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# From thermal pressurization to dilatant strengthening during stick-slip ruptures on saturated saw-cut thermally cracked westerly granite

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Earthquakes result from the transient frictional weakening of faults during co-seismic slip. Dry faults weaken due to the degradation of fault asperities by frictional heating (e.g. flash heating). In the presence of fluids, theoretical models predict faults to weaken by thermal pressurization of pore fluid. Despite theoretical predictions, not only numerical models seldom consider the Pressure-Temperature dependence of the fluid properties, but experimental data is also scarce on rock-fluid interactions during dynamic rupture under realistic stress conditions. This study seeks to elucidate how fluid thermodynamic properties influence the respective roles of thermal pressurization and flash heating in fault weakening.
Here, dynamic stick-slip events (SSEs) were experimentally produced under low and high pore fluid pressure conditions on samples of Westerly granite, previously heat treated to enhance their permeability. To investigate the mechanisms driving frictional weakening, fluid pressure was directly monitored on and off the fault during SSEs using in-situ pore fluid sensors. Acoustic emissions, both amplified and unamplified, provided microseismic counts, location, magnitude and rupture velocities of each SSE. The post-SSE temperature was assessed using Raman spectroscopy on a carbon layer deposited along the fault surface.
Preliminary experimental results highlight the transition from thermal pressurization (TP) to dilatant strengthening (DS) and off-fault damage depending on the stress regime. At low shear stress and compaction stage, TP was observed as a coseismic increase in pore fluid pressure for each SSE. On the contrary, in the later stages of our experiment, at higher shear stress accompanied with dilatancy, SSEs were preceded by a pre-seismic drop of on-fault pore fluid pressure, followed by a large coseismic one. Off-fault pore fluid pressure showed a slight increase throughout all SSEs. Strain responses in the sample bulk exhibit unique patterns: dynamic dilatancy followed by dynamic compression during early SSEs, and static dilatancy followed by dynamic compression during later SSEs. Rupture velocity inversions predominantly indicate supershear characteristics. Finally, the slow transition between TP and DS was accompanied by a long phase during which only slow stick-slip ruptures were observed. The mechanism underlying this inversion and the role of fluid pressure behaviors on fault weakening remains to be analyzed.
Eventually, key physical and seismic parameters derived from the experiments will inform numerical models, which will be compared against thermal pressurization theory—adjusted to account for fluid thermodynamic property dependencies—and extrapolated to crustal depths (~2–10 km) where natural earthquake nucleation typically occurs.

## Speaker information

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