Earthquake rupture zones: ground-surface and focal-depth observations

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The structure of earthquake rupture-zones at the focal depth is enigmatic. At the earth surface, large, recent earthquakes frequently generate impressive gashes and fault scarps. These surface features however, cannot be related to the rupture-zone at depth because soft sediments and surface waves strongly modify the surface features. Exhumed faults that had been active and later uplifted commonly display many details of ancient fault zones. However, exhumed faults reflect the superposition of many earthquakes (with or without creep) and the rupture of a single earthquake cannot be recognized.

This lack of observations of earthquake rupture zones led, in general, to a concept that earthquake instability occurs by fast slip along a smooth, thin, frictional surface. This concept is based on laboratory experiments (e.g., stick-slip and moving blocks), analysis of gouge-zones of exhumed faults and seismic modeling of “mathematical” dislocations. It is argued here that an actual rupture-zone of an earthquake is a complex structure of highly fractured which is more similar to the rupture zone of an intact rock than to a smooth sliding surface.

The argument for complex rupture zones is based on the processes of dynamic fracturing of brittle materials. It was demonstrated experimentally that tensile fractures which propagate at velocity exceeding 0.4 the Rayleigh wave speed develop complex structure by hierarchical bifurcations and branching at the fracture front. This branching absorbs the access energy at the fracture front. We think that fast propagating, dynamic shear fractures bound to display equivalent complexity. The experimental observations of dynamic slip event (e.g., Rosakis et al.) and field observations will be discussed. For all the above reasons, it appears the best environment to study earthquake rupture-zones are deep mines.