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The Au-Cu epithermal deposit at Palai-Islica, Almeria, SE of Spain: Preliminary data

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ABSTRACT: The following sequence of hydrothermal alterations has been identified within the epithermal gold/copper-bearing deposit at Palai-Islica: propylitic, sericitic, argillitic (extending over a surface area of some 2.5 x 1.7 km^2), and silicic (±carbonatation). Mineralization appears in association with quartz veins, stockworks and layers of silica with sulphides (pyrite±chalcopyrite±other minor sulphides and native gold). Three fluids have been identified related to the mineralization: (A) a high-temperature, high-salinity fluid (magmatic?); (B) a fluid of relatively constant temperature and very variable salinity; and (C) a lower temperature and relatively low, constant salinity fluid (ground waters?). The considerable difference in the nature of these fluids (due mainly to the isothermal mixing of A and B fluids and a heterogeneous entrapment of the solutions -due possibly to boiling-) seems to have been responsible for the precipitation of gold.

1. INTRODUCTION

Associated with the Cabo de Gata-Cartagena volcanic belt (hereafter referred to as CG-C VB) there are a great number of hydrothermal polymetallic deposits containing varying proportions of gold, silver and related metals, such as Fe-Zn-Cu-Bi-Hg-Pb-As-Sb-Sn-Ba-REE-Te, which have been exploited to a greater or lesser extent since distant times. The interest of this volcanic belt is clearly evident in the sheer number of mining sites found in the region (more than 3,000 between Cabo de Gata and Cartagena), some of them date back some 2,000 years or more. Some of these mines have also achieved considerable output and during the last century the region became one of the most important base-metal producers in Europe.

The CG-C BV can be divided into three main mining districts: Cabo de Gata (Au-Te-Ag-base-metal deposits); Herrerías-Sierra Almagrera (Ag-Ba-base-metal deposits); and Aguilas-Cartagena (base metals). These hydrothermal deposits range from epithermal to mesothermal in character and in detail they vary enormously in aspects such as host rocks, types of alteration, parageneses, textures, paragenetic sequencies and mineralogical expression of precious metals, all of which makes it extremely difficult to establish any general criteria for the exploration of these types of deposits. Nevertheless, mining in the region is presently increasing; an open-cast mine has recently been opened at Herrerías [Ba-Ag-(Fe-Pb)] and a mining project is being considered at Mazarrón [Zn-(Cu-Ag-Au)]. The mining company SERRATA RESOURCES S.A. is carrying out exploration work at the Palai-Islica gold/copper-bearing deposit, an area of argillic alteration extending over a surface of some 2.5 x 1.7 km^2.

A multidisciplinary study is being carried out on the Palai-Islica deposit at Carboneras in the Province of Almería (SE of Spain) to evaluate their metal-bearing potential. For this article we have taken the preliminary data from that study, particularly those referring to: 1) the characterisation of the hydrothermal alterations in the host rocks and their spatial distribution; 2) the identification of the mineralogy of the deposit; and 3) the microthermometric analysis of their fluid inclusions. The object of the study is to arrive at a better understanding of the circulation of the mineralising fluids and the mechanisms of their reaction with the host rock and thus provide information to evaluate the Palai-Islica deposit and support the exploration of new mineralised bodies within this region.

2. GEOLOGICAL SETTING

On a regional scale the CG-C BV forms part of the

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eastern end of the Internal Zone of the Betic Cordillera (Figure 1). This volcanic belt, Neogene in age, was formed within the context of a subduction zone during a contraction regime, which was then followed by an extension regime after the continental collision (Dewey, 1988). The consequences of this

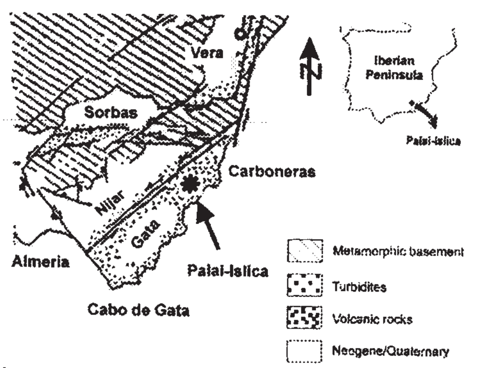

Figure 1. Geological map of the region (adapted from Fernandez Soler, 1992)

latter regime, among others, were (García Dueñas *et al.*, 1992): 1) a thinning of the continental crust; 2) the formation of strike-slip and normal low-angled faults and associated structures (e.g. the N40-50°E Carboneras and the N10-20°E Palomares faults); and 3) the development of Neogene volcanic rocks of calc-alkali, potassic and shoshonitic calc-alkali, and ultrapotassic and basaltic series, enclosed mainly in the various levels of the metamorphic basement of the Alpujarride and Nevado-Filabride complex (López-Ruiz and Rodríguez-Badiola, 1980).

During the Miocene, in association with this volcanic activity and the system of faults and fractures controlling it, there developed a series of hydrothermal systems. The hot fluids [up to 400-450°C, according to Morales (1994)] reacted strongly with the host rocks and thus, in some districts, gave rise to the formation of wide areas of mineralisation/alteration, normally with a zonation in their spatial distribution (Fernández-Soler, 1992). The most important of these sites are Cabo de Gata, Rodalquilar, Carboneras (Palai-Islica), Herrerías-Sierra Almagrera (El Jaroso, El Arteal), Aguilas (El Charcón, Ermita de la Cuesta de Gos, Reina del Cielo), Mazarrón (Los Perules, San Cristobal, Coto Fortuna) and Cartagena.

At Palai-Islica deposit, three main geological units are distinguished:

1. Volcanic rocks of the Cabo de Gata calc-alkali series, which correspond mainly to Tortonian amphibolitic andesites and dacites, appearing in the form of either agglomerates, lavas or pyroclastics. These rocks are frequently brecciated (tectonic and hydrothermal breccias) and show considerable hydrothermal alteration.

2. Palaeozoic-Mesozoic basement rocks (gneisses, schists, micaschists, quartzites and phyllites) belonging to the Nevado-Filabride and Alpujarride complexes.

3. Subhorizontal, Pliocene-Quaternary sediments partially covering the volcanic rocks and the metamorphic basement.

The gold-bearing mineralisation is found realted to the hydrothermal alterations in the volcanic rocks.

Associated with the N40-50E Carboneras fault system, there are abundant normal faults and secondary strike-slip faults in the area. This system facilitated the circulation of hydrothermal fluids.

3. VOLCANIC ROCKS AND HYDROTHERMAL ALTERATION

The host rocks to the mineralisation are amphybolitic andesites of porphyritic texture. The phenocrystals consist of green hornblende, normally altered to chlorite with metallic ores, plagioclase, commonly altered to sericite, and minor quantities of quartz, which are generally preserved after alteration. The matrix is devitrified glass, occasionally transformed to chlorites, sericites or other clay minerals.

Throughout the study zone the host rocks show considerable hydrothermal alteration, caused by their interaction with the mineralising fluids. Petrographic and X-ray difraction studies of the altered rocks reveal the following:

1. The degree to which the original texture is preserved does not always maintain a strict relationship with the extent to which the original mineralogy has been preserved (i.e. there are examples of the original porphyritic texture being preserved and the igneous mineralogy being totally pseudomorphosed by alteration products, whilst on the other hand, there are also examples of the original texture being totally destroyed whilst remains of the original minerals are preserved.

2. A sequence of the protolith minerals in function of their resistance towards hydrothermal alteration can be established: glass (practically always altered) ➔ hornblende ➔ plagioclase ➔ quartz (almost always unaltered).

3. The following types of hydrothermal alteration have been identified (in ascending order of intensity): propylitic, sericitic, argillitic, and silicic. Late processes of carbonatation and the presence of residual gypsum have also been observed. A general spatial pattern has been established: the propylitic alteration occupies the outermost part of the deposit, whilst the silicic alteration is found in the inner part of the deposit and frequently is related to gold. The main characteristics of each type of mineralisation are decribed below.

A. Propilitic alteration: Amphiboles are completely transformed (chlorites±carbonates±massive

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quartz) whilst the plagioclases are only partially altered (sericites±carbonates±epidotes). The original texture of the protolith tends to be preserved.

B. Sericitic alteration: This involves a significant degree of transformation of the igneous paragenesis into sericite and quartz and, to a lesser extent, into chlorite. The mineralogy and original texture are more poorly preserved than in the former alteration. The transformation of hornblende to sericite ± chlorite is consistent with the crytallographic continuity of original hornblende, which is gradually lost concomitantly with an increase in the intensity of the alteration.

C. Argillitic alteration: This includes a massive transformation into clay minerals such as illites and smectites. Furthermore, the old plagioclase and hornblende phenocrystals are replaced by coarse - grained sericites. Masses of kaolinite and jarosite also appear frequently above the piezometric level.

D. Silification: This alteration has taken place to varying degrees and is locally associated with zones of intensive chloritization. The weakest form is that of a partial replacement of the original volcanic components by silica. In more advanced cases it has resulted in the formation of veins and masses of quartz. The economically interesting mineralisations are often associated with the most intensive silification. In the case of the mineralised veinlets the silica is massive and appears either in the form of granular aggregate xenomorphs or with typical open spaces growth textures (crustifications, comb structures, epitaxial growths of euhedral crystals etc.). Quartz crystals can often be found as pseudomorphs of older carbonate crystals, in some places containing remains of a sericitic and chloritic nature.

Apart from these alterations described above there are less frequent carbonates (dolomite or siderite, either in veins or replacing amphibole or plagioclase phenocrystals) and late residual gypsum.

4. MINERALISATION

In the Palai-Islica area the mineralisation generally appears in association with veins and veinlets of quartz enclosed within the altered volcanic rocks, or to a much lesser extent as disseminations. These veins form, in places, stockworks and layers of silica with sulphides.

The Palai-Islica mineralisation is of the Fe-Cu-Au type and consists principally of fine-grained, xenomorphous, iron and copper sulphides and quartz. The ore mineralogy comprises predominantly pyrite (four types of which have been identified) ±chalcopyrite with sphalerite, galena, pyrrhotite, bornite, tetrahedrite-tennantite, sulphosalts of Pb-Bi-Ag, marcasite and covellite as accessories. Also noteworthy are native gold and tellurides (Figure 2).

Along general lines we can deduce a formation sequence as follows:

Q➔Sph-Po-Cp-Bn➔Cp-Sph-Gn➔Mc-Chalcocite-Carbonates-Gypsum.

Lastly, in terms of the entire deposit, we can see compositional zoning in such a way that the central part is composed of an Fe-Cu-Au paragenesis, whilst in the more distal areas the proportion of Zn-Pb increases compared to Fe-Cu-Au.

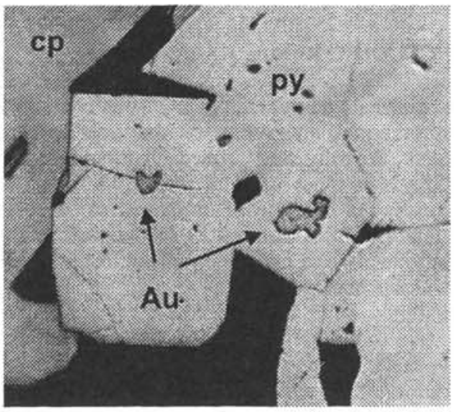

Figure 2. Native gold within pyrite (field width 400μ).

5. FLUID INCLUSIONS

We made a microthermometric study of the fluid inclusions contained in quartz crystals using a LINKAM THMSG 600 heating/refrigerating stage with a TMS93 controler (Fluid Inclusion Laboratory, University of Granada). A petrographic study of the fluid inclusions (FI) leads us to conclude that there are three types present: (1) a not very abundant, L+V+S, triphase FI; (2); an L+V biphase FI, by far the most common FI, with a varying degree of fill between 20% and 50%; and (3) few and very small, monophase FI, distributed haphazardly throughout the quartz crystals.

The microthermometric characteristics of each type of FI are the following:

Type 1. Hypersaline inclusions with a total Th between 304°C and 361°C and salinity between 38.5 and 43.4 wt% NaCl eq.

Type 2. Mostly inclusions with a eutectic temperature of between – 60°C and – 50°C, a temperature of final hydrohalite melting between – 54°C and – 30°C, an temperature of final ice melting between – 30.1 °C and –0.2 °C (salinity between 0.4 and 29.2 wt% NaCl eq.) and TH (L+ V➔L) = 120 at 350°C. We are dealing therefore with a polysaline fluid composed of H_2O-NaCl-$CaCl_2$. By comparing the TH *versus* salinity parameters we can distinguish

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two groups of fluid inclusions, one very variable in salinity (between 3 and 32 wt% NaCl eq.) and fairly constant temperature (250°C to 300°C) and the other low in salinity (between 5 and 10 wt% NaCl eq.) and lower homogenisation temperature, cooling from 250-300°C to 120°C. Due to the relatively small size of the third type of fluid inclusion we have not as yet been able to arrive at any microthemometric characterisation.

6. CONCLUDING REMARKS

The petrological and mineralogical characteristics of the hydrothermal alterations of the gold-bearing Palai-Islica deposit, their zoned distribution, ore mineralogy and types of fluid inclusions found in them correspond to those of an epithermal deposit within andesitic rocks, in which the mineralisation was controlled by the interaction of hot mineralising fluids with the host rocks.

Three fluids have been identified: (A) a high-temperature fluid (TH = 330°C ± 20°C) and salinity of between 41±3 wt% NaCl eq.); (B) a fluid of relatively constant temperature (TH ≈ 275°C) and very variable salinity, from 3 to 32 wt% NaCl eq.); and (C) a lower temperature fluid (TH = 120°C to 250°C) and a relatively constant salinity of 6±3 wt% NaCl eq. The transition between these fluids seems to have been responsible for the transport and precipitation of the metals studied. As far as gold is concerned, for example, this could have been transported in the form of complex and precipitated as a consequence of these complex' being destabilised by the brusque change in both temperature and salinity.

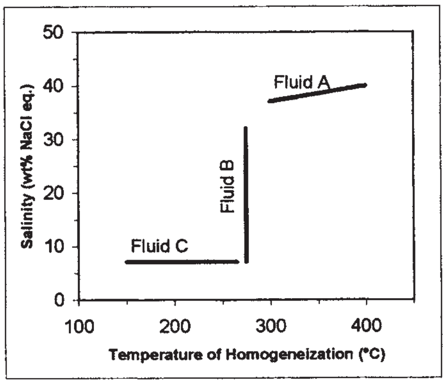

Figure 3. Temperature of homogeneization versus salinity of different fluid types.

As for the genetic processes (Figure 3), we are lead to believe that two processes occurred: (1) the mixing of a hot, saline fluid, represented by fluid A (magmatic?), which during its ascent mixed with another cooler fluid of much lower salinity (ground waters?), represented by fluid C. If this were the case then fluid B would represent the evolution between the two former extreme-condition fluids (A and C) and points to an isothermal mixing of the high salinity fluid A with the low salinity fluid C; (2) a second process, in which the variable degrees in the contents of some of the FI's and the presence of a monophase FI suggest a heterogeneous entrapment of the solutions, due possibly to boiling in certain specific areas. Nevertheless, at the moment we have not sufficient evidence to confirm this hypothesis of the existence of boiling because our samples are too shallow to have penetrated the boiling zones of the system.

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