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Slip behaviour of carbonate-bearing faults subjected to fluid pressure stimulations

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Earthquakes caused by fluid injection within reservoir have become an important topic of political and social discussion as new drilling and improved technologies enable the extraction of oil and gas from previously unproductive formations. During reservoir stimulation, the coupled interactions of frictional and fluid flow properties together with the stress state control both the onset of fault slip and fault slip behaviour. However, currently, there are no studies under controlled, laboratory conditions for which the effect of fluid pressure on fault slip behaviour can be deduced. To cover this gap, we have developed laboratory experiments where we monitor fault slip evolution at constant shear stress but with increasing fluid pressure, i.e. reducing the effective normal stress. Experiments have been conducted in the double direct shear configuration within a pressure vessel on carbonate fault gouge, characterized by a slightly velocity strengthening friction that is indicative of stable aseismic creep. In our experiments fault slip history can be divided in three main stages: 1) for high effective normal stress the fault is locked and undergoes compaction; 2) when the shear and effective normal stress reach the failure condition, accelerated creep is associated to fault dilation; 3) further pressurization leads to an exponential acceleration during fault compaction and slip localization.
Our results indicate that fault weakening induced by fluid pressurization overcomes the velocity strengthening behaviour of calcite gouge, resulting in fast acceleration and earthquake slip. As applied to tectonic faults our results suggest that a larger number of crustal faults, including those slightly velocity strengthening, can experience earthquake slip due to fluid pressurization.