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TIME CONSTRAINTS ON THE METAMORPHIC EVOLUTION OF TAUERN ECLOGITES FROM DIFFUSION MODELLING

by

E. Dachs[1] & A. Proyer[2]

[1]Institut für Mineralogie und Petrologie
Universität Salzburg, Hellbrunnerstrasse 34, A-6020 Salzburg
[2]Institut für Mineralogie und Petrologie
Universität Graz, Universitätsplatz 2, A-8010 Graz

Discontinuous zoning profiles in garnet can be used as geo-speedometers, giving good constraints on the time span between the formation of a discontinuous growth zone in garnet and the time of closure to intracrystalline cation diffusion by modelling the time required for the observed compositional profile to form from an assumed original sharp compositional step, such as caused by a hiatus in growth, either during one metamorphic episode or during a polymetamorphic history.
An eclogite sample from the Glockner area of the Hohe Tauern, Austria [1] contains garnet with a very pronounced compositional discontinuity between a Mn-rich core with inclusions of amphibole, calcite and magnetite and an Fe-rich rim with inclusions of omphacite and dolomite. Epidote, paragonite and quartz occur as inclusions in both zones. The jump in composition (pronounced in X_{Fe} and X_{Mn}, Fig. 1) also marks a microtextural discontinuity (the core hosts a large number of generally small inclusions, the rim has very few inclusions of generally larger size) and is interpreted as the result of an omphacite-forming and garnet-consuming reaction.

A solution to the problem of the interdependent diffusion of the four cations Fe, Mg, Mn and Ca within a single phase can be obtained analytically by one-dimensional modelling of a half-infinite space with fixed (plateau-) compositions on either side of the discontinuity. In this case a number of simplifications and assumptions are necessary: An "effective binary diffusion coefficient (EBDC)" is calculated from the four single diffusion coefficients; single values for temperature and for the difference in composition have to be used in the calculation throughout.

A much higher flexibility can be obtained by (one-dimensional) numerical modelling: Each point along the compositional profile is used in the calculation, so any shape of the original (pre-diffusion) profile can be conceived and tested. No EBDC is needed and any PT-path, or segment of it, as obtained from petrologic reasoning, may be used for the geologic time span in question. This gives an additional flexibility of modelling the changes in composition as a function of position (in the profile), pressure, temperature and time. Diffusion coefficients (calculated according to [2]) are also reevaluated as functions of P, T and composition during each iteration.

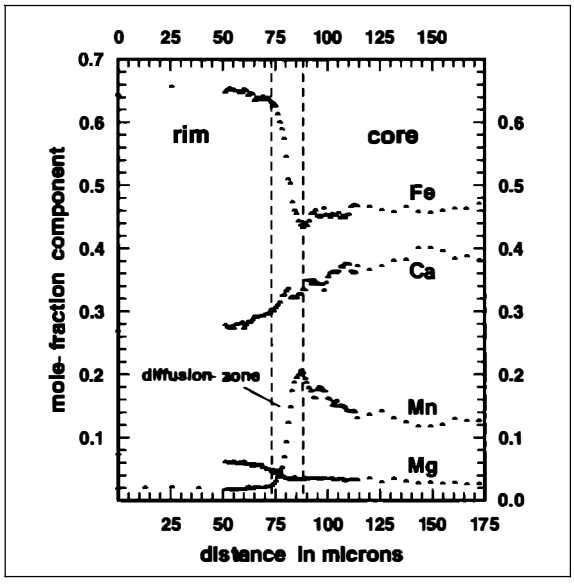

Figure 1

Discontinuous zoning profile preserved in a garnet from eclogite sample G5 (locality Gamsgrube, Grossglockner area), showing the development of a ~15 µm wide diffusion zone between the compositionally contrasting core- and rim regions.

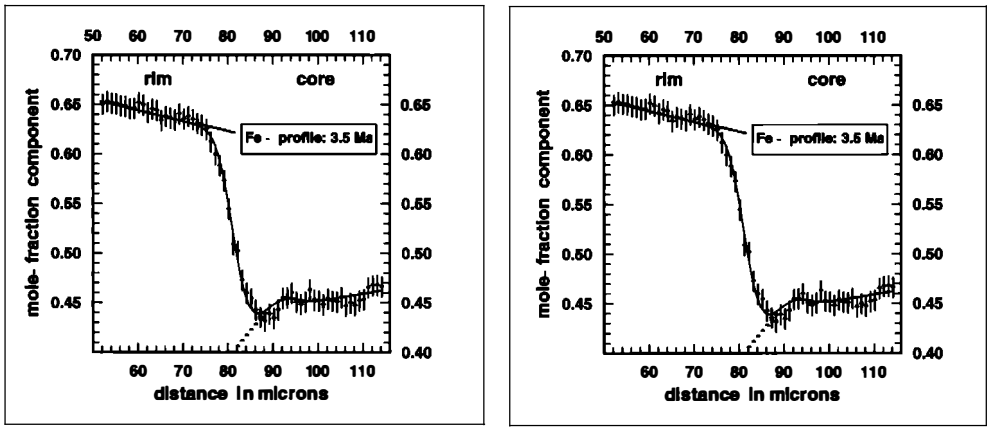

Figure 2

Numerical modelling of the diffusion-zone from the garnet-profile of Fig. 1. The pre-diffusional composition in the diffusion zone has been extrapolated from the compositional trends visible in the adjacent internal core- and external overgrowth zone (dots). Error bars mark ± 0.01 in the mole-fractions of the measured profile. Results of the numerical diffusion modelling are shown by the solid curve that fits the pronounced step in the Fe- and Mn-profile at 3.5 Ma. The imposed PT-path is that derived for the Grossglockner eclogites by [1].

The garnet investigated has a very complex zoning pattern which also varies in different directions. Despite of these complexities it was possible to obtain similar times not only for different elements from one profile but also for different profiles. Diffusion lasted from the time of rim growth along the prograde path through peak conditions (17 kbar/570°C) to about 450°C, 4 kbar on the retrograde path for maximal 3.5 Ma (Fig. 2) which points to rapid tectonic events related to exhumation of these Tauern eclogites.

References

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[2] CHAKRABORTY, S. & GANGULY, J. (1992): Cation diffusion in aluminosilicate garnets: experimental determination in spessartine-almandine couples, evaluation of effective binary diffusion coefficients, and application. - Contrib Mineral Petrol 111:74-86.