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Diopside-titanian pargasite intergrowth in magmatic pockets and metasomatic haloes from Balmuccia mantle peridotite

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Most technological and geological materials are coherent multiphase systems, and the phases are often arranged in a complicated spatial pattern forming microstructures which, on the one hand, record the history of the material itself, but also have dramatic effects on its physical properties. A highly unusual tight alternation of diopside and titanian pargasite lamellae is observed in samples from spinel dunites belonging to the subcontinental mantle peridotite body of Balmuccia, (Ivrea-Verbano Zone, Italy). Aim of this work is to reconstruct their mechanism of formation. These dunites show pockets related to melt infiltration characterised by early crystallisation of mm-long grains with such tight clinopyroxene-amphibole intergrowth. Amphibole crystallises lately as discrete phase, locally overgrowing the grains with amphibole-clinopyroxene intergrowth, being never in spatial continuity with the thin amphibole lamellae. A combined approach which makes use of scanning and transmission electron microscopies, electron backscatter diffraction (EBSD), electron diffraction and X-ray Absorption Spectroscopy (XAS) has been used to characterize the two phases and their relative sizes and orientation. SEM and EBSD inspections showed that in some grains, the thickness of the clinopyroxene lamellae ($\sim$20 μm) is around ten times that of amphibole, whereas in other cases the thicknesses of the two phases are comparable (2-5 μm). EBSD maps revealed an extremely ordered phase separation, in which amphibole lamellae, as well as the late crystals, are all parallel to (010) in the pyroxene, as expected on the basis of crystallographic considerations and in agreement with TEM observations. Diffraction contrast images showed the presence of finer (less than 100 nm) amphibole lamellae in the diopside, as well as the presence of semi-coherent interfaces giving rise to dislocations. Moreover, chain-width defects within the titanian pargasite have been revealed by HR-TEM images. TEM energy dispersive analyses revealed major element gradients across alternation of nm-scale lamellae, with diopside showing Al, Ti, Na and Fe increasing towards the contact with amphibole. Preliminary insights into the local structure of Ti4+, indicating a highly distorted octahedral coordination, have been obtained by means of XAS at the Ti-K edge performed on the same crystals.
On the basis of these observations, hypotheses on the origin of the tight alternation of diopside and titanian pargasite lamellae in such magmatic systems will be discussed.