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Post-injection induced seismicity provoked by superposition of different mechanisms.

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Induced microseismicity is a controversial issue related to fluid injection into deep geological formations. The occurring of felt earthquakes after stopping injection especially generates concern, because the correlation between injection and seismic activity is unclear. Thus, advancing in its understanding is crucial to minimize its occurrence. Here, we perform numerical simulations of hydraulic stimulation of deep geothermal systems to analyze the mechanisms that may induce or trigger co- and post-injection seismicity. Apart from the direct impact of fluid pressure increase, we acknowledge thermal effects due to cooling and stress redistribution due to fault slip. We analyze the effect of these three processes both separately and superimposed.

We find that preferential flow through conductive fractures or fault zones provokes pressure and temperature perturbations that result in not only heterogeneous variation of the stress field, but also highly anisotropic variations of the local stress tensor. Anisotropic variations tend to stabilize some fractures, but destabilize others. Moreover, shear slip causes a significant variation of the stress field that enlarges the range of critical fracture orientations. We find that, given the different response times of mechanical, hydraulic and thermal effects, post-injection seismicity may occur on non-critically oriented faults that were originally stable. During injection, such faults become destabilized by thermal and shear slip stress changes, but remain static by the superposition of pressure forcing. However, they become unstable and fail when the pressure forcing dissipates shortly after injection stops abruptly.