Back-Arc Origin for Chromitites of the Dobromirtsi Ultramafic Massif

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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-whelites, meta-pyroxenites. Most of these ultramafic bodies contain 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 Dobromirtsi 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 DOBROMIRTSI ULTRAMAFIC MASSIF

The Dobromirtsi 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 clinopyroxene.

Serpenitization 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 Dobromirtsi 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 chromitite occur along a single horizon rich in dunites which is concordant with the mylonitic foliation of the meta-harzburgites.

The Dobromirtsi chromitites show variable degrees of metamorphic alteration depending on the size of the ore body and chromium/silicate ratio. Thus, big ore bodies are less altered than mid-size and small ore bodies, and chrome from massive chromitites displays less alteration than chrome 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), chrome 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 chrome 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 chrome from the Dobromirtsi 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).

Kamenetsky et al. (2001) have provided
experimental constraints showing that the contents of Al_{2}O_{3} and TiO_{2} in chromite are linearly correlated with the contents of Al_{2}O_{3} and TiO_{2} 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 Dobromiritsi high-Cr chromite had 12-14 wt% Al_{2}O_{3} and 0.3-0.5 TiO_{2}. In contrast, chromite of Dobromiritsi high-Al chromite was in equilibrium with melts containing ~15 wt% Al_{2}O_{3} and 0.8-0.9 wt% TiO_{2}.

Melts in equilibrium with high-Cr chromite overlap those of high-Mg island arc tholeiites (IAT) and boninites (10.6-14.4 wt% Al_{2}O_{3}) whereas those in equilibrium with chromite of high-Al chromite overlap high-Mg IAT (11.4-16.4 wt% Al_{2}O_{3}; Augé 1987) and MORB (~15 wt% Al_{2}O_{3}; 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 TiO_{2} 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 Dobromiritsi 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 Mayari-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 Dobromiritsi high-Al chromitites 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 Al_{2}O_{3} and Ti to the BABB melts that have produced the high-Al massive chromitites hosted in the back-arc mantle of Mayari-Cristal (15-16 wt Al_{2}O_{3}, TiO_{2}, Fe/MgO; González-Jiménez et al. 2011). Our observations are consistent with the data of Bazylev et al. (1999) with analogous dykes and sills that intrude the chromitite-hosted peridotite which also show intra-oceanic subduction-related transitional IAT/MORB geochemical signatures. All these observations taken together suggest that the Dobromiritsi chromitites could have formed in an intra-oceanic back-arc setting above a supersubduction zone as described for other ophiolitic chromitites (e.g., Zhou et al. 1998; Rollinson 2008; González-Jiménez et al. 2011).

ACKNOWLEDGEMENTS

Funding support for this work has been provided by Australian Research Grants (WLG, SYO; R and NJP) the ARC Centre of Excellence for Core to Crust Fluid Systems and the Spanish "Ministerio de Ciencia e Innovación" Grant CGL2010-14848 and CGL2010-15171, and the Junta of Andalucía research grants RNM-131 and 2009RNM4495. The analytical data were obtained using instrumentation funded by DEST Systemic Infrastructure Grants, ARC LIF, NCRIS, industry partners and Macquarie University.

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