GEOPHYSICAL RESEARCH LETTERS, VOL. 24, NO. 16, PAGES 2051-2054, AUGUST 15, 1997

High-resolution seismic reflection profiling of the Santa Monica Fault Zone, West Los Angeles, California

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Abstract. High-resolution seismic reflection data obtained across the Santa Monica fault in west Los Angeles reveal the near-surface geometry of this active, oblique-reverse-left-lateral fault. Although near-surface fault dips as great as 55° cannot be ruled out, we interpret the fault to dip northward at 30° to 35° in the upper few hundred meters, steepening to ≥65° at 1 to 2 km depth. A total of ~180 m of near-field thrust separation (fault slip plus drag folding) has occurred on the fault since the development of a prominent erosional surface atop ~1.2 Ma strata. In the upper 20 to 40 m strain is partitioned between the north-dipping main thrust strand and several closely spaced, near-vertical strike-slip faults observed in paleoseismologic trenches. The main thrust strand can be traced to within 20 m of the ground surface, suggesting that it breaks through to the surface in large earthquakes. Uplift of a ~50,000-year-old alluvial fan surface indicates a short-term, dip-slip rate of ~0.5 mm/yr, similar to the ~0.6 mm/yr dip-slip rate derived from vertical separation of the oxygen isotope stage 5e marine terrace 3 km west of the study site. If the 0.6 mm/yr minimum, dip-slip-only rate characterizes the entire history of the fault, then the currently active strand of the Santa Monica fault probably began moving within the past ~300,000 years.

1. Introduction

The 1994 Mw 6.7 Northridge earthquake clearly demonstrated the hazards posed by faults within the Los Angeles metropolitan region. Because these faults are so close to major population centers, large earthquakes (Mw 7.0 to 7.5) on them could potentially cause more damage than the long-awaited 'Big One' (Mw ~8) on the more distant San Andreas fault (WGCEP, 1995; Dolan et al., 1995; Heaton et al., 1995). This study focuses on one of these urban faults, the Santa Monica fault in northwestern Los Angeles (Figure 1). Reliably assessing the seismic hazards posed by these faults requires accurate knowledge of numerous parameters, including the location, geometry, slip rate, recurrence interval, and kinematics of recent fault movements. Although geomorphologic mapping and paleoseismologic trench studies reveal much about these parameters, subsurface data are also necessary to understand the history and three-dimensional geometry of faulting.

Paper number 97GL01940.
0094-8534/97/97GL-01940$05.00

The regional geologic structure and geometry of faults in the Los Angeles area have been interpreted from extensive seismic reflection and drill hole data obtained during petroleum exploration (e. g., Wright, 1991; Schneider et al., 1996; Tsutsumi, 1996; Tsutsumi et al., in review). Exploration data are acquired to delineate hydrocarbon reservoirs primarily at 0.5 to ~6 km depth. Consequently, a data gap commonly exists between the base of trench data (~5 m), from which the most recent earthquakes can be characterized, and the top of industry seismic reflection and drill hole data (>~200 m), which provide the overall fault geometry. In this paper, we describe high-resolution seismic reflection data, acquired from the 15-to-300 m depth range of the Santa Monica fault, that provide useful constraints on the geometry, deformation rate, and kinematics of recent fault motions.

2. The Santa Monica Fault

The Santa Monica fault is part of a system of east-trending reverse, oblique-slip, and left-lateral strike-slip faults that extends >200 km along the southern edge of the Transverse Ranges of southern California. The Santa Monica fault extends westward 40 km along the southern edge of the Santa Monica Mountains (the southernmost of the Transverse

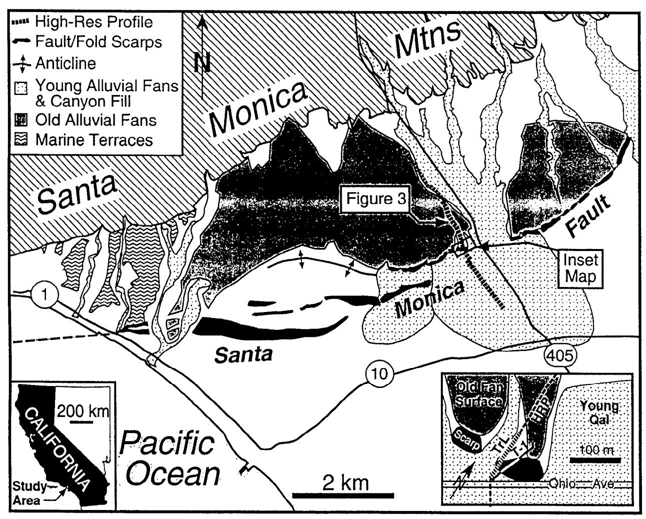

Figure 1. Map of the surficial trace of the Santa Monica fault (from Dolan et al., in review). Note location of main high-resolution seismic reflection profile. Inset map shows locations of trench and high-resolution profiles. T-1, trench; TrL, 'Trench Line' profile; HRP, Main profile.