Using Earthquake Data to map Faults in 3-D: Applications and Results

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Knowledge of the 3-D shape of active faults is of fundamental importance in many fields, from earthquake hazards, to oil exploration, to regional tectonics and seismotectonics. We have developed techniques in 3-D fault modeling whose applications range from models of single fault surfaces or small groups of faults, which can be used in earthquake hazards evaluation, to regional tectonic models. An example of how these techniques can be applied to the imaging of individual structures is that of the Northridge thrust in southern California. We were able to determine the 3-D geometry of the fault that generated the M 6.8, 1994 Northridge earthquake from the aftershocks of this event. It was also possible to determine the geometry of several nearby faults, some of which were previously unknown and are capable of producing damaging earthquakes. Complex fault networks can be modeled too, and the interactions between faults studied in detail. An example of this is the San Andreas fault system near San Gorgonio Pass in southern California. At San Gorgonio Pass we imaged the fault network using over 43,000 relocated small earthquakes. We then applied our knowledge of the network geometry to examine possible earthquake triggering scenarios in order to determine the likelihood of a major rupture of the San Andreas fault from the Salton Sea Los Angeles. A study of the 3-D structure of the crust in central Taiwan, where the M 7.6, 1999 Chi-Chi earthquake produced a large number of aftershocks, is an example of modeling applied to regional tectonics, and mountain building in particular. We imaged for the first time the large detachment beneath Taiwan. This detachment had been postulated by several authors, but never seen directly before, thus its exact geometry was unknown. Most faults capable of producing major earthquakes are connected to this detachment at depth. The results obtained from 3-D imaging allowed us a new test of critical-taper wedge mechanics, and suggest that the shape of the detachment controls the reversal of topographic slope across Taiwan.