STRUCTURAL CONTROL OF GOLD OCCURRENCES IN THE AROUCA REGION AND THEIR RELATIONSHIPS TO THE CARBONIFEROUS TROUGH SHEAR ZONE (NW PORTUGAL)

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Abstract: The gold occurrences identified near Arouca (NW Portugal) are mainly controlled by secondary structures within silicification bands or fault zones, where some mineralized quartz veins and quartz breccias occur. Structural data show that the development of such structures can be ascribed to the D_3 and late-D_3 deformation phases recorded in the Central Iberian autochthon. Nevertheless, the most important mineralizing event is mainly coeval with the late-D_3 deformation episode. These occurrences also show structural similarities with the other Au and Sb-Au mineralizations north-westwards, in the Valongo and Gondomar areas respectively. The structural control of the mineralized structures shows that their development is consistent with the Carboniferous Trough Shear Zone (CTSZ) evolving path, to which most of them are closely related. Still, further data is needed to prove if this relationship is also a genetic one.

Resumo: As ocorrências auríferas identificadas na região de Arouca (NW de Portugal) desenvolvem-se principalmente no seio de bandas de silicificação ou de zonas de falha, onde ocorrem veios e brechas de quartzo mineralizados. Dados de índole estrutural demonstram que o desenvolvimento destas estruturas é atribuível aos impulsos das fases de deformação D_3 e tardi-D_3 que se identificam no autóctone da Zona Centro-Ibérica. Contudo, o principal episódio mineralizante ocorre preferencialmente associado à fase tardi-D_3. Os dados obtidos mostram ainda que o controlo estrutural destes é similar ao evidenciado pelas mineralizações de Au e Sb-Au conhecidas a NW, nomeadamente na zona de Valongo e Gondomar, respectivamente. O controlo estrutural das estruturas mineralizadas demonstra que o seu desenvolvimento é consistente com a evolução globalmente delineada para a Zona de Cisalhamento do Sulco Carbonífero, com a qual, de resto, a maioria se encontra espacialmente associada. Quanto a uma possível relação genética, os dados são ainda insuficientes para o demonstrarem.

Key Words: Gold; Arouca; structural control; shear zone; quartz veins; silicification bands.
Palavras-chave: Ouro; Arouca; controlo estrutural; zona de cisalhamento; veios de quartzo; bandas de silicificação.

1. Introduction and geological setting

The Carboniferous Trough Shear Zone (CTSZ) represents a major structural feature of the Northwestern domain of the Central Iberian Zone autochthon. This shear zone borders the SW limb of the D_1 Valongo anticline, striking NNW-SSE to NW-SE. Several Au and Sb-Au occurrences are in close relation to both structures and belong to a major metallogenetic province extending from Póvoa de Varzim (N of Porto) to the Castro Daire granite to the SE, along a NNW-SSE to NW-SE direction (see figure 1).

There is a close relationship between the Sb-Au mineralizations and the CTSZ. These mineralizations, located mainly to the SW of the CTSZ, have developed during the late-D_3 deformation event identified in the Carboniferous Trough, responsible for the reverse left lateral movement of the shear zone (Domingos *et al.*, 1983). This is in good agreement with the structural control of the mineralized quartz veins, and is also supported by the development of such veins simultaneously in ante-Ordovician (Schist and Graywacke Complex) and Carboniferous rocks (*e.g.* Ferreira *et al.*, 1971; Gonçalves & Itard, 1992). As a matter of fact, recent exploration studies in Alto do Sobrido - Medas region (Gonçalves & Itard, 1992) showed that part of the mineralized structures correspond to N80E to E-W *en echelon* quartz veins, within N-S to N20E dextral shear zones with variable degree of silicification. These shear zones most probably represent the conjugate shears of the CTSZ during the late-D_3 deformation event. It is also identified a late deformation event responsible for the sinistral shear in the quartz veins and the development of late N40E quartz tension gashes. Still, there is a lack of knowledge concerning the relation between the mineralizing events and the development of the quartz veins. Nevertheless, the E-W quartz veins correspond to the main mined structures in the past (Ferreira *et al.*, 1971).

The Au mineralizations, developed mainly in the NE limb of the Valongo anticline, are hosted by the Arenig quartzites. The mineralized quartz veins show two distinct orientations: N95E to N130E (rarely N50E to N60E) near the anticline hinge at Valongo and N20E (rarely N120E) to the SE, near Banjas mine (Cassard & Carvalho, 1989; Cassard & Urien, 1990). According to these authors, and based on the available structural data, the development of both structures can be ascribed to the same deformation event, consistent with the development of the Valongo anticline. Nevertheless, the *en echelon* pattern exhibited by the N20E structures and their late reactivation as dextral faults is consistent with the D_3 and late-D_3 stress field (Iglesias & Ribeiro, 1981; Domingos *et al.*, 1983). Therefore, the mineralization timing may be correlative of D_3 to late-D_3 period. This situation doesn't explain why the Au-quartz veins near Valongo show a different orientation. One possible explanation may be their earlier development, which may also explain why the orebodies show two deformation phases in the Moirama mine (Cassard & Carvalho, 1989). The paragenetic sequence shows that the deposition of gold is associated with the later quartz (Combes *et al.*, 1992), nevertheless, the relation between the development of the quartz veins and the mineralizing event(s) it is not clear.

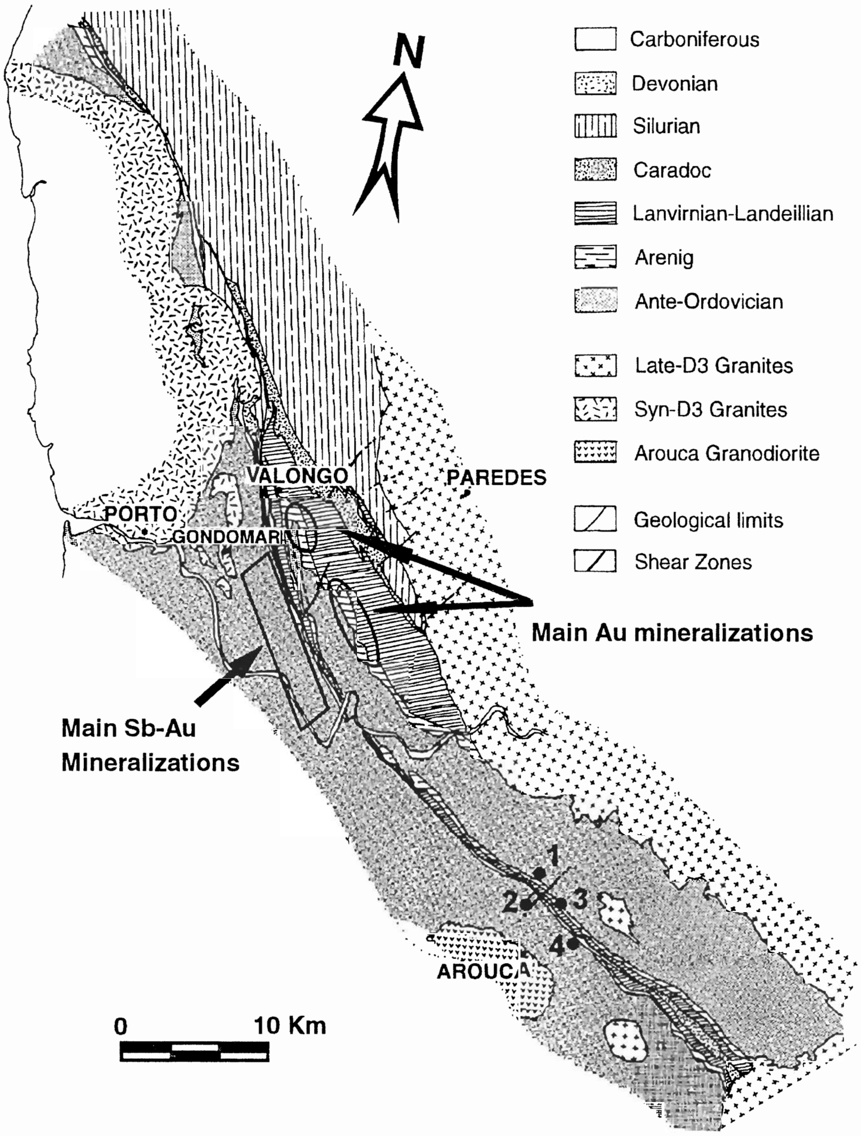

Figure 1. Geological map of the Valongo anticline area (Central Iberian autochthon), with the location of the main Au and Sb-Au mineralizations, as well as of the gold occurrences near Arouca: **1:** Vila Cova; **2:** Toural W; **3:** Toural E; **4:** Chiqueiro

2. The gold occurrences in the Arouca region

In the Arouca region (SE of the metallogenetic province), four gold occurrences were identified - Vila Cova, Toural E, Toural W, and Chiqueiro areas (see figure 1) - which were object of several geological exploration campaigns for Sb and Au (recently and in the past) (*e.g.* Ferreira *et al.*, 1971; Afonso & Gonçalves, 1991). These occurrences are located either to the SW of the CTSZ, hosted by ante-Ordovician lithologies (Chiqueiro and Toural W) or in the SW limb of the Valongo anticline hosted by the same lithologies (Vila Cova), or by the Arenig quartzites (Toural E). The CTSZ has a general direction of N120E to N130E in this area. The identified occurrences are domains of variable silicification of the host rocks, with the development of several quartz veins, sometimes with disseminated sulphides (mainly arsenopyrite, pyrite, and chalcopyrite) in different proportions. Hydrothermal activity comprises the deposition of different quartz generations and phyllosilicates (mostly K-micas) late in the sequence. Presently, most of the mineralized quartz veins exhibit extensive oxidation features, and show variable intensity of weathering according to the depth of the exposure. At lower altitudes, arsenopyrite is replaced by scorodite, and pyrite and chalcopyrite by iron oxides/hydroxides. At higher altitudes there is total replacement of the sulphides by iron oxides/hydroxides.

Vila Cova - Figure 2A

The main structure at Vila Cova is a post-cleavage silicification band with several folded quartz veins. The silicification crosscuts the regional S_1 schistosity in domains with N-S direction and becomes parallel to it in domains with a N140E direction giving rise to a global N160E strike. The folded quartz veins sometimes have iron oxides/hydroxides replacing former sulphides (pyrite and chalcopyrite) and are generally earlier than the microcrystalline quartz of the silicification of the host rocks. The S_1 cleavage is often folded with the development of a crenulation cleavage. It was also possible to observe shear criteria within the silicified host rocks which demonstrates that this structure represents a shear zone. The sense of movement was not determined due to the lack of oriented samples. Finally it is worth noting the presence of late tension gashes with undeformed quartz striking N70E-N80E and crosscutting the silicification band.

Toural W

In this area, a dextral shear zone striking N120E with 2 m width affects the D_1 folds of the surrounding rocks. Inside this zone, an intense silicification of the host rocks is developed as well as some subparallel quartz veins and quartz breccias with iron oxides/hydroxides. The planes of some of the veins show a late dextral movement with the development of quartz breccias.

Toural E - Figure 2B

This area has a similar context to the one described for the Au-quartz veins near Valongo, and is characterized by the development of a silicification band striking N120E, cut by a late dextral fault zone which was object of ancient mining activity. This fault zone has a N170E strike rotating to N-S in the southern extremity. Both quartz veins and quartz breccias with iron oxides/hydroxides and rare arsenopyrite are found within the fault zone.

Chiqueiro - Figure 2C

The occurrence of several mineralized quartz veins confer a greater interest to this area, which shows some ancient mining activity. The host rocks are silicified and show some ferruginization along bands of different width striking N120E. The quartz veins have a N-S to N20E direction, and generally have an *en echelon* pattern. Some of these veins were developed inside the silicification bands. Therefore, these bands may correspond to ancient dextral shear zones, which is also supported by the existence of dextral ductile fault planes striking N135E. Several subparallel planes to the silicification bands have been later reactivated, causing the brecciation of some of the quartz veins. Sometimes, the contact of these veins is also brecciated. The area extends to the SE, where some more mineralized quartz veins outcrop.

3. Discussion and conclusions

The available data, especially the geological mapping and structural analysis, show that the mineralized structures developed mainly during the D_3 and late-D_3 deformation phases. The silicification bands of Toural W and Chiqueiro correspond to minor dextral shear zones consistent with the D_3

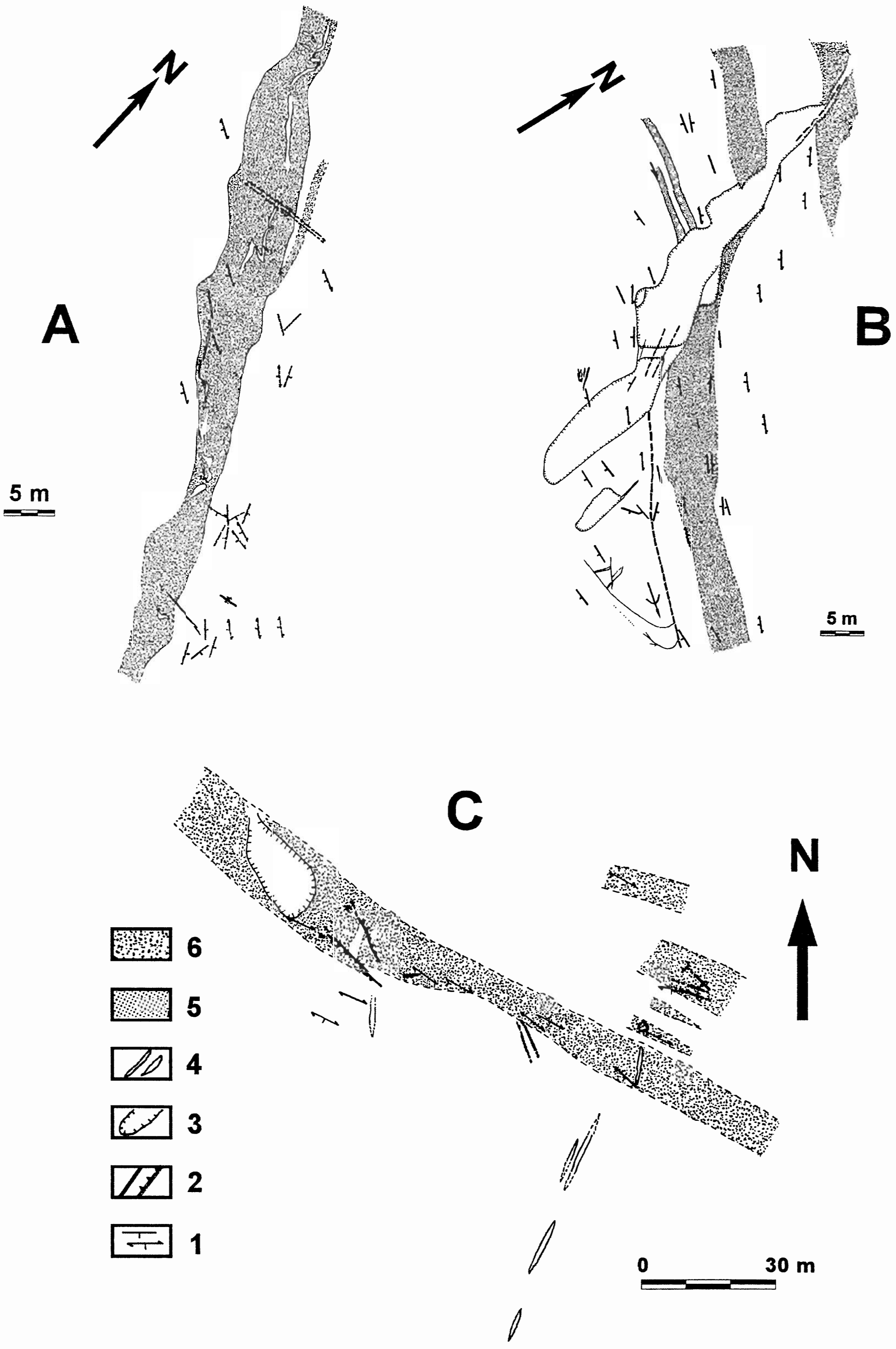

Figure 2. Detailed geological maps of Vila Cova (**A**), Toural E (**B**) and Chiqueiro (**C**) areas. **1:** S_0 and S_1; **2:** Fault trace; **3:** Mining works; **4:** Quartz veins; **5:** Quartzite beds; **6:** Silicification bands

stress field (Iglesias & Ribeiro, 1981). This same episode may explain the formation of the main quartz veins at Chiqueiro, and constitutes a probable hypothesis for the formation of the veins at Toural E with similar directions. It was not possible to prove whether the silicification band at Toural E is also a minor shear zone or not. At Vila Cova, the available data is insufficient to determine which deformation event was responsible for the development of the shear zone. Nevertheless, it is constrained to be post-D_1 since it is later than the development of the S_1 schistosity. As to the folded quartz veins, the evidence points to an earlier development than that of the shear zone.

The stress field during the late-D_3 deformation event, which caused reactivation of CTSZ as a reverse sinistral shear zone (Domingos *et al.*, 1983), may well be the cause of the reactivations of fault planes observed at Chiqueiro (consistent with the movement of the CTSZ). The same stress field may also explain the reactivation of the planes in the quartz veins in spite of lack of data concerning the associated movement. At Toural E, the development of the dextral fault zone results from reactivation of the former quartz veins which cause their brecciation, and can be ascribed to the late-D_3 deformation event. At Vila Cova, the development of the late tension gashes crosscutting the silicification band is also consistent with this same episode.

The observation of polished thin sections from samples of all areas shows that the mineralizing events are generally late. This is quite evident in samples from Chiqueiro, Toural E, and Toural W, where the sulphides are associated with the late, less deformed, quartz. The exception is the occurrence of arsenopyrite at Chiqueiro, which is earlier. Nevertheless, the electrum particles are associated with the late sulphides. This is also supported by recent geochemical rock analyses from Chiqueiro that shows the highest gold values in the quartz breccias (up to 7 ppm) within the late reactivated planes. Therefore, strong evidence led us to consider the mineralization event to be late-D_3. At Vila Cova, the observations also corroborate these conclusions, but there are some doubts in the association of some oxidized material (sulphides?) with the earlier quartz.

The gold occurrences described above (with the exception of Vila Cova) show structural similarities with the Sb-Au and Au mineralizations in the whole province. This is particularly evident for the case of Toural E - Banjas mine area (*e.g.* Cassard & Urien, 1990), as well as for Chiqueiro (and possibly Toural W) - main Sb-Au mineralizations in the NW (*e.g.* Gonçalves & Itard, 1992). It is quite pertinent to note the inexistence at Chiqueiro of mineralized quartz veins related to the late-D_3 event, which constitute one of the main type of structures mined for Sb (and Au) in the province.

As to the genetic link between these gold occurrences and the CTSZ, the available structural data indicates that the quartz vein development is a consequence of the shear zone evolving path. However, work is still in progress in order to investigate the possible source of the mineralizing fluids and to establish a metallogenetic model for these occurrences.

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