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Grain-boundary diffusion coefficient based on variation of quartz grain sizes in metacherts around a contact aureole

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Grain-boundary diffusion coefficient is the most important parameter for considering metamorphic and deformation processes. Grain-boundary (or bulk) diffusion coefficients have been estimated experimentally (Farver and Yund, 1990, 2000) or naturally (Joesten, 1983). According to Farver and Yund (2000), the temperature dependence of silicon (bulk) diffusion in the novaculite is described by the Arrhenius parameters: D0 = 3.7 x 10ˆ-10 m2/s and Q = 137+/-18 kJ/mol, and D0 = 6.2 x 10ˆ-9 m2/s and Q = 178+/-38 kJ/mol for the hydrothermal and dry experiments, respectively. On the other hand, variation of the quartz grain sizes in nodular chert in the Christmas Mountains contact aureole was matched by a normal grain growth model in which the temperature dependence of the Arrhenius function along temperature-time history calculated by an one-dimensional thermal modeling. Assuming the grain boundary width of 1 nm, the data permit an estimate of the coefficient for the grain-boundary diffusion of oxygen in quartz as D = 8.07 x 10ˆ-10 exp(-210 x 10ˆ3/RT). Therefore, there is significant difference between the coefficients for a quartz aggregate estimated experimentally and naturally.

In this study, we evaluate the grain-boundary diffusion coefficient by the same scheme of Joesten (1983). We collected metachert samples from the contact aureole around the Hanase-Bessho quartz diorite (Kiji et al., 2000) at the Hanase Pass, Kyoto. Photomicrographs are taken under optical microscope and scanning electron microscope. The grain boundaries are traced using drawing software (Canvas), and grain sizes as equivalent diameter of circles are estimated by ImageJ. The quartz grain sizes vary systematically with the distance from the quartz diorite. We calculated temperature-time history using a one-dimensional thermal model. Based on Arrhenius plot of the observed quartz grain sizes and calculated temperatures, we estimated the activation energy 140+/-16 kJ/mol that is comparable with the value for silicon bulk diffusion estimated by Farver and Yund (2000) for hydrothermal experiment. Furthermore, using the value estimated here, we obtained the value of D0 = 5 x 10ˆ-12 m2/s.

References: Kiji, M., Ozawa, H. and Murata, M. (2000) Cretaceous adakitic Tamba granitoids in northern Kyoto, San'yo belt, Southwest Japan. Jour. Mineral. Petrol. Sci., 29, 136-149.

Keywords: grain-boundary diffusion coefficient, quartz, normal grain growth, contact aureole, termal model, grain size