

GEOCHEMISTRY OF GRANITIC APLITE-PEGMATITE VEINS AND SILLS AND THEIR MINERALS FROM CABEÇO DOS POUPOS, SABUGAL, CENTRAL PORTUGAL

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INTRODUCTION

Pegmatites are derived from granitic melts and experimental work supports this mechanism (London 2008), which has been successfully tested (e.g. Shearer *et al.* 1992; Neiva *et al.* 2008) although pegmatites contain fluxes such as B, F, P and Li in addition to H₂O. The mineralogy, geochemistry and petrology of granites from the Sabugal area and aplite-pegmatite veins and sills from Cabeço dos Poupos within this area are presented, using the data to identify the mechanisms responsible for the origin of these rare-element pegmatites. The zoning of micas and columbite-tantalite crystals from these aplite-pegmatite veins and sills are described.

GEOLOGY

In the Sabugal area, seven Variscan two-mica granites intruded the Cambrian schist-metagraywacke complex (Fig. 1). The emplacement of the granites was controlled by the last ductile deformation phase D3 of Namurian-Westphalian age. The ID-TIMS U-Pb zircon and monazite ages show that granite G1 is 309.2±1.8 Ma and syn- to late-D3, while most of the other granites are 300±3 Ma and late-D3, and G7 is 299±3 Ma and late- to post-D3. Many granitic aplite-pegmatite veins and sills trending mainly E-W and WNW-ESE, cut granites G2, G6 and G7. An area was selected to study these veins and sills cutting the granite G6 (Fig. 1), which produced a metasomatic

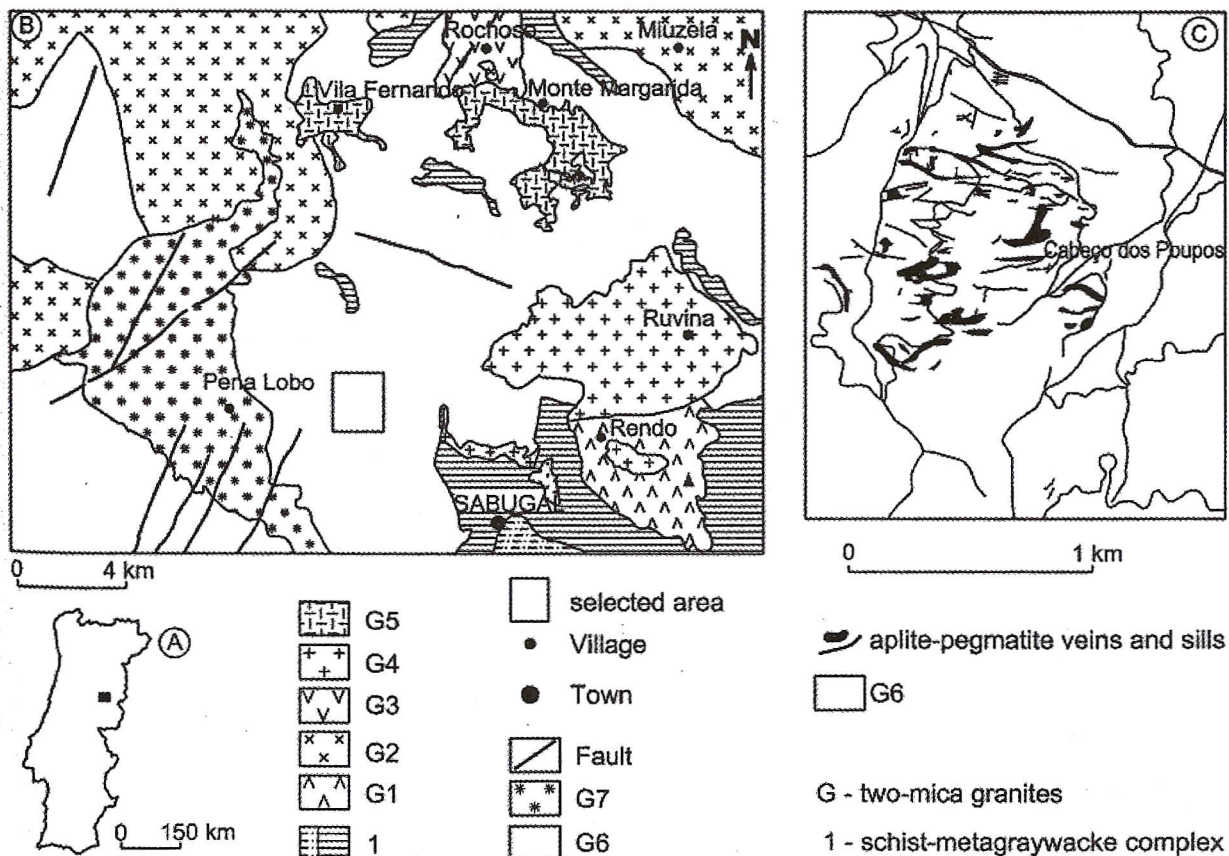


FIGURE 1. (a) Location of the Sabugal area on the map of Portugal. (b) Simplified geological map of the Sabugal area, mainly to show the granites and location of the Cabeço dos Poupos area. (c) Geological map of the Cabeço dos Poupos area.

zone enriched in zinnwaldite and up to 15 cm thick in the host granite. Pegmatites are of beryl-columbite-phosphate subtype. Most aplite-pegmatite veins and sills have an aplite layer at the footwall followed upward by a pegmatite layer and an aplite-pegmatite layer at the hanging wall. Some veins and sills contain up to 5-6 layers. The veins are 10 cm - 15 m thick and up to 700 m long, whereas the sills are up to 2.5 m thick and 200 m long.

PETROGRAPHY

All granites have phenocrysts of K-feldspar and some also contain phenocrysts of plagioclase. The granites contain quartz, microperthitic orthoclase and microcline, plagioclase, biotite, muscovite, zircon, apatite, monazite and ilmenite. Most of them also contain tourmaline. Sillimanite occurs in G1 and andalusite in G2.

The aplite-pegmatite veins and sills contain quartz, microperthitic orthoclase and microcline, albite, muscovite, lithian muscovite, tourmaline, beryl, zircon, columbite-tantalite, cassiterite, apatite and triplite. Rare zinnwaldite and very rare lepidolite also occur close to the contact with the host granite G6, whereas rare polythionite occurs in an aplitic intermediate layer.

WHOLE-ROCK GEOCHEMISTRY

All granitic rocks are peraluminous with A/CNK ranging between 1.11 and 1.50. Granites G2, G3 and G7 define a series, whereas granites G5 and G6 define another series (Fig. 2). Some granitic aplite-pegmatite veins and sills have similar CaO, MgO, Sn, Rb, Sr and Li contents to those of granite G7 and others also have similar MgO, Rb and Li contents to those of G3 (Figs. 2a, b, c). There are gaps between the veins and sills and granites G1 and G4 (Fig. 2a, b, c) and G1 is one of the richest granites in total FeO, Sr and Ba contents. Variation diagrams for granites G5 and G6 and aplite-pegmatite veins and sills define fractionation trends (Figs. 2d, e, f) and veins and sills have lower total FeO, MgO, CaO, Sr, Zr, Y and Ba contents and higher SiO₂, F, Sn, Rb and Li contents than these two granites. The chondrite normalized REE pattern of a pegmatite is subparallel to those of granites G5 and G6. All the REE contents of the pegmatite are lower than those of the granites. Whole-rock $\delta^{18}\text{O}$ values plotted versus total FeO values show a gap between aplite-pegmatite veins and sills and granites G1 and G4. Most veins and sills have lower $\delta^{18}\text{O}$ values than the granite G7, but similar or higher than those of the granite G6 and up to 0.46‰. These rare-element pegmatites belong to the REL-Li subclass, beryl type and beryl-columbite-phosphate subtype (Černý & Ercit 2005).

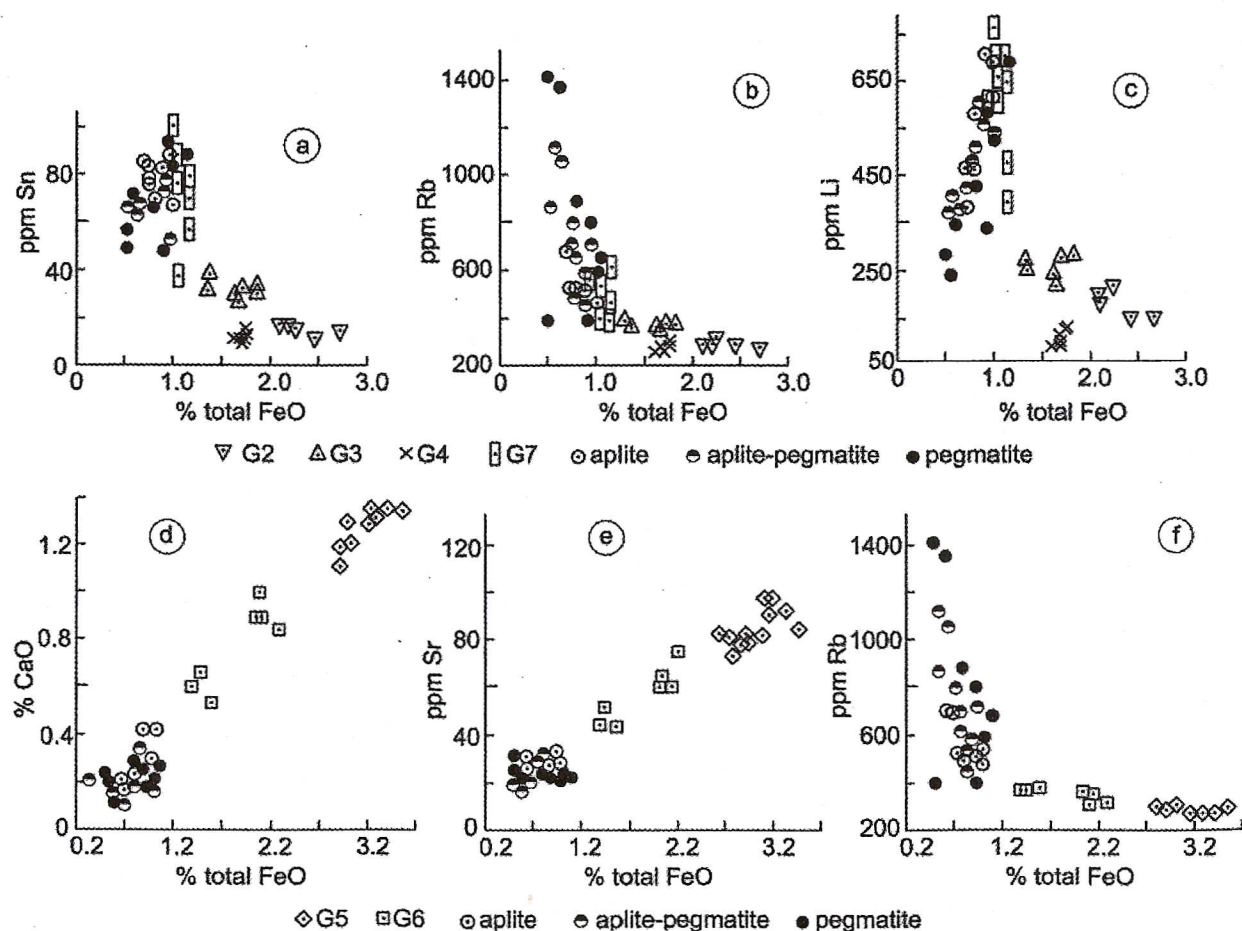


FIGURE 2. Selected variation diagrams of granites from the Sabugal area and granitic aplite-pegmatite veins and sills from Cabeço dos Poupós, suggesting that these veins and sills are related to the series G5-G6.

GEOCHEMISTRY OF MINERALS

Ba content of K-feldspar from aplite-pegmatite veins and sills is similar to lower than that of K-feldspar from all granites of the area. Albite (An_0 - An_5) from these veins and sills has lower Ca content than phenocryst and matrix plagioclase from all granites, except G7. In general, K-feldspar has higher P_2O_5 content than coexisting plagioclase. P_2O_5 contents of feldspars may depend on phosphorus content in the crystallizing melt. P_2O_5 contents of K-feldspar and albite from aplite-pegmatite veins and sills reach higher values than in feldspars from all granites. D[P]Kf/Pl ranges between 1.0 and 2.4, showing no significant fractionation of phosphorus between coexisting feldspars. The distribution of P between Kf-Pl pairs is only in equilibrium in granites G5 and G6.

In aplite and pegmatite, subhedral lithian muscovite surrounds relics and penetrates along cleavages of primary muscovite and contacts are sharp, showing an apparent oscillatory zoning. The former has higher Fe^{2+} , Li, F, Rb contents and lower Al^{VI} , $Al^{IV}+Al^{VI}$ and OH contents than the latter. Subhedral and radial lithian muscovite from aplites are apparently oscillatory zoned, showing sharp contacts between lighter and darker zones. The lighter zones are richer in Fe^{2+} , Li, F and poorer in Al^{VI} , $Al^{IV}+Al^{VI}$ and OH than the darker zones. Primary muscovite and lithian muscovite from aplite-pegmatites have higher Fe^{2+} , Li, Rb, F contents and lower Mg content than primary muscovite from granites G5 and G6 and define a trend in the Li-Mg diagram. In aplite-pegmatite, very rare lepidolite partially surrounds lithian muscovite and has higher Si, Fe^{2+} , Mn, Li, K, Rb, F contents and lower Al^{IV} , Al^{VI} , Na contents than lithian muscovite. Zinnwaldite from aplite-pegmatite penetrates along cleavages and partially surrounds lithian muscovite. Locally zinnwaldite and lithian muscovite from aplite-pegmatite are intergrown and show different orientations. All the contacts are sharp. Zinnwaldite has higher Fe^{2+} , Mn, Li, F contents and lower Al^{VI} , $Al^{IV}+Al^{VI}$ and OH contents than associated lithian muscovite. Rare polyolithionite partially surrounds lithian muscovite from aplite and the contact is sharp. The border has higher Si, Li, Rb and F contents and lower Al^{VI} , $Al^{IV}+Al^{VI}$, OH contents than the core.

Columbite-tantalite occurs associated with albite, K-feldspar, quartz, muscovite and beryl. Columbite-(Fe) is more abundant than columbite-(Mn). Tantalite-(Fe) is rare. Individual crystals of columbite-(Fe) or consisting of columbite-(Fe) and columbite-(Mn) are oscillatory zoned, involving several elements, and

locally present a partial thin rim of tantalite-(Fe). The contacts are sharp. Cassiterite crystals are rare, unzoned, consist of nearly pure SnO_2 and contain similar small Fe, Nb and Ta contents. Fluorapatite is the most abundant phosphate. The triplite shows a significant range in F/(F+OH).

MAGMA RELATIONS

Variation diagrams of major and trace elements (Fig. 2) suggest that the aplite-pegmatite veins and sills from Cabeço dos Poupos are related to the series defined by granites G5 and G6, which is supported by the facts that the REE pattern of a pegmatite is subparallel to those of these two granites, $\delta^{18}O$ values of veins and sills are close to those of G6 and primary muscovites from the two granites and aplite-pegmatites and lithian muscovite from the latter define a trend in the Li-Mg diagram. Least squares analysis of major elements shows that the aplite-pegmatite veins and sills are derived from the granite G5 magma by fractional crystallization of quartz, K-feldspar, plagioclase, biotite and ilmenite. The calculated Sr and Ba contents decrease and Rb content increases versus the decrease in the weight fraction of melt remaining during fractional crystallization. However, the calculated Sr and Ba contents are up to 2 and 6 times higher, respectively, than the determined contents, while the calculated Rb content ranges from 0.7 to 1.0 times lower to similar to the determined content, indicating that LIL elements are controlled by magmatic fluxes and fluids. Cassiterite and columbite-tantalite minerals are also probably controlled by these fluxes and fluids.

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