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Chlorine-rich amphibole in deep layered gabbros as evidence for brine/rock interaction in the lower oceanic crust: a microstructural and experimental study

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The occurrence of amphiboles in the lower oceanic crust indicates the presence of water during rock formation or alteration, either in the parental melt or in reacting hydrothermal fluids. Amphibole-rich high temperature metamorphic veins and magmatic dykes are found in MOR-associated layered olivine gabbros from Wadi Wariyah of the deep palaeocrust of the Sumail ophiolite, Sultanate of Oman. These veins contain different types of amphiboles: pargasite, hornblende, actinolite and Cl-rich pargasite. In some cases, amphibole grains are zoned and contain a range of compositions, from pargasite formed at magmatic conditions to Cl-rich pargasite formed at subsolidus conditions. Pargasite and ferropargasite are found containing up to 5 wt% Cl (1.4 a.p.f.u.). This variety of amphibole compositions occurring in layered gabbros evidences a complex history of brine/rock interaction and hydrothermal cooling at the base of the oceanic crust. However, the precise origin of these amphibole- and Cl-rich veins associated to hydrothermal activity is still poorly understood. We investigated the formation of Cl-rich amphibole by means of a microstructural study using EBSD (electron backscattered diffraction) and, in addition, an experimental simulation of hydrothermal processes affecting amphibole formation in gabbro at subsolidus conditions.

The microstructural EBSD study on natural gabbro from Oman confirms that the hydrothermally-formed amphiboles (hornblende, actinolite, Cl-pargasite) are epitactic in relation to high-temperature pargasite areas adjacent to them. This implies a coherent process, where magmatic pargasite formed initially was subsequently transformed by a Cl-rich hydrothermal brine and fluid at decreasing temperatures, ranging from the magmatic regime down to greenschist facies.

Experiments were performed with a starting material of millimetre-sized pargasite pieces (with Cl content <0.02 Cl wt%) and added olivine gabbro powder (ol+plg+cpx+mt) with an excess of highly saline fluid (H_2O + 20 wt% NaCl) at a temperature of 750 °C, a pressure of 200 MPa, and oxygen fugacity of QFM+1. Our experimental results show rims and reaction zones of newly formed magnesiohornblende surrounding cores of the starting amphibole. After the experiment, we observe a decrease of olivine, plagioclase and magnetite content, and an increase in amphibole, with decreasing IVAl and A-site occupancy compared to the starting material, indicating the alteration of pargasite to magnesiohornblende. A decrease in Ti in newly-formed magnesiohornblende is coherent with low-T amphibole formation. Only a minor increase in Cl content is observed in some cases: up to 0.2 Cl wt% which is significantly less than observed in the Cl-pargasite from natural gabbros (5 wt% Cl). These results evidence limitations in the experimental setup in terms of achieving the conditions needed to form high Cl amphibole such as in the natural gabbros studied.