FLUIDS ASSOCIATED WITH Pb-Ag MINERALISATIONS OF FACUCA DEPOSIT (NORTHERN PORTUGAL).

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The old mine of Facuca is located immediately SE of Vila Cova (Vila Real - Trás-os-Montes) not to far from an old iron (magnetite) mine of Vila Cova (Marão Mountain). In the Facuca deposit (also known by Cando mine), during the first half of the XX century a brecciated quartz vein was exploited for lead and silver, bearing macroscopically visible sulfide minerals, essentially arsenopyrite, pyrite, galena and sphalerite (Neiva, 1955; Priem, 1962).

Geology

The Variscan belt is characterised by several geotectectonic 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 obduction-collision belt and it is described as a stacking of large-scale thrust crustal nappes, between 380 and 340 Ma. The inner zone of the orogen is represented by the "Central Iberian Zone" (CIZ) in the Iberian Peninsula (Dias, Ribeiro 1995).

In the NW of the Iberian Peninsula, three main phases of deformation D1, D2 and D3 are usually considered responsible for the structuration of this part of the Variscan belt, the last one being intra-Westphalian in age.

At the higher structural 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 regional metamorphism, of low-pressure type (T 650 to 700°C at P< 5 kb) was reached during or just after D2 being Lower-Carboniferous in age. The latest stage of ductile deformation of the basement corresponds to D3, intra-Westphalian in age. After a later essentially brittle phase D4 is responsible for two conjugated fracture systems striking NNE-SSW and NNW-SSE.

The Facuca area belongs to the autochthonous units of CIZ. The area comprises essentially of metasedimentary rocks and Variscan granites of different types. The mineralized vein is situated between rocks of the Lower Ordovician. Nearby a thrust occurs, striking N130°E and dipping 30° SW, separating this formation from the "Complexo Xisto-Grauváquico" (Desejosa Formation) ante-Ordovician in age. The main foliation (S1) strikes from N120°E to N140°E dipping 30 to 40° NE. The effect of the thermal metamorphism, due to the emplacement of the two-mica granite, is not distinguishable from the regional metamorphism (Pereira, 1989). The peak of regional metamorphism, of low-pressure type (T 650 to 700°C at P< 5kb) was reached during or just after D2 being lower - Carboniferous in age.

The structure of the vein is generally complex, which results from a poliphasic infilling of quartz. However the vein is filled by massive milky quartz (QI), with a brecciated zone near the footwall. This outer zone is characterised by a breccia cemented with quartz. The vein has a N130°E strike and a NE dip of 50° to 80°; the thickness amounts to about 40-60cm. The vein has a visible extension of 300m.

Mineralogy

The ore minerals are essentially arsenopyrite, pyrite, galena and sphalerite being quartz the main gangue mineral. The mineralogical and geochemical electron microprobe studies, allowed the further identification of chalcopyrite, pyrrhotite, violarite, freibergite, stephanite, pyrargyrite as hypogene mineral assemblage and anglesite, cerussite, scorodite, covellite, bornite, hematite and limonite as secondary alteration products. The mineralogical study helps to establish a chronological depositional sequence composing four main stages: *a first stage* (Ni, Co, As, Fe) characterized by deposition of pyrrhotite, pentlandite, arsenopyrite I and pyrite I; *a second stage* (As, Fe, Zn, Cu) with arsenopyrite II, sphalerite and chalcopyrite I; *a third stage* (Zn, Pb, Ag) contains galena, freibergite, stephanite, pyrargyrite, pyrite II and chalcopyrite II. Secondary alteration products as Pb-sulphates, Cu- sulfides, Fe-arsenates and anglesite characterize the *late stage*.

As previously mentioned quartz is the main gangue mineral. Usually occurs as a milky quartz variety (QI) generally as large anhedral crystals with highly undulous extinction. More rarely idiomorphic crystals occur and that happens when they crystallized in small geodes. It occurs associated with almost all the observed primary minerals, sometimes infilling their fractures suggesting that the quartz is the first mineral of the vein and after continued to precipitate until the later stages of mineralization.

Fluid inclusion studies

The fluid inclusion studies were carried out in two types of quartz, a clear quartz associated with arsenopyrite II (QII) and subhedral to euhedral quartz spatially associated with galena (QIII). No microthermometric analyses have been made on the fluid inclusions in the earliest milky deformed quartz (QI) due to their small size. Microthermometric and microspectroscopic

Raman studies revealed the presence of three fluid types: (1) aqueous-carbonic H_2O-CO_2-CH_4-N_2-NaCl; (2) aqueous with low salinity H_2O-NaCl (Lw_1) and (3) aqueous with high salinity H_2O-NaCl-$CaCl_2$ (Lw_2 and Lw_3).

The aqueous-carbonic fluids have been observed in primary and pseudosecondary fluid inclusions (Lc-w and Lw-c type) in QII and QIII. All the fluid inclusions have two phases at room temperature with a degree of filling (Flw), varying from 0.50 to 0.70. These fluid inclusions have a melting temperature of CO_2 ($TmCO_2$) ranging from –63.2 to –61.1° already suggest the presence of volatile compounds other than pure CO_2 (CH_4 and N_2) that was confirmed by Raman microprobe analysis. CO_2 is the dominant species in the volatile phase ranging from 59.7 to 95.0mol %. CH_4 is in the 5.0-40.3mol % range. N_2 content ranges from 10.5 to 4.7mol %. Homogenization temperature of CO_2 ($ThCO_2$) to the vapor phase in the range of –17.2 to 3.1°C. The Tmcl is in the range 10 to 14°C. Total homogenization temperatures (Th to the liquid phase) range from 240 to 360°C in (Lc-w) and 160 to 320°C in (Lw-c) corresponding to the minimum trapping temperature of the fluids.

The Lw_1 fluids occur as planes of fluid inclusions (FIPs) and/or as clusters in QII. The Flw varies from 0.70 to 0.95. Melting temperature of ice (Tmi) ranges from –5.5 to –0.1°C (calculated salinity between 0.18 to 8.55 wt%NaCl eq.) (Bodnar, 1993) and homogenization (Th) occurs in the liquid phase between 102 to 200°C.

The Lw_2 fluids occur as clusters in QIII, the Tmi ranges from -32.5 to -21.2°C corresponding to an high salinity varying from 21.6 and 25.7 wt%$CaCl_2$ eq. (Goldstein & Reynolds, 1994). Th occurs in the liquid phase in the range 102 to 145°C.

The Lw_3 fluids occur in PIF in QIII, the Tmi ranges from -47.1 to -37.8°C, corresponding to the highest salinity (between 27.3 and 29.7 wt%$CaCl_2$ eq.) with Te around -70°C. Th occurs in the liquid phase in the range 82 to 100°C.

Discussion and conclusions

In other studied examples from Northern Portugal the early fluids, considered as "metamorphic fluids" (in ante-D3 quartz veins), are aqueous and sometimes contain clathrates of CH4 and/or CO2 and are assumed as resulting from dehydration processes (Guedes et al., 2002). Due to the fluid/rock interaction those fluids were modified and acquired a more complex composition richer in CO2 and/or CH4 in the volatile phase. Examples of these fluids are those trapped within milky quartz vein matrix that could support the earlier sulfides (arsenopyrite) and are related to the thermal peak induced by the peraluminous two-mica granite emplacement (311 Ma). The latter fluids evolve towards dominantly aqueous fluids with low salinities and probably of meteoric origin. These conditions indicate a considerable basement uplift and/or pressure fluctuations at the end of the D3 phase (305 to 300 Ma) (Dória et al., 1995; Noronha et al., 2000)

Most of the fluids that migrated within the higher crust at the end of the Variscan orogeny were "metamorphic waters" s.l. that were mixed with surficial waters along with a decrease in P and T conditions. The main driving forces affecting this migration were the structural discontinuities (acting as a draining zones), the emplacement of syntectonic and then post-tectonic granites and the uplift and general decompression of the Variscan units.

The youngest fluids correspond to aqueous high saline and low temperature fluids (Guedes et al. 1999). The resemblance between these fluids and other responsible for similar barren and mineralised veins associated with post-Variscan structures on a European scale (Canals et al., 1992), indicates that at least part of the fluid history of the vein is post-Variscan. The dating of these phenomena is questionable due to the non-existence of Permo-Cretaceous formations in the area.

We assume, in the example of the Facuca vein, that the aqueous-carbonic fluids associated with earlier sulfides resulted from the interaction fluids/host rocks and the aqueous fluids related to galena represent superficial fluids and brines.

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