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Microphysical mechanisms controlling slip stability in calcite-rich fault gouges

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It is well established that for an earthquake rupture to nucleate on a natural fault the sliding medium within the fault, i.e. the fault gouge, must exhibit velocity weakening frictional properties. Fault frictional behavior is usually modeled empirically using Rate-and-State-dependent Friction (RSF) "laws". However the deformation mechanisms controlling the velocity dependence of slip are still not well understood. We have investigated the microphysical processes leading to velocity weakening slip in calcite(-rich) fault gouges. We performed dry and wet direct shear friction experiments at a constant effective normal stress (50 MPa) at sliding velocities of 0.1-10 μm/s, at temperatures ranging from $\sim$20 to 150°C. Our results show a transition from velocity strengthening to velocity weakening slip above $\sim$100°C. The presence of water does not affect this transition. After each experiment we analyzed ultrathin sections prepared from the sheared gouges using light microscopy. The sheared samples generally show pervasive R1- and, less common, R2- and P-shears, plus sharply defined boundary shears. The boundary and R1 shear bands are characterized by grain comminution to sub-micron size plus a strong Lattice Preferred Orientation (LPO) in the shear band cores. At the light microscopy scale (>1 μm), no differences were found between the microstructures of the velocity weakening and velocity strengthening samples. Focused Ion Beam SEM work is ongoing in an attempt to establish any finer scale differences. Nonetheless, the results suggest that the processes controlling friction and slip stability operate on the nanometer-scale, and involve crystal plasticity in combination with cataclasis and grain size reduction, with compaction via plasticity perhaps competing with dilatant granular flow. Our results, especially the effect of temperature, have important implications for shallow focus seismicity in tectonically active carbonate-bearing terrains, providing possible constraints on the upper limit of the seismogenic zone.