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Effect of the fault zone architecture on injection-induced seismicity

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Injection of a large amount of wastewater for subsurface energy activities can increase pore pressure and change the stress field. In particular, direct pore-pressure diffusion and/or indirect stress transmission are primarily responsible for destabilizing the fault system, potentially inducing earthquakes. Understanding the potential to induced seismicity due to water injection in a reservoir requires characterization of both fault-zone permeability structure and the response of that structure to changes in pore pressure and stress over time.
The incorporation of low-permeability clay or shale into the fault core via deformation is commonly accepted to describe the permeability reduction in the fault system where the fault core and damage zones typically show heterogeneous and anisotropic properties. The presence of low- (or high)-permeability structures within the fault zone can prevent (or enhance) pore-pressure diffusion even along the conductive pathway and subsequent gradients will perturb the stress state.

In this three-dimensional modeling study, we simulate a three-layer formation where the basement is intersected by a strike-slip fault. We examine the full poroelastic response of the faults to fluid injection and perform the mechanical analysis along the fault zone using the Coulomb stress change. Low-permeability barriers within a high-permeability fault cause localized pressure buildup, subsequently a larger Coulomb failure stress. For a low-permeability fault where poroelastic stress still weakens the fault, high-permeability structures can magnify fault instability depending on injection operations and/or bounding basement properties. Simulation results demonstrate that the impact of wastewater injection on seismic hazards requires accurate characterization of the fault zone architecture. In addition, comparison of 3D and 2D simulations will be performed to evaluate if 2D numerical simulations will address the same mechanistic behaviors compared to 3D simulations.

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