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Multicomponent Diffusion Modeling of Garnet: a Tool To Estimate Burial and Exhumation Rate of Metamorphic Complexes

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The occurrence of high-pressure rocks, mainly preservation and formation of concentration gradient within garnet or at its contact with other minerals provide evidence for the geodynamic processes of subduction and exhumation of crustal material within orogenic belts. With combination of the results from experimental data on diffusion coefficients and thermobarometric analyses from natural material, the measured concentration profiles in mineral can be used to estimate burial and exhumation rates of rock underwent high-pressure metamorphism. Diffusion modeling is based on definition of initial and boundary conditions, diffusion coefficients and the P-T-t history over which the diffusion takes place. During geological processes, diffusion in multicomponent minerals such as garnet results from simultaneous flow of more than two components. In garnet the diffusion of Mg, Fe, Mn and Ca are coupled to each other. The diffusion profiles measured in the microprobe can be modeled using the approach, proposed by Chakraborty and Ganguly (1991).

Starting with the initial profile shapes and calculated diffusion coefficients, a finite difference modeling scheme can be employed to calculate diffusion profiles. In this forward modeling approach, calculations are carried out until a good match is obtained with the observed, high resolution (points measured at l micron spacing) profile shapes near the interface of two minerals or two compositionally different garnets. It is here that a full multicomponent simulation is more useful than using effective binary diffusion coefficient – only for a rather limited range of time scales is possible to simultaneously reproduce the shapes of profiles for all elements. The time scale corresponding to the simulation that yields the best fit with the observed profiles is taken to be the one taken to traverse the P-T path being modeled. The method was used for burial and exhumation rate for two garnets of different composition, where the older garnet forms core and younger mantle. The simulation was don for a time scale estimated according to the P-T path. Diffusion coefficient was calculated for Mn, Mg and Fe, where Ca was treated as dependent component. The advantage of such simultaneous calculation is that it allows subtle details of variations in compositional profiles to be interpreted and considerably reduces the uncertainty in retrieved time scales that may be obtained from using only one profile. The modeling suggests that a minimum subduction/exhumation rate of ~4cm/a and heating/cooling rates on the order of 100–260 °C/Ma for a 60 °C subduction angel are required to preserve the observed compositional zoning overall while modifying the zoning at the interface between two garnets to the extent observed.

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