BE AND ZN BEHAVIOR DURING ANATETIC FORMATION OF EARLY PEGMATOID MELTS IN VARISCAN TERRAINS – AN EXAMPLE FROM THE ARGA PEGMATITE FIELD, NORTHERN PORTUGAL

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In the region of Serra de Arga, Dias (2012) and Dias & Gomes (this volume) identified a set of peraluminous pegmatoid veins that are anatectic in origin. Silurian host rocks enriched in fluxing constituents underwent partial melting to produce these veins. From the genetic viewpoint, they exhibit compositional and textural similarities to muscovite and abyssal class pegmatites. Equilibrium metamorphic assemblages suggest that melting occurred at temperatures of 650-710 ° C and pressures 2.9-4.2 kbar (andalusite and sillimanite isograds). These veins exhibit several structures and mineral associations that resulted from primary evolution of melts and derived fluids. The presence of schlieren suggests that these melts were mobile, with selective separation via filter-pressing and seismic-pumping. These processes may be responsible for the formation of cumulate cordierite textures. Some segregated veins exhibit internal zonation that resulted from *in situ* fractional crystallization. The final stages are marked by subsolvus and subsolidus evolution of the primary mineral assemblage, often associated with ductile-brittle deformation that facilitated percolation of the fluids responsible for the alteration.

Pegmatoids with this petrogenetic framework show marked beryllium enrichment which is attributed to the transference of highly anomalous Be contents from pre-metamorphic volcanic protoliths that underwent alkaline metasomatism. Nearby tourmalinites, amphibolites, metavolcanic rocks (leptite-like rocks with abundant oligoclase), and heterogeneous tourmaline and apatite rich phyllites have Be contents between 4 and 10 ppm. These highly differentiated values are strongly above the average values of the crust and mantle. The results of batch-melting modeling of the enclosing tourmalinites are consistent with this origin.

In addition to the high Be content in the protoliths, Be incorporation in segregation melts is also related to the incompatible nature of Be as it is easily incorporated into the melt. The absence of cordierite and sillimanite, which easily incorporate Be, allow Be to enter the melt phase. The following mineralogic assemblages reflect the different generations of vein deposits present: 1. chrysoberyl and beryl in veins associated with the typomorphic peraluminous minerals cordierite and andalusite; 2. chrysoberyl in quartz-muscovite facies with prismatic sillimanite and lazulite-scorzalite; 3. chrysoberyl and beryl in quartz-muscovite veins; 4. beryl in peraluminous sodic-potassic veins with montebrasite comb-structure growths; 5. beryl in cordierite pseudomorphs in the type 1 veins; 6. metasomatic emerald in melanosomes peripheral to type 3 veins; 7. chrysoberyl, quartz and sillimanite intergrowths in reaction coronas between beryl and albite in sodic-potassic peraluminous veins with typomorphic lazulite-scorzalite. Assemblages 1 and 2 imply chrysoberyl equilibrium or late crystallization of Cord + And + Mu and Sil + Qz + Mu + Ab ± Fk. Chrysoberyl is present only in mineral assemblages where andalusite and cordierite are abundant and in quartz impoverished facies. In veins with lazulite-scorzalite, chrysoberyl is associated with muscovite and gahnite. Both chrysoberyl and gahnite may be included in the Al phosphate. In type 3 occurrences, beryl occurs as oversized comb-structured crystals consistent with rapid crystallization. Chrysoberyl occurs predominantly along the main concentrations of muscovite within the veins. Assemblages 5 and 6 result from alteration by late fluids, processes which tend to occur at low T. Emerald occurs in biotite and tourmaline melanosomes. Type 7 assemblages with chrysoberyl formed at the expense of beryl (BASH system compatible reactions), possibly in connection with a thermal anomaly resulting from emplacement of Variscan granites. This temperature anomaly was high enough to metamorphose pegmatoids to transition beryl => chrysoberyl (Gomes, 1997).

The subsolidus reequilibration of cordierite would produce quartz + beryl intergrowths and muscovite/chlorite replacement masses. Geometric patterns of Be release from the cordierite lattice produce the following textures: 1 – beryl-quartz intergrowths in the core of pseudomorphs enveloped by chlorite + muscovite; 2 - texturally disseminated beryl in the micaceous and chloritic mass, forming low granulometry crystals with oscillatory concentric zoning; 3 - various coronitic aspects of beryl within the pseudomorphs suggests the deposition in inter-granular spaces after sub-graining of precursor cordierite. This occurred during cycles of deformation and late-stage alteration of cordierite. In the first scenario, for a relatively consistent beryl modal proportion of 25%, a concentration of 3.25 wt% of Be in the primary cordierite is inferred. The average beryl modal proportions in the assemblage with chrysoberyl is 1.5% (in scenario 2). Beryl related to the subsolidus alteration of cordierite retains a relatively high Fe and Mg content (Fe>Mg) with Cs_2O ranging from 0.13 to 0.24 wt. %.

Typological analysis of evolutionary trends interpreted from the variability of beryl composition, suggest the existence of a convergence domain in a Al- (Na + K + Cs) - (Fe + Mg + Ti + Cr + V + Mn) *apfu* ternary diagram. In this diagram it is possible to isolate the following convergence composition Al_{93} $(Na + K + Cs)_4$ $(Fe + Cr + Ti + V + Mg + Mn)_3$.

Textural and mineralogic analysis suggest that gahnite, with an average composition of $(Zn_{0.6},Fe_{0.34},Mn_{0.01})Al_2O_4$, accompanies all primary beryl growth. Gahnite crystals are euhedral to subhedral and exhibit ordered intergrowths with quartz. Particularly interesting are the star-like intergrowths of gahnite and quartz that often occur as inclusions in beryl. They may represent early intergrowths that crystallized prior to beryl, thus are true inclusions, or are the result of symplectitic intergrowths. The Zn required to form gahnite was also derived from the volcanic host rocks and may have been released from zincian biotite or by desulfurization of sphalerite in the protolith during metamorphism (e.g. Spry & Scott, 1986). Gahnite also occurs in albitic veins associated with abundant tourmaline, hambergite, rhodizite-londonite, pollucite and OH-herderite, possibly formed under late-stage, low temperature conditions.

The observed Be enrichment correlates with the degree of partial melting, suggesting that it is behaving as a compatible rather than an incompatible element in these Mg and Fe enriched peraluminous melts. This may lead, in appropriate metamorphic conditions, to early Be extraction in ferromagnesian phases and Al oxides which crystallize under desilication conditions. However, Be concentration increases in the remaining liquid phase during fractionation and becomes abundant in the late-stage hydrothermal fluids, suggesting that this behaviour transitions to incompatible.

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