The Li-rich Alto da Misarela pegmatite (Barroso-Alvão field, Portugal): Petrography, mineralogy and relationship to the Variscan magmatism

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Introduction

Pegmatites are common rocks in the Galicia-Trás-Os-Montes Zone (GTOMZ) and the Central Iberian Zone (CIZ), both belonging to the Iberian Massif (Spain and Portugal). Mostly they are relatively small bodies comprising simple mineralogy of quartz, feldspars and micas. However, more evolved pegmatites with Li±F-P-B-Be mineralization are also rather common. The Alto da Misarela pegmatite, which is the object of this study, belongs to this category. It is located in the Barroso-Alvão (BA) pegmatite field, in the GTOMZ. Together with quartz, feldspars and micas, the Alto da Misarela pegmatite contains locally high concentrations of Li-rich minerals, such as spodumene and petalite, with Fe-Mn phosphates as accessory minerals.

The abundance of Li ± Sn pegmatitic bodies in the BA field, together with its distinct regional zoning, has attracted scientific and economic interests in the region. The most accepted model for the generation of highly fractionated pegmatites, such as those related to the GTOMZ and the CIZ, is the fractional crystallization of parental granitic melts, causing the enrichment in incompatible elements in the residual melts as fractionation proceeds. In this study we discuss the mineralogy, petrology and geochemical affinity of the Alto da Misarela pegmatite to potential parental granites, which may contribute to a better understanding of the relationships between the Li mineralization of the GTOMZ and the Variscan granites of this region.

Geological setting and pegmatite description

The Alto da Misarela pegmatite is located in the BA pegmatite field, close to the thrust fault that separates the GTOMZ from the CIZ. The rocks of this region consist of metapelitic schists and more rarely, carbonaceous and graphitic schists of late Ordovician to lower Devonian age (Ribeiro et al., 2000). These rocks were multiply intruded by Variscan granitoids and underwent synorogenic, prograde low to medium P, high T metamorphism (Ribeiro et al., 2007). In the BA region different types of granitic rocks occur, which have been classified according to their relationship to the Variscan deformation phases (D1, D2 and D3) (Ferreira et al., 1987). In terms of pegmatite genesis, the relationship between syn-D3, two-mica granites and the BA pegmatites has been proposed by Almeida et al. (2002) and Lima (2000). During the syn-D3 stage a large amount of pegmatitic dykes have intruded the BA region.
The Alto da Misarela pegmatite is a dyke-like body with variable dipping. According to the present level of exposure, the dyke has a thickness of ≈ 5 m and a horizontal length of ≈ 50m. It shows a heterogeneous texture without any distinct internal zonation. Its mineralogy is relatively simple, with quartz, plagioclase, K-feldspar, muscovite, spodumene and petalite, as main mineral phases, and montebrasite and ferrisicklerite as accessory minerals. Along the contact with the host rocks, feathery K-feldspar crystals growing perpendicularly to the contact towards the pegmatite core are common. The metasedimentary host rocks show a strong tourmalinization close to the contact with the pegmatitic body. This type of host rock alteration is commonly observed around pegmatitic bodies of the CIZ (e.g. Roda-Robles, 1993; Martins, 2009; Vieira, 2010).

Mineralogy

Feldspars

Plagioclase and K-feldspar are the most abundant minerals in the Alto da Misarela pegmatite, being randomly distributed within the body. In some cases crystals can be up to 20 cm in length. Under the microscope, K-feldspar occurs as microcline with the characteristic tartar twin. Some crystals show cloudy-dirty patches, which may be related to subsolidus Na-metasomatism. Plagioclase shows occasionally myrmekitic intergrowths with quartz. "Chess-board" albite (Fig. 1, left), which has been often related to subsolidus albitization processes, is relatively common. Plagioclase composition corresponds to albite (<0.1 wt. % CaO). The P content in both plagioclase and K-feldspar is relatively low, generally <1 wt. %.

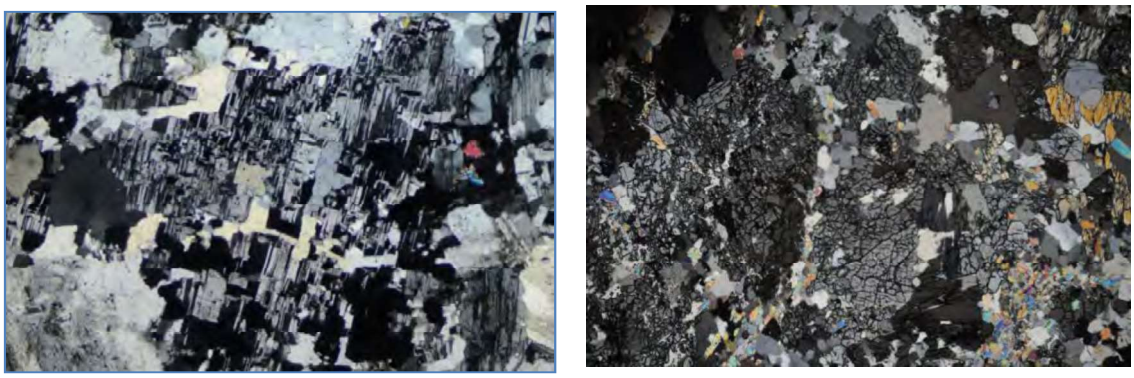

Figure 1. *Left: Plagioclase showing "chessboard texture". Right: intergrowth of spodumene + quartz replacing primary petalite. The Size of the micro photographs is 1.8 x 2.6 mm.*

Micas

The micas found in the Alto da Misarela pegmatite belong to the muscovite-lepidolite series. In hand specimen scale, micas form medium- to fine-grained whitish crystals. Under the microscope the primary micas have tabular shapes while secondary micas occur as very fine grains replacing Li-rich minerals and feldspar and growing along micro fractures. Electron microprobe analyses reveal that the F content of the micas is very low. Taking into account the usually strong positive correlation between F and Li for the micas belonging to the muscovite-lepidolite series (e.g., Tindle & Webb, 1990; Tischendorf et al., 1997; Roda-Robles et al., 2006; Roda et al., 2007), the chemical composition of the micas from the Alto da Misarela pegmatite would correspond to muscovite. The low F content implies that the F activity in the Alto da Misarela pegmatite melt was not high enough to form Li-rich micas, despite the high Li-contents of the melt.

Li- aluminosilicates

The Li-aluminosilicates petalite and spodumene are abundant in the Alto da Misarela pegmatite. Both occur as very fined to centimetric whitish to greyish crystals, with a distinct cleavage. Under the microscope the grains may be replaced by fine-grained sericite or cookeite, which suggests subsolidus reactions between these Li-aluminosilicates and the residual pegmatitic fluids. Spodumene is commonly intergrown with quartz (Fig. 1, right), which is the isochemical replacement of petalite by spodumene plus quartz when P and T decrease (London & Burt, 1982).

Phosphates

The observed phosphates belong to the ferrisicklerite-sicklerite series (Fe-Mn phosphates) and amblygonite-montebrasite series (Li-Al-F phosphates). The Fe/(Fe+Mn) ratio in the ferrisicklerite, which is usually considered to decrease as the fractionation degree of the hosting pegmatite increases, is in the range 0.72-0.73, indicating that the fractionation degree in this pegmatite was high but not extreme.

The first phosphates formed were probably the Fe-Mn phosphates and, when the melt was depleted in Fe and Mn, the Li and F activity increased favouring the crystallization of Li-Al phosphates, which are characteristic of pegmatites with a high fractionation degree.

Tourmaline

Tourmaline has only been found in the country rock. It is a result of subsolidus processes related to a fluid phase, most probably exsolved from the pegmatitic melt. Boron, which partitions preferably into the fluid phase, caused the replacement of the biotite of the hosting mica schists by tourmaline. Under the microscope tourmaline appears as very fine-grained, euhedral prismatic crystals, with a concentric chromatic zoning from brownish in the core to yellowish-orange at the margin. The crystals analyzed belong to the schorl-dravite series, with 8-10 wt.% FeO and 3.5-4 wt.% MgO. There is a slight increase of Fe accompanied by a decrease in Mg from the core to the border of the crystals, which may be related to temperature decrease during tourmaline crystallization.

Geochemical modelling and discussion

According to Černy & Ercit (2005), the Alto da Misarela pegmatite can be classified as a rare element class, complex type, petalite subtype, with a high fractionation degree. The pegmatite is spatially related to the two-mica, syn-D3 granites of Barroso and Boticas, and to the biotite, post-tectonic granite of Pedras Salgadas. In order to evaluate the potential petrogenetic relationships between the pegmatite and these granites, geochemical modelling has been performed (Fig. 2), using the Rayleigh equation proposed by Neumann (1954): $C_1/C_0 = F^{(D-1)}$; where C_1 is the weight concentration (ppm) of the incompatible elements Li, Rb and Cs and the compatible element Ba in the residual melt; C_0 the concentration of those elements in the parental melt; F the fraction of melt; and, D the global distribution coefficient (K_D used as proposed by Jolliff et al. 1986). According to the modelling results the most likely parental granite would be the Barroso granite (Fig. 2). In order to achieve the pegmatite composition, the modelled melt has to be highly fractionated, around 80% for the less evolved facies of the pegmatite, and close to 90% for the most evolved facies. The fact that the fractionation degree of the Alto da Misarela pegmatite is not extreme could be related to the low activity of F during its crystallization.

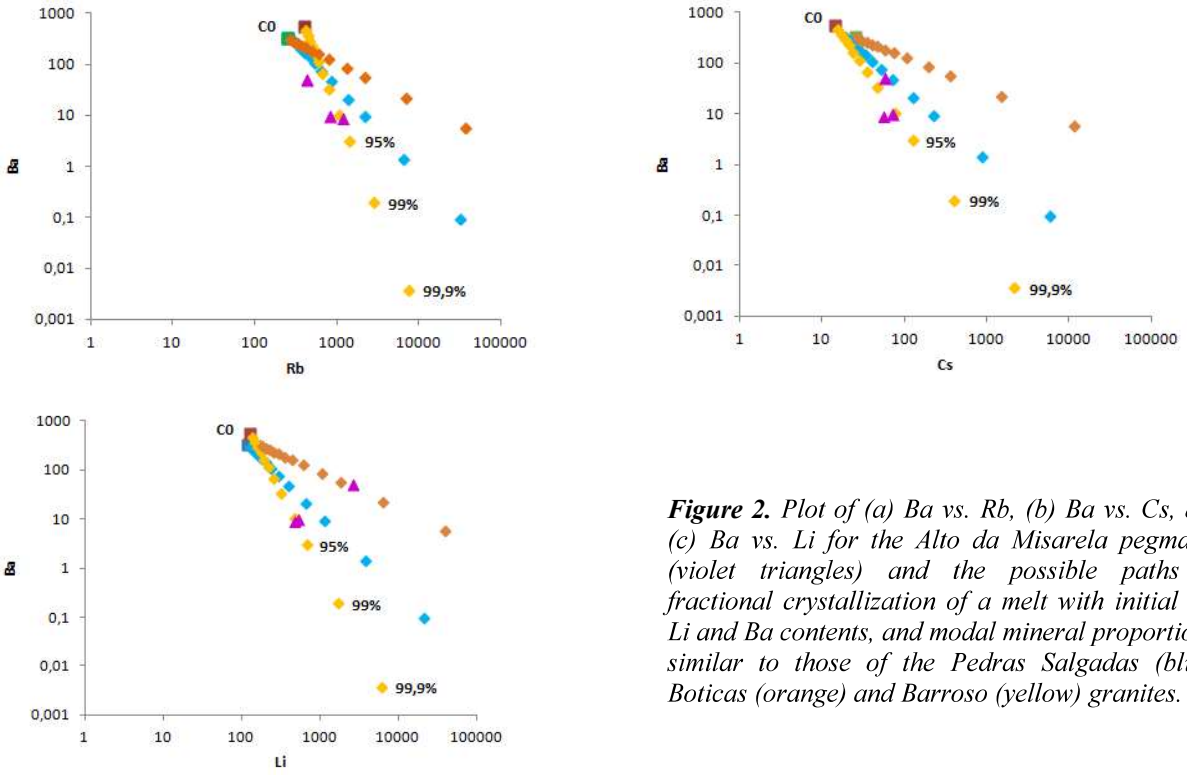

Figure 2. *Plot of (a) Ba vs. Rb, (b) Ba vs. Cs, and (c) Ba vs. Li for the Alto da Misarela pegmatite (violet triangles) and the possible paths of fractional crystallization of a melt with initial Rb, Li and Ba contents, and modal mineral proportions, similar to those of the Pedras Salgadas (blue), Boticas (orange) and Barroso (yellow) granites.*

The results obtained from the mineralogical and geochemical study, together with the geochemical modelling (Fig. 2), indicate that the Alto da Misarela pegmatite may be considered as a highly evolved

pegmatite that may be originated by fractional crystallization of the late Variscan Barroso granite. The H_2O oversaturation of the system resulted in the exsolution of an aqueous fluid that may have caused albitization of feldspars, the formation of "gilbertite" and "cookeite", and the tourmalinization of the country rock.

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