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The Influence of Calcite on The Mechanical Behavior of Quartz-Bearing Gouge

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Mechanical heterogeneities along faults can result in diverse and complex fault slip. These heterogeneities can vary spatially and temporally and may result from changes in fault structure or frictional properties. The accumulation of calcite in non-carbonate faults, via cementation or entrainment, is likely to alter the frictional properties of that fault gouge. Furthermore, widespread observations of calcite as cement, veins, or cataclasites in non-carbonate hosted faults indicates that calcite is readily available and could play an important role during fault reactivation at shallow- and mid-crustal earthquakes.

We report on laboratory experiments designed to explore the mechanical behavior of quartz/calcite mixtures as a means to better understand the evolution in behavior of quartz-bearing gouge in the presence of exotic calcite. We sheared mixtures of powdered Carrara marble (>98% $CaCO_3$) and disaggregated Ottawa sand (99.8% SiO_2) at constant normal stresses of 5 and 50 MPa under saturated conditions at room temperature. We performed slide-hold-slide tests, 1-3,000 seconds, and velocity stepping tests, 0.1-1000 μm/s, to measure the amount of frictional healing and velocity dependence of friction respectively.

At low normal stress, the addition of calcite to quartz-based synthetic fault gouge results in increases in the steady-state frictional strength, and rates of frictional healing and creep relaxation of the gouge. In particular, with the addition of as little as 2.5 wt% calcite, the frictional healing rate increases by 30%. Microstructural observations indicate that shear is accommodated by distributed deformation throughout the gouge layer and that calcite undergoes significantly more comminution compared to quartz. Large quartz grains frequently show minor rounding of angular edges with fine-grained calcite often penetrating fractures.

The in-situ addition of calcite to fault gouge, by either the circulation of fluids or the involvement of carbonate rocks in faulting, could lead to significant and progressive changes in fault behavior, i.e. the fault could be frictionally stronger, heal/seal faster, and be more frictionally unstable. At shallow crustal conditions, increased temperature and the concentration of fine-grained calcite along shear surfaces would result in the amplification of the observed behaviors.