Shallow low velocity fault zone layer in the Karadere-Duzce Branch of the North Anatolian Fault Based on Analysis of Trapped Waves

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A week after the August 17, 1999, Mw7.4 earthquake on the North Anatolian fault, we deployed a 10-station PASSCAL seismic network along and around the Karadere-Duzce branch of the fault, in a region where the surface rupture is in bedrock. In January-February 2000 we deployed 16 additional sensors in a “T’ array along and normal to the fault for 14-19 days, before removing both arrays. Accurate aftershock locations around the surface rupture in our network region indicate a north-dipping fault with a dip angle that is about 80 degrees near the surface and becomes shallower with depth. One goal of the deployments was to provide a high resolution imaging of the fault zone structure at depth using waveform modeling of seismic fault zone guided waves. We identify trapped waves in the data as relatively large-amplitude long-period oscillations after the S body waves that exist only in stations located within about 100 m of the rupture. Examination of waveforms produced by several 1000's aftershocks shows that such trapped waves are commonly generated by events that are well outside the fault zone. The time difference between the S arrival and peak amplitude in the trapped waves group does not grow systematically with increasing source-receiver separation along the fault.

The results imply that the trapping of seismic energy in the Karadere-Duzce rupture zone is generated by a shallow fault zone layer that extends only to a depth of a few km. This conclusion is based in part on a large parameter-space study of 3D wave propagation in irregular fault zone structures (Igel et al., 2001; Jahnke et al.; 2001, Fohrmann et al., 2001; Igel et al., this meeting). Calculations from those studies indicate that a shallow fault zone layer can trap seismic energy generated by events outside and below it, while the generation of trapped waves in a deep fault zone layer require sources that are very close to the fault. The inferred shallow fault zone layer may correspond to the top part of a flower-type structure or may exist as isolated blobs or slivers of shallow damaged fault zone rock. The results are compatible with our analysis of trapped waves at the Parkfield segment of the San Andreas fault (Michael and Ben-Zion, 1998, 2002) and the rupture zone of the 1992 Landers, CA, earthquake (Peng et al., 2001, 2002a, 2002b). As with our Parkfield and Landers work, we obtain excellent fits to fault zone waveforms recorded in the Karadere-Duzce rupture with synthetic seismograms generated by the 2D analytical solution of Ben-Zion and Aki (1990) and Ben-Zion (1998). The waveform modeling employs a genetic inversion algorithm that maximizes the correlation between observed and synthetic waveforms (Michael and Ben-Zion, 2002). The synthetic waveform fits suggest that the shallow damage zone has effective waveguide properties characterized by a thickness of order 100 m, a velocity decrease of about 30% relative to the surrounding rock, and an S-wave quality factor of about 30.