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Multistage growth of Fe–Mg–carpholite and Fe–Mg–chloritoid, from field evidence to thermodynamic modelling

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We provide new insights into the prograde evolution of HP/LT meta-sedimentary rocks on the basis of detailed petrologic examination, element-partitioning analysis, and thermodynamic modelling of well-preserved Fe-Mg-carpholite- and chloritoid-bearing rocks from the Afyon zone (Anatolia). Study samples, stemming from three different areas of the metamorphic belt, include typical quartz–carpholite veins as well as quartz-free and quartz-bearing phyllites. All samples exhibit multiple stages of carpholite, whereas zoning was until now rarely documented in this type of rocks. We document continuous, and discontinuous compositional (ferro-magnesian substitution) zoning of carpholite (overall XMg = 0.27–0.73) and chloritoid (overall XMg = 0.07–0.30), as well as clear equilibrium, and disequilibrium (i.e. reaction-related) textures involving carpholite and chloritoid, which consistently account for the consistent enrichment in Mg of both minerals through time, and the progressive replacement of carpholite by chloritoid. Mg/Fe distribution coefficients calculated between carpholite and chloritoid vary widely within samples (2.2–20.0). Among this range, only values of 7–11 correlate with equilibrium textures, in agreement with data from the literature. Equilibrium phase diagrams for (NaK)FMASH rock compositions are calculated using a newly modified thermodynamic dataset, including most recent data for carpholite, chloritoid, chlorite, and white mica, as well as further refinements for Fe-carpholite, and both chloritoid end-members, as required to reproduce accurately petrologic observations (phase relations, experimental constraints, Mg/Fe partitioning). Modelling reveals that Mg/Fe partitioning between carpholite and chloritoid is greatly sensitive to temperature, and calls for a future evaluation of possible use as a thermometer, valid for blueschist-facies conditions, which has so far been missing. In addition, calculations show significant effective bulk composition changes during prograde metamorphism due to the fractionation of chloritoid formed at the expense of carpholite. We retrieve P–T conditions for several carpholite and chloritoid growth stages (i) during prograde stages using unfractionated, bulk-rock XRF analyses, and (ii) at peak conditions using compositions fractionated for chloritoid. The P–T paths reconstructed for the Kütahya and Afyon areas shed light on contrasting temperature conditions for these areas during prograde and peak stages.