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Effect of pore pressure on frictional properties of talc under high normal stress

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Pore fluid pressure is a critical parameter governing the overall mechanical strength of plate boundary faults. Recent geophysical observations have suggested the importance of fluids in seismogenic processes. The role of pore fluid pressure at the brittle-plastic transition zone is especially important because this zone, located at the deepest part of the seismogenic zone, supports large shear stress during interseismic periods and therefore releases large energy at seismic events [1]. However, it is not well documented how pore fluid pressure influences frictional properties of faults at the depth, which is mainly due to the difficulty in conducting laboratory friction experiments at high pressures and temperatures that are comparable to the middle to lower crust and mantle. To overcome the limitation of experimental conditions, we used talc as an analogue material, which shows brittle-plastic transitional behaviors at relatively low pressures and temperatures.

Previous works on rock mechanics have suggested that the yield strength of rocks is governed by effective stresses $Se = S - C$ Pp, where S is total stress, Pp is pore fluid pressure, and C is a factor between 0 and 1. The observations in the brittle regime are well accounted for by $C = 1$ [2]. In the fully plastic deformation regime, however, yield stress is not significantly affected by pore pressure and the strength would not be lost even if Pp is equal to C [3]. This is quite different from the brittle deformation at shallow crustal levels. In the brittle-plastic transitional regime, intermediate behaviors between fully brittle and fully plastic deformation are expected. As a first step to quantify the fluid effects, we conducted friction experiments of talc at various Pp and C conditions.

Cylindrical samples of talc, from Gvangjsih, China, 20mm in diameter, were cut at an angle of 30˜{o} to the sample axis. The surfaces were ground with carborundum (#400). A small hole (3mm in diameter) through the center of each talk piece ensured adequate communication of the water between the precut surfaces with the rest of the pore pressure system. The specimen was loaded by a gas-medium triaxial apparatus and sheared under an axial displacement rate of 1 um/s. We used water as a pore fluid. All measurements were performed under conditions of room temperature. Experiments were conducted under the following four types of stress paths: (a) pore pressure was held constant at 0 MPa, and confining pressure was increased from 10 MPa to 110 MPa, and then decreased 10 MPa. (b) Confining pressure was held constant at 110 MPa, and pore pressure was decreased from 100 MPa to 0 MPa, then increased up to 100 MPa. (c) Confining pressure was held constant at 110 MPa, and pore pressure was increased from 0 MPa to 100 MPa. (d) Confining pressure was held constant at 110 MPa, and pore pressure was held at 100 MPa for a hour before axial loading, and then was decreased to 0 MPa and the specimen was sheared.

When we compared the results of shear stress measurements on the stress path (a) with others and derived the constant C in the effective stress law, C was almost equal to 1 through whole stress path in the case of (b). On the other hand, in the case of (c), the results could not be explained when $C = 1$. C of (d) was almost 1, but the peak shear stress were approx. 1.5 times larger than that of (a). These results indicate that C depends on the stress path and that the effective stress law cannot be directly applied to talc under these conditions.

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References: [1] C.H. Scholtz, The mechanics of earthquakes and faulting, 2nd ed., 2002. [2] M.S. Paterson and T.-F. Wong, Experimental rock deformation - the brittle field, 2nd ed., 2005. [3] I. Shimizu, Chikyu Monthly, 32, 3 (2010).

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