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Deep geothermal systems interpreted by coupled thermo-hydraulic-mechanical-chemical numerical modeling

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The dynamic response of the geothermal reservoirs of Soultz-sous-Forêts (NE France) and a new site in Iceland are theoretically studied upon fluid injection and production. Since the Soultz case can be considered the most comprehensive project in the area of enhanced geothermal systems (EGS), it is tailored for the testing of forward modeling techniques that aim at the characterization of fluid dynamics and mechanical properties in any deeply-seated fractured cystalline reservoir [e.g. Held et al., 2014].
We present multi-physics finite element models using the recently developed framework MOOSE (mooseframework.org) that implicitly consider fully-coupled feedback mechanisms of fluid-rock interaction at depth where EGS are located (depth > 5 km), i.e. the effects of dissipative strain softening on chemical reactions and reactive transport [Poulet et al., 2016]. In a first suite of numerical experiments, we show that an accurate simulation of propagation fronts allows studying coupled fluid and heat transport, following preferred pathways, and the transport time of the geothermal fluid between injection and production wells, which is in good agreement with tracer experiments performed inside the natural reservoir. Based on induced seismicity experiments and related damage along boreholes, we concern with borehole instabilities resulting from pore pressure variations and (a)seismic creep in a second series of simulations. To this end, we account for volumetric and deviatoric components, following the approach of Veveakis et al. (2016), and discuss the mechanisms triggering slow earthquakes in the stimulated reservoirs.
Our study will allow applying concepts of unconventional geomechanics, which were previously reviewed on a theoretical basis [Regenauer-Lieb et al., 2015], to substantial engineering problems of deep geothermal reservoirs in the future.

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