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Three dimensional failure envelopes for complex fault systems. A numerical investigation

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The shear rupture strength of a fault has long time been related to the frictional properties and the stress conditions applied to its surface. However, faults in the Earth's crust are parts of fault systems and are therefore frequently segmented, branched or more complex in their 3-D shape. This complexity results in strong fault mechanical interaction through their stress field, which implies heterogeneities in their slip distribution and magnitudes. The rupture strength of a fault zone or a fault system must therefore be dependent both on the frictional properties of the fault surfaces and their 3-D geometry. With a numerical approach, we propose to investigate the shape of macroscopic shear failure envelopes as a function of the geometry of different synthetic and natural 3D fault systems, and its interplay with static friction laws.

The numerical modeling is performed using iBem3D (former Poly3D), a 3D Boundary Element Method (BEM) using linear elasticity in heterogeneous, isotropic whole- of half-space, with application in structural geology for the evaluation of the deformation and perturbed stress field associated with surfaces of displacement discontinuity. In this code, each fault is discretized as a complex 3D triangulated surface with specific boundary conditions such as the static Coulomb friction inequality constraint. In order to run thousands of simulations by varying the far field stress parameters as well as the coefficient of friction , we use Scribble a scripting language for iBem3D. The remote variables are incremented in 20 steps, whereas the critical friction variable is determined by a 20 steps dichotomy, leading to a total of 8,000 simulations. 3D failure envelopes are consequently generated and plotted as complex surfaces for several scenarios of fault configuration.

Results show that macroscopic failure envelopes for the whole fault system are non planar and potentially complex in shape, as the function of the 3-D fault system geometry. This modelling approach has been applied to simulate seismic hazard in the 3D fault system of the Olkiluoto nuclear waste repository site. In this model, friction, cohesion and ice thickness represent the three variables of the failure envelope, and aims at relating computed slip patches and residual stress along reactivated faults with seismic hazard and fault leakage capacity.