

Biotite Geochemistry as an Exploratory Vectoring Tool in the Zafranal Cu Porphyry Deposit, Southern Peru

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Vectoring toward mineralized centers in porphyry Cu systems remains a key challenge, particularly in deposits with complex intrusive architectures and multiple magmatic–hydrothermal pulses, where conventional lithological and structural criteria may be insufficient to discriminate fertile intrusions. Mineral geochemistry provides an alternative by recording the physicochemical conditions of magma–fluid interaction. Among commonly used mineral vectors, biotite is less commonly used despite its stability during early magmatic and hydrothermal stages and its ability to incorporate elements sensitive to these processes.

This study evaluates hydrothermal biotite geochemistry as a vectoring tool in the Zafranal Cu porphyry deposit, southern Peru. The system comprises metamorphic and volcano-sedimentary rocks intruded by multiple dioritic to quartz dioritic bodies, forming a complex intrusive framework with well-developed hydrothermal zonation dominated by potassic alteration. Biotite was sampled from intrusive units with variable mineralization and alteration intensity.

Major and trace element compositions were determined by electron microprobe. The dataset was evaluated using XMg [$\text{Mg}/(\text{Mg}+\text{Fe})$] as a primary discriminator, combined with bivariate relationships involving F, Ti, Mn, and Cl, to identify compositional trends and define biotite populations.

Results reveal systematic compositional variations, with XMg effectively distinguishing at least two populations: (1) low XMg, higher Ti–Mn, reflecting a magmatic signature, and (2) high XMg, F-enriched and Ti–Mn depleted, consistent with hydrothermal overprint. These populations correlate with intrusive phases and alteration styles, particularly potassic alteration associated with hypogene Cu mineralization.

Biotite geochemistry thus records the magmatic–hydrothermal evolution of the system and enables discrimination of intrusive units with contrasting mineralization potential, supporting exploration vectoring at the deposit scale. These results highlight its applicability as a vectoring tool in comparable porphyry Cu systems.