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Numerical simulation of hydroshearing in fractured crystalline rock at the Bedretto Underground Laboratory (Switzerland)

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Hydroshearing, or shear stimulation, is recognized as the main method to exploit geothermal energy in hot low-permeability crystalline rocks at depth. It consists of enhancing permeability via injection-induced shear slip and dilation of preexisting fractures. Hydroshearing usually causes some induced microseismicity, sometimes of sufficient magnitude to be felt on the surface. Thus, high-pressure fluid injection to enhance fracture permeability should be made carefully to avoid inducing earthquakes above the acceptable magnitude.
The process of hydroshearing is theoretically well understood and numerical models are capable of simulating it. However, fundamental investigations at the field scale are limited. This study focuses on the modeling of a hydraulic stimulation carried out at the Bedretto Underground Laboratory for Geosciences and Geoenergies (BULGG), in Switzerland, to investigate hydro-mechanical coupled processes due to fluid injection into fractured granite. We examine three numerical models with increasing complexity (a model with calibrated time-variable permeability, a model with strain-dependent permeability, and a model incorporating viscoplasticity with strain weakening and dilatancy) to improve the simulation and capture the hydro-mechanical response of the fractured rock mass.
The first model yields a reasonable fitting to measured overpressures at the injection borehole. Yet, the pore pressure distribution and the corresponding poromechanical response of the rock are not well captured. Employing an embedded model to calculate permeability changes as a function of volumetric strain improves the temporal evolution of overpressure at the injection borehole at the early stages of stimulation, but overestimates it once the fracture undergoes shear slip. Using a viscoplastic constitutive law with strain softening and dilatancy results in an additional enhancement of fracture permeability and thus a better reproduction of the monitored overpressures. The results show that the timestamps of monitored microseismic events correlate well with the times when permeability enhancement surpasses the previously maximum amount in each injection cycle.

Participation

In-Person

References

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