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The role of fluid pressure in fault creep vs. frictional instability: insights from rock deformation experiments on carbonates

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Fluid overpressure is one of the primary mechanisms for tectonic fault slip. This mechanism is appealing as fluids lubricate the fault and fluid pressure, Pf, reduces the effective normal stress that holds the fault in place. However, current models of earthquake nucleation imply that stable sliding is favored by the increase of pore fluid pressure. Despite this opposite effects, currently, there are only a few studies on the role of fluid pressure under controlled, laboratory conditions. Here, we use laboratory experiments, conducted on a biaxial apparatus within a pressure vessel on limestone fault gouge, to: 1) evaluate the rate- and state- friction parameters as the pore fluid pressure is increased from hydrostatic to near lithostatic values and 2) fault creep evolution as a function of a step increase in fluid pressure. In this second suite of experiments we reached 85% of the maximum shear strength and than in load control we induced fault slip by increasing fluid pressure. Our data show that the friction rate parameter (a-b) evolves from slightly velocity strengthening to velocity neutral behaviour and the critical slip distance, Dc, decreases from about 100 to 20 μm as the pore fluid pressure is increased. Fault creep is slow (i.e 0.001μm/s) away from the maximum shear strength and for small increases in fluid pressure and it accelerates near the maximum shear strength and for larger fluid pressure build-ups, where we observe episodic accelerations/decelerations that in some cases evolve to small dynamic events. Our data suggest that fluid overpressure can increase aseismic creep with the development of frictional instability. Since fault rheology and fault stability parameters change with fluid pressure, we suggest that a comprehensive characterization of these parameters is fundamental for better assessing the role of fluid pressure in natural and human induced earthquakes.