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Modeling the effects of hydraulic stimulation on geothermal reservoirs

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Geothermal energy represents a huge power source that can provide clean energy in potentially unlimited supply. When designing geothermal energy production from deep hot rocks, permeability is considered to control the economic efficiency of the heat extraction operations. In fact, a high permeability heat exchanger is required to achieve a cost-competitive power generation. The typical procedure entails intercepting naturally fractured rocks and enhancing their permeability by means of stimulation. Hydraulic stimulation is the most widely used method. It involves the massive injection of a large volume of water at high flow rates to increase the downhole pore pressure. This overpressure reduces the effective stresses, which tends to induce shearing along the fracture planes. In this way permeability is enhanced due to dilatancy, especially in the direction perpendicular to shear. These processes usually trigger microseismic events, which are sometimes of sufficient magnitude to be felt by the local population. This causes a negative impact on the local population and may compromise the continuation of the project. Hence, understanding the mechanisms triggering these induced micro-earthquakes is important to properly design and manage geothermal stimulation and operations so as to prevent them.
We analyzed the thermo-hydro-mechanical response of a fractured deep rock mass subjected to hydraulic stimulation. Considering that seismicity is triggered when failure condition are reached, we studied the variation of the stress regime due to the hydraulic and thermal perturbations during fluid injection. Starting with a simplified model with constant permeability fault zones, more sophisticated schemes are considered to simulate the behavior of the discontinuity zones, including permeability variation associated to temperature, pressure and stress regime changes. Numerical simulations are performed using the finite element numerical code CODE_BRIGHT, which allows to solve fully coupled thermo-hydro-mechanical problems. Results allowed to estimate the impact of the hydraulic stimulation on the overall behavior.