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A microphysical model for fault gouge friction applied to subduction megathrusts

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A microphysical model is developed for the steady state frictional behaviour and slip stability of illite-quartz fault gouge, deformed under subduction megathrust P-T conditions. The model assumes a phyllosilicate-supported microstructure in which rate-independent frictional slip on aligned phyllosilicates and thermally activated deformation of intervening quartz clasts occurs. At low slip rates or high temperatures, thermally activated deformation of the clasts is easy, accommodating slip on the phyllosilicate foliation. With increasing velocity (decreasing temperature), shear of the quartz clasts by the thermally activated mechanism becomes more difficult, increasing the shear stress, until slip is activated on phyllosilicates anastomosing around the clasts. Slip on this curved foliation leads to dilation, balanced at steady state by compaction through thermally activated clast deformation. Model predictions, taking pressure solution as the thermally activated mechanism, show broad agreement with previous experiments on illite-quartz gouge. Notably, both show three regimes of velocity dependence. Changing the slip rate, effective normal stress and quartz fraction in the model shifts the three regimes in temperature, as seen experimentally. Extrapolation of the model to earthquake nucleation slip rates successfully predicts the onset of velocity-weakening behaviour at the temperatures associated with the up-dip seismogenic limit. The results suggest that the location of the seismogenic zone on subduction megathrusts is controlled by fault rock compaction through pressure solution of quartz, competing with dilatation.