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Magmatic structure and geochemistry of the Luanga Mafic–Ultramafic Complex: Further constraints for the PGE-mineralized magmatism in Carajás, Brazil

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ABSTRACT

The Luanga Complex is part of the Serra Leste Magmatic Suite, a cluster of PGE-mineralized mafic–ultramafic intrusions located in the northeastern portion of the Carajás Mineral Province. The Luanga Complex is a medium-sized layered intrusion consisting of three main zones: i. the lower Ultramafic Zone comprising ultramafic adcumulates (peridotite), ii. the Transition Zone comprising interlayered ultramafic and mafic cumulates (harzburgite, orthopyroxenite and norite) and iii. the upper Mafic Zone comprising a monotonous sequence of mafic cumulates (norite) with minor orthopyroxenite layers. Several PGE-mineralized zones occur in the Transition Zone but the bulk of the PGE resources are hosted within a 10–50 meter thick interval of disseminated sulfides at the contact of the Ultramafic and Transition Zones. The compositional range of cumulus olivine ($Fo_{78.9–86.4}$) is comparable to those reported for layered intrusions originated from moderate primitive parental magmas. Mantle normalized alteration-resistant trace element patterns of noritic rocks are fractionated, as indicated by relative enrichment in LREE and Th, with negative Nb and Ta anomalies, suggesting assimilation of older continental crust. Ni contents in olivine in the Luanga Complex (up to 7500 ppm) stand among the highest values reported in layered intrusions globally. The highest Ni contents in olivine in the Luanga Complex occur in distinctively PGE enriched (Pt + Pd > 1 ppm) intervals of the Transition Zone, in both sulfide-poor and sulfide bearing (1–3 vol.%) rocks. The origin of the PGE- and Ni-rich parental magma of the Luanga Complex is discussed considering the upgrading of magmas through dissolution of previously formed Ni-rich sulfide melts. Our results suggest that high Ni contents in olivine and/or orthopyroxene provide an additional exploration tool for Ni–PGE deposits, particularly useful for target selection in large magmatic provinces.

1. Introduction

The Luanga Complex is part of a cluster of PGE-mineralized mafic–ultramafic intrusions located in the eastern portion of the Carajás Mineral Province, denominated Serra Leste Suite. This suite consists of several small to medium sized intrusions that host PGE mineralizations of different styles, including PGE associated with chromitite layers, stratabound magmatic base metal sulfide zones and hydrothermal alteration zones (e.g., Diella et al., 1995; Ferreira Filho et al., 2007; Teixeira et al., 2015). These layered intrusions have Neoarchean ages (e.g., Machado et al., 1991; Teixeira et al., 2015) that overlap with the ca. 2.75 Ga extensive basaltic magmatism of the Carajás Mineral Province (e.g., Trendall et al., 1998), thus representing coeval magmatic events at the scale attributed to large igneous provinces (LIP; Ernst et al., 2005). The spatial association of PGE-mineralized layered intrusions of the Serra Leste Suite suggests that they originated from a PGE-fertile parental magma (Ferreira Filho et al., 2007; Teixeira et al., 2015). How magmas with distinctive geochemical characteristics that enhance the origin of Ni–Cu–PGE deposits are formed and whether such compositions are systematically associated with Ni–Cu–PGE deposits are a debated issue (e.g., Fiorentini et al., 2010; Griffin et al., 2013; Zhang et al., 2008). Some studies have proposed that LIP containing Ni–Cu–PGE deposits have magmas with distinctive geochemical compositions, usually attributed to specific characteristics of the subcontinental lithosphere (e.g., Griffin et al., 2013; Maier and Groves, 2011). However, other studies indicate that a systematic association of unusual magmas and magmatic deposits is not supported by current data (e.g., Barnes et al., 2015; Fiorentini et al., 2010). In this study we present anomalously high Ni content for olivine in rocks of the Luanga Complex. Sobolev et al. (2005, 2007) have used extensive data on olivine compositions to suggest that high Ni contents in olivine occur in mantle melts from sources containing high proportions of recycled oceanic crust, due to the predominance of pyroxene over olivine in the source. Kerr and Leitch (2005), however, have attributed Ni-rich

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magmas with elevated PGE contents to processes that lead to the dissolution of previously formed sulfides during magma ascent.

This paper presents the first extensive geological and geochemical characterization of the Luanga Complex, the layered intrusion that hosts the most significant stratiform/stratabound PGE mineralization in Carajás (Ferreira Filho et al., 2007). Our results provide evidence for an anomalous Ni-rich magmatism associated with the PGE-mineralized Luanga Complex. We compare our results with previous studies of layered intrusions in the Carajás Mineral Province as well as worldwide in order to evaluate the petrological processes that take place during the evolution of PGE-fertile districts. This study provides additional data to the ongoing debate about whether Ni–Cu–PGE deposits are favored or not by specific magma compositions.

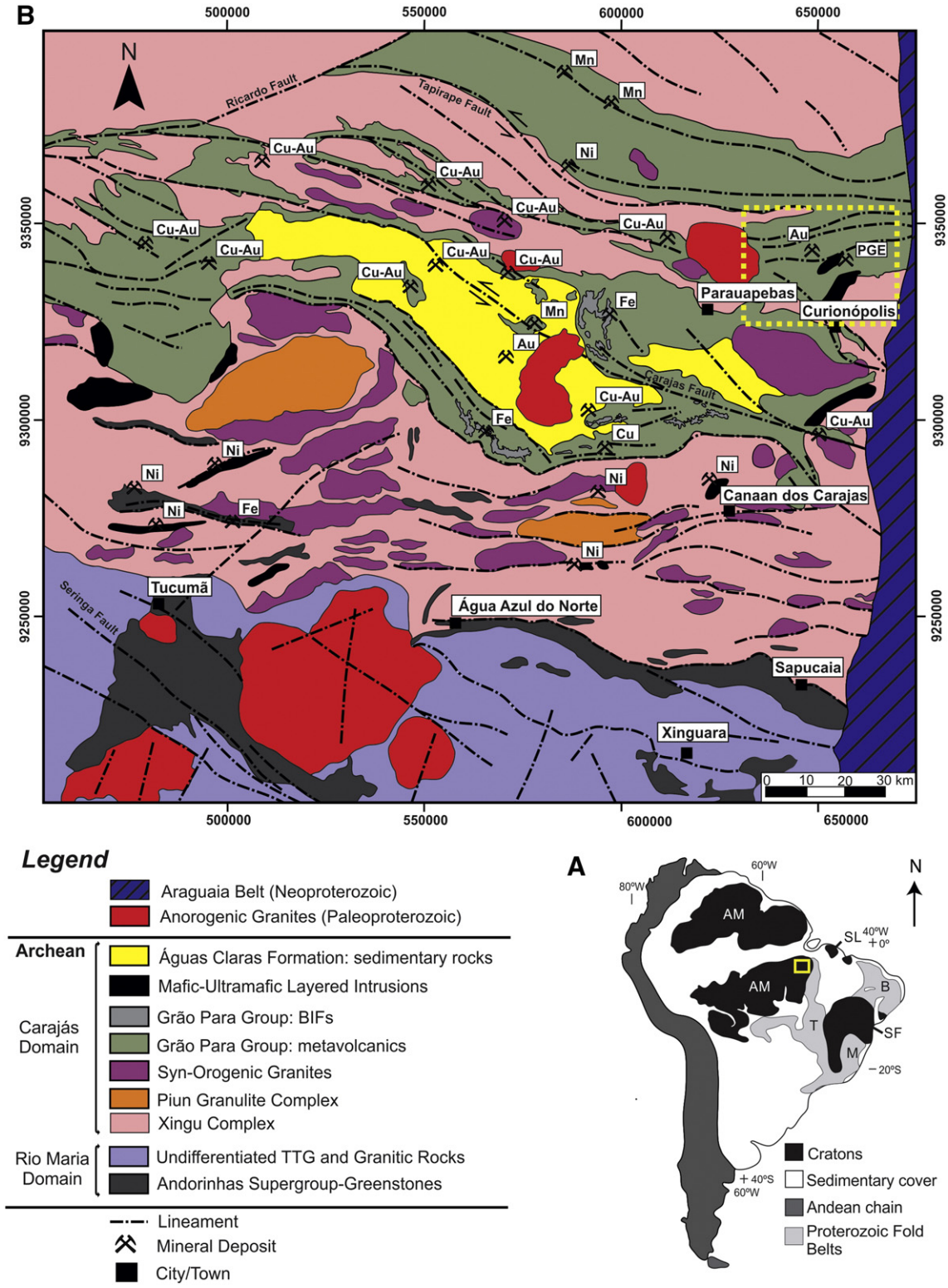

Fig. 1. A) Location of the Carajás Mineral Province. AM — Amazonian Craton; B — Borborema Province; M — Mantiqueira Province; SF — São Francisco Craton; T — Tocantins Province. B) Geology and mineral deposits of the Carajás Mineral Province (modified from Vasquez et al., 2008). The dashed rectangle indicates the position of Fig. 2.