



Unveiling the Transbrasiliano fault system in northern Paraná Basin using airborne magnetic data

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Abstract

Six airborne magnetic surveys were analyzed with the matched filtering and tilt derivative methods to estimate source depths within the Transbrasiliano fault system in northern Paraná Basin, Brazil. Our interpretation defined the structural framework within three main depth zones, illuminating deep crustal, basement, and basin magnetic sources. The deepest zone exhibits three major northeast-trending crustal discontinuities related to the Transbrasiliano lineament, dividing the region into four geotectonic compartments. In the intermediate depth zone, basement anomalies show dextral displacement westward, with important splay faults from the major transcurrent faults. Shallower sources include granitic and alkaline intrusions, the Serra Geral basalts boundaries, and reactivated brittle structures.

Introduction

The Transbrasiliano lineament (Figure 1, TBL in the inset) is a Neoproterozoic northeast-trending transcurrent fault system (Schobbenhaus *et al.*, 1975) that separates two major tectonic domains in the South America Platform (Cordani *et al.*, 1984). The western domain is comprised mainly of the Amazonian craton, whereas the eastern domain is a set of orogenic belts, allochthonous blocks, and cratonic rocks. During the time of the Gondwana supercontinent (600 Ma), the African Hoggar-Kandi lineament and the TBL were linked (Caby, 1989) in northern Ceará by the Sobral-Pedro II shear zone. This major fault system produces a distinctive, continent-scale magnetic discontinuity from the Congo region, Africa, to Sierras Pampeanas, Argentina (Fairhead and Maus, 2003; Ramos *et al.*, 2010). Along the northern flank of Paraná basin, the magnetic expression of the TBL shows disparate trending directions.

At least three important reactivation episodes affected the TBL. Two of them occurred during Cambrian-Ordovician and Silurian-Devonian time, forming small cratonic basins, including Jaibaras in Ceará state, and Água Bonita in Tocantins, respectively. The third

episode is related to the opening of the Atlantic Ocean in Cretaceous time.

Northeast- and northwest-striking basement structures were widely reactivated in the Paraná basin, causing block-bounded uplifts and subsidence. The initial troughs of the Paraná basin were developed within northeast-trending structures (Zalán *et al.*, 1991; Heilbron *et al.*, 2000), some associated with the TBL. Late Ordovician isopachs of the Paraná basin show NE-SW trending alignments, suggesting sedimentation controlled by the TBL (França *et al.*, 1995; Milani, 1997).

Our study consisted of two main approaches. The first one provides a better understanding of the tectonic framework of the Transbrasiliano lineament in northern Paraná basin. The second one identifies geological evidence for how that tectonic controlled the evolution of the Paraná Basin, from initiation of subsidence to later reactivation.

The study area is located at the northern Paraná basin and includes parts of Goiás (GO), Mato Grosso (MT), and Mato Grosso do Sul (MS) states (Figure 1).

Geology of the study area

Although the study area is partially covered by Cenozoic sediments of the Araguaia and Pantanal formations, most of the area exhibits exposures of Paraná basin sedimentary units and underlying basement.

An important NE-SW-trending fault crosses the northern flank of the Paraná basin near Bom Jardim de Goiás and marks the tectonic contact between two types of Neoproterozoic basement. The eastern basement is recognized as the Arenópolis Magmatic Arc, which consists of orthogneiss units that generally separate volcano-sedimentary belts (Pimentel and Fuck, 1992). The western basement is represented by the Paraguay fold belt, mainly comprised of the Cuiabá Group, consistent of metasedimentary rocks, strongly folded and metamorphosed during the Brasiliano orogeny (Alvarenga and Trompette, 1993).

According to Zalán *et al.* (1991), the most common northeast-trending structures in the Paraná basin are related to strike-slip tectonics, including *en echelon* faults, reverse faults and folds, and flower structures. The preferable kinematic character is transcurrent movement, as observed in the TBL. The opening of the Atlantic Ocean in Cretaceous time formed extensional northwest-trending structures that accommodate tholeiitic basalt dikes in Jurassic-Eocene time, and alkaline

intrusions in the Late Cretaceous in the Paraná basin (Almeida and Melo, 1981). The major depocenter comprises the thickest basalt of this basin, reaching up to 2000 m deep.

Methodology

Our analysis was based on the anomalous magnetic field; i.e., the total measured field corrected for diurnal variations, the main geomagnetic field (IGRF), and leveling errors. These data were compiled from six airborne geophysical surveys (Figure 1) with variable characteristics, as described in Table 1.

Our primary motivation was to enhance magnetic lineaments possibly related to tectonic structures. The tilt derivative (Miller and Singh, 1994) of the magnetic anomalous field was used to delineate and qualitatively estimate the depth of linear magnetic sources (Salem *et al.*, 2010).

In addition, we used the matched filtering analyses (Phillips, 2001) to separate magnetic anomalies into additive components representing different source depths. This technique is based on potential field spectra (Spector and Grant, 1970), where radially symmetric parts of the spectra are modeled to determine amplitude and Wiener filters that enhance anomalies originating from important depth ranges (Phillips, 2001).

Our analysis was developed based on two main anomalous magnetic field grids. The first grid was developed by merging all of the individual grids (Table 1), with the exception of the Paraná basin survey, which used more regional acquisition parameters. The Merged-grid provides a high-resolution view of magnetic anomalous field variations for the entire study area. The second grid in our analysis was derived from the Paraná basin survey alone.

Table 1 – Main features of the airborne geophysical surveys.

Projects*	1012	2009	2022	2025	3009	Paraná Basin
Flight-line spacing	1km	1km	1km	1km	0,5km	6km
Flight direction	N-S	N-S	N-S	E-W	N-S	N-S
Flight height	150m	120m	150m	150m	100m	1800m

*1012- Iporá; 2009 – Alto Garças; 2022 – Barreiro; 2025- Rondonópolis; 3009-Goiás 01

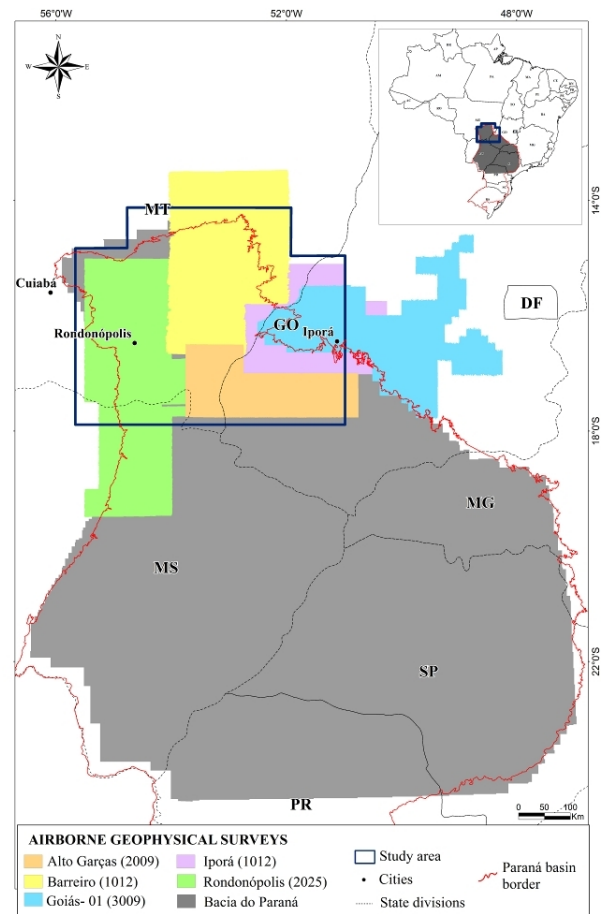


Figure 1 – Location of the study area and the airborne geophysical surveys.

Results

Our procedure is described in the flowchart of figure 2. Using matched filtering analyses of the Paraná basin survey, we determine three main source zones at 26, 6 and 0.8 km depth; using matched filtering analyses of the Merged-grid four source zones were found at 16, 5.4, 1.1 and 0.3 km depth. The shallower zones for each grid were not used due to high-frequency noise.

The TILT derivative was used to delineate linear structures from the depth section.

We identified four main regions separated by three major NE-SW trending magnetic discontinuities (Figure 2). These domains were named after geographic locations as follows, from east to west: Arenópolis, Bom Jardim de Goiás, Rondonópolis and Poxoréo. The strong magnetic discontinuity separating the Arenópolis and Bom Jardim de Goiás domains (A) is named after the Serra Negra fault (Seer, 1985). Northwestward, we define the Baliza (B) and General Carneiro (C) lineaments. The NW-SE lineament (D) is also an important structure, here named the São Vicente lineament, which crosses the São Vicente granite in the Mato Grosso.

Discussion

Linear magnetic signatures with large wavelengths separate distinct magnetic domains that originate from the deepest parts of the magnetic section. We determined depths of 16 and 26 km by applying matched filtering to the Merged-grid and Paraná basin survey, respectively (Figure 2). The lineaments correspond to NE-SW crustal discontinuities of the Precambrian basement, separating different geotectonic compartments. The Serra Negra lineament separates the Arenópolis magmatic arc from a different Precambrian terrain, probably belonging to the Paraguay Belt.

The intermediate zone lies at 5.4 or 6 km depth, as determined from the Merged-grid and Paraná basin survey, respectively. We interpret this zone as plastic to brittle domains that possibly provided the development of regional structures, represented by first-order lineaments in figure 2. Dextral sigmoidal lineaments are strongly enhanced at this depth level. Dextral offsets in trend of higher frequencies lineaments, when compared to deeper zones, reflect possible narrowing of the fault system root and the appearance of shallower and brittle splay faults from this major structure.

The 1 km depth level is related predominantly to brittle tectonism, with linear magnetic features. The magnetically well-expressed Serra Negra fault is the tectonic contact between the Devonian sequence of the Paraná Basin and the Cambrian Macacos granite, suggesting that the Serra Negra lineament was reactivated as a fault after the Devonian period. NW-SE trending lineaments obliterate most of NE-SW structures. The São Vicente discontinuity is the most pronounced magnetic feature with this trend. Seismicity and Cretaceous alkaline plutons are aligned along these structures (Figure 2). The basalts of the Serra Geral Formation are strongly enhanced at this level.

The tilt derivative analysis illuminated several highly deformed 500 Ma granite plutons, which we interpreted to have been deformed by dextral sigmoidal shear zones.

Conclusions

The first tectonic elements of the Transbrasiliano lineament shear zone were related to the NE-SW trending Serra Negra and General Carneiro lineaments. Subsequent reactivation invoked dextral strike-slip deformation, manifested by the Baliza lineament and displacement of the Macacos granite along the Serra Negra fault.

The NE-SW dextral Transbrasiliano transcurrent system and subsequent reactivations cause subsidence that accommodated the initial sediments of Paraná basin. It also caused vertical and horizontal displacements along faults that formed smaller depocenters.

The Mesozoic Atlantic Ocean opening resulted in northwest-trending structures, which affected and contributed to reactivation processes of the northeast-trending structures associated with the Transbrasiliano lineament. Northwest-striking structures remain seismically active today.

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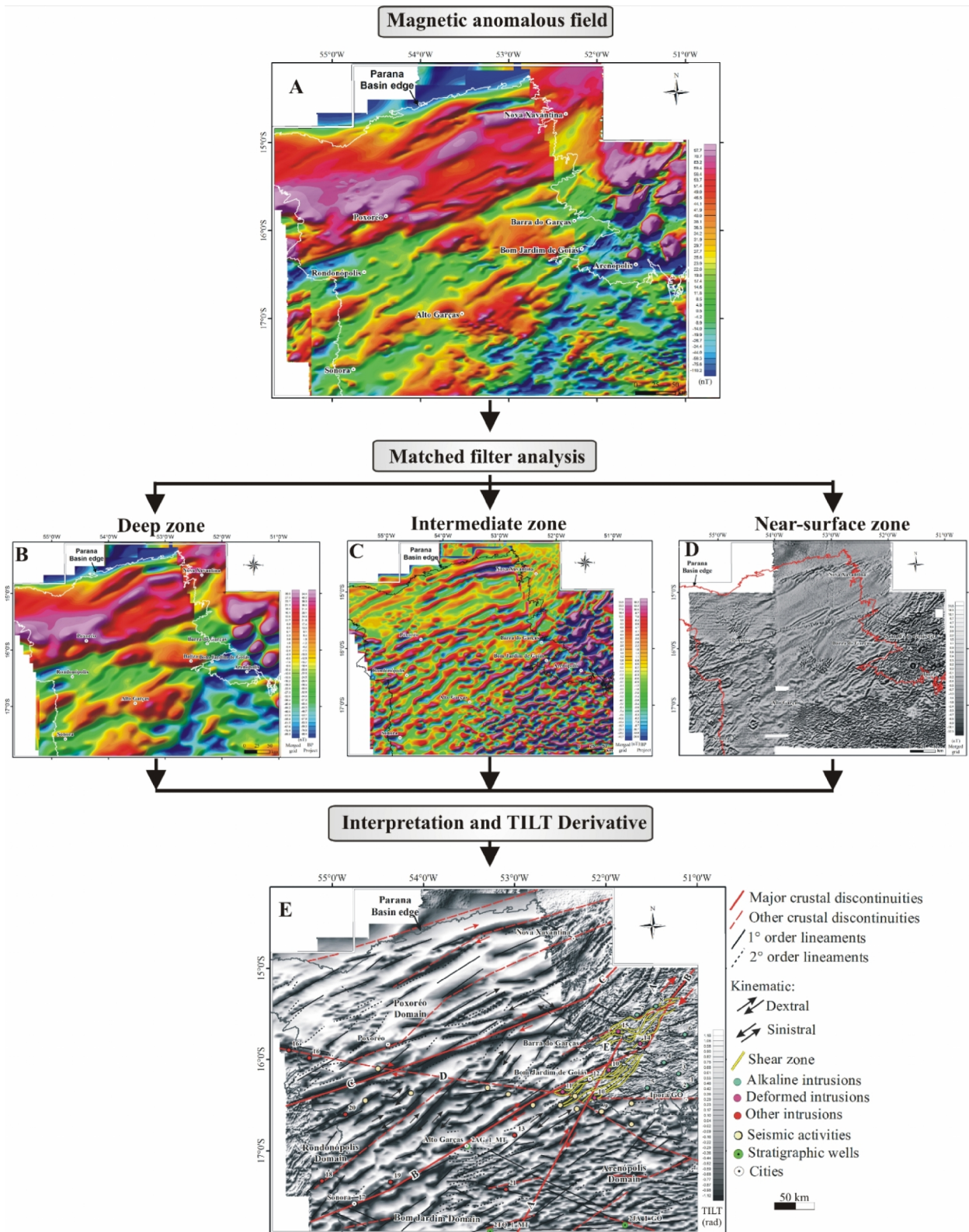


Figure 2 – Grids and interpretation derived by application of matched filtering analysis and tilt-derivative analyses. In A to C and E images, the Paraná basin survey grids overlays the merged-grid. **A**: Anomalous magnetic field. **B to D**: Matched filtering results. **E**: Tilt derivative and the interpreted geological features. Lineaments A to D are, as follows: Serra Negra, Baliza, General Carneiro and São Vicente.