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Numerical modelling of the effects of Young's modulus on fault displacement

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Seismogenic faults are often modelled as mode II or mode III cracks in semi-infinite elastic bodies or half spaces. These models normally assume that the elastic properties of the crustal segment hosting a fault are uniform, that is, that the host rock is homogeneous and isotropic. Although such assumptions may be justified (and needed) when using closed-form analytical solutions, they are definitely not justified when trying to understand fault-displacement profiles as measured along the rupture sites following earthquakes. This follows because field studies show that there are thick zones around major faults where the mechanical properties of the host rock are affected by fault itself. And these properties, in turn, largely determine the slips that occur during individual earthquakes.

More specifically, field studies during the past decades indicate that all major faults zones consist of several mechanical units that run parallel with the fault plane. The main units are a damage zone (consisting primarily of fractures) and a fault core (characterised by fault rocks such as breccia and gouge). The field observations, however, also show that the attitudes and intensities of the fractures associated with the damage zones change with distances from the fault cores. This fault-damage zone is thus commonly composed of subzones, all of which have different mechanical properties.

During the evolution of an active seismogenic fault, the effective Young's moduli of its damage zone and fault core normally decrease. By contrast, for an inactive fault, the effective Young's moduli of the core and damage zone may increase because of healing and sealing of the associated fault rocks and fractures.

We made many numerical models on dip-slip and strike-slip fault zones consisting of fault cores and damage zones of various thicknesses and Young's moduli (stiffnesses).

We divide the damage zone into several subzones where each subzone has a Young's modulus depending on its mechanical properties, mainly the fracture frequency. The main results of the numerical models may be summarised as follows.

First, in models where the damage-zone thickness around a fault increases with time, the maximum displacement (u) on the fault, for a fault of a given length and loading conditions, gradually increases. This implies that, for an active seismogenic fault of a rupture (trace) length (L), the ratio of the maximum displacement (u) to the rupture (trace) length of the fault decreases with time.

Second, the fault-displacement curves remain geometrically similar irrespective of the maximum displacement. Thus, when the damage-zone increases in thickness as the fault zone evolves, the fault slip generated during a particular earthquake may increase in size, as indicated above. Nevertheless, during the evolution of the fault its displacement (slip) profile remains similar as regards shape; namely, a smooth, convex curve with a maximum displacement at the fault centre and the minimum displacements at the lateral tips of the fault.

Gudmundsson, A., 2004. Effects of Young's modulus on fault displacement. C.R. Geosciences, 336, 85-92.