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Hydro-mechanical modeling of seismogenic asperity loaded by aseismic slip through TOUGH-BIEM simulation

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We consider seismogenic asperities loaded by aseismic slip on a fault, which is induced by fluid circulation, as a simple example of fault reactivation. For this purpose, we combine two methods. The TOUGH2 (Transport Of Unsaturated Ground water and Heat) code is used for modeling the pore pressure evolution within a fault and then a Boundary Integral Equation Method (BIEM) is applied for simulating fault slip, including aseismic slip on the entire fault plane and fast slip on seismogenic asperities. The fault permeability is assumed stress-dependent and therefore is not constant but varies during a simulation. We adopt the Coulomb friction and a cyclic slip-strengthening-then-weakening friction model governing the fault slip, which allows for repeated asperity slip. We were able to demonstrate the entire process from the fluid injection, pore pressure increase, aseismic slip to seismogenic asperity slip. We tested a step-like increase of injection rate with time, which is common for hydraulic fracturing and reservoir stimulation at deep geothermal sites. Under this configuration, the pore pressure increase is not proportional to the injection rate, as the permeability depends on the stress. Fault slip on seismogenic asperities is triggered repeatedly by surrounding aseismic slip. We find, in a given example, that the recurrence of the fast slip on asperity is approximately proportional to the injected fluid volume, inferring that the aseismic slip amount increases proportionally to the fluid volume as well.