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Slip-localization within confined gouge powder sheared at moderate to high slip-velocity

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Slip along faults in the upper crust is always associated with comminution and formation of non-cohesive gouge powder that can be lithified to cataclasite. Typically, the fine-grained powders (grain-size < 1 micron) build a 1-10 cm thick inner-core of a fault-zone. The ubiquitous occurrence of gouge powder implies that gouge properties may control the dynamic weakening of faults. Testing these properties is the present objective.
We built a Confined ROtary Cell, CROC, with a ring-shape, ∼3 mm thick gouge chamber, with 62.5 and 81.2 mm of inner and outer diameters. The sheared powder is sealed by two sets of seals pressurized by nitrogen. In CROC, we can control the pore-pressure and to inject fluids, and to monitor CO_2 and H_2O concentration; in addition, we monitor the standard mechanical parameters (slip velocity, stresses, dilation, and temperature). We tested six types of granular materials (starting grain-size in microns): Talc (<250), Kasota dolomite (125-250), ooides grains (125-250), San Andreas fault zone powder (< 840), montmorillonite powder (1-2), kaolinite powder and gypsum. The experimental slip-velocity ranged 0.001-1 m/s, slip distances from a few tens of cm to tens of m, effective normal stress up to 6.1 MPa.
The central ultra-microscopic (SEM) observation is that almost invariably the slip was localized along principal-slip-zone (PSZ) within the granular layer. Even though the starting material was loose, coarse granular material, the developed PSZ was cohesive, hard, smooth and shining. The PSZ is about 1 micron thick, and built of agglomerated, ultra-fine grains (20-50 nm) that were pulverized from the original granular material. We noted that PSZs of the different tested compositions display similar characteristics in terms of structure, grain size, and roughness. Further, we found striking similarities between PSZ in the granular samples and the PZS that developed along experimental faults made of solid rock that were sheared at similar conditions. The ultra-fine grains and extreme slip localization in these experiments are generally similar to ultra-cataclasites found in exhumed faults-zones, and the intensely pulverized gouge found in drilling across active faults.