EGU21-3329, updated on 01 Dec 2021
https://doi.org/10.5194/egusphere-egu21-3329
EGU General Assembly 2021

The impact of fault permeability on the nucleation of injection-induced earthquakes

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Injection-induced seismicity has become a central issue in the development of subsurface energy technologies such as enhanced geothermal energy, unconventional hydrocarbon production, wastewater injection, geologic carbon sequestration, or underground gas storage. The effect of the hydraulic properties of faults on the nucleation of earthquakes is a key aspect poorly understood. Our research question is how these properties may alter the onset of slip, the nucleation pattern, the nucleation length, and the time to nucleation.

We simulate earthquakes by means of sophisticated 2-dimensional computational models where earthquakes are triggered by fluid injection. The fault frictional contact is described by the Dieterich–Ruina rate-and-state law. Rock is simulated as a poroelastic solid and we couple fluid flow and rock mechanics.

Our model allows us to explain the impact of longitudinal and transverse fault permeability on the mechanisms that control the evolution of fault strength and shear stress during the nucleation. We find that the nucleation is controlled by the pressure and shear stress profiles along the fault, which in turn are driven by the fault hydraulic properties. Therefore, fault permeability exerts a fundamental control on the scaling of the nucleation length, the nucleation pattern, and the time to nucleation.

Acknowledgements: Project supported by a 2019 Leonardo Grant for Researchers and Cultural Creators, BBVA Foundation. The BBVA Foundation accepts no responsibility for the opinions, statements and contents included in the project and/or the results thereof, which are entirely the responsibility of the authors.