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Modelling roughness evolution and debris production in faults using discrete particles

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The frictional strength and stability (hence seismic potential) of faults in the brittle part of the crust is closely linked to fault roughness evolution and debris production during accumulated slip. The relevant processes may also control the dynamics of rock-slides, avalanches and sub glacial slip thus are of general interest in several fields. The quantitative characterisation of fault surfaces in the field (e.g. Candela et al. JGR, 2012) has helped build a picture of fault roughness across many orders of magnitude, however, since fault zones are generally not exposed during slip and gouge zones rarely preserved, the mechanical implications of evolving roughness and the important role of debris or gouge in fault zone evolution remain elusive. Here we investigate the interplay between fault roughness evolution and gouge production using 3D Discrete Element Method (DEM) Boundary Erosion Models. Our fault walls are composed of many particles or clusters stuck together with breakable bonds. When bond strength is exceeded, the walls fracture to produce erodible boundaries and a debris filled fault zone that evolves with accumulated slip. We slide two initially bare surfaces past each other under a range of normal stresses, tracking the evolving topography of eroded fault walls, the granular debris generated and the associated mechanical behaviour. The development of slip parallel striations, reminiscent of those found in natural faults, are commonly observed, however often as transient rather than persistent features. At the higher normal stresses studied, we observe a two stage wear-like gouge production where an initial 'running-in' high production rate saturates as debris accumulates and separates the walls. As shear, and hence granular debris, accumulates, we see evidence of grain size based sorting in the granular layers. Wall roughness and friction mimic this stabilisation, highlighting a direct link between gouge processes, wall roughness evolution and mechanical behaviour. We demonstrate that Boundary Erosion Models provide a convenient way to track fault wall erosion, roughness development and related mechanical behaviour during slip and crucially, may help unravel the competing processes that control the dynamics of slip at many geological interfaces.