

Environment of Ore Deposition in the Cerro Quema Gold-Copper Deposit (Azüero Peninsula, Panama)

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INTRODUCTION.

The Cerro Quema (CQ) Au-Cu deposit is located in the Azüero Peninsula, SW Panama (Fig. 1). Previous studies were carried out on the economic potential of gold mining in the area (Torrey and Keenan, 1994) and did not focus on understanding the genesis of the deposit. Therefore the origin of fluids related to the ore and alteration processes remained unclear.

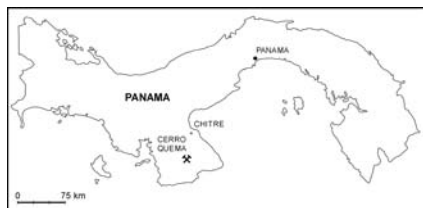


fig. 1. Location of the Cerro Quema Au-Cu deposit.

In the present work, mineralogical, fluid inclusion and stable isotope data (ore and alteration minerals) are presented in order to understand the origin and evolution of the hydrothermal system in the Cerro Quema district.

GEOLOGIC SETTING.

Panama microplate is situated in the southern part of Central American and constitutes the youngest segment of the land bridge between North and South American plates.

During Late Cretaceous this region was characterized by the subduction of the Farallon plate beneath the Caribbean plate. Subsequently, an arc-magmatism developed on top of the Caribbean plate. The Cerro Quema Au-Cu deposit is hosted by fore-arc basin rocks of this volcanic arc.

The study area is constituted by volcanic and volcanoclastic sediments interbedded with hemipelagic

limestones, submarine dacite lava domes and by crosscutting basaltic-andesitic dikes, belonging to the Río Quema Formation (RQF), a fore-arc infill sequence (Corral et al., in press).

The Cerro Quema Au-Cu deposit is constituted by several mineable bodies, named La Pava, Cerro Quemita and Cerro Quema, related to an E-W trending regional fault system. Estimated gold resources are 10⁶ metric tonnes with an average gold grade of 1.26g/t (Torrey and Keenan, 1994).

HYDROTHERMAL ALTERATION AND MINERALIZATION.

The Cerro Quema deposit is characterized by the presence of a widespread hydrothermal alteration. The alteration pattern is clearly fault controlled, following E-W trending regional faults. Alteration develops concentric halos. Mineralization is hosted by andesites and dacitic lava domes of the RQF.

A mineralogical study of the hydrothermal alteration has been carried out on surface and drill core samples from the La Pava, Cerro Quemita and Cerro Quema bodies, using optical microscopy, SEM-EDS and XRD. Results show an alteration pattern characterized by the presence of three zones:

- An inner zone, characterized on surface by vuggy silica with hematite, goethite and rutile. At depth it has quartz, alunite-natroalunite, aluminium-phosphate-sulphate minerals (APS), dickite, barite, pyrite, enargite and rutile. This mineral paragenesis corresponds to the advanced argillic alteration zone.
- An outer rim, composed of kaolinite, illite and interlayered illite-smectite in

both, surface exposures and at depth, corresponds to the argillic alteration zone.

- A propylitic zone, only observed in drill core samples and apparently unrelated to the previous alteration zones, has pyrite, chlorite, calcite and siderite.

The ore minerals consist of disseminated pyrite, chalcopyrite, enargite and a poorly developed stockwork of quartz, pyrite, chalcopyrite and barite with traces of galena and sphalerite. Gold occurs as disseminated microscopic grains of native gold and as "invisible gold" within the crystalline structure of pyrite (Corral, 2008), in the advanced argillic alteration zone.

FLUID INCLUSION AND STABLE ISOTOPE DATA.

Microthermometric data has been obtained from secondary fluid inclusions in primary quartz phenocrysts from the volcanic host rock affected by the advanced argillic alteration. Due the size (up to 10µ) only a few measurements could have been made. Fluid inclusions are biphasic (L+V) at room temperature and depict homogenization temperatures (Th) from 190 to 230°C (n=7) and melting ice temperatures (Tmi) from -0.1 to -3.0°C (n= 5). Stable isotopes ratios have been analyzed on vuggy quartz, kaolinite-dickite, alunite-natroalunite, pyrite, enargite and barite. The results are shown in Table 1.

DISCUSSION

The presence of vuggy silica, alunite-natroalunite and enargite in addition to the hydrothermal alteration pattern are compatible with a high sulfidation epithermal system. Assuming that secondary fluid inclusions

palabras clave: Cerro Quema, Alunite, Pirita, Isotopos Estables.

key words: Cerro Quema, Alunite, Pyrite, Stable Isotopes.

	$\delta^{18}\text{O}$	δD	$\delta^{34}\text{S}$
Quartz	+10.4 to +12.0 (n=3)	-	-
Kaolinite	+14.0 to +17.4 (n=4)	-30.0 to -44.0 (n=6)	-
Alunite	+1.8 to +9.8 (n=8)	-	+15.0 to +17.4 (n=4)
Barite	+2.7 to +11.6 (n=5)	-	+14.1 to +16.9 (n=5)
Pyrite	-	-	-7.2 to -11.7 (n=10)
Enargite	-	-	-9.3 to -11.2 (n=2)

Table 1. Isotope values (in ‰) of the different mineral species.

in quartz phenocrysts formed during the ore deposition-alteration stages, the Th/Tmi data indicate that the hydrothermal system was dominated by low salinity (up to 5% NaCl eq.) and moderate temperature (190-230 °C) fluids.

With a mean deposition temperature of 240 °C (data from pyrite-alunite isotope geothermometry), the $\delta^{18}\text{O}$ of the fluid in equilibrium with vuggy quartz, calculated from the equation of Mathshisa et al., (1979), ranged from +1.0 to + 2.6‰, pointing to the presence of surface waters in the system during vuggy quartz precipitation. For a similar temperature, calculated δD and $\delta^{18}\text{O}$ of hydrothermal fluids during kaolinite-dickite formation, ranged from -46 to -60‰ and from +10.3 to +13.7‰, respectively (using the equations of Gilg and Sheppard, (1996) and Sheppard and Gilg, (1996) for deuterium-water and oxygen-water fractionations). The high $\delta^{18}\text{O}$ values suggest an isotopic exchange of mineralizing fluids with host and enclosing rocks, especially volcanoclastic sediments and limestones, during kaolinite-dickite formation.

The high $\delta^{34}\text{S}$ values of alunite ($\approx +17\text{‰}$) together with the negative values of coexisting pyrite and enargite are compatible with a magmatic hydrothermal origin of alunite (Rye et al., 1992). The $\delta^{34}\text{S}$ values of barite, similar to alunite, suggest a related sulfur source.

The $\delta^{34}\text{S}$ values of pyrite and enargite coexisting with alunite, reflect a isotopic

equilibrium between H_2S and SO_4^{2-} in the fluids (Fig. 2). If this is the case, coexisting pyrite-alunite pairs give equilibration temperatures between 224 and 274 °C (Ohmoto and Rye, 1979), slightly higher than the Th's measured in the fluid inclusions. This difference might be due to the P effect on the trapping temperature of the fluids during mineralizing event.

In contrast with the sulfur isotope composition, the $\delta^{18}\text{O}$ of alunite shows a wider range of values (+1.8 to +9.8‰). Calculated $\delta^{18}\text{O}$ of fluids in equilibrium with alunite (using the equation of Stoffregen et al, 1968) at a temperature of 240 °C, range from -1 to +7‰. However, calculated $\delta^{18}\text{O}$ of fluids during barite precipitation (using the equation of Lloyd, 1968), range from +4 to +4.8‰. These data suggest a mixing in different proportions between surface and magmatic fluids during alunite-natroalunite and barite precipitation.

CONCLUSIONS.

The Cerro Quema Au-Cu deposit formed due to a high sulfidation hydrothermal system as deduced from the mineralogy and geochemical data. Mineralization is related to E-W trending faults that affected dacite lava domes and andesites of the RQF. Ore mineralogy is constituted by native gold, pyrite, chalcopyrite, enargite, and minor amounts of sphalerite and galena. Hydrothermal alteration is represented by an advanced argillic, argillic, and minor propylitic halos. Ore

deposition took place from fluids of low salinity up to 5% wt NaCl eq.) and moderate temperatures ($\approx 240\text{ °C}$). S isotope data of sulfides and sulfates indicate a sulfur source of magmatic origin. O and D data of silicates and sulfates (quartz, kaolinite, alunite-natroalunite and barite) suggest an important contribution of surface fluids during sulfate precipitation and hydrothermal alteration.

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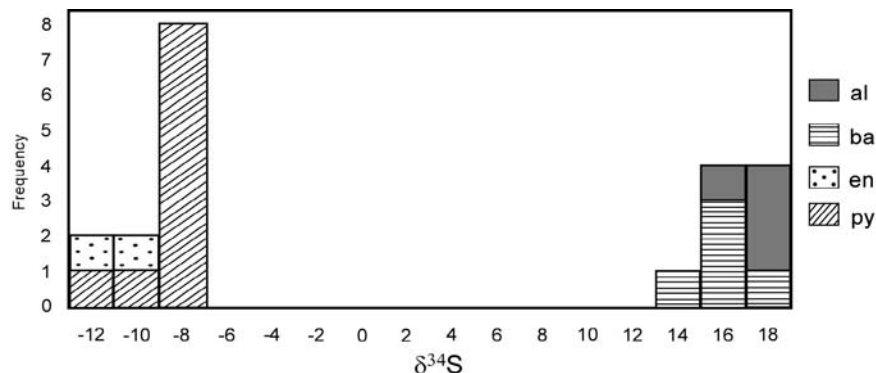


fig 2. $\delta^{34}\text{S}$ values of al: alunite, ba: barite, en: enargite and py: pyrite