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Electrical Resistivity Tomography (ERT) through curved lines. A possible solution for acquisition inside mining pits?

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Introduction

In the context of iron mining in Carajás, a region within the Amazon biogeographical province, the management of groundwater emerges as a particularly intricate hydrogeological challenge. The region's primary ore, friable hematitite, has been demonstrated to function as an effective aquifer. It is imperative to exercise meticulous oversight regarding the reduction of water levels, thereby ensuring the seamless progression of mining operations. Another hydrogeological challenge in Carajás is the region's geological complexity, which includes intrusions and mafic flows that generate confined aquifers. These aquifers have the potential to induce instability in excavations, precipitate the emergence of water unrelated to the lowering of the aquifer, and compromise the safety of operations, thereby impeding the progress of mining plans.

In this context, the application of geophysics to map the groundwater is more than useful, but necessary for a more precise well location, as to mitigate the risk of water resurgence at the base of the pit, and also to assist the identification of risk zones, enabling the company to implement preventive and control measures, such as drilling relief wells and installing appropriate drainage systems.

Method and/or Theory

Electrical resistivity tomography (ERT) acquisitions typically adhere to a standard protocol, involving the delineation of linear segments over a grid with uniform inter-line spacing. This approach is widely recognized as a best practice for obtaining reliable results for geological subsurface interpretation. However, given the complexity of acquiring straight lines in the iron ore pits of Vale, a new approach was proposed. The methodology was proposed for testing in a manner that deviated from the conventional grid of lines. The proposed approach entailed the collection of data along the berms, resulting in the formation of curved lines surrounding the exploration pit wherever possible.

In this work, electrode spacings between 5 to 20 meters were used depending on the line elevation location and the aim of the area acquisition (well location or smaller groundwater flows). Also, different electrodes arrays such as dipole-dipole, Schlumberger, and gradient were used to check the assertiveness of the geophysical modelling in relation to geological subsurface modelled by previous drilling results.

Results and Conclusions

The methodology has previously been implemented in two distinct pits within the Serra Norte complex in Carajás, yielding substantial positive outcomes with respect to the objectives of well location and identification of areas susceptible to water emergence. In N5 South pit, the results of the study led to the identification of a lowering well, which exhibited flow rates of approximately 110 m^3/hour. In N4WS pit 4, no wells have yet been located, but preliminary results indicated a high-risk zone in the southern portion of the pit and this finding was subsequently confirmed by the geotechnical team, thereby avoiding risks to the iron ore extraction operation in this region.

Even though the majority of ERT inversion algorithms do not consider the three-dimensional flow of electric current (i.e., the case of curved lines in ERT acquisitions), the preliminary results have been shown to be effective for hydrogeological applications in the Carajás geological context.