

A comparison of selected Precambrian Brazilian chromitites: Chromite, PGE-PGM, and Re/Os as parental source indicators

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Abstract

Mineralogical and geochemical studies were carried out in chromitites belonging to the mafic–ultramafic bodies of Niquelândia, Luanga, and Campo Formoso, which are, respectively, included in the Goiás Massif and the Amazon and São Francisco cratons. The main platinum-group minerals (PGM) included or associated with chromite grains are laurite in Niquelândia and Campo Formoso and sperrylite and braggite in Luanga. The most common primary base metal sulfides (BMS) are pentlandite, chalcopyrite, and minor pyrrhotite. Also present are base metal alloys (BMA), such as awaruite, and the BMS millerite, pyrite, and copper as secondary mineral phases linked to later alteration process. The Luanga chromitites display the lowest Cr₂O₃/Al₂O₃ and Cr₂O₃/FeO_t ratios. The chondrite-normalized profiles are strongly enriched in the platinum PGE subgroup (PPGE, Pt, Pd, Rh). The average Pd/Ir ratio (24.2) and ¹⁸⁷Os/¹⁸⁸Os values (0.17869–0.18584) are very high. Niquelândia chromitites have higher Cr₂O₃/Al₂O₃ and Cr₂O₃/FeO_t ratios than Luanga. Its PGE contents are low and chondrite-normalized profiles depleted, mainly in the PPGE subgroup. The average Pd/Ir ratio (0.45) and ¹⁸⁷Os/¹⁸⁸Os values (0.12598–0.12777) are low. Campo Formoso chromitites have the highest Cr₂O₃/Al₂O₃ and Cr₂O₃/FeO_t ratios; its average Pd/Ir ratio (0.72) and chondrite-normalized profiles (except the pronounced Ru spike) are closer to those of Niquelândia. The remarkable differences in terms of chromite bulk-composition, PGE contents and patterns, Pd/Ir ratios, and ¹⁸⁷Os/¹⁸⁸Os values associated with probable distinctions in the inferred geochemical compositions of the respective parental magmas indicate that the Luanga and Niquelândia complexes originated from distinct parental sources. Geochemical and isotopic features indicate that Luanga chromitites and associated rocks are consistent with a parental magma, either originated from an enriched mantle reservoir or strongly contaminated, whereas Niquelândia derives from a depleted mantle source, which displays a slightly positive Os anomaly.

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1. Introduction

This article deals with chromitites from selected Archean–Proterozoic mafic–ultramafic complexes of Brazil. One of its aims is to describe the mineral chemistry of these chromitites, their base metal sulfides (BMS), base metal alloys (BMA), platinum-group elements (PGE), and platinum-group minerals (PGM). Another goal is to compare available geochemical and isotopic data of the chromitites, obtained from original and published analyses, and discuss the relationship between these data and the parental source materials.

This work concentrates on three chromitite layers from the following stratiform complexes (Fig. 1): Niquelândia (Goiás), Luanga (Pará), and Campo Formoso (Bahia).

2. Analytical methods

Analyses on minerals and alloys were performed on polished sections using an A.R.L. microprobe equipped with a Tracor-Northern energy dispersion solid-state detector. The system operated at an accelerating voltage of 20–25 kV and a sample current on brass of 20 nA. The standards used for the PGM analyses were pure elements; natural standards were employed for the analyses on chromites, silicates, and sulfides. The results were corrected for matrix effects using a modified version of the MAGIC IV program.

Whole-rock ore samples were analyzed at Activation Laboratories Ltd, Ancaster, Ontario. The procedure involves

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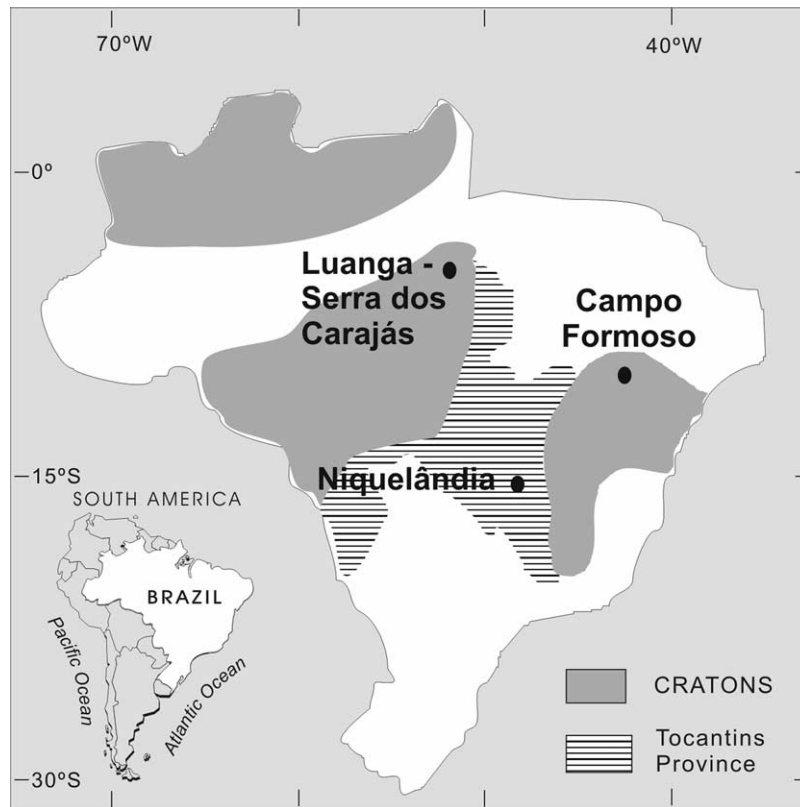


Fig. 1. Location of the selected Brazilian chromitite bodies.

a fire-assay preconcentration followed by instrumental neutron activation analyses. The detection limits are 1 ppb for Os, 0.1 ppb for Ir, 5 ppb for Ru, 0.2 ppb for Rh, 5 ppb for Pt, and 2 ppb for Pd.

To avoid potential Re contaminations from steel and tungsten carbide crushing equipment, all whole-rock powders for Re/Os isotopic analysis were prepared using a ceramic jaw crusher and an agate mill. The jaw crusher and mill were thoroughly cleaned between samples by crushing aliquots of clean quartz and cleaned again prior to the preparation of the aliquot of rock powder to be analyzed. The Carius tube isotope dilution procedure employed in the measurement of Re and Os concentrations and Os isotopic compositions is similar to the method developed by Shirey and Walker (1995). During this study, total chemistry and mass spectrometry blanks were 26 pg for Re and 1.5 pg for Os. Blank corrections were insignificant for all analyzed samples. Analyses over a period of 4 years of an Os isotopic mass spectrometry standard provided by the Carnegie Institution of Washington-Department of Terrestrial Magnetism (DTM), prepared using Johnson–Matthey ammonium hexachlorosmate (batch 5.56870A), yielded a mean $^{187}\text{Os}/^{188}\text{Os}=0.17367\pm 0.00058$ (external reproducibility at the 2σ level, $n=24$), within error of the DTM value of 0.17429 ± 0.00055 (Shirey, 1997). The γ Os constant used for geochronological calculations was $1.666\times 10^{-11}\text{y}^{-1}$ (Smoliar et al., 1996).

3. Niquelândia complex

3.1. Geological data

The Niquelândia complex, together with the Barro Alto and Cana Brava complexes, belongs to a 350 km NNE-trending belt in central Goiás, Brazil. These mafic–ultramafic stratiform complexes are part of the Goiás Massif, a complex geotectonic unit that appears in the Tocantins Province. The Goiás Massif is made up mainly of Archean and Proterozoic rocks (Fig. 2). The Niquelândia complex is composed of two main superposed sequences dipping westward: the lower unit (LS) in the eastern and the upper unit (US) in the western part of the body. The LS includes a basal gabbro zone (BGZ), a basal peridotite zone (BPZ), a layered ultramafic zone (LUZ), and a layered gabbro zone (LGZ), whereas the US comprises an upper gabbro-norite zone (UGAZ) and an upper amphibolite zone (UA) (Girardi et al., 1986).

The age and postmagmatic evolution of the complex are controversial. According to Girardi et al. (1986), the Niquelândia body represents a single igneous complex submitted to high-T subsolidus reequilibration prior to low-grade metamorphism. Correia et al. (1997), using SHRIMP U–Pb and Re–Os systematics, determine an age of 2.0 Ga for it. Pimentel et al. (2004a), based on U–Pb and Sm–Nd data, propose that the complex is composed of two layered intrusions. This model implies that the upper intrusion, which

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