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The microscopic basis for strain localisation in porous media

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The spontaneous emergence of localized cooperative deformation is an important phenomenon in the development of shear faults in porous media. It can be studied by empirical observation, by laboratory experiment or by numerical
simulation. Here we investigate the evolution of damage and fragmentation leading up to and including system-sized failure in a numerical model of a porous rock, using discrete element simulations of the strain-controlled uni-axial compression of cylindrical samples of different finite size.

As the system approaches macroscopic failure the number of fractures and the energy release rate both increase as a time-reversed Omori law, with scaling constants for the frequency-size distribution and the inter-event time,
including their temporal evolution, that closely resemble those of natural experiments. The damage progressively localizes in a narrow shear band, ultimately a fault 'gouge' containing a large number of poorly-sorted non-cohesive fragments on a broad bandwidth of scales, with properties similar to those of natural and experimental faults. We determine the position and orientation of the central fault plane, the width of the deformation band and the spatial and mass distribution of fragments.

The relative width of the deformation band decreases as a power law of the system size and the probability distribution of the angle of the damage plane converges to around 30 degrees, representing an emergent internal coefficient of friction of 0.7 or so. The mass of fragments is power law distributed, with an exponent that does not depend on scale, and is near that inferred for experimental and natural fault gouges. The fragments are in general angular, with a clear self-affine geometry. The consistency of this model with experimental and field results confirms the critical roles of preexisting
heterogeneity, elastic interactions, and finite system size to grain size ratio on the development of faults, and ultimately to assessing the predictive power of forecasts of failure time in such media.