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Inferring Fault Zone Structure from the Azimuthal Variation in the Stacked P-spectra of Earthquake Clusters

Fault damage zones can influence various aspects of the earthquake cycle, such as the recurrence intervals and magnitudes of large earthquakes. The properties and structure of fault damage zones are often characterized using dense arrays of seismic stations located directly above the faults. However, such arrays may not always be available. Hence, our research aims to develop a novel method to image fault damage zones using broadband stations at relatively larger distances. Previous kinematic simulations and a case study of the 2003 Big Bear earthquake sequence demonstrated that fault damage zones can act as effective waveguides, amplifying high-frequency waves along directions close to fault strike via multiple reflections within the fault damage zone. The amplified high-frequency energy can be observed by stacking P-wave spectra of earthquake clusters with highly-similar waveforms (Huang et al., 2016), and the frequency band which is amplified may be used to estimate the width and velocity contrast of the fault damage zone.

We attempt to identify the high-frequency peak associated with fault zone waves in stacked spectra by conducting a large-scale study of small earthquakes (M1.5–3). We use high quality broadband data from seismic stations at hypocentral distances of 20-80 km in the 2019 Ridgecrest earthquake regions. First, we group the Ridgecrest earthquakes in clusters by their locations and their waveform similarity, and then stack their velocity spectra to average the source effects of individual earthquakes. Our results show that the stations close to the fault strike record more high-frequency energies around the characteristic frequency of fault zone reflections. We find that the increase in the amount of high-frequencies is consistent across clusters with average magnitudes ranging from 1.6-2.4, which suggests that the azimuthal variation in spectra is caused by fault zone amplification rather than rupture directivity. We will apply our method to other fault zones in California, in order to search for fault damage zone structures and estimate their material properties.

Session: Above the Seismogenic Zone: Fault Damage and Healing in the Shallow Crust

Type: Oral

Room: 208C

Date: 4/19/2023

Presentation Time: 05:15 PM (local time)

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