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Effects of asperities distribution on induced seismicity and permeability during deep underground exploitation

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Many induced earthquake sequences could be seen as the rupture of brittle asperities along a fault zone, in response to fluid pressure changes generated by an injection at depth. Furthermore, the relocation of seismicity shows that these brittle patches only cluster on particular regions of the fault zone, which indicates that other portions of the fault are either creeping or not activated during the injection. This shearing behavior indicates heterogeneous permeability conditions within the fault zone. Here, we investigate the injection-induced seismic response of a heterogeneous fault plane: the fault core is represented by brittle asperities with low permeability, while the fault damage zone, embedding the core, features a higher permeability and ductile matrix. We simulate the fluid flow and pressure evolution by means of a hydrogeological numerical simulator, accounting for the heterogeneous. Seismicity occurs then on the asperities, represented as unstable patches that can reactivate following a Mohr-Coulomb criterion. The hydrogeological and first-order mechanical models are implicitly coupled to account for effects of shear displacement on the permeability changes.

We performed a sensitivity analysis on the parameter affecting the pressure distribution and cloud of seismicity, such as coupling parameters, density of asperities, and initial permeability distribution. Results show that such permeability changes may cause at a later time, after injection stopped, a change in seismicity propagation. Although simplified, our first-order analysis provides a reasonable explanation of the induced seismicity propagation during fault stimulation.