Temperature-dependent frictional strength of dolerite in an argon atmosphere

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Since 1990’s, high velocity friction experiments (up to several m/s) on many types of rocks have revealed that frictional strength significantly decreases with increasing slip rate at seismic slip rates (e.g., Tsutsumi and Shimamoto, 1997; Di Toro et al., 2011). Coseismic weakening mechanisms are due to temperature rise including flash heating, melt lubrication or thermal pressurization (e.g., Rice, 2006; Hirose and Shimamoto, 2005). Although the important role of temperature rise in fault motion are widely recognized, there is just a few studies which investigated the effect of temperature on frictional properties at intermediate to high slip rates (e.g., Noda et al., 2011). Yao et al. (2015) conducted the high velocity friction experiments using host blocks with different thermal conductivity values, and reported that the amount of slip-weakening increases with decreasing thermal conductivity values of host blocks. This implies that an ambient fault temperature has a large effect on the frictional strength at the coseismic slip rates. We therefore performed friction experiments at a wide range of temperatures and slip rates, and investigated the effect of temperature on the friction coefficient (μ).
Experiments were conducted on dolerite (Belfast, Northern Ireland) using a rotary shear deformation apparatus at Chiba University. Dolerite samples were sheared at a normal stress of 1 MPa, slip rates of 1 to 300 mm/s, slip displacements of 10 - 20 m at each slip rate and temperatures of 20 - 500°C in an argon atmosphere with an oxygen concentration of 0.2 %. A high-frequency induction coil surrounding the sample holders is used to heat up the sample holders and the rock samples.
At 20°C and 100°C, the dolerite showed velocity weakening at the range of slip velocities 1 - 30 mm/s with μ ranging 0.81 - 0.83 at 1 mm/s and of 0.73 at 30 mm/s. Whereas at high temperatures >300°C, friction is almost constant (μ = 0.81 - 0.85) at < 30 mm/s. At 100 mm/s, the behavior is slight velocity strengthening at 20°C and 100°C with μ = 0.75 - 0.79 and clear velocity-weakening at more than 300°C with μ = 0.67 - 0.76. At 300 mm/s, the dolerite showed strong velocity weakening at all temperatures investigated. The amount of weakening (i.e., the drop in friction, $\Delta\mu$) increases with increasing temperature ($\Delta\mu$ = 0.1 - 0.38). Thus, the frictional properties of dolerite are affected by not only slip rate but also the ambient temperature. Our results suggest that rocks at depths are energetically favored for earthquake ruptures to propagate deeper.

Keywords: friction, temperature dependence, dolerite

