Epithermal gold mineralization in Costa Rica, Cordillera de Tilarán – mineralogy and fluid inclusions

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Epithermal gold mineralization in quartz veins forms part of a large ore belt extending in the NW–SE direction parallel to the Cordillera de Tilarán, Costa Rica. It is confined to the Aguacate Group volcanic arc, which consists of tholeiite basalt to basaltic andesite lavas accompanied by abundant pyroclastics and breccias of andesite composition. This group of effusive rocks is of Miocene to Pliocene age (2.1 to 23.0 Ma, Bellon and Tournon 1978). The Aguacate Group is discordantly overlain by the Monteverde Formation, which is Pleistocene in age (2.2 to 1.0 Ma, Alvarado et al. 1992). The Monteverde Formation is characterized by the occurrence of more acid, calc-alkaline volcanism with dominant andesites and by the absence of regional hydrothermal alteration.

Volcanites of the Aguacate Group were intruded by granitoids of the Guacimal pluton exposed over an area of *c.* 15 × 6 km, and elongated in the NW–SE direction. Grey porphyric biotite granite is the dominant rock type of the Pluton, whereas more mafic varieties (monzodiorites to gabbros) are much less abundant. The K–Ar dating yielded ages of 7.2 to 3.9 Ma (Alvarado et al. 1992).

Epithermal gold-bearing mineralization corresponding to the SADO type (Mosier and Sato 1986) occurs exclusively in the Aguacate Group. Gold-bearing quartz veins are related to fault and fracture of steep inclinations, accompanied by pronounced hydrothermal alteration. The key tectonic zones strike NW–SE but the majority of the ore veins are controlled by local extensional structures of Riedel shear type in the NE–SW, N–S to NNW–SSE directions. The brecciation, mylonitization and healing of deformed structures suggest that three main pulses of mineralization took place during the hydrothermal process (Mixa et al. 2011).

The age of the mineralization, is estimated in the period between the intrusion of the Guacimal Pluton and effusions of the discordant volcanic Monteverde Formation, which is devoid of mineralization (i.e. between *ca.* 6.0 and 2.1 Ma).

The gold is present as electrum (30 and 42 mass % Ag) grown as tiny inclusions up to 25 µm in size grown in quartz, pyrite and arsenopyrite. The other ore minerals are chalcopyrite, galena, sphalerite and marcasite and less abundant to scarce acanthite, pyrargyrite, greenockite, covellite, bornite and cassiterite. The principal elements exhibiting significant positive correlations with Au are Ag, Sb, As, Pb and Hg.

The Cu–Pb–Zn sulphides, which occasionally form massive vein and nest-like ores, prevail in the Guaria–Guacimal district and the Moncada mine. The gold content in this type of mineralization is low or negligible.

Three main generations of quartz suggest a multi-stage hydrothermal process. The first includes fine-grained massive quartz of grey-white, grey and grey-black colour exhibiting greasy to glassy lustre. This type of quartz forms several meters-thick veins, which are the richest in gold. The Au contents commonly range in tens ppm and exceptionally even exceed 100 ppm. The second generation is represented by coarse prismatic quartz, often forming druses filled with crystals max. 1 cm in size. This quartz type is frequently accompanied by base-metal sulphides with increased gold contents. The third generation represents the final stage of the hydrothermal ore-forming process, producing fine-grained snow-white quartz of sugary appearance. Au contents do not exceed 10 ppm.

Primary and pseudosecondary inclusions in quartz I occur mostly in the apical parts of small euhedral quartz crystals. These inclusions show variable *φ*(liq) ranging from 0.5 to 0.95. Due to the variable *φ*(liq), the inclusions in clusters with *φ*(liq) of 0.9 were measured, and the temperatures of homogenization (T_h) fluctuated from 156 to 248 °C (Fig 1). The salinity of an aqueous solution varied from 0.2 to 2.9 eq mass% NaCl. NaCl is assumed to be the major compound of aqueous solutions (T_e = –22.1 °C).

The growth zones of quartz II are characterized by primary and pseudosecondary H_2O inclusions, with *φ*(liq) varying from 0.7 to 0.8. Rare accidental solids can be found in these inclusions. The temperatures of homogenization range between 182 and 288 °C, and the salinity of an aqueous solution is very low, not exceeding 2.1 eq mass NaCl. The eutectic temperature (T_e = -23.4 to –31.0 °C) indicates an H_2O-NaCl, ± KCl, ± $FeCl_2$, ± $MgCl_2$ type of solutions.

Fine-grained euhedral crystals of quartz III rim the coarse-grained quartz II. The primary and pseudosecondary inclusions show variable *φ*(liq) (0.5–0.95). Liquid-only or vapour-only inclusions were also found. Due to the variable *φ*(liq) the inclusions in clusters with *φ*(liq) = 0.8 to 0.95 were measured and the obtained T_h values range from 146 to 248 °C, and the salinity of an aqueous solution from 0.2 to 2.7 eq mass% NaCl.

Round to irregular grains of sphalerite from the Guacimal gold deposit are enclosed in quartz I. Secondary H_2O inclusions with consistent *φ*(liq) (0.7 – 0.8) were observed along healed microfractures in sphalerite. The T_h values of these inclusions range from 214 to 282 °C. The salinity of an aqueous solution is low (0.7–3.1 eq mass % NaCl), but slightly higher than that in inclusions trapped in quartz. The T_h of secondary inclusions corresponds to those of the primary inclusions measured in quartz II.

Coarse-grained prismatic quartz and quartz aggregates from the Moncada base-metal mine contain primary H_2O-type inclusions. They exhibit consistent *φ*(liq) around 0.7. The T_h values range between 248 and 278 °C, and the salinity of an aqueous solution is slightly higher, ranging from 0.5 to 4.3 eq mass% NaCl The eutectic temperatures (T_e = –25.5 to –29.4 °C) indicate H_2O–NaCl type of solution, with a small admixture of K ± Fe ± Mg chlorides.

Gold mineralization is interpreted as being the product of shallow hydrothermal circulation of dominantly meteoric waters, whose motion was triggered by the thermal gradient around the Guacimal Pluton granitic intrusion. The depth of the mineral precipitation is estimated to have varied at least between 500 and 1200 m below the paleosurface.

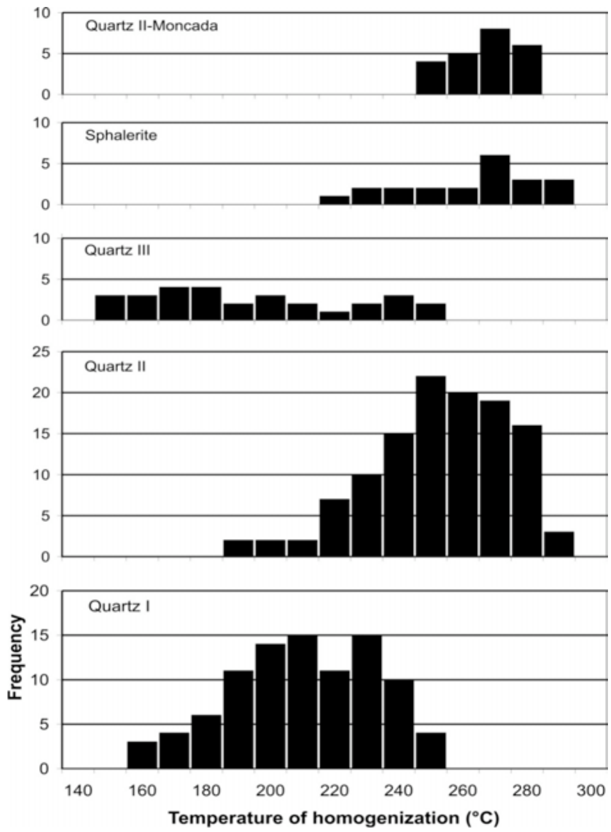

Fig. 1. Histogram of homogenization temperatures for fluid inclusions in various types of quartz and sphalerite of the Au-bearing and base-metal veins of the Aguacate Group volcanic arc

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