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Three-dimensional resistivity patterns and radiometric features of relocated bauxite deposits: Southeastern Brazilian case study

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Three-dimensional resistivity patterns and radiometric features of relocated bauxite deposits: Southeastern Brazilian case study

Bauxite, the main raw material used in aluminum production, is a strategic mineral resource for various industrial sectors, including transportation, packaging, and civil engineering. In recent decades, its importance has expanded into the energy transition sector, with critical applications in photovoltaic panels, wind turbines, and energy storage technologies. While lateritic deposits remain the main focus of global exploration, deposits associated with reworked talus and colluvial processes in rugged terrain are gaining increasing economic and scientific attention. These deposits are often overlooked in conventional exploration models and present specific challenges for characterization and assessment of mineral potential.

This study investigates a bauxite deposit in the Cruzeiro region, São Paulo (Brazil), which is currently under active mining, through the integration of audio-frequency magnetotelluric (AMT) and high-resolution gamma spectrometry data. Data acquisition included: (i) eight AMT stations, spaced 50 meters apart, with recording periods ranging from 10^{-4} to 0.1 seconds; and (ii) 40 gamma spectrometry measurement points, covering an area of approximately 500 × 100 meters. The AMT data were processed using robust methods, and dimensionality analysis indicated predominantly three-dimensional behavior. The 3D inversion, performed using a regularized non-linear algorithm with full impedance tensor and tipper data, produced a well-fitting resistivity model highlighting strong subsurface heterogeneity.

Gamma spectrometric data, acquired in counts per second (cps), were corrected for background radiation and spectral overlap among the potassium (K), uranium (U), and thorium (Th) windows, in accordance with IAEA protocols. The corrected counts were then converted into actual concentrations (K in %, U and Th in ppm) using equipment-specific calibration factors. The data were georeferenced and interpolated in a GIS environment to produce thematic maps showing the concentrations of individual K, U, and Th, as well as a ternary RGB map.

Integrated interpretation of the datasets revealed three main conductive domains: (i) a shallow conductive layer (10–30 m thick), associated with bauxite and clay minerals (e.g., gibbsite and kaolinite), which corresponds to a gamma signature characterized by low uranium and potassium concentrations and high thorium content—a typical pattern of leached lateritic profiles; (ii) an intermediate resistive zone (up to 400 m thick), interpreted as preserved crystalline basement; and (iii) a deep conductive zone, whose presence is supported by the data, although its lower boundary exceeds the resolution of the AMT method within the investigated period range (10^{-4} to 0.1 s).

The spatial overlap between the shallow conductive layer and gamma anomalies suggests intense previous leaching, followed by bauxite remobilization via talus and colluvial processes. This interpretation is supported by the lateral dispersion of thorium anomalies and the irregular geometry of the shallow conductor. Although the deep conductor was clearly detected, its nature requires further investigation (e.g., broadband MT or potential field methods) to determine its extent and origin, which may be related to faulted structures, deep fluid circulation, or secondary mineralization.