# PETROGENESIS OF PERALUMINOUS ANATECTIC PEGMATOIDS

**P. A. Dias[1], C. Leal Gomes[2]**
[1] CIG-R, University of Minho, Braga, Portugal; patriciasdias@gmail.com
[2] DCT, University of Minho, Braga, Portugal

In the region of Serra de Arga (Minho, Portugal) peraluminous veins were evaluated in an effort to characterize these deposits and determine the processes involved in their genesis. Although these veins exhibit textures similar to those typical of pegmatites that formed from fractional crystallization of a granitic melt, they are mineralogically distinct from pegmatites that outcrop nearby (syn-tectonic relatively to late Variscan deformation, 330 Ma). Thus, this project focuses on the parental enclosing rocks as a potential source for these veins, through partial melting and metamorphic segregation processes. Nevertheless, because metamorphic conditions did not reach sufficiently high pressures and temperatures to induce melting, as evidenced by the absence of extensive migmatitization in the nearby terrains, it is likely that constituents such as B, F, P and Li present in pre-metamorphic protoliths resulted in a depression of the *liquidus* temperature and facilitated partial melting and subsequent segregation.

The adjacent outcrop area is a meta-volcanosedimentary terrain that lies between the Orbacém thrust and the Vigo-Régua shear zone. In this area, metamorphosed pelitic formations are interbedded with calc-silicate rocks including amphibolites, black schists, quartz phyllites, tourmalinites and felsic metavolcanics. These sedimentary and volcanogenic rocks underwent medium-high grade metamorphism. Deformation associated with the D2 Variscan phase (340 Ma) is well represented in this sector and have allowed for P-T increments and peaks needed for melting, mainly at host sites, corresponding to low pressure domains, where *liquidus* depressor constituents were mobilized producing peraluminous melts.

In addition to these fluxing elements, the potential protoliths were enriched in incompatible elements that were remobilized into the segregated products. Be, Li, Nb, Ta and Sn contents of potential protolithic facies were normalized to average values of the crust and mantle and equivalent rocks. These elements are enriched by several orders of magnitude in the protoliths. The remobilization of these incompatible elements is reflected in the presence of Ti-Nb-Ta-Sn oxides, Be minerals (beryl and chrysoberyl) and Li minerals (montebrasite) in the vein deposits. Deformation and metamorphism of ilmenite may have released Nb and Ta that led to the formation of struverite, Fe-columbite and tapiolite.

The diversity of texture and mineral assemblages within these veins allowed for a classification based on the proportions of essential minerals (andalusite, sillimanite, cordierite, feldspars) and the presence of some typical accessory phases (corundum, beryl, chrysoberyl, lazulite-scorzalite) (Dias, 2012). The proposed model for melt generation and mobilization begins with dehydration and fluid release; fluxes can be mobilized at this stage or during the anatexis of volatile enriched rocks where partial melting forms discrete units that are not continuous or migmatitic. These partial melts formed under hydrous conditions where the collection of newly-formed leucosomes was accommodated by dilation that arose during Variscan deformation. This syn-kinematic melt generation formed vein-like structures via "filter-pressing" and "seismic-pumping" mechanisms. Subsequent modification of the melt through fractional crystallization is evidenced by the mineral zonation within the veins. The method of melt generation can be inferred from textural and mineralogical analysis of veins at micro and mesoscopic scales. In one location at Serro, on the northern flank of Serra de Arga, incipient leucosome mobilizations and veins that typically host cordierite are enclosed in tourmalinites. The mineralogy and texture of these units appear to be related to the production and evolution of melt material as the leucosomes occur as small stringers where garnet may form as the result of incongruent melting of tourmaline. These stringers can evolve into larger volume domains that are segregated into zones containing predominantly cumulate cordierite associated with zones containing andalusite + cordierite + muscovite + garnet + apatite that host tourmalinite schlieren indicative of magmatic flow. Because these veins have a marked mafic character, they may represent segregations from a more leucocratic melt. Proximal to these mafic veins are thicker leucocratic veins. They are composed of cordierite and chrysoberyl along the margins with andalusite further inward marking the transition to a quartz-muscovite core. Garnet restite stringers are also present. These veins may have formed by mobilization of a more fractionated and hydrated anatectic magma. The coexistence of these transitions, suggests that the veins formed by partial melting of the host tourmalinite in which subsequent separation of a leucocratic and fractional crystallization produced more leucocratic melts.

The P-T regime for partial melting was determined using a garnet-biotite geothermometer (Hodges & Spear, 1982) and the presence of the garnet-quartz-plagioclase-sillimanite assemblage (Hodges & Crowley, 1985). This yielded pressures between 2.9-4.2 kbar and temperatures between 650-710 º C. Additionally, the presence of iron-rich cordierites is consistent with low pressure conditions for melts generation. Thus, is likely that an intermediate path of decreasing pressure under isothermal conditions produced melts that were mobilized into the cordierite stability field which could be possible at the transition and regression gap between second and third Variscan folding phases.

These data suggest that the segregated veins represent an initial stage of melt mobilization in the vicinity of productive lithologies and may also be considered predecessors of widespread anatexis that was capable of producing granitic rocks such as St. Ovídeo granite. Normative compositions of the veins and St. Ovídeo granite, in the Qz-Ab-Or diagram, support the idea that, to some extent, these pegmatoids tend to S type granitic compositions.

The partial melting origin for the pegmatoids was evaluated using a batch melting model for Rb, Ba, and Sr for several of the potential parent lithologies. Batch melting of tourmalinites could be produced with mobilization of 30% to 90% melt. A more elaborate attempt to simulate tourmalinite melting to produce rocks with the assemblage andalusite + cordierite + quartz ± muscovite ± apatite ± chrysoberyl ± struverite ± tapiolite using Ba, Rb, Sr, Be, and REE showed that 10% melting could produce compositions similar to the veins if an early separation of a mineral fraction composed of 62% plagioclase + cordierite was coupled with additional melting of apatite and garnet.

**Acknowledgements**

This work received support from Fundação para a Ciência e a Tecnologia (FCT) through a PhD fellow. The chemical analytical work was possible with the contribution and support of LNEG - S. Mamede de Infesta to which we are duly acknowledged. The authors also thank the conference reviewers and editors whose suggestions and comments substantially improved the abstract.

CIG-R is supported by the Pluriannual program of the Fundação para a Ciência e a Tecnologia, funded by the European Union (FEDER program) and the national budget of the Portuguese Republic (PEst-OE/CTE/UI0697/2011).

**References**

Dias, P. A. (2012): Análise estrutural e paragenética de produtos litológicos e mineralizações de segregação metamórfica – Estudo de veios hiperaluminosos e protólitos poligénicos Silúricos da região da Serra de Arga (Minho). PhD thesis, University of Minho, Portugal, 464p.

Hodges, K. V. & Spear, F. S. (1982): Geothermometry, geobarometry and the $Al_2SiO_5$, triple point at Mt. Moosilauke, New Hampshire. Am. Mineral., 67, pp. 1118-1134.

Hodges, K.V. & Crowley, P.D. (1985): Error estimation and empirical geothermobarometry for pelitic systems. Am. Mineral., 70, pp. 702-709.