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Using electron backscatter diffraction to determine the formation mechanism of mineral inclusions in garnet

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Determining the origin of mineral inclusions is a key problem in petrology. Assuming different inclusion formation mechanisms can lead to dramatically different petrological interpretations. Crystallographic orientation relationships (CORs), systematic relationships between the crystallographic orientations of crystals sharing boundary segments, are sensitive to the mechanisms of inclusion formation. Electron backscatter diffraction (EBSD) in the scanning electron microscope yields highly spatially resolved information about host-inclusion CORs. EBSD point analyses allow collection of large COR datasets, while retaining a link to the location of every measured inclusion and any shape preferred orientation (SPO) relative to host crystallography and microstructures. Based on combined COR, SPO and location information, we can differentiate between multiple origin hypotheses where COR formation is predicted, and the large number of measurements achievable allows observation of the relative frequency of different CORs.

Acicular rutile inclusions in garnet with SPOs parallel to garnet crystal directions are often interpreted based on microstructures alone as products of exsolution, implying the existence of precursor Ti-bearing garnet. We studied rutile needles from metapegmatite garnets from two localities with separate geological histories. Rutile needles occur in zones that extend parallel to garnet {112} (both localities) and {110} (one locality) crystal planes. Needles are elongated parallel to <111> (both localities) and <100> (one locality) directions in the garnet hosts. The majority of needles show a “specific” (completely fixed) COR to the garnet host. Several different CORs can be found within a single garnet domain and the frequency of different CORs varies both between domains from the same locality and between localities. Despite the existence of several CORs, there is a systematic link between the rutile-garnet COR exhibited by a given needle inclusion and its elongation direction relative to the crystallography of both garnet and rutile.

A comparison with literature datasets of CORs from garnets with acicular rutile inclusions reveals that both the type and frequencies of rutile-garnet CORs found in metapegmatite garnets differ strongly from those found in garnets of purely metamorphic origin. CORs judged to result in a poor alignment between rutile and garnet structures are considerably more frequent in the metapegmatite samples.

In garnets from one locality, the SPO of rutile needles does not favour all crystallographically equivalent garnet <111> directions equally. Instead, needles are preferentially elongated parallel to garnet <111> directions at high angles to the garnet facets defined by inclusion zoning. SPO and

COR of the rutile needles thus depend on the orientation of the growing garnet interface, which is incompatible with an exsolution origin for these inclusions. Oriented nucleation of rutile at the garnet interface and subsequent simultaneous growth of both phases can account for these observations.

These results show the power of combining spatially resolved COR data with SPO information. An exsolution origin for rutile needles cannot be proposed based on needle SPO alone, and specific CORs are not necessarily indicative of an exsolution origin for rutile needles even if they occur together with an SPO relative to the garnet host.

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