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To what degree can rocks become weak during deformation?: Fracturing-dissolution-mass transfer-precipitation creep

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The megaquake underneath the pacific ocean off the northeast Japan revealed important facts on crustal dynamics of the Japanese island. Among them, a new suggestion on the magnitude of differential stress in the crust is important. After the megaquake, peculiar earthquakes occurred in places, where earthquakes do not frequently occur. A typical example was an earthquake caused by normal faulting near the Iwaki-city, northeast Japan, where the stress field of a weak E-W compression was changed to that of an E-W extension. Based on the facts, Yoshida et al. (2012) estimated that the magnitude of differential stress was on the order of 1 MPa in upper crust. In this presentation, we will discuss the newly arising problems of crustal dynamics in Japanese islands, and also whether or not rocks can be deformed by such low differential stresses (i.e. *c.* 1 MPa), if this estimate of flow stresses is in fact correct.

We have been studying deformation processes and mechanisms in rocks at brittle ductile transition conditions, which seem to control the strength of upper crust, based on microstructural analyses in naturally deformed rocks. Deformation behaviors at the conditions of brittle-ductile conditions can be observed in metamorphic rocks formed at great depths, because these are elevated from ductile to brittle regions across the depth of brittle-ductile transition. For example, pervasive semi-brittle micro-faulting occurred in quartz schist from the Sambagawa metamorphic rocks at brittle ductile transition conditions. Here, although quartz layers were truncated by micro-faults, very-fine grained dynamically recrystallized quartz grains were also formed along them (i.e. micro-shear zone), suggesting components of ductile deformation. Further, very-fine-grained white mica was formed along the micro-faults, suggesting fluid percolation. With increasing deformation, the density of micro-faults increased, accompanied by the widening of micro-shear zones and associated decrease of the volume fraction of undeformed lenses. Perhaps, dissolution-precipitation creep dominated in micro-shear zones, having led to stress concentration in undeformed lenses, which were subsequently fractured. It is inferred that the rocks became softened with the increasing volume fraction of micro-shear zones.

Similarly, broken and displaced quartz detrital grains are observed in meta-sandstones deformed at brittle-ductile conditions from the Kamuikotan metamorphic rocks, northern Japan. Fibrous overgrowth of quartz occurred between the broken and displaced fragments of quartz, which appears as if these grains themselves restore the original shape. On the other hand, embayment occurred toward quartz grain sides at the boundary between quartz and white mica grains, suggesting dominant dissolution of quartz at this type of boundaries. Further, cataclasites formed along the Median Tectonic Line at the conditions of brittle-ductile conditions in the Cretaceous, and new minerals precipitated from fluids in the space created by fracturing and displacement of protolith forming minerals. The fracturing is accompanied by element migration via fluids, thus the degree increases with increasing degree of fracturing. In conclusion, deformation occurred by dissolution-mass transfer-precipitation assisted by fracturing under the conditions of brittle-ductile transition, by which significant weakening can be generated in rocks.

Keywords: differential stress in the upper part of crust, strain softening, micro-fracturing, dissolution, mass transfer, precipitation of minerals