

## Fluid inclusion study of the Arcos Deposit, Lugo, Spain: preliminary results

Martínez-Abad, Iker, Cepedal, Antonia and Fuertes-Fuente, Mercedes

Department of Geology, University of Oviedo, Arias de Velasco s/n, 33005, Oviedo, Spain.

### Introduction

The Arcos deposit (Lugo, NW of Spain) was discovered in 2001 by the Outokumpu company. This deposit along with the mineralization of Castro de Rey and Valiña constitutes the Villalba Gold District (Martínez-Abad et al., 2011a), is a newly defined gold mineralized area in the NW of Spain. Two types of ore deposits were distinguished in the district, a gold skarn with Bi-Te-Au metal assemblage and low temperature polymetallic deposits with Au-As-Sb and Ag-Pb-Zn±Cu±Au geochemical signatures. While both deposit styles are present in the Castro de Rey area, only the latter is present in Valiña and Arcos. Based on the geological and mineralogical characteristics of the mineralized areas, Martínez-Abad et al. (2011a) proposed an intrusion-related gold system (Lang et al., 2000) for the Villalba Gold district, where the Arcos deposit would represent the type of deposit formed peripheral to intrusions. In this paper we present a preliminary fluid inclusion study of the Arcos mineralization to establish the composition of the fluids involved in the mineralizing process and the P-T conditions during this event.

### Geological setting

The Arcos deposit is located in the West Asturian Leonese Zone (Julivert et al., 1972) of the Iberian Massif. The sedimentary rocks in Arcos consist of sandstones, slates and impure limestones of Lower Cambrian age that were folded, thrust, faulted and metamorphosed during the Variscan Orogeny (Martínez Catalán et al., 1990). During the Late-Variscan, the area was affected by N-S, E-W and NE-SW trending fault systems. Several rhyolitic dikes intruded along N-S faults, showing near vertical dips and low angle-sub-horizontal dips in sill-like apophyses. Spatially related to the rhyolites, low temperature polymetallic mineralization occurs disseminated in

altered host rocks and within veins (centimetrical in scale) located along fractures, bedding and cleavage planes.

### Arcos deposit

The Arcos mineralization was developed in at least two phases. The first consists of fine-grained sulphides: pyrite, arsenopyrite and gold bearing As-rich pyrite, in a matrix of quartz and/or calcite. This stage occurs disseminated in silicified impure limestone and calcareous slates (jasperoids) as well as infilling veins and fault breccias. Gold mainly occurs as refractory in the As-rich pyrite (Martínez-Abad et al., 2011b). In the second stage, which replaces the early one, base metals, Ag-rich tetrahedrite and Pb/Sb sulphosalts occur along with quartz, carbonate and chlorite. Eventually, younger veins with fluorite, carbonate and chlorite crosscut the mineralization stages cited above as well as the rhyolites dikes.

### Fluid inclusion study

This preliminary fluid inclusion study was carried out in samples of quartz from a mineralized jasperoid and samples of fluorite from the later veins cited above. Two types of aqueous-carbonic fluid inclusions were defined: type Lw-(c) in the jasperoid and type Lw-c in the fluorite.

Type Lw-(c) inclusions occur as small clusters or, sometimes, isolated in the quartz crystals. We consider them as primary according to Roedder's criteria (1984). Their morphologies are irregular, prismatic and elongated with sizes of between 8 and 16 µm. They contain two phases at room temperature and the volumetric fraction of the aqueous phase is from 65 to 75%. From the microthermometric results,  $T_e$  was around -20.8 °C. The main interval of  $T_m(\text{ice})$  is between -5.1 and -3.6 °C.  $T_m(\text{cla})$  was between 7.1 and 9.1 °C.  $T_h(\text{total})$  was between 187 and 268 °C to the liquid state, with the most values lying between 230 and 240 °C.

Type Lw-c inclusions occur in clusters and isolated in the fluorite crystals. We consider them as primary. Their morphologies are prismatic, elongated and negative crystals with sizes of between 30 and 60  $\mu\text{m}$ . They contain three phases at room temperature and the volumetric fraction of the aqueous phase is between 45 and 80%. Some of these inclusions contain a crystalline solid, which may be a carbonate. There is no sign of dissolution during the heating experiments and this solid is anomalously large compared to its host inclusion, therefore we interpreted it as a trapped mineral. From the microthermometry results,  $T_m(\text{CO}_2)$  was between -57.1 and -56.6  $^{\circ}\text{C}$ .  $T_h(\text{CO}_2)$  varied from 25.6 to 30.5  $^{\circ}\text{C}$  to both liquid and vapour state.  $T_{\text{eut}}$  was around -20.8 $^{\circ}\text{C}$ . The main interval of  $T_m(\text{ice})$  was between -0.5 and -3.7  $^{\circ}\text{C}$ .  $T_m(\text{cla})$  was between 8.1 and 9.9  $^{\circ}\text{C}$ .  $T_h(\text{total})$  was between 186 and 265  $^{\circ}\text{C}$  to the liquid state, with most values lying between 220 to 230  $^{\circ}\text{C}$ .

## Discussion

In type Lw-(c), the presence of a volatile component is only detected from clathrate formation. Since  $T_m(\text{cla})$  is below 10  $^{\circ}\text{C}$ , the main volatile in this type of inclusion is probably  $\text{CO}_2$ . Salinity from  $T_m(\text{cla})$  is between 2.7 and 6.1 mass% NaCl. In type Lw-c, the  $T_m(\text{CO}_2)$  close to -56.6  $^{\circ}\text{C}$  and  $T_m(\text{cla})$  below 10  $^{\circ}\text{C}$  indicate that the main volatile is  $\text{CO}_2$ . In this case, salinity from  $T_m(\text{cla})$  is between 2.9 and 5.3 mass% NaCl. In both types,  $T_{\text{eut}}$  indicates NaCl as the most probable solute in the aqueous phase, according to Potter & Brown (1977).

Bulk composition, density and isochores of representative fluid inclusions were calculated to estimate the minimum P-T conditions and composition of the fluid related to ore deposition in the studied jasperoid and the fluid related to later fluorite deposition. These data were calculated using the "Clathrate" and "Fluids 1" packages (Bakker, 1997, 1998, 2003). The composition of the fluid involved in the ore deposition in jasperoids and trapped by type Lw-(c) inclusions is  $x(\text{H}_2\text{O}) = 0.91\text{--}0.94$ ,  $x(\text{CO}_2) = 0.036\text{--}0.046$ ,  $x(\text{NaCl}) = 0.008\text{--}0.016$  with a density range of 0.69–0.78  $\text{g/cm}^3$ . Isochores show that for a minimum trapping temperature of 300  $^{\circ}\text{C}$ , the minimum corresponding pressures are below 500 bars.

The composition of the fluid involved in the fluorite deposition and trapped by type Lw-c inclusions is  $x(\text{H}_2\text{O}) = 0.80\text{--}0.89$ ,  $x(\text{CO}_2) = 0.07\text{--}0.15$ ,  $x(\text{NaCl}) = 0.008\text{--}0.015$  with a density range of 0.83–0.89  $\text{g/cm}^3$ . Isochores show that the trapping of this low-salinity aqueous carbonic fluid took place under the minimum conditions ( $T_h, P_h$ ) of between 210 and 242  $^{\circ}\text{C}$  at pressures from 275 to 605 bars.

Carbonic and aqueous carbonic fluids characterize the intrusion-related gold systems environment. The temperatures and pressures attending precipitation of gold and related metals span broad ranges of <200  $^{\circ}\text{C}$  to >600  $^{\circ}\text{C}$  and <0.5 to >3.0 kbar (Lang et al., 2001). According to these authors, the metallic assemblage described in Arcos and the composition and P-T conditions of the fluids related to ore deposition in the studied jasperoids are those expected in deposits formed peripheral to intrusions. Moreover, the fluid related to fluorite deposition represents a later stage of aqueous carbonic fluid circulation under similar P-T conditions.

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Autor(en)/Author(s): Martinez-Abad Iker, Cepedal Antonia, Fuerte-Fuente Mercedes

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