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Gold mineralisations in the Canan area, Lepaguare District, east-central Honduras: Fluid inclusions and geochemical constraints on gold deposition

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ABSTRACT

Gold mineralisations in the Canan area (Honduras) occur within altered metamorphic rocks crossed by quartz veins which filled the fractures where the hydrothermal fluids carrying gold flowed. Quartz crystals of the veins contain abundant fluid inclusions which have been divided into four main types on the basis of the petrographic features and microthermometric data. The association of L-rich and V-rich inclusions with the same major components supports boiling at the time of entrapment. The trapped hydrothermal fluid consists of an aqueous solution (0.9–4.8 wt.% NaCl equivalent) plus a CO_2–CH_4-bearing bubble. Some fluid inclusions contain graphite of hydrothermal origin. Microthermometric and spectroscopic data on fluid inclusions indicate that hydrothermal fluids carrying gold were at T = 300 °C, P = 500–1400 bar, log $fO_2 \sim -37.6 \pm 2.5$ and with a pH value of 2.9 ± 0.4. Large amounts of sulphides (mainly pyrite) are associated with gold. We infer that Au was transported as Au–S complex, in particular as Au(HS)°. The activity of sulphur in the hydrothermal fluids was at least 10^{-2}. The precipitation of gold can be related to several processes that reduced the stability of AuHS°: 1) boiling and vapour loss following the pressure drop caused both by fracture opening and fluid uprise, 2) sulphidation as a result of the presence of Fe^{2+} (and other metal cations) from the mineralogical alteration (mainly of biotite and chlorite) in the wall-rocks and 3) hydrothermal alteration of feldspars and micas into kaolinite and diaspore with increase in pH of the hydrothermal fluids. The mineralogical, petrological, geochemical features and the geological setting are broadly consistent with those of orogenic-type gold deposits.

1. Introduction

Over the past decades, several studies on the relationships between the gold deposits hosted in quartz veins and alteration halos due to hydrothermal fluid infiltration have been published (e.g., Andrada de Palomera et al., 2012; Boiron et al., 1991; Cepedal et al., 2013; Esmaeily et al., 2012; Garofalo et al., 2002; Phillips and Powell, 2009). Intensive host-rock alteration around the quartz veins shows distinct mineralogical changes that are indicative of metasomatic processes due to hydrothermal fluids. The amount of precipitation of native elements and the type of hydrothermal alteration minerals are strongly dependent on the physical–chemical nature of the mineralising fluids and the host-rock composition. In several gold deposit, the mineral assemblages occurring in the quartz veins and in the associated altered wall-rocks have been described (e.g., Botros, 2004; Callaghan, 2001; Deksissa and Koeberl, 2005; Miur, 2002). On the contrary, the chemical features of the fluids associated with the gold deposition and rock alteration are not yet fully understood (Klein et al., 2002; Yang et al., 2006; Su et al., 2008).

The study of fluid inclusions in minerals from hydrothermal veins is very important to infer the composition of the fluids that have deposited gold and other associated metals. The fluid inclusions contain low-salinity mixed aqueous–carbonic fluids, where H_2O and CO_2 are the major molecular components, CH_4 is a common minor component, and N_2 is present in trace (Groves et al., 2003, and references therein; Ridley and Diamond, 2000). The CO_2 concentration is always greater than 5 mol%; the relative amounts of H_2O, CO_2, and CH_4 may vary as a consequence of phase separation (boiling) during pressure fluctuations (Spooner et al., 1987). The aqueous component of the fluids contains 1–15 wt.% NaCl equivalent (Ridley and Diamond, 2000). Other types of fluids are H_2O-poor carbonic fluids and low- to moderate-salinity aqueous fluids. Pure carbonic fluids or pure aqueous low-salinity fluids are rare (Ridley and Diamond, 2000). However, there is no scientific consensus regarding the origin of Au-carrying fluids. In the orogenic gold deposits, the distinction between magmatic and metamorphic origin for fluids is difficult due to the close association between magmatic and metamorphic rocks and the strong structural control. Furthermore, in such a complex situation, fluids from different sources may extensively mix along their pathways (Ridley and Diamond, 2000).

The Honduras region (Central America) is a well-known metallogenic province, which is represented by several areas of hydrothermally altered

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metamorphic rocks that are related to the Late Cretaceous–Early Tertiary magmatic systems extending from Guatemala to Costa Rica (e.g., Roberts and Irving, 1957; Samson et al., 2008; Sundblad et al., 1991; Williams-Jones et al., 2010). However, with the exception of gold deposits in the Rosario Mining District (San Juancito Mts.; Carpenter, 1954) and Minas de Oro District (Central Highlands; Drobe and Cann, 2000), very little is known about the genesis of the gold deposits in this region. Recent investigations in Central–Eastern Honduras (Bersani et al., 2009; Mattioli et al., 2014) were focused on the gold deposits in the Canan area (Lepaguare District, Olancho Department). In this location, gold mineralizations are hosted in metamorphic rocks from sub-greenschist to granulite facies. Gold is found in both quartz veins and disseminated (with sulphides) in the altered host-rock. Particularly, the quartz of the veins is rich in fluid inclusions that were trapped during hydrothermal growth or because of the healing of the fractures.

In this paper, we report a detailed fluid inclusions study of the Au-quartz veins from Canan that integrates and completes the work of Bersani et al. (2009). Our purpose is to contribute to the knowledge of the physico-chemical characteristics of the Au-mineralising fluids and the conditions of transport and deposition of gold in orogenic environments.

2. General setting

2.1. Geodynamic and geological background

The geodynamic evolution of Honduras is the result of the complex interaction along a triple junction among the North American plate, the Cocos plate and the Caribbean plate (e.g., Guzman-Speziale, 2001; Mann and Burke, 1984, 1988; Rogers and Mann, 2007; Silva-Romo, 2008). This interaction is responsible for the Central American subduction system, which consists of a north-eastwards slab subduction under the Caribbean and the North American plates. The subduction is oblique to the plate boundary, and both transpressional and transtensional tectonics seem to be active (Alvarez-Gòmez et al., 2008).

The Caribbean plate includes minor crustal blocks like the Chortis block, which has traditionally been referred to the Precambrian–Paleozoic continental nucleus of Northern Central America (Rogers et al., 2007; Fig. 1). The Chortis block is separated from the North American plate by the Motagua–Polochic sinistral transform fault (northern side), and from the Cocos plate by the Middle American Trench (Fig. 1). Recent studies (e.g., Rogers and Mann, 2007; Rogers et al., 2007) show that the Chortis block can be divided into different tectonic terranes. Its Paleozoic metamorphic basement consists of well-foliated, graphitic and sericitic schists (Cacaguapa Schists; Carpenter, 1954; Horne et al., 1976) that extensively crop out in the study area (Fig. 1A). This Paleozoic basement is overlain by a fairly thick sequence of Jurassic to Cretaceous sedimentary rocks which are comprised of three main units: Agua Fria and Atima formations, belonging to the Yojoa Group, and Valle de Angeles Formation (Mills et al., 1967; Rogers et al., 2007). During the Upper Cretaceous–Lower Tertiary (Ratschbacher et al., 2009), the Paleozoic basement and its Mesozoic sedimentary cover were intruded by granodiorite plutons which crop out in the south and in the north-northwest sectors of the investigated area (Fig. 1A).

The Canan area is located in the Lepaguare District, between the southern margin of the Lepaguare Valley and Rio Guayape, about 100 km north-east of Tegucigalpa (Fig. 1). The Lepaguare valley represents an important boundary between extensional and strike–slip structures mainly related to the Guayape fault system, which is one of the major tectonic structures within the Chortis block of the Caribbean Plate. In particular, the Canan mining area is located between the La Rosa–Campamento and Juticalpa–Rio Jalán fault systems (Fig. 1A), which represent different strands of the main Guayape fault system and have main left lateral transtensional kinematics. The main gold mineralisation occurs just where the northern shear zone (Dos Bocas–Quebrada Los Mochos) cuts the N–S striking faults at Dos Bocas (Fig. 1B).

2.2. Canan ore deposit

The Canan ore deposit roughly corresponds to the extent of the quartz veins and hydrothermally altered host-rocks. A summary of the main rock types and mineral assemblages of the different zones of the Canan ore deposit, as well as those of the unaltered metamorphic host-rocks, is reported in Table 1.

The quartz veins are hosted in the Cacaguapa Schists and have a variable thickness, ranging from 2 to 30 cm, with an average of 15 cm; at the intersections of the two fracture systems the thickness of the quartz-veins significantly increases up to 1 m. The veins exhibit a variety of textures, including massive, ribboned, banded and stock-works with anastomizing gashes and dilations. Quartz is always the main phase of the veins, ranging from 90 to 100 vol.%, and two types of textures can occur locally, even in the same vein (Table 1). Quartz crystals often enclose sulphides, sulphosalts, Fe-oxides–hydroxides, and native elements such as gold, silver, bismuth and arsenic. Gold is rare in the quartz veins, occurs as inclusions in yellow, small (2–10 μm) grains of pyrite and fills small cracks in a complex association with pyrite–chalcopyrite. The quartz crystals of the veins are often rich in fluid inclusions.

The hydrothermally altered zones extend from the veins outwards from few centimetres to 1.5 m in thickness, depending on the host-rock and vein width. Starting from the unaltered metamorphic host-rock, we distinguished three main alteration zones of the wall-rocks, which graded into each other and represented different stages of the same alteration process due to variation of the fluid/rock ratio (Robb, 2010; Table 1). The distal zone is marked by the presence of chlorite (clinochlore type). The intermediate zone is volumetrically the largest one and is characterised by the dominant presence of muscovite. The association of quartz + muscovite + pyrite is prevailing; chalcopyrite, arsenopyrite, galena, sphalerite, Fe-oxides–hydroxides, phosphates, sulphosalts and native elements occur in variable amounts. Native elements are represented by gold, silver and Platinum Group Elements. This zone smoothly grades into a proximal zone with a progressive increase in clay minerals and vuggy silica. Clay minerals, mainly kaolinite, replace aluminosilicates such as feldspars. Sulphides, hematite, goethite, chlorite and rutile can be also present in the proximal zone, where partly limonitized, disseminated or veinlet-type pyrite is the main ore mineral. The presence of goethite and limonite support a late interaction with meteoric water.

2.3. Gold mineralisation

The grain size of gold is generally from 2 μm to 1 mm in diameter. Based on morphology, grain-size, fineness and composition, we were able to distinguish three types of gold. Type-1 gold refers to grains with a rounded shape (ovoid, spherical, elongated) and striated surfaces, and is 20–50 μm (rarely up to 1 mm) in size. This type of gold occurs in the intermediate zone. Small grains (100 μm to 1 mm) of Ag and other native elements (PGEs) are rarely associated with Type-1 gold. Type-2 gold is 5–10 μm in size, occurs as euhedral–subhedral grains and is directly attached to (or included in) pyrite and arsenopyrite. This type of gold is generally present in the quartz-veins. Type-3 gold occurs as sub-microscopic (<2 μm) euhedral grains often intimately associated in aggregates (10–20 μm in size). It also forms dense clusters on the surface of Type-1 gold. Type-3 gold contains Ag up to ~15 wt.%.

3. Methods

The studied samples are from surface trenches (10–50 m in length, 2–3 m in depth) and underground channels (up to 10 m in length) around the quartz veins. All the samples were collected underneath