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Aeromagnetometric characterization of the Icó Horst and the inflexion between Tucano Norte Sub-basin and Jatobá Basin, Northeastern Brazil

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Abstract Summary

The Recôncavo-Tucano-Jatobá (RTJ) Rift corresponds to an aulacogen located in northeastern Brazil. The Tucano Norte Sub-basin and the Jatobá Basin represent the northern portion of this rift and cover an area of approximately 13,800 km², comprising the states of Bahia, Sergipe, Pernambuco and Alagoas. The objective of this research was to characterize the structural framework of the Icó Horst in the subsurface by integrating geological-geophysical data, using aeromagnetic surveys. The methodology involved the application of enhancement filters to produce thematic maps that aided in the geophysical interpretation of the study area, particularly in terms of structural features, based on correlation with 3D modeling using the VOXI routine. The results obtained helped clarify the genesis and tectonic-structural evolution of this aulacogen and improved the understanding of the geological configuration of the Icó Horst at depth.

Introduction

The break-up event of the supercontinent Gondwana during the Mesozoic (~130 Ma) resulted in the formation of the South Atlantic Ocean and the development of several sedimentary basins (*Asmus & Ponte, 1973*), such as the Recôncavo, Tucano and Jatobá basins.

The Tucano Basin is subdivided into three sub-basins: Southern, Central and Northern (*Milani & Davison, 1988*). The Tucano Norte Sub-basin (TNSB), with a regional N-S trend, comprises the states of Bahia and Sergipe, covering an area of approximately 8,800 km² (*Magnavita et al.,* 2003). The Jatobá Basin (JB), with an area of 5,000 km² and a predominant NE-SW orientation, extends across the states of Pernambuco and Alagoas (*Costa et al.,* 2003).

The Icó Horst (IH) is a prominent structural feature in the context of these sedimentary basins, marking the inflection zone between the TNSB and the JB (*Peraro, 1995*). This structural high is located precisely at the boundary between the two basins. In a petroleum system, a horst can play a critical role as a hydrocarbon migration pathway (*Xu et al., 2024)* and may also function as a structural trap (*Khomsi et al., 2019*).

Geological Context

The study area is part of the Recôncavo-Tucano-Jatobá (RTJ) Rift, which comprises a series of N-S and NE-SW trending sedimentary basins and sub-basins with low magmatism (*Magnavita, 1992*). These basins are associated with the regional geodynamic of the São Francisco Craton (*Almeida, 1967*) and the geological setting of the Borborema Province (*Almeida et al*., 1981), as well as the rifting episode of the Gondwana supercontinent.

The basement of these basins consists of rocks from the Pernambuco-Alagoas Terrane (PEAL) and metasediments of the Sergipano Belt (*Costa et al.,* 2007). The geological evolution of this aborted rift system is related to the breakup of Gondwana and the subsequent opening of the South Atlantic Ocean during the Early Cretaceous (*Magnavita and Cupertino, 1988*).

The sedimentary and stratigraphic record in the TNSB and the JB can be described in four main stages (*Costa et al.,* 2007; *Hispagnol, 2024*): Syneclise and Pre-, Syn-, and Post-Rift phases, containing characteristic Depositional Sequences.

Methods

The aeromagnetic data used in this study was supplied by the Geological Survey of Brazil (SGB/CPRM). Three aerogeophysical surveys were utilized: Paraíba-Rio Grande do Norte-Pernambuco-Paraíba (1091) – CPRM, 2010; Oeste de Tucano (1103) – CPRM, 2011a; Paulo Afonso-Teotônio Vilela (1104) – CPRM, 2011b.

These surveys have compatible acquisition parameters, including the same direction (N-S), flight lining spacing (500 m) and control lines (10 km) apart in the E-W direction. The nominal flight altitude of the projects was 100 m.

The methodology of this work consisted of creating a database and generating thematic maps using the Geosoft Oasis Montaj (Seequent) Educational platform software. The Total Magnetic Intensity (TMI) was interpolated using ¼ of the distance between the aerogeophysical surveys,

resulting in cells measuring 125 x 125 m. The method used was minimum curvature (*Briggs, 1974*).
In order to highlight magnetic features associated with geological structures, enhancement filters were applied:
The Reduction to Pole (RTP) filter (*Baranov & Naudy, 1964*) is applied to eliminate the dipolar effect of the TMI field, in which the RTP equation transforms the dipolar response of the TMI data into a simple monopolar anomaly centered on the magnetic source. For its application, the average geomagnetic inclination of the study area is -23.24º, the geomagnetic declination in the region is -22.49º and the intensity of the Total Magnetic Field used is 25,324.865 nT.
The First Vertical Derivative (Dz) filter (*Cooper & Cowan, 2011*) applied to the RTP map highlights shallow magnetic anomalies associated with magnetic lineaments. This filter has been applied in recent decades to highlight structural features such as horsts.
The Tilt Derivative (TDR) filter (*Miller & Singh, 1994*), applied to the RTP map, helps to demarcate the edges of magnetic features. The TDR equation can be calculated as the arctangent of the ratio between Dz and the root of the sum squared of the partial derivatives of the horizontal components.
The 3D inversion method used in this study was conducted using the VOXI Earth Modeling^{TM} extension on the Oasis platform, employing the Cartesian Cut Cell (CCC) inversion algorithm developed by *Ingram et. al* (*2003*), later simplified by *Ellis* and *MacLeod* (*2013*). This method allowed to construct a 3D model of the Icó Horst in the subsurface by estimating the physical properties (in this case, contrast of the rocks: magnetic susceptibility SI) using aeromagnetic data.

Results
The RTP map (TMI_RTP) illustrates magnetic intensity values ranging from 68.32 to -81.68 nT (Fig. 1). The black polygon on the map designates the location of the IH, which demonstrates elevated magnetic intensity values, approximately between 23.33 to 29.29 nT. This high magnetic intensity may be associated with the mineralogical composition of the PEAL lithologies, including granites, metavolcanics and high-grade metamorphic rocks with ages from the Archean to Proterozoic (*Brito Neves, 2019*).

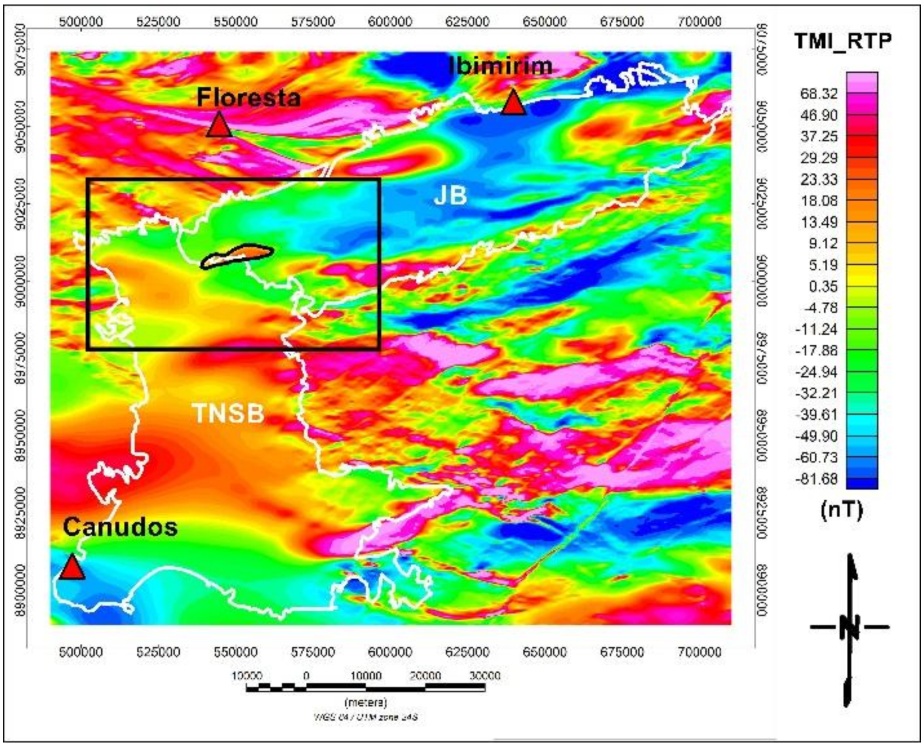

Figure 1: TMI_RTP map of the study area highlighted by the bold square. Red triangles correspond to cities in Bahia (Canudos) and Pernambuco (Floresta and Ibimirim) states. The black polygon delineates the Icó Horst (IH). White lines represent the contour of these sedimentary basins. TNSB: Tucano Norte Sub-basin; JB: Jatobá Basin.

The Dz map (Fig. 2A) presents magnetic intensity rate values from 0.0211 to -0.0251 nT/m. As can be seen, this filter highlighted the shallower structural features (dashed lines), including the faults on the basin-edge as well as the magnetic lineaments with NE-SW, NW-SE and E-W trends. The limits of the IH were delimited with a black polygon to facilitate its identification on the map.
The TDR map (Fig. 2B) shows magnetic signatures between 1.218 to -1.446 rad. After appling the TDR to the magnetic data reduced to the pole, the resulting values range from - π/2 to + π/2. These values represent, respectively, the edge and the center of the causative body (*Cooper & Cowan, 2008*). Due to its ability to normalize long- and short-wavelength frequencies (*Verduzco et al., 2004*), it was possible to demarcate magnetic domains from this map, i.e., areas that present different patterns of magnetic anomalies. Several high-intensity magnetic bodies were outlined (solid black contours), as well as multiple magnetic lineaments and faults on the basin edge (dashed lines). It is noted that the magnetic anomalies are associated with the basin inflection process, of which the anomalies present in the TNSB portion have a NW-SE trend, while the anomalies demarcated in the JB region have NE-SW direction. In addition, the importance of the IH in this context is noted, since it appears to be located at the center of this inflection. A magnetic anomaly is also observed to the southeast of the IH, that may be associated with another structural high which has not been mapped yet.

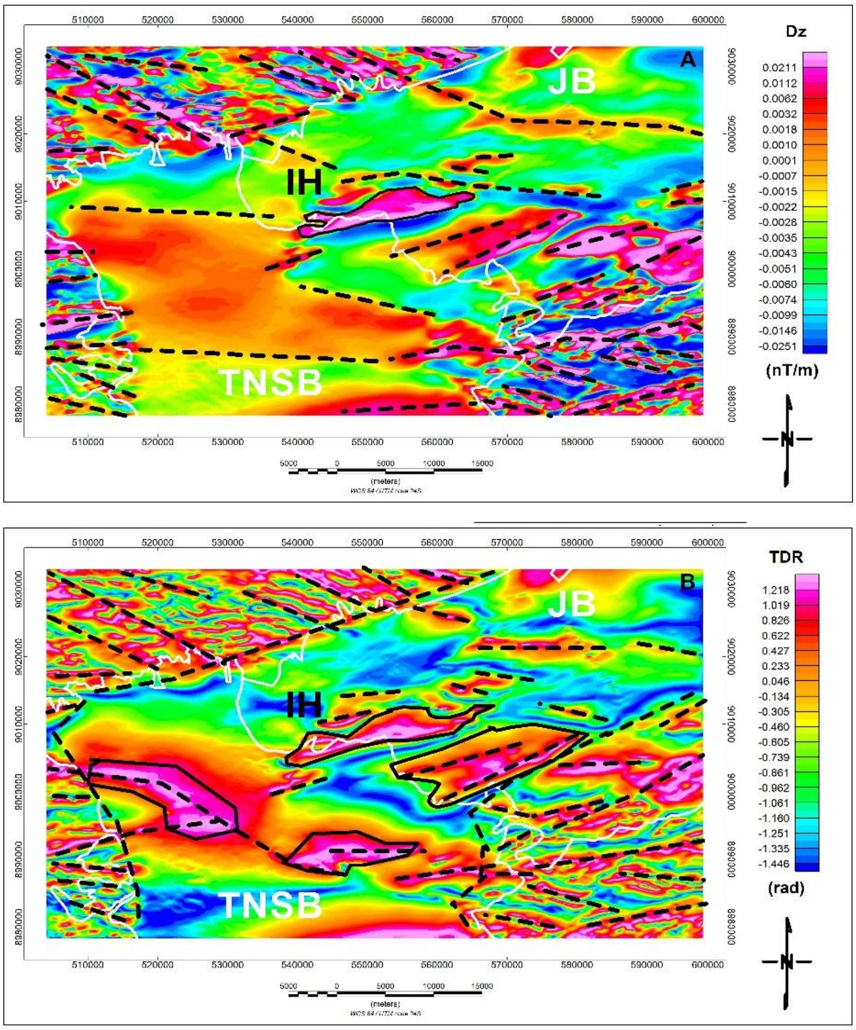

Figure 2: Dz (Fig. 2A) and TDR (Fig. 2B) maps of the study area with the magnetic lineaments (dashed lines) and with the contour of some high magnetic anomalies (black solid lines). White lines represent the boundaries of these sedimentary basins. TNSB: Tucano Norte Sub-basin; JB: Jatobá Basin. IH: Icó Horst.

The 3D inversion using the VOXI routine (Fig. 3) allowed the visualization of the subsurface geometry of the IH, represented as an isosurface with a magnetic susceptibility contrast of 1.04 x 10^{-3} SI. This structural high is characterized by an irregular geometry, with an elongated morphology along the X-direction. The top of this structural feature occurs at around 2,000 m, while its basal portion reaches a maximum depth of approximately 7,150 m.

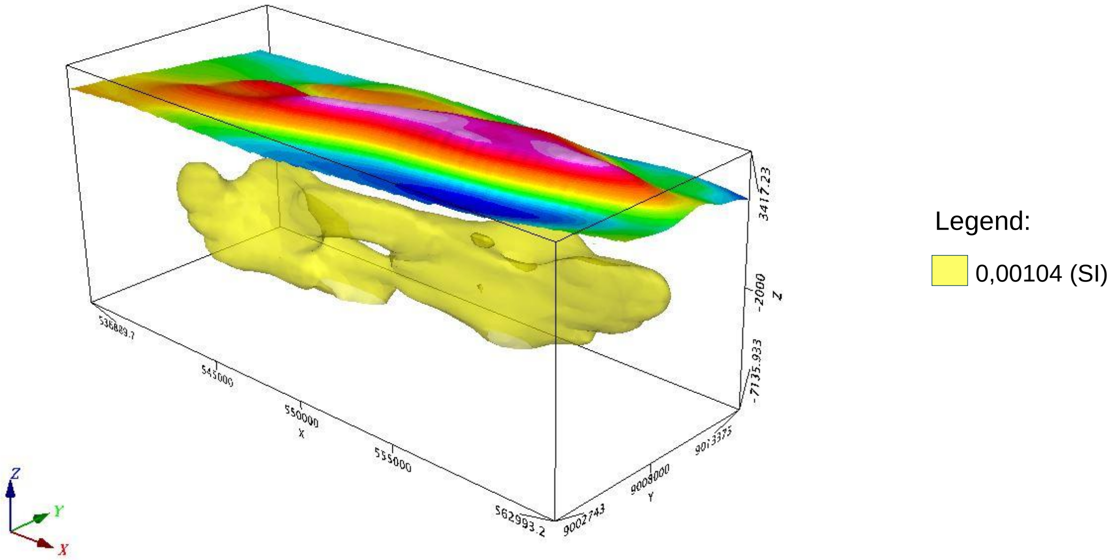

Figure 3: 3D perspective of the Icó Horst.

Conclusions

The generation of thematic maps revealed that the basins exhibit compartmentalization in blocks, with some magnetic anomaly patterns in their interior. Additionally, fault systems and magnetic domains with various orientations were identified in both the inner and marginal portions of these basins. Furthermore, the VOXI routine enabled to estimate the shape, depth and extension of the Icó Horst in subsurface. Therefore, the integration of aeromagnetic maps with the 3D modeling provided a better visualization of the structural features in the inflexion region between Tucano Norte Sub-basin and Jatobá Basin, with emphasis on characterizing the structural framework of the Icó Horst in depth. As a consequence, the results obtained contributed to a more refined geological-geophysical interpretation of this area.

Acknowledgments

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