Weak and unstable frictional behaviors of brucite under dry and wet conditions

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Brucite (Mg-hydroxides) is one of the main mineral phases in serpentinite and formed by the hydration of ultramafic rocks. Although brucite has not been focused for a long time because of the lack of observation due to its fine-grained nature, recent studies found that brucite stably exists with antigorite at a hydrated mantle wedge (Kawahara et al., 2016). Long-term slow-slip events at the mantle wedge can be explained by the high effective normal stress due to the water consumption by the production of brucite (Mizukami et al., 2014). Moreover, the presence of brucite may change the frictional stability of rocks in the mantle wedge. Despite its potential effect on seismic activities in hydrated ultramafic settings, frictional behaviors of brucite were not fully understood. Here we report fundamental frictional behaviors of brucite investigated by a series of friction experiments.

Friction experiments with a chemically synthesized nanoparticle (70 nm in diameter) of brucite were conducted by using the double direct shear apparatus at Hiroshima University. Both room dry and water-saturated conditions with different applied normal stresses (10, 20, 40, and 60 MPa) were tested. The maximum shear displacement was 20 mm. Sliding velocity was set to 3 μm/sec for the run-in process. Velocity step tests were also conducted several times with 33 μm/sec. The results were fitted to the equation of rate- and state-dependent friction (RSF) law for the quantitative analyses of frictional instabilities.

For dry experiments, the steady state friction coefficient was found to be about 0.40 and unstable behaviors (velocity-weakening or stick-slip behaviors) were observed under all the normal stress conditions. Clear peaks were observed at the shear displacement of 2 mm showing inverse correlation to the applied normal stress. For wet experiments, the steady state friction coefficient was about 0.25. Peak values also inversely correlated to the normal stress, but values were smaller than those in the dry cases. Velocity-weakening behaviors were observed for normal stresses of 10 and 20 MPa but the response to the velocity step turned into velocity-strengthening at higher normal stress conditions of 40 and 60 MPa. Stable frictional behavior at high normal stresses is consistent with a previous experimental study conducted at a normal stress of 100 MPa (Moore & Lockner, 2007). Values of a and b in the RSF law for dry experiments were found to be smaller than for wet experiments and the critical slip distances d_c for dry experiments were shorter than for wet experiments.

Since antigorite shows a higher friction coefficient than brucite, unstable frictional behaviors of brucite could contribute to earthquake nucleation at the hydrated ultramafic settings. Note that temperature effect was not investigated in this study. In the presentation, we will discuss the mechanisms of the observed frictional behaviors through the microstructural observations of the experimental gouges and further the implication for seismic activities in natural ultramafic settings based on the experimental results and the previously proposed models.

Keywords: Friction experiment, Brucite, Ultramafic settings