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Carbonation of Peridotite by CO_2-rich Fluids: Listvenite formation in the Advocate Ophiolite (Newfoundland)

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Listvenites are magnesite-quartz rocks formed by a sequence of reactions of CO_2-rich hydrothermal fluids with serpentinite, and are considered as natural analogues for carbon sequestration by mineral carbonation [1]. Here, we present the result of the petrological study of an association of listvenite (magnesite-quartz), soapstone (talc-magnesite) and carbonated antigorite-serpentinite in the mantle section of the Advocate Ophiolite Complex (Newfoundland) [2], a natural laboratory for the investigation of carbonation of serpentinites because all the reaction progress steps are recorded in a 20 – 30 m wide and 1 km long zone oriented parallel to a major regional thrust fault. Preserved Cr-spinel with similar composition as those in serpentinized harzburgite (Mg/Mg+Fe = 0.5 – 0.65; Cr/Cr+Al = 0.5 – 0.7), and high Cr and Ni contents in the carbonated lithologies demonstrate that the listvenites formed from mantle peridotites. Brucite-dolomite-magnetite veins, recrystallization of lizardite to antigorite in serpentinized harzburgite, and the absence of metamorphic olivine or tremolite constrain the temperature of carbonation between 280 ˚C and 400 – 450 ˚C. The bulk rock Fe^{3+}/Fe_{total} strongly decreases with progressive carbonation, from 0.65 – 0.8 in brucite-bearing, antigorite-rich harzburgites to 0.1 – 0.3 in talc-magnesite rocks and listvenites. This is reflected by an increasing Fe-content in magnesite, talc and antigorite in soapstone and decreasing modal abundance of magnetite. Hematite and goethite form in soapstone and listvenite due to an increasing oxygen fugacity with progressive fluid-rock interaction, as predicted by thermodynamic models [3] Magnesite in listvenites preserves Fe-poor cores with magnetite inclusions — representing incipient carbonation of serpentinized harzburgite — and an oscillatory zoned Fe-rich inner and Fe-poor outer rim. These zones correspond to Mn-enriched magnesite formed from brucite and olivine carbonation, Fe-rich magnesite in equilibrium with relatively Fe-poor talc formed by serpentine carbonation, and Fe-poor magnesite after talc carbonation. Quartz in listvenite occurs interstitial between zoned, euhedral magnesite as interconnected aggregates that are preferentially oriented parallel to the orientation of talc aggregates in Qtz-bearing soapstone, indicating that deformation was coeval to carbonation. Quartz-magnesite veins are abundant in listvenites. They are mainly oriented at high angles to the foliation of soapstone, suggesting that ductile deformation in talc-rich domains caused extensional fractures and fragmentation in the more brittle listvenites, a process that may have provided a positive feedback on the coeval influx of CO_2-rich fluids despite increasing volume during progressive carbonation. The studied sequence of arrested reactions and their microstructures are in good agreement with infiltration of CO_2-rich fluids, which likely is a common process in fore-arc supra-subduction settings.

References:

1. *Matter & Kelemen, 2009, Nature Geoscience 2, 837-841.*
2. *Bédard & Escayola, 2010, Canadian Journal of Earth Sciences, 47, 237-253.*
3. *Klein & Garrido, 2011, Lithos 126, 147-160.*

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