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The nucleation patterns of injection-induced earthquakes

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Recent observations have shown that changes in pore pressure due to the injection of fluids into underground formations may induce potentially damaging earthquakes or increase the sensitivity of injection sites to remote triggering. The basic mechanisms behind injection-induced seismicity are: (1) the increase of pore pressure reduces the effective normal compressive stresses, while induces deformations in the rock which increase the total normal compressive stress, and (2) the poroelastic effect causes additional shear stresses along the fault, with either a stabilizing or destabilizing effect depending on both the fault orientation and the injection well location.

We have developed a numerical simulation procedure to analyze the features involved in the nucleation of injection-induced earthquakes. The framework includes both fault frictional contact described by the Dieterich–Ruina rate-and-state law and poroelastic constitutive relations for the rock. We model the earthquake triggering through the injection of a fluid near a strike-slip fault surrounded by a homogeneous two-dimensional saturated domain and investigate the nucleation phase until the seismic rupture. The knowledge of the fault response during this phase is essential, since nucleation patterns may provide the key to detect preseismic signals and estimate the magnitude of the resulting earthquake. We also elucidate the poroelastic effects on the nucleation process. Finally, we describe the mechanisms that control the evolution of the fault shear strength and the path to instability, as well as the nucleation styles.

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