Ni-serpentine nano flakes in the garnierite ore from Campello Monti (Strona Valley, Italy): Népouite with some pecoraite outlines and the processing of Ni-containing ore bodies

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ABSTRACT

The garnierite ore at Campello Monti occurs as dark green colloform concretions covering surfaces, fractures, and filling veins in harzburgite rocks. The representative composition (Ni₂₋₀.₄Mg₀₋₁₄Cu₀₋₁₈Co₀₋₁₀₂₋₀.₇₆Si₂₋₀₄O₄(OH)₁₄) is consistent with a 7 Å phase, namely pecoraite or népouite. Relevant chemical features are an exceptionally high Ni/Mg ratio, a significant level of Cu substituting for Ni, and a low content of S, possibly in tetrahedral sites.

Olivine and orthopyroxene in the harzburgite host rock are only partially serpentinized, do not contain detectable Ni, and are almost iron free. The green coating probably originated from groundwater solutions that leached nearby weathered peridotites and sulfide ores, and deposited less-mobile elements along fractures and voids of the host peridotite, just outside their provenance area.

Bulk techniques such as X-ray powder diffraction and infrared spectroscopy do not confidently distinguish between népouite and pecoraite, although the comparison with synthetic, implicitly pure polymorphs indicates népouite as the best matching phase. On the other hand, HRTEM clearly shows that garnierite is mostly constituted by plumose aggregates made of curved crystals with frayed tips, a few nanometers thick along the stacks and a few tens of nanometers long (nano flakes). All known lizardite stacking sequences, namely 1T, 2H₁, and 2H₂, have been locally observed, even though most crystals show stacking disorder.

The recorded nanostructure suggests possible explanations for the recurrent anomalies (low oxide totals, high ³V/²⁺M cation ratios, etc.) found in EMP analyses of garnierites. The small grain size, the high density of defects, and the structural arrangement actually intermediate between lizardite and chrysotile probably explain the ambiguities that occurred during the characterization with bulk techniques. The results obtained in this study may have important implications for ore processing methods.

Keywords: Garnierite, népouite, nanoparticles, transmission electron microscopy

INTRODUCTION

Serpentinites originate from the hydrothermal alteration of ultramafic rocks. They are abundant at mid-ocean ridges, where the oceanic crust forms and almost contemporarily may experience retrograde metamorphism. Serpentinites are therefore also abundant at subduction zones, where two plates of oceanic lithosphere that are mostly ultrabasic in composition converge and where a large amount of fluids circulate along transform faults and “outer rise” fractures (Kerrick 2002). As a corollary, considerable outcrops of serpentinites occur along orogenic belts, sampled from the down-going slab and exhumed by tectonics after the included basin is completely recycled.

Serpentine minerals are hydrous magnesium silicates with the ideal formula Mg₅Si₄O₄(OH)₄, which occur in nature in four principal polymorphs distinguished by the shape of the building TO layer. Lizardite is the serpentine mineral that forms flat layers. Different polytypes with different stacking of the TO layers have been reported so far (e.g., Mellini and Zanazzi 1987; Brigatti et al. 1997). Chrysotile adopts a cylindrical structural arrangement in which the tetrahedral sheet occupies the internal position and is the main constituent of asbestos (e.g., Cavallo and Rimoldi 2013 and references therein). Antigorite is based on a wave-like structure in which the tetrahedral sheet periodically inverts polarity (Capitani and Mellini 2004). Different antigorite structures (polysomes) are possible depending on the wavelength (Capitani and Mellini 2006, 2007). A rarer polymorph is polygonal serpentine, which forms fibers with a polygonal cross section made up of flat layers in sectors. The number of sectors is always either 15 or 30, with curved connections between them (Mugnaioli et al. 2007).

Ni-serpentines are much less abundant in nature. The Ni analog of chrysotile is pecoraite (Faust et al. 1969), whereas the Ni analog of lizardite is népouite (Brindley and Maksimović 1974). Ni-analogs for antigorite and polygonal serpentine have not been reported so far. Ni-serpentines are important ore minerals for Ni (e.g., Butt and Cluzel 2013; Villanova-de-Benavent et al. 2014). Nickel is extracted from two principal types of ore deposits: (1) sulfide ores, normally developed by a magmatic concentration process, and (2) laterite ores, supergene deposits formed by the pervasive chemical and mechanical weathering of the parent rock, commonly peridotite. Laterite ores are further distinguished