Change in chemical composition of pore water in a fault gauge layer during frictional sliding experiments: Preliminary results

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Tectonic deformations in the Earth's crust including earthquakes are often monitored sensitively by observing chemical composition, temperature and water level of ground water. It has been reported that ion contents of radon (Rn), chloride (Cl^-), sulfate ($SO_4{}^{2-}$) and so on in the ground water changed before earthquakes. These changes might be related to a precursory phenomenon before earthquakes. However we do not have an appropriate model that explains quantitatively the change of ion content in the pore water in relation to the physical mechanism of earthquake nucleation. Here we analyze chemical composition of pore fluid passing through a gauge layer during frictional sliding to investigate a physical relationship between its chemical composition and frictional behavior of the fault.

We conducted two series of tri-axial friction tests on a synthetic fault containing a layer of Westerly granite gouge powder whose grain size is between 100 and 250 micrometers, at a temperature of 300 degrees, fluid pore pressure of 30 MPa, and effective normal stress of 50 MPa. One series was conducted under shear deformation at an axial loading rate of 0.1 micrometer/second to examine variation of the chemical composition of the pore fluid associated with fault slip. Another series was conducted under isotropic pressure condition to evaluate only time-dependent change of the chemical composition of the pore fluid. During these experiments, the pore fluid of distilled water was flowed through the granite powder from an upstream pore pressure line (UPPL) to a downstream pore pressure line (DPPL). We collected the samples of the pore water at the end of the DPPL by opening the valve that separates inside high pressure and outside atmospheric pressure. A servo-controlled pore pressure generator attached at the UPPL was used to prevent the pore pressure from decreasing due to the sampling of the pore water at the DPPL. Temperature decreased from 300 degrees at the fault to room temperature at the sampling point of the pore water on the DPPL whose volume is about 3.1 cm^3. The pore water at the sampling point should leave some amount of the dissolved elements in the DPPL while it passed through the DPPL. In this experimental assembly, it can be checked whether fluids passing through but far away from faults preserve information on their frictional behaviors. The pore water samples were analyzed for the concentration of Al, Ca, Fe, K, Mg, Na and Si by using inductively coupled plasma atomic emission spectrometry (ICP-AES). The samples were acidified by adding 0.5 mol/l HCl to avoid mineral precipitation in the sample cases.

In the deformation test, the shear strength of the gauge layer increased with slip, and reached to a yield point at an axial displacement of around 0.2 mm. After that point, the gradient of the strength curve decreased gradually and became almost flat, which corresponds to a friction coefficient of 0.6. The comparison between the deformed and undeformed tests showed that the shear deformation affects the concentrations of Al dissolved in the pore water. The concentration increased with time in the undeformed test. In the deformed test, the concentration of Al also increased with time before the yield point same as the undeformed test, but it turned to decrease slightly after the yield point. The concentration of Si and Fe are higher in the deformed test than the undeformed test. However the difference is possible to result from another cause, such as heterogeneity of gouge samples, because their concentrations measured before the deformation of the deformed test is higher than that of undeformed test. The concentrations of Ca, K and Mg are similar in both tests. Although we do not explain systematically why the concentration of only Al was related to shear deformation, we could suggest that Al might be a useful marker to monitor a mechanical process in the fault.