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3D textural and geochemical porphyroblast analysis: unravelling the integrated history of nucleation, growth and deformation

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A better understanding of the petrogenetic processes operating in a rock during metamorphism can be achieved by considering the spatial distribution of mineral phases. Hence, the quantitative analysis of microstructure in metamorphic rocks has long been the subject of research, and recently the application of high-resolution micro-computed tomography (μ-CT) to parameterise the 3D size, shape and spatial distribution of porphyroblastic minerals has become more common. In particular, the widespread study of garnet in order to constrain metamorphic pressure-temperature-time (P-T-t) histories can be augmented by μ-CT assessment. The spatial extent and degree to which a rock system is chemically equilibrated during garnet-forming reactions is likely to impact the crystal size distribution and chemical composition of garnet porphyroblasts. Therefore, the 3D distribution of a garnet population may provide nuanced insight into its history of nucleation, growth and deformation. Application of μ-CT also facilitates selective rock sectioning, permitting a more complete geochemical characterisation of the heterogeneity within natural systems.

We present case studies in which the integrated numerical assessment of rock microstructure and mineral chemistry yields insight into the controls influencing regional rock metamorphism. Examples are derived from well-characterised schists of the inverted Barrovian metamorphic sequence in the Sikkim Himalaya, which provides an ideal natural laboratory in which to investigate fundamental controls on the formation of porphyroblastic textures. In particular, disparate garnet morphologies in samples modelled to have experienced comparable P-T conditions of garnet crystallisation are investigated in order to determine the influence that local variations of chemical and physical parameters (e.g., heating rate, degree of deformation, precursor rock fabric) may have had on garnet texture. Numerical simulation of garnet crystallisation, aided by the knowledge of accurate crystal size distributions from μ-CT, is also shown to yield insight into the relative distribution and rates of garnet nucleation through a P-T-t interval. Details pertaining to relative magnitudes and timing of rock deformation may additionally be revealed using comparative microstructural studies. We aim to demonstrate that systematic high-resolution textural and chemical characterisation of natural samples may provide even greater insight into metamorphic crystallisation than previously known.