Evolution of fault surface state during frictional weakening of quartz rocks

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Siliceous rocks such as novaculite and quartzite display dramatic weakening of frictional strength at slip velocities of >1 mm/s [Goldsby and Tullis, 2002; and Di Toro et al., 2004].It has been suggested that the frictional weakening likely resulted from production and shearing of hydrated amorphous silica layer along a fault in quartz rocks. However, there exists little information on the frictionally-generated material; consequently the mechanism of the weakening remains poorly understood. In this study, to better characterize the state evolution of the fault surfaces of quartz rocks during the slip-weakening, we have performed SEM and stereo microscope observation of the fault surface and XRD analysis of the gouge formed on the fault.
All the experiments in this study were conducted using a rotary-shear, intermediate-to high-velocity friction testing machine in Kyoto University. The test samples used for the friction experiments were chert from the Tamba Belt, northern Kyoto prefecture, Japan, which is a Jurassic accretionary complex, and single crystal of quartz (a synthetic crystal). A pair of solid cylinders with a ring-shaped end surface (inner and outer diameter of 5 mm and 25 mm) was cored from the samples. Experiments were carried out under a constant normal stress condition of 1.5 MPa and at slip velocities of 105 mm/s, 10.5 mm/s and 1.05 mm/s.
Experimental results reveal that slip-weakening occurs at all the tested slip velocity conditions. At slip velocity of 105mm/s, both of the quartz and the chert specimens show very low friction coefficient value of 0.1 to 0.2 after the slip-weakening. The values of the slip-weakening distance (D_c) of this study are 0.2 to 0.3 m for the quartz specimens and 0.7 to 1.5 m for the chert specimens, respectively. These values are by an order of magnitude smaller than the D_c value reported in Hayashi and Tsutsumi [2010]. The D_c value appears to depend on the parallelism of the initial fault surfaces.
Fault surfaces after the experiments are covered by white, fine-grained gouge. The SEM observation reveals the development of asymmetric flake-like structure on the sliding surface, which is characterized by tearing of the surface material with approximate size of 100 to 300 μm. The XRD analyses reveal that only the chert specimen that had slipped for large displacement after the slip-weakening behavior contains amorphous material. This result suggests that the gouge material formed during the slip-weakening period is not amorphous.

