Automated Quantitative Mineralogy Applied to the Hydrothermal Footprint of the Paulo Afonso Cu Deposit, Carajás Mineral Province

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In the context of modern mineral exploration, automated quantitative mineralogy is emerging as a powerful tool to enhance data quality and mineral system understanding—an increasingly crucial factor as exploration strategies shift towards data-rich, model-driven approaches. To characterize the hydrothermal footprint of the Paulo Afonso Cu-Au deposit, a total of 46 samples were investigated through petrographic analysis. A selected subset of 12 samples was further analyzed using the Elemission ECORE (a high-speed LIBS scanner), with results validated using the TESCAN TIMA (SEM-EDS). Automated quantitative mineralogy was applied to process the data obtained from ECORE and TIMA, using supervised machine learning algorithms for mineral classification, resulting in detailed mineralogical data for each sample. The Carajás Mineral Province, located in the southeastern portion of the Amazon Craton, Brazil, hosts several IOCG-type mineralizations. Among them, the Paulo Afonso deposit stands out as a Cu-Au deposit located approximately 16 km from Salobo—a world-class copper deposit—and is associated with the Cinzento Shear Zone. At Paulo Afonso, the host rocks are metamorphosed granites that have been intensely altered by hydrothermal processes. A distal sodic alteration zone was identified, mainly characterized by albitization, overlain by a potassic zone dominated by biotite formation. In proximal zones, a chloritic halos were observed. Calcic alteration becomes more prominent in the mineralized zone, with amphiboles forming a Ca-Fe (actinolite + magnetite) envelope around the mineralization, which occurs as disseminated chalcopyrite, in veins and hydrothermal breccias. The results obtained using the ECORE scanner demonstrate the effectiveness of the method as a rapid, preparation-free tool with high efficiency in the chemical and textural characterization of hydrothermal alteration associated with Cu-Au mineralization in the Paulo Afonso deposit. These findings highlight the promising application of automated quantitative mineralogy for defining mineralogical footprints, offering significant potential for mineral exploration strategies.