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Dilation and compaction accompanying changes in slip velocity in clay-bearing fault gouges

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Many natural fault cores comprise volumes of extremely fine, low permeability, clay-bearing fault rocks. Should these fault rocks undergo transient volume changes in response to changes in fault slip velocity, the subsequent pore pressure transients would produce significant fault weakening or strengthening, strongly affecting earthquake nucleation and possibly leading to episodic slow slip events. Dilatancy at slow slip velocity has previously been measured in quartz-rich gouges but little is known about gouge containing clay. In this work, the mechanical behaviour of synthetic quartz-kaolinite fault gouges and their volume response to velocity step changes were investigated in a suite of triaxial deformation experiments at effective normal stresses of 60MPa, 25MPa and 10MPa. Kaolinite content was varied from 0 to 100wt% and slip velocity was varied between 0.3 and 3 microns/s.

Upon a 10-fold velocity increase or decrease, gouges of all kaolinite-quartz contents displayed measurable volume change transients. The results show the volume change transients are independent of effective normal stress but are sensitive to gouge kaolinite content. Peak dilation values did not occur in the pure quartz gouges, but rather in gouges containing 10wt% to 20wt% kaolinite. Above a kaolinite content of 10wt% to 20wt%, both dilation and compaction decreased with increasing gouge kaolinite content. At 25MPa effective normal stress, the normalised volume changes decreased from 0.1% to 0.06% at 10wt% to 100wt% kaolinite. The gouge mechanical behaviour shows that increasing the gouge kaolinite content decreases the gouge frictional strength and promotes more stable sliding, rather than earthquake slip. Increasing the effective normal stress slightly decreases the frictional strength, enhances the chance of earthquake nucleation, and has no discernible effect on the magnitude of the pore volume changes during slip velocity changes.

Low permeabilities of clay-rich fault gouges, coupled with the observed volume change transients, could produce pore pressure fluctuations up to 10MPa in response to fault slip. This assumes no fluid escape from an isolated fault core. Where the permeability is finite, any pore pressure changes will be mediated by fluid influx into the gouge. Volume change transients could therefore be a significant factor in determining whether fault slip leads to earthquake nucleation or a dampened response, possibly resulting in episodic slow slip in low permeability fault rock volumes.