macla SEM Sociedad Española de Mineralogía

Geology, geochemistry and mineralogy of the Loma de Hierro Ni-laterite deposit, Venezuela

Cristina Domènech (1*), Salvador Galí (1), Marite P. Ancco (1), Cristina Villanova-de-Benavent (2), Josep M. Soler (3), Williams Meléndez (4), José Rondón (5), Joaquín A. Proenza (1)

(1) Departament de Mineralogia, Petrologia i Geologia Aplicada, Facultat de Ciències de la Terra, Universitat de Barcelona (UB), Martí i Franquès s/n, 08028 Barcelona, Catalunya (España)
(2) School of Environment and Technology, University of Brighton, Lewes Road, BN4 2GJ Brighton (Reino Unido)
(3) Institute of Environmental Assessment and Water Research, IDAEA-CSIC, 08034 Barcelona, Catalunya (España)
(4) Instituto de Ciencias de la Tierra, Universidad Central de Venezuela, Av. Minerva, Caracas 1053 (Venezuela)
(5) Instituto Nacional de Geología y Minería, Av. Lecuna, Parque Central, Torre Oeste, Caracas 1015 (Venezuela)
* corresponding author: cristina.domenech@ub.edu

Palabras Clave: Níquel, Loma de Hierro, laterita. | **Key Words:** Nickel, Loma de Hierro, laterite.

INTRODUCTION

Ni-laterite deposits host over 60% of the word land-based Ni resources (McRae, 2018). They formed from the weathering of Mg-rich ultramafic rocks exposed to the surface under favorable topography and climatic conditions. The typical Ni-laterite profile is characterized by a partially serpentinized parent rock (protolith) at the bottom followed by a saprolite horizon (dominated by secondary Si- and Mg-bearing minerals), and a limonitic horizon, dominated by goethite that evolves to hematite with time (e.g. Golightly, 2010). Ni originally liberated from olivine is concentrated in different secondary minerals such as goethite in the limonite and garnierites, secondary serpentines and/or smectite in the saprolite zone (Pelletier 1996; Villanova-de-Benavent et al. 2014). Ni-laterites are classified according to their dominant Ni-bearing ore in (a) hydrous-Mg-silicate, (b) clay and (c) oxide type deposits (Brand et al. 1998).

The Caribbean region accounts for about 10% of the world's Ni resources. Eastern Cuba and the central Dominican Republic contain the largest reserves. They have recently been characterized as worthy targets for critical metals (Aiglsperger et al., 2016). Other Ni-laterite deposits in the region such as that of Loma de Hierro in Venezuela have been under exploitation but limited information is available. In this study, a preliminary geological, geochemical and mineralogical description of the Loma de Hierro Ni-laterite deposit is presented.

THE LOMA DE HIERRO Ni-LATERITE

The Loma de Hierro deposit is located 50 km SW of Caracas at 1200-1400 m of altitude and developed over a Cretaceous serpentinized peridotite body. With an elongated shape (ENE direction), its dimensions are 21 km × 5 km and a thickness of 5-25 m. Laterite is well developed along plateaus and mild slopes, and thinner or non-existent along steep slopes (Jurkovic, 1963; Soler et al. 2008). Laterization started in the Oligocene-Miocene (~20 Ma ago).

The sampled profile is ~30 m thick. From bottom to top, a parent rock peridotite, a saprolite (~20 m) and a limonite zone (10 m) are recognized. The transition between the parent rock and saprolite is progressive and the degree of alteration is apparent by color and density changes (increase of porosity), while the limit between saprolite and the limonitic horizon is sharp and irregular (Fig. 1).

Samples were collected in March 2017. Major and minor element concentrations were determined by XRF and ICP-MS at the Actlabs Laboratories (Canada). Thin and polished sections were studied by optical microscopy. SEM-EDS, EMP and XRD measurements were performed at the Centres Científics i Tecnològics of the UB (CCiT-UB, Spain) and mineral quantitative analyses were performed by the Rietveld method using the TOPAS V4 software.

Fig 1*. Field view of the investigated Ni-laterite profile from the Loma de Hierro deposit (Venezuela).*

WHOLE ROCK CHEMISTRY

Fig. 2 shows the major element chemical composition of the studied profile. There is a clear distinction between the Fe-rich zone (the upper 3 m) and the lower Mg- and Si-rich zone (saprolite). The Mg discontinuity is clearly marked at 3-4 m depth. NiO contents are around 2wt% in the saprolite zone, while they significantly decrease in the limonite zone. In this zone, Cr and Co contents increase compared to those in the saprolite.

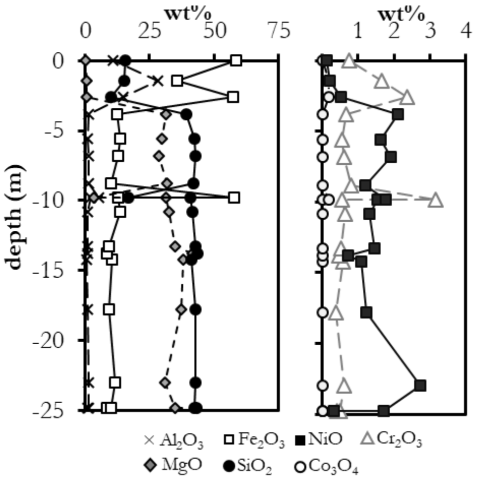

***Fig 2**. Major element and Cr, Ni and Co concentrations (wt%) as a function of depth in the studied profile.*

MINERALOGY OF THE PROFILE

The parent rock is a partially serpentinized harzburgite-with 70wt% forsterite, 20wt% enstatite, ~4wt% serpentine (Srp-I) in fractures and grain boundaries and other minor minerals (magnetite, Cr-spinel) (Fig.3a).
The saprolite horizon preserves the primary texture of the parent rock, but olivine and enstatite are progressively altered to Ni-enriched serpentine (Srp-II) and talc (and possibly other minor phyllosilicates) (Fig.3b). Veins are often filled by garnierite, with very high Ni contents (up to 22wt% NiO). In the limonitic horizon, most of the Si and Mg have been leached, and only Fe- and Al-oxyhydroxides and quartz remain (30wt% goethite, 15wt% hematite, 25wt% gibbsite, 10wt% quartz). Relict Cr-spinel crystals are preserved. The amount of hematite is higher at the top of the limonitic horizon, which is Ni-poor contrasting with other lateritic ore deposits in the Caribbean area.

DISCUSSION AND CONCLUSIONS

As most of Ni is found in garnierites and Srp-II in the saprolite zone, the Loma de Hierro Ni-laterite deposit is classified as a hydrous-Mg-silicate type deposit. Its location in a tectonically active region and its high altitude would have allowed the development of a thick saprolite horizon by maintaining a low phreatic level and a thin limonite horizon because of high erosion rates (Butt and Cluzel, 2013), which in addition may account for removal, transport and redeposition of this material. Compared to other deposits, e.g. Moa Bay in Cuba, the limonite horizon is Ni-poor but rich in hematite. Due to the ageing processes, Ni would have been leached from goethite and accumulated in the serpentine II and garnierites below.

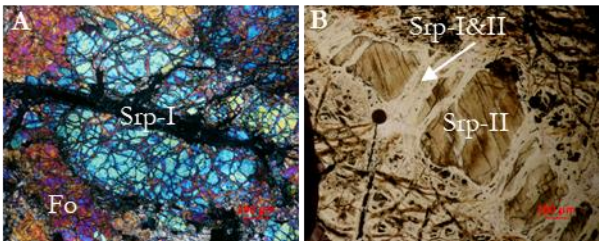

***Fig 3**. Optical photomicrographs showing characteristic textures of the described horizons. A) Crossed-polar image of forsterite (Fo) and serpentine I (Srp-I) in the protolith. B) Plane-polarized light image of an enstatite crystal totally altered to serpentine II (Srp-II) and crosscut by veins filled with Srp-I and Srp-II in the upper saprolite horizon.*

ACKNOWLEDGEMENTS
The authors thank the personnel from Minera Loma de Níquel for permission to access the mine and assistance in the field.

REFERENCES

Aiglsperger, T., Proenza, J. A., Lewis, J. F., Labrador, M., Svojtka, M., Rojas-Purón, A., Longo, F. and Durisova, J. (2016): Critical metals (REE, Sc, PGE) in Ni-laterites from Cuba and the Dominican Republic. Ore Geol. Rev. **73**, 127–147.

Butt, C.R.M. & Cluzel, D. (2013): Nickel laterite ore deposits: weathered serpentinites. Elements **9**, 123–128.

Brand, N.W., Butt, C.R.M., Elias, M. (1998): Nickel laterites: classification and features. AGSO J Australian Geol Geoph **17,** 81–88.

Golightly, J.P. (2010): Progress in understading the evolution of nickel laterites. Soc Eco Geo Spe Pub 15, 451–485.

Jurkovic, I. (1963): Some geochemical aspects about the genesis of the nickel deposit Loma de Hierro (Venezuela). Geoloski Vjesnik 17, 103–112.

McRae, M.E. (2018): Nickel. USGS mineral commodity summaries, **703**, 648-7743.

Pelletier, B. (1996): Serpentines in nickel silicate ore from New Caledonia. Australasian Institute of Mining and Metallurgy Publication Series - Nickel conference, Kalgoorlie (Western Australia) **6/96** 197–205.

Soler, J.M., Cama, J., Galí, S., Meléndez, W., Ramírez, A., Estanga, J. (2008): Composition and dissolution kinetics of garnierite from the Loma de Hierro Ni-laterite deposit, Venezuela. Chem. Geol **249**, 191-202.

Villanova-de-Benavent, C., Proenza, J.A., Galí, S., García-Casco, A., Tauler, E., Lewis, J.F., Longo, F (2014): Garnierites and garnierites: textures, mineralogy and geochemistry of garnierites in the Falcondo Ni-laterite deposit, Dominican Republic. Ore Geol Rev **58**, 91–109.