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Grain-scale Response and Aggregate Deformation Processes in Experimentally Deformed Carbonate and Shale Gouges

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In limestone-on-shale thrust faults, such as those that are common in foreland-thrust regimes world wide, carbonates typically comprise the hanging wall, and shale comprises the footwall. Generally, a cataclasite is developed in both the carbonate and shale materials, and there is a zone of mixing in which the shale cataclasite contains clasts of carbonate cataclasite. Both the hangingwall and footwall cataclasites can be foliated and the degree of strain partitioning between the cataclasites is unknown.

Triaxial frictional sliding experiments were conducted on 20 mm diameter by 50 mm length cores containing a 1 mm thick, gouge layer along a 30° angle sawcut. Porous Berea sandstone ($\phi \approx$17%) and impermeable Badshot dolomite were variously paired to give contrasting forcing block properties. Gouge material was created from quartz-bearing phyllosilicate-rich shale (31% quartz, 39% muscovite, 18% clinochlore, 11% feldspar) combined in various volumetric proportions with reagent grade calcite powder (80% calcite, 20% dolomite) with an average grain size of $\sim$5 μm. The mechanical tests demonstrated the following relationships: (1) temperature is more important than pore fluid pressure in decreasing the strength of carbonate gouge; (2) at room temperature carbonate gouge is significantly stronger than any shale-carbonate composite gouge; (3) at 150°C, pure carbonate gouge is weaker than 75% and 50% shale composites; (4) gouges containing shale continue to strain harden throughout the duration of the experiments; and (5) it appears that pore fluid pressure is necessary for stick-slip (seismic) behaviour. A general observation was that gouges were stronger than the Berea sandstone (i.e. damage zone weaker than core zone) that led to attrition of the gouge wall rock and its incorporation into the gouge. Measured 'frictional' strength is in this case a combination of displacement in the gouge and fracture in the wall rock.

In order to further elucidate the processes controlling the latter behaviour, specifically the effect of pore fluid pressure, detailed microstructural study (optical microscopy, scanning and transmission electron microscopy) of calcite and shale gouge deformed between dolomite-dolomite and sandstone-dolomite blocks has been undertaken. At a first-order level, the forcing blocks impose distinct boundary conditions, with the porous sandstone enabling an irregular slip contact, whereas dolomite blocks have discrete contacts, typically with strain localized here with intense grain-size reduction. The evolution of compositional and mechanical layering within the gouges (Riedel shears and/or grain variations) controls the hardening, softening and localization, with commensurate variations in grain-scale deformation processes. Of particular interest is the inferred onset of intracrystalline deformation in the calcite gouges, and what influence, if any, this rheological response has on the aseismic-seismic transition during stick-slip. These observations from controlled experiments provide a key database for comparison with naturally deformed fault gouge.