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The role of fluid pressure in frictional stability and earthquake triggering: insights from laboratory experiments

Cristiano Collettini (1,2) and Marco Scuderi (1,2)

(1) Dipartimento di Scienze della Terra, Università di Roma LA SAPIENZA, (2) Istituto Nazionale di Geofisica e Vulcanologia, Roma

Fluid overpressure has been proposed as one of the primary mechanisms that facilitate earthquake slip along faults. However, elastic dislocation theory combined with friction laws suggests that fluid overpressure may inhibit the dynamic instabilities that result in earthquakes, by controlling the critical fault stiffness (kc). This controversy poses a serious problem in our understanding of earthquake physics, with severe implications for both natural and human-induced seismic hazard. Nevertheless, currently, there are no systematic studies on the role of fluid pressure under controlled, laboratory conditions for which the evolution of friction parameters and slip stability can be measured. We have used a state-of-the-art biaxial rock deformation apparatus within a pressure vessel, in order to allow a true triaxial stress field, in a double direct shear configuration. We tested carbonate fault gouge, Carrara marble, sieved to a grain size of 125 μm. Normal stresses and confining pressure were held constant throughout the experiment at values of 5 to 40 MPa, and the pore fluid pressure was varied from hydrostatic up to near lithostatic values. Shear stress was induced by a constant displacement rate and sliding velocities varied from 0.1-1000 μm/s, in order to evaluate slip stability via rate- and state- dependent frictional parameters, such as (a-b), Dc and kc. Our data show that sliding velocity controls the values of friction parameters. In addition we observe a general increase of (a-b) and a decrease of Dc with increasing fluid pressure. Our observations suggest that fluid overpressure does not only facilitate fault reactivation but it also influences frictional parameters with important implications for fault stability and earthquake triggering.