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Velocity-weakening in Phyllosilicate-bearing Fault Gouges

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Rotary shear experiments performed on a fault gouge analogue system i.e. muscovite plus halite and brine, have shown that the presence of the phyllosilicate phase and operation of pressure solution have large effects on the frictional behaviour of the gouge under conditions where cataclasis and solution transfer can operate in the halite matrix phase. Our experiments have shown that while 100% halite and 100% muscovite samples exhibit rate-independent frictional/brittle behaviour, the strength of mixtures containing 10-30% muscovite is both normal stress and sliding velocity dependent. At low velocities (<1 μm/s), the strength increases with increasing velocity and normal stress, and a strong mylonitic foliation develops. At high velocities (>1 μm/s), velocity-weakening frictional behaviour occurs, along with the development of a structureless, cataclastic microstructure. The observed velocity-weakening effect is much larger than typically seen in friction experiments. Micromechanical modelling of the behaviour observed in the velocity weakening (cataclastic) regime indicates that this behaviour can be explained in terms of a granular flow process involving competition between intergranular dilatation and compaction by pressure solution. The predictions of the model agree well with the experimental results. Extension of this model to quartz-mica systems implies that the presence of phyllosilicates can strongly promote (unstable) velocity weakening behaviour at rapid slip rates on natural faults, under mid-crustal conditions. Static stress drop predictions based on the model agree reasonably with estimates from seismic observations. Our results may help explain the discrepancy between laboratory-derived rate-and-state friction parameter values for dry, low strain and/or single phase rock systems, with the values inferred from seismological data.