Influence of swelling on frictional property of smectite gouge

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Smectite is a major component of shallow crustal fault gouges (Vrolijk and van der Pluijm, 1999), and is thought to have large influence on their slip behaviors (e.g., Moore and Lockner 2007; Oohashi et al. 2015). In this study we performed ring-shear friction experiments on water-saturated Na-montmorillonite powders to examine the influence of smectite swelling, one of typical features of smectite, on the frictional property of smectite gouges.
Experiments were conducted using a rotary-shear friction apparatus (Institute of Geology, China Earthquake Administration; Yao et al., 2011; Hou et al., 2012) wtih a variable electrolyte concentrations up to 3*M* NaCl under normal stresses of 1.0 and 2.0 MPa. The SWy-2 powder of 2.5 g and 0.75 g of waters with different salinities were placed and dropped between two solid-cylindrical specimens of Indian gabbro to make ~1 mm thick gouge layer, within a Teflon sleeve holding the gouge. Teflon friction was corrected using an intercept method (Mizoguchi et al. 2007).
The experiments demonstrate that the frictional coefficient shows a peak value at the onset of sliding (0.15~0.5), followed by a gradual decrease to less than 0.1 in all runs. The steady state frictional coefficient is dependent on salinity of pore water, and it is as low as ~0.01 when sheared with distilled water, whereas it increases to ~0.05 with 3*M* NaCl solution. According to the Gouy-Chapman (GC) theory (i.e., interparticle forces arising from the overlap of diffuse electric double layers between the charged plates), the higher swelling pressure is expected in lower salinity condition due to expansion of the diffuse double layers. The application of the extended GC theory proposed by Komine and Ogata (2004) predicts that in-situ swelling pressure of the present gouge sample saturated with distilled water reach as high as ~1.5 MPa, almost equivalent to the normal stress loaded during the test, while the interparticle force is rather attractive in the higher salinity conditions (1.0 and 3.0 *M*) caused by the enhancement of the van der Waals force. These results suggest that the swelling pressure can effectively reduce the effective normal stress exerting on the smectite platelets as argued by Chatterji and Morgenstern (1990), leading to the apparent reduction in the frictional coefficient at lower salinity conditions. Our experiments also indicate that frictional property of smectite-rich gouges is governed by pore fluid physico-chemical conditions in natural fault zones.

Keywords: smectite gouge, swelling, friction experiment

