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Infrastructures, local stresses, slips, and fluid-transport properties of active faults

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Fault zones consist of two main hydromechanical units: a fault core and a fault damage zone. The core is primarily composed of breccia and gouge and other fault rocks whereas the damage zone, while containing some lenses of breccia, is characterised by fractures of various types. In a seismogenic fault that is frequently active, the core is normally soft (with a low Young's modulus). If the fault is inactive for a long time, however, healing, sealing and secondary mineralisation may make the core stiff (with a high Young's modulus).

The fracture frequency in the damage zone is often quite variable, but normally decreases with distance from the core-damage zone boundary. Fracture frequency and orientation affects the rock stiffness: normally, the higher the frequency the lower the effective stiffness in a direction perpendicular to the main fracture direction. It follows that the stiffness of a damage zone commonly changes, normally decreases, on approaching the fault core.

During inactive periods, the fault damage zone is normally the part of the fault zone which has the highest permeability. However, just prior to and following a major slip (an earthquake) on a fault, the permeability of the core and, especially, the core-damage zone contact may increase enormously. This permeability increase may have great effects on the transport of crustal fluids such as groundwater and geothermal water. The size of the rupture zone, including the fault plane, as well as the permeability effects on the surrounding rocks depend much on the local stresses associated with the fault zone just prior to the earthquake. Similarly, the fault slip during the earthquake depends much on this stress state. The stress conditions, in turn, are largely a function of the mechanical properties, particularly the stiffness, of the rocks in the damage zone and in the core as well as the thicknesses of these units.

Field observations indicate that the cores and, in particular, the damage zones tend to increase in thickness with total fault displacement (fault age). Here we present new numerical models on strike-slip fault zones showing how the local stresses and displacements (slips) depend on the stiffnesses of the core and the damage zone. We vary the stiffness of the core, depending on whether the fault zone is highly active or has been inactive for a long time prior to the present earthquake. The results show that when the damage zone becomes thicker (measured in a direction perpendicular to the trend of the fault zone) then, for a given fault geometry and loading conditions, the fault slip (displacement) increases. This indicates that as an active strike-slip fault becomes older, the slips in individual equal-length ruptures would tend to increase.

We also made numerical models where the lateral tips of a strike-slip fault end inside, or nearby, soft inclusions such as hyaloclastite mountains - as are common in the South Iceland Seismic Zone. The results show, first, that when the fault tips end in the weak inclusion, then the displacement (size of slip) is mostly similar along the entire fault until near the tips where it decreases abruptly. Second, when the soft inclusions are at gradually increasing distances from the fault tips, the fault displacement becomes more similar to that of the same fault in a homogeneous, isotropic material (without inclusions). Also, in this second case the fault displacement is generally much less than when the fault tips are located near, or inside, soft inclusions. These results have important implications for the sizes and shapes of strike-slip fault profiles when the fault tips end within soft inclusions such as hyaloclastite mountains, as are common in South Iceland, or active rift zones as are common at tips of oceanic transform faults worldwide.

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