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Fluid viscosity controls earthquakes nucleation

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Monitoring of geothermal reservoirs demonstrated the relationship between injection of pressurized fluids close to a fault zone and the increase of seismicity. However, the role played by fluid viscosity in the nucleation of induced and natural earthquakes remains poorly constrained.

Here, we reproduced the earthquake cycle in a laboratory fault under both room-humidity and drained pore fluid conditions (P_f=2 MPa, with fluids having viscosities of 1, 10, 108 and 1226 mPa•s at 20 ˚C, respectively). We used a rotary shear apparatus (SHIVA) that allowed us to investigate precursory patterns and to explore general stability criteria for earthquake nucleation. The experimental procedure consisted in increasing step-wise the shear stress ($\Delta\tau$=0.5 MPa every t=1000 s) acting on experimental granitic faults under a constant effective normal stress s_n=10 MPa and allowing the slip rate and slip to adjust spontaneously.

Under room-humidity conditions, the step-wise increase in τgriggered initially slow slip-rate (creep, V<<1 mm/s) and short-lived (slip<<0.01 mm) high slip rate (V∼1 mm/s) stick-slip events which eventually evolved into high slip rate (V∼10 mm/s) and long-lived slip (>10 mm) events (on-fault main shocks). Instead, in the presence of viscous fluids, slip evolved from slow slip rate to long-lived high slip rate events without precursory events. The nucleation of the first large slip event occurred at same shear stress (∼7 MPa, corresponding to a typical friction coefficient of m=tvs_n ∼0.7) and independently of the viscosity of the fluid. However, the slip necessary to spontaneously arrest the long lived slip event increased with the viscosity of the fluid.

The experimental evidence suggests that the injection of the more viscous fluids in pre-loaded faults triggers large (seismic) slip without seismic precursors. As a consequence, once the stiffness of the natural reservoir is known, the kind of monitoring for seismic hazard studies should change with the type of fluid injected: for low viscosity fluids, seismic monitoring might be enough (i.e., the traffic light system). For high viscosity fluids, seismic attenuation and especially measurements of creep rates are more important.