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The effect of geometrical irregularities on damage zone width: Modeling and field observations

Yuval Tal[1] and Daniel Faulkner[2]
[1]Department of Geological and Environmental Sciences, Ben-Gurion University of the Negev, Beer-Sheva, Israel (yuvtal@bgu.ac.il)
[2]Department Earth, Ocean and Ecological Sciences, University of Liverpool, Liverpool, UK (faulkner@liverpool.ac.uk)

Geological and geophysical observations of fault zones reveal that fault cores are surrounded by regions of damaged rocks consist of fractures at a wide range of length scales with decaying intensity with distance from the fault core. The main mechanisms proposed for the development of off-fault damage include slip on faults with geometrical irregularities, migrating process zones, and dynamic damage from the passage of earthquake ruptures. Field observations of relatively deep exhumed fault zones have shown that fault damage zone width scales with the displacement on a fault. In this study, we combine such observations with numerical modeling to test what is the dominant mechanism producing off-fault damage at depth of several kilometres.

The field data [Faulkner et al., 2011] include measurements of micro-fracture damage zone width from small displacement fault zones within the Atacama fault zone in northern Chile that formed at ∼6 km depth within a dioritic protolith. An increase in damage zone width with displacement is clearly seen. We perform simulations of slip on synthetic faults, with roughness properties similar to that of natural faults, and examine how the total slip and roughness characteristics affect the extent and intensity of inelastic deformation to constrain the geometrical and frictional properties that could generate the observed damage. To accurately account for the effects of geometrical irregularities on the fault and allow slip that is large relative to the size the minimum roughness wavelength, we use the mortar finite element method, in which non-matching meshes are allowed across the fault and the contacts are continuously updated. Inelastic deformation of the bulk is modelled with Drucker–Prager viscoplasticity, which is a simple choice for describing cracked medium and is closely related to the Mohr–Coulomb model. Our results indicate that, for the depth and fault lengths in the field data, geometrical irregularities produce the scaling of damage zone width with displacement observed in the field and suggest that this, rather than the other mechanisms, produce most of the damage.