Fault strength of the ancient Median Tectonic Line at the brittle-ductile transitional depths

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To explore the fault strength at the middle crustal levels close to the brittle-ductile transition zone, we conducted friction experiments using natural fault rocks exposed along the Median Tectonic Line (MTL). The experiments were performed on powdered samples of cataclasite and protomylonite, which are originated from tonalite or basic rocks in the Ryoke belt on the northern side of MTL. Cataclasites contain ˜30 wt.% mica and clay minerals. Among them, chlorite-rich cataclasite (Chl-cataclasite) contains ˜14 wt.% chlorite, and mica-rich cataclasite (Ms-cataclasite) contains ˜14 wt.% white mica. Chlorite is a hydrous mineral commonly observed in basic metamorphic rocks and fault zones, and is known to have low friction coefficients about 0.3 at hydrothermal conditions (Okamoto et al., 2019).

Chlorite geothermometer (Bourdelle *et al.*, 2013) yields a bimodal distribution (230–240˚C and 290–340˚C) for the protomylonite sample. The low-temperature chlorite occurs as blobs with the diameter of ˜1–2 mm, which contain lamella of white mica. These chlorite grains are considered as pseudomorphs of biotite. The high-temperature chlorite filled fractures and interstice of grains. We therefore interpreted that brittle deformation first occurred at a temperature around 300˚C and subsequent hydrothermal alteration occurred at 230–240˚C. Chl-cataclasite also shows a bimodal temperature distribution (180–220˚C and 240–300˚C), although no clear relationships between temperatures and microstructures were found.

To simulate the deformation conditions at depth, friction experiments were conducted at temperature of 300˚C, normal stress of ˜300 MPa, and pore fluid pressures of 120 MPa and 240 MPa, using the hydrothermal ring shear apparatus at Utrecht University. Sliding velocities were varied from 0.001 mm/s to 0.1 mm/s in the velocity stepping tests. The steady-state friction coefficients obtained for protomylonite were ˜0.68, whereas those for Ms- and Chl-cataclasites were ˜0.65 and ˜0.56 at 120 MPa, and ˜0.87 and ˜0.66 at 240 MPa, respectively. Velocity stepping tests yielded velocity-weakening or neutral behaviours, although existing laboratory data for pure chlorite gouges mostly show velocity-strengthening behaviours. Our results indicate that fault strengths and sliding behaviours in the middle crusts are not drastically changed by the presence of phyllosilicates even if chlorite contents in fault zones are relatively high (<14 wt.%).

Herein we also report new results of stress-stepping tests, constant-velocity large-displacement tests, velocity-stepping tests at a higher temperature (450˚C), and discuss their implication to the crustal strength at the brittle-ductile transitional zone.

References:

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Keywords: differential stress, fault strength, friction, Median Tectonic Line

