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Strength and stability of calcite gouge sheared at 20-600°C

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As strong earthquakes often nucleate at depths corresponding to the frictional-viscous transition, it is important to understand the velocity dependence of fault zone shear strength throughout the transition. We conducted ring shear experiments on simulated pure calcite gouges at constant temperatures (T) of 22, 100, 200, 400, 490, 500, 540, and 590°C, while performing displacement rate stepping tests within the range v=0.01-100 μm/s. All experiments used a constant pore water pressure (10-60 MPa) and a constant effective normal stress (50 MPa). For experiments conducted at T≈22°C, the results showed a near-constant strength (τ≈30-37 MPa) and stable velocity strengthening at all displacements. For T>22°C, a peak strength (τpk≈33-56 MPa) developed at low displacements (0.5-2 mm), followed by weakening to a near-constant (average) value (τ≈15-42 MPa) depending on slip rate. Velocity weakening was observed in each experiment conducted at T≈100-540°C, where the magnitude of velocity weakening generally increased with increasing temperature and decreasing slip rate, which often resulted in unstable slip i.e. stick-slips. At 500°C, at v=0.01 μm/s, stick-slip showed a strength drop from ∼41 to ∼13 MPa, hence a stress release of nearly 70%! Experiments conducted at T≈590°C showed stable sliding throughout and velocity strengthening. Recovered sheared microstructures of samples deformed at T≈22°C showed shear bands characterized by a sub-micron grain size and a Crystallographic Preferred Orientation (CPO), similar to microstructures from earlier experiments conducted using a direct-shear geometry. For samples deformed at T>400°C, ultra-fine grained shear bands with a CPO also developed. However, strongly elongated grains up to 30 μm in size adjacent and bending into the shear band suggest that plasticity played a role in accommodating some of the deformation. Our results demonstrate that calcite fault rocks can slide unstably at temperatures as high as 550°C, implying that faults cutting limestones in a ductile regime can potentially host seismicity with significant stress drops.