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Major- and Trace-element modelling in Garnet along Eclogite P-T Paths

M. Konrad-Schmolke (1), T. Zack (2), P.J. O'Brien (1) and D. Jakob (3)

(1) Universität Potsdam, Dept. of Geosciences, (2) Universität Heidelberg, Inst. of Mineralogy, (3) Universität Mainz, Dept. of Geosciences (mkonrad@geo.uni-potsdam.de)

Compositional growth patterns in metamorphic minerals are important for the extraction of information about intrinsic and extrinsic parameters during metamorphism as such chemical variations in minerals often preserve detailed information about the temporal physico-chemical evolution of the host rock. Apart from major elements, metamorphic minerals often preserve a complex trace element zonation that might also be indicative for mineral reactions and associated kinetic processes, such as transport- or interface-controlled element incorporation in metamorphic phases. Knowledge of such disequilibrium processes is crucial for the understanding of mineral growth and microstructural development but, more importantly, can also yield insights into trace element transport within and between reacting bodies.

In this work we combine thermodynamic forward models that yield detailed information on mode and major element composition of stable phases with a mass balance distribution of rare earth elements (REE) among the calculated stable assemblage during high pressure metamorphism. The aim of this study is to interpret a combination of modelled major- and trace element zonation patterns in complexely zoned ultra-high pressure (UHP) garnets from the Western Gneiss Region (WGR, Norway), in order to study trace element distribution and thermodynamic equilibrium during garnet growth in a subducted slab.

All investigated garnets show signs of multiple growth zones and preserve complex growth zonation patterns with respect to both, major and rare earth elements. Generally two types of major element zonation patterns occur: that with abrupt composi-

tional changes that correspond with the growth zones and that with compositionally homogeneous interiors followed by abrupt chemical changes towards the rims. Despite the differences in the major element zonation, the REE element patterns are almost identical in all garnets. The garnets show core-to-rim variations that can be divided into four distinct zones with characteristic REE patterns. In the garnet cores (Zone 1) the normalised REE content increases steadily from light (LREE) to heavy rare earth elements (HREE). From inner to outer core the normalised contents of HREE decrease, whereas the medium (MREE) and LREE contents remains constant. Towards the inner part of the rim the decrease in normalised HREE contents is amplified and also the MREE concentration is slightly decreased resulting in a moderately bended pattern that changes only weakly from inner to central rim (Zone 2). Towards the outer part of the rim the REE pattern is characterised by a drastic increase in Dy, Ho and Er whereas the increase in other REE concentrations is only limited (Zone 3). In the outermost parts of the rim an increase in the MREEs is associated with a slight decrease in the HREEs resulting in a strongly bended pattern with a maximum between Tb and Dy (Zone 4).

Our thermodynamic forward models can reproduce the complex major element zonation patterns and growth zones in the natural garnets and predict garnet growth during four different reactions: (1) chlorite breakdown, (2) epidote breakdown, (3) amphibole breakdown and (4) garnet growth from cpx at UHP conditions. Mass-balanced REE distribution among the modelled stable phases based on partition coefficients from the literature yielded REE zonation in garnet that closely resembles that observed in the natural samples. Due to fractionation effects and contrasting REE patterns in the educt phases, core-to-rim REE zonation in garnet develops distinct REE enrichment zones characteristic for the minerals involved in the garnet-forming reaction. Complex REE patterns and local peaks, formerly interpreted to result from transport-controlled REE uptake in garnet can be explained by fractionation effects and changes in the mineral assemblage due to mineral breakdown reactions.