Decompression of high-grade metamorphic mafic rocks constrained by small-scale compositional layering, Gföhl Unit, Moldanubian Zone

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Mafic–ultramafic lenses embedded in felsic granulites of the Gföhl Unit, Moldanubian Zone, are considered as mantle fragments incorporated into mid-crustal levels of the Variscan orogenic crust. We investigated a several 100 m sized mafic lens mainly formed by eclogites. Several samples were collected from loose boulders. Petrographic features provide evidence for an early HP-HT eclogite-facies peak metamorphism overprinted to variable degrees by HT granulite-facies metamorphism at lower pressures.

The primary eclogite facies mineral assemblage comprises garnet, sodium-rich clinopyroxene (up to $X_{Na\_M2} = 0.29$), kyanite, rutile and quartz. The rocks are characterized by compositional layering on the mm-scale, which is reflected by corresponding systematic variation of the compositions of garnet porphyroblasts. The garnets show homogeneous compositions in their internal domains defining plateaus, the compositional characteristics of which correlate with the compositional layering of the rocks and vary from Alm_{19} Prp_{55} Grs_{27} to $Alm_{15\text{-}18}$ $Prp_{42\text{-}50}$ $Grs_{32\text{-}43}$. The systematic variation of garnet compositions with the bulk rock compositional layering testifies to lack of equilibration on the mm scale during HP-HT eclogite-facies metamorphism.

The HT-granulite-facies overprint is evident from the breakdown of the eclogite facies mineral assemblage. This is evident, for example, from the formation of sapphirine–spinel–an-rich plagioclase symplectites in garnet supposedly replacing garnet-hosted kyanite and clinopyroxene inclusion. Another peculiar feature is represented by the partial resorption of garnet by plagioclase and clinopyroxene in the form of corrosion tubes penetrating the garnet in a worm-like fashion. Finally, garnet is partially or entirely replaced by plagioclase–spinel–orthopyroxene—clinopyroxene symplectite, where Grs-rich garnets are systematically more strongly affected by this replacement than Grs-poor garnets. Quartz is consumed during the decompression reactions and can only be found as rare relic grains. When relic quartz is surrounded by a clinopyroxene matrix, the clinopyroxene becomes successively more Si-rich due to inverse Tschermak substitution towards the relic quartz grain.

Throughout the samples and irrespective of the layer they pertain to, the garnets show similar pronounced secondary compositional zoning in the outermost 200 μm. The zoning is characterized by a strong decrease of the Grs content accompanied by an increase of the Alm and Prp contents towards the rim. The compositional changes in garnet are gradual suggesting diffusion-mediated re-equilibration at decreasing pressures, and the composition of the garnet at the interface to the rock matrix is the same throughout the specimen indicating that the rock equilibrated on the cm scale during the HT overprint.

Pressure and temperature were estimated on the basis of equilibrium phase diagrams. They indicate peak pressures above 1.8 GPa and temperatures of around 1000 °C for the primary mineral assemblages and the different garnet cores. In accordance with peak P-T, the garnet rims indicate pressures of around 1.2 GPa with the same temperature.

Considering the regional metamorphic setting of the Moldanubian Zone, the relatively localized secondary chemical zoning of garnet at its rim indicates that the granulite-facies metamorphism was remarkably short-lived and suggests rapid transport of the mafic-ultramafic lithologies from mantle depths to the mid-crustal level. Very likely incorporation of the relatively hot mafic lens into a supposedly cooler dominantly felsic environment led to immediate cooling of the mafic lens.