

Back-Arc Origin for Chromitites of the Dobromirski Ultramafic Massif

JOSÉ M^a GONZÁLEZ-JIMÉNEZ (1), VANESSA COLÁS (2), IVANINA SERGEEVA (3), WILLIAM L. GRIFFIN (1), SUZANNE Y. O'REILLY (1), FERNANDO GERVELLA (4), THOMAS KERESTEDJIAN (3), ISABEL FANLO (2), MAREK LOCMEIS (1), NORMAN PEARSON (1). ELENA BELOUSOVA (1)

(1) ARC Centre of Excellence for CCFS and GEMOC ARC National Key Centre, Department of Earth and Planetary Sciences, Macquarie University, Sydney, NSW 2109, Australia.

(2) Departamento de Ciencias de la Tierra. Ciudad Universitaria. Universidad de Zaragoza. C/ Pedro Cerbuna 12. 50009, Zaragoza (España)

(3) Geological Institute, Bulgarian Academy of Sciences, 24 Georgi Bonchev Str., 1113 Sofia, Bulgaria.

(4) Departamento de Mineralogía y Petrología and Instituto Andaluz de Ciencias de la Tierra (Universidad de Granada-CSIC), Facultad de Ciencias, Granada, Spain

INTRODUCTION

The Variegated Complex (Haydoutov et al. 2004) of the Rhodope Massif (or Rhodope Metamorphic Core Complex) in south Bulgaria and Northern Greece is composed of alternating sediments and igneous rocks with a high-grade metamorphic overprint; it hosts several ultramafic bodies with "ophiolitic" affinity. The ultramafic sequences of these ophiolitic bodies are made up of highly deformed peridotites (meta-harzburgites and meta-dunites with minor amounts of lherzolites) and rocks of the cumulate sequence, including meta-dunites, meta-wherlites, meta-pyroxenites. Most of these ultramafic bodies contains chromite deposits whose origin within the ophiolite environment is unknown.

The goal of this contribution is to start to fill this knowledge gap by targeting the Dobromirski Ultramafic Massif, which is the biggest and best-exposed ultramafic body in the Rhodope area. We carried out detailed geochemical work on the distribution of major and minor elements in chromite deposits hosted in this ultramafic body. Our results provide strong support for the ophiolitic nature of the ultramafic body and its hosted chromitites and suggest that it formed in a back-arc basin.

THE DOBROMIRSKI ULTRAMAFIC MASSIF

The Dobromirski Ultramafic Massif is a lens-like ultramafic body (total exposed area 11 km²) located in the southernmost area of the Bulgarian part of the Rhodope Core Complex.

The rocks of the massifs are of unknown age and consist of metamorphosed harzburgites and dunites hosting chromitite bodies, also metamorphosed.

All these rocks are cut by strongly folded (nearly isoclinal) centimeter-thick veins of clino- and ortho-pyroxenites.

Serpentinization is the predominant type of metamorphic alteration of the ultramafic rocks, although extensive peridotite/fluid interaction, including chloritization, carbonatization and talc-forming processes, are also recognized along fault zones and tectonic contacts.

CHROMITITE BACKGROUND

Chromitites at Dobromirski are lenses (or pods) which were already mined for chromium during the Second World War. The size of the pods is highly variable, ranging from few hundred tons up to 250,000 tons. All these chromitites occur along a single horizon rich in dunites which is concordant with the mylonitic foliation of the meta-harzburgites.

The Dobromirski chromitites show variable degrees of metamorphic alteration depending on the size of the ore body and chromite/silicate ratio. Thus, big ore bodies are less altered than mid-size and small ore bodies, and chromite from massive chromitites displays less alteration than chromite from semi-massive and disseminated chromitites. As a result, all chromitite bodies show higher degrees of alteration in their peripheral parts (González-Jiménez et al. 2009). Alteration is recorded in individual chromite grains as irregular to concentric optical and compositional zoning revealing the superimposition of two alteration events (González-Jiménez et al., 2009). During the first event (zone 1), chromite is enriched in FeO and Cr₂O₃, and loses Al₂O₃, with little or no variation in Fe₂O₃ content. The second alteration event

(zone 2) is characterised by the formation of chromite strongly enriched in Fe₂O₃. Locally a transition zone is observed between zones 1 and 2 characterised by behaviour of FeO, Cr₂O₃ and Al₂O₃ similar to that observed during the first event but with a slight enrichment in Fe₂O₃.

CHEMISTRY OF CHROMITE

Electron-microprobe analysis reveals that the pristine cores of chromite from the Dobromirski chromitite have Cr# [Cr/(Cr+Al) atomic ratio] varying between high-Cr and high-Al (0.74-0.55) and with variable Mg# [Mg/(Mg+Fe²⁺) atomic ratio = 0.69-0.60], a range of compositions that overlaps that typical for podiform (ophiolitic) chromitites (Fig. 1).

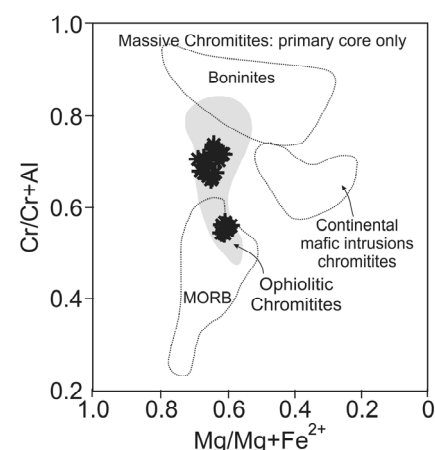


fig 1. Plots of the chemistry of chromite (major elements) in terms of Cr# [Cr/(Cr+Al) atomic ratio] vs Mg# [Mg/(Mg+Fe²⁺) atomic ratio] for chromite of chromitites from the Dobromirski Ultramafic Massif. Fields after Mukherjee et al. (2010).

CHROMITITE PARENTAL MELTS

Kamenetsky et al. (2001) have provided

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* corresponding author: jose.gonzalez@mq.edu.au

experimental constraints showing that the contents of Al₂O₃ and TiO₂ in chromite are linearly correlated with the contents of Al₂O₃ and TiO₂ in melt inclusions. The use of this approach allows estimation of the composition of the melt from which the chromite has precipitated. Applying this approach, we have estimated that the melt compositions in equilibrium with chromite of Dobromirski high-Cr chromite had 12-14 wt% Al₂O₃ and 0.3-0.5 TiO₂. In contrast, chromite of Doromirski high-Al chromite was in equilibrium with melts containing ~15 wt% Al₂O₃, and 0.8-0.9 wt% TiO₂.

Melts in equilibrium with high-Cr chromite overlap those of high-Mg island arc tholeiites (IAT) and boninites (10.6-14.4 wt% Al₂O₃) whereas those in equilibrium with chromite of high-Al chromite overlap high-Mg IAT (11.4-16.4 wt% Al₂O₃; Augé 1987) and MORB (~ 15 wt% Al₂O₃; Wilson 1989). These melts are geochemically similar to those that have precipitated podiform chromitites in the mantle sequence of ophiolites elsewhere (e.g., Melcher et al. 1997; Rollinson 2008, Pagé and Barnes 2009; González-Jiménez et al. 2011) but are distinctively lower in TiO₂ than those that have produced chromitites in crustal domains (e.g., Mondal et al. 2006; Mukherjee et al. 2010).

A comparison with primary chromite from massive chromitite samples of other ophiolitic chromitites, whose setting within the ophiolite environment has been well-established, suggests that high-Cr chromitites of Dobromirski very likely did not crystallize from high-Mg, low-Ti island arc melts like those boninite-like ones that produced the high-Cr chromite of podiform chromitites hosted in highly depleted fore-arc peridotites of the Thetford Mines in Canada (Pagé and Barnes 200) or Rutland island ophiolite in India (Gosh et al. 2009). Rather they probably were formed from high-Mg, high-Ti island arc tholeiites similar to those that have precipitated high-Cr massive chromitites in the back-arc mantle of Mayarí-Cristal in Cuba (González-Jiménez et al. 2011) and the northern part of the Oman (Rollinson 2008) ophiolites. On the other hand, the composition of the Dobromirski high-Al chromites overlap that of spinel precipitated from MORB and modern back-arc basin lavas, implying parental melts of affinity close to back-arc basin basalts (BABB). Interestingly, such a melt is identical in

terms of Al₂O₃ and Ti to the BABB melts that have produced the high-Al massive chromitites hosted in the back-arc mantle of Mayarí-Cristal (15-16 wt Al₂O₃, TiO₂, Fe/MgO; González-Jiménez et al. 2011). Our observations are consistent with the data of Bazylev et al. (1999) Mafic dykes and sills that intrude the chromitite host peridotite which also show intra-oceanic subduction-related transitional IAT/MORB geochemical signatures. All these observations taken together suggest that the Dobromirski chromitites could have formed in an intra-oceanic back-arc setting above a suprasubduction zone as described for other ophiolitic chromitites (e.g., Zhou et al. 1998; Rollinson 2008; González-Jiménez et al. 2011).

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