

Dynamics of earthquake rupture through branched and offset fault systems

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The rupture zones of major earthquakes often involve geometric complexities, like fault bends, multiple strands, branches and stepovers. How do earthquakes choose their paths through such complex fault systems? What makes rupture stop? When and why might a fault branch be preferred? Would the rupture continue as well along the main fault? Can we see the directivity of past ruptures from structures left in their wake? What are the origins of high frequency ground motion? How do short fault branches interact with the main rupture propagation? Could they arrest rupture? How do supershear ruptures differ from the more typical sub-Rayleigh ones? We address some of these by focusing on the fracture mechanics of rupture transitions through branched or offset fault junctions, and on off-fault stressing associated with rupture propagation. Basic considerations suggest that whether a branch fault is followed or not depends on the orientation of the pre-stress state and the speed of propagation at the junction. Numerical simulations of rupture dynamics based on slip-weakening failure have reinforced and refined the concepts of path selection at junctions and near-fault damage. Resulting predictions are shown to be in qualitative accord with observations on natural thrust (including subduction) and strike-slip fault systems, including those active in recent California earthquakes and others worldwide, and with laboratory studies of rupture dynamics. Understanding the mechanics of rupture through offset fault systems is equally important, and some progress has been made to answer the question of whether a rupturing fault would stop or not, and comparisons were made with historical earthquakes. Often, fault branching and offsets occur simultaneously, and questions still abound; that is, in a given geological setting, it is not yet possible to fully predict the dynamic behavior of a developing rupture. Of course there is still an added complexity stemming from the past earthquakes on the same fault system, and their stress/damage effects; a start has been made on addressing that.