The Bragança Podiform Chromite Field in NE Portugal

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Abstract. The Bragança Chromite field is located in NE Portugal approximately 10 km west of the town of Bragança. The field is known for its hundreds of chromite prospects and small podiform chromitite mines. All the prospects and mines ceased operation in the early fifties. Previous studies have concluded that the chromitite may contain PGE's which have rekindled the interest in the area. Geologically the Field is located within the allocthonous Complexes of the Galiza - Trás-os-Montes Zone that tectonically overlaps with the Central Iberian Zone. The host rocks to mineralisation [metaperidotites (harzburgites, lherzolites and dunites) and metapyroxenites] occur in the uppermost unit of the Bragança Massif – The Upper Allocthonous Thrust Complex (UATC) which comprises four tectonic sequences with a very complex tectonometamorphic and geodynamic evolution as well as polyphase metamorphism and intense multiphase deformation.
Podiform chromitite mineralisation is known from the small Valongo, Pingarela and Abissêdo mines but the most common mineralisation is fine, disseminated chromite present mostly in the metadunites but also in the metaperidotites. Six recent boreholes have yielded the following maximum values: 114 ppb Pt; 170 ppb Pd, 5500 ppm Cr and 2500 ppm Ni.

Keywords: Podiform chromitite, chromite, PGE's, Upper Allocthonous Thrust Complex (UATC), Bragança Massif

1 Introduction

The Bragança Chromite Field is an approximately 50 km^2 area located 10 km west of Bragança in north eastern Portugal where there are hundreds of small prospects as well as a few small chromite mines. This field has also been investigated for PGE mineralisation associated with the chromite (Bridges, 1992; Bridges et al., 1993). Mining activity ceased in the 1950's but in light of the recent rise in metal prices, the area has seen a reactivation of the interest for PGE's.

2 Regional geologic setting

The Bragança Chromite Field is located within the Allochthonous Complexes of the Galiza – Trás-os-Montes Zone that tectonically overlaps with the Central Iberian Zone (Fig. 1) and the host rocks to mineralisation occur in the uppermost unit of Bragança Massif: the Upper Allochthonous Thrust Complex – UATC (Bridges et al., 1995) also called the Continental Allochthonous Terrane – CAT (Marques 1994).

The Bragança Massif (also known as the Bragança Complex; Fig. 1A) is a nappe pile and comprises four units in tectonic contact, which are from base to the top:

1. A parautochthonous sequence;
2. A lower allochthonous sequence;
3. Ophiolite Units and
4. An upper allochthonous sequence.

The Bragança Massif shows a very complex tectonometamorphic and geodynamic evolution, revealed by its rock assemblage, the polyphase metamorphism and the intense multiphase deformation.

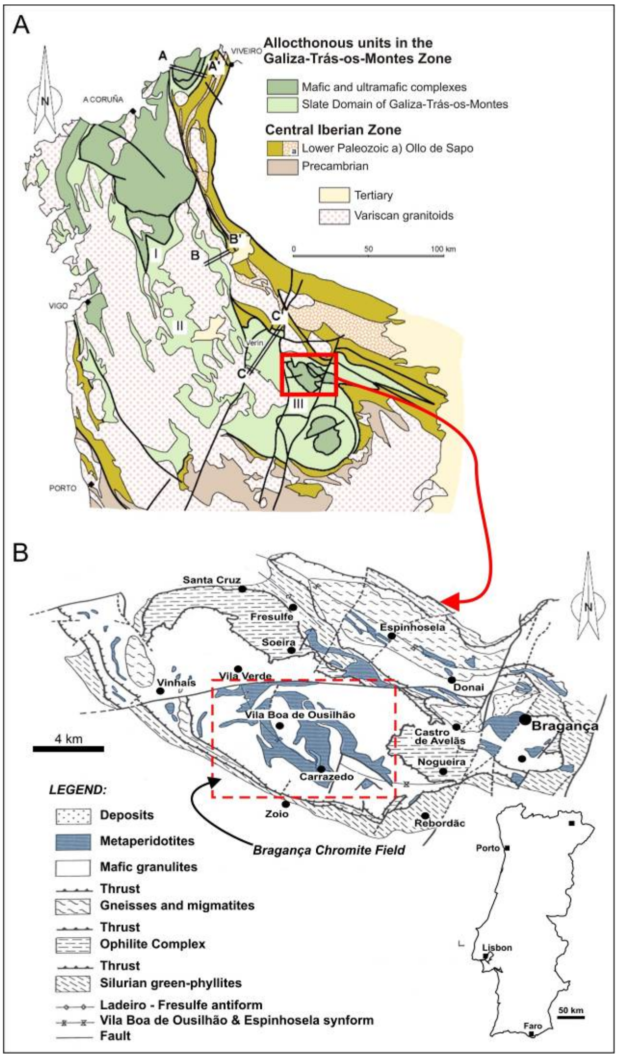

Figure 1. A- Allocthonous units of the Galiza - Trás-os-Montes Zone (after Arenas et al. 2004) and B - Geological map for the Bragança Massif showing the divisions between the main tectonic units (After Prichard et al. 1991).

3 Geology of the UATC

The UATC comprises three main units, two of them with a synformal structure (Vila Boa de Ouzilhão Synform and the Espinhosela Synform) and one with an antiformal structure (the Ladeiro antiform). The study area lies within the Vila Boa de Ousilhão Synform (Fig. 1B) (Marques 1994).

Petrographically the UATC is characterised by the presence of mafic, intermediate and felsic granulites, eclogites, rocks of continental tholeiitic affinity (grabbroic, peridotitic and anorthositic) and ultramafic rocks. The latter comprise peridotites and pyroxenites. The (meta)peridotites include mainly harzburgites, a few lherzolites and dunites. The pyroxenites are represented by clinopyroxenites (some of which are garnet-bearing), orthopyroxenites, rare websterites and werhlites (Santos 1998).

The ultramafic lithologies are intensely metamorphosed and serpentinised where the latter is more evident in the olivine-rich peridotites that have acted as conduits for the circulation of fluids responsible for this process. The pyroxenite layers show intense amphibolitisation that when total transforms these into *"hornblendites"* locally with a pegmatoid texture.

The origin of the ultramafic units in the UACT remains controversial as they may be associated both with an oceanic lithospheric environment or an intrusive layered complex at the base of the continental crust.

This ultramafic sequence contains chromite mineralisation.

From a geodynamic point of view there is no consensus and two main models are evoked:

- Marques (1994) considers the geodynamic evolution of UATC with two orogenic cycles. The first, a Pan-African or Cadomian, with five stages: 1- Continental *rifting*, 2- oceanic *rifting*, 3- subduction; 4- continental collision; 5- post collisional decompression. The second, of Variscan age, with four stages: 1- intracontinental *rifting*; 2- oceanic *rifting*; 3- subduction/obduction; 4- continental collision. For this author the ultramafic rocks of the UATC can be related with stage 5 of the first cycle, when ultrabasic magmatism activity with a continental affinity took place;

- Other authors, such as Arenas et al. (2004), explain the tectonic and geodynamic evolution of the allocthonous units of NW Iberia with a simple but large cycle, started in the Lower Palaeozoic (eo-Variscan in age) and culminating in the Late Palaeozoic (late-Variscan age). They consider the allocthonous units of high and medium pressure and temperature of the UATC as belonging to the same terrain which was accretioned to Laurentia during eo-Variscan times and the high metamorphic event is a consequence of this accretion. According to this model, the ultramafic rocks of UATC have island arc affinities.

4 Mineralisation

Previous studies (Neiva 1948; Bridges 1992) have described massive-style chromite (chromitite) podiform mineralisation associated with metadunite bodies that are intercalated with the metaperidotites. Notable chromitite bodies (pods) were exploited in the 40's mainly at Valongo, Carrazedo (Pingarela Concession) and Abissêdo (both presently mined out). These pods may correspond to tectonically disrupted lenses of chromitite (Bridges 1992). Disseminated chromite (Fig. 2) is also found in the metadunites and metaperidotites. The disseminated chromite varies in size from 0.1mm to 2 mm that locally may define millimetre- or centimetre-thick layers of (finely) disseminated chromite. Microscopically the grains are generally anhedral composed of fragmented chromite (Fig. 2) and rimmed in places by magnetite. These magnetite rims are wispy in nature and < 10 μm wide and represent the ferrichromite alteration typical of serpentinised and chloritised chromite-bearing rocks of the UATC. The chromite core compositions have 100Cr/(Cr+Al) ratios around 75 suggesting boninitic affinities derived from a depleted mantle source at a destructive plate margin although this remains an open question.

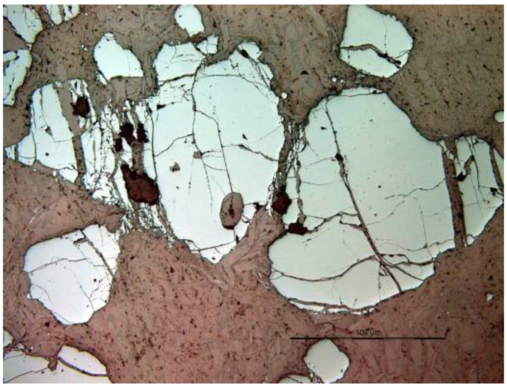

Figure 2. Disseminated chromite in handspecimen sample of disunite collected in one of the many mine dumps (above) and photomicrograph of the chromite grains in thin-section (below; both samples are from the Valongo area).

Low grade metamorphism associated with chloritisation and serpentinisation has caused remobilisation of the chromite at grain margins subsequently deposited around serpentine grains as a fine network.

The ultramafic rocks of the UATC also contain Ni minerals as well as magnetite. These occur as disseminated, subrounded composite grains comprising grains of outer magnetite with inclusions of pentlandite which itself contains inclusions of millerite (Fig. 3). These composite grains are generally small rarely exceeding 50 μm in length.

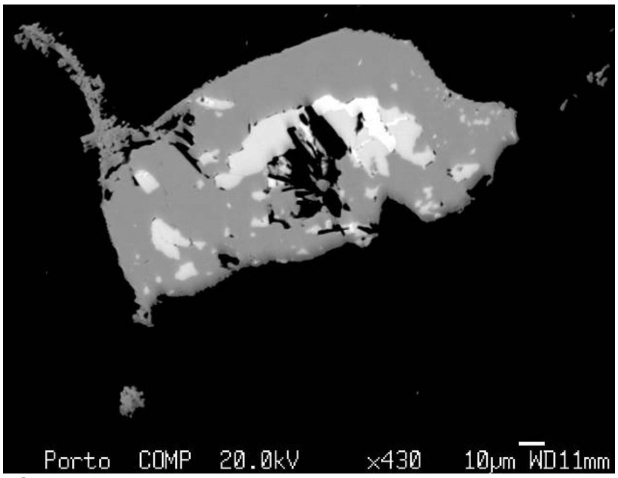

Figure 3. Backscattered electron photomicrograph of a composite grain consisting of an outer layer of magnetite (dark grey) enclosing pentlandite (light grey) which has inclusions of millerite (whitish grey).

5 PGE mineralisation

The PGE mineralisation occurs mainly associated with chromite mineralisation but also associated with silicate ultramafic lithologies [metaharzburgites and metapyroxenites]. PGE's are essentially present as sulphide phases as grain inclusions in chromite nuclei, borders as well as discrete grains in the serpentine gangue. The PGE's in the metaharzburgites and metapyroxenites occur also as a sulphide phase showing enrichment in the latter lithologies (Bridges 1992).

Recently the area has been targeted for PGE exploration and, for the first time, it was drilled. A total of 6 drill holes were drilled but none of these intersected podiform chromitite. The obtained values for PGE corroborated the values of the previous studies with the highest occurring in the Cabrões Nappe (Cabeço da Pedrosa), which has been less affected by the latter phases of deformation (Marques 1994) with values up to 114 ppb Pt and 170 ppb Pd in metadunites with disseminated chromite. Chromium values in a drill hole in the same area yielded values that vary between 1300 to 5500 ppm Cr in medium grained, serpentinised metadunite with disseminated chromite and magnetite. Nickel values vary from 300 in a metapyroxenite sample to 2500 ppm in a metadunite sample.

6 Discussion

There are still a few questions regarding the Bragança Chromite Field.

- It is not yet clear what the geodynamic environment associated with the genesis of the ultrabasic complex and its subsequent evolution is, nor its relationship with the surrounding lithologies;
- Neither is it fully explained what the structural and tectonic control of the metadunites within the metaperidotites and the distribution of chromitite bodies within the metadunites is;
- The importance, if any, of serpentinisation and hydrothermal mobilisation of PGE's (e.g. Figueiredo 1998) in the distribution of PGE mineralisation especially within the metapyroxenites, *hornblendites* and metaperidotites should be better understood.

Research continues.

Acknowledgements

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References

Arenas R, Catalán, JRM and Garcia, FD (2004) Zona de Galicia - Trás-os-Montes. In: (eds. Vera, JA), Geologia de España, 884p.

Bridges JC (1992) Platinum-group elements in the ultrabasic rocks of the Bragança massif, northern Portugal. Ph. D. thesis, The Open University, Milton Keynes, 256pp.

Bridges JC, Prichard HM, Neary CR and Meireles CA (1993) Platinum group element mineralization in chromite-rich rocks of Bragança Massif, northern Portugal. Transactions of the Institute of mining and Metallurgy (Section B: Applied Earth Science) 102: B55-134.

Bridges JC, Prichard HM and Meireles CA (1995) Podiform chromitite-bearing ultrabasic rocks from the Bragança Massif, northern Portugal: Fragments of island-arc mantle? Geological Magazine 132 (1): 39-49.

Neiva JMC (1948) Rochas e minérios da região de Bragança - Vinhais. Serviço Fomento Mineiro, Memórias 14: 251 pp.

Figueiredo MJPP (1998) Estudo da mobilidade hidrotermal do crómio e elementos do grupo da platina no Maciço de Bragança. MSc thesis (unpubl.), University of Lisbon, 166 p.

Marques FGO (1994) Estudo tectónico das rochas infracrustais do Manto de Soco do SW do Maciço de Bragança (Trás-os-Montes). PhD Thesis (unpubl.), Fac. of Science, Univ. of Lisbon, Portugal.

Prichard HM, Bridges JC, Neary ER, Ribeiro A, Marques FGO, Barriga F, Munhá JM, Pereira E, Meireles CA and Ribeiro ML (1991) Platinum-Group Element mineralization in two basic / ultra basic complexes in northern Portugal: (A) The Platinum-Group Elements; mineralogy and analysis; (B) Structural and lithological controls on mineralization. Report for the Raw Materials Research Programme of the Commission of the European Communities. Joint Research Centre (MAIM - 0075-C), Bruxels, Belgium, 122p.

Santos JFHP (1998) Geoquímica de litologias básicas e ultrabásicas da Unidade Alóctone Superior do Maciço de Bragança. PhD thesis (unpubl.), University of Aveiro, 402p.

LA-ICP-MS zircon U-Pb dating of porphyries in the Qiagong iron skarn deposit, Tibet, China

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Abstract Monzonitic granite porphyry and quartz-phyric porphyry are related to hydrothermal alteration and Fe-Cu-Pb-Zn mineralization at the Qiagong skarn deposit in the middle part of the Gangdese mineralization belt, Tibet, China. Both of the intrusions are peraluminous. The monzonitic granite porphyry has a high-K calc-alkaline composition whereas the quartz-phyric porphyry is shoshonitic. Zircons from these two porphyries were dated using the LA-ICP-MS method and the U-Pb ages are 68.8 ± 2.2 Ma and 64.6 ± 1.6 Ma, respectively. The ages and metal associations for these two intrusions are unique in the Gangdese belt, and may lead to new understandings of the geodynamic setting.

Keywords. Qiagong Fe skarn, Tibet, Zircon dating, LA-ICP-MS

1 Introduction

The collision between the India and Asia plates since ~65 Ma have been subdivided into the main collision stage (~65–41Ma), late collision stage (~40-26 Ma), and post-collision stage (~25-0 Ma; Hou et al., 2006a). The collision has produced several metallogenic belts in the Tibet, Yunnan, Sichuan, and Qinghai provinces of China. These include the Yulong, Gangdese and Bangonghu-Nujiang belts. In the Gangdese belt, the known mineralization are mostly in the eastern part, including main collision stage skarns (~45 Ma; Hou et al., 2006a) and post-collisional porphyry and skarn deposits (15±1 Ma; Hou et al., 2006a). The main collision stage mineralization was interpreted to be caused by magmas with mixed crustal-mantle sources, formed during relaxation after the initial collision (e.g., Hou et al., 2006a).

Recently in the middle part of the Gangdese belt, several deposits in a mineralization zone were discovered, including the Qiagong skarn. In this abstract, we report new magmatic ages from the Qiagong Fe-Cu skarn deposit. The ages are significantly older than those obtained previously from the eastern part of the Gandese belts, which has important implications for interpretations of the geodynamic setting of this metallogenic province.

1 Geology of the Qiagong skarn

The Qiagong iron skarn is located in the Xietongmen County of Tibet, China, in the middle part of the Gangdese belt (Fig.1). It is one of three skarns that define a NE mineralized trend. The others are the Nazha Cu skarn and the Jiangga Fe skarn. Little research has been reported on these skarns. At Qiagong, iron in skarns and Pb-Zn in distal fluorite-calcite veins are being mined from small scale open pits and artisanal workings. Copper sulfides are present, but Cu is not mined for by the local owner, therefore its resources cannot be estimated.

The geology of the Qiagong area includes the Cretaceous Takena Formation limestones, pelitic siltstones and siltstones, and the Eocene Nianbo Formation felsic lavas and welded tuffs. The Takena Formation was intruded by coarse-porphyritic granite in the southern and western part of the district. The granite was in turn intruded by monzonitic granite porphyry. Quartz-phyric porphyry occurs as small dykes (most less than 0.5m in width) in granite and monzonitic granite porphyry. Granodiorite and a quartz-phyric porphyry stock reportedly occur in the northeast part of the district, but their relationships with other intrusions are unknown. The monzonitic granite porphyry has a peraluminous, high K calc-alkaline composition, whereas the quartz-phyric porphyry is peraluminous and shoshonitic in character.

The Qiagong skarn occurs at the contact zone between the Takena limestones and the monzonitic granite porphyry, and to a lesser extent is also associated with the quartz-phyric porphyry. Quartz-phyric porphyry dykes have cut the monzonitic granite porphyry, but have not been observed in the skarns. The skarns are composed mostly of garnet, epidote, actinolite, chlorite, quartz, and calcite, with magnetite, hematite, and minor pyrite, chalcopyrite and pyrrhotite. In distal locations, Pb-Zn-Cu mineralization produced veins that contain galena, sphalerite, chalcopyrite, fluorite and calcite. Alteration and mineralization at Qiagong can be divided into three stages: (1) garnet skarn stage; (2) epidote-quartz stage and (3) quartz-calcite stage, according to the crosscutting relationship. Zonation in the skarn is not yet well defined, in contrast to other skarn deposits such as the Big Gossan Cu-Au skarn, Indonesia (Meinert et al, 1997), the Gaspe Cu-Mo skarn, Canada (Meinert, 1997), and the Empire Cu-Zn skarn, USA (Chang and Meinert, 2004, 2008).