Affinity between bismuth and gold in the Marmato gold deposit, Colombia: A probable case of the liquid bismuth collector model*

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The Marmato gold deposit occurs in the Late Miocene, Middle Cauca gold belt, in the Western Cordillera of Colombia, 80 km south of Medellin. Open pit resources are estimated at 12.4 Moz Au and 75 Moz Ag with grades of 1.1 g/t Au and 5.1 g/t Ag. Past production is 2.3 Moz Au over five centuries. Marmato lies within the Romeral Terrane, an oceanic terrane of probable Late Jurassic to Early Cretaceous age that was accreted along the N-S trending Romeral Fault in the Aptian. This is partly covered by Neogene sediments and volcanic rocks, into which the composite Marmato stock was intruded.

Mineralization is structurally controlled with dominant NW and WNW trends, which developed from reactivated basement structures and as Riedel shears under WNW-ESE compression in a sinistral transpressional shear system related to the oblique collision of the Panama arc from the NW with the northern Andes. Gold mineralization is porphyry-hosted, and is late stage, post-intrusion. Five main porphyry pulses have been identified, named P1 to P5 from oldest to youngest, The age of the porphyry intrusions is bracketed by new CA-TIMS 206Pb/238U zircon dates of the P1 dacite stock of 6.87 ± 0.03 Ma, and P5 dacite dikes of 6.00±0.02 Ma. Sericite alteration has also been dated at 5.6 ± 0.6 Ma. Mineralization extends over 1,400 m vertically and is open at depth. Two main zones of mineralization have been identified. The Upper Zone between 1,500 to 900 m.a.s.l, mainly comprises massive, sulfide-rich, relatively quartz-poor, gold-bearing base metal veins and veinlets with sericite-illite-smectite-ankerite-pyrite wall-rock alteration which overprints pervasive propylitic alteration. This zone has a mineral assemblage dominated by pyrite-arsenopyrite-Fe rich sphalerite-pyrrhotite-chalcopyrite and electrum gold (average 65%Au, 35%Ag), with sulfur fugacity measured between -9.2 to -11 log fS2 from sphalerite, which classifies it as a low to intermediate sulfidation epithermal deposit. The Lower Zone, below 900 m.a.s.l and is still open at depth below 200 m.a.s.l, comprises sulfide and quartz rich veinlets and minor veins, with a mineral assemblage characterized by pyrrhotite-chalcopyrite-bismuth minerals and free gold (average 94% Au, 6% Ag). Bismuth concentrations are 2–5% in the sulfides in the Upper Zone, while native bismuth and bismuth minerals are present in the Lower Zone associated with free gold. Fluid inclusion measurements show that the mineralizing fluid is compatible with a H2O–NaCl fluid with magmatic sulfur, and homogenization temperatures and salinities varying from the top to the bottom of the deposit between 305.45 to 395.4°C and 4.96 to 11.93 wt% NaCl eq. respectively. Cathodoluminescence shows strongly zoned quartz with some internal zones of amorphous silica, indicating repetitive fluid flow. Quartz is occasionally replaced by late carbonate.
The vertical extension of the gold mineralization over 1,400 meters, relatively high temperatures, affinity between gold and bismuth, repetitive fluid flow events and the origin from a reduced, near neutral mineralizing fluid, are all evidence of the probably role of the liquid bismuth collector model during the mineralization, concurrent with tectonic uplift, generating the vertical zonation.