# Toward an understanding of fluid-induced growth of oscillatory-zoned garnets in Group-C eclogites: Temporal constraints from nanoscale cation-diffusion modeling

*Ryo Fukushima[1], Tatsuki Tsujimori[1], Nobuyoshi Miyajima[2]

1. Tohoku University, 2. Bayerisches Geoinstitut, University of Bayreuth

Low-temperature (*T*) eclogite (a.k.a. Group-C eclogite), which occurs in Phanerozoic high-pressure/ultrahigh-pressure (H*P*-UH*P*) metamorphic complexes, has attracted great attention for understanding slab-fluid behaviors in subduction zones. Among their notable petrological/mineralogical signatures, prograde-zoned porphyroblastic garnet with oscillatory zoning in minor- or trace-elements is the most intriguing and enigmatic object. Recent studies have suggested that the unique chemical zoning can be formed with repeated fluid infiltrations during the slab eclogitization, and even envisaged that such fluid pulses occur in a period of less than a few million years accompanied by intermediate-depth seismicity (e.g., Viete et al., 2018). In this study, by performing nanoscale cation-diffusion modeling within natural garnet-hosted omphacite, we attempted to constrain the growth rate of the oscillatory-zoned rim to discuss intraslab geochemical processes, likely facilitated by slab-derived fluids.

We focused on the syngenetic omphacite inclusion in Syros eclogite depicted in the Figure 9 of Fukushima et al. (2021) [Am. Mineral.]. Considering Fe heterogeneity (~130 nm in width) within the garnet-hosted omphacite, we assumed that the peak-*T* residence time of the eclogite was too short to erase the compositional gap with thermal relaxation of $Fe^{2+}$–Mg. As the omphacite inclusion lies just inside of the oscillatory-zoned, outer shell of the garnet (~300 μm in width), the peak-*T* annealing time would be equivalent to the growth duration of the oscillatory-zoned garnet shell. By analyzing 18 representative Fe intensity profiles, we estimated the product of the diffusion coefficient and time as $\log_{10}[Dt, m^2] = -16.4 \pm 0.6$ (1s). Then, applying experimentally determined $Fe^{2+}$–Mg interdiffusivity in diopsidic clinopyroxene, we obtained the growth durations of the oscillatory-zoned garnet rim as $\log_{10}[t, yr] = 2.8 \pm 0.9$ (1s, at $T = 560 \pm 25$℃) and $\log_{10}[t, yr] = 3.6 \pm 0.8$ (1s, at $T = 530 \pm 17$℃). Although the uncertainty is too large to precisely determine the duration, these values imply that the garnet rim grew faster than typical garnet porphyroblasts with a confidence of ~80%.

However, a question that arises here is, if the outer shell grew rapidly, what is the cause of this event? Our *P*–*T* pseudosection modeling did not show any transitions of garnet-forming reactions at around the peak metamorphic condition. Moreover, the extent of nucleation overstepping was calculated to be typical values (<~30℃ or <~1.5 kJ per mole garnet), which may preclude exceptionally rapid growths of the entire garnet. Therefore, we conclude that significant fluid-infiltration and subsequent reaction catalyzation and/or cation mobilization is required to produce such oscillatory-zoned garnet rims. This interpretation is consistent with the prevailing idea of fluid-induced oscillatory-zoning formation, and might provide a critical constraint on fluid-involved garnet-growth kinetics during incipient eclogitization of subducted slab. Furthermore, this result demonstrates the potential of nanoscale geochemical analyses for discussing short-span (<~$10^4$ years) geological events, including megathrust earthquakes in subduction zones.

Keywords: garnet, eclogite, oscillatory zoning, intermediate-depth seismicity, scanning transmission electron microscopy, cation diffusion

 