BRAZIL GOLD'91, E.A. Ladeira (ed.) © 1991 Balkema, Rotterdam. ISBN 90 6191 195 8

Gold-silver mineralisations associated with the Vilariça Fault, NE Portugal

A. Mateus & F.J.A.S. Barriga
Universidade de Lisboa, Portugal

ABSTRACT: The Vilariça structure is a late Variscan left lateral strike-slip fault which metallogenetic potential remains obscure. Its Northern segment is often underlined by siliceous hydrothermal precipitates of variable shape and thickness, sometimes extremely enriched in iron and other metallic elements. Their development may be explained by deep fluid circulation in restricted areas, certainly related with coalescence of strike-slip fault segments, during the different stages of fault propagation. In the França sector some subsidiary structures of the Vilariça system are mineralised, and the gold (as electrum) occurs intimately associated with siderite, arsenopyrite, pyrite and galena. Thus the superficial late metal-enrichment of some brecciated quartz fillings is the product of sulphide and carbonate alteration. Structural style, hydrothermal alteration patterns, fluid inclusion data, and the striking development of oxide crusts and breccias in other fault segments, enable the recognition of some strike-slip dilatant jogs as potential ore targets concerning to Au-Ag mineralisations at depth.

1 INTRODUCTION

An expressive number of gold-silver (± antimony) mineralisations occur in the Centro-Iberian Zone (**CIZ**), a fundamental unit of the Hercynian basement in Northern Portugal (fig. 1A). Most of these have been detected and exploited since (pre ?)-Roman times, although only one (Minas de Jales) is currently being worked.

Existing data relative to some Au-districts in the **CIZ** show that different types of gold occurrences with different ages can coexist spatially. So, to detail guides for exploration, it is important to examine the principal metallotects pertaining to each gold mineralisation, including structural, lithological, stratigraphical and geochemical controls.

In this article we summarise the preliminary results obtained via study of some metal-rich segments of the Vilariça strike-slip fault. They represent the first example in Portugal of gold-silver mineralisations associated to dilatant jogs in strike-slip brittle and semi-brittle fault systems.

2 REGIONAL GEOLOGY

The **CIZ** is an important unit of the Northern branch of the Iberian Variscan Fold Belt (e.g. Ribeiro, 1974; Ribeiro, 1981). The autochthon domain of this geotectonic unit is essentially composed by Lower Paleozoic sediments (mostly slates and interbedded graywackes of Cambrian age, and Ordovician quartzites with intercalations of slates), overlying a Precambrian gneissic basement. Generally, these rocks experienced three main episodes of Hercynian deformation and regional metamorphism of low-pressure type (chlorite - andalusite zones), and are intruded by syn- and late-orogenic granitoid bodies (fig. 1A).

The first phase of deformation (D_1), of probable Upper Devonian age, is responsible for E-W folds with sub-horizontal axial planes at lower structural levels and subvertical axial planes at upper levels. The third one (D_3), of Upper Carboniferous age, generated E-W upright folds in the metasediments, refolding the earlier structures. In some areas (e.g. Três Minas), the brittle structures in Ordovician quartzites associated with

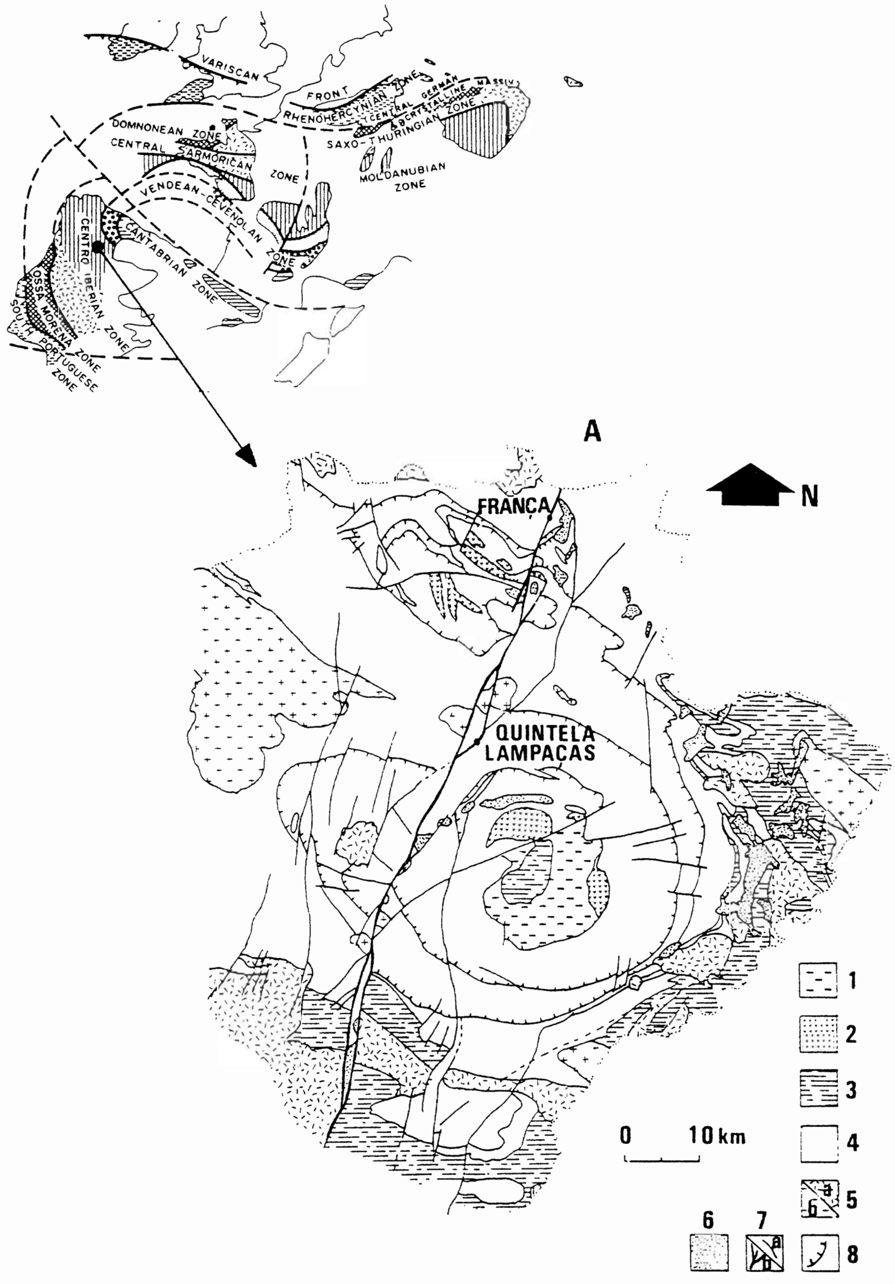

Fig.1 A- Paleogeographic and tectonic Variscan units in the Iberian Peninsula. B- Synthetic geological setting of the Vilariça fault zone (Northern segment) and its localisation in the **CIZ** (simplified after Ribeiro, 1974). 1- Precambrian basement; 2- Pre-Variscan mafic and ultramafic rocks; 3- Upper Precambrian to Cambrian slate and graywacke complex; 4- Ordovician to Upper Devonian (?) slates, quartzites, graywackes, conglomerates, and other basement rocks; 5- a) syn-Variscan granites, b) late-Variscan granites; 6- Cenozoic cover deposits; 7- a) fault, b) Vilariça fault zone; 8- major thrust plane.

this (re)folding were object of Roman exploitation; the saddle-reefs contains sulphides (pyrite ± arsenopyrite) and native gold (Portugal Ferreira , 1971). The D_3 episode is also responsible for the generation of two sets of subvertical strike-slip shear zones (ENE-WSW, sinistral, and NW-SE, dextral; Iglesias and Ribeiro, 1981), which are clearly related with some gold occurrences (e.g. Rio de Silos and Penedono - Armamar). In these cases, the mineralisation consists of quartz lenses with sulphides (arsenopyrite + galena, and minor pyrite) and native gold ± silver. The second impulse (D_2), is a localised episode related to the emplacement of allochthonous units and thrust reactivation of D_1 shear zones in some sectors of the autochthon domain (Dias, 1986); sometimes this deformation event constrained the emplacement of syn-D_2 acid batholiths (Munhá et al., 1984; Ribeiro et al., in press).

In late Variscan times, the basement was strongly fractured, leading to the development of a profuse set of strike-slip faults (NNE-SSW, sinistral; NW-SE, dextral), in which the Vilariça system is one of the main sinistral structures (Ribeiro, 1974; Arthaud and Matte, 1975, 1987). The geometry of these faults is locally constrained by D_3 shear zones, namely the dextral ones, and other pre-existing structural anisotropies. Their reactivation during Neogene and Quaternary times, with different tectonic styles, is well supported by field evidence and historical-instrumental seismicity (Ribeiro, 1984; Moreira, 1985; Cabral, 1985, 1986, 1989).

3 STRUCTURAL AND GEOLOGICAL CONTEXT OF MINERALISATIONS

3.1 The Vilariça Fault

The Vilariça structure is a left-lateral strike-slip fault generated at the end of the Variscan Orogeny (Upper Westphalian - Stephanian), with a complex history during its propagation (Stephanian - Early Permian) and reactivation episodes in Neogene and Quaternary times (Ribeiro, 1974; Cabral, 1989; Mateus and Barriga, in prep.). The fault zone, nearly 250 km long, NNE-SSW, affected all the structures of the Hercynian basement in CIZ and Galiza - Trás-os-Montes Sub-zone (fig. 1B). The displacement of some geological references reaches a maximum of 8 km in the Northern segment, namely in the Moncorvo area (the nucleation sector of the Vilariça fault; Ribeiro et al., 1983/85, 1990; Mateus, 1989). Fracturing and hydrothermal circulation along the Vilariça fault produced a great variety of fault rocks and quartz veins, which are being object of detailed studies in some selected areas (see Mateus, 1989). The siliceous fillings, particularly expressive in the Northern segment of the fault in Trás-os-Montes, show variable shape and thickness. Nevertheless, their development suggests extensive circulation of hydrothermal fluids in restricted areas, certainly related with coalescence of en échelon strike-slip fault segments during the successive episodes of fault propagation. In some domains, the quartz fillings are strongly brecciated and enriched in iron and other metallic elements. The striking development of oxide crusts and red breccias (hematite-enriched), besides their chemical signature, suggest the presence of primary gold-silver-sulphide-carbonate mineralisations at depth (Mateus and Barriga, 1990; this study).

3.2 The França lode gold deposit

In the França area (N of Bragança), the Vilariça fault is divided into various branches striking from N-S to N20E (fig.2). This is a typical phenomenon at brittle shear terminus zones(e.g. Tchalenko, 1970; Wilcox et al., 1973; Sylvester, 1988). These accidents cut all the Upper Ordovician sequence (quartzites interbedded with black schists), and are generally underlined by abundant fault gouge. Quartz fillings with rhombohedral morphology are also present; usually they are brecciated and exhibit prominent enrichment in hematite ± goethite. Near the fault planes, the slates show pronounced brittle deformation and strong hydrothermal alteration. Comprehensive petrography enabled distinction of two mineral parageneses of low temperature (< 200°C) and pressure (< 1 kbar). The stability of quartz + vermicular chlorite + hematite ± high Fe-sericite, and illite-smectite + goethite ± quartz suggest the percolation of oxidising and near-alkaline fluids during the last stages of Vilariça propagation (Mateus, 1989, Mateus and Barriga, in prep.).

In the Southwest part of this area,

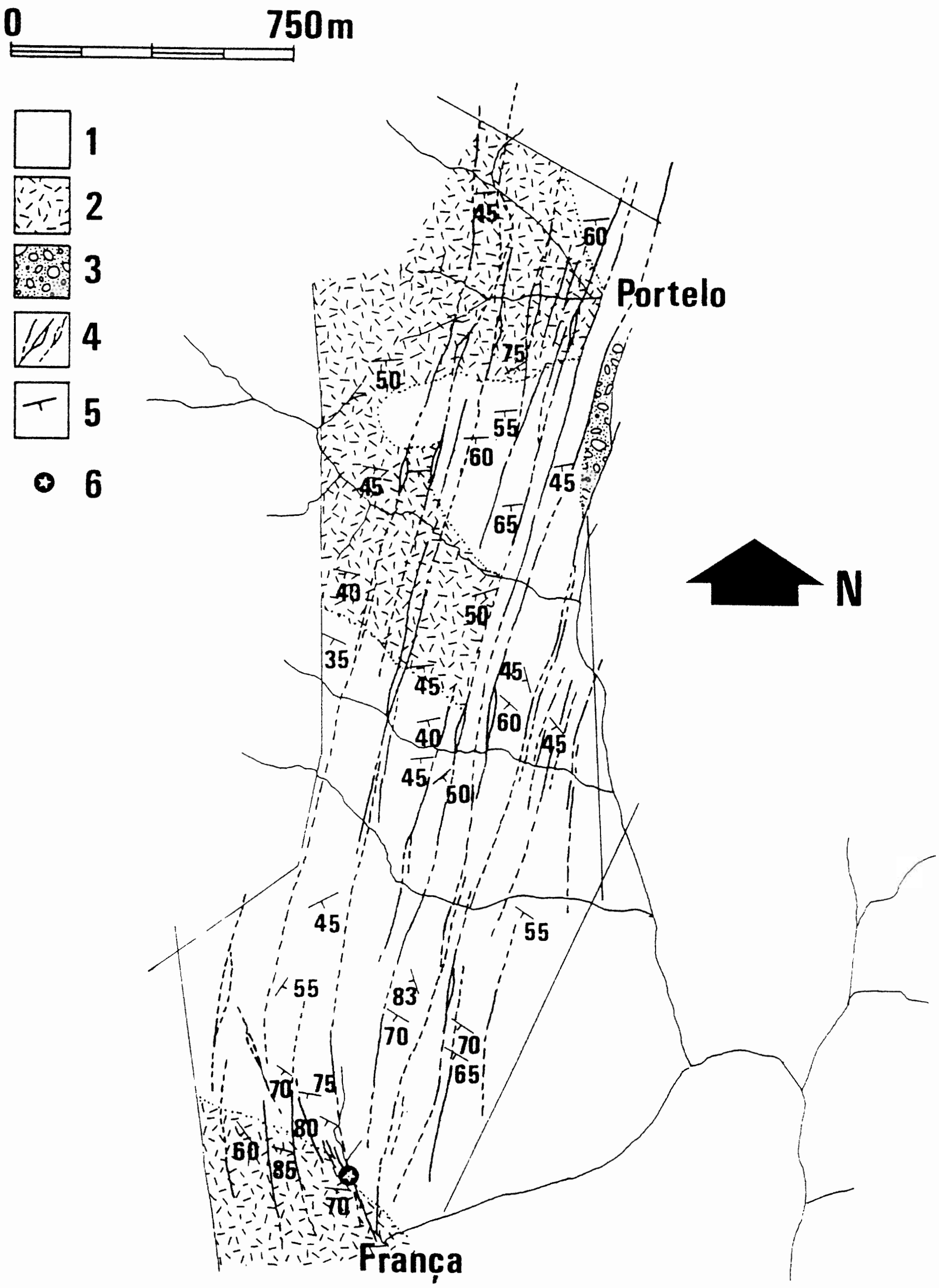

Fig.2 Geological map of the França sector. 1- Slates with thin iron lenses and carbonaceous horizons (Landeillian); 2- Quartzites interbedded with (black) schists (Arenigian/Lanvirnian ?); 3- "Raña" cover deposits; 4- Fault zone underlined by brecciated, iron-enriched quartz fillings; 5- Regional foliation S_1; 6- Mining works.

subsidiary structures of the Vilariça system (N15-30W, subvertical) are part of the França lode deposit. These irregular veins show discontinuous development and are often cut by late subvertical fracture arrays trending N30-40E, sometimes accompanied by another system (N60-80W, 55-65SE). Gold (as electrum) occurs associated with arsenopyrite, pyrite, and galena. Quartz and carbonates (mostly siderite) are the main non-metallic minerals in the mineralised veins. The wall rock alteration is given by the association of quartz + carbonate + high Fe-chlorite ± sericite ± pyrite, which is consistent with the circulation of reduced and slightly acidic fluids at temperatures and pressures lower than 300 °C and 2 kbars, respectively. This mineral paragenesis is often replaced by low-temperature assemblages (< 200 °C).

Gold anomalies are sometimes found in fault gouge zones and red breccias clearly related to the Vilariça system. However, in the França area, the Vilariça fault system intersects a nearly perpendicular (N70-80W, subvertical) auriferous sinistral shear zone syn D_1 or D_3 (?). In this main structure the mineralisation occurs generally along the footwall of thin and irregular quartz-veins oriented N80-100E, 40-50S. These veins usually exhibit "en échelon" disposition and sometimes there is evidence of horizontal left displacement, enabling their classification as hybrid Riedel fractures (e.g. Gamond, 1983, 1987, Hancock, 1985).

As a consequence it is difficult to prove a genetic relationship of the França gold-silver mineralisation with hydrothermal activity related to the Vilariça system. This can only be accomplished through the study of other Vilariça fault segments, away from intersections of other tectonic accidents. Currently available data, pertaining to Trás-os-Montes segments of the Vilariça fault where hydrothermal activity was detected, enabled selection of Quintela de Lampaças area (N of Macedo de Cavaleiros) as the best sector for study.

3.3 The Quintela de Lampaças segment

Geological mapping of the Quintela de Lampaças area show that the fault zone has an anomalous direction (N60E) and brings to contact the para-autochthonous formations (quartzo-pelites with thin intercalations of psamites) with allochthonous units (essentially greenshists and acid tuffites) - fig.3. The fault zone is here underlined by expressive quartz-fillings (nearly 2 km long and 0.5 to 20 m thick), which experienced strong brecciation and spectacular enrichment in iron and other metallic elements. The chemical signature of these breccias and crusts suggests that they can be interpreted as a surface expression of deep gold-silver-sulphide-carbonate mineralisation (Mateus and Barriga, 1990).

The siliceous mass comprises different quartz generations, and the typical microstructures exhibited by the main generations are typical of semi-brittle and brittle deformation regimes. The earlier quartz generations are characterised by temporal cyclicity and spatial coexistence of brittle and plastic deformation. This behaviour is probably related to tectonic stress cycling along the fault zone at temperatures between 250-300°C and pressures lower than 1.5-2 kbars (Mateus et al., in press). The subsequent quartz generations are affected by brittle structures only, attesting the action of fragile mechanisms under temperatures and pressures lower than 250°C and 1 kbar, respectively. Locally, the brittle mechanisms promote the development of quartz-cataclasites (with abundant specular hematite and box-works) and different kinds of breccias (Mateus, 1989; Mateus et al., in press).

The hydrothermal alteration experienced by the wall rocks is very extensive and the earlier association quartz + sericite + chlorite + albite ± epidote ± calcite reflects the circulation of reduced and acid fluids, CO_2 and K^+ enriched, at temperatures and pressures lower than 300°C and 2 kbars, respectively (Mateus, 1989; Mateus and Barriga , in prep.). These results are consistent with stable isotope signature given by the $^{18}O/^{16}O$ content in the earlier quartz generations (Mateus et al., in prep.). Moreover, preliminary results on primary fluid inclusions in quartz of this stage (Terrinha et al., 1987), show that depict homogenisation temperatures ranging from 184 to 273°C, low salinities (near 2-5 eq.wt.% NaCl), and a volumetric fraction of CO_2 around 10-20% at room temperature.

Subsequent alteration parageneses are restricted to the domains of high permeability, and the stable association of quartz + adularia + vermicular

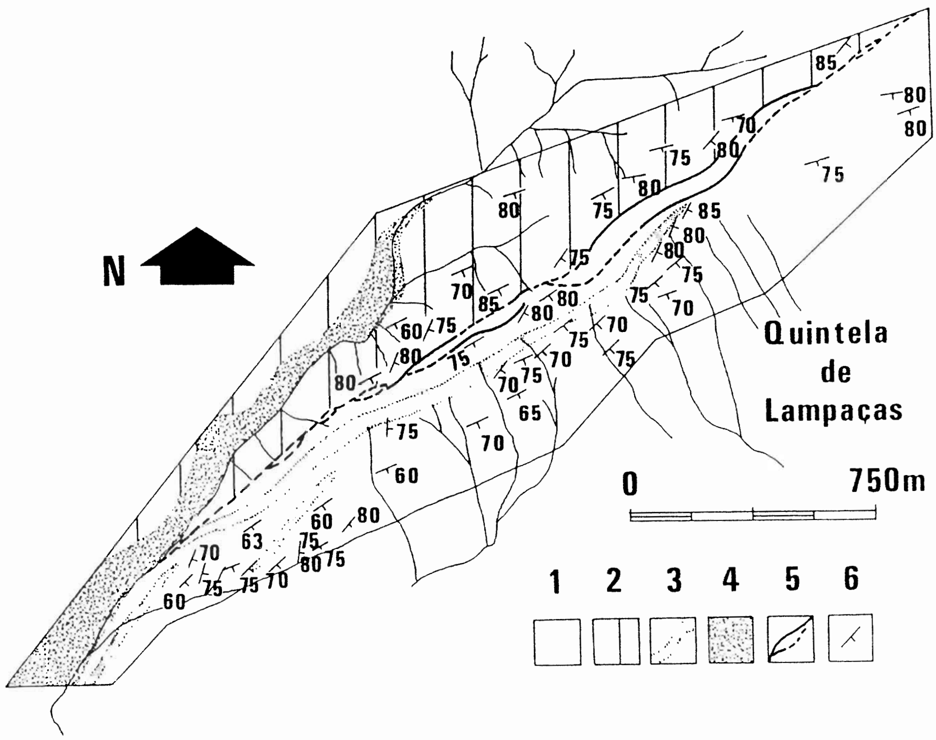

Fig.3 Geological map of the Quintela de Lampaças sector. 1- greenshists and acid tuffites of the Centro-Transmontano Domain (allochthonous unit); 2- quartzo-pelites with thin intercalations of psamites of the Peri-Transmontano Domain (para-autochthon unit); 3- metagabbros; 4- alluvial sediments; 5- quartz fillings of the Vilariça Fault zone; 5- regional foliation S_1.

chlorite + hematite ± high Fe-sericite supports the circulation of oxidising and slightly alkaline fluids at temperatures between 200 ± 20°C and 150 ± 10°C and pressures around, or less than, 1 kbar. These Fe- (± Mg) enriched hydrothermal solutions are characterised by expressive values of $aSiO_2$ ($<$ 3.16×10^{-2}) and high $a(K^+)/a(H^+)$ ratios ($>10^3$). This mineral assemblage is usually replaced by illite/smectite + goethite ± quartz, suggesting the action of oxidising and near alkaline fluids under temperatures and pressures lower than 150°C and 1 kbar, respectively. In this context, the deposition of some oxides, namely hematite and pirolusite, within the quartz fillings, is compatible with primary sulphides and carbonates alteration in an environment characterised by average values of pH and Eh around 7 and -0.3, respectively (Mateus and Barriga, in prep.).

4. Concluding statement

The similarities between the alteration patterns and the chemical signatures of crusts/breccias from the França lode gold deposit and Quintela de Lampaças quartz fillings, suggest that the hydrothermal system associated to the Vilariça fault was productive in gold and silver. The structural control of mineralisation is related with the development of dilatant jogs and subsidiary structures generated in semi-brittle and brittle deformation regimes, during Vilariça strike-slip fault propagation. However, not all the siliceous precipitates were metal enriched. The study of the geochemical constraints imposed by host lithologies, as well as the analysis of the physico-chemical conditions for gold-silver deposition in this hydrothermal system and subsequent probable reworking, are the main issues for further work.

Acknowledgments

The authors are most grateful to A. Ribeiro for his stimulus and profitable discussions about regional and local geology. They are also extremely indebted to W.S. Fyfe for his encouragment and fruitful suggestions. They also express appreciation to Prominas SARL, in particular to A. Barros, for warm hospitality, underground guidance and access to unpublished data on the França lode gold deposit.

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