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Towards a better understanding of the transport properties and growth kinetics of metamorphic rocks

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Many metamorphic and deformation processes depend on the structure of grain boundaries and the transport properties of the intergranular medium (IGM). While it is generally accepted that the bulk of the chemical transport at moderate metamorphic conditions takes place through the IGM, knowledge of the transport properties of the IGM with regards to trace elements is still scarce. Here, we present an approach to estimate the length scales of chemical transport through natural samples, using the microstructural and compositional properties of garnet porphyroblast populations. This approach also provides insight into the kinetics of crystal growth, improving our understanding of microstructure development in geological materials.

According to our results, the rate of heating during Barrovian metamorphism has a first order control on the length scales of trace element transport through the IGM. Whereas the extent of equilibration in the IGM was at the sub-mm scale with regards to the distributions of trace elements in a rock that experienced heating of more than 100 C/Myr, these elements equilibrated in the IGM over several cm in rocks that experienced heating at a rate approximately two orders of magnitude slower. The deformation of the rock matrices during crystal growth had a minor influence on these equilibration lengths. Since the major element distributions were equilibrated in the IGM of all samples, interface-reaction controlled garnet growth can be inferred.

The compositional zoning of each of the populations indicates that growth was size-dependent, with slower growth rates for smaller crystals compared to simultaneously grown rims of larger crystals. Differences in the growth rates are as large as 45 % in each of the samples studied. Since all crystals analyzed are equally shaped in a given sample, we infer that the increased contributions of crystal edges and corners to the surface areas of smaller crystals reduced the rates of interface reactions. This indicates (i) that the surface to volume ratios of the crystals had a negative impact on the rate of their overall growth, and (ii) that for the range of heating rates experienced, size-dependent interface-controlled growth suitably describes the size evolutions of the crystal populations.