Systematic High-Resolution Imaging of the Karadere-Düzce Branch of the North Anatolian Fault

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The spatial extent and material properties of the damaged fault zone rock have important implications for many aspects of earthquake behavior. Fault zone structures with material discontinuity interfaces and low-velocity layers of damaged fault zone rock can produce several indicative wave propagation signals, including scattering, anisotropy, non-linearity, and guided head and trapped waves. We perform a systematic analysis of such signals from seismic data recorded by a PASSCAL seismic network deployed along and around the Karadere-Düzce branch of the north Anatolian fault during the 1999 Mw 7.4 İzmit and Mw 7.1 Düzce earthquake sequences. Our results can be summarized as follows: The observed fault zone trapped waves are generated by relatively shallow structures that extend generally only over the top ~3-4 km of the crust. The shallow trapping structure is ~100 m wide and is surrounded by broader (~ 1 km) anisotropic and scattering zones that are also confined primarily to the top 3 km. The average delay times for ray paths that propagate along the rupture zone are larger than for the other paths. The apparent crack density in the damaged shallow fault zone rock is about 7%. Systematic analyses of anisotropy and scattering measured from waveforms generated from repeating earthquakes do not show precursory temporal evolution of properties before the Düzce mainshock. The anisotropy results show small co-seismic changes. However, the scattering results show clear co-seismic changes and post-seismic logarithmic recovery after the Düzce mainshock. A strong correlation between the co-seismic delays and intensities of the strong ground motion generated by the Düzce mainshock implies that the radiated seismic waves produce the velocity reductions in the top portion of the shallow crust.