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Influence of fluid pressure level on the nucleation of laboratory earthquakes.

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Recent seismological observations highlighted that both aseismic silent slip or foreshock sequences can precede large earthquake ruptures (Tohoku-Oki, 2011, Mw 9.0; Iquique, 2014, Mw 8.1; Illapel, 2015, Mw 8.3). Moreover, experimental studies demonstrated that pore fluid pressure contributes to the on onset of stable or silent slip, suggesting that pore fluid pressure could control the behaviour of earthquake's nucleation. However, the influence of pore fluid pressure level on the earthquake nucleation behaviour remains poorly understood. Here, we report for the first time, experimental results regarding the nucleation of stick-slip instabilities (laboratory proxies for earthquakes) conducted on Westerly Granite saw-cut samples. Experiments were conducted under stress conditions representative of the upper continental crust, i.e confining pressures from 50 to 125 MPa; fluid pressures (water and argon) ranging from 0 to 45 MPa; and temperatures ranging from 25 to 500˚C.

In all conditions tested, we observe that slip evolves exponentially up to the main instabilities. While this precursory stage is escorted with an exponential increase of acoustic emissions in dry conditions, precursory slip remains silent in presence of fluid, independently of the fluid pressure level. The amount of precursory slip (uprec) depends on both fluid pressure and initial shear stress. While increasing the initial shear stress leads to larger precursory slip, increasing the fluid pressure seems to reduce the amount of precursory slip leading to instabilities. Independently of the fluid pressure level, we demonstrate that the amount of precursory mechanical work (τ* uprec) released prior to the mainshock (the energy dissipated during the precursory stage) scales linearly with the fracture energy of the main instability ($\Delta\tau$* ucos). These results suggest that the intensity of the precursory stage is a function of the strength of the asperity which is eventually going to rupture.

Our experimental observations imply that the initial background stress and the pore fluid pressure level control the intensity and the nucleation behaviour of the fault. Such observation indicates that (i) that the presence of foreshock sequences is not systematic during earthquake nucleation and seems attenuated in presence of water, (ii) large ambient pore fluid pressure could reduce the intensity and the duration of the precursory stage.