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Strain partitioning and structural development in evolving fault zones: 3D numerical simulations

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Strain localization has important implications for the mechanical strength and stability of evolving fault zones. Structural fabrics interpreted as strain localization textures are common in natural and laboratory faults, however, the dynamic microscale processes controlling localization (and delocalization) are difficult to observe directly. Discrete numerical models of faulting allow a degree of dynamic visualization at the grain scale not easily afforded in nature. When combined with laboratory validation experiments and field observations, they become a powerful tool for investigating the dynamics of fault zone evolution. We present a method that implements realistic gouge evolution in 3D simulations of granular shear. The particle based model includes breakable bonds between individual particles allowing fracture of aggregate grains that are composed of many bonded particles. During faulting simulations, particle motions and interactions as well as the mechanical behavior of the entire system are continuously monitored. We show that a model fault gouge initially characterized by mono-disperse spherical aggregate grains gradually evolves, with accumulated strain, to a wide size distribution composed of spherical and angular fragments. The comminution process yields a textural signature that is quantitatively comparable to natural and laboratory produced fault gouges. Mechanical behavior is comparable to a first order with relevant laboratory data. Simulations also reveal a strong correlation between regions of enhanced grain size reduction and localized strain. Thus in addition to producing realistic fault gouge textures, the model offers the possibility to explore direct links between strain partitioning and structural development in fault zones. This could permit investigation of subtle interactions between high and low strain regions that may trigger localization - delocalization events and therefore control macroscopic frictional stability and hence the seismic potential of evolving fault zones.