Ore Geology Reviews 80 (2017) 947–960

Contents lists available at ScienceDirect

Ore Geology Reviews

journal homepage: www.elsevier.com/locate/oregeorev

Origin and evolution of mineralizing fluids and exploration of the Cerro Quema Au-Cu deposit (Azuero Peninsula, Panama) from a fluid inclusion and stable isotope perspective

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ARTICLE INFO

Article history:
Received 3 April 2016
Accepted 5 September 2016
Available online 6 September 2016

Keywords:
Cerro Quema
fluid inclusions
stable isotopes
alunite-pyrite
exploration

ABSTRACT

Cerro Quema is a high sulfidation epithermal Au-Cu deposit with a measured, indicated and inferred resource of 35.98 Mt. @ 0.77 g/t Au containing 893,600 oz. Au (including 183,930 oz. Au equiv. of Cu ore). It is characterized by a large hydrothermal alteration zone which is interpreted to represent the lithocap of a porphyry system. The innermost zone of the lithocap is constituted by vuggy quartz with advanced argillic alteration locally developed on its margin, enclosed by a well-developed zone of argillic alteration, grading to an external halo of propylitic alteration. The mineralization occurs in the form of disseminations and microveinlets of pyrite, chalcopyrite, enargite, tennantite, and trace sphalerite, crosscut by quartz, barite, pyrite, chalcopyrite, sphalerite and galena veins.

Microthermometric analyses of two phase (L + V) secondary fluid inclusions in igneous quartz phenocrysts in vuggy quartz and advanced argillically altered samples indicate low temperature (140–216 °C) and low salinity (0.5–4.8 wt% NaCl eq.) fluids, with hotter and more saline fluids identified in the east half of the deposit (Cerro Quema area).

Stable isotope analyses (S, O, H) were performed on mineralization and alteration minerals, including pyrite, chalcopyrite, enargite, alunite, barite, kaolinite, dickite and vuggy quartz. The range of $\delta^{34}S$ of sulfides is from −4.8 to −12.7‰, whereas $\delta^{34}S$ of sulfates range from 14.1 to 17.4‰. The estimated $\delta^{34}S_{\Sigma S}$ of the hydrothermal fluid is −0.5‰. Within the advanced argillic altered zone the $\delta^{34}S$ values of sulfides and sulfates are interpreted to reflect isotopic equilibrium at temperatures of ~240 °C. The $\delta^{18}O$ values of vuggy quartz range from 9.0 to 17.5‰, and the $\delta^{18}O$ values estimated for the vuggy quartz-forming fluid range from −2.3 to 3.0‰, indicating that it precipitated from mixing of magmatic fluids with surficial fluids. The $\delta^{18}O$ of kaolinite ranges from 12.7 to 18.1‰ and δD from −103.3 to −35.2‰, whereas the $\delta^{18}O$ of dickite varies between 12.7 and 16.3‰ and δD from −44 to −30. Based on $\delta^{18}O$ and δD, two types of kaolinite/dickite can be distinguished, a supergene type and a hypogene type. Combined, the analytical data indicate that the Cerro Quema deposit formed from magmatic-hydrothermal fluids derived from a porphyry copper-like intrusion located at depth likely towards the east of the deposit. The combination of stable isotope geochemistry and fluid inclusion analysis may provide useful exploration vectors for porphyry copper targets in the high sulfidation/lithocap environment.

1. Introduction

The Azuero Peninsula in southwestern Panama shows evidence of widespread hydrothermal activity as indicated by the existence of several Au-Cu mineral occurrences including the Cerro Quema high sulfidation epithermal Au-Cu deposit (Fig. 1). The Cerro Quema deposit was discovered in 1988 by the Compañía de Exploración Minera S. A. (CEMSA) during geological and metallogenetic studies by the United Nations Development Program (UNDP; 1965), and today is one of the most prospective exploration projects in Panama. The Cerro Quema deposit consists of several mineralized zones: from east to west, Cerro Quema, Cerro Quemita, and La Pava (Fig. 2). The measured, indicated and inferred resources as of 2014 are 35.98 Mt. @ 0.77 g/t Au containing a total of 893,600 troy ounces Au of which 183,930 troy ounces are gold

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http://dx.doi.org/10.1016/j.oregeorev.2016.09.008
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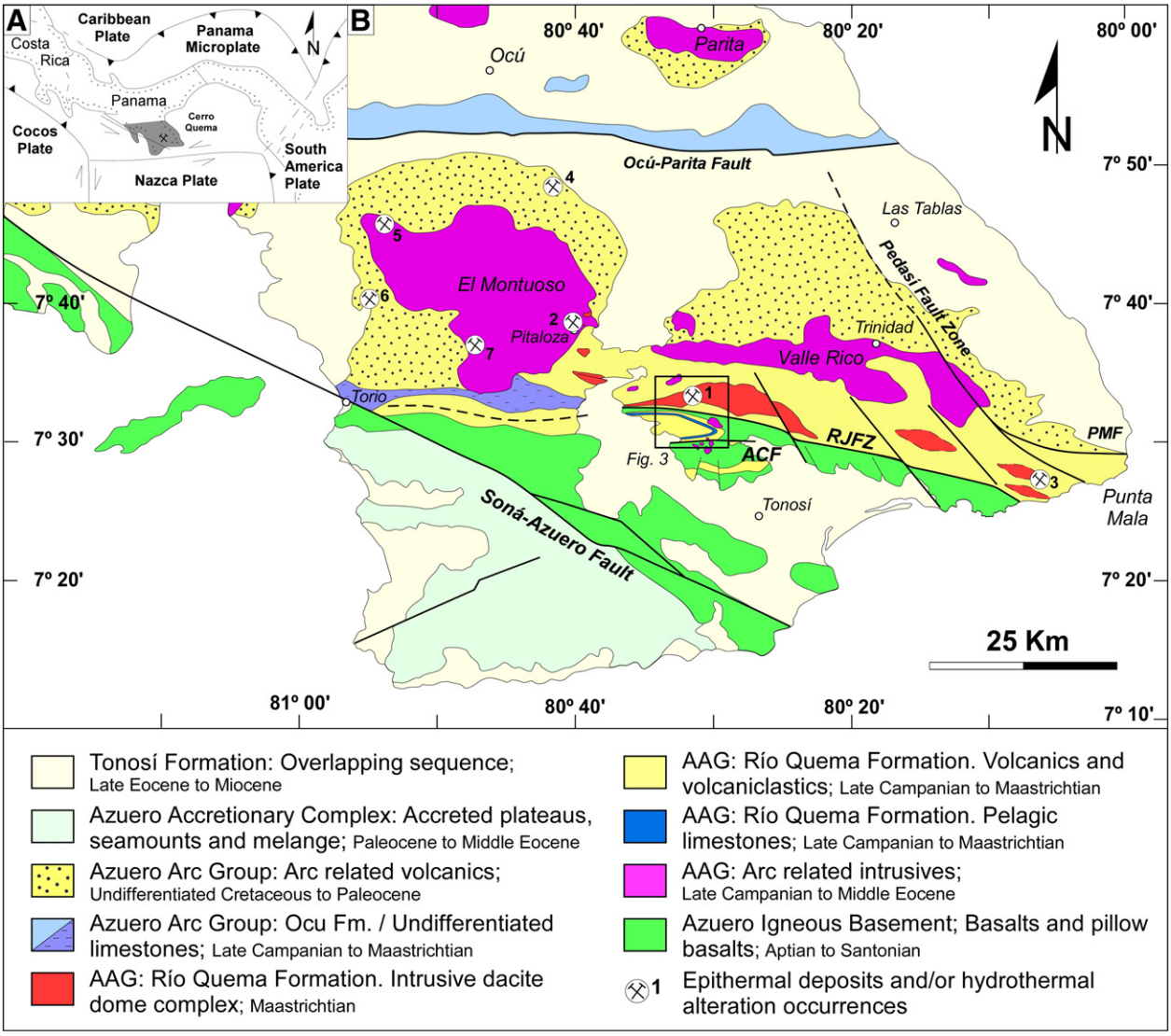

Fig. 1. A) Plate tectonic setting of south Central America. B) Simplified geological map of the Azuero Peninsula and mineral occurrences. AAG: Azuero Arc Group, ACF: Agua Clara Fault, PMF: Punta Mala Fault, RJFZ: Río Joaquín Fault Zone (After Dirección General de Rercursos Minerales (DGRM) (1976); Buchs et al., 2010; Corral et al., 2011, 2013). Mineral ocurrences: 1) Cerro Quema, 2) Pitaloza, 3) Juan Díaz, 4) Las Minas, 5) Quebrada Barro, 6) Quebrada Iguana, 7) Cerro Viejo.

equivalent of the contained copper (Sutcliffe et al., 2014). Additional mineralized bodies are found to the east —the Cerro Idaida, East Quema Jungle, and Cerro Pelona prospects— but the Au and Cu grade and content of these prospects have not yet been determined.

The first geological studies of the Azuero Peninsula (e.g., Del Giudice and Recchi, 1969; Ferencic, 1970; Kesler et al., 1977) noted the potential for Au and Cu deposits in the region. Later works specifically on the Cerro Quema deposit focused on geology (Horlacher and Lehmann,

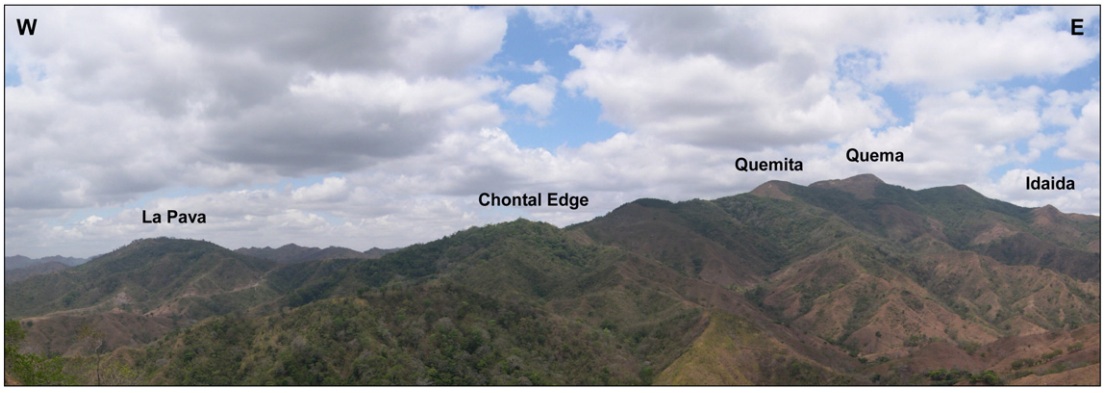

Fig. 2. Overview of Cerro Quema including La Pava, Cerro Quemaita, Cerro Quema and Cerro Idaida ore zones.