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Mn-Ilmenite in the Marmato and Aguas Claras Gold Deposits, Colombia: Implications for Magma Genesis and Magnetic Geophysical Techniques

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The Marmato and Aguas Claras porphyry suites (MACS) host epithermal Au-Ag and porphyry Au-Cu mineralization, respectively, in one of the premier mineral provinces of Colombia, the Middle Cauca gold belt, in the Western Cordillera. Mineralization is associated with late Miocene dacite-andesite porphyry intrusions, named P1 to P5 from oldest to youngest for the Marmato suite and AP1 to AP5 for the Aguas Claras suite. Open-pit resources for the Marmato gold deposit are estimated at 14.4 million ounces (Moz) Au and 90 Moz Ag with grades of 0.92 g/t Au and 5.71 g/t Ag contained in 489 million tonnes, at a cutoff grade of 0.3 g/t Au.

A total of 93 wavelength-dispersive electron-probe microanalysis (WDS-EPMA) analyses on ilmenite and magnetite crystals from the Marmato and Aguas Claras porphyry suite intrusions were carried out at the University of Brasilia and the Laboratory of Lithological Characterization of the National University of Colombia with a JEOL JXA-8500 EPMA and JEOL JXA-8230 EPMA, respectively, both possessing XRM area mapping and backscattered electron imaging capabilities. The measurements were done with a primary W^{6+} beam source of approximately 20 to 85 nA at 20 KeV. The primary ion beam diameter was 1 to 5 μm.

Textural observations show that magmatic ilmenite occurs as widely distributed idiomorphic crystals throughout the samples of the Marmato and Aguas Claras porphyry suites, except in intrusion AP1, where magmatic anhydrite occurs. Magmatic magnetite crystals occur occasionally in the Marmato suite. Abundant hydrothermal magnetite occurs in the Aguas Claras suite and magmatic magnetite may also be present. WDS-EPMA analyses show that the ilmenites are Mn bearing (up to 14.7 wt %) with representative calculated structural formulas of $(Mn_{0.3})Fe_{0.7}TiO_3$,$(Mn_{0.1})Fe_{0.9}TiO_3$ and $(Mn_{0.1}Fe^{3+}{}_{0.2})Fe^{2+}{}_{0.8}Ti_{0.9}O_3$, depending on the pyrophanite and hematite end-member proportions, which are up to 23.9% and 16.6%, respectively. On the other hand, the calculated structural formula from WDS-EPMA analyses for magmatic magnetite is $(Ti_{0.1}Al_{0.1})Fe^{2+}{}_{1.1}Fe^{3+}{}_{1.7}O_4$, while for hydrothermal magnetite it is $Fe^{2+}Fe^{3+}{}_{1.9}O_4$.

Mn-ilmenite indicates high f_{O_2}, which follows a relatively oxidizing cooling trend up to near the ilmenite-hematite solvus, close to f_{O_2} >FMQ+3, and is consistent with magmatic anhydrite crystallization (>FMQ+2.5). This is highly relevant for magma genesis, indicating a highly oxidized-type ilmenite series for the Marmato and Aguas Claras porphyry suites. On the other hand, the relative abundance of magmatic Mn-ilmenite versus magmatic-hydrothermal magnetite has important consequences for the rock magnetism of the Marmato and Aguas Claras porphyry suites, resulting in low magnetic susceptibility values and a strong reduction of the natural remanent magnetization intensities, which is highly important

for magnetic geophysical techniques as corroborated by the aeromagnetic image of the Marmato and Aguas Claras porphyry suites. Finally, according to the work of and from WDS-EPMA analyses, magmatic-hydrothermal magnetite from the Marmato and Aguas Claras porphyry suites shows a signature consistent with porphyry-type deposits where the magnetite formation temperature was above 500°C (magmatic) and between 300° and 500°C (hydrothermal).