Petrogenetic information stored in needle-shaped rutile inclusions in pegmatoid garnet

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We investigate the petrogenetic information stored in needle-shaped rutile inclusions hosted by garnet. For this purpose, microstructural and compositional zoning of almandine-spessartine garnet (Grt) in a pegmatoid from the Gföhl Unit (Bohemian massif, AT) is correlated with host-inclusion crystallographic and shape orientation relationships along the transition between microstructurally distinct garnet growth zones. The transition from the Grt core to the garnet rim (R1) is defined by a gradual increase in the aspect ratio of rutile (Rt) inclusions accompanied by a reduction in Grt colour intensity. The coloured outer core of Grt hosts equant rutile inclusions, whereas the uncoloured Grt zone R1 contains rutile needles of c. 100 – 150 μm length (Figure 1).

More than 11 different crystallographic orientation relationships (CORs) between Grt host and Rt inclusions are known (Hwang et al. 2016; Griffiths et al. 2016). The new dataset documents a systematic correlation of the shape preferred orientations (SPOs) of rutile inclusions in garnet, and the CORs between the two phases. This allows grouping specific CORs according to the particular crystallographic axes that coincide with the needle elongation directions: Group A Rt⟨103⟩‖Grt⟨111⟩*, Group B Rt⟨001⟩‖Grt⟨111⟩** and Group C Rt⟨001⟩‖⟨100⟩***. The two microstructural domains show remarkable differences in the frequencies of these COR groups. In the outer core of garnet Group A CORs are predominant (> 70%), while Grt zone R1 shows a predominance of Group B CORs, as well as a significantly higher abundance of CORs assigned to Group C, which are almost absent in the outer core.

As the major element profile of garnet along this microstructural transition is continuous, and the trace element distribution in Grt allows us to exclude significant re-equilibration by diffusion, we conclude that other factors than changes in the PT-conditions are responsible for the differences in the garnet microstructure and COR frequencies.

Growth zone R1 is characterized by the exclusive presence of Qtz inclusions and elevated Na_2O and OH^- content compared to the Grt core, implying an increase in the water activity during R1 growth. Hydrogen content in Alm-Sps garnet has been confirmed to increase from wall to core zones of pegmatites and to serve as tracer for their evolution (Arredondo et al. 2001). Consistently, we also observe an increase in anorthite content in matrix plagioclase (Pl). In analogy to basaltic systems, Pl crystallising from a melt at constant or decreasing temperature can be referred to an increase in water activity (Lange et al. 2009, Housh and Luhr, 1991). Therefore, change in Pl-composition caused by increasing water activity could represent the source of Si and Na during R1 garnet growth. In summary, the observed compositional zoning trends of garnet and plagioclase are consistent with an increase in H_2O concentration of the melt, without need for significant changes in PT-conditions during garnet core and R1 growth.

The comparison of the studied sample with a pegmatite garnet from the Koralpe (Eastern Alps, AT) shows remarkable similarities (Griffiths et al. 2014; 2016). There, the coloured garnet core comprises mostly equant rutile inclusions and corundum, while colourless garnet rim domains contain needle-shaped rutile inclusions and aluminosilicates, and are intergrown with Qtz. Most interestingly, the Koralpe pegmatite garnet rim also has a higher abundance of Group B CORs, compared to the garnet core domains of the same sample. We conclude that the observed microstructural transition is possibly connected with an increase of Si and/or H_2O-concentration in the melt.

As the formation of dispersed needle-shaped rutile inclusions in garnet is often referred to exsolution from the host garnet (Griffin et al. 1971; Gou et al. 2014), the frequencies of shape preferred orientations (SPOs) of rutile in garnet zone R1 were studied on the basis of > 2500 rutile needles. We observe SPOs of rutile along particular garnet crystal directions, where rutile needle elongation parallel to <111>Grt by far exceeds Rt needle elongation direction parallel to <100>Grt. Based on the assumption that the exsolution of rutile inclusions from garnet would lead to equal abundance of SPOs in symmetrically equivalent directions, each individual needle orientation was counted in R1 zones of two {112}Grt growth sectors corresponding to different crystallographically equivalent garnet facets. We find that those rutile needles parallel to <111>Grt with the lowest angle to the garnet growth direction have a higher abundance, whereas rutile needles with their elongation direction parallel to the particular Grt growth facet plane are absent in both studied growth sectors. Due to this growth-related effect on the SPO frequencies we conclude that the rutile needles originate from co-growth with their host crystal (Griffiths et al. 2020).

* Group A contains the specific CORs with a common axial relationship: COR-1, 2, 2', 3, R3a and an undescribed COR defined by Rt ⟨100⟩‖Grt{112} and Rt ⟨320⟩‖Grt{120},

** Group B contains COR-4 and 4b,

*** Group C contains COR-5 and 5a (Hwang et al 2016; Griffiths et al. 2016).

Figure 1. Optical micrograph (plane polarized light) of the microstructural transition from the outer garnet core to the garnet growth zone R1 in a {112}Grt growth sector. Note the increasing aspect ratio of rutile (Rt) inclusions and the decrease in garnet (Grt) colour intensity from the outer core to R1.

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