Japan Geoscience Union Meeting 2010
(May 23-28 2010 at Makuhari, Chiba, Japan)

SSS021-11 Room: 302 Time: May 27 16:30-16:45

Fluid migration and mechanisms for strength reduction at the brittle-ductile transition zone in the upper part of crust

Toru Takeshita[1*], Seizo Mori[2]

[1]Hokkaido University, [2]Hokkaido University

Based on the brittle strength determined by the failure experiments of rocks and flow laws estimated by deformation experiments of quartzite (e.g. Gleason and Tullis, 1995), the depth and differential stress at the brittle-ductile transition is calculated to be ca. 12.5 km and 600 MPa, respectively. Here, it is assumed that pore-fluid pressure is equal to hydrostatic pressure, strain rate is 10-15/s, geothermal gradient is 20 oC/km. Although the calculated depth of brittle-ductile transition is not much different from the depth of lower-limit of inland earthquakes, such high differential stresses have not been observed in nature. Accordingly, some softening mechanisms, in particular those which lower the brittle strength of rocks, must have operated in nature. Once, the decrease of strength occurs in fault zones in the crust, strain will be localized into the fault zones, which will become such mature fault zones to generate earthquakes. Recently, Beaumont et al. (2004) have shown based on numerical simulations that the Higher Himalayan Crystalline Sequence can be exhumed by faulting, only if the friction of upper crustal rocks is lower than one-third of the experimental value, also indicating that some softening mechanisms operated in nature.
We have recently documented that numerous normal faults were formed at the conditions of the brittle-ductile transition in some horizons of the Sambagawa metamorphic rocks, the activation of which brought the metamorphic rocks to the upper crustal level. Along these normal faults, quartz fibre veins precipitated, indicating that the reduction of frictional stress could be caused by fluid overpressure. Furthermore, the grain size reduction is another softening mechanism, which progressed for a long time. Principal microstructures in various schists with different compositions are shear bands and associated grain size reduction. For example, actinolite schist consists of preferentially oriented very-fine grained actinolite, in which closed faults probably formed by unstable sliding develop. Also, in both pelitic and quartz schists, phengite and chlorite precipitated from the solution. Since the basal slip of these minerals are weak (fs=0.3), these rocks are softened. In the core samples drilled through the Median Tectonic Line in the Mie Prefecture, similar occurrences of alteration minerals such as muscovite and chlorite are observed in cataclasite and phyllonite, by which the coefficient of friction is also lowered.
For the formation of such weak altered rocks, chemical reaction assisted by fluid migration is very important (reaction softening). It is noted that extensive metasomatism perhaps occurred to form these altered rocks. For example, to form phengite in quartz schist and phyllonite from albite constituting granitic cataclasite, a lot of potassium (K) is necessary, which must flow in from the outside. Also, a lot of Mg, Fe, Ca, etc. migrate through fluids. Since migration of chemical elements is controlled by the rate of chemical reaction and diffusion, the model of fluid migration is only possible through the detailed analyses of these processes. It is stressed that the analyses of migration of elements in exhumed fault zones are very important to interpret geophysically observed fluid distribution in the crust.

Keywords: fluid migration, brittle-ductile transition zone, shear bands, softening mechanism, coefficient of friction, grain size reduction in rocks