



## Discussion

## Comments on the paper “Ochreous laterite: a nickel ore from Punta Gorda, Cuba” by Oliveira et al.

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The paper, “Ochreous laterite: a nickel ore from Punta Gorda, Cuba,” by Oliveira et al. (2001) presents a characterization of oxidized nickel ore from the Punta Gorda deposit in the Moa district (eastern Cuba). The authors assume that the nickel ore derives from an ophiolitic association (serpentinized ultramafic rocks, olivine gabbros, and plagiogranites) strongly affected by lateritization. They note that ‘no extensive study has so far been published about the Ni mineralization in regard to the mineralogical and chemical nature of the ore’ and reach the conclusion that nickel is associated with goethite and cobalt with manganese minerals. The authors find two ore types, Ni-rich (1.56–2.06%) and Ni-poor (0.24–0.96%), and infer that the two types are related to differences in the parent rocks. Oliveira et al. contend that the Ni-rich ore derives from peridotites containing Ni-bearing orthopyroxenes and that the Ni-poor ore forms from peridotites containing Al-clinopyroxene depleted in Ni. Despite their interesting attempt, we believe these points require some critical comments that point to possible alternative interpretations.

First, the Moa-Baracoa ophiolitic massif consists of a lower unit of mantle tectonites made up of serpentinized harzburgite with minor dunite, ‘impregnated peridotite’ (plagioclase- and clinopyroxene-bearing peridotite), wehrlite, and pyroxenite and a crustal sequence composed of layered gabbro (olivine gabbro and gabbro-norite) and discordant pillowed basalts and sediments of the Quiviján Formation (Guild, 1947; Wadge et al., 1984; Ríos and Cobiella, 1984; Fonseca et al., 1985; Iturralde-Vinent, 1989, 1996, 1998; Keer et al., 1999; Proenza et al., 1999a,b). Towards the top of the mantle tectonites, the harzburgite contains increasing amounts of dunite, gabbro sills, and

chromitite, which form elongated pseudotabular bodies parallel to the foliation of the host harzburgite, as well as discordant dikes of gabbro and pegmatitic gabbro (Fig. 1). This upper zone has been considered as forming part of the Moho Transition Zone (MTZ) (Proenza et al., 1999a,b).

Second, Oliveira et al. (2001) ignore many published studies on the geological, mineralogical, and chemical characteristics of the Cuban lateritic nickel deposits (Kudelasek et al., 1967; Vera, 1979; Formell and Oro, 1980; Vershinin et al., 1984; Quintana-Puchol, 1985; Ostroumov et al., 1985, 1987; Cordeiro et al., 1987; Rojas-Purón et al., 1993; Rojas-Purón and Carballo, 1993; Capote et al., 1993; Almaguer and Zamarzry, 1993; Rojas-Purón and Beyris, 1994; Rojas-Purón and Orozco, 1995; Almaguer, 1995, 1996; Lavaut, 1998). These studies contain extensive results about the Ni mineralization in the Moa district and conclude that Ni in ochreous laterite is associated with goethite and Co with manganese minerals (asbolanes).

Third, the differences in the mineralogical and chemical composition of the Ni-rich and Ni-poor ores cannot be explained by the presence of Ni-bearing orthopyroxene or Ni-depleted, Al-rich clinopyroxene in the parent rock, as Oliveira et al. (2001) conclude, because the Moa peridotites are made up of only harzburgites and dunites (Proenza et al., 1999a,b), neither of which contains significant clinopyroxene. The average forsterite and NiO content of olivine in the harzburgites is 91.0 and 0.39 wt%, respectively, whereas in dunites, these values are 91.5 and 0.38 wt% (Table 1). The Ni content of orthopyroxene is very low (NiO < 0.1 wt%), usually below the detection limit of the electron microprobe (Table 1). However, clinopyroxene-bearing harzburgites are very scarce in the whole Moa-Baracoa massif. Therefore, the Ni-rich ore can only derive from harzburgite and dunite

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## Moa-Baracoa Massif

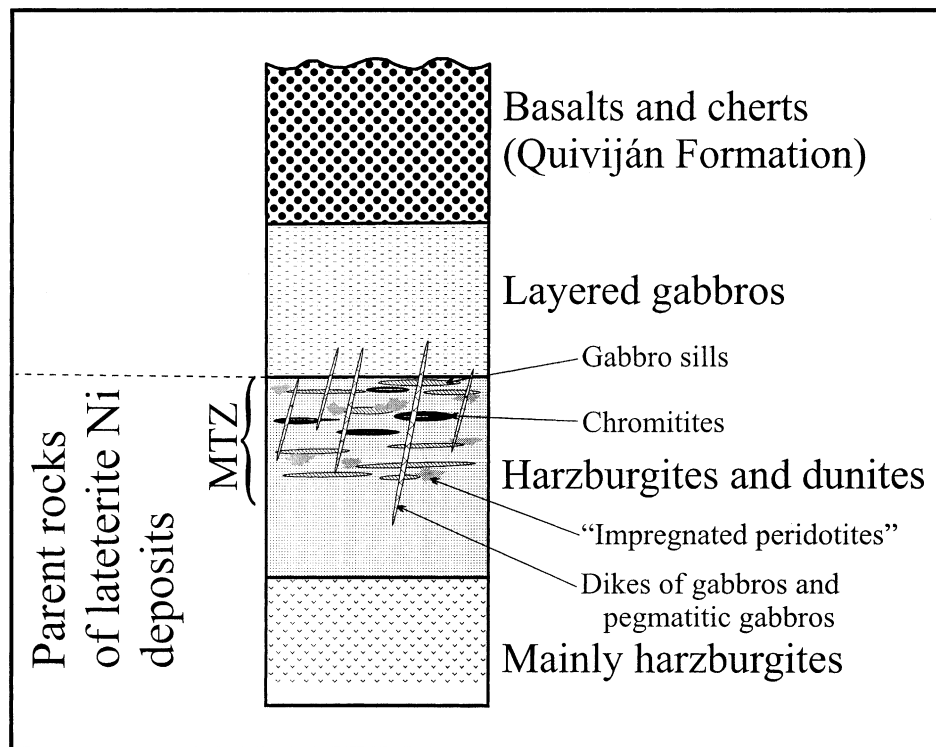


Fig. 1. Geological section (diagrammatic) through the Moa-Baracoa Ophiolitic massif (modified after Proenza et al., 1999b).

containing Ni-rich olivine (Table 1, Fig. 2). In contrast, the Ni-poor (Al-rich) ore can be related to the bodies of gabbros and ‘impregnated peridotites’ that are present in the MTZ of Moa district (Fig. 1). Gabbroic sills and dikes intruding harzburgite and dunite in the MTZ are a characteristic feature of the Moa-Baracoa Ophiolite massif, as well as of other ophiolitic complexes (Kelemen et al., 1997). In the Moa district, the size of the concordant gabbro sills varies from a few centimeters to 100 m long and 3–5 m thick. These bodies are frequently finely layered, comprising millimeter-thick olivine-rich layers alternated with olivine-

free gabbro layers, and evolve laterally to ‘impregnated peridotites’ (mainly plagioclase- and clinopyroxene-bearing dunite) (Proenza et al., 1999a,b).

Fourth, the Punta Gorda deposit exhibits structures characteristic of redeposited laterites (Formell, 1979; Formell and Oro, 1980). Laterites formed on slopes were periodically transported to lower zones, overlying early formed laterites. Subsequently, lateritic processes modified the layering of the redeposited laterite. This redeposition obliterates the primary zoning of the lateritic profile.

Table 1

Selected aspects of the mineral chemistry of the Moa mantle sequence and lower crustal sequence primary phases (Proenza et al., 1999a,b)

Rock type	Olivine		Orthopyroxene			Clinopyroxene				Plagioclase	Cr-spinel	
	Fo	NiO	En	NiO	Al <sub>2</sub> O <sub>3</sub>	Mg#	Wo	NiO	Al <sub>2</sub> O <sub>3</sub>	An	Cr#	NiO
Harzburgite	91.0	0.39	89.0	<.10	2.00						0.54	<0.10
Dunite	91.5	0.38	89.0	<.10	1.90						0.46	<0.20
Impregnated peridotite	90.0	0.32				92.0	45.5	0.00	2.87		0.54	<0.10
Gabbro sill	89.1	0.29				89.2	47.7	0.00	4.16		0.48	<0.10
Pegmatitic gabbro dike						81.5	45.0	0.00	2.36	60.0		
Layered gabbro												
Olivine gabbro	85.5	0.16	84.5	<.03	1.27	88.6	43.3	0.00	2.28	73.0		
Gabbronorite			69.0	<.06	1.15	78.0	43.3	0.00	2.19	62.2		

Fo = 100[(Mg/(Mg + Fe)]; En = 100[Mg/(Mg + Ca + Fe<sup>2+</sup> + Fe<sup>3+</sup> + Mn)]; Mg# = 100[Mg/(Mg + Fe)]; An = 100[Ca/(Ca + Na + K)]; Wo = 100[Ca/(Ca + Mg + Fe<sup>2+</sup> + Fe<sup>3+</sup> + Mn)]; Cr# = Cr/(Cr + Al); other values in wt%.

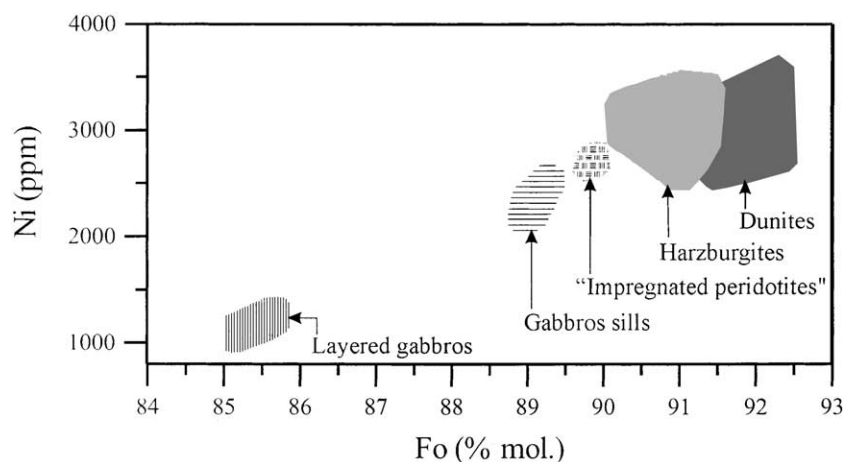


Fig. 2. Ni content versus Fo content plot of olivine from different rocks of the MTZ and the lower crust in the Moa-Baracoa Ophiolitic massif (adapted from Proenza et al., 1999b).

In conclusion, the field geological evidence and existing chemical and mineral data preclude orthopyroxene as a major source of the Ni in the Ni-rich ore and suggest that the primary source of the Ni-rich ore is the olivine contained in harzburgite and dunite. These data also exclude clinopyroxene-rich rocks as a source of the Ni-poor ore. On the contrary, the ores formed by laterization of sections of the upper mantle interbedding sills of Ni-poor gabbros.

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