ANAIS XIX CBGq

XIX Congresso Brasileiro de Geoquímica

XIX CBGq

Congresso Brasileiro de Geoquímica

Geoquímica, Ciência e Sociedade

09 a 11/Agosto/2023 ARACAJU / SERGIPE

ISBN: 978-65-00-72908-5

CBL

9 786500 729085

REVEALING THE GEOCHEMICAL FINGERPRINTS OF HYDROTHERMAL NICKEL MINERALIZATION IN JAGUAR DEPOSIT THROUGH ADVANCED MULTIVARIATE STATISTICAL ANALYSES

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The Jaguar deposit in the Carajás Mineral Province is a unique hydrothermal nickel mineralization characterized by extensive hydrothermal alkali alteration, similar to IOCG deposits. This deposit consists of elongated orebodies with sub-vertical geometry along the intersection of the Canaã and McCandless fault systems. Three orebodies were studied: Jaguar South, Jaguar Central, and Onça Preta. The former two are hosted in felsic subvolcanic rocks and exhibit biotite-apatite, albite-magnetite, and biotite-chlorite alteration, with subsequent calcic alteration (actinolite) and mineralization (pyrite, sphalerite, chalcopyrite and millerite). In contrast, in the Onça Preta orebody, hosted in granite-gneiss and minor ultramafic rocks, the mineralization comprises chalcopyrite and millerite associated with phlogopite and chlorite within alteration with amphibole-magnetite-apatite and overprinted by talc, magnetite, calcite, and chlorite alteration. Multivariate statistical analyses were used to identify the geochemical signature of different alteration and mineralization zones within the deposit. Moreover, the results are used to support a genetic model and provide exploration constraints. The whole-rock geochemical data encompassing 29 elements from 220 drill holes were analyzed using hierarchical clustering (HC), principal component analysis (PCA) and Self- Organizing Maps (SOM). The study was divided into three stages: preprocessing, machine-earning classification, and unsupervised analyses. Approximately 51% of the samples were not previously assigned to a given classification, and thus four machine-learning algorithms were tested to classify each sample. Random Forest was selected due to its high overall classification accuracy. The unsupervised analysis uses HC, PCA, and SOM to find patterns in the geochemical data and allow for the unbiased identification of sets of elements defining geochemical groups. The PCA on centered log ratio-transformed data shows the least-altered rocks and barren lithologies in different groups and opposite directions from mineralization. Although host units and hydrothermal facies are mainly associated with Cd-Ag-Bi-Sb-W and Na-Zr-Ti-K-Ba-Al, the mineralization has a Ni-Co-P-Zn-Cu-S signature. The HC indicates that mafic-ultramafic sources may have contributed significantly to forming the mineralization in the three orebodies, as revealed by associations of chalcophile and siderophile elements. The SOM clustering shows that the mineralization presents geochemical signatures similar to magnetite and apatite facies, which envelope the ore zones. The SOM clusters related to the mineralization sub-sampled low-grade to high-grade nickel and copper zones. Another important finding is that the ore zone-related SOM cluster is enriched in Co, W, and Zn in the Onça Preta orebody, suggesting distinct metal sources from the leaching of mafic and felsic rocks.

KEYWORDS: LITHOGEOCHEMICAL ZONING, METAL ENDOWMENT, MINERAL EXPLORATION

SUPPORT: Centarus S.A., ADIMB, CAPES, Intra (Poli-USP)