The nucleation of injection-induced earthquakes: The role of poroelasticity

David Santillán, Universidad Politécnica de Madrid. Departamento de Ingeniería Civil: Hidráulica, Energía y Medio Ambiente, Spain.
Juan-Carlos Mosquera, Universidad Politécnica de Madrid. Departamento de Mecánica de Medios Continuos y Teoría de Estructuras, Spain.
Luis Cueto-Felgueroso, Universidad Politécnica de Madrid. Departamento de Ingeniería Civil: Hidráulica, Energía y Medio Ambiente, Spain.

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Recent observations have shown that changes in pore pressure due to the injection or extraction of fluids from underground formations may induce potentially damaging earthquakes or increase the sensitivity of injection sites to remote triggering. The basic mechanism behind injection-induced seismicity is a change in effective stress, which weakens preexisting faults.

We have developed a numerical framework with fault frictional contact described by the Dieterich–Ruina rate- and state-dependent constitutive law and we model rock as a poroelastic solid. We investigate the nucleation phase earthquakes, the transition from quasi-static stable sliding to dynamic rupture. 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 study the poroelasticity effects on the earthquake nucleation process. We describe the mechanisms that control the evolution of the fault strength and the path to instability, as well as the nucleation styles leading to unstable slips. Our result indicates that the poroelastic coupling plays an important role on the earthquake nucleation, resulting in lower slips and nucleation lengths, as well as a delayed onset of the instability.

Figure 1: Left: Schematic of the model. We simulate water injection at constant flow rate into a horizontal square poroelastic domain of size 5000 m. A fault of length 2000 m intersects the domain. The injection well is 100 m far from the fault. We impose tectonic stress at the boundaries with a ratio of 2. Right: Evolution of slip at the point of the fault where the rupture starts prior to the dynamic phase for three sets of the parameters of the rate-and state friction model. In the insets we plot the evolution of the slip-velocities along the fault for two cases.