Session: Fluid, Friction and Rheology, (invited)

"Interactions between pore fluid and granular dynamics in shearing fault gouge"

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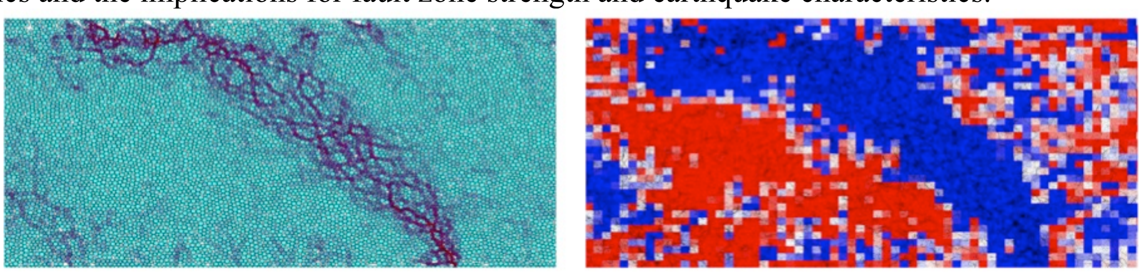
Some earthquake-prone fault zones slip with surprisingly small frictional resistance, which may indicate fluid processes are important. Slip within natural fault zones often occurs within a layer of unconsolidated porous granular fault gouge. Slip along such a fault requires breaking and re-making the network of grain contacts (force chains) that provides frictional resistance. Since deformation of granular material always involves localized and transient dilation and compaction, pore fluid between the grains will experience pressure perturbations that can both drive flow and affect the grain motions.

We use the Goren et al. (JGR, 2011) coupled discrete element/finite difference model for deformation of dense, saturated granular material to explore the interactions between fluid and grain forces during shear at earthquake velocities (on the order of 1 m/s). A set of idealized grains is confined between undeformable but permeable fault blocks. Local variations in permeability (taken to be a Kozeny-Carman function of local porosity) are restricted onto a finite-difference grid for solving pore fluid pressure perturbations. Drag forces on individual grains are calculated from interpolated pressure gradients, fully coupling the two phases together.

Although the confining fault blocks are taken to be highly permeable (a drained system), when sheared at earthquake velocities, grain rearrangements in the layer are fast enough that significant pressure perturbations form where shear is localized. At low effective confining stresses (less than a few MPa), these pressure perturbations tend to restrict shear to boundaries of the granular layer (where pressure can be more easily relieved by flow into the surrounding rock). Fluid pressure effects enhance variability in the contact network, in some cases creating isolated groups of force chains surrounded by completely liquefied regions where fluid pressure exceeds confining stress. In these cases, the overall frictional resistance of the layer is greatly reduced and highly time-variable, while localized regions of the fault still experience high shear stresses that can damage the wall rock and widen the gouge zone. We will explore the grain-scale dynamics and the implications for fault zone strength and earthquake characteristics.



(Left) Contact stresses (purple = high contact forces, blue = no contact forces) in part of a shearing granular layer (Right) Fluid pressure perturbations (blue = low pressure, red=high pressure) at the same instant in this region.