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Grain-boundary diffusion rates inferred from grain-size variations of quartz in metacherts from a contact aureole

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Abstract

We evaluate a temperature-dependent coefficient for grain-boundary diffusion in quartz aggregates using grain size data from a contact aureole, based on the coupling of a numerical model for the temperature-time history of the contact aureole with a model for the kinetics of diffusion-controlled grain growth. The metachert samples were collected from the contact aureole of the Hanase-Bessho quartz diorite at Hanase Pass, Kyoto, Japan. The quartz grain sizes vary systematically with distance from the quartz diorite. We calculated the temperature-time history using a one-dimensional thermal model, validated by peak metamorphic temperature estimates that are based on the degree of graphitization of carbonaceous material in metapelites, as characterized by Raman microspectroscopy. To minimize the sum of the squares of the errors between the measured and calculated grain sizes, based on the normal grain growth law together with the temperature-time history, we estimated the activation energy and pre-exponential factor in the α-quartz field to be 208 kJ/mol and 1.1×10^{-8} m^2/s, respectively, assuming a grain-boundary width of 1 nm. The grain-boundary diffusion rates for temperatures in the greenschist and amphibolite facies are similar to those determined in natural or laboratory grain-coarsening experiments, but differ significantly from those determined in tracer diffusion experiments. During grain-size-sensitive deformation, "effective" grain-boundary diffusion rates may be intermediate between the rates of diffusion along and across the grain boundary, and would be higher than the grain-boundary diffusion rates estimated by grain-coarsening experiments, and lower than those by tracer diffusion experiments.

Keywords: Grain-boundary diffusion, quartz aggregates, grain sizes, contact aureole, normal grain growth