RECONSTRUCTION OF THE WEATHERING PROFILE OF THE VILARIÇA STRIKE-SLIP FAULT ZONE IN THE FRANÇA SECTOR (N OF BRAGANÇA); METALLOGENETIC CONSEQUENCES.

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ABSTRACT: In the França sector three main types of (mineralized) fault breccias can be recognized. Breccias of type C (2-7 ppm Au, 70-80 ppm Ag) are extremely enriched in sulphides ± carbonates and outcrop at 700 m of altitude. These rocks constitute the non-weathered equivalent of breccias type B (0.5-22 ppm Au, 70-100 ppm Ag), outcropping between 745 and 730 m of altitude, where the abundance of Fe-oxides is the result of the destruction of primary minerals. Breccias of type A (enriched in Fe-oxides/hydroxides) outcrop usually above 750 m of altitude (20-110 ppb Au, 0.1-0.5 ppm Ag) and represent the final product of the intense chemical weathering. Type B breccias represent the enrichment zone of the weathering profile, where the reprecipitation of some metals (e.g. Cu, Au, Ag) took place. The use of mass balance equations for supergene elements shows that the altitude of the paleo-oxidation surface is consistent with the present elevation (≈900m) of the ancient, well-preserved, regional pediplanation of Late Pliocene age.

The fault rocks sampled along the Vilariça strike-slip fault zone in the França sector (N Bragança) include mainly quartz breccias and fault gouges. In general, quartz breccias are related to highly fractured domains of the tectonic structures, where multiple overprinting of different quartz-vein arrays can occur.

Quartz breccias associated to the Vilariça fault can be grouped into three major subtypes: (1) **Breccias A** (20 to 110 ppb Au and 0.1 to 0.5 ppm Ag) - earthy and highly porous, iron-manganese enriched matrices, which may also contain sparse pyrite ± arsenopyrite relics. Minor amounts of hydrous-phyllosilicates (hydrosericites ± illites ± smectites) complete the observed mineralogical paragenesis; (2) **Breccias B** (0.5-22 ppm Au and 70-100 ppm Ag)- massive, sometimes earthy, matrices with abundant relics of primary minerals (mostly siderite, pyrite and arsenopyrite) which are surrounded and corroded by complex mixtures of metal oxides/hydroxides and arsenates. The occurrence of this breccia type, like the further one (type **C**), is circumscribed to the ancient mine works in the França mine area, and the elevation of the present outcrops ranges from 735 to 745 m; (3) **Breccias C** (2-7 ppm Au and 70-80 ppm Ag) - massive matrices which comprise sulphides showing brittle deformation (particularly pyrite, arsenopyrite and galena), primary phyllosilicates (sericite ± chlorite), and, sometimes carbonates (fragmented). These fault rocks, outcropping near 700 m of altitude and occurring within one major tectonic branch of the Vilariça system that in higher topographic levels exhibits **B** and **A** breccia subtype fillings, are solely present in the França mine area and were probably object of

Roman exploitation. **Fault gouges and/or friable late-quartz breccias** (0.002-0.5 ppm Au, 0.1 to 3 ppm Ag) are present along some fault domains of the Vilariça structure, particularly in those where compact quartz fillings are missing. These fault rocks comprise always abundant fragments of variable dimension of the surrounding metamorphic rocks and exhibit local enrichments in iron and manganese oxides/hydroxides. The matrix of the late breccias typically consists of quartz, hydrous-phyllosilicates, and minor amounts of pyrite, goethite, pirolusite, and hydrated arsenates.

From the above description, it is obvious that breccias of type **B** represent an altered product of breccias **C**, since the development of oxides is clearly the result of the destruction of primary minerals. Furthermore, our data show that fault breccias **A** (preserved at higher topographic levels) can be interpreted as the final product of the intense chemical weathering in the near surface environment, and that the horizontal chemical gradients along the fault zone are negligible. The establishment of this weathering profile that is based on the spatial distribution and geochemical analyses of 10 samples (outcropping between França and Portelo) is also consistent with the mineralogical variation and geochemical signature of the fault gouges that fill some fault segments South of França (NNW-NW of the Rabal village).

In general, the relative proportions of the major oxides is compatible with the mineralogical content of the examined (mineralized) fault breccias. The relatively high P_2O_5 concentration in friable late-breccias is probably a result of the nature and extent of host-metamorphic fragments incorporated into these rocks, namely clasts of phyllites and lidites of Silurian age, which usually contain P minerals (mostly variscite) as accessory phases. The incorporation of host-rock lithologies into fault rocks explains also the anomalous abundances of Sc, V, Cr, Co and Ni found in some samples; regarding this interpretation it is worthy to note that the V and Co contents are covariant with Sc, Al and, to a lesser extent, with Zr values. The distribution of Mn is quite variable and apparently does not exhibit any particular correlation with the remaining metals; high Mn concentrations (>100 ppm) are however characteristic of quartz breccias **B** and **C**, as well as some samples of fault gouges. With similar distributions, Cu and Zn concentrations are the highest in quartz breccias. Pb high values can be found in quartz breccias **B** and **C** only. The distribution of gold shows high positive affinity with As and Pb, and less perfect covariant relationships with Fe and Sb, which is consistent with the mineralogical nature of these rocks.

The geochemical profiles of the analysed elements (abundances versus altitude) almost always show striking discontinuous variations between 730 and 750 m of altitude, corresponding in general to the fault zone horizon where breccias **B** are preserved. The pattern followed by the chemical profiles of Fe, Au (fig.1A), Pb (fig.1B), and Ga illustrate clearly both the strong and efficient leaching experienced by these elements in the upper levels of the weathering profile, and the development of a pronounced positive peak circumscribed to the intermediate horizon of the fault zone profile, suggesting that conditions for their solubilization and subsequent mobility were achieved. Although less obvious, similar paths can also be found for Zn, Cu, Mn, and Ag distributions. It should be noted however that the unexpected relatively high contents of Zn and Cu in the upper levels of the weathering profile (where protolith concentrations are approached) can be interpreted as a result of their fixation in authigenic minerals, which is compatible with the gradual increase of Th, U and P concentrations towards the higher levels of the fault zone, suggesting enrichment from external sources, perhaps meteoric waters.

Other prominent characteristic of the geochemical profiles obtained is illustrated by the behavior of elements such us Sb (Fig.1C), S, As (and CO_2), which have been removed from all levels, although less so at the 730-750 m horizon. Therefore, one may conclude that they behave as perfectly mobile elements during development of the weathering profile over primary mineralized fault breccias **C**. The remaining analysed elements show more variable behavior. Very few elements (with the possible exception of Zr (fig.1D) , and perhaps Y) seem to have been immobile in the course of the weathering profile development (data are inconclusive for Al).

According to the previous interpretation, some metals (like Fe, Cu, Pb, Zn, Au and Ag), were locally moved from a depleted source zone (represented by breccias **A**) to a complementary enriched horizon, where reprecipitation took place (fault zone level represented by breccias **B**). In these circumstances, mass conservation constraints imposed by the two related and sequential chemical subsystems (Brimhall et al., 1985; Brimhall and Dietrich, 1987), enable some inferences about the chemical weathering and geomorphological evolution experienced by the Vilariça fault zone.

The altitude of the paleo-oxidation surface, estimated from the average leached column height of Pb, Zn and Ga, with an enrichment blanket thickness of the order of 25 m which top is now at 750 m of altitude, is consistent with the present elevation (≈ 900 m) of the ancient, well preserved, regional pediplanation of Late Pliocene age. Anomalously high elevations for the paleo-oxidation surface are obtained when we include in the calculations the estimated maximum leached column heights of Pb, Zn, Ga and Cu. The values obtained are however geologically realistic, suggesting that a minimum of 40-100 m of erosion must have taken place after pediplanation development. Accepting an average age of pediplanation development being 2.5-2 Ma, the estimated erosion rates range from 0.016-0.04 mm to 0.02-0.05 mm per year, respectively. It is also important to point out that the vertical component of movement associated to the reactivation of the Vilariça system in França sector during Quaternary times is unanimously considered to be very small and therefore should not be a significant source of error in these estimations.

For the remaining supergene metals (Au, Ag and Fe), the calculated elevation of the paleo-oxidation surface is negatively anomalous. For gold and silver, the corresponding low topographic anomalies can be explained by the existence of significant lateral fluxes, probably controlled by the Montesinho ridge which stood out in relief during the regional episode of erosion of Late Pliocene age, determining the geometry of the paleoground-water table. Our modelling suggests also that lateral fluxes for Ag are far greater than the ones obtained for Au, which is interpreted as an evidence for a greater stability of silver complexes during the development of the weathering profile.

The obtained large negative lateral flux of iron and/or the abrupt decrease in its concentration in protolith specimens required by the estimated low topography anomaly, are not consistent with the mineralogical paragenesis shown by the examined fault rocks. The best explanation for the data is as follows: the leached horizon of the fault zone profile presently preserved between 820 and 750 m of altitude may have been covered by a true iron hat (now eroded). In fact, none of the observed weathered lithologies may be classified as a fully developed iron hat, given the systematic preservation of uncorroded angular quartz fragments, and the sporadic occurrence of pyrite relics. Therefore, most of the iron contained in the original section remained unaccounted for in our calculations, producing an underestimation of the altitude of the paleo-oxidation surface.

The implications of our work are obvious and far-reaching: in the Iberian Peninsula, apparently barren veins are frequently seen standing out in the landscape, at altitudes where, according to our data, no geochemical anomalies are to be expected. These may sometimes correspond to blind deposits.

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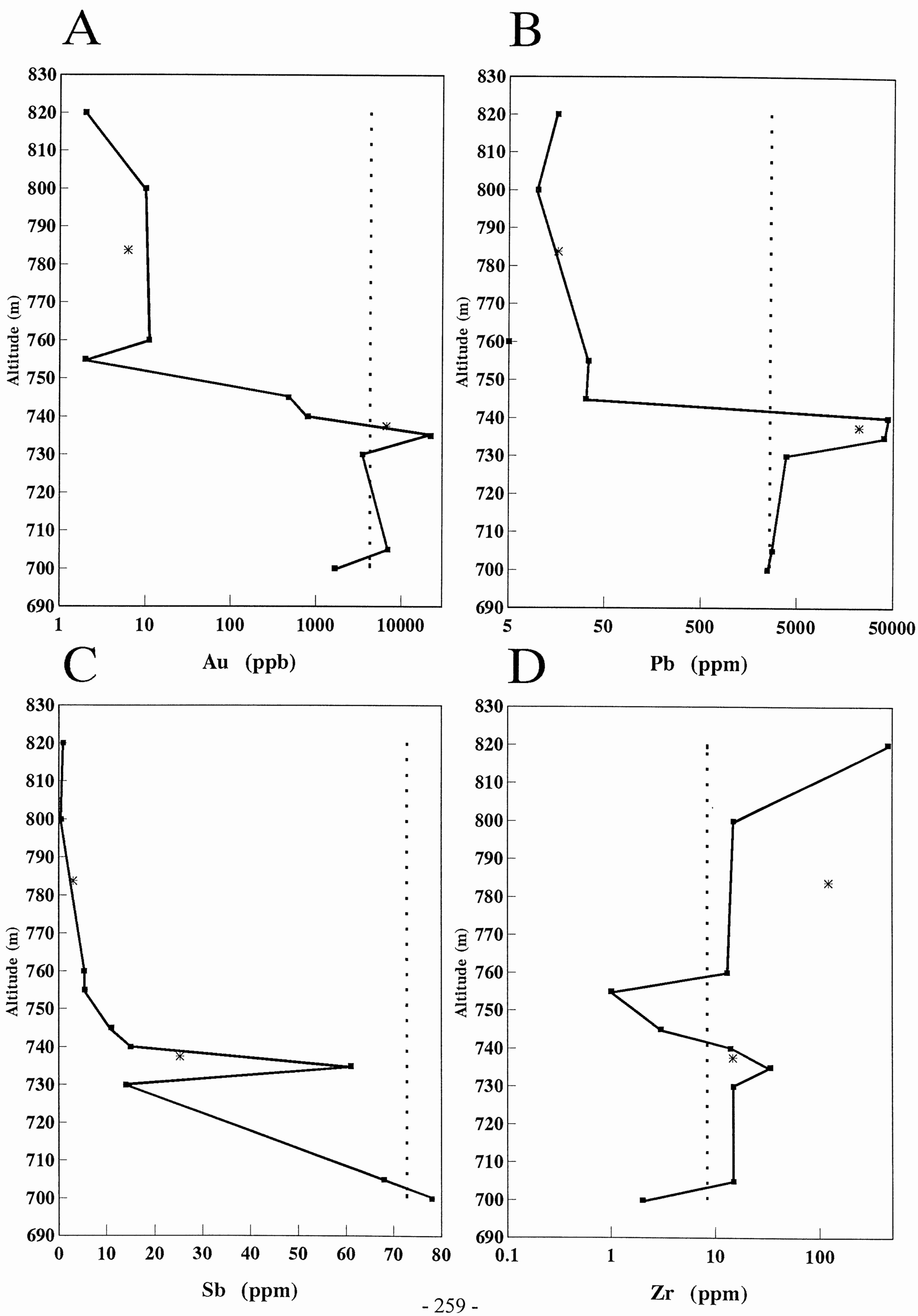
FIGURE CAPTION

Chemical profiles of Au (A), Pb (B), Sb (C), and Zr(D) for the Vilariça fault breccias in the França-Portelo sector. Dotted lines represent the average concentration of two protolith samples (breccias type C), and the asterisks illustrate the average concentration of the remaining two breccias groups (types A and B).



A
B
C
D
Altitude (m)
Au (ppb)
Pb (ppm)
Sb (ppm)
Zr (ppm)