Interpretation of Airborne Geophysical Data from the Structural Framework of Jaibaras Rift, Ceará, Brazil

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Abstract

The magnetic and gamma spectrometric study of airborne geophysical data presented in this work was conducted to better understand the tectonic-magmatic relationships involved in the formation of the Jaibaras Rift, Borborema Province. Therefore, a qualitative and quantitative interpretation of the airborne geophysical data was performed to determine seven distinct geophysical domains and the structural configuration with lineaments in the NE-SW direction and E-W inflections in the region.

Introduction

Several geological studies conducted in the northwestern region of Ceará in the last 50 years have shown that this area is one of the most interesting and complex areas in the country, especially when considering its geological evolution (Oliveira & Mohriak, 2003). The understanding of the relationships between extensional deformation, basement structure reactivation and the architecture of the resulting rift can be achieved through integrated interpretation of magnetic and gamma ray spectrometric airborne data.

The main objective of this research is to map both the structural framework of Jaibaras Basin and the main magmatic events, based on its geophysical signature.

The studied area is located in northeast Brazil, more specifically in NW Ceará, and encompasses the rocks associated with the Jaibaras Basin and its tectonic framework. It is limited by longitudes 41° and 40ºW and latitudes 4°20' and 3°10'S (Figure 1).

Regional Geological Context

The Jaibaras rift (Figure 1) is the largest Late Neoproterozoic-Early Paleozoic basin within the Precambrian terrains of the Borborema Province and its African counterpart of the Nigerian Shield (Oliveira, 2001). The rift is set on the limit between two distinct crustal domains: (1) Ceará Central (DCC), to the southeast of the study area, comprises medium-high grade metamorphic rocks of the Ceará and Tamboril-Santa Quitéria complexes, representing a Neoproterozoic supracrustal sequence and a large granite-migmatite association, respectively (Fetter *et al.*, 2003), aside from several sin-, late- and post-tectonic granite intrusions; and (2) Médio Coreaú (DMC), comprising Early Paleoproterozoic basement rocks of the Granja Complex, Neoproterozoic supracrustal sequences of the Martinópole and Ubajara groups and the Meruoca and Mucambo granites. The domains are separated by the Sobral-Pedro II shear zone (SPIISZ), which is part of the Transbrasiliano Lineament.

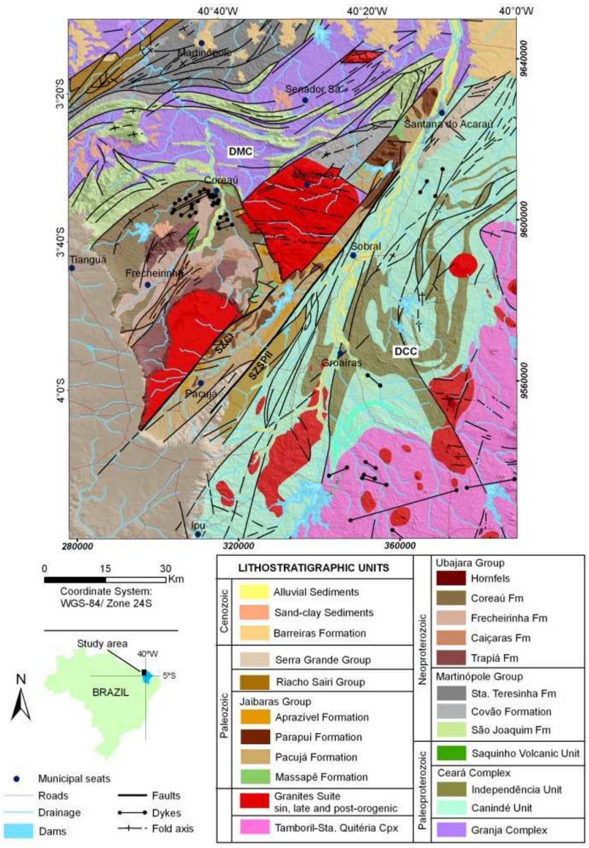

Figure 1: Geological map of the structural framework of Jaibaras Basin. Crustal domains: DCC – Central Ceará, DMC - Médio Coreaú; Shearing zones: SZSPII - Sobral-Pedro II, SZCI – Café-Ipueiras (Scale - 1:500.000; CPRM, 2003).

The Ubajara Group (Figure 1) is characterized by a continental margin tectonic-sedimentary cycle, showing proximal and distal psammitic lithofacies, and a marine metacarbonatic sequence, that culminates in a metarkose and metagreiwacke sequence. The Coreaú dike swarm consists mainly of dacite and rhyolite with isolated portions of basic rocks and xenoliths. The dikes are discontinuous and sub-parallel; their main direction is N80ºE with sub-vertical dip.

Jaibaras Basin stratigraphy is marked by two distinct sequences: (1) Lower Alpha, represented by the Massapê and Pacujá formations and the Parapuí suite (Figure 1); and (2) Higher Alpha, also represented by the Aprazivel Formation, including also Parapuí volcanics (Parente et al., 2004). According to Oliveira & Mohriak (2003), the end of the deposition should be marked by the onset of sedimentation of the Eosilurian Serra Grande Group of the Parnaiba Basin. The Meruoca Granite intruded the Lower Alpha sequence. Thus, it is possible to infer maximum and minimum ages for the Lower and Higher Alpha sequences, between 560 and 540 Ma; and 540 and 440 Ma, respectively.

The sand-clay sedimentary deposits that appear on the northernmost part of the area are associated with Barreiras Formation (Figure 1). The alluvial sediments consist of blocks and pebbles of rocks or quartz that are associated with quartz sand.

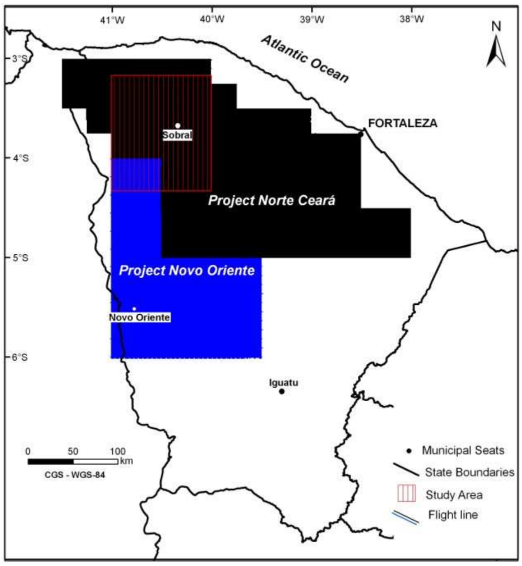

Figure 2: Map of Ceará showing the localization of Norte do Ceará and Novo Oriente projects; study area marked in red.

Airbone geophysical data

The set of airborne geophysics data (Figure 2) used in the work, was supplied by Serviço Geológico do Brasil (CPRM) as digital files. These data were collected as part of the Norte do Ceará and Novo Oriente projects, between 2008 and 2010. The high resolution aeromagnetic and gamma spectrometric profiles of Norte do Ceará project were determined by flying 111,080 km at average altitude of 100 m, with sampling intervals of 0.1 s and 1 s for magnetometer and spectrometer, respectively. The flight lines were NS oriented and spaced 500 m. The quality control lines were EW oriented and spaced 10 km. The data of the Novo Oriente project were obtained in a similar fashion; however, the surface area covered was smaller (Figure 2).

Magnetometry

Initially, the magnetic data were incorporated into the database and organized as GDB files, using Oasis Montaj 7.0.1 GEOSOFT. The database was carefully reviewed and survey control lines were excluded, and problems related to flight altitude were addressed.

The aeromagnetic data were corrected for diurnal and main component of the geomagnetic field variations (*International Geomagnetic Reference Field – IGRF*). These data were then interpolated into 125 m regular grid, which corresponds to one quarter of the flight line spacing, by the bi-directional method – BIGRID in order to generate the anomalous magnetic field (Figure 3). BIGRID promoted the best results in terms of spatial data distribution among several interpolation methods tested. After the interpolation for each project data, the grids Norte do Ceará and Novo Oriente, were then fitted together, using the GRID KNITTING routine.

The power spectrum of the magnetometric signal (Figure 4) was generated to obtain less noisy results regarding spectral separation of shallow and deep sources, since these sources cause magnetic anomalies. The deep sources may reach up to approximately 7.0 km depth and the shallow ones vary between 1.0 and 2.5 km (Figure 4). The higher frequencies, whose wavelength is twice the distance between two successive observations are called Nyquist frequencies (Davis, 1986).

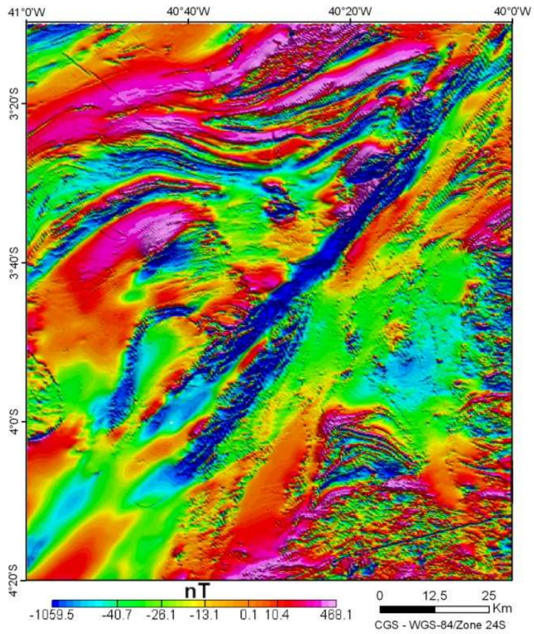

Figure 3: Anomalous magnetic field of Jaibaras Basin structural framework.

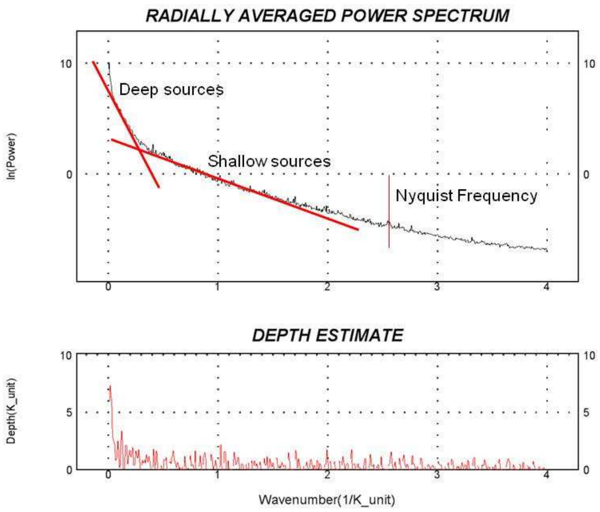

Figure 4: Mean radial power spectrum of the anomalous magnetic field of the studied area.

After this procedure, several filtering techniques were applied to improve the signal/noise relationship and to highlight specific features of the magnetic sources. Figure 5 shows the processing steps of the main magnetic products generated for the Jaibaras Rift area.

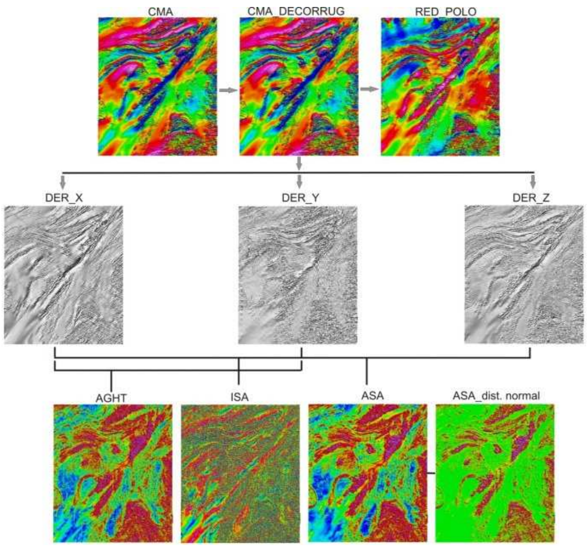

Figure 5: Processing steps of the aeromagnetic data of the Norte do Ceará and Novo Oriente projects.

Gamma ray spectrometry

Aerogammaspectrometric data of both projects, Norte do Ceará and Novo Oriente, were organized and selected as previously described for the aeromagnetic data. However, the fit using the GRID KNITTING routine was not good. This fact can be attributed to the unevenness of the data, which were acquired by different companies on different dates. Therefore, this paper presents only the data of Norte do Ceará project.

The minimum curvature interpolation method, RANGRID, performed best statistically and visually and was also fast. The data were interpolated into a regular grid of 125 m, and then the maps of Potassium (K), Thorium (Th), Uranium (U) channels were prepared, as well as Total Count (TC), Th/U, U/K, and U/Th ratios, integrations, and ternary compositions in false color among the elements. Figure 6 presents the processing steps of the aerogammaspectrometric data of Norte do Ceará project.

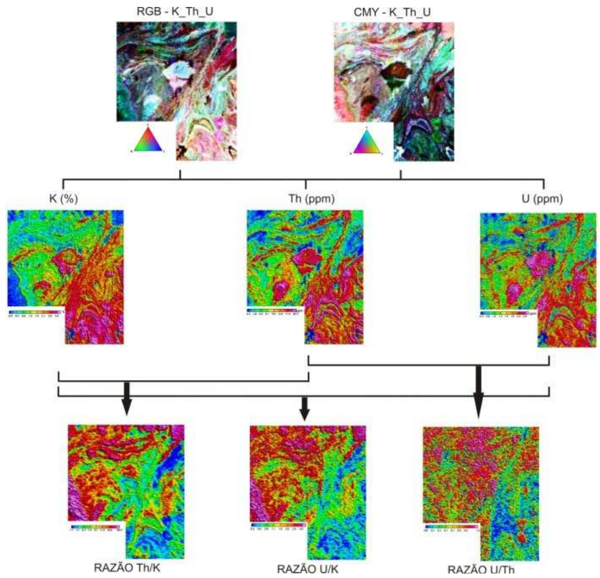

Figure 6: Processing steps of aerogammaspectrometric data of Norte do Ceará project.

In the central part of the area, there is noticeable high frequency noise along the NS flight lines (Figure 7a). These noises are caused by variations of surveying flight altitude, allied with the rugged topography of the terrain in this region. Directional Cosine filter was used to mitigate the noise (Figure 7b).

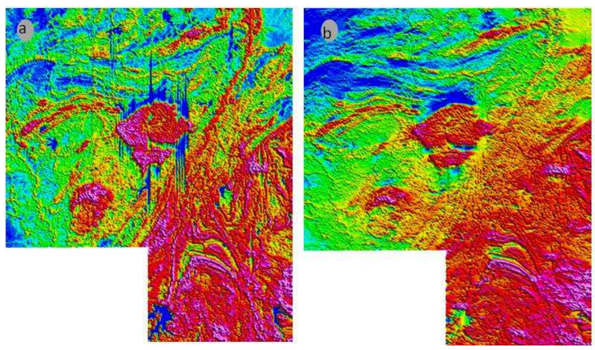

Figure 7: Map of radiometric anomalies – Total Count, (a) displays strong noise along flight lines; (b) after using Directional Cosine filter to mitigate the noise.

Discussion

Qualitative interpretation of the airborne geophysics data was performed based on the geophysical signature of seven distinct domains and within the surface geological context of the study area (Figures 1, 8, 9, 10 and 11).

The main magnetic alignments of the study area (Figure 8) were determined from the maps of magnetic anomalies of the slope of the analytical signal (ISA) and from the first vertical derivative (DZ). These lineaments show NE-SE and E-W as the preferential directions. Subordinate lineaments are NW-SE oriented. The DG1 (Figure 9), which corresponds to Granja Complex and Martinópole Group rocks (north of DMC), is dominated by intense magnetic lineaments in the E-W direction with NE-SW inflection, and displays a pattern of elongated anomalies of short wave length, which are associated with structural alignments of the crystalline basement (Figure 1).

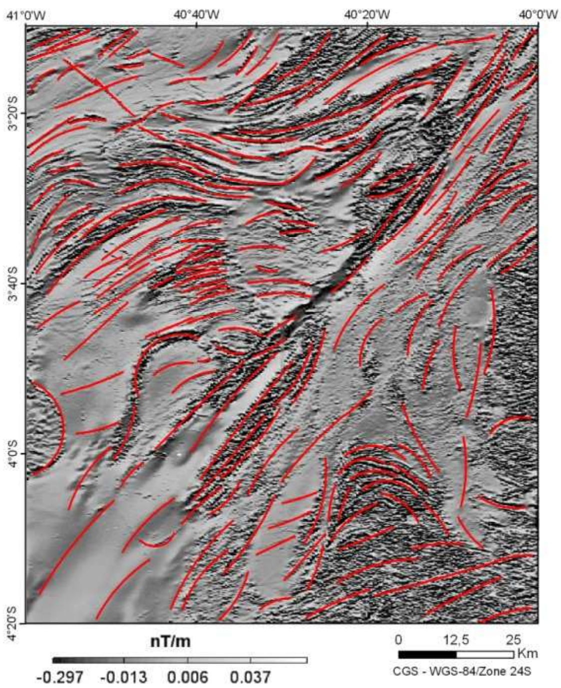

Figure 8: Map of magnetic anomalies of the first vertical derivative showing the main magnetic lineaments.

The magnetic signature shows that the Meruoca and Mucambo granites (DG3 and DG4) have low magnetic contents. The volcanic rocks of Parapuí Suite show positive anomalies as high as 0.3 nT/m (Figure 9). The rocks Coreaú dike swarm are associated with a strong magnetic dipole (Figure 3), with anomalies laid out towards N80E, located west of DG3. DG5 is associated with the rocks of the Jaibaras Basin. This area is marked by a very strong magnetic relief, with strong positive anomalies, whose source is related to the Parapuí volcanic rocks (basalts and andesites). The southeastern area that corresponds to the rocks of the DCC, is characterized by more homogeneous magnetic relief, with a well characterized contact between the metamorphic rocks of Canindé Unit and Tamboril- Santa Quitéria Complex (DG6 and DG7).

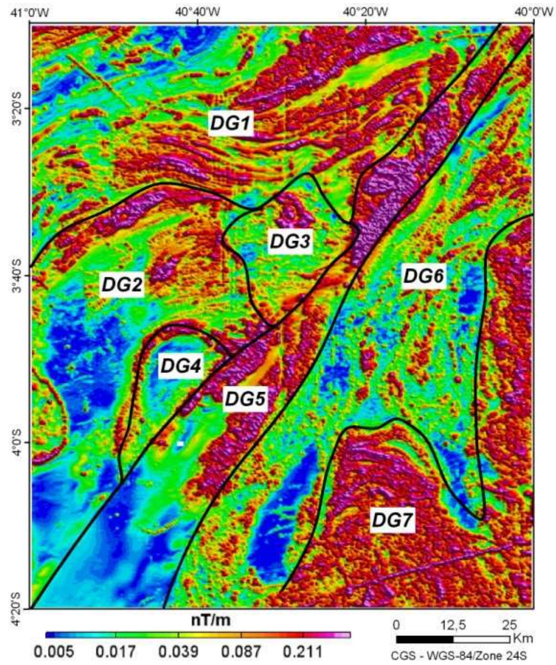

Figure 9: Amplitude of the analytical signal and the interpretation of the main geophysical domains (from DG1 to DG7).

The total count gammaspectrometric map (Figure 10) provides good information on the lithological units of the area, as well as structural lineaments of the crystalline basement.

The Jaibaras Rift (DG5) displays an inexpressive radiometric relief, with low levels of radiation in all channels and lack of any significant feature. Its boundaries are well defined in the image of ternary composition RGB in false color (Figure 11). The contrast is established by the transition of the areas DG5 and DG6. This region is associated to the Shear Zone Sobral-Pedro II (SZSPII), which is part of Transbrasiliano Lineament.

The northern area – DMC displays low radiation values (DG1 in Figure 11) associated with the medium- to high-grade rocks of the Granja Complex and the supracrustal rocks of the Matinópole Group. The rocks of the Ubajara Group and Coreaú dike swarm (DG2) have average radiation values, the contact with the rocks of the crystalline basement (Granja Complex) being well defined to the north. The Meruoca intrusion (DG3) displays high radiometric values especially at its borders, where hydrothermal processes were active during the rise of the pluton. The Mucambo granite (DG4) is also characterized by high count values, especially to the north, where the peaks reach up to 15 μR/h (Figure 10).

The DCC is marked by anomalous high values (7.0 and 15 μR/h) with anisotropic character. The rocks of the Tamboril-Santa Quitéria formation display high radiation amounts and a well defined contact with the rocks of Ceará Complex. It is also possible to observe a strong elongated anomaly, extending from the northeast to the south of the area, which is related to alluvial sediments of the Acaraú river (Figure 11).

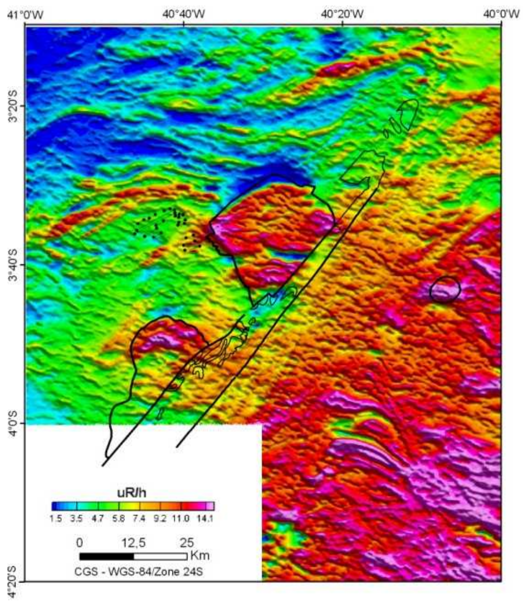

Figure 10: Map of radiometric anomalies of the CT channel showing the border faults of Jaibaras Rift and major igneous bodies.

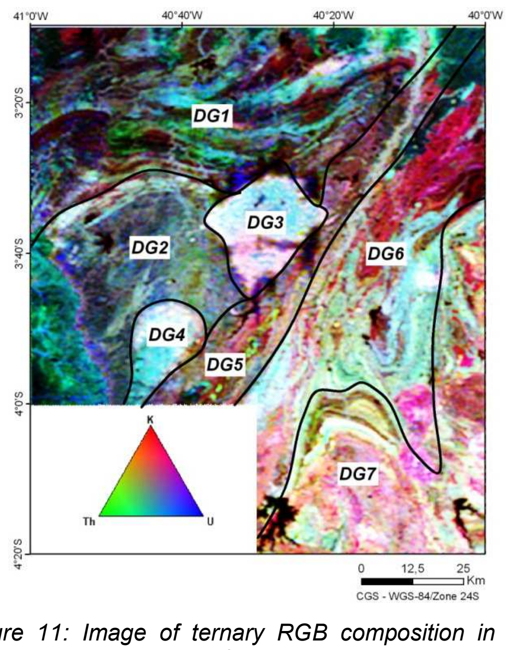

Figure 11: Image of ternary RGB composition in false color and interpretation of the main geophysical domains (DG1 to DG7).

Conclusions

The geophysical mapping of seven geophysical domains in the study area provides important insights into the spatial distribution of geological units that form the structural substrate of Jaibaras Rift, as well as major structural lineaments of the region.

The geophysical maps show the regional structuring marked by magnetic and gamma spectrometric lineaments oriented in the E-W direction and with slight NE-SW inflection in the DMC and NE-SW direction in the Jaibaras Rift. The DCC is more homogeneous, and displays a well defined contact between the rocks of the Ceará and Tamboril-Santa Quitéria complexes.

The signature of the geophysical sources characterizes seven domains, some of them not yet mapped in the known surface geology.

Acknowledgments

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