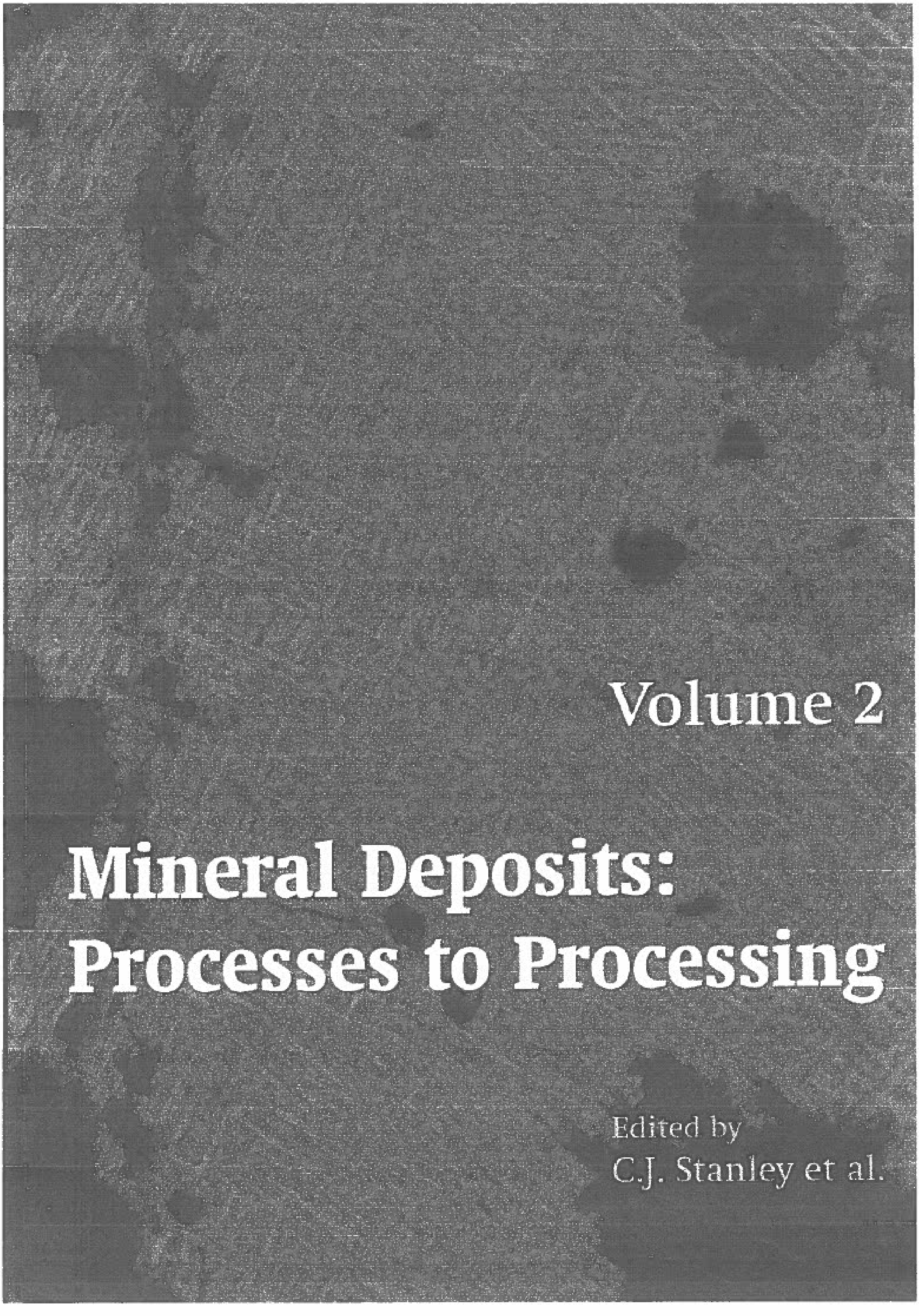

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Exploration for lithium deposits in the Barroso-Alvão area, Northern Portugal

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ABSTRACT: Results of a multidisciplinary study on lithium-rich pegmatites-aplite veins are presented. These results confirm the economic importance of the Barroso-Alvão area (North of Portugal). Dense swarms of pegmatite-aplites veins are encountered in metasedimentary rocks, Silurian in age, and define an almost 20 km alignment parallel to the regional Hercynian structural trend. Spodumene, with subordinate petalite, forms the main economic minerals. Subsolidus feldspar and/or muscovite alteration is the rule, with the large decrease of Li (only eucryptite in small amount is growing) which is leached out of the system. These pegmatite bodies appear to be of good quality for the ceramic industries.

1 INTRODUCTION

In course of the geological cartography project at the 1:50,000 scale on the sheet 6-C (Cabeceiras de Basto), one of the authors (F.N.) noted the occurrence of pegmatite-aplite veins mineralised with spodumene at Covas do Barroso (municipality of Montalegre), Portugal.

Studies in mineralogy, petrology and geochemistry already undertaken on these occurrences, have demonstrated their importance, especially in terms of Li-mineralogy and Li-chemical anomalies (Charoy & Noronha 1988; Charoy et al. 1990; Noronha & Charoy 1991; Charoy et al. 1992; Lima et al. 1997; Lima et al. 1998).

Because of the industrial importance of lithium, (mainly in glass and industries), the Instituto G0eológico e Mineiro (IGM, Portuguese Geological Survey) undertook exploration for lithium occurrences in the area between the Barroso and Alvão Mountains, in order to define the extension of the pegmatite belt and to characterise the extent of Lithium.

2 GEOLOGICAL SETTING

The Barroso-Alvão area (Alto Tâmega, Northern Portugal) contains a large population of several tens of pegmatite-aplite veins (Fig. 1). These pegmatite-aplite bodies are hosted by medium grade (andalusite zone) metasediments (Silurian in age) of the southern part of the Middle Galicia-Trás-os-Montes geotectonic zone (Ribeiro et al. 1979). Three phases of Hercynian deformation (D1 to D3) and 3 superimposed schistosities (S1 to S3) have been recognised in this metamorphic series (Noronha & Ribeiro 1981).

Several types of granite bodies are present in the vicinity of the pegmatite belt (Fig. 1). They are different in mineralogy (biotite or two-mica granites) and timing with regard to D3 (intra-Westfalian) deformation phase. Because of their macroscopic structure (deformation by post-consolidation stress), the pegmatite-aplite veins are older than the last unfoliated, post-tectonic, post-D3, biotite granite generation (Ferreira et al. 1987).

Two types of pegmatite-aplite veins (the numerous pegmatites scattered although the two mica granites are not considered in this study because they are barren), are encountered in the field:

- the first, generally of small size, is represented by a large number of thin (metre-sized), mainly aplitic veins, frequently kaolinised, which can support a low grade cassiterite mineralization. They will not be discussed further below;
- the second is composed of larger pegmatite-aplite veins. This pegmatite family is heterogeneous in density distribution, with locally swarms of several veins of various sizes. Some of them can be tracked for a length of nearly 1 km along strike, and 100 m (when flat) in outcrop width. Their average thickness (quantifiable only in a few cases) is highly variable, from less than a few metres up to almost forty metres across.

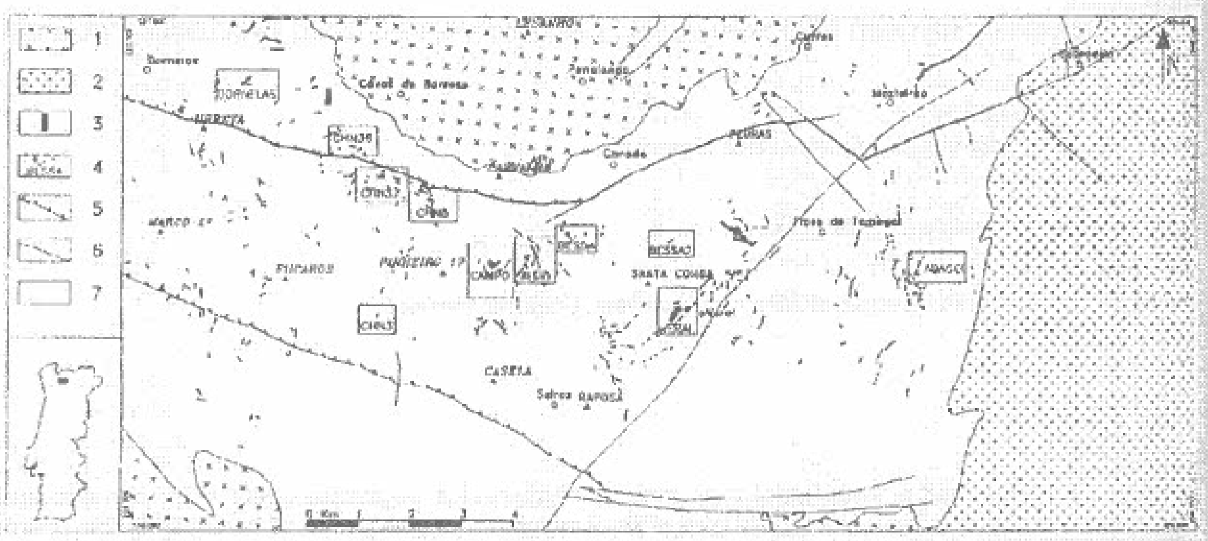

Figure 1 - Simplified map of the Geology in the Barroso-Alvão area (adapted from Noronha & Lima 1993 and Noronha et al. 1998, Geological Maps of Portugal 6C-Cabeceiras de Basto and 6D-Vila Pouca de Aguiar at the 1:50,000 scale).
1 - Syntectonic granite; 2 - Post-tectonic biotitic granite; 3 - Pegmatite-aplite veins; 4 - Pegmatite-aplite veins with lithium; 5 - Thrust; 6 - Fault; 7 - Silurian metasediments;

Pegmatite vein emplacement and dip are mainly controlled by the D2 structures, which can be locally deformed by the late D3 event (crenulation with vertical axial planes striking at 120° E on average). All of them are texturally composite with aplitic and pegmatitic fabrics mixed together in variable proportions and spatial relations. They are more rarely texturally banded in rough parallelism to host rock contacts. Both textures are intricate and appear contemporaneous. Veins, because of their small size, are globally homogeneous, and never lithologically zoned, contrary to those in many giant pegmatites. Contacts between pegmatite bodies and enclosing schists are sharp. The host micaschists at the footwall are often, but not always, very disturbed, strongly folded and silicified as synschistose tongues, suggesting some forcible emplacement (Brisbin 1986; Cerny 1991). Flat enclaves (half a metre in size) of micaschists, structurally similar to those of the footwall, can be occasionally encountered enclosed inside the pegmatite bodies, with a common reaction rim of recrystalized biotite. Only a few of these large pegmatite-aplite veins support a consequent Li-mineralization as spodumene (Charoy et al. 1992).

3 EXPLORATION AND RESEARCH INVESTIGATIONS

Intensive exploration was restricted to the areas occupied by metasediments, limited to the N by the Barroso granites, on S and SW by the Cabeceiras de Basto granites and on E by the Vila Pouca de Aguiar granites (see Fig. 1). This works includes the cartography at the 1:5,000 scale of the areas where the pegmatite-aplite veins supporting spodumene occur. Because they apparently encompass much of the variations in mineralogy of the Li-rich mineral sequence and subsequent alteration patterns, three veins (Alijó, Veral and Adagoi, see Figure 1 for location) were selected (Table 1), among the already recognised Li-pegmatite-aplite bodies in the district, for a drilling campaign by IGM. Ten drill holes of exploration with lengths between 14.57 m and 93.94 m, permit to collect 437 m of core with NQ diameter (46 mm), with an average recovery of 92%. Two channel samples were collected, with a weight of 323 kg for a 42.65 m length in ALJ-3-R and 177.5 kg for a 30.4 m length in ADG-2-R. Two large samples, representative of a rich and poor ore respectively, were also cut off. Table 1 show the most important features of the drilled veins.

Table 1. The essential characteristics of the veins.

Vein	Attitude	Maximum width	Outcrop extension
Alijó	N 345° ; 75° W	37 m	380 m
Veral	N25° ; 25° W	8.5 m	280 m
Adagoi	N 25° ; 60° W	35 m	300 m

4 PEGMATITE-APLITE GEOCHEMISTRY

Extensive sampling from outcrops and drill cores has been made for petrographical, mineralogical and chemical investigations. The fundamental rockforming assemblage of these Li-rich pegmatite-aplites is fairly simple and mostly granitic in bulk composition.

The lithium mineralization is mainly expressed as spodumene laths (up to 30 cm long) with euhedral habit, or more rarely, as irregular, poecilitic aggregates, suggesting several episodes of precipitation (Charoy et al. 1992). Petalite is also present, often as a continuous coating on spodumene crystals or as long blades in pseudo-vugs with euhedral quartz between spodumene laths. Such particular textural relationships suggest with some confidence that petalite precipitates from a fluid along an interconnected spodumene-liquid interface. Montebrasite is also present in small amount. Subsolidus mineral alterations show definite and consistent sequences of development. Selective corrosion, up to complete replacement, of spodumene by albite (± muscovite) and of petalite by K-feldspar and/or eucryptite, is widespread.

The pegmatitic facies offers the richest values in Li (Noronha & Charoy 1991). Table 2 presents a selection of the most significant Li contents for the three mineralised structures. Alijó and Adagoi have Li values up to 1.3 wt% which signifies that almost 1/3 of the sample is constituted by spodumene. These high values decrease drastically through subsolidus alteration. They fall down to 0.07 wt% in altered samples and even less along kaolinized fractures. Lithium is leached out from the system (only partly fixed in secondary eucrytite) and can form a distinct anomalous halo (0.1 wt% Li) in metasediments close to the contact of the veins (Lima et al. 1997).

5 CONCLUSIONS

The results of this project highlight the real economic potential of the pegmatite belt of the Barroso-Alvão area, along a NW-SE alignment almost 20 km long (Dornelas-Covas de Barroso-Alijó-Veral-Adagoi) and parallel to the Hercynian D3 structural event. Spodumene, by far the most common Li-mineral, is magmatic in origin. Petalite can be locally present, precipitating from a Li-rich fluid phase, after the drop in regional pressure. Extensive drilling has shown a large development of a superimposed feldspathic alteration which, in turn, replaces both Li-minerals and leaches out of the system most of the lithium (low temperature eucryptite in minor amount).

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Table 2. Most significative Li values obtained during exploration.

Vein	Drilling hole nº	Interval (m)	Li_2O grade (%)
Alijó	ALJ - 1	12.50	0.45
Alijó	ALJ - 2	12.00	1.10
Alijó	ALJ - 3	37.00	1.25
Veral	VR - 1	3.88	0.86
Veral	VR - 2	1.50	0.71
Veral	VR - 3	2.95	0.80
Adagoi	ADG -2	11.45 4.07	1.16 1.10
Adagoi	ADG -3	3.16 3.60 4.72	1.03 0.50 0.73
Vein	**Channel sample nº**	**Interval (m)**	**Li_2O grade (%)**
Alijó	ALJ-3-R	2.50 15.48 2.20	1.05 1.51 1.65

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