Hydration and amorphization of quartz rocks during high-velocity frictional sliding: An examination of fault gouge from friction experiments of synthetic quartz

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Various types of rocks and fault gouges display weakening of frictional strength at high-velocities, and in many cases, it is caused by high-temperature faulting processes such as frictional melting and thermal decomposition of fault materials. On the other hand, siliceous rocks display weakening of frictional strength at relatively slow slip velocity of ~1 mm/s. This weakening is a specific phenomenon because frictional heat is not sufficient to induce the high-temperature transformation reactions in this slip velocity range [Di Toro et al., 2004]. Goldsby and Tullis [2002] proposed gel lubrication model to explain the weakening of siliceous rocks; in which model frictional weakening likely results from production and shearing of hydrated amorphous silica layer along a fault in quartz rocks. But the relationship between the frictional weakening and hydration and amorphization of fault gouge is not clear yet.

This study aims to elucidate the mechanism of the frictional weakening observed for siliceous rocks. We conducted a series of friction experiments on synthetic quartz samples using a rotary-shear, intermediate- to high-velocity friction testing machine. Experiments were carried out under a constant normal stress condition of 1.5 MPa and at slip velocities of 5 μm/s, 10 μm/s, 105 μm/s, 1 mm/s, 10 mm/s and 105 mm/s. In this study effect of drying the sample on the frictional behavior were examined by introducing dry air to the chamber of the sample. After the friction tests, the gouge material on the slip surfaces were collected and analyzed by FTIR.

The frictional behavior of the synthetic quartz differs between room humidity and dry conditions; velocity weakening was observed for both conditions, however, velocity weakening starts at lower slip velocities for the dry experiments. Under DRY conditions, the frictional weakening occurs at slip velocity around 10 μm/s. From the results of the FTIR analysis, hydration of the gouge is confirmed for all the samples tested in this study. The FTIR result also indicates that the faster the slip velocity, the more the crystal structure of the gouge is destructed.
It is showed that under both DRY and Room Humidity conditions, at least the gouge generated on the friction surface of the sample which showed slip weakening is hydrated, consistent with the weakening model of Goldsby and Tullis [2002].

