Trace element zoning patterns in garnet – can we distinguish between reaction path and kinetics?

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Compositional growth zonations in garnet contain information about important geochemical, mineralogical and petrological rock properties. A detailed interpretation of complex zoning patterns in metamorphic garnet is often hindered by the lack of knowledge about the contributions of kinetic and equilibrium effects to the trace element incorporation. We combine thermodynamic calculations together with mass balanced trace element distribution among coexisting phases with diffusion models that simulate kinetically controlled element transport in a reacting host rock. Comparison of the model results with natural garnets enables detailed interpretation of commonly observed major and trace element patterns in high-pressure (HP) and ultra-high pressure (UHP) garnets in terms of reaction paths and physico-chemical properties of the host rock. Our models show that the kinetic influence on rare earth element (REE) incorporation into garnet is limited in most rocks at the early stages of garnet growth and increases with increasing grade of rock transformation. We show that REE zoning patterns can be used to distinguish between cold (lawsonite-stable) and warm (epidote-stable) prograde reaction paths. Chromium concentration variations in garnet are also an excellent source of information about the reaction path. The Cr distribution in garnets from different UHP samples reflects initial transformation of magmatic clinopyroxene to garnet+omphacite as well as the formation of garnet from omphacite at UHP conditions.

We would like to emphasise that detailed investigation and interpretation of trace element patterns in metamorphic garnet gives important insight into the reaction path of the host rock, which in turn has crucial implications for the interpretation of geochronological data from (U)HP garnets.