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Frictional properties of chlorite and talc at high-pressure hydrothermal conditions

The main purpose of this study is to clarify frictional properties of the crust and the subduction zone megathrusts by laboratory experiments. In order to obtain accurate mechanical data of the crustal materials, we should use several different types of rocks which reflect actual variation in crust, and deformation apparatuses that can apply a wide variety of pressure and temperature conditions. In this study, we focus on the role of hydrous minerals in fault zones and designed frictional experiments on (1) powdered and single crystalline chlorite, (2) fault rocks that exposed along the Median Tectonic Line (MTL), and (3) talc. These experiments were performed by using a hydrothermal ring shear apparatus at Utrecht University in collaboration with Prof. Dr. Christopher J. Spiers and Dr. André R. Niemeijer. To understand elementary processes of frictional slips of crustal materials at realistic physical conditions of the island–arc crusts and subduction zones (i.e. high–temperature, high–pressure and high–pore pressure conditions), we applied total normal stresses up to 500MPa, pore fluid pressures up to 240 MPa and temperatures up to 600°C.

1. Chlorite

Chlorite is a common phyllosilicate mineral formed over a wide temperature and pressure range. For instance, in wet basalt, chlorite is formed at pressures up to ~2.5 GPa and at temperatures of ~150–600°C (Schmidt & Poli, 1998, EPSL). Chlorite is therefore distributed not only at major faults such as MTL, but also at a subduction zone, for example in subducting metamorphic crust and in hydrated mantle wedge as a metamorphic/metasomatic mineral. Furthermore, phyllosilicate–rich materials are considered to contribute weakening of fault–zones. Chlorite could have contributed to fault strength and slip behaviour of subduction zone megathrusts and inland earthquake faults.

Figure 1. Starting material of single crystalline chlorite

We crushed single crystalline chlorite into powders with the grain size of ~20–50 micrometres and also cut out ring-shaped starting material. During experiments, normal stress of 300 MPa was applied while temperature and pore fluid pressure were changed from room temperature to 600°C, and from 120 to 220 MPa. The values of friction coefficient vary with temperature, increasing from ~0.20–0.30 below 400°C to ~0.3–0.4 above 500°C. The velocity stepping experiments were conducted in the slip velocities ranging from 0.0003 mm/s to 0.1 mm/s. Velocity strengthening behaviour was observed at almost of all experimental conditions. Furthermore, there are no effects of pore fluid pressure and normal stress on friction coefficient and frictional behaviour s of powdered chlorite. Although limited numbers of experiments could be done on single crystalline chlorite, their friction coefficients were lower than those of powdered chlorite. Friction coefficient of single crystalline chlorite increases with increase of velocity or shear displacement probably due to granulation of the chlorite sheets.

2. Fault rocks developed along the Median Tectonic Line

We used two cataclasite and one mylonite samples collected from the outcrops close to MTL by Arai (2017, MSc thesis, Hokkaido Univ.). Mylonite is probably the host rock of cataclasites. Two cataclasites have ~30 wt.% clay minerals but the clay mineral composition is different. One contains ~14 wt.% white mica and the other contains ~14 wt.% chlorite. In this study, we used ~10 cm^3 cube of fault rocks to make their < 50 micron powders.

Figure 2. Sample material after experiments

Experiments were performed at temperature of 300°C, normal stress of 300 MPa, and pore fluid pressure of 240 and 120 MPa. Although the number of experiments we could perform were limited, friction coefficient of three fault rocks larger than 0.55 was confirmed. Furthermore, friction coefficients of two cataclasites at pore fluid pressure of 220 MPa were larger than those at 120 MPa.

3. Talc

Talc is a minor constituent of hydrated mantle peridotites, but is known to be formed at the boundary of the mantle wedge and subducting sediments by metasomatic reactions. Therefore, talc is used in experiments to know frictional properties of the slab-mantle interface. In order to observe the steady state friction coefficient of talc, we performed large displacement experiments on two ring-shaped talc rocks. The displacements where steady state value is confirmed vary between 5–56 mm, but observed steady state friction coefficients are 0.1–0.2.

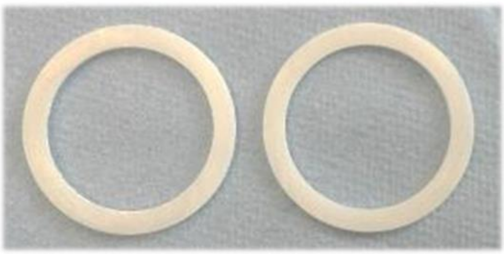

Figure 3. Ring-shaped talc rock