Subsurface Structure of the San Andreas Fault: Probable Analog to the North Anatolian Fault

R. D. Catchings, M. J. Rymer, and M. R. Goldman
U.S. Geological Survey, MS 977, 345 Middlefield Road, Menlo Park, California, USA
catching@usgs.gov

The San Andreas fault (SAF) is a right-lateral, strike-slip fault that extends approximately 1200 km from southernmost California to the Mendicino triple junction. Like the right-lateral, ~1200-km-long North Anatolian fault (NAF), the SAF is capable of generating large-magnitude earthquakes along most of its length. To better understand the subsurface geometry and the velocity structure of the SAF, we acquired a series of P-wave seismic reflection and refraction profiles at multiple locations across the near-surface traces of the SAF. The reflection images show that the SAF is characterized by multiple fault strands near the surface, with many of the faults merging into a more narrow fault zone at a depth of several kilometers. In general, the SAF is characterized by steeply dipping P-wave low-velocity zones (approximately 10 to 40%) in the upper few kilometers. The low-velocity zones occur at multiple scales, ranging in width from a few meters to more than a kilometer. At the San Andreas Fault Observatory at Depth (SAFOD) in central California, the upper few kilometers of the SAF is characterized by an approximately 1.5-km-wide, southwest-dipping low-velocity zone (about 35%) at the surface that tapers to a 0.5-km-wide zone at depth of about 1 km. Seismic reflection images and surface geologic mapping show that the low-velocity zones are composed of a complex array of faults within a wedge of tectonically transported sedimentary rocks. At the epicenter of the 1989 M 6.9 Loma Prieta epicenter, our data show that the SAF is characterized by a 3-km-wide, northeast-dipping low-velocity zone (10 to 25%) in the upper 4 km. Near San Francisco, the surface trace of the SAF that ruptured during the 1906 M 7.9 San Francisco earthquake is characterized by a 75-m-wide, northeast-dipping low-velocity zone (about 40%) in the upper 50 m. All these low-velocity zones represent decreases in P-wave velocities across the SAF at scales varying from meters to kilometers. Explosive-generated seismic waves recorded along the fault zone show that high-amplitude trapped or guided waves travel within the low-velocity zones. During large-magnitude earthquakes, the SAF low-velocity zones may act as guides for high-amplitude seismic energy. These observations suggest that the SAF may generate particularly strong shaking within 1 to 3 km of its surface trace. Because the SAF and NAF have similar characteristics including length, slip rate, and 3-D geometries, comparison would be useful. We recommend high-resolution, active-source seismic profiling both across and along the NAF in order to make this comparison.

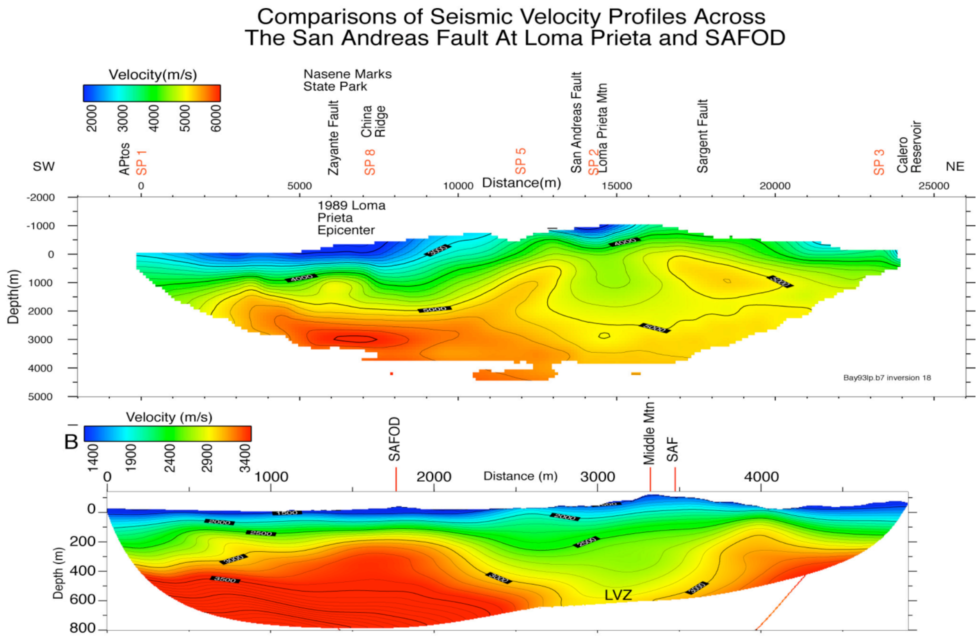

Fig. 1. (a) Seismic P-wave velocity structure across the San Andreas fault at the epicenter of the 1989 M 6.9 Loma Prieta earthquake within the Santa Cruz Mountains in northern California. Velocities are in km/s and depth and distance are in meters. Note the several-kilometer-wide low-velocity zone beneath the surface trace of the San Andreas fault. (b) P-wave velocity structure across the San Andreas fault at the San Andreas Fault Observatory at Depth (SAFOD) near Parkfield, California. The velocity scale is different than that in Fig. 1a, but note the low-velocity zone beneath and southwest of the San Andreas fault.

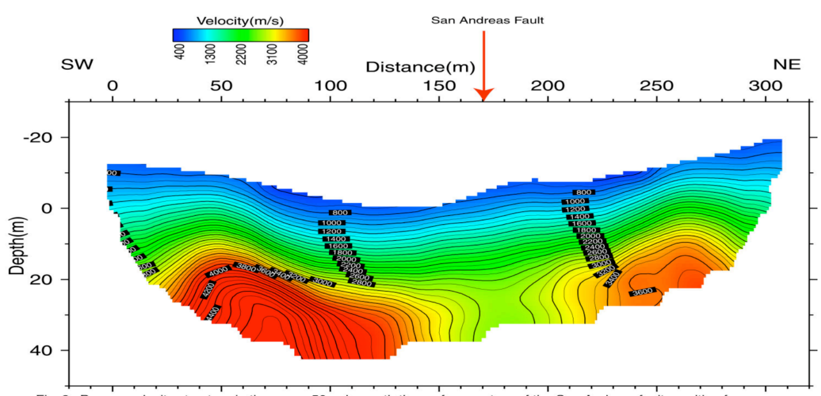

Fig. 2. P-wave velocity structure in the upper 50 m beneath the surface rupture of the San Andreas fault resulting from 1906 M. 7.9 San Francisco earthquake. This short seismic profile is located in the Santa Cruz Mountains in northern California. Note the well-defined low-velocity zone below a depth of 20 m.

Fig. 2. P-wave velocity structure in the upper 50 m beneath the surface rupture of the San Andreas fault resulting from 1906 M. 7.9 San Francisco earthquake. This short seismic profile is located in the Santa Cruz Mountains in northern California. Note the well-defined low-velocity zone below a depth of 20 m.