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Snowball garnet growth in pelites

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Snowball garnets are intuitively believed to be unambiguous shear sense indicators. Hence, they are among the most used microstructures for interpreting metamorphic-deformational history of a rock. However, despite the apparently robustness of this shear sense marker, two controversial models exist on how to account for their development. One model argues for porphyroblast rotation with respect to the foliation whereas the second one implies rotation of the foliation with respect to the garnets. This is particularly problematic, since the two possible mechanisms for the formation of snowball garnets implicate opposite shear sense in the foliation. So far, most attempts to test the rotational and non-rotational models have focused on microstructural evidences for or against rotation. However, this approach failed to properly resolve this issue since most geometries observed in snowball garnets can be explained by both the rotational and the non rotational model.

Investigations of the chemical composition, crystallographic orientation, and three-dimensional shape of snowball garnets revealed several characteristics which enable us to distinguish between rotational and non rotational models. The snowball garnet samples were collected from the Lukmanier Pass area in the central part of the Swiss Alps. The occurrence of such garnets is restricted to specific lithostratigraphic levels characterized by thin alternations of quartz and micas-rich layers. Crystallization/deformation relationships indicate that the snowball garnets developed during a crustal thickening that produced a very strong crenulation cleavage and associated microlithons. Most importantly, the snowball garnets are commonly located on a line which corresponds to the crenulation lineation associated with this crustal thickening phase. This feature suggests that the onset of the garnet crystallization post-dated the microlithons formation.

Chemical major elements mapping, electron backscattered diffraction analysis, and high-resolution X-ray computed tomography imaging indicate that two distinct mechanisms govern the growth of snowball garnets from the Lukmanier pass area (central Swiss Alps). A first stage of simultaneous growth and rotation of the crystal was likely responsible for the onset of the development of the spiral-shape geometry of the studied garnets. Subsequent static crystallization is demonstrated by (1) the record of the temporal evolution of the Mn concentration from core to rim, (2) the relationship between deformation and crystallographic orientation and (3) post-kinematic garnet crystallization along deformed micas rich layers. On basis of these observations, the spiral shape geometry of the snowball garnets from the Lukmanier is believed to overestimate the true amount of rotation experienced by the crystal. Our data show the importance of combining different approaches to assess the mechanism leading to the development of snowball garnet porphyroblasts.