

Mechanisms of garnet growth in eclogites of the Zermatt-Saas Fee unit, Western Alps

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Thesis Abstract

Garnets are one of the key metamorphic minerals used to study peak metamorphic conditions or crystallization ages. Equilibrium is typically assumed between the garnet and the matrix. This thesis attempts to understand garnet growth in the Zermatt-Saas Fee (ZSF) eclogites, and discusses consequences for Sm/Nd and Lu/Hf dating and the equilibrium assumption.

All studied garnets from the ZSF eclogites are strongly zoned in Mn, Fe, Mg, and Ca. Methods based on chemical zoning patterns and 3D spatial statistics different growth mechanisms depending on the sample studied. Garnets from the Pfulwe area are grown in a system where surface kinetics likely dominated over intergranular diffusion kinetics. Garnets from two other localities, Nuarsax and Lago di Cignana, seem to have grown in a system where intergranular diffusion kinetics were dominating over surface kinetics, at least during initial growth.

Garnets reveal strong prograde REE+Y zoning. They contain narrow central peaks for Lu + Yb + Tm = Er and at least one additional small peak towards the rim. The REE Sm + Eu + Gd + Tb = Dy are depleted in the cores but show one prominent peak close to the rim. It is shown that these patterns can be explained using a transient matrix diffusion model where REE uptake is limited by diffusion in the matrix surrounding the porphyroblast. The secondary peaks in the garnet profiles are interpreted to reflect thermally activated diffusion due to a temperature increase during prograde metamorphism. The model predicts anomalously low $^{176}\text{Lu}/^{177}\text{Hf}$ and $^{147}\text{Sm}/^{144}\text{Nd}$ ratios in garnets where growth rates are fast compared to diffusion of the REE, which decreases garnet isochron precisions.

The sharp Lu zoning was further used to constrain maximum Lu volume diffusion rates in garnet. The modeled minimum pre-exponential diffusion coefficient which fits the measured central peak is in the order of $D_0 = 5.7 \cdot 10^{-6} \text{ m}^2/\text{s}$, taking an activation energy of 270 kJ/mol. The latter was chosen in agreement with experimentally determined values. This can be used to estimate a minimum closure temperature of around 630°C for the ZSF zone.

Zoning of REE was combined with published Lu/Hf and Sm/Nd age information to redefine the prograde crystallization interval for Lago di Cignana UHP eclogites. Modeling revealed that a prograde growth interval in the order of 25 m.y. is needed to produce the measured spread in ages.