A Coulomb Stress Model to Simulate Induced Seismicity Due to Fluid Injection and Withdrawal in Deep Boreholes.

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Abstract

Fluid injection and withdrawal in deep wells is a basic procedure in mining activities and deep resources exploitation, i.e. oil and gas extraction, geothermal exploitation, geothermal permeability enhancement and waste fluid disposal.
All these activities have the potential to induce seismicity, as dramatically demonstrated by the 2006 Basilea earthquake of magnitude ML=3.4. The mechanism of induced seismicity, despite several decades of experience, is not known in details, preventing an effective assessment and/or mitigation. In this work, we give an interpretation of induced seismicity based on the computation of Coulomb fracture stress changes resulting from fluid injection/withdrawal at depth, mainly focused to interpret induced seismicity due to Enhanced Geothermal System (EGS) reservoir stimulation. Seismicity is in fact, theoretically, more likely where Coulomb fracture stress changes are larger. For modeling purposes, here we simulate the thermodynamic evolution of the system where fluids are injected/withdrawn. The retrieved changes of Pressure and Temperature are subsequently considered as sources of incremental stress changes, which are then converted to Coulomb stress changes on favored faults, taking into account also the background regional stress. Numerical results are then applied to simulate the water injection stimulation used to create the fractured reservoir at the Soultz-sous-Forets (France) EGS site. The obtained results show that our approach gives a very good description of induced seismicity, and gives a natural explanation to the different impact between fluid injection and withdrawal. In particular, it accurately reproduces induced seismicity at EGS sites, thus representing a powerful tool for its interpretation and mitigation.