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Microstructural evidence for a dehydration and self-rehydration front in contact metamorphic serpentinites (Valmalenco, Italy)

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The identification of hydration and dehydration reactions in natural rocks is crucial for the quantification of the deep water cycle. We have targeted one of the simplest possible systems to investigate dehydration reactions – the contact metamorphic overprint of greenschist facies serpentinites in the Eastern part of the Bergell intrusion (Northern Italy). Antigorite reacts to olivine + talc + chlorite at a distance of about 300-750 m from the contact, producing nicely equilibrated and well preserved rocks. At 300 m from the contact, the assemblage olivine + anthophyllite + chlorite + tremolite occurs (expected temperature range of 650-700 ˚C). Surprisingly, anthophyllite is mainly present as elongated pseudomorphs in the olivine dominated matrix and all rocks display a strong retrograde overprint with late talc. Previous studies attributed this assemblage to peak metamorphic conditions. However, 70 m from the contact orthopyroxene has been newly discovered. The inclusions of anthophyllite and olivine indicate orthopyroxene formation through the reaction olivine + anthophyllite = orthopyroxene + water occurring at ∼700 ˚C. Additionally, orthopyroxene contains inclusions of chlorite, Al-spinel and hornblende indicating partial chlorite breakdown. Also these rocks display extensive rehydration with the replacement of orthopyroxene by talc, explaining why previous studies have overlooked the orthopyroxene-in reaction. At 40 m from the contact, the absence of chlorite inclusions in orthopyroxene, Al-spinel occurrence in the matrix and Al-rich orthopyroxene inclusions in olivine indicate full chlorite breakdown according to the reaction chlorite = olivine + spinel + orthopyroxene + water. The most Al-rich orthopyroxene was only found as inclusions in olivine. The assemblage olivine + spinel + orthopyroxene + hornblende indicates that peak metamorphic conditions reached ∼730 ˚C during contact metamorphism, 160 ˚C higher than previously reported. Also the peak metamorphic assemblage is heavily retrogressed. Former Al-spinel is replaced by magnetite-rich cores rimmed by chlorite, an important marker in the field for the peak assemblage. Orthopyroxene is replaced by anthophyllite confining rehydration between 650-700 ˚C in the vicinity of the contact.

The detailed microstructural investigation combined with experimental data and thermodynamic calculations allow the reconstruction of an invariant point at about 3 kbar, 700 ˚C where two of the most important low pressure dehydration reactions (anthophyllite- and chlorite-out) in ultramafic rocks cross each other, providing an important pressure marker. Moreover, our study provides evidence for extensive high temperature hydration immediately following peak dehydration. This feature is explained by fluid movement from the antigorite breakdown reaction (that occurs in the outer contact aureole, where dehydration postdates peak metamorphism) towards the intrusion, essentially representing a self-rehydration and retrogression of the peak assemblage.