Coexistence of Cr- and Al-rich ophiolitic chromitites in a small area: the Sagua de Tánamo district, Eastern Cuba

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ABSTRACT: Small ophiolitic chromite deposits occur within Sagua de Tánamo district (Eastern Cuba). These deposits exhibit massive, disseminated and banded textures, and enclosed in amphibole-bearing dunite and harzburgite that show mantle tectonite textures. Chromite exhibits large and continuous compositional variations from typical Al-rich (Cr# = 0.45-0.54) at Rupertina deposit, to Cr-rich (Cr# = 0.65-0.75) at Guarina deposit. These compositional variations occur between deposits separated less than 3 km. The high PGE concentrations are found in high-Cr chromitites (up to 3713 ppb of total PGE), whereas high-Al chromitites (#Cr < 0.6) systematically are poor in PGE. In general, the #Cr in chromite ore has a positive correlation with total IPGE contents. The genesis of such a continuous spectrum of chromitite can be related with a progressively changing (in time and space) hybrid melt (Mg-rich calc-alkaline melt + highly hydrated melt) at different levels in the supra-subduction oceanic mantle.

1 INTRODUCTION

T.P. Thayer (1964, p. 1501) wrote: “… In some districts, however, like Grant Country, Oregon and Sagua de Tánamo, Cuba, the chromite mineral in separate but otherwise apparently identical deposits may differ by 20 percentage points in Cr2O3. Within such districts or regions there is likely to be a uniform pattern of compositional variation…”. In the Sagua de Tánamo district case, the Thayer’s words were “prophetic”.

The Sagua de Tánamo district is the smallest of the three chromite mining districts comprising the Mayarí-Baracoa ophiolitic belt. It contains both Al-rich (25 deposits) and Cr-rich (10 deposits) chromite ore. These deposits were extensively exploited in the past (preamble, and during Second World War) when produced several thousands tons of ore, averaging 40-45% Cr2O3 (Thayer, 1942). Recent studies on Sagua de Tánamo chromitites can be found in Murashko & Lavandero (1989), Kovács et al. (1997) and Proenza et al. (1998, 1999).

In this paper we present the results of a detailed study of chromite composition in chromite deposits and associated peridotites of the Sagua de Tánamo district (Eastern Cuba). We also present new PGE data on chromitites. Finally, we discuss on the possible genesis of the large, continuous spectrum of Cr content in the different chromite bodies.
Lavanderó, 1989), surrounded by variably thick dunite envelopes. Usually the contact between chromitite and dunite takes place along a zone of disseminated ore, and a positive correlation exist between the thick of the dunite envelope and Cr_2O_3 content of chromite in the hosted chromitite. The studied chromitite bodies are concordant with the foliation of the enclosing peridotites, but Kovács et al. (1997) mention that some others are clearly discordant.

Unusual rock types, spatially related with some ore bodies, consist of fine-grained, discordant lenses and coarse-granular dikes (veins) of amphibolites. Amphibole is associated with strongly altered plagioclase and may represents 90 vol.% in concordant bodies and 50 vol.% in discordant dikes.

3 TEXTURE AND MINERALOGY OF CHROMITE ORE

Primary chromite textures are typically massive, disseminated and banded, and frequently show pull-apart fractures. However, late shearing and faulting gave rise to mylonitic, and cataclastic textures. Interglomerular minerals are olivine, amphibole (edenite with up to 2.17 wt.% Cr_2O_3), serpentine and chlorite, with traces of disseminated magnetite, Fe-Ni sulphides and Fe-Ni alloys. Chromite grains have primary inclusions of olivine (Fo = 96) and amphibole (pargasite with up to 3.28 wt.% Cr_2O_3).

4 CHROMITE CHEMISTRY

Chemistry of chromite ore shows a wide compositional range from high-Al (Rupertina deposit) to high-Cr (Guarina deposit) compositions. Cr# [Cr/(Cr+Al)] varies from 0.45 to 0.75 (corresponding to 37-56 wt.% Cr_2O_3 and 13-31 wt.% Al_2O_3) and Mg# [Mg/(Mg+Fe^2+)] from 0.57 to 0.74 (Fig. 2). Mg# is generally low in samples containing large amounts of interstitial amphiboles. TiO_2 content range between 0.1 and 0.48 wt.% and Fe_2O_3 between 0.4 and 4.6 wt.%. Minor amounts of MnO (0.12-0.3 wt.%), V_2O_3 (0.1-0.37 wt.%), NiO (0.1-0.3 wt.%), and ZnO (< 0.15 wt.%) were also detected.

The chemical composition of accessory chromite from the associated peridotite vary according to the Cr# of the enclosed chromitite (Fig. 2). Disseminated chromite in dunite surrounding relatively high-Cr chromitites (Cr# > 0.6) has similar or slightly higher Cr# (0.58-0.80) compared with that of the chromitite but shows lower TiO_2 contents (0.08-0.24 wt.% versus 0.1-0.48 wt.%). Chromite from the adjacent harzburgite shows lower Cr# (0.36-0.57) and TiO_2 contents (0.03-0.16 wt %). In contrast, accessory chromite in dunite surrounding relatively high-Al chromitites (Cr# < 0.6), shows higher Cr# (> 0.58) and similar or slightly higher TiO_2 contents (0.17-0.23 wt.% versus 0.1-0.22 wt.%) than that from the enclosed chromitites. Chromite from the associated harzburgite shows even higher Cr# (0.58-0.66) and lower TiO_2 contents (0.08-0.14 wt.%) than that from dunite.

5 PGE DISTRIBUTION

The results of whole-rock PGE analyses show that, despite the differences in PGE concentration, all chromitites samples are enriched in the Ir subgroup (IPGE: Ir, Os and Ru) with respect to Pd subgroup (PPGE: Rh, Pt, and Pd). Thus, most of the analysed chromitites have negatively slope chondrite-normalised PGE patterns, as reported in ophiolitic chromitites elsewhere.
In high-Cr chromitites PGE contents vary from 197 to 3713 ppb, and the IPGE abundances are usually higher than 0.1 times chondritic values. The highest PGE content were obtained from the Caridad deposit (up to 3713 ppb).

In high-Al chromitites PGE contents range from 18.3 to 224 ppb, and IPGE concentrations are usually below 0.1 times chondritic values. The lowest PGE values were found from the Rupertina deposit (82 ppb of total PGE).

With the exception of the Cr-rich Caridad deposit (an unusually PGE-rich deposit), the chromitites studied exhibit a good correlation between ΣIPGE and #Cr (r ~ 0.86).

Figure 2. Variations of Cr# [Cr/(Cr+Al)] vs. Mg# [Mg/(Mg+Fe2+)] of chromite in chromitite and associated dunite and harzburgite of the Sagua de Tánamo district. The average of total PGE values also are shown for all deposits. See text for discussion.

6 DISCUSSION

Relevant features of the studied chromite deposits from the Sagua de Tánamo district can be summarised as follows:
1) chromite from relatively close (< 3 km) chromitite bodies, systematically hosted in harzburgite, exhibits a large range of reciprocal Cr-Al variation;

2) in high-Cr chromitites (Cr# ≥ 0.6) both Cr# and TiO2 contents of chromite increases progressively from that disseminated in the associated harzburgite to that disseminated in dunite and to that from massive chromitite (with the only exception of Caridad deposit, Fig. 2), on the contrary, in high-Al chromitites TiO2 increases and Cr# decreases from harzburgite to dunite and to chromitite;
3) in general, chromitites exhibit a good correlation between ΣIPGE and #Cr;
4) most chromitite, dunite and harzburgite contain primary, interstitial edenitic amphibole;
5) some chromitites include concordant lenses of fine-grained amphibolites and/or are cut by dikes of coarse-grained amphibolites.

The chemical trend defined by the composition of chromite from harzburgite to dunite and to chromitite in high-Cr chromitite is similar to most trends reported in Cr-rich chromitite elsewhere except for the TiO2 enrichment in chromitites relative to the host dunite. In contrast, the trend defined by Al-rich chromitites evidences that the parental melt of chromitite was richer in Al2O3 than that in equilibrium with the host.

These chemical variations in chromite (specially in Al-rich chromitites) suggest that the parental melt of chromitite was different and, probably, more evolved than that in equilibrium with the host. It could generate by the addition of incompatible elements and volatiles to the melts in equilibrium with the enveloping dunite.

According to Malpas et al. (1997), the close association of high-Cr and high-Al chromitites, hosted by harzburgite and lherzolite respectively, suggest a formation in a fore-arc environment. However, the all Sagua de Tanamo chromitites are hosted in depleted harzburgites. In addition, harzburgite hosting Al-rich chromitite is relatively more depleted than that harzburgite hosting Cr-rich chromitite.

Proenza et al. (1999) explain this chemical disequilibrium considering that dunite represents porous melt flow channels formed by melt/rock reactions with enclosing harzburgites. In this model, chromitite crystallized, in a supra-subduction oceanic mantle, as a consequence of the increase of fO2 by mixing of the melts circulating in dunite channels with hydrous, oxidizing melts derived from dehydration of the subducting oceanic lithosphere.

On the other hand, the correlation between total PGE (mainly IPGE) and Cr# observed in Sagua de Tánamo chromitites is in agreement with previous works elsewhere. In general, it is accepted that PGE contents of chromitites tend to increase with the increase of Cr content in chromite (e.g. Zhou et al., 1998) since PGE contents depend on their concentration in the parental melt (e.g. Barnes et al., 1985). Thus, the presence of PGE-rich and PGE-poor chromitites in the same mining district also suggest
that different parental melts were involved in the formation of the chromitite bodies.

The continuous spectrum of chromite chemistry probably is the consequence of the progressive change (in time and space) of the composition of the parental hybrid melt (Mg-rich calc-alkaline melt + highly hydrated melt), mainly caused by the addition of the chemically variable, oxidized volatile-rich melt. The volatile-rich nature of this melt (and the resulting hybrid melt) is in agreement with the widespread distribution of amphibole in harzburgite, dunite and chromitite.

7 CONCLUSIONS

The composition of the Sagua de Tánamo chromitite bodies shows a wide, and continuous Cr-Al variations. They represent a good example of coexistence of Cr- and Al-rich chromitites in a small area (< 3 km).

The compositional variation of chromite from Sagua de Tánamo district evidence a strong chemical disequilibrium between chromitite and its host peridotite, suggesting that chromitite formation cannot be accounted for by cotectic crystallization of chromite and olivine of the same parental melt. Thus, it is necessary to consider magmatic processes others than partial melting and fractional crystallization. Most likely, the genesis of Cr- and Al-rich chromitites from Sagua de Tánamo can be related to melt/peridotite reactions, and a progressively changing hybrid melt at different levels in the supra-subduction oceanic mantle.

The high PGE concentrations are found in Cr-rich chromitites, whereas Al-rich chromitites systematically are poor in PGE. Finally, the PGE-rich chromitites of Caridad deposit (up to 3713 ppb), reported here, will be a new target of PGE exploration in Sagua de Tánamo district, especially the high-Cr chromitites.

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