# Structural and Paragenetic Analysis of Swarms of Bubble Like Pegmatites in a Miarolitic Granite from Assunção South – Viseu – Central Portugal

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Shallowly emplaced hydrated granitic magmas may produce miarolitic cavities, some of which are lined with minerals. Essential to the formation of miarolitic cavities is exsolution of a fluid phase that results from fluid immiscibility when $P_{fl} > P_{lit}$. Whether volatiles escape or are entrapped within the melt is a function of both temperature and pressure. Entrapment is more likely if heat is rapidly dissipated from a rapidly cooling melt, thus miaroles are more common in fine-grained rocks. The less dense volatiles rise into the apical zones of a magma chamber when the degree of crystallization of the melt is low (e.g. Candela, 1997).

The Ferreira de Aves pluton (Viseu) is a two-mica syn-to late tectonic granite associated with the 3rd phase of Variscan deformation (300-330 Ma). This deformation led to conditions during magma emplacement that were conducive to exsolution of a vapor phase. The miarolitic rock is a fine-grained granite that abruptly transitions to porphyritic, medium-grained granite. Large miarolitic pegmatites emplaced at higher levels in the magma chamber are zoned irregular bodies with a quartz core, beryl and Li-phosphates. This suggests the miarolitic granite represents a region in the magma chamber where bubbles coalesce to form large pegmatites (Leal Gomes and Nunes, 2003). The structural control of these granites is well defined as they strike N35°E, parallel to regional shear structures and sub-parallel to the orientation of the plutonite cupola.

The mineralogical assemblage in the miaroles is similar to that of the parental granite, essentially quartz, feldspar and muscovite. Individual and small (between 5 $cm^3$ and 1 $dm^3$) miaroles may be clustered into swarms. The average bubble volume is 86 $cm^3$ for a population of 130 measured miaroles. Most miaroles are lenticular with significant deformation from spherical shapes. This may be due to magmatic flow with low viscosity of the liquid. The three axes of the ellipsoids are a) – stretching, parallel to the flow lineation; b) – flattening; c) - orthogonal to b. The dominant flow lineation direction is N45°E, subparallel to the major transcurrent surrounding structures.

The mineral assemblages in the miaroles are variable and can be subdivided as follows: 1)- *quartz + chlorite ± muscovite ± alkali-feldspar intergrowths*, 2)- *void with inward crystallizing quartz + muscovite ± microcline;* 3a)- *quartz + muscovite ± K-feldspar ± F-apatite, non-graphic quartz + schorl or chlorite + quartz as late-stage phases;* 3b)- *microcline ± quartz ± muscovite coating the cavity and late green lepidolite or chlorite/chamosite ± muscovite ± goethite ± kaolinite;* 4)- *dominant microcline inward crystallization; 5)- late graphic schorl/quartz; 6)- quartz ± muscovite lining the cavities and late green lepidolite or chlorite/chamosite ± pyrrothite.* The most important distinction in these assemblages is the variability of potassium feldspar, tourmaline and the late mineral assemblages. Type 1 bubbles represent the early stages of morphological and mineralogical development. The size and intergrown minerals suggest they resulted from small amounts of exsolved fluids. In morphologically evolved miaroles, cavities are small and localized with inward growth of quartz, muscovite and feldspar (Fig. 1-A). Type 3b miaroles host larger amounts of alkali-feldspar, which lines cavities filled with quartz and muscovite or other phylossilicates (Fig. 1-B). The bubbles richer in alkali feldspar may indicate higher rates of inward fractionation, and the establishment of liquid-liquid interfaces relative to the granite. In other cases, K-feldspar occurs in the form of one or two included megacrysts (Fig. 1-C). In type 6 occurrences, feldspar is particularly scarce, occurring in units with tourmaline, lepidolite or chlorite / chamosite and eventually late-stage pyrrhotite that fills in the interstitices (Fig. 1-D). As a result of the enrichment in boron, tourmaline is relatively abundant. Some unusual bubbles contain only graphic intergrowths of tourmaline and quartz (Fig. 1-E).

Along the periphery of most bubbles, centimeter scale halos are rich in albite and depleted in quartz and ferromagnesian minerals. It is in type 5 and 6 occurrences, with scarce or absent feldspar and graphic tourmaline, that the albitic surrounding volume is greater.

Additionally, bubbles often show radial fractures resulting from hydraulic stress release.

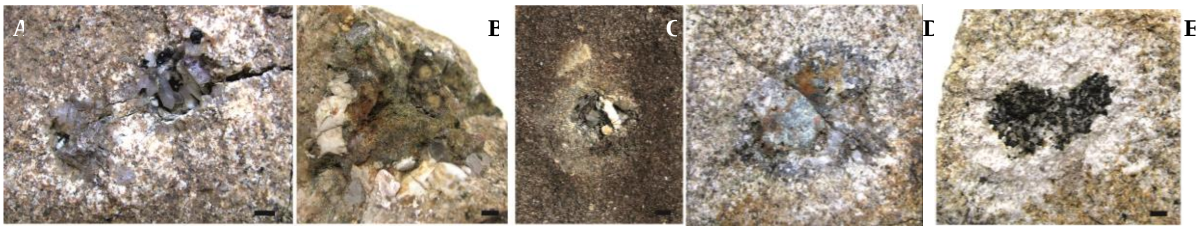

**Fig. 1:** –Examples of miarolitic pegmatites with contrasting forms and mineral assemblages. Scale bar is 0.5 cm.

Through the above observations it was possible to identify a consistent structural pattern of distribution of bubbles within the granitic host and a mineralogic typology determined by the abundance and textural arrangements of some typomorphic phases. From this, it is deduced:

Transcurrent kinematics promotes decompression and enhances fluid immiscibility, with decisive influence on the amount of bubbles along structural corridors.

i. Mobility in apical fronts generating growth is marked internally by inward crystallization and uprising late assemblages; the higher boron enrichment promotes low viscosity magmatic flow.

ii. Petrographic arguments suggest granite / pegmatite transitions characterized by liquid-liquid interfaces and fractionation conditions generating internal zoning.

iii. The domain of immiscibility occurs at low degree of crystallization of the host with rare phenocrysts in the surrounding granitic matrix.

iv. Evolutionary trends are the result of the following events: *fractional crystallization, early equilibrium crystallization* or *late metasomatism - immiscibility*.

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