
The Layered Mafic-Ultramafic Complexes of the Tocantins State, Central Brazil: Recently Discovered Large Proterozoic Intrusions with Favorable Potential to Host PGE Deposits

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Introduction

Magmatic Ni-Cu-PGE deposits can be grouped into two major types (Naldrett et al., 1989; 1999), those that are mined primarily because of their contained Ni and Cu, and those mined primarily because of their PGE content. While the first group encompasses several deposits formed at distinct environments, including volcanic-associated deposits, deposits located at the base or at feeder conduits of layered intrusions, and deposits associated to extra-terrestrial impact; world-class PGE deposits are restricted to large Archean to Paleoproterozoic layered intrusions emplaced into stable tectonic terranes (Bushveld, Great Dyke, Stillwater). Large layered intrusions and/or areas where clusters of several layered intrusions occur represent thus prospective targets for PGE deposits. This paper describes for the first time the geology of several large Proterozoic layered intrusions in the Tocantins State, central Brazil (Fig. 1).

Regional Geology

The studied layered mafic and mafic-ultramafic intrusions are located at the Tocantins Province, which represents a large Brasiliano (Neoproterozoic) orogen formed between the São Francisco and Amazonian cratons (Fig. 1). The layered intrusions occur at the northern part of the Brasília belt (Pimentel et al., 2000), an area of poorly exposed Precambrian terranes which are partially covered by Phanerozoic sediments. Mafic and mafic-ultramafic intrusions were discovered and delineated during an exploration program developed by Verena Minerals Corporation, including airborne geophysics and drilling. They consist of elongated bodies oriented parallel to the NE regional trend, forming a 120 km-long array which disappears under the Paleozoic-Mesozoic Parnaíba Basin (Fig. 1). The metamorphosed and tectonized layered intrusions are mainly hosted by metamorphic volcanic-sedimentary sequences to the West and by high-grade terranes of the Porto Nacional Complex to the East. Several

Neoproterozoic tectonized granites (Quaresma and Kotschoubey, 2001) indicate the importance of the Brasiliano magmatic-tectonic-metamorphic event in the region. Geochronological data for the layered complexes are so far restricted to Pb-Pb zircon dating of the Carreira Comprida Anorthosite (Gorayeb and Moura, 2001), suggesting a $2,071 \pm 4$ My age for the magmatism.

The geochronology and tectonic setting of the mafic and mafic-ultramafic layered intrusions are still poorly constrained. The overall tectonic scenario of large metamorphosed and tectonized layered intrusions within the Brasiliano belt closely resembles what is described for the large layered complexes in central Brazil, the Niquelândia, Barro Alto and Canabrava complexes located 500 km to the South (Ferreira Filho, 1998; Ferreira Filho and Pimentel, 2000; Pimentel et al., 2000). However, any attempt to correlate these two groups of layered complexes is hampered by the lack of geochronological and petrological data for the layered complexes of the Tocantins State.

The Layered Intrusions

The layered mafic and mafic-ultramafic intrusions of the Tocantins State are assigned to three groups on the basis of rock types, assemblage of cumulus minerals, geophysical anomalies and regional field association (Table 1).

The Carreira Comprida Anorthosite (Fig. 1) includes a large area (Table 1) of predominantly plagioclase and ilmenite-magnetite cumulate rocks. The structure and magmatic stratigraphy of the Carreira Comprida Anorthosite are unconstrained due to poor exposition. Coarse-grained anorthosite, a plagioclase and magnetite-ilmenite cumulate with postcumulus Ca-rich clinopyroxene and quartz, is the most frequent rock type. Interlayered gabbro-norite, olivine norite, leucotroctolite and anorthosite occur at the Crixás river section of the layered body. Accessory phases, including cumulus apatite and intercumulus quartz, indicate extensive fractionation of the mafic magma. Olivine compositions range from moderately forsteritic (up

to Fo 69) for the olivine + plagioclase cumulates, to highly fayalitic (Fo 11) for olivine + plagioclase + pigeonite + apatite cumulates. The primary cumulates are variably transformed into metamorphic equivalents characterized by tectonic

foliation and pervasive metamorphic recrystallization. Metamorphic assemblages indicate that peak metamorphism reached the granulite facies of metamorphism.

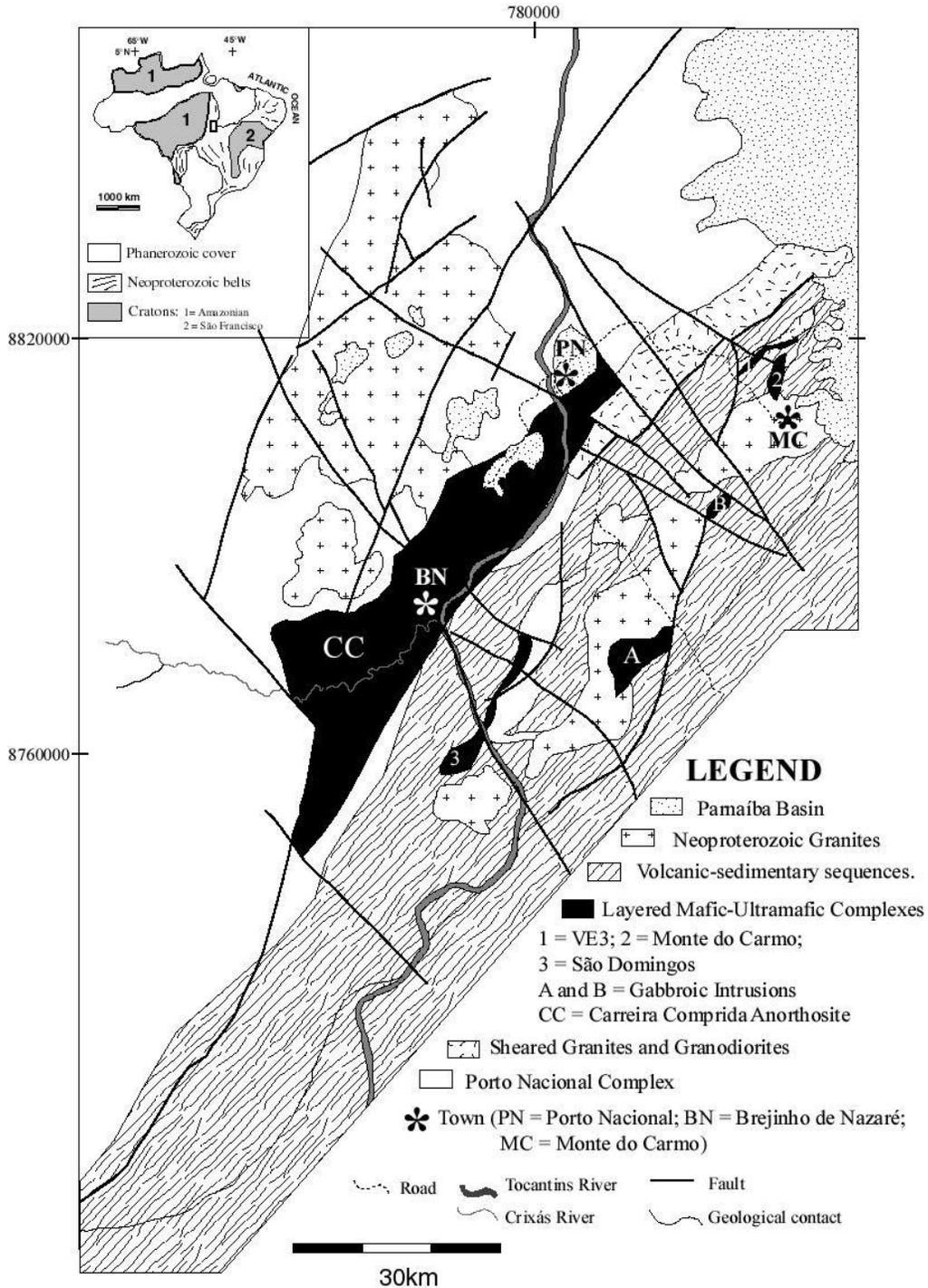


Figure 1. Geology of the Porto Nacional region, Tocantins State.

Table 1. Mafic and mafic-ultramafic intrusions of the Tocantins State.

Intrusion/Group	Areal Extent (for each intrusion)	Major Rock Types (for the whole Group)	Cumulate Assemblage (for the whole Group)	Olivine
Group 1				
Carreira Comprida	85 x 10 km	Anorthosite, Gabbro, Leuco-troctolite, Gabbroonorite	Pl; Pl+Ol; Pl+Ol+Pig Pl + Ol + Pig + Ap	Fo = 11-69 Ni = < 850 ppm
Group 2				
VE3	10 x 0.8 km	Wherlite; Gabbro	Ol+Cpx±Chr;	Fo = 84-86
Monte do Carmo	7.5 x 2.5 km	Clinopyroxenite;	Cpx ; Cpx+Pl	Ni = 600-1300 ppm
São Domingos	26 x 3 km			
Group 3				
Intrusion A	14 x 3.5 km	Metabasites	No magmatic silicates	
Intrusion B	5 x 1.8 km		preserved.	

Pl = plagioclase; Ol = olivine; Pig = pigeonite; Ap = apatite; Chr = chromite.

The VE3, Monte do Carmo and São Domingos mafic-ultramafic complexes (Fig. 1 and Table 1) consist of a high proportion of ultramafic to mafic rocks. These intrusions are poorly exposed but well delineated by significant geophysical anomalies. Drilling at the southern part of the VE3 body intercepted several hundred meters of interlayered wherlite (olivine + clinopyroxene ± chromite cumulates), clinopyroxenite (cpx cumulates) and gabbro (cpx + plagioclase cumulates). Olivine compositions are quite forsteritic (up to Fo 86) for olivine + clinopyroxene cumulates drilled at the VE3 body. Similar rock types outcrop at the Monte do Carmo complex. The rocks are variably transformed into foliated metamorphic equivalents (talc-tremolite serpentinite, talc-serpentine tremolite, hornblende, amphibolite) characterized by pervasive metamorphic recrystallization at the amphibolite facies of metamorphism.

Poorly exposed gabbroic intrusions (Intrusions A and B of Fig. 1 and Table 1) occur at the eastern part of the NE trend of layered complexes. These intrusions consist mainly of recrystallized mafic rocks and have distinct geophysical features when compared to the mafic-ultramafic complexes.

Conclusions

The mafic and mafic-ultramafic layered complexes of Tocantins represent one of the most extensive igneous associations of their type in Brazil. Broad generalizations about layered intrusions hosting significant PGE deposits, such as Archean or Paleoproterozoic age, emplacement into stable tectonic terranes, large areal extent and

significant ultramafic component, are mainly contemplated for the layered complexes at the Tocantins State. This discovery provides an additional target for PGE exploration in Brazil.

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