Temperature dependence of frictional properties of opal gouge and its implications for faulting along subduction-zone megathrusts

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We conducted triaxial friction experiments on opal gouge at a confining pressure of 150 MPa, a pore water pressure of 50 MPa, temperatures (T) of 25–200°C, and axial displacement rates (V_{axial}) changed stepwise among 0.1, 1 and 10 μm/s, in order to investigate its temperature-dependent frictional properties and their controlling factors. Because opal is known as a main component in chert on the Pacific plate subducting at the Japan Trench, its frictional properties would be applicable to those of chert subducting there.

The results showed frictional strength increasing with increasing T, rate-weakening behavior at $T \geqq 100$°C, where frictional strength decreases or increases when V_{axial} is increased or decreased, and stick slips at $T \geqq 150$°C. When fitted by the rate- and state-dependent friction constitutive law, steady-state friction coefficient μ_{ss} increases with increasing T or decreasing V_{axial}, while $a-b$ (rate dependence of μ_{ss} implying stable (aseismic) faulting if positive, i.e., rate strengthening, and potentially unstable (seismic) faulting if negative, i.e., rate weakening) decreases with increasing T or decreasing V_{axial}, and becomes ≈0 at 50°C and negative at $T \geqq 100$°C, being larger negative at higher T or lower V_{axial} in the latter case.

These results indicate that frictional properties of opal gouge are dependent on not only T but also V_{axial}, suggesting that a thermally activated process is responsible for the observed frictional properties. Gouge layer at higher T contains a smaller fraction of submicron-size particles, which have likely been dissolved away at higher T. In addition, gouge layers at $T \geqq 100$°C do not show clear cataclastic microstructures, but are rather dense. These microstructures suggest the activation of thermally activated pressure solution during the experiments, which promoted gouge densification to increase frictional strength with increasing T or decreasing V_{axial}, thereby decreasing $a-b$ to <0 at $T \geqq 100$°C. Our results also show that $a-b \approx 0$ at 50°C, suggesting that the transition from aseismic faulting to seismic faulting occurs at ≈50°C along the megathrust at the Japan Trench subduction zone if the megathrust is located in chert on the subducting Pacific plate.

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