

Simulated garnet-clinopyroxene geothermometry of eclogites

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Metamorphic temperatures are commonly derived from the experimentally calibrated fractionation of selected elements amongst coexisting mineral phases. The blocking temperature of any exchange reaction is the temperature under which the kinetics of this reaction becomes extremely slow with respect to a geologically significant time interval. The equilibrium temperature obtained by using experimental data to the distribution of elements between specific areas (rim, core) of coexisting mineral phases is related in a complex way to the blocking temperature of reactions involving these elements. For instance, one can suspect that interdiffusion of Fe and Mg in garnet between the rim and the core takes place at temperatures where diffusion within coexisting clinopyroxene crystals is completely shut down. Temperatures derived from the assumption of rim-rim garnet-clinopyroxene equilibrium might in this case be seriously in error. Because it integrates information on spatial concentration gradients, the theory of blocking temperature (Dodson, 1973) does not immediately apply to in-situ distribution of elements.

The Fe-Mg thermometer widely used to infer the 'equilibration' temperature of garnet-clinopyroxene assemblages of eclogites is modelled as the progressive blocking of diffusion-limited exchanges between coexisting mineral phases. It is argued that the fast grain boundary model in which equilibrium is achieved through exchange of Fe and Mg circulating in an interstitial medium fast enough for the rate-limiting step to be volume diffusion in each mineral phase. A semi-analytic solution is found and the influence of the cooling history, grain size distribution, and rock composition on the temperature at which the Fe-Mg exchange between garnet and clinopyroxene is frozen are quantitatively evaluated.

In particular, the model simulates the temperatures that would be obtained from the concentration of Fe and Mg in the rim of adjacent garnet and pyroxene crystals such as those commonly obtained by electron probe. For eclogites, the simulations show that correct peak temperatures are retrieved as long as the temperature of the metamorphic climax does not exceed 650°C. At higher climax temperatures, rim-rim temperatures underestimate the peak temperature and cluster towards 650°C. Fast cooling, however, strongly limits diffusive equilibration. In crustal-type eclogites, cooling rates of a few degrees per Myr at 700°C and of a few tens of degrees at 800°C preserve the record of the peak temperature. It is shown that these results are largely independent of the chemical composition of the garnet and clinopyroxene. On the contrary, the mineral grain size and the respective proportions of garnet and pyroxene have a major effect on retrogressive diffusion. For eclogites formed at a temperature of 800°C and under conditions of slow cooling, the record of the climax temperature is preserved by crystal rims as long as the volume of pyroxene is smaller than that of garnet and crystal size is millimetric or larger. The choice of the particular set of experimental data for the diffusion coefficients is found to be immaterial. We suggest that the temperature of the metamorphic climax of eclogites is best estimated from the composition of clinopyroxene rims combined with that of the inner edge of the diffusion boundary layer fringing the coexisting garnet grains.

References

- Dodson, M.H. (1973) *Contrib. Mineral. Petrol.*, **40**, 259-74.