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Rheology and transport properties of faults and earthquake generating processes: current status and future perspectives

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Integrated studies of seismology, fault rocks, fault rheology, transport properties of fault zones, physical properties of fault zones and mechanical analyses of earthquake generation are needed to understand the mechanisms of earthquakes. The present session has been planed so workers in relevant fields get together to discuss the physics of earthquake generation. I would like to summarize the current status of the studies of rheology and transport properties of faults and also would like to attempt focus on important future tasks based on the discussions in the present session.

As for the earthquake generating processes, I believe that high velocity frictional properties are essential although much needs to be done in this area. Notable recent findings are (1) detection of heat generation along fault using ESR signals which might enables one to determine temperature rise along slipping surfaces during earthquakes, (2) high velocity friction experiments that revealed overall features of high velocity behavior of faults mostly under dry conditions. T. Hirose and myself performed detailed experimental studies on frictional melting processes and proposed a physical model for the highly non-linear analyses of the melting processes. High-velocity friction experiments have to be extended to wet environments since tribochemical effects may be very important.

Thermal pressurization and fluidization of gouge in a extreme case have been proposed as an important mechanism for dynamic weakening of faults during earthquake. But it is still unclear whether the significant build up of pore pressure occurs or not. Our group at Kyoto University performed about 400 runs and obtained several thousands permeability values for samples collected from about 10 faults using a gas apparatus. Permeability structures of fault zones are variable and on the whole shows intermediate properties between significant and insignificant thermal pressurization regimes. We also have data on the effects of deformation on fault rocks to discuss possible changes in permeability prior to earthquakes. Analyses of fluid flow during earthquake generation based on real permeability structures are needed to evaluate the thermal pressurization processes.

A controversy in the last 15 years or so is the difference in Dc of several orders between seismically determined values and those measured in conventional friction experiments. Dc for natural faults is very difficult to determine for natural faults. Hirose has shown that fractal dimension of melting surface and the growth of molten layer can be correlated with the weakening behavior. The thickness-displacement data on pseudotachylytes in the Outer Hebrides indicates Dc of the order of several decimeters, the same order to the seismically determined values. The controversy may be solved taking into account of the frictional heating, although the effect of scaling still remain difficult problem to evaluate. Dc problems will also be discussed based on other processes such as the width of deformation zones.

Finally I would like to list up important unsolved problems in large-scale fluid flow, brittle to plastic (ductile) transition.