Integrated Airborne Magnetic and Gamma-Ray Data Applied for Structural Analysis on a section of the Transbrasiliano Lineament – Central Brazil

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Abstract

Southern Tocantins features a very complex geological scenario concerning the lithological units and structural context. The main structural feature of the region is the Transbrasiliano Lineament (TLB) a continental scale discontinuity that resulted from the collision of continental blocks at the end of the Neoproterozoic.

The opportunity to cover a large area in a small time with high resolution data has turned the geophysical airborne techniques as the most frequently used tools for geological mapping. In the study area, geophysical images provide useful information of deep crustal structures as well as of shallow geological units and soils.

In this work, an integrated study of airborne magnetic and gamma-ray geophysical data was carried out to highlight the arrangement of crustal blocks, their relations and boundaries.

Introduction

The Transbrasiliano Lineament (TBL) (Schobbenhaus *et al.* 1975) is a continental wide discontinuity between the Amazonian Craton and the eastern South American Platform, representing a mega-structure that was active during Gondwana supercontinent amalgamation, from Late Neoproterozoic to Early Paleozoic (Cordani and Sato 1999, Cordani *et al.* 2000, Almeida *et al.* 2000).

The origin and evolution of this structure have been widely discussed by many authors in the last decades, including Costa and Hasui (1988), Hasui *et al.* (1994), Cordani and Sato (1999), Almeida *et al.* (2000) and Dantas *et al.* (2007). However, recent studies conducted in the region of Porto Nacional-Natividade (Chiarini, 2007) reinforce the idea that the TBL is related to late (post-collisional) stages of the Brasiliano Orogeny.

Field techniques have proven effective for decades in detailed mapping, for the recognition of lithologic and structural features. However, at regional scale, it is sometimes difficult to cover the entire area *in situ*, due to the high costs of this kind of survey. With this purpose geophysical techniques have been widely used for the study of suture zones of continental scale as a tool for defining units and carrying out structural studies (Grauch *et al.* 2001; Dantas *et al*. 2006; Chiarini, 2007; Stewart *et al.*, 2009).

High-resolution airborne geophysical methods have been an important tool in large-scale geological mapping in central Brazil (e.g. Blum, 1999; Chiarini, 2007). This paper comprises an integrated study of airbone magnetic and gamma-ray data in order to carry out a structural analysis and contribute to the understanding of the structural context and arrangement of crustal blocks in southern Tocantins affected by the Transbrasiliano Lineament. It represents the first step of a work whose goal is to understand the origin of this structure and its role in the development of the Brazilian continental crust.

Geological Setting

The influence region of the TBL in the work area fits into the context of the Tocantins Province. This province, described by Almeida *et al*. (1981) as one of the major structural units that comprise the Brazilian geological framework is defined as a set of orogens resulting from the collision of three continental blocks: Amazonian, São Francisco and Paranapanema cratons. The province is subdivided into the Brasília, Araguaia and Paraguay belts. In turn the Brasília Belt, at the western border of the São Francisco Craton, comprises a thrust and fold belt, metamorphic core, Goiás Massif, and the Goiás Magmatic Arc (Fuck et al. 2006).

Hasui et al. (1994) described the work area as the amalgamation of various continental blocks related to a Precambrian collisional process. Other authors such as Dantas *et al.* (2006) relate this process to the end of the Neoproterozoic, as the culminating event of convergence and collision of crustal blocks, including metamorphism of supracrustal rocks at their boundaries, post-tectonic events and thermal reactivation at the end of the Brasiliano Orogeny.

These subsequent reactivations in the region are closely linked to the context of the TBL, featuring the Serra Azul and Serra Grande transcurrent systems (SATS and SGTS, Hasui *et al.* 1994, Dantas *et al.* 2006, Chiarini, 2007). These large scale shear zones define the limit of large crustal blocks in the region, affecting mainly the transition zone between the Araguaia and Brasília belts (**Figure 1)**.

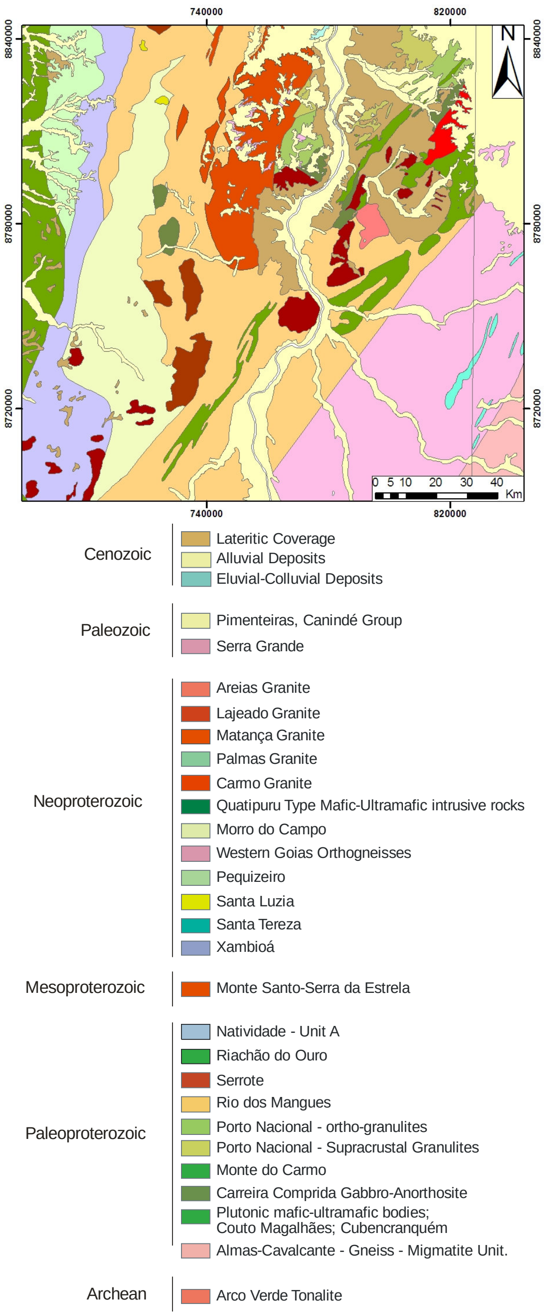

Figure 1:1:1.000.000 Geological Map from the work area. Modified from Oliveira *et al.* 2004.

Data

The used database represents a fraction of the Airborne Survey of Tocantins **(Figure 2)**, located in southern Tocantins, extending over a small portion of northern Goias, conducted by the Geological Survey of Brazil (CPRM). The survey was carried out by AeroGeoPhysica Latin America (LA-AGP) (CPRM, 2006).

The survey was carried out by Cessna aircrafts, flying constant ground clearance with a nominal height of 100 meters. The flight lines follow the N-S direction and 500 meters spacing, while the tie lines are E-W and 10 km spaced.

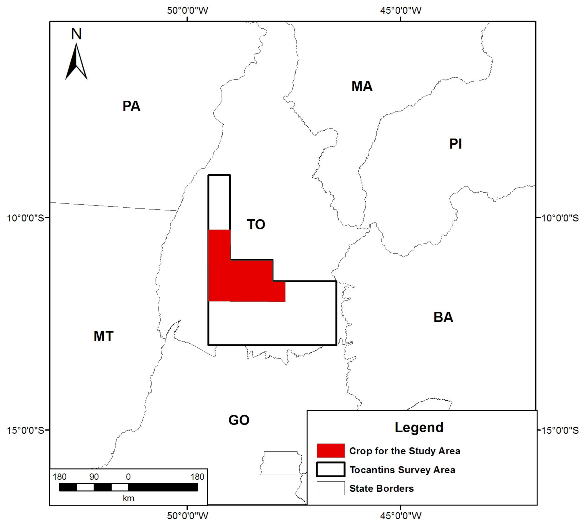

Figure 2: Location map for the Tocantins Aerogeophysical Survey.

Methods

For the purpose of this study two softwares were used: Oasis Montaj Geosotf 7.01, for processing and visualization of geophysical data and ESRI ArcGIS 9.2 for data integration and interpretation.

Magnetic data were expressed as the anomalous magnetic field (AMF) **(Figure 3)**, which is the total measured field corrected of the main geomagnetic field (IGRF) and excluding the leveling errors. Gamma spectrometry data were expressed into energy channels for each radio-element, besides the total count channel. Both databases were checked for its integrity and consistency. These procedures are necessary to check for errors in the survey and the presence of spikes.

The next step consisted on interpolating the magnetic and gamma-ray data on regular grids. The choice of the right gridding method and parameters for each data is important to keep the data fidelity to the original sample locations. As an airborne survey with a large volume of data arranged in parallel flight lines, the most appropriate interpolation method is BIGRID (Billings & Richards, 2000). The bi-directional interpolation method is based on the direction of flight line by the method of cubic splines. It is suitable for data collected on lines since it reinforces the trend of structures in the area. In this case the cell size used was 125 meters, representing a quarter of the flight lines spacing (500m).

Based on the anomalous magnetic field other magnetic products were generated. The use of horizontal and vertical derivatives, specially the first vertical derivative image **(Figure 4)** was important in determining lateral limits of the units, magnetic lineaments and other linear features. The linear transformations, especially the analytic signal amplitude (ASA) **(Figure 5)**, were essential products for accurate determination of the sources of anomalies and discrimination of magnetic domains.

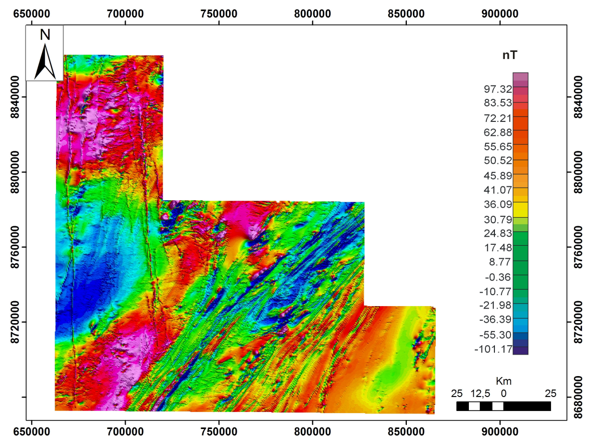

Figure 3: Image of the Magnetic Anomalous Field data.

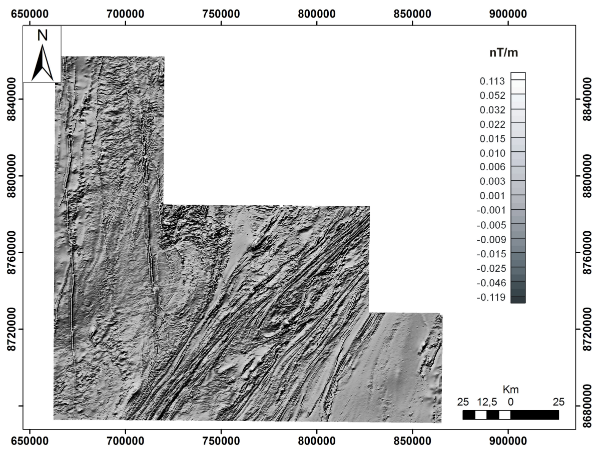

Figure 4: Image of the first vertical derivative data.

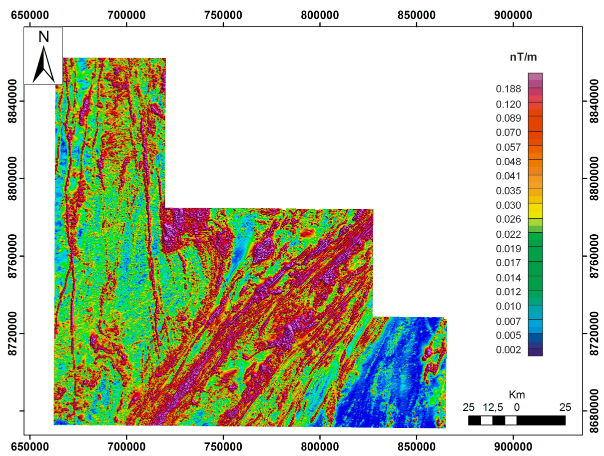

Figure 5: Image of the Analytical Signal Amplitude data.

The gamma-spectrometric channels (K, Th, U and TC) were also interpolated and used to generate maps of U/K, Th/K, and U/Th ratios. Moreover ternary compositions were generated **(**RGB and CMY, **Figure 6)**, optionally merged with the digital terrain model. The correlation and interpretation of these products were used for determining the major gamma-spectrometric domains.

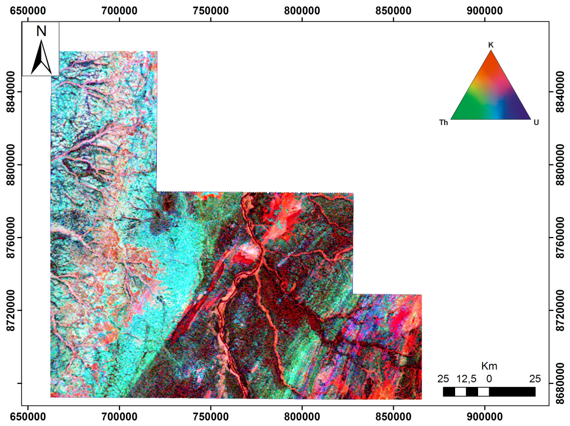

Figure 6: Ternary Image (RGB) of the K, Th, U radio elements.

Qualitative Interpretation of Geophysical data

The geophysical magnetic and gamma-spectrometric products were integrated and interpreted, allowing the discrimination of several litho-structural domains. These domains were analyzed and then compared to available data of the Tocantins Province. The overall analysis implies that the geophysical data display more details than the existing maps.

Magnetic Lineaments

The vertical and horizontal derivatives were used to interpret the magnetic lineaments (**Figure 7**). The resulting map shows at least three different zones according to lineament density and behavior.

The central area, characterized by shear zones, presents a high density of lineaments striking NE-SW; some high frequency zones are associated with the main shear zones that crosscut the units; regional folds may also be observed in this zone.

The areas outside the central zone are both calm in magnetic lineaments, despite some linear structures in the western area, which are probably related to mafic dikes. The contrast between the crustal blocks is clearly delineated by major lineaments coincident with shear zones of regional expression.

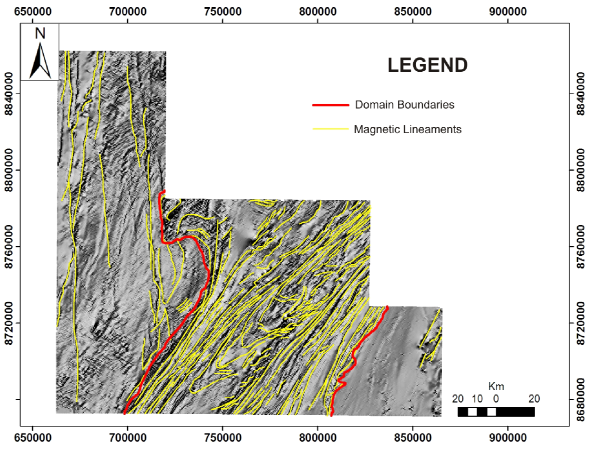

Figure 7: First vertical derivative interpreted for the magnetic lineaments.

Magnetic Domains

The magnetic domains map **(Figure 8)** was interpreted using the Anomalous Magnetic Field and the Analytic Signal. The domains were separated taking into account their magnetic relief and anomalies characteristic. It was possible to divide the area into three main magnetic domains separated by strong gradients.

Magnetic Domain A (MD-A), in the west, features a heterogeneous magnetic relief, alternating several areas of flat relief associated to low magnetic anomalies, intercalated with high linear anomalies striking N-S, probably associated to dykes. It is related to the Araguacema (including the units of the Baixo Araguaia Supergroup) and Porto Nacional blocks (Hasui *et al.* 1994; Chiarini, 2007). **Magnetic Domain B (MD-B)**, central, is about 90 KM wide and represents the transition region between the two adjacent domains. It features high frequency linear anomalies, aligned in a NE-SW trend, indicating geological features of shear zones and regional folds; this area coincides with the Porangatu Block (Hasui *et al.* 1994; Chiarini, 2007). The eastern **Magnetc Domain C (MD-C)** is represented by weak and low frequency magnetic anomalies, representing a soft magnetic plateau locally disturbed by some high magnetic anomalies, which corresponds to the Mara Rosa Magmatic Arc. The boundaries between these tectonic blocks are marked by strong magnetic gradients with high contrasts, connected to shear zones systems of regional expression, trending NE-SW, controlled by the Transbrasiliano Lineament.

A detailed analysis of the main domains reveals a series of sub domains of diverse magnetic properties within each group. These subdivisions may represent geological contrasts within the crustal blocks in depth.

Gamma-spectrometric Domains

Integration of the interpreted images developed for each radio-element plus the ternary image resulted in a final interpretation of the gamma-spectrometric domains of the region (**Figure 9**). These areas were individualized according to the concentration of each radio-element (K, Th, U) as well as their radiometric "texture". Each domain was then analyzed for the relative content of each element, resulting in five classes, according to their amount on each domain: Low, Medium-Low, Medium, Medium-High and High.

Conclusions

Geophysical airborne methods have proven efficient for the structural mapping and domains discrimination at the suggested scale for this work. The maps generated during this stage will be important to conduct the studies at the field stage.

There is no obvious correlation between the magnetic and gamma-spectrometric domains. The main reason for such a distinction may be the high contrast between the thick soil layers that cover the crustal scale structures. Nevertheless, there is resemblance locally regarding the main NE-SW structural trend. Besides some outcropping units will feature similar limits for both geophysical data.

The magnetic lineaments corroborate the results obtained in the magnetic domains interpretation. The central domain (B) is correlated to the central shear zone area, featuring a high density of lineaments. The higher frequency zones in the lineament map, represented by magnetic highs in the analytic signal data are related to the main shear zones of the Transbrasiliano System.

These results reinforce the importance of the shear zones during the development of this area, working as contact for distinct crustal blocks and eventually concentrating ore deposits. The three described domains are separated by regional scale shear zones related to the context of the Transbrasiliano Lineament and show correlation with the available geological data.

The gamma ray domains image shows a very detailed discrimination of geological units in the region. The concentration of recent sediments is also very clear. The ternary image features nice correlation with the 1:1.000.000 map developed by the Brazilian Geological Survey, despite the fact that the geophysical image shows a larger variety of units, which will be followed up in future field work.

Acknowledgements

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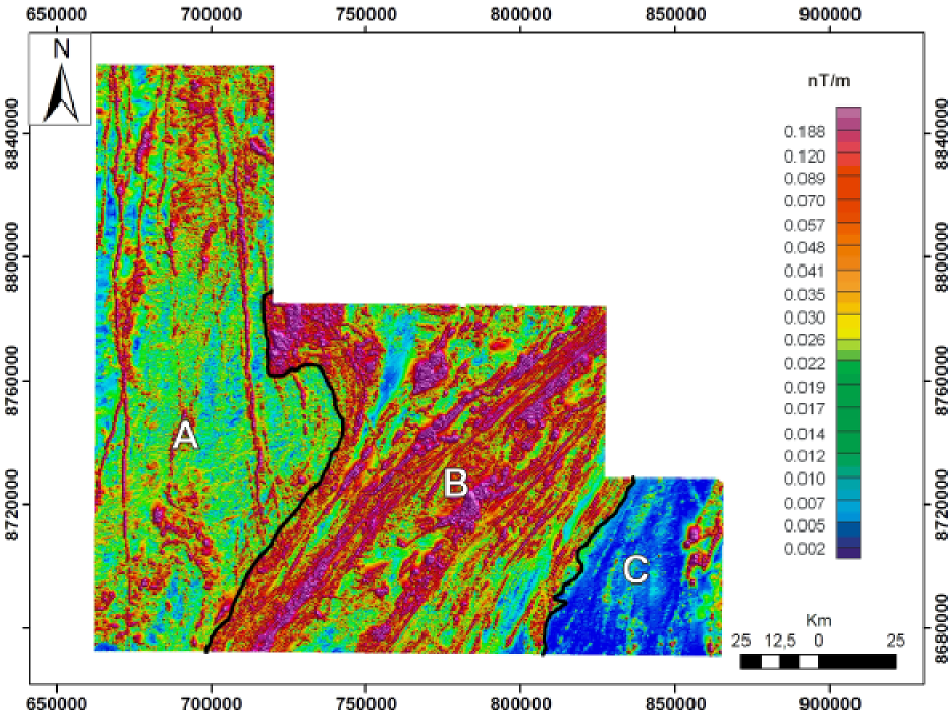
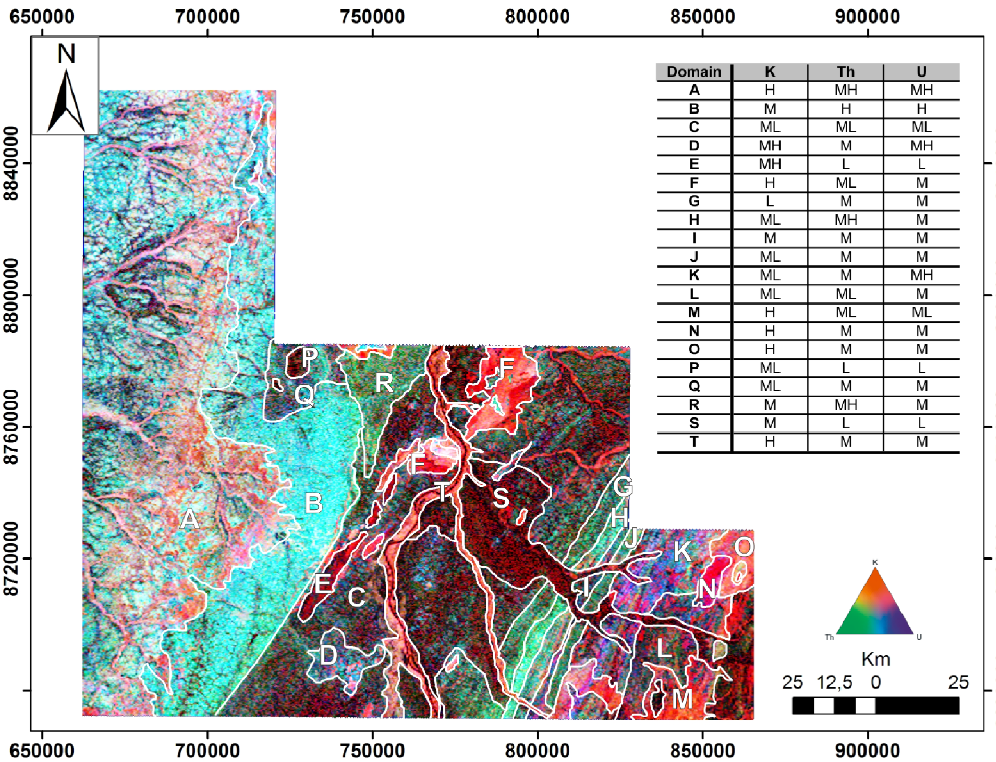


Figure 8: Analytic Signal Amplitude Image interpreted for the Magnetic Domains.



Domain	K	Th	U
A	H	MH	MH
B	M	H	H
C	ML	ML	ML
D	MH	M	MH
E	MH	L	L
F	H	ML	M
G	L	M	M
H	ML	MH	M
I	M	M	M
J	ML	M	M
K	ML	M	MH
L	ML	ML	M
M	H	ML	ML
N	H	M	M
O	H	M	M
P	ML	L	L
Q	ML	M	M
R	M	MH	M
S	M	L	L
T	H	M	M

Figure 9: RGB ternary image for the K-Th-U radio elements. The box shows the relative amount of the elements for each domain (L – Low; ML – Medium Low; M – Medium; MH – Medium – High; H – High)

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