Effects of damage-zone thickness on fault displacement
Poster

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When viewed as ideal elastic cracks, seismogenic faults are often modeled as mode II or mode III cracks in semi-infinite elastic bodies or half spaces. These models normally assume the rock to be homogeneous and isotropic. Such assumptions may be justified and necessary when using closed-form analytical solutions for fault displacement. They are not justified, however, when we attempt to understand fault-displacement profiles along earthquake rupture sites or in paleofault studies. This follows because crustal segments hosting faults are, as a rule, not homogeneous and isotropic, but rather heterogeneous and anisotropic. In particular, the fault rocks commonly form layers or units parallel with the fault plane. Also, the mechanical properties of the rocks next to the fault change as the fault develops (Gudmundsson 2004). During repeated earthquakes in a seismogenic fault zone, two main rock units develop around the fault plane. One unit is the core, located next to the fault plane and normally composed of soft (low Young's modulus) breccia, gouge, and other cataclastic rocks. The other unit is the damage zone, containing some cataclastic rocks but characterized by fractures of various types. Field studies show that the fracture frequency in the damage zone is often quite variable, but normally decreases with distance from the core-damage zone boundary; similar results are obtained for microfaults in laboratory experiments (Shimada 2000). The higher the fracture frequency, the lower will be the effective Young's modulus (stiffness) in a direction perpendicular to the main fracture trend. The Young's modulus of a damage zone thus normally decreases on approaching the fault core (Fig. 1). On the basis of variations in fracture frequency, the damage zone associated with a fault can commonly be divided into several subzones or units, each with a different effective stiffness (Gudmundsson & Brenner 2003).

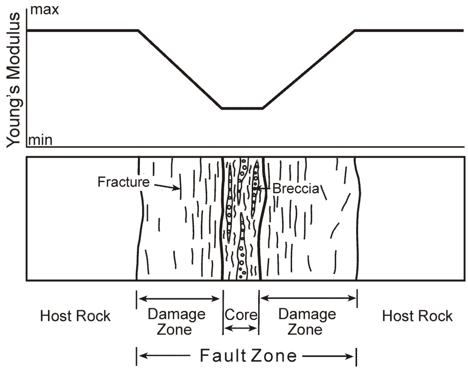

Figure 1: Fault zones consist of two main mechanical units: a comparatively thin core and a much thicker damage zone. The effective Young's modulus (stiffness) gradually decreases from the host rock to the boundary between the core and the damage zone.

Field studies also show that as the fault zone evolves the core and the damage zone both increase in thickness. A fault zone composed of units (core and damage zone) with stiffnesses that are different from those of the host rock develops local stresses that may be very different from the far-field stresses (Gudmundsson & Brenner 2003).

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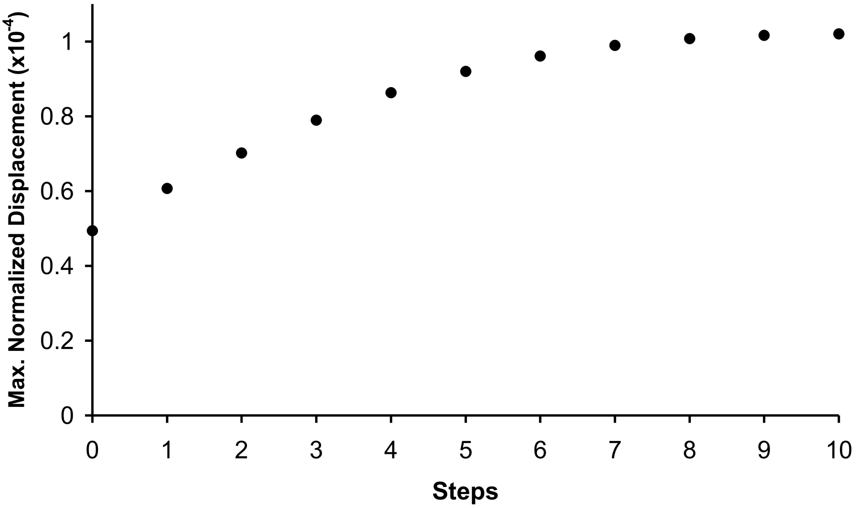

Figure 2: Boundary-element model of fault displacement when the damage-zone thickness is gradually increased in 10 steps, showing the maximum normalized displacement (MND) in the fault center in each of the steps. Here MND $= 10^4 \frac{\text{MD}}{\text{FL}}$, where MD is the maximum displacement and FL the fault length, both expressed in model length units.

Using these observations as a basis, we present numerical results on how the fault slip in a fault zone, for given fault geometry and loading conditions, may change when the thickness of its damage zone increases. Our results indicate that when the damage-zone thickness gradually increases, the maximum displacement on the fault also increases (Fig. 2). It follows that the fault slip generated during a particular earthquake, including the postseismic slip, may gradually increase with increasing damage-zone thickness. Thus, for an active seismogenic fault of constant rupture (trace) length, the ratio of the maximum displacement to the rupture length should decrease with time. These theoretical results are supported by field observations.

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