Tectonic Framework of the Central Portion of the Brasília Belt

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Abstract

The Brasília Belt is the largest and most complex unit of the Tocantins Province, recording important episodes of West Gondwana formation. To explain the evolution process of the Brasília Belt two main hypotheses are considered in literature. The first one states that the Goiás Massif was a microcontinent that was amalgamated to the western part of the São Francisco Craton in the Neoproterozoic era. The second hypothesis considers that the Goiás Massif was a part of the western edge of the São Francisco paleocontinent in the early Proterozoic, and that its basement would be covered by metasedimentary rocks of the Paranoá and Bambuí groups. To test both hypotheses, the goal of this study is to characterize the geophysical signatures of tectonic blocks, the Goiás Magmatic Arc (GMA), Goiás Massif (GM) and the external zone (EZ), based on aeromagnetic and satellite and ground gravity data. Additionally, this project aims to define contact regions between these units and to indicate a possible crustal suture zone. For this purpose, enhancement techniques were applied to data in order to facilitate the integration and interpretation of the data such as Vertical Derivative, Total Horizontal Gradient, Tilt Derivative and Tilt Derivative of total horizontal gradient. The magnetic data present NE-SW trends, which according to matched-filter extend to at least 19 km depth. The matched-filter applied in windows for each block indicates that the block's deeper sources (10.2 km) are shallower than those of GMA and EZ blocks (12,1 km and 11.9 km, respectively). Bouguer anomalies (WGS 2012 and ground data) confirm the regional NE-SW trend observed in the magnetic data. Both highlight intermediate intensity anomalies in the EZ and GM blocks, and in the GMA block gravity anomalies intensity is higher. The high gradients in the GM block are associated with mafic-ultramafic complexes. According to the data, it is observed that the Rio Maranhão Fault is not a deep structure, indicating that the Goiás Massif possibly belongs to the basement of the São Francisco paleocontinent.

Introduction

The studied area is geographically located in the center of the state of Goiás (central region of the Tocantins Province), between Brasília, in the southern portion, and Porangatu, in the north of the area (Figure 1). Tectonic framework analysis was carried out by magnetic and gravimetric methods.

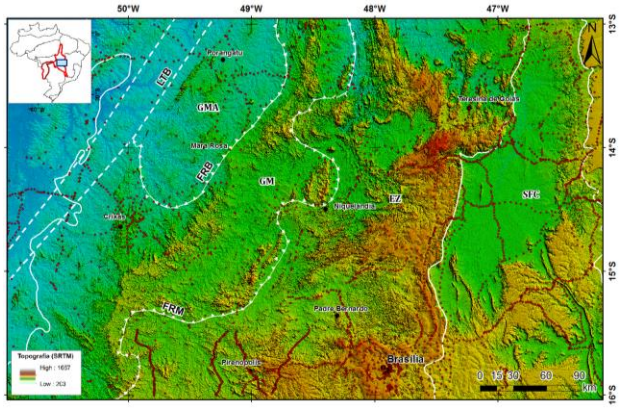

Figure 1 - Map of the study area, Federal District and northern portion of the Goiás state, with geographical state boundaries.

To study the tectonic framework in the central portion of the Brasília Belt, a model of crustal blocks was used, considering the tectonic compartments earlier suggested (Pimentel *et al.,* 2004; Valeriano *et al.*, 2008; Fuck *et al.*, 2014, 2017). The model is subdivided into external zone, internal zone, Goiás Massif and Goiás Magmatic Arc. Rio Maranhão and Rio dos Bois fault systems are the main limits between these units.

There are two main hypotheses to explain the tectonic evolution of the Brasilia Belt. The first one considers that the Goiás Massif was a microcontinent that was amalgamated to the western part of the São Francisco Craton in the Neoproterozoic era, as proposed by Brito Neves and Cordani (1991), Blum and Pires (1996), Pimentel *et al.* (1999, 2000), Valeriano *et al.,* (1995, 2008), Cordani *et al.* (2013).

The second hypothesis indicates that in the Mesoproterozoic, the Goiás Massif constituted the western border of the São Francisco paleocontinent, which was strongly affected by a series of events during the Neoproterozoic period. This proposal was suggested by Fuck (1994), Pereira and Fuck (2005), Soares *et al.*, (2006), Carminatti (2006), Martins-Neto (2007), D'el-Rey Silva *et al.*, (2008, 2011), Ventura *et al.,* (2011), Brito Neves and Fuck (2013), Fuck *et al.,* (2014).

Method

In this work, Bouguer's gravimetric data and terrestrial anomaly were used in addition to aerial magnetometry data in order to contribute to the understanding of the tectonic context of the area.

Magnetic data from seven aerogeophysical surveys were used. This comprises the survey from the Brazil-Canada Geophysical Project (PGBC), two surveys from the Geology of Brazil Project (PGB), and four from the Aerogeophysical Project of the Goiás State, made available by the Goiás State Government (SIEG / MME) and the geological Survey of Brazil (CPRM). The results of this study are presented in Figure 2.

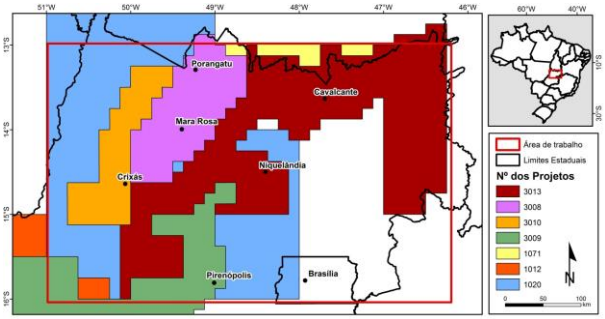

Figure 2 - Map with aerogeophysical projects covering the study area, represented by survey codes according to the caption.

The processing and integration of magnetic data in the work area were carried out under the Transbrasiliano Lineament project (Vidotti *et al.,* 2011). The aeromagnetic surveys covering the work area have flight lines with N-S direction, with spacing between 500 and 2000 m. The tie lines have perpendicular direction to flight lines, with space ranging from 5 to 22 km and flight height between 110 to 150 m (table 1).

Table 1 – Geophysical projects covering the study area

Project	Year	Project Code	Organization Responsible	FL*	Direction FL*	Flight height	TL**
PGBC	1975	1020	DNPM	2000 m	N-S	150 m	14 km
Iporá	1973	1012	CPRM	1000 m	N-S	150 m	22,5 km
Complemento do Tocantins	2006	1071	CPRM	500 m	N-S	100 m	10 km
Arco Magmático de Arenópolis - Seq. Juscelandia	2004	3009	CPRM	500 m	N-S	100 m	5 km
Arco Magmático de Mara Rosa	2004	3008	CPRM	500 m	N-S	100 m	5 km
Oeste do Arco Magmático de Mara Rosa	2005	3010	CPRM	500 m	N-S	100 m	5 km
Paleo-neoproterozoico Nordeste de Goiás	2006	3013	CPRM	500 m	N-S	100 m	5 km

*FL – flight lines; ** - TL- tie lines.

The Bouguer satellite anomaly data (figure 3A) were obtained from the World Gravity Map 2012 – WGM 2012 (Bonvalot *et al.* 2012), with 1"x 1' spacing, which is part of a data set with computer grids on a global scale, made available by the Bureau Gravimetrique International (BGI). This information was obtained from the Geopotential Model 2008 (EGM 2008), acquired by the National Geospatial Intelligence Agency (NGA). The data were interpolated using the kriging method (Krige, 1966; Cressie, 1990).

The data of terrestrial gravimetry are public and part of a compilation of previous projects developed by Vidotti et al. (1998) and other institutions, such as the Brazilian Institute of Geography and Statistics (IBGE), Institute of Astronomy, Geophysics and Atmospheric Sciences of the University of São Paulo (IAG/USP) (figure 3B). Interpolation of land data was accomplished by Minimum Curvature (Briggs, 1974) with 6,000 m cells (figure 3B).

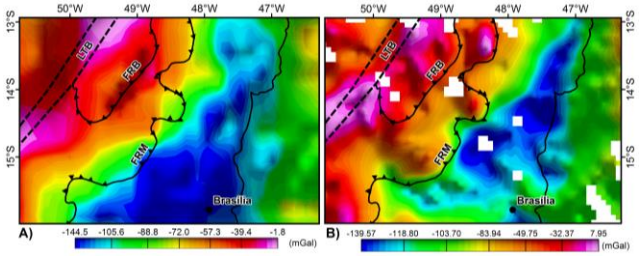

Figure 3 - A) Bouguer anomaly satellite map; B) Bouguer anomaly map of terrestrial data. Tectonic limits based on Pimentel *et al.* (2004) and Fuck *et al.* (2014). LTB – Transbrasiliano Lineament; FRB – Rio dos Bois fault; FRM – Rio Maranhão fault.

In order to highlight the anomalies, filters were applied on the map of the anomalous magnetic field to which the directional derivatives were initially applied in Gx, Gy and Gz (Telford et al., 1990). Furthermore, THG - Total Horizontal Gradient (Cordel, 1979; Cordell and Grauch, 1985; Grauch and Cordell, 1987, Blakely, 1995), TG - Total Gradient or 3D Analytical Signal (Nabighian, 1972, 1984; Roest et al., 1992; Nabighian et al., 2005) Tilt Derived of Tilt Derivative (Miller and Singh, 1994; Verduzco et al., 2004) and Total Horizontal Gradient Tilt Derivative (Ferreira et al., 2010). The main products used for the analysis of magnetic structures and variation of vertical derivative can be seen in figures 4 A, B, C and D.

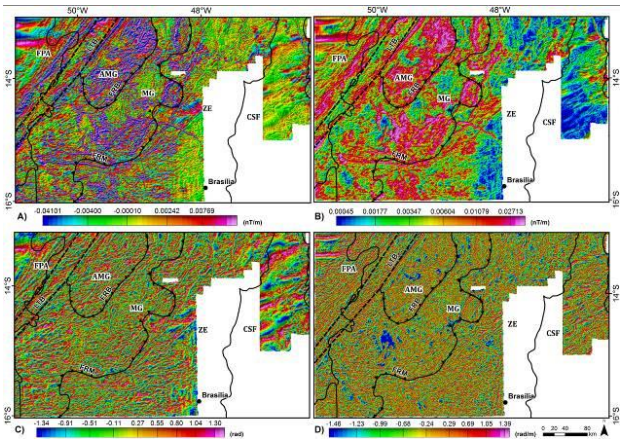

Figure 4 - Products of the anomalous magnetic field for extraction of the magnetic lineaments, with tectonic limits based on the modified map of Pimentel et al. (2004) and Fuck et al. (2014). A) Vertical derivative map. B) Total horizontal gradient map. C) Derivative tilt map. D) Tilt derivative of the total horizontal gradient map. Tectonic domains: SFC - São Francisco Craton; EZ - external

zone; GM - Goiás Massif; GMA - Magmatic Arc of Goiás; FPA - Araguaia Range; main faults: FRM - Fault Rio Maranhão; FRB - Rio dos Bois fault. The dashed lines indicate the Transbrasiliano Lineament.

Satellite data were used to perform qualitative analysis of mantle response anomalies while terrestrial gravimetric data brought information from structures to shallower crust sources.

Results

The qualitative interpretation of the data began with the extraction of magnetic lineaments of 1st, 2nd and 3rd orders. These were differentiated according to their extension and values of signal intensity as a function of high and low frequencies, as well as the gradient variation between the units. Matched-filter (Phillips, 2001) was applied so as to verify the continuity of the lineaments and to obtain an estimate of the continuity of these features in depth.

Figure 5 shows that the extracted lineaments have a preferred direction NE-SW, following the trend of the Transbrasiliano Lineament. This reveals that the system of transcurrent faults exerts a strong influence over the region. In the southeastern part of the area there is no aeromagnetic survey, implying a lacuna of information about the contact relation and the magnetic structures between the external zone and the São Francisco Craton in this region.

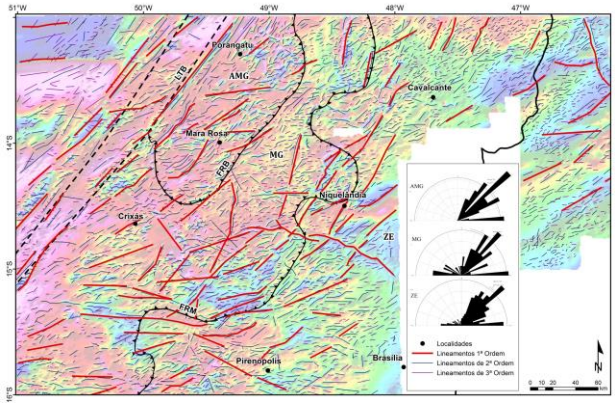

Figure 5 - Map of magnetic lineaments interpreted from the products of the anomalous magnetic field on the CMA map, showing rosette diagrams of the tectonic domains studied, known geotectonic limits and localities of the region. The geotectonic limits of the study area are based on the modified map of Pimentel et al. (2004) and Fuck et al. (2014). LTB - Transbrasiliano Lineament; FRB - Rio dos Bois fault; FRM - Rio Maranhão fault; GMA - Magmatic Arc of Goiás; GM - Goiás Massif; EZ - External Zone; SFC - São Francisco Craton.

From the interpretation of the power spectrum in the CMA data in the matched-filter, four estimates of depths of sources were obtained: shallow, 700 m; intermediate, 2 km and 8 km; and deep, 19 km (figures 6 A, B, C and D). In the depth estimation performed on the Bouguer anomaly map (Figure 7A) four depth ranges of sources were obtained: shallow, 2 km; intermediate / shallow, 7 km; intermediate, 15 km; and deep, 50 km. Although 4 intervals of gravimetric sources were obtained in the matched-filter, the sources located at 2 km are not indicated for characterization of the tectonic blocks, as well as the indication of contacts between them due to the low resolution of the map.

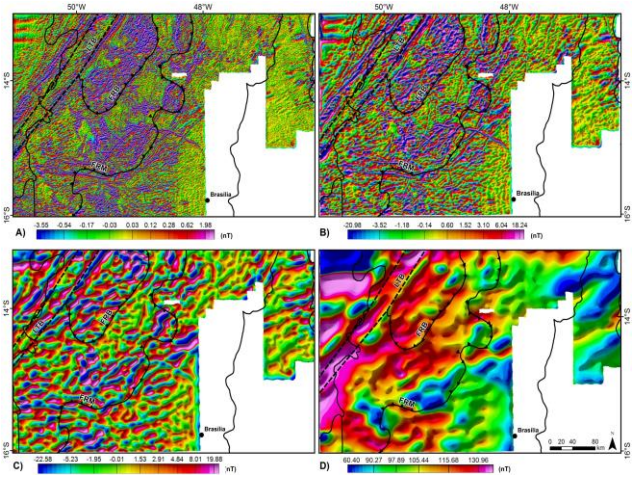

Figure 6 – Matched-filter maps obtained from the CMA data for shallow and intermediate sources, with tectonic limits according to Pimentel et al. (2004) and Fuck et al. (2014). The dashed lines indicate the projection of the Transbrasiliano Lineament. Maps of sources: shallow 700 m (A); intermediate to 2 km (B), intermediate to 8 km (C); deep to 19 km (D). LTB - Transbrasiliano Lineament; FRB - Rio dos Bois fault; FRM - Rio Maranhão fault.

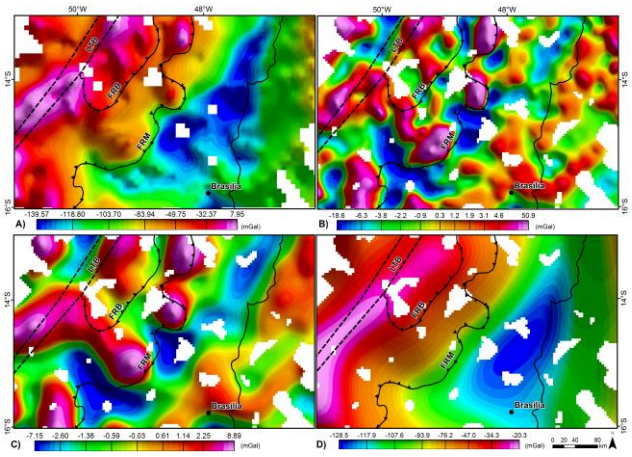

Figure 7 - Bouguer anomaly maps of terrestrial data (A). Matched-filter maps of Bouguer satellite anomalies, 7 km (B), 15 km (C) and 50 km (D). The geotectonic limits based on Pimentel et al. (2004) and Fuck et al. (2014). LTB - Transbrasiliano Lineament; FRM - Rio Maranhão fault; FRB - Rio dos Bois fault.

Conclusions

In the extracted magnetic structures, directional variations were observed in the tectonic blocks (figure 5). In the external zone block, the 1st-order lineaments usually have NNE-SSW direction. There are inflections in the WNW-ESE direction, forming sigmoids in the Megaflexure

of the Pyrenees (Fonseca et al., 1995) or the Pyrenees Syntaxis (Araújo Filho, 1999). In the GM block there are also 1st order structures with direction NNE-SSW and NE-SW.
In the GMA block the 1st-order lineaments have NE-SW and E-W direction. By means of these lineaments, it was possible to notice that there is a similarity of directions of the magnetic structures between the external zone blocks and the Goiás Massif, which can be observed in the map and in the rosette diagrams in Figure 5. Matched-filter maps revealed that the magnetic structures with NE-SW direction could be observed in sources up to 19 km, this being the preferred trend of the area, and parallel to the Transbrasiliano Lineament.

The combined analysis of the magnetic and gravimetric anomalies data demonstrated the relationship of the observed anomalies with large faults and shear zone, according to the map of structural geology extracted from Lacerda Filho et al. (2004) and Souza et al. (2004). Data from the WGS 2012 satellite model contributed to the preliminary analysis of the Bouguer anomaly from the area, clearly showing the NE-SW trend of the regional units (Figure 7A). In the terrestrial gravimetric data, Bouguer anomaly demonstrates the same structural direction (Figure 7B).

In the Bouguer terrestrial anomaly, it was observed a variation of approximately 120 mGal NW-SE, interpreted by Marangoni et al. (1995) as a relative continental crust overlap. Thus, the data suggest that the Rio Maranhão Fault constitutes an intracontinental structure without depth expression. Furthermore, in Rio dos Bois Fault System there is a region of discontinuity, indicating a suture zone between the Magmatic Arc of Goiás and the Goiás Massif. The presence of the mafic-ultramafic complexes of Cana Brava, Niquelândia and Barro Alto in the Goiás Massif justifies the gravimetric highs in this region.

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