22 Identifying Undetected Early Aftershocks Associated with the 12 August 1998 $M_w$ 5.1 San Juan Bautista Earthquake

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22.1 Introduction

Aftershocks are triggered by abrupt changes of stress induced by a larger earthquake. Detailed images of spatiotemporal changes in aftershock activity help delineate the mainshock rupture area. However, large numbers of early aftershocks are not detected because they are masked by large amplitudes and long duration of seismic coda waves from the mainshock and other aftershocks. Peng and Zhao (2009) have demonstrated that $\sim 10,000$ aftershocks during the first three days following the 2004 $M$ 6.0 Parkfield earthquake were undetected by the standard earthquake-detection algorithm of the Northern California Seismic Network (NCSN). We focus on the detection of uncatalogued aftershocks after the 12 August 1998 $M_w$ 5.1 San Juan Bautista (SJB) earthquake. This event was the largest historic earthquake in the SJB area and was associated with a large slow slip event (Uhrhammer et al., 1999). Additionally, Nadeau and McEvilly (2004) and Templeton et al. (2008) found accelerations in repeating microearthquake frequency accompanying the 1998 slow slip event.

22.2 Identification of Undetected Early Aftershocks

Following Peng and Zhao (2009), we have been identifying undetected early aftershocks with a cross-correlation based approach. We use waveforms from 248 SJB earthquakes detected by the NCSN during a 10-day period spanning the 1998 SJB earthquake (9 August through 18 August, 1998) as templates to identify additional, previously undetected earthquakes. Using continuous data recorded by the closest two seismic stations to the 1998 SJB event (BK.SAO and NC.BVY; less than 4 km from the mainshock), our preliminary analysis has detected $\sim 900$ individual earthquakes, with the averaged cross-correlation threshold of 0.7 (Figure 2.45). We have identified four times more aftershocks than listed in the NCSN catalog (Figure 2.46). We also searched for small foreshocks immediately preceding the mainshock (e.g., Dodge et al., 1996; Bouchon et al., 2011), but no events were detected during the two minutes preceding the mainshock. We currently assign the locations of the detected events to that of the template events providing the highest cross-correlation values (Figure 2.46a).

With the detected early aftershocks, we find that a highly productive burst of aftershocks started 17 hours after the mainshock (Figure 2.46b). In this aftershock episode, $\sim 100$ events occurred within a 3-hour period. These aftershocks occurred in the northwest part of the rupture area (Figure 2.46b). This aftershock episode may be the result of the redistribution of stress induced by the 1998 SJB earthquake. Apparently strain and creepmeter data of the associated slow slip event do not resolve an acceleration of slip associated with this accelerated aftershock activity.

Figure 2.45: (a) Top panel shows averaged cross-correlation functions based on SAO.BK.BHN and BVY.NC.EHZ data. Highest cross-correlation values were plotted at individual time steps from cross-correlation functions for the 248 template events. Black arrows indicate identified events using the threshold with averaged cross-correlation value of 0.7 (dashed line). Bottom panel shows observed seismograms (black) recorded at BK.SAO in the N-S component with a 2-6 Hz bandpass filter. Waveforms shown in red and blue are the newly detected events and the NCSN events (the first 10-s data). Event ID: 51061864. (b) Detected early aftershock at $\sim 160$ s after the mainshock shown in grey area in Figure 2.45a using the template event nc51061864 (M 0.85) occurring $\sim 4$ days after the mainshock. Waveforms shown in black and green are the continuous and the template waveforms, respectively.
Figure 2.46: (a) Cross-section view of the newly detected and NCSN events (circles) along the San Andreas fault in the SJB area (NW to SE) color-coded by the logarithmic time after the mainshock (red star). The purple diamond is the location of the characteristically repeating earthquake sequence shown in Figure 2.47. (b) Left panel shows the occurrence times of aftershocks since the 1998 SJB mainshock as a function of the along-strike distances. The blue circles are the events listed in the NCSN catalog and the red triangles are newly detected events from the cross-correlation analysis. Right panel shows the cumulative numbers of aftershocks from the NCSN catalog (blue) and this study (red).

22.3 Characteristically Repeating Microearthquakes

As a complementary study to Nadeau and McEvilly (2004) and Templeton et al. (2008), we are identifying smaller characteristically repeating earthquakes around the rupture area of the 1998 SJB earthquake. We have analyzed ~6,000 SJB earthquakes in the NCEDC earthquake catalog between 1984 and June 2011 and found ~350 candidate repeating earthquake sequences. By integrating the early aftershock and repeating microearthquake catalogs, we found that some of the newly identified early aftershocks are characteristically repeating microearthquakes (Figure 2.47). We now focus on completing the repeating microearthquake catalog in the vicinity of the 1998 SJB earthquake, to better characterize the accelerated deep fault creep induced by the 1998 SJB mainshock.

22.4 Acknowledgements

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22.5 References


