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Gamma-ray spectrometry inversion applied to the Carajás Mineral Province: improved delineation of hydrothermal alteration zones

Jessica Weihermann (Colorado School of Mines), Adalene Silva (Universidade de Brasília), Francisco José Fonseca Ferreira (Federal University of Paraná), Saulo Pomponet Oliveira (Federal University of Paraná)

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Introduction

Airborne gamma ray spectrometry (AGRS) is a key method in regional mineral exploration due to its capacity to map surface geochemistry across large areas. However, standard processing methods often introduce interpretation challenges caused by oversimplified assumptions, including constant flight height, neglect of detector footprint overlap, and allowance of negative concentrations. Such limitations can hinder the identification of subtle geological features related to hydrothermal alteration zones, which are commonly associated with IOCG (Iron Oxide Copper-Gold) mineral systems in the Carajás Mineral Province (CMP), northern Brazil. This study focuses on reprocessing AGRS data from CMP using an inversion approach to improve the clarity, continuity, and interpretability of radiometric signals in two strategic regions of the CMP: region one, covering the Cinzento and region two the Aquiri target areas. In the Carajás Mineral Province (CMP), AGRS is particularly relevant because the region is covered by lateritic profiles and dense vegetation that limit traditional geological mapping.

Method and/or Theory

This study focused on two priority areas Cinzento and Aquiri target regions. The data originates from three overlapping airborne surveys by the Brazilian Geological Survey (SBG): Oeste do Carajás, Rio Maria, and Tucuruí. These surveys partially overlap, and inconsistencies between blocks have been previously observed due to differences in acquisition parameters and interpolation methods. The inversion technique previously published and validated (Weihermann et al., 2021, 2023), models the gamma-ray response of the detector using a log barrier formulation to enforce positivity and account for the spatial footprint of the sensor. The resulting inverted maps of potassium (K), equivalent uranium (eU), and equivalent thorium (eTh) from which derivative products were calculated: the F parameter (highlighting K-enrichment), K/eTh ratio (indicator of hydrothermal processes), and Ud and Kd parameters (indicative of anomalous potassium or uranium values derivated from rocks secondary processes). These maps were used to characterize the radiometric expression of potential mineralized systems and lithological boundaries.

Results and Conclusions

The inverted AGRS maps provided enhanced spatial resolution and greater continuity of radiometric anomalies compared to standard methods. Artifacts caused by inconsistent survey parameters and edge effects between project boundaries were notably reduced. In overlapping areas where standard processing produced mismatches in signal amplitudes, the inversion aligned these responses and offered a consistent radiometric pattern across survey joins. In region one, the inversion reduced amplitude mismatches between adjoining project blocks, allowing clearer identification of hydrothermal alteration zones and structural trends. In region two, derived maps such as K/eTh and F parameter emphasized hydrothermal alteration halos surrounding mineralized systems and highlighted prospective zones not clearly defined in the original data. This refined interpretation offers new insights into the distribution of alteration zones and reinforces the importance of inversion techniques for high resolution AGRS data analysis in complex geological provinces like Carajás.