

Platinum-Group Element Mineralization in Chromitites of the Niquelandia Layered Intrusion (Central Goias, Brazil): New Findings by the Use of the Hydroseparation (HS) Technology

Giorgio Garuti¹, Nickolay S. Rudashevsky², Vladimir N. Rudashevsky³, and Federica Zaccarini¹

¹ Department of Earth Sciences, University of Modena (Italy)

² Joint-Stock Company Mekhanobr-Analyt, 21-Linia, 8a, St. Petersburg, 199026 (Russia)

³ The Centre of New Technologies, RAS, Grazhdansky ave., 14, St. Petersburg, 195220 (Russia)
e-mail: garutig@unimo.it

Introduction

Chromite deposits of the Niquelandia layered intrusion (Central Goias, Brazil) are not widely dealt with in the literature, in particular, not much is known about the real extent and nature of the Platinum-group element (PGE) mineralization associated with them. White et al. (1971) reported (Pt+Pd+Rh) concentrations of 160-3420 ppb for one chromitite layer, with Pt reaching up to 2860 ppb. On the other hand, the microscope investigation of chromitites could not find any mineralogical evidence of the observed Pt anomaly (Ferrario and Garuti 1988), while a recent analysis of chromitites yielded total-PGE in the range 70-200 ppb and Pt concentrations systematically lower than 15 ppb (Ferreira et al. 1995). In order to shed light on the origin of such contrasting results, the new hydroseparation (HS) technology was applied to one selected chromitite sample and revealed the presence of coarse grains of Pt-Fe alloys which had previously escaped the investigation of polished sections (Rudashevsky et al. 2000). This paper provides an overview of the Niquelandia chromite-PGE mineralization, based on a new set of mineralogical and geochemical data.

Geological setting and petrography of the chromitites

The Niquelandia layered intrusion was emplaced in the Middle Proterozoic (1560-1600 Ma) as a result of continental rifting, and underwent amphibolite to granulite facies metamorphism at about 770-795 Ma (Ferreira et al. 1994). Exposition to the surface was followed by deep weathering of ultramafic rocks, generating economic deposits of silicate nickel during the Tertiary erosion cycle (Barros de Oliveira et al. 1992). The layered intrusion forms a monocline dipping westwards 40°-60°, with an estimated thickness of 10-14 km. Chromitite layering occurs at two stratigraphic levels located in the ultramafic zone, at about 1 and 2 km from the base respectively (Fig. 1).

The lower horizon (CHR-1) consists of the

repetition of centimetric chromitite seams in a 1 m thick tabular zone, within partially serpentinized dunite. The chromite is usually fresh or locally rimmed with ferrian chromite. Accessory sulfide is rare in the chromitite (0.005 - 0.035 wt% S), but tends to increase in the adjacent dunite (0.04 - 0.12 wt% S), suggesting that sulfur saturation was achieved during this stage of fractionation.

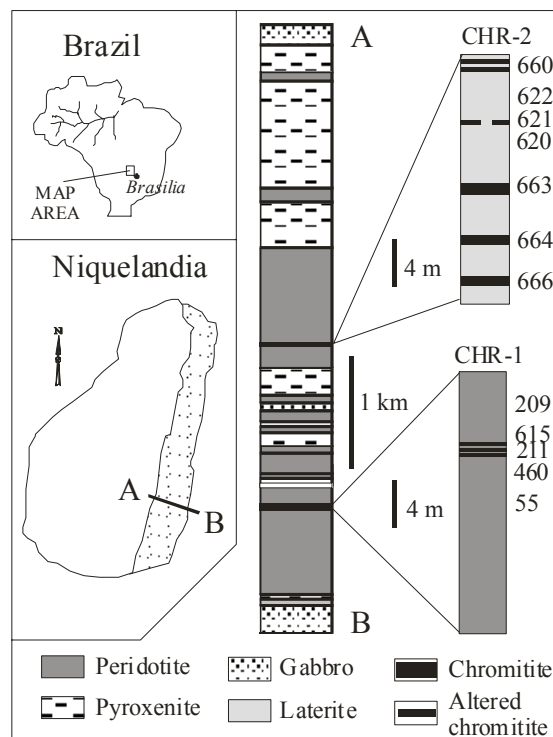


Figure 1. Simplified cross-section through the ultramafic units of the Niquelandia layered intrusion showing the stratigraphic location of the chromitite layers. CHR-1: 615, 460, 211 (chromitite), 55, 209 (adjacent dunite). CHR-2: 666, 664, 663, 660 (chromitite), 620 (laterite), 621, 622 (weathered chromitite). Sample 660 was treated with the hydroseparation technique

The sulfides occur as drop-like grains representing relics of an intercumulus sulfide melt, however their mineral assemblage dominated by pentlandite, veined with magnetite, appears to have been modified by low temperature alteration. The Ni/Fe distribution-coefficient between olivine and sulfide is in excess of 20 (Fig. 2), indicating that the sulfide lost part of the Fe^{2+} by oxidation (Thompson et al., 1984).

The upper chromitite horizon (CHR-2) comprises several sub-layers of up to 1 m in thickness, distributed over a stratigraphic interval of about 20-30 m, completely embedded in the laterite cover (Fig. 1). No relic of the primary silicate assemblage is preserved, the weathering products consisting of serpentine, chlorite, smectite, kaolinite, and garnierite, along with abundant goethite, hematite, amorphous Fe-hydroxides, and minor amorphous silica and quartz. The chromitite consists of a hard, utterly massive aggregate of closely interlocked chromite grains, usually having solid cores and intensively pitted boundaries. Kaolinite, goethite and amorphous Fe-hydroxides form the filling of pits and fractures. Geikielite and subordinate rutile occur at the grain boundaries of chromite, sometimes associated with kaolinite and iron oxides. Sulfides are extremely rare accounting for S concentrations of less than 0.002 wt% S.

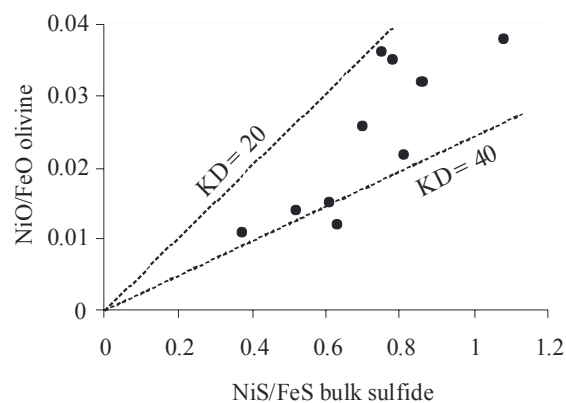


Figure 2. Relationships between NiO/FeO ratio of olivine and the NiS/FeS ratio of sulfide for partially serpentinized peridotite from the Niquelandia layered intrusion. Lines of constant distribution-coefficient are indicated for K_D of 20 and 40. The NiS/FeS ratio in sulfide was calculated from the modal proportion and microprobe composition of pentlandite, chalcopyrite, and pyrrhotite constituting the interstitial droplets in peridotite.

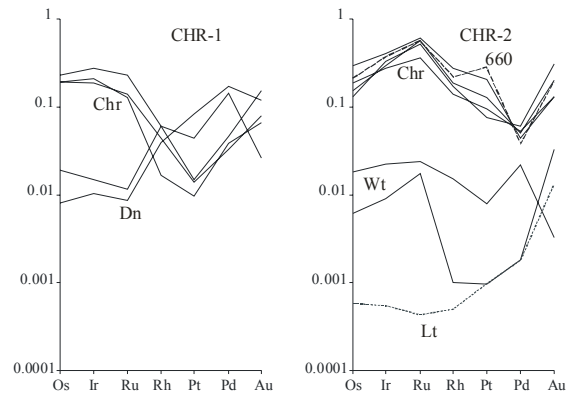


Figure 3. Chondrite-normalized PGE patterns for the 12 samples listed in Fig. 1. (Left) chromitite (Chr) and dunite (Dn) from CHR-1. (Right) chromitite (Chr), laterite (Lt), and weathered chromitite (Wt) from CHR-2. The profile of sample 660 is shown. Normalization values according to Naldrett and Vongruenewaldt (1989).

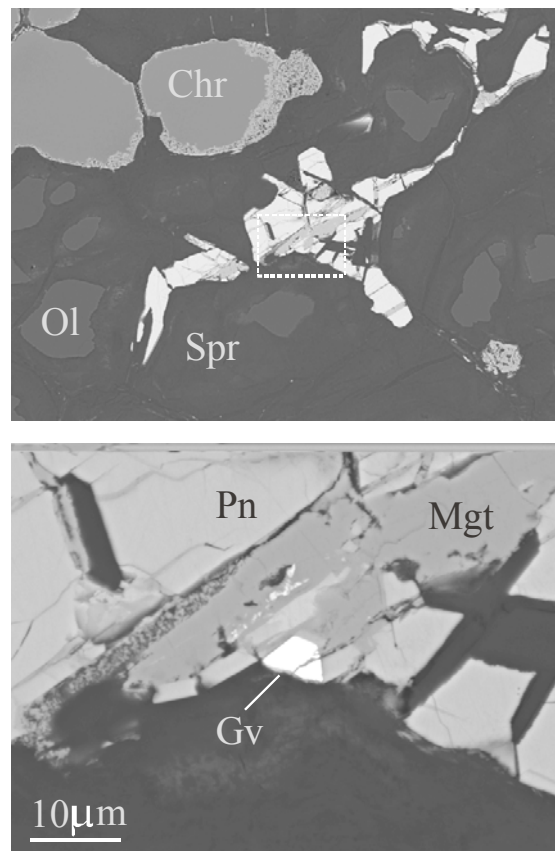


Figure 4. (Upper) large sulfide droplet and chromite (Chr) rimmed with ferrian chromite in a matrix of serpentine (Spr) and olivine (Ol) of partially serpentinized dunite CHR-1. (Lower) enlargement of the sulfide droplet showing geversite (Gv) associated with pentlandite (Pn) and magnetite (Mgt) veins.

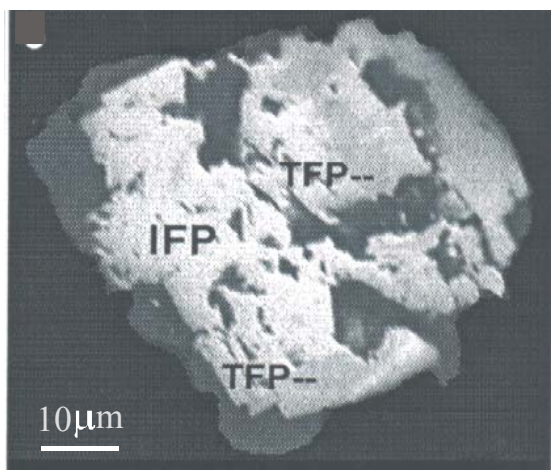


Figure 5. Large grain of isoferroplatinum (IFP) and tetraferroplatinum (TFP) associated with chromite in the HS concentrate from chromitite 660.

Platinum-group element mineralization

Concentrations of PGE and Au were determined in 9 chromitites and 3 adjacent rocks by ICP-MS after Ni-sulfide fire assay, at the X-Ray Assay Laboratories (Don Mills, Ontario, Canada). Total PGE amounts range 334-482 ppb in CHR-1 chromitite, 162-175 ppb in the adjacent dunite, and 650-1080 ppb in CHR-2 chromitite, but systematically drop down to the detection limits in the laterite and strongly weathered chromitites.

The CHR-1 chromitites have negative PGE patterns of ophiolitic type (Fig. 3) that is accounted for by scattered inclusions of laurite in the chromite. The adjacent dunite has positive PGE patterns, and contains a variety of Pt and Pd PGM (moncheite, merenskyite, sobolevskyite, stumpflite, geversite, and Pt-Fe alloy) and only one grain of laurite. These minerals are mainly associated with the interstitial sulfides droplets (Fig. 4), and therefore may have been reworked at low temperature (Ferrario and Garuti 1988), however their mode of occurrence provides evidence for the original precipitation of Pt and Pd with the sulfide melt.

The PGE patterns of CHR-2 chromitites are intermediate between the profiles of ophiolite- and Bushveld-type chromitites, and resemble the PGE patterns of chromitites from the Stillwater complex (Naldrett and VonGruenewaldt 1989). The total PGE content and $(\text{Pt}+\text{Pd})/(\text{Os}+\text{Ir}+\text{Ru})$ increase from the basal layer upwards, reaching the maximum Pt concentration of 290 ppb in the uppermost chromitite 660. The study of polished sections revealed a predominance of laurite and erlichmanite, along with accessory irarsite, and Os-Ir alloys ($< 15 \mu\text{m}$), and only three Pt-Fe alloys over a total of 220 PGM grains observed in the CHR-2.

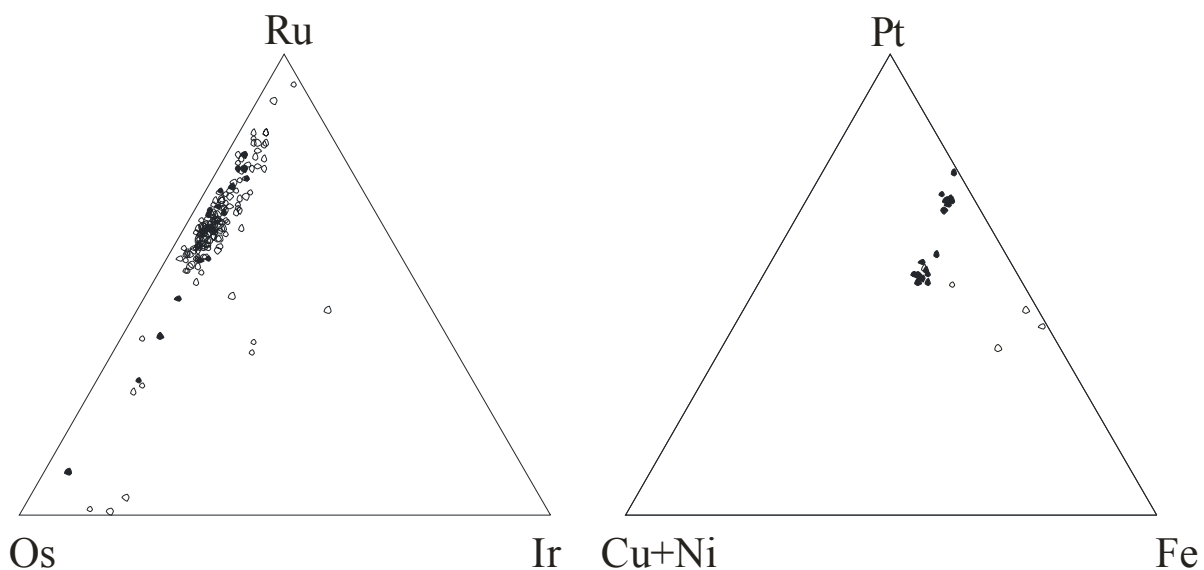


Figure 6. Composition of Ru-Os-Ir sulfides and Pt-Fe alloys from polished sections (open circles) and concentrate (filled circles).

Results of the hydroseparation (HS) method

The HS technique was applied to 1.3 kg of chromitite 660 and yielded a heavy mineral concentrate containing: 16 laurites, 3 erlichmanites, 19 Pt-Fe alloys, 1 kashinite and 1 (Ru,Fe)-oxide (?), and other minerals never described before in the Niquelandia chromitites (sphalerite, molybdenite, acanthite, breithauptite, barite, and bastnäsite, lead, silver, copper, nickel, gold, and antimony). The Pt-Fe alloys may reach grain size of 100 µm, and frequently occur associated with chromite (Fig. 5). Compositions of Ru-Os-Ir sulfides and Pt-Fe alloys from the concentrate are compared with those reported by Ferrario and Garuti (1988) in Figure 6. Statistical assessment of these results in terms of PGE mass balance indicates that the HS data match the whole-rock (Pt+Pd)/(Os+Ir+Ru) ratio better than the microscopic observations, and provides a more complete characterization of the PGM assemblage (Rudashevsky et al. 2002).

Concluding remarks

1) The inconsistency observed among PGE data reported from the Niquelandia chromitites may depend on differences in sampling and analytical methods, or even may be due to the different degree of alteration of the analyzed samples, since altered material appears to be strongly depleted in PGE. The mineralogical results obtained with HS re-evaluate to some extent the data reported by White et al. (1971), showing a relative abundance of Pt-phases in CHR-2, although the remarkable Pt grade of 2.86 ppm could not be confirmed.

2) We assume as did Ferreira et al. (1995) that the Niquelandia chromitites originated by mixing of two magmas at different stage of differentiation. Mineralogical observations in CHR-1 suggest that laurite and chromite were early liquidus phases, and soon after sulfur saturation was achieved causing precipitation of (Pt,Pd)-rich sulfide droplets which preferentially collected in the adjacent dunite. The complementary PGE distributions shown by the adjacent chromitite and dunite would support this conclusion.

3) The deep alteration of the ultramafic host of CHR-2 prevents any consideration as it regards the original presence of sulfides in these rocks. The PGM responsible for the Pt enrichment in chromitites are alloys (not sulfides) which are considered to have crystallized at high temperature, owing to their frequent association with chromite. Establishment of conditions suitable for the direct crystallization of Pt-Fe alloys from the silicate magma would necessarily imply that sulfur saturation was not achieved.

4) The discovery of “exotic” minerals

associated with chromitites inside ultramafic cumulates, suggest that at least one of the mixing magmas was enriched in incompatible elements (Mo, Zn, Pb, Ag, Ba, Ce, La), although we cannot exclude the possible contribution of some post-magmatic process.

References

- Barros Oliveira S.M. De, Trescases, J.J. and Melfi, A.J., 1992: Lateritic nickel deposits of Brazil. *Mineralium Deposita*, 27: 137-146.
- Ferrario, A. and Garuti, G., 1988: Platinum-Group Minerals in chromite-rich horizons of the Niquelandia Complex (Central Goias, Brazil). In Prichard, H.M., Potts, P.J., Bowels, J.F.W., and Cribb, S.J. (eds.) *Geo-Platinum 87*, 261-272, Elsevier Applied Sciences, London and New York.
- Ferreira Filho, C., Kamo, S.L., Fuck, R.A., Krogh, T.E. and Naldrett, A.J., 1994: Zircon and rutile U-Pb geochronology of the Niquelandia layered mafic and ultramafic intrusion, Brazil: constraints for the timing of magmatism and high grade metamorphism. *Precambrian Research*, 68: 241-255.
- Ferreira Filho, C., Naldrett, A.J. and Asif, M., 1995: Distribution of Platinum-Group Elements in the Niquelandia layered mafic-ultramafic intrusion, Brazil: Implications with respect to exploration. *The Canadian Mineralogist*, 33: 165-184.
- Naldrett, A.J. and Von Gruenewaldt, G., 1989: Association of Platinum-Group Elements with chromitite in layered intrusions and ophiolite complexes. *Economic Geology*, 84: 180-187.
- Rudashevsky, N.S., Garuti, G., Kretser, Yu. L., Rudashevsky, V.N., Zaccarini, F., and Andersen, J.C.Ø. 2002: The separation of accessory minerals from rocks and ores using the hydroseparation (HS) technology – method and application to the CHR-2 chromitite of the Niquelandia intrusion, Brazil. *Transactions of the Institution of Mining and Metallurgy* (submitted).
- Thompson, J.F.H., Barnes, S.J. and Duke, J.M., 1984: The distribution of nickel and iron between olivine and magmatic sulfides in some natural assemblages. *The Canadian Mineralogist*, 22: 55-66.
- White, R.W., Motta, J. and Arraujo, V.A. De, 1971: Platiniferous chromitite in the Tocantins complex, Goias, Brazil. In *Geological Survey Research 1971*, U.S. Geological Survey Professional Papers, 750D, D26-D33.

