakes.

Repeating Quakes on the Calaveras

Owing to their occurrence within the fault zone itself, repeating earthquakes provide more direct information on the geometry and time-variability of creep on faults at depth, and for the more complex situation expected within the deep Calaveras fault zone, the addition of repeating earthquake information should help constrain estimates of deep fault strain accumulation significantly. With this in mind, we compiled a catalog of characteristically repeating earthquakes (CREs) on the Calaveras fault over an ~ 29.5 year period along an ~85 km long fault section with spatio-temporal coverage that includes the hypocenters of the 1984 Morgan Hill $M_w 6.2$ and 2007 Alum Rock $M_w 5.2$ earthquakes (Figure 2.22.1).

Survey of Deep Slip Rate from Repeaters

One interesting feature of the spatial distribution of the repeating sequences is that a fairly large number occur on what Manaker et al. (2005) call the Alum Rock seismic trend just SW of the Alum Rock earthquake (ellipse in Figure 2.22.1). A survey view of the repeater inferred slip information for the entire study segment is shown in Figure 2.22.2. Between -10 to 15 km NW, an initially high and decreasing rate of accumulating slip beginning in 1984 corresponds to the post-seismic slip response of the Calaveras to the 1984 Morgan Hill $M_w 6.2$ earthquake (hypocenter at 13 km NW). The Alum Rock trend of repeaters appears as the southwest splay between 20 to 30 km NW in map view. As this study progresses, it will be interesting to see what kind of slip behavior this and other secondary structures have. We will also look at a number of cross-sections of the relocated repeating and non-repeating seismicity stepping along the fault to further illuminate other structural discontinuities and how deep fault slip is partitioned on these structures. This information will also be combined with InSAR, GPS and other diverse geodetic datasets to provide improved constraints for a kinematic model of the variability of interseismic creep on the Calaveras fault. The goals of the modeling effort are to better delineate creeping zones on the Calaveras fault and their rates through time, to detect previously unknown transient slip events and to better characterize known events, such as postseismic slip following the 2007 Alum Rock earthquake.

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References


