Velocity-dependent friction of granitoid gouge under hydrothermal conditions: A contribution to understanding of fault zone seismicity

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Fault gouges of granitoid composition represent the principal non-cohesive tectonites within fault zones in the continental crust. Their velocity-dependent friction is crucial for understanding earthquake nucleation and the depth distribution of fault-related seismicity in granitoid shear zones (Wehrens et al. 2016; Blanpied et al. 1998). In the framework of rate-and-state friction laws (RSF), the friction parameter \((a-b)\) is measured in sliding experiments to describe the velocity dependence of friction in fault gouges (Scholz, 1998). A velocity-strengthening system is frictionally stable, \((a-b) > 0\), whereas a velocity-weakening system can be frictionally unstable, \((a-b) < 0\). In earthquake mechanics, velocity weakening is prerequisite for stick-slip deformation, i.e. the nucleation of earthquakes. Although \((a-b)\) values of granitoid gouge are sensitive to varying temperature conditions and sliding velocities, only a few studies have examined this velocity-dependence under hydrothermal conditions.

To address this issue, we conducted velocity stepping sliding experiments under hydrothermal conditions by using a ring shear apparatus. The powdered starting gouge was derived from a granitoid mylonite collected at the NAGRA Grimsel Test Site (Central Swiss Alps). The applied velocity steps were 1-3-10-30-100 \(\mu\text{m/s}\). Pore fluid pressure and the effective normal stress were 100 MPa. Temperatures explored ranged from 20-650 °C. Values of \((a-b)\) were obtained from RSF model inversions of the evolution of friction coefficients at mechanical steady state conditions. Our experiments showed pronounced changes in \((a-b)\) values with across the full range of temperatures up to 650 °C and velocities investigated. At temperatures below \(-100\ °\text{C}\) and above \(-400\ °\text{C}\), we observed mostly velocity strengthening with positive \((a-b)\). In contrast, velocity weakening with negative \((a-b)\) was observed between \(-100\ °\text{C}\) and \(-400\ °\text{C}\). Samples deformed at a sliding velocity of 100 \(\mu\text{m/s}\) deviated slightly from this trend, as \((a-b)\) values were negative between \(-200\ °\text{C}\) and \(-400\ °\text{C}\).

The presented experimental study demonstrates a significant influence of temperature and sliding velocity on velocity-dependence during deformation of granitoid gouge. We suggest that the observed transitions in velocity dependence reflect an interplay of interactions. In terms of crustal faulting, our data suggest the existence of a seismogenic window that limits the depth distribution of earthquakes on faults in granitoid shear.
REFERENCES

