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3D distribution of primary melt inclusions in garnets by X-ray microtomography

Bernardo Cesare (1), Matteo Parisatto (1), Giuseppe Cruciani (2), Lucia Mancini (3), and Luca Peruzzo (4)

(1) Department of Geosciences, University of Padova, via G. Gradenigo 6, 35131 Padova, Italy (bernardo.cesare@unipd.it), (2) Department of Physics and Earth Sciences, University of Ferrara, via G. Saragat 1, 44122 Ferrara, Italy, (3) Elettra - Sincrotrone Trieste S.C.p.A., S.S. 14 - km 163.5 in AREA Science Park, 34149 Basovizza (Trieste), Italy, (4) CNR - Istituto di Geoscienze e Georisorse, via G. Gradenigo 6, 35131 Padova, Italy

We have applied X-ray computed microtomography (X-μCT) to investigate the three-dimensional (3D) spatial distribution of primary melt and fluid inclusions in garnets from the metapelitic enclaves of El Hoyazo, Spain. The attention is focused on a particular case of inhomogeneous distribution of inclusions, characterized by inclusion-rich cores and almost inclusion-free rims (i.e. zonal arrangement), that has been previously investigated in detail only by means of 2D conventional methods. Different experimental X-μCT configurations, both synchrotron radiation- and X-ray tube-based are employed, in order to explore the limits of the technique. The internal features of the samples are successfully imaged, with spatial resolution down to a few micrometers.

By means of dedicated image processing protocols, the lighter melt and fluid inclusions can be separated from the heavier host garnet and from other non-relevant features (e.g., other mineral phases or large voids). This allows to evaluate the volumetric density of inclusions within spherical shells as a function of the radial distance from the center of the host garnets. The 3D spatial distribution of heavy mineral inclusions is investigated as well, and compared with that of melt inclusions.

Data analysis reveals the occurrence of a clear peak of melt and fluid inclusions density, ranging approximately from 1/3 to 1/2 of the radial distance from the center of the distribution and a gradual decrease from the peak outwards. Heavy mineral inclusions appear to be almost absent in the central portion of the garnets and more randomly arranged, showing no correlation with the distribution of melt and fluid inclusions. In order to reduce the effect of geometric artefacts arising from the non-spherical shape of the distribution, the inclusion density was calculated also along narrow prisms with different orientations, obtaining plots of pseudo-1D distributions. The results show that the core-rim transition is characterized by a rapid (but not step-like) decrease in inclusion density, occurring in a continuous mode. X-ray tomographic data, combined with electron microprobe chemical profiles of selected elements, suggest that despite the inhomogeneous distribution of inclusions, the investigated garnets have grown in one single progressive episode in the presence of anatectic melt. The continuous drop of inclusion density suggests a similar decline in (radial) garnet growth, which is a natural consequence in the case of a constant reaction rate.

Our results confirm the advantages of high-resolution X-μCT compared to conventional destructive 2D observations for the analysis of the spatial distribution of μm-scale inclusions in minerals, owing to its non-invasive 3D capabilities. The same approach can be extended to the study of different microstructural features in samples from a wide variety of geological settings.