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Mechanism transition in quartz aggregates from dislocation to micro-faulting and dissolution-precipitation creep

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For dissolution-precipitation creep in quartz, which is classified into grain boundary diffusion creep (i.e. Coble creep), little experimental work on the polycrystals has been performed. Nakashima (1995) has inferred the grain boundary diffusion coefficient (D_{gb}) in quartz aggregates at atmospheric pressure and at room temperature, and its activation energy. However, if these values are directly employed, it is inferred that strain rate by dissolution-precipitation creep at 350 ^{o}, is estimated to be 10^{-7} to 10^{-11}/s (Nakashima, 1995; Shimizu, 1995), which is 4 to 8 orders of magnitude faster than that in natural rocks (e.g. 10^{-15}/s). The discrepancy between nature and experiments could be ascribed to the fact that in deforming metamorphic rocks under high pressure, the grain boundary is not fully wetted (i.e. fluid-channel is not completely connected), and hence the natural D_{gb} is much smaller than the experimental one. Due to this reason, observations on natural dissolution-precipitation processes in quartz and estimates on deformation conditions are important for inferring the constitutive equation. We will give two examples on natural dissolution-precipitation creep in quartz schist from central Shikoku.

(1) Micro-faulting and dissolution-precipitation creep in the Sambagawa quartz schist, Niihama district

The Sambagawa schist in this area experienced intense normal faulting, which occurred under subgreenschist conditions (ca. 300 ^{o}C) during exhumation before the D3 open upright folding (i.e. D2 normal faults). In the quartz schist samples, micro-faults are extensively developed at thin-section scale. There are two types of micro-faults: one is shear band type, along which new phengite grows, and the other is shown by very-fine-grained quartz aggregates, which are perhaps formed by cataclasis. In highly sheared quartz schists, a type I crossed girdle quartz c-axis fabric is preserved in lenses bounded by shear bands. However, in wide shear bands, although a type I-like quartz c-axis fabric is preserved, its symmetry is destroyed. On the other hand, in samples where the volume ratio of phengite is high, and recrystallized quartz grains do not show wavy-extinction and exhibit irregular shape, the number of those grains with the c-axis parallel to the X (elongation) axis increases, resulting in the random c-axis fabric.

(2) Dissolution-precipitation creep in quartz schist from the Omoiji district, Northern Chichibu belt

In this quartz schist, the layers less than 1 mm thick with different grain sizes of quartz alternate. It seems that the volume fraction of phengite increases as the grain size of recrystallized quartz decreases. The fact could indicate that the original volume fraction of phengite, which pins the growth of quartz, is different between layers, and controls the recrystallized grain size of quartz. Quartz c-axis fabrics strongly develop in relatively coarse grains (D=40 micron). However, their intensity decreases as the recrystallized grain size decreases. Finally, in fine-grained recrystallized quartz with D=20 micron, the quartz c-axis fabrics are very weak or almost random.

Discussion: In the quartz schist, those grains with the c-axis parallel to the X-axis are not formed by micro-faulting alone. However, the symmetry is destroyed by micro-faulting, which causes differential rotation of the recrystallized grains. During dissolution-precipitation creep, the c-axis fabrics become randomized due to the precipitation of quartz with c-axes in various orientations, including the X-direction. Summarizing the mechanism transition from dislocation to dissolution-precipitation creep, micro-faulting occurs first, resulting in the increase in the volume fraction of phengite, which subsequently causes the mechanism transition. The fact suggests that the differential stress is lower in the two-phase aggregates of quartz plus mica than in the single-phase quartz (i.e. reaction softening).