STUDY OF EARTHQUAKE FAULT ZONE STRUCTURES BY AFTERSHOCK LOCATION AND HIGH-FREQUENCY WAVEFORM MODELING

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Abstract

In this study, I analyzed high frequency waveforms of local earthquakes to map crustal faults and to investigate fine structures of fault zone (FZ). In order to determine the fault plane of the 18 April 2008 Illinois earthquake, I first developed a sliding-window cross-correlation (SCC) detection technique and applied the technique to continuous waveforms recorded by the Cooperative New Madrid Seismic Network stations. The technique detected more than 120 aftershocks down to ML 1.0 in the 2 week time window following the mainshock, which is three times more than the number of aftershocks reported by the seismic network. Most aftershocks happened within 24 hrs of the mainshock. I then relocated all events by the double-difference relocation algorithm. Accurate P- and S-wave differential arrival times between events were obtained by waveform cross correlation. After relocation, I used the L1 norm to fit all located events by a plane to determine the mainshock fault plane. The best-fit plane has a strike of $292° \pm 11°$ and dips $81° \pm 11°$ to the northeast. This plane agrees well with the focal mechanism solutions of the mainshock and four largest aftershocks. By combining the aftershock locations and focal mechanism solutions, I concluded that the 18 April earthquake occurred on a nearly vertical left-lateral strike-slip fault orienting in the west-northwest-east-southeast direction. The fault coincides with the proposed left-stepping Divide accommodation zone in the La Salle deformation belt and indicates reactivation of old deformation zone by contemporary stresses in the Midcontinent.

To investigate fine structures of the San Jacinto fault zone and the Calico fault zone in southern California, I used P- and S-wave travel times and waveforms of local earthquakes recorded by temporary arrays across the faults. In the San Jacinto fault zone study, I developed a method to determine the depth extent of the

low-velocity zone (LVZ) associated with a FZ using S-wave precursors. The precursors are diffracted S waves around the edges of LVZ and their relative amplitudes to the direct S waves are sensitive to LVZ depth. I applied the method to data recorded by three temporary arrays across three branches of the San Jacinto fault zone. The FZ dip was constrained by differential travel times of P waves between stations at two side of the FZ. Other FZ parameters (width and velocity contrast) were determined by modelling waveforms of direct and FZ-reflected P and S waves. I found that the LVZ of the Buck Ridge fault branch has a width of ~150 m with a 30–40 per cent reduction in V_p and a 50–60 per cent reduction in V_s. The fault dips 70° to southwest and its LVZ extends only to 2±1 km in depth. The LVZ of the Clark Valley fault branch has a width of ~200 m with 40 per cent reduction in V_p and 50 per cent reduction in V_s. The Coyote Creek branch is nearly vertical and has a LVZ of ~150 m in width and of 25 per cent reduction in V_p and 50 per cent reduction in V_s. The LVZs of these three branches are not centred at the surface fault trace but are located to their northeast, indicating asymmetric damage during earthquakes.

In the Calico fault zone study, I performed a systematic analysis of travel times from earthquakes located on the northeastern and southwestern sides of the fault. The FZ width and velocity contrast were determined by modeling waveforms of direct and FZ-reflected waves. The FZ dip was constrained by arrival times of earthquakes from both sides of the Calico fault. Arrival time advances at southwestern stations for two northeastern events were used to constrain the LVZ depth. I found a 1.3-km-wide LVZ with 40 per cent reduction in V_p and 50 per cent reduction in V_s of the Calico fault. The fault dips 70° to northeast and its LVZ extends only to ~4 km in depth. The LVZ is not centred at the surface fault trace, but is shifted to southwest.