Dynamics of Fault and Fracture Networks

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Earthquakes occur on a fault (or a fault network) where the brittle crust is already weakened and the deformation tends to localise. However, these faults themselves form a complex network, at kilometric scales, of such localised zones. These fault networks, loaded at a fairly constant rate in the far-field, are 'frictionally locked' for a long period of time (inter-seismic period, 10's - 1000's of years), allowing the medium to accumulate strain energy, until a 'slip instability' develops (nucleation) at a particular location releasing the accumulated strain energy and radiating stress waves. It then becomes dynamically unstable leading to its growth (dynamic rupture propagation, 10's - 100's of seconds). As it grows along the fault network, it tends to choose its 'path' based on a complex interplay between local stress state (pre-existing before and changing during the rupture), frictional resistance (which evolves through time) and the overall 'stiffness' of the medium hosting the fault network. For eg. the 1992 M_w7.3 Landers earthquake in the eastern California shear zone ruptured a part of the complex fault network where it navigated bends, branched and jumped from one fault to another before arresting. To add to this kilometric scale complexity of fault networks, smaller scale fracture networks (10's - 100's of meter) are activated 'off-fault' during earthquake propagation. Such smaller scale fracture networks are collectively called the 'off-fault damage' and are activated because of large stress concentration carried by the tip of the dynamic rupture propagating on the complex fault network making them intimately coupled with each other. Thus, the accumulated strain energy is released not only by the rupture navigating a complex fault network but by also shattering the crust with smaller scale fracture networks in the damage zone. Developing, understanding and modelling the underlying physics of fault network dynamics will allow us to quantify the susceptibility of fault network to devastating earthquakes and its associated ground accelerations. The talk is divided along two themes. The first one is to understand how the fault network operates over large time scales allowing us to model creep, slow slip events and earthquakes. The second theme is to understand how a dynamic rupture navigates a complex fault network, how it activates off-fault damage and the coupling between them.