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Procedia Earth and Planetary Science 17 (2017) 1 – 4

Procedia
Earth and Planetary Science

15th Water-Rock Interaction International Symposium, WRI-15

# Fluids and Variscan metallogenesis in granite related systems in Portugal

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**Abstract**

Most of the fluids that migrated in the higher crust at the end of Variscan orogeny were modified waters that were mixed with surface water during the decrease of the P-T conditions. The crustal discontinuities, the emplacement of the granitic rocks, the uplift and general decompression of the Variscan units were the main driving forces for this migration. In Iberian province some of the granites played also an important role in the ore forming processes supplying heat to drive the mineralizing system rather than being the source of fluids or metals. The existence of magmatic fluids although likely was never of importance, leaving practically no evidence of their existence in the fluid inclusion record. This is in contrast with large batholiths dominating other Sn-W provinces of the Variscan Belt such as the Cornubian and Erzegebirge where granites supplied significant amounts of fluid for the mineralizing process.

Peer-review under responsibility of the organizing committee of WRI-15

*Keywords:* Fluid inclusions; mineralizations; Variscan orogeny; granites

## 1. Introduction

The Variscan metallogenic province of Iberian Peninsula is one of the most important of Europe. It contains deposits of several types being the W ones the leading sources of tungsten in Europe[1].The Variscan Orogeny has a main role on the geology of Western Europe. The Variscan belt is characterized by several geotectonic zones roughly E-W trending with specific and peculiar paleogeographic, tectonic, metamorphic and magmatic characteristics. Tectonic characteristics of the European Variscides are those of a classical subduction-obduction-collision belt with a stacking of large-scale thrusts, between 390 and 320 Ma[2].

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Peer-review under responsibility of the organizing committee of WRI-15
doi:10.1016/j.proeps.2016.12.002

The inner zone of Variscan belt, in the Iberian Peninsula, is represented by "Central Iberian Zone" (CIZ).

In the NW of the Iberian Peninsula three main phases of deformation D1, D2 and D3 are usually considered responsible for the structure, the last one being intra-Westphalian in age[3]. At the higher levels the D1 structures are well-preserved; at lower levels, the D1 structures were transposed by D2 giving rise to the regional schistosity (S2). In the metamorphic domains a peak of orogenic metamorphism, of low pressure type (T~ 650 to 700$^oC$ at P<5kb) was reached during or just after D2 being Lower Carboniferous in age. Regional ductile shears acting symmetrically in the basement induced thrust systems on surface; the latest stage of ductile deformation of the basement corresponds to D3.

The CIZ plutonic magmatism is represented by synorogenic granites. Based on their geological, petrographical and geochemical characteristics, the granites are divided into two main groups. The first consists of two-mica granites, which are dominantly syntectonic (syn-D3: 315–310 Ma). They are considered S-type resulting from the crystallization of wet peraluminous magmas originated at a mesocrustal level, it origin is closely related to the orogenic metamorphism and the granites outcrop on the core of thermal domes nearly coincident with D3 structural antiforms[4]. The second group consists of biotite granites. Their age of formation is either syn-D3 (320–315 Ma), late- to post-D3 (310–305 Ma), or post-D3 (290–280 Ma)[5,6] and are considering as having originated at deep crustal levels and would correspond to dry magmas. Associated with the two-mica granites emplacement a thermal peak was registered (T from 500 to 550$^oC$ and P from 300 to 350 MPa) and associated with the biotite granites, namely the post-tectonic, a thermal metamorphism (T from 500 to 550 $^oC$ and P from 150 to 200 MPa).

As for the granites there are several metallogenic events. Related with the first group of granites there are essentially Li-Sn pegmatites and quartz veins with cassiterite precipitated during the early stage and generally associated with quartz, muscovite and arsenopyrite; with the second group of granites there are the W (Sn) and W(Mo-Cu-Sn) in quartz-vein deposits. Wolframite is the main oxide and followed by sulfides (first pyrite, pyrrhotite, sphalerite, chalcopyrite, stannite and after minor sulfides such as marcasite, galena, Pb-Bi-Ag sulfosalts). Finally there was late quartz ± carbonates ± chlorite.

In order to reconstruct the complex history of the hydrothermal systems (from 340 to 270 Ma) we selected and studied specific sectors in Northern and Central Portugal. To accomplish this task paleofluids trapped within fluid inclusions (FI) from minerals of metamorphic rocks and mineralized structures of different types and ages associated with Variscan systems were studied.

## 2. Samples and methodology

Petrography of fluid inclusions were carried in metamorphic quartz from distinct metamorphic contexts, minerals from Sn-Li pegmatites, quartz from Au-As, W (Sn, Cu) and W (Mo, Cu, Sn) mineralized structures. Fluid inclusion studies were performed using a Chaixmeca and a Linkam stages and a Horiba Jobin-Yvon LabRaman spectrometer interfaced to Olympus microscopes. Raman spectra were obtained using the 632.8 nm emission line of HeNe laser (20 mW). The quantification of the different species in the inclusions was obtained following procedures described by[7]. Bulk composition and density were computed from P-V-T-X properties of individual fluid inclusions in the C-O-H-S system[8]. Bulk composition and density of representative fluid inclusions were calculated from microthermometric measurements and Raman analyses of the volatile phase using a clathrate stability model[9] and the CLATHRATES packaged software[10]. Isochores were calculated with the ISOC computer program of the FLUIDS package[11]. The ionic composition of the fluid inclusions was determined by the crush–leach technique as detailed in[12]. The anions Cl and Br were analyzed by ion chromatography on double-distilled water leaches using a Dionex 45001 HPLC.

## 3. Results and discussion

The earlier fluids were observed in metamorphic quartz; they are aqueous with $CH_4$ and/or $CO_2$ and resulted from metamorphic dehydration processes[13]. Due to fluid/rock interaction those fluids were modified to fluids enriched in $CO_2$ and/or $CH_4$ at trapping conditions of P from 350 to 400 MPa and T from 500 to 550°C.

Examples of this type of fluids are those trapped within milky quartz vein matrix that would support the earlier sulfides (arsenopyrite) associated with cassiterite and latter wolframite and are contemporaneous with a thermal peak related with syntectonic and late tectonic granites emplacement (Figure 1). With the continuous input of