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Hydro-mechanical modeling of injection-induced seismicity at the Deep Heat Mining Project of Basel, Switzerland

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Fluid injection in subsurface reservoirs often induces seismicity, which is a limiting factor in the deployment of geo-energies, as it is the case for Enhanced Geothermal Systems (EGS). EGS are commonly deep granitic reservoirs subject to hydraulic stimulation in order to enhance the fracture permeability and consequently the heat production. Injection-induced seismicity occurs also after the stop of injection, and in many cases the largest earthquakes occur after the shut-in. The counterintuitive post-injection large magnitude seismicity is still not well understood and its modelling is necessary to improve the understanding of the processes triggering the seismicity. Pressure-driven processes, as pore pressure increase and poroelastic stress/strain variations, have been identified as triggers of seismicity, together with stress interactions, thermal disparities and geomechanical interactions. We design a coupled hydro-mechanical 2D model of the well-known case of post-injection induced seismicity of Basel EGS (Deep Heat Mining Project at Basel, Switzerland, 2006). We use CODE_BRIGHT, a finite element method software able to perform monolithic coupled thermo-hydro-mechanical analysis in geological media. The faults respond to a Mohr-Coulomb failure criterion with strain weakening and dilatancy, which allow to simulate fault reactivation and its aperture variation. The model is able to reproduce the pressure and stress variations, and the consequent fault reactivations through the simulations. The Basel EGS has been well documented and its characteristics are available. We are able to reproduce the spatio-temporal induced seismicity. Yet, our current numerical method takes long computational time. To speed up simulations, we simplify the model geometry by grouping faults that yield similar static stress transfer, computed with the code Coulomb3, which solves an analytical solution to compute stress changes caused by fault slip. The combination of numerical with analytical solutions is an effective way of obtaining faster computing models. By simultaneously assimilating monitoring data in real-time with an efficient computing model would enable a better understanding of the fluid-injection effects on the stability of the reservoir, and potentially the mitigation of the induced seismicity.