Porphyries and Mafic Dykes related to the late to post-Variscan Magmatism in the Central Iberian Zone (CIZ)

Encontro Ciência 2021, Lisbon, 28 – 30th June

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1. Introduction

The onset of the final stages of the Variscan orogeny in the Central Iberian Zone (CIZ) is marked by the emplacement of several late to post-tectonic granite melts. The following transition into an extensional regime is associated with subvolcanic magmatism, commonly represented by veins and masses of rhyolitic porphyries, dolerites, and lamprophyres. In Portugal and Spain, these hypabyssal lithologies are fairly abundant. However, even though there are several papers concerning the petrography, geochemistry, and geochronology of the Spanish specimens, up until now the Portuguese counterparts have only been poorly studied.

2. Goals

The main goals of the present study are the following:
- To establish the mineral assemblage of the porphyries and mafic dykes under consideration based on petrographic observations;
- To infer the composition of the source(s) from which these rocks derived, as well as their geotectonic setting, considering the results of the geochemical analyses (bulk-rock, mineral chemistry, and isotopes);
- To determine whether the felsic and mafic dykes are genetically related with each other, or with the granites to which they are spatially related;
- To ascertain crystallization ages using U-Pb geochronology;
- To study the magnetic and structural fabrics of selected vein-like lithologies through the analysis of AMS (anisotropy of magnetic susceptibility) data;
- To define the magnetic mineralogy of the dykes based on several techniques used for rock magnetism studies (such as IRM curve acquisition and treatment, Lowrie-Füller and Cisowski tests, acquisition of thermomagnetic curves, etc.);
- To compare the geochemical and petrophysical data concerning the study objects with similar data regarding porphyries and mafic dykes from other regions of Europe;
- To understand the dynamics and relationship between the acid and basic magmatism in the late to post-collisional setting of the Variscan orogeny in the Central Iberian Zone;
- To develop a geodynamic model capable of explaining the petrogenesis, emplacement, magma flow, and alterations associated with these lithologies.

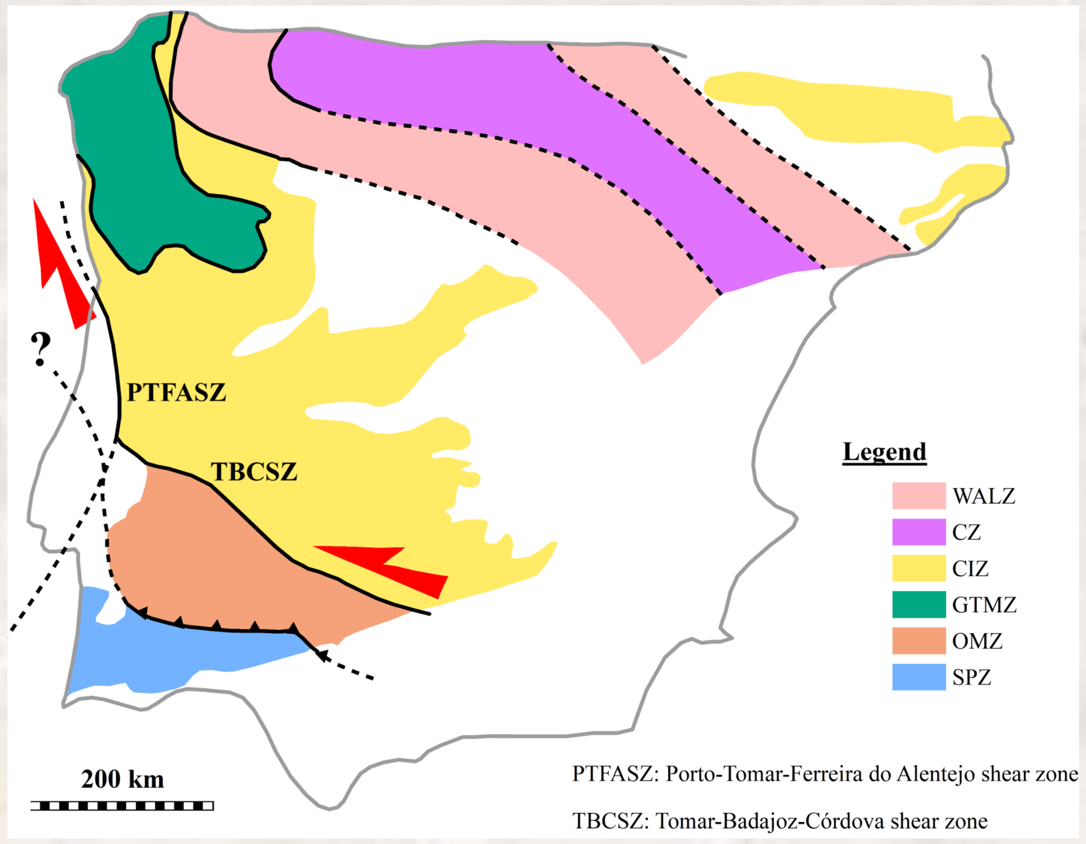

Figure 1 – Location of the Central Iberian Zone in the Iberian Massif setting (adapted from Dias et al., 2016). Legend: WALZ – West Asturian-Leonese Zone; CZ – Cantabrian Zone; CIZ – Central Iberian Zone; GTMZ – Galicia-Trás-os-Montes Zone; OMZ – Ossa-Morena Zone; SPZ – South Portuguese Zone.

3. Methodologies and Results

So far, the methodologies that have been applied to achieve the goals listed above were: (i) Petrography; (ii) Whole-rock Geochemistry; (iii) SEM-EDS (*i.e.*, Scanning Electron Microscopy coupled with Energy-Dispersive X-ray Spectroscopy); (iv) Raman Microspectroscopy; (v) Rb-Sr and Sm-Nd Isotope Geochemistry; (vi) U-Pb Geochronology; (vii) AMS analysis; and (viii) IRM (Isothermal Remanent Magnetization) curve acquisition and treatment.

3.1) Petrography

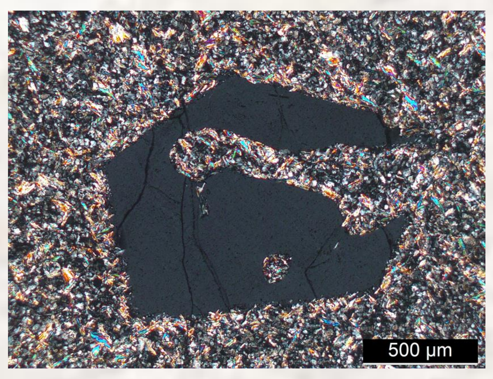

Figure 2 – Embayment on a quartz phenocryst of the Póvoa de Agrações porphyry (Vila Pouca de Aguiar region, northern Portugal). Microphotograph taken in XPL.

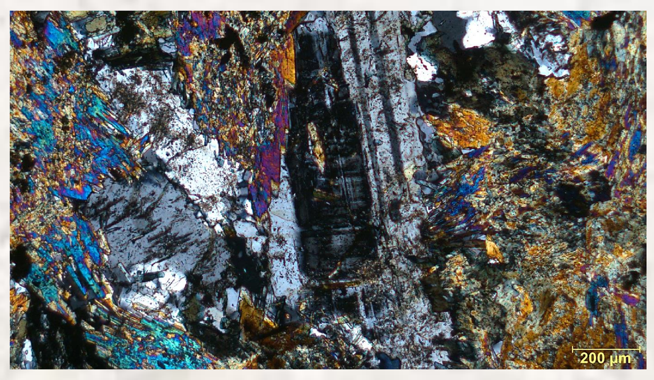

Figure 3 – Subophitic texture of a dolerite from the Penafiel region (northern Portugal). Microphotograph taken in XPL.

3.2) Whole-rock Geochemistry

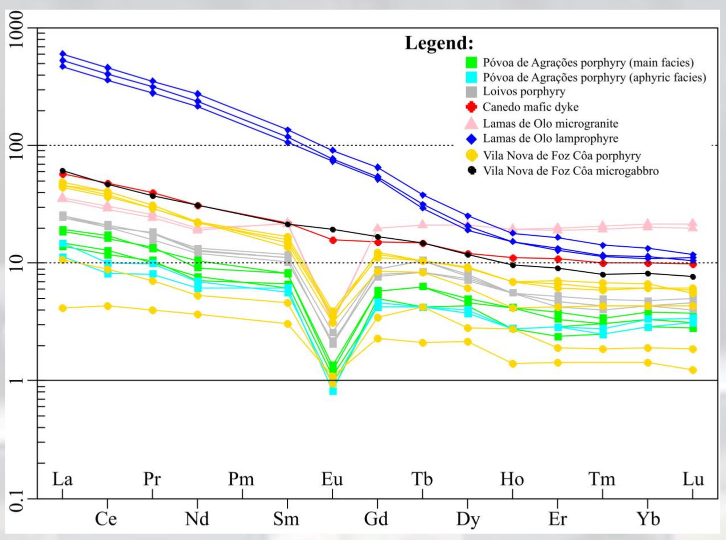

Figure 4 – REE spectra of several porphyries and mafic dykes from the Portuguese section of the Central Iberian Zone. Chondrite normalization values after Boynton (1984).

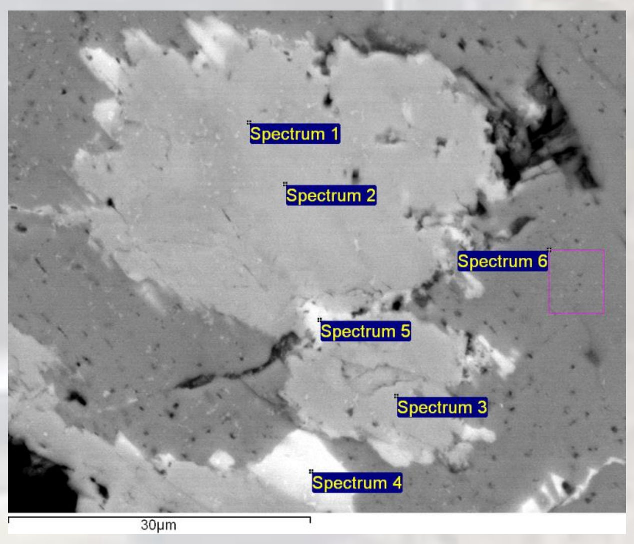

Figure 5 – BSE image of scorzalite crystals from the Póvoa de Agrações porphyry (Vila Pouca de Aguiar region, northern Portugal).

3.3) SEM-EDS

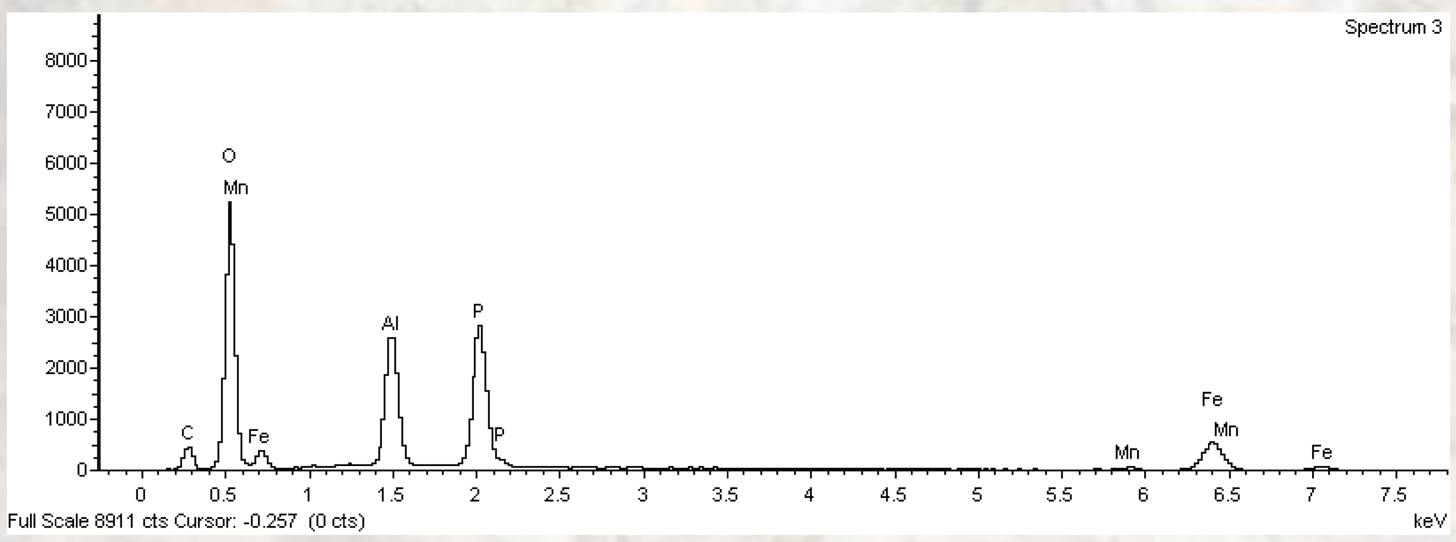

Figure 6 – X-ray spectrum of the analyzed crystal.

3.4) Raman Microspectroscopy

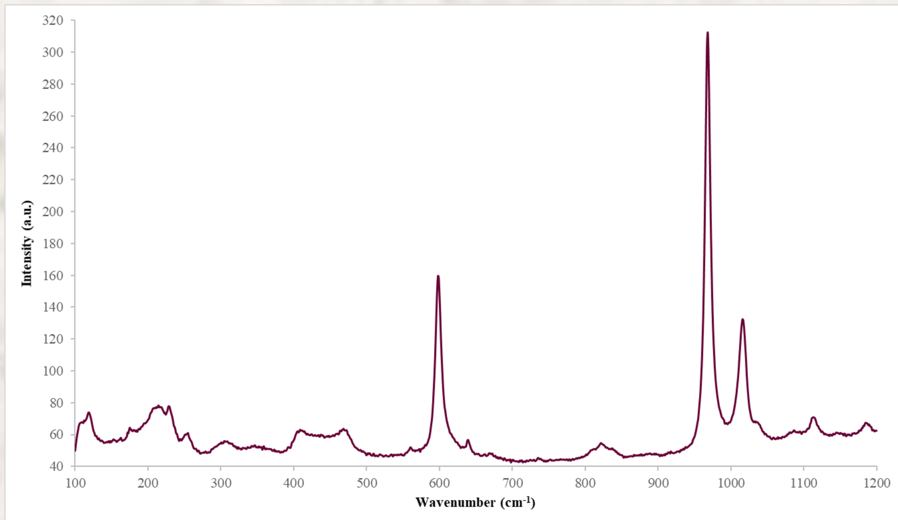

Figure 7 – Raman spectrum of childrenite from the Póvoa de Agrações porphyry (Vila Pouca de Aguiar region, northern Portugal), showing three intense peaks at 600, 968 and 1016 cm^{-1}.

3.5) Isotope Geochemistry

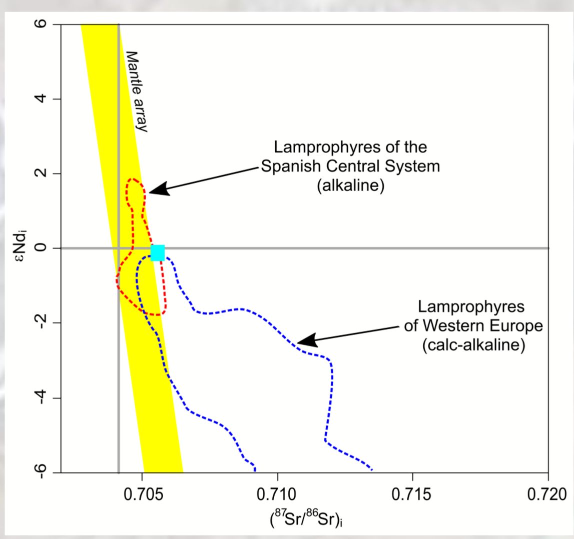

Figure 8 – Rb-Sr and Sm-Nd isotope composition of the Lamas de Olo lamprophyre (Celorico de Basto region, northern Portugal).

3.6) Geochronology

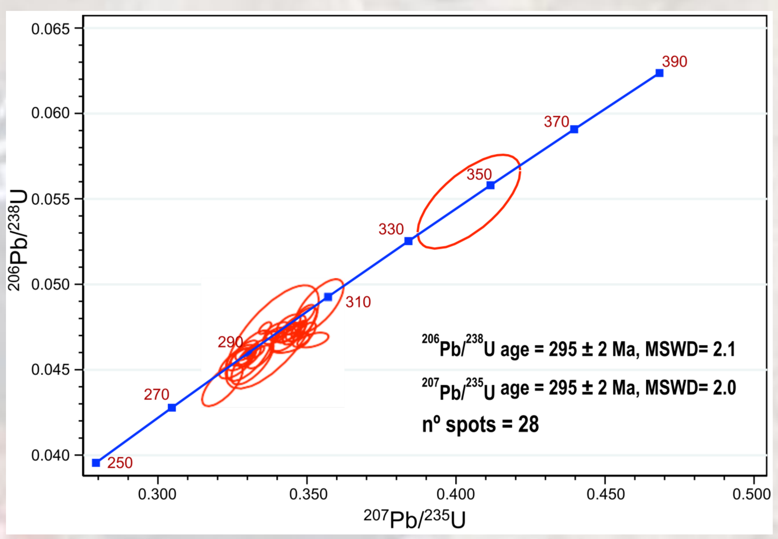

Figure 9 – Wetherill concordia plot for the Lamas de Olo lamprophyre (Celorico de Basto region, northern Portugal).

3.7) Anisotropy of Magnetic Susceptibility

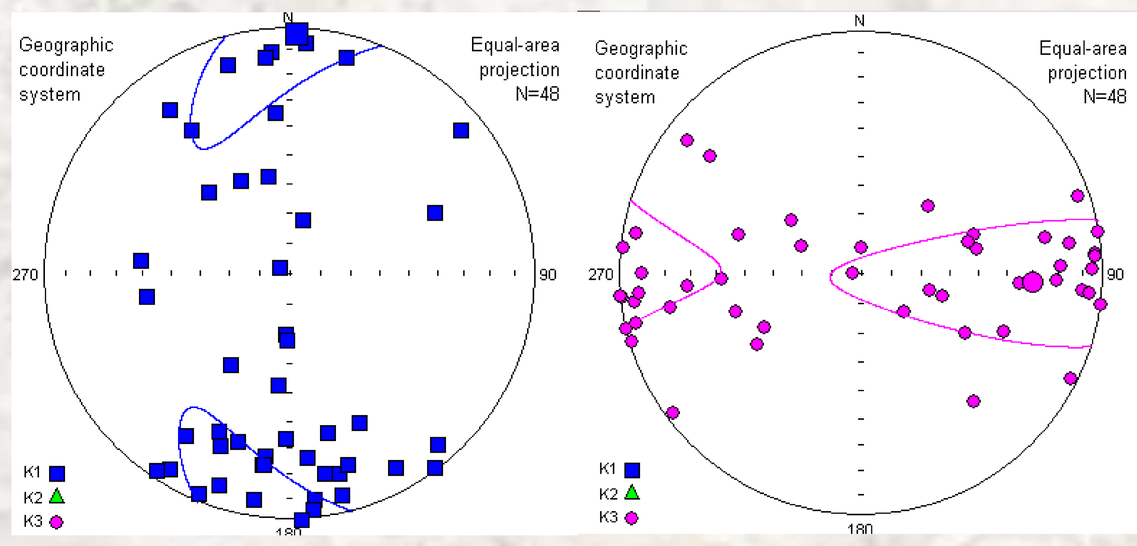

Figure 10 – Stereographic projection of magnetic lineations (K_1) and magnetic foliation poles (K_3) for the Loivos porphyry (Vila Pouca de Aguiar region, northern Portugal; equal area projection on the lower hemisphere). Ellipses represent confidence areas.

3.8) IRM curves

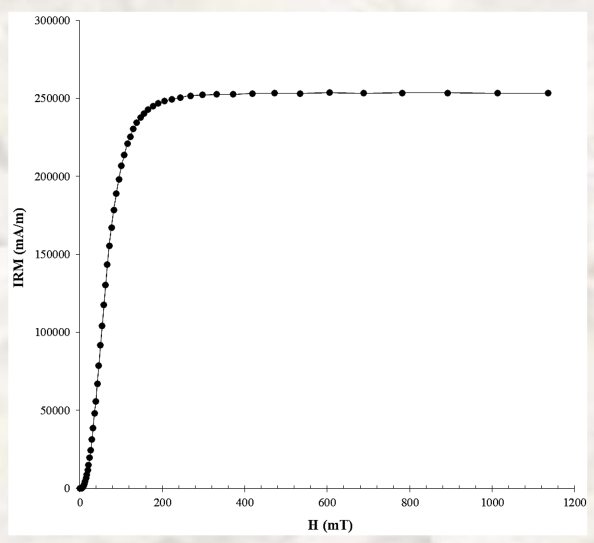

Figure 11 – IRM acquisition curve for the Vila Nova de Foz Côa microgabbro (northern Portugal).

(4) Some Remarks

- The studied rocks are seemingly related to the Permo-Carboniferous hypabyssal magmatism that is widespread throughout the NW and SW of Europe;
- The felsic dykes (mainly granitic or rhyolitic porphyries) were most likely derived from evolved crustal sources which were poorly affected or unaffected by mantle contamination;
- Most specimens were significantly influenced by hydrothermal alterations, as indicated by several petrographic and geochemical pieces of evidence;
- So far, the studied dykes and spatially associated Variscan granites do not present any geochemical features indicative of possible genetic relationships;
- A few porphyries are enriched in rare metal incompatible elements (such as Li, Be, Rb, Cs, Nb, Ta, Sn, and W) which, according to the geochemical and SEM-EDS results, are concentrated in the following minerals: muscovite, potassium feldspar, ilmenite, brookite, anatase, columbite-tantalite, and cassiterite;
- The previous enrichment seemingly resulted from igneous processes. However, hydrothermal fluids might have also played an important role;
- The textural evolution of the porphyries was probably conditioned by fast cooling, volatile loss, subsolidus annealing, isothermal decompression, and magma mixing;
- Considering the bulk magnetic susceptibility, the mineral assemblage of the felsic dykes is paramagnetic. This magnetic behavior is caused by the presence of iron-rich minerals such as biotite, cordierite, and ilmenite, with the biotite crystals dominating the magnetic fabric of the veins;
- The magnetic fabrics of the studied rocks vary from case to case. They suggest either a deep or shallow rooting of the dykes, and mostly, a subhorizontal magma flow at higher structural levels;
- Nonetheless, the AMS results also point to the lack of genetic relationships between the veins and the associated granites;
- On the other hand, the mafic dykes have possibly resulted from the partial melting of deep-seated enriched mantle sources, located in the lithospheric mantle. Source enrichment was presumably caused by subduction-related materials and metasomatism triggered by carbonate-rich fluids;
- The petrogenesis of a few mafic melts might have been conditioned by assimilation and fractional crystallization. Lower crust materials (such as granulites) were probably involved in the contamination process;
- So far, based on the contents in trace elements, including REE, the mafic melts have apparently resulted from low-degree melting of the respective sources, which were seemingly garnet and spinel-bearing;
- The mafic specimens are rich in magnetite which is responsible for the ferromagnetic behavior and higher bulk magnetic susceptibility;
- Based on the results obtained after the treatment of the IRM acquisition curves, even the felsic dykes with the lowest magnetic susceptibilities also have magnetite. However, in these specimens, other magnetic phases of higher coercivity, such as hematite and/or goethite, clearly dominate the remanence signal.

Acknowledgements: *This work is supported by the Portuguese Foundation for Science and Technology (FCT), through the project ref. UIDB/04683/2020 – ICT (Institute of Earth Sciences). The main author is also financially supported by FCT through an individual PhD grant (reference SFRH/BD/138818/2018).*