Garnierite Mineralization from Falcondo Ni-Laterite Deposit (Dominican Republic)

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INTRODUCTION.

Mine geologists use the term "garnierite" for the green Ni-rich silicate minerals that occur in many Ni-laterite deposits. However, garnierite is not a mineral species recognized by the Commission on New Mineral and Mineral Names (CNMMN). Actually, garnierite is a general name for the Ni-Mg hydrosilicates that usually occur as an intimate mixture that commonly includes two or more of the following minerals: serpentine, talc, sepiolite, smectite, and chlorite (e.g. Brindley and Hang, 1973; Springer, 1974; Brindley et al., 1979; Gleeson et al., 2004).

Here, we report new data on the mineralogical composition and mineral chemistry of garnierite veins in Ni laterites presently being mined from the Falcondo Mine in the central Dominican Republic. Samples were investigated using X-ray diffraction (XRD), optical microscopy, scanning electron microscopy (SEM), transmission electron microscopy (TEM), and electron probe microanalysis (EMPA).

DOMINICAN Ni-LATERITE PROFILE

Ni-laterite is well-developed over the Loma Caribe serpentinized peridotites, exposed in the Cordillera Central of the Dominican Republic. The Loma Caribe peridotite is one of the occurrences of ophiolite-related ultramafic rocks that crops out along the northern plate margin of the Caribbean Plate (Lewis et al., 2006; Proenza et al., 2007).

In Dominican Ni-laterites most of the nickel is found in the saprolite zone below a relatively thin cover of limonite. These deposits are classified as the hydrous silicate-type. The saprolitic zone accounts for 40% of the total ore reserves.
In the Dominican Republic upward movement of the serpentinized peridotites occurred in the late Oligocene and it is generally agreed that the peridotites were exposed to weathering and erosion in the early Miocene. Lateritization began at this time, and continues today but it is not suggested that optimum conditions for laterization have necessarily been continuous since the Early Miocene, but that they remained favorable for a mature lateritic soil profile to develop. This Miocene land surface was subsequently broken into blocks by vertical movements associated with transpressional movement along major faults (Lewis et al., 2006).

GARNIERITE MINERALIZATION: MODE OF OCCURRENCE.

Most of the garnierite ore is found in the saprolite horizon (Fig. 1) as tension fracture-fillings (mm to cm-thick veins). It also occurs as a boxwork fabric, thin coating on joints, and in small tension gashes in the limonite zone. Garnierite ores also occur in unweathered peridotite, as vein fillings and thin coatings.

Three types of breccia are distinguished, all with complex textures and mineralogy:
(i) fault breccias mainly composed of sepiolite-falcondoite and quartz.
(ii) breccias consisting of hard saprolitized peridotite clasts cemented by garnieritic material.
(ii) breccias of garnierite fragments cemented by a later generation of garnierite of different composition (fig. 2).

Commonly garnierites display typical colloform texture, characteristic of the fill of open spaces from a solution. However, in most samples, the colloform garnierite is fractured and brecciated, and the fragments are cemented by a second generation of garnierite. Quartz and chalcedony fill the remaining pore spaces in the vein.

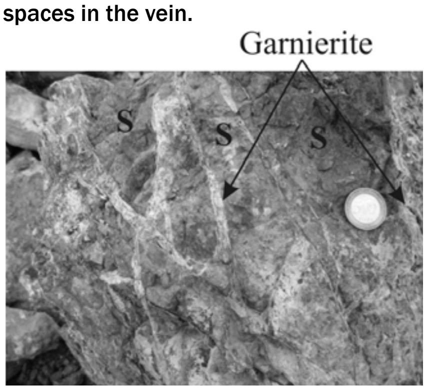

fig 1. Garnierite veins in saprolite horizont. S: saprolitized peridotite.

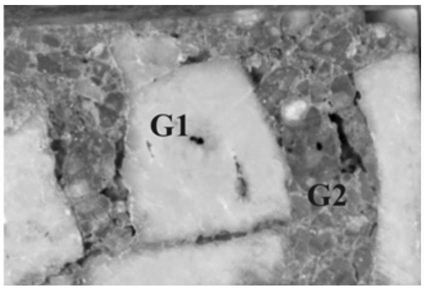

fig 2. Garnierite fragments (G1: mainly Ni-rich sepiolite and quartz) cemented by later generation of garnierites (G2: mainly Ni-rich talc). Wide of photography 4.5 cm.

MINERALOGICAL CHARACTERIZATION.

The mineralogy of the garnierite mineralization is highly variable. XRD patterns of garnierites show peaks at ~7 Å and ~10 Å, characteristic of the structures of serpentine group minerals and talc-like minerals. The dominant serpentine mineral is lizardite 1T. In

palabras clave: Níquel, laterita, garnierita, nepouita, falcondoita, Republica Dominicana, Caribe.	*key words:* Nickel, laterites, garnierite, nepouite, falcondoite, Dominican Republic, Caribbean.

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addition, XRD results show that garnierite veins include sepiolite-falcondoite and quartz, commonly associated with "chrysoprase" (a green cryptocrystalline variety of quartz with ~ 2 wt% Ni).

Powder diffraction profile refinement and TEM analysis confirmed the structure type for both sepiolite and falcondoite, with refined cell parameters of 13.385(4), 26.955(9), 5.271(3) Å and 13.33(1), 27.03(2), 5.250(4) Å and space group Pncn. Estimated crystallinity for sepiolite (average size 14 nm) is much better than that observed in falcondoite (average size 9 nm). TEM images of sepiolite display aggregates with a characteristic fibrous morphology (fibers > 3 μm).

The "garnierite"-like minerals have composition ranging from: (i) Ni–bearing talc to willemseite (up to 25 wt% Ni), ii) Ni-lizardite to nepouite (up to 34 wt% Ni), and iii) Ni-sepiolite to falcondoite (up to 24 wt% Ni) (fig. 3). Systematically, Ni-rich phase are iron-poor (< 0.5 wt% Fe), indicating a secondary (neoformed) origin. The amounts of Al, Cr, Ti, Ca, Na and K are very low.

Some EMPA show significant deviations from the composition of talc, serpentine and sepiolite series, (octahedral/tetrahedral cation ratios and the water contents calculated by difference). These deviations are consistent with the presence of quartz intergrown with garnierites and the fine-grained mixture of Ni-containing serpentine and talc (Brindley and Hang, 1973; Springer, 1974 Brindley et al., 1979). From fig. 3 it is evident that garnierite samples with an intermediate composition, between talc (high Si/(Mg+Ni ratio) and serpentine (low Si/(Mg+Ni ratio) correspond to mixtures of talc-like minerals and serpentine, consistent with the XRD results.

DISCUSSIONS AND CONCLUSIONS.

Fault breccias containing garnierite clasts in turn cemented by garnierite is evidence of syn-tectonic precipitation of supergene Ni-Mg hydrosilicates. This relationship between brittle tectonic structures and generation of laterite profile has been well documented in New Caledonian lateritic weathering profile (Cluzel and Vigier, 2008). According to Genna et al. (2004), the dominant deformation mechanism is of the crack-seal type.

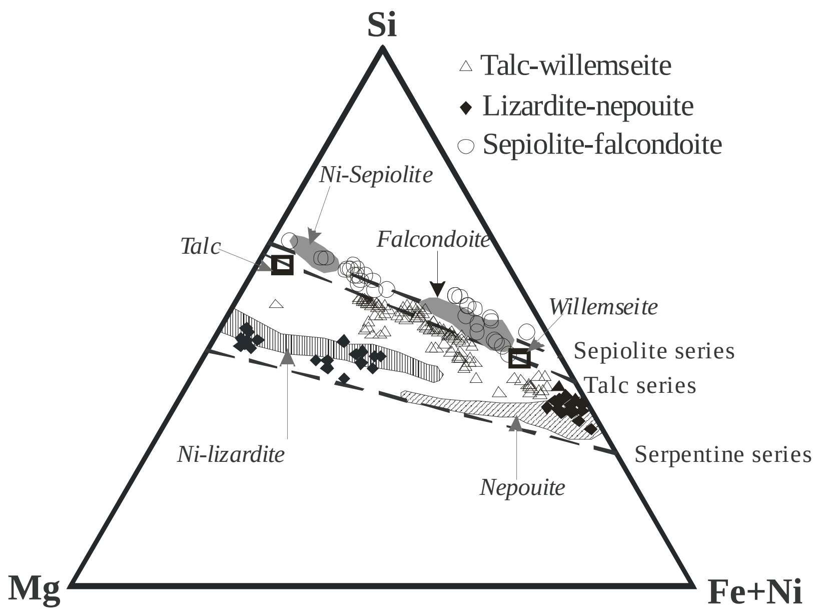

fig 3. Si-Mg-(Fe+Ni) ratios for Ni-bearing hydrosilicates in garnierite ores from Falcondo Mine (Dominican Republic). Compositional fields are taken from Brand et al. (1998).

Our results show that Dominican garnierites consist of fine-grained mixture of three solid solutions: lizardite-nepouite, talc-willemseite, and sepiolite-falcondoite. From XRD and EMPA, the components of the mixtures can be identified or the mole fractions of the diverse phase can be calculated.

Characterized talc-like minerals belong to the willemseite [$(Ni,Mg)_3SiO_4O_{10}(OH)_2$] - talc [$(Mg)_3SiO_4O_{10}(OH)_2$] series. Very often Ni rich talc-like minerals (d_{001} ~10Å) in Ni-laterites have been referred to as the kerolite-pimelite series [$(Mg,Ni)_3Si_4O_{10}(OH)_2.H_2O$] (e.g. Brindley et al., 1979; Gleeson et al., 2004). However, kerolite and pimelite are not mineral species recognized by the CNMMN.

Finally, chemical compositions of Dominican sepiolite-rich garnierite cover a large interval of falcondoite-sepiolite solid solution (Fal_3 and Fal_{70}). These compositions suggest a complete miscibility along the sepiolite-falcondoite join.

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