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Geophysical reassessment of the Azimuth 125° Lineament: emplacement model and propagation of its dikes

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Abstract

This study analyzes the area along the Azimuth 125° Lineament (Az 125°) supposed to occur from Rondônia to Rio de Janeiro, in Brazil. The lineament is an important structural feature in association with great carbonatite and kimberlite complexes in Brazil (e.g., Goiás and Alto Paranaíba Alkaline Provinces), consisting of extensive NW-SE oriented faults. The origin of the Az 125° Lineament and its dikes emplacement are widely discussed. The main intention of this work is to propose a model of emplacement of the Az 125° dikes. Also, some important magnetic characteristics of the lineament are presented. The magnetic data clearly define the features of the Az 125° in the southern portion of the study area, but we found no magnetic geophysical evidence that this lineament occurs from the Mato Grosso state to the Rondônia state. The dikes that compose the great Az 125° feature have distinct magnetic attributes, as their polarities (normal and reversed). It is suggested that the alternating polarity is due to local re-magnetization sometime after their intrusion. It is proposed that the dikes were positioned along a zone of lithospheric weakness and their propagation was facilitated due to the occurrence of mid-crustal axial feeder chambers.

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1. Introduction

The Azimuth 125° (Az 125°) Lineament was first described by Bardet (1977) as a sequence of diamond deposits aligned from Abaeté (Minas Gerais) to Rio Machado (Rondônia) oriented on an NW-SE belt. Bardet (1977) defined it as a belt with 1800 km long and about 200 to 300 km wide. The region of the Az 125° and its associated mineralization was also studied by other researchers, who named the lineament in other ways. Chaves and Neves (2005) called it as Pará de Minas Dike Swarm and Schobbenhaus et al. (1975) named the Az 125°, in the Triângulo Mineiro region, as the Alto Paranaíba Lineament. Latterly, Coelho and Chaves (2016, 2017) suggested the Az 125° as part of the Transminas Dike Swarm. Pereira et al. (2008) designated this azimuth as one of the most important metallotect related to kimberlite diatreme intrusions in Brazil. As similar as Bardet (1977), Gonzaga and Tompkins (1991) also indicated that Az 125° occurs in the state of Rondônia, however, they pointed that the lineament follows to the state of Rio de Janeiro (Fig. 1).

Dike swarms can be established in an extensive range of tectonic settings, over a wide variety of scales and including a diversity of magma compositions (Le Pera, 2014). Giant dike swarms denote traces of magmatic events that are represented by, perhaps, the highest production of magma and effusion rates in the geological record. Generally, giant swarms are associated with the creation of enormous flood basalt provinces and continental breakup. The orientation and density of dike systems can register the stresses that affected the crust at the time of their emplacement (Fialko and Rubin, 1999).

Part of the Az 125° was extensively studied by Moraes Rocha (2013) and Moraes Rocha et al. (2014), who worked in its central portion and divided it into three magnetic lineament systems with distinct magnetization characteristics, associated with different tectonomagmatic processes. These authors interpreted the Az 125° as a great system of faults filled by basic magma during at two or three different phases.

The Az 125° Lineament is commonly indicated by some authors to occur from the state of Rondônia to the state of Rio de Janeiro, and it was proposed for the studied area the polygon that involves the elongated NW-SE trend, as shown in Figure 1.

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In arched areas and fault zones, as at the edges of the Paraná, Paranaíba (Almeida 1986), and Amazonas basins (Biondi 2003), often occurs great alkaline–carbonatite complexes and kimberlite provinces. Most of them are related to main structural lineaments as Transbrasiliano, Blumenau, and Az 125° (Fig. 1). The Az 125° Lineament is the most important one regarding the distributions of kimberlite and carbonatite complexes in Brazil (Gonzaga and Tompkins 1991).

It is known that there is a relevant geographical relation between the Goiás Alkaline Province (GAP) and Alto Paranaíba Alkaline Province (APAP) with the Az 125°, once they resulted from extreme magmatic activity that happened in the Upper Cretaceous (Dutra et al. 2012). Chemical and thermal influences from mantle plumes have been associated with the development of these provinces (Gibson et al. 1995, 1997; Thompson et al. 1998). One of the suggestions is that the magmatism related to the GAP and APAP occurred as a consequence of the Trindade plume in Upper Cretaceous (Crough et al. 1980; Gibson et al. 1995, 1997; Thompson et al. 1998).

In this work, the magnetic data was the basis for the study of the Az 125° Lineament. Geophysics is a significant tool for getting geological knowledge and information. The magnetic method has predominated in recent geological studies of Precambrian areas. Structures as faults, basic dikes, and rock contacts can usually be recognized by their magnetic signatures. Ultramafic rocks, such as kimberlites, are often related to these features and, due to their high magnetic susceptibility, can be identified in the same manner (Power et al. 2004). This recognition is also based on the lithological and structural characterization of the lateral variances in the physical properties of the crust (Airo 1999). To classify and define environments structured by tectonomagmatic processes, magnetic and gravimetric geophysical methods, mainly, are often applied at different scales (Marangoni and Mantovani 2013).

The tectonic history and the mechanisms of emplacement of continental dike swarms spreading across great distances remains an obscure subject. The origin and emplacement of the Az 125° Lineament have been subject of discussion. The main goal of this work is to propose a model of the emplacement of the Az 125° dikes.

Previous studies show that the Az 125° is well defined by magnetometry in the southern portion of the study area, from the limits with the Transbrasiliano Lineament (TB) to the state of Minas Gerais. Thus, defining if the Az 125° occurs from its limits with the TB to the state of Rondônia is also an objective of this work.

FIGURE 1 – Map presenting geological provinces and main structural lineaments of Brazil, the area of study (polygon in red), and the segments of the Az 125°– Rondoniense (RO); Parguazense (PA); Brasiliano (DL - Dunites and Lamprophyres); Brasiliano (CK - Carbonatites and Kimberlites); Brasiliano (SF - Syenites and Phonolites). Adapted from Gonzaga and Tompkins (1991), Delgado et al. (2003), Schobbenhaus and Brito Neves (2003), and Curto et al. (2013).

2. The Azimuth 125° Lineament

The Az 125° is a large set of NW-trending faults formed during the Brasiliano Event (Moraes Rocha 2013; Moraes Rocha et al. 2014). Its southeastern portion is composed of three mainly lineaments systems constituted by mafic dikes with distinct magnetic signatures (Fig. 2; Table 1; Moraes Rocha et al. 2014).

The NW-trending structures related to the Azimuth 125° are enhanced by the aeromagnetic data. At field trips, only a few dikes were mapped, once they sporadically outcrop at places where erosion processes and weathering action could expose them. Moraes Rocha et al. (2014) mapped five dikes related to the Az 125° in Goiás and Minas Gerais states. Most of them appear as centimeter- to meter-sized block outcrops and show attributes of hypabyssal intrusive rocks; they are composed by dark gray olivine gabbro and olivine diabase with phaneritic texture.

3. Geological Context

The study area comprises the Amazonas Craton, Tocantins, Paraná, São Francisco and Mantiqueira provinces (Fig. 1). It involves the whole extension of the Az 125° Lineament, which is believed to extend from Rondônia State to the coast of Rio de Janeiro State.

Most of the area is located in the southern portion of Amazonas Craton, limited to east, south, and southeast by rocks generated during the Brasiliano Orogenic Cycle (930 to 540 Ma; Pimentel and Fuck 1992). Over the years, several compartmentalization models have been suggested for the craton. Studies supported by geochronological dating and Sm-Nd isotopic data suggest a division into eight geotectonic provinces, which evolution is attributed to accretion processes, related to the development of magmatic arcs (Transamazônica, Carajás-Imatacá, Rondônia-Juruena, and Tapajós-Parima) or to the recycling of continental crust (Rio Negro, Amazônia Central, Sunsás, and K'Mudku; Santos et al. 2000). This craton is covered by the Phanerozoic basins: Maranhão (to the northeast), Xingu and Alto Tapajós (to the south), Parecis (to the southwest), Solimões (to the west), Tacutu (to the north), and Amazonas (to the center). An extensive zone of the Az 125° covers the Parecis Basin.

The Tocantins Structural Province (Almeida et al. 1977) comprises a system of Brasiliano Orogens, characterized by fold and thrust belts named Paraguay, Brasília, and Araguaia, that resulted from the collision and convergence of three continental plates (Delgado et al. 2003): São Francisco Craton (east); Amazonas Craton (west); and Paranapanema Craton (southwest). Reworked Archean and Paleoproterozoic terrains during the Brasiliano cycle form the basis of the Province (Delgado et al. 2003).

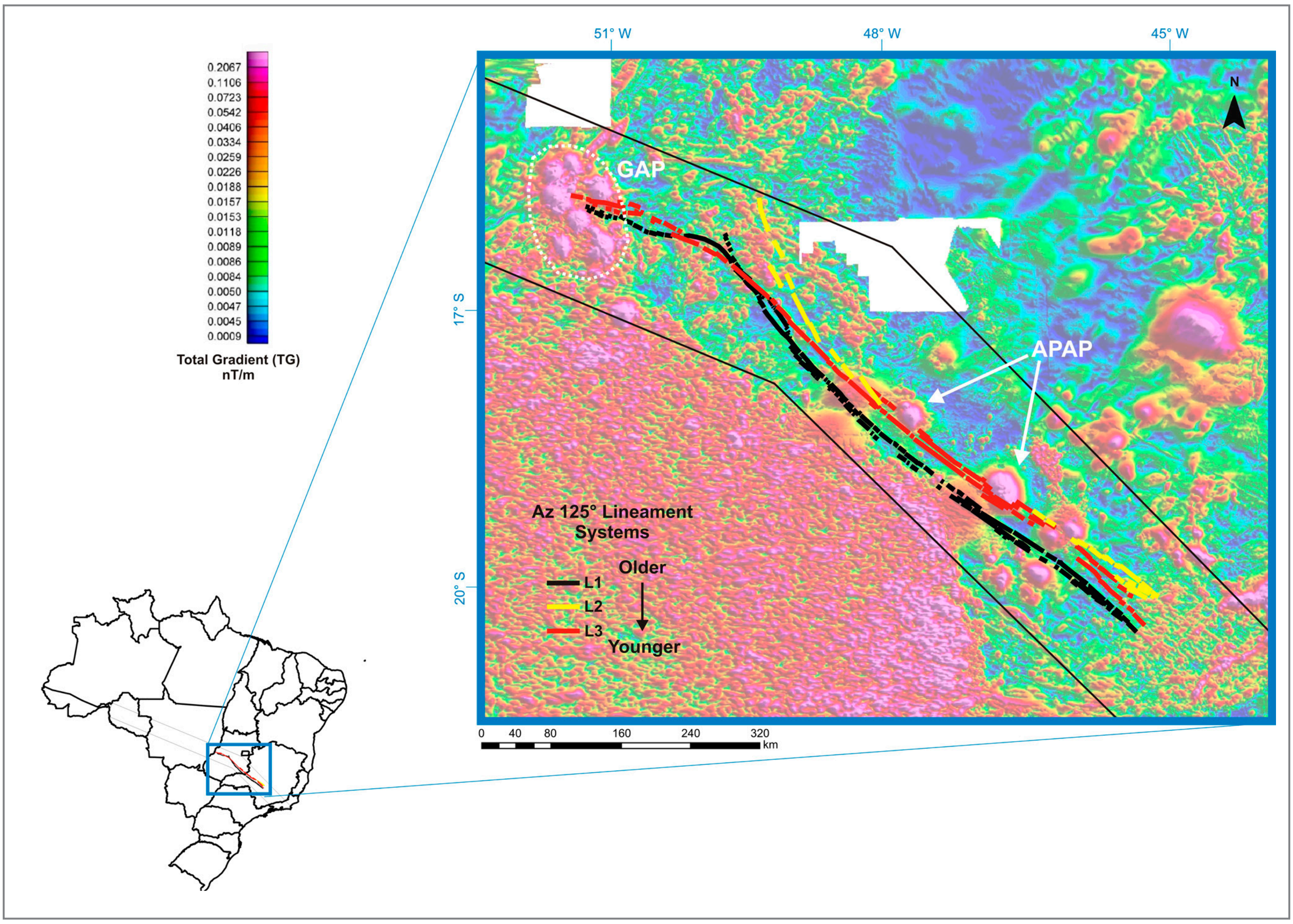

FIGURE 2 - Map of Total Gradient (TG) with the three main lineament systems that compose the central portion of the Az 125° (modified from Moraes Rocha et al. 2014). GAP: Goiás Alkaline Province, APAP: Alto Parnaíba Alkaline Province.

TABLE 1 – L1, L2, and L3 systems of Az 125° Lineament main characteristics (based on Moraes Rocha et al. 2014).

Lineament System	Estimative of Age (based on Moraes Rocha et al., 2014)	Magnetic Polarity
L1	Upper limit at 790 Ma	Normal
L2	Lower limit at 622 Ma	Normal
L3	118-622 Ma	Reversed

The Paraná Province comprises an area that exceeds 1,600,000 km² of the South America Continent (Petri and Fúlfaro 1983). It represents an intracratonic basin: it is entirely contained in the South American plate and does not present a direct relationship with the margins of this plate. It constitutes a sedimentary region and in its limits there is a sedimentary-magmatic succession with ages from the Late Ordovician to the Late Cretaceous (Milani 2004). It is on terrains that were extremely disturbed by tectonic, magmatic and metamorphic events of the Brasiliano Cycle (Melfi et al. 1988). The Paraná Province persisted from the Late Ordovician to the end of the Mesozoic as an autonomous unit of subsidence and sedimentation-magmatism, interrupted by the activities of the "Wealdenian Reactivation" and opening of the South Atlantic (Almeida 1969).

The São Francisco Province is related to the Paleoproterozoic and Neoproterozoic orogenies. The Paleoproterozoic orogeny was responsible for the welding of the different Archean crustal segments in the southern and northern portions of the Province. The Neoproterozoic orogeny reworked the paleocontinent margins, by constructive and destructive lithospheric processes, resulting in the definitive shape of the Province. However, intra- and pericratonic rift systems developed from the Paleo/Mesoproterozoic to the Mesozoic also contributed by modifying the thickness and geothermal nature of the lithospheric keels formed in the Archean. Despite the reworking during Proterozoic orogenies, isotopic, geochronological, and geochemical data of kimberlitic minerals indicate that the nuclei of the several Archean crustal segments were preserved in both portions of the Province (Pereira 2007).

The Mantiqueira Province denotes a Neoproterozoic orogenic system situated in the southern and southeastern portions of Brazil. It includes the Ribeira, Araçuaí, Southern Brasilia, São Gabriel, and Dom Feliciano orogens. It was developed during the Brazilian-Pan African Neoproterozoic Orogeny, which resulted in the amalgamation of the Western Gondwana paleocontinent. The evolution of the Proterozoic orogeny started with the diachronic disappearance of the Adamastor and Goianides oceans, located to the east and to the west of the São Francisco paleocontinent. Subduction processes developed magmatic arcs and were followed by arc-continent and continent-continent collisions. These events were diachronic throughout the area of the province: the oldest collisions are recorded in the São Gabriel Orogen (~ 700 Ma) and the Apiaí-Guaxupé Terrains (~ 790 Ma). They were succeeded by collisions in the Dom Feliciano Orogen (~ 600 Ma) and in the Southern Brasilia Orogen, in the Apiaí-Guaxupé Terrains (~ 630 to 610 Ma). The collisions occurred in the Araçuaí and in the Ribeira orogens between 580 and 520 Ma. From the Cambrian to the Ordovician (510 to 480 Ma) occurred the tectonic collapse of the Mantiqueira Province orogens (Heilbron et al. 2004).

4. Materials and Methods

The magnetic data used in this work is the result of processing performed by Correa et al. (2016b). Each geophysical survey was analyzed separately. The data were processed with the Oasis Montaj™ software, version 9.0 (Geosoft 2016). The magnetic data are presented in nanotesla (nT). Data were checked for consistency and the spatial distribution analysis of the flight lines was conducted to eliminate positioning errors and data noise. The bidirectional interpolation method was used to generate a grid for each aerogeophysical survey in the Oasis Montaj™ software by using the Bi-grid function (Geosoft 2016). For the integration of each aerogeophysical survey, the suture method (Johnson et al. 1999) was applied. Due to the large dimensions of the study area, the MF7 magnetic lithospheric model was used to recover the wavelengths over 330 km with a filtering technique described in Correa et al. (2016b). The result was a new regular grid of the Anomalous Magnetic Field (AMF), which was the basis for other magnetic products, as Total Gradient (TG), Euler Deconvolution, etc.

4.1. Euler Deconvolution

A technique for analyzing magnetic profiles was proposed by Thompson (1982). This technique, named Standard Euler Deconvolution (SED), applies the first order x, y, and z derivatives to limit depth and location of several ideal targets as cylinder, sphere, contact, and dike, defined by a specific structural index.

The SED algorithm was applied to estimate the magnetic source depths along the study area. It was calculated based on the AMF and was operated for structural index 1 (sills and dikes; Reid et al. 1990; Geosoft 2016). It was created 121 profiles perpendicular to the Az 125° Lineament features. For each profile, was generated a ".dta" format file containing the distance (calculated from the x and y position channels at a spacing of 125 meters) and the AMF value. These files were imported and processed in the EULDEP software (Durrheim and Cooper 1998).

After several tests, the window size was defined as the maximum size enabled by the software (about 300 times the size of the data spacing). The maximum depth to the top of the magnetic sources varied according to each profile. The SED solutions from EULDEP program were then exported as image files. The visual analysis of these images allowed us to verify which solutions were geophysically coherent, that is, the best solutions were those grouped around a point. In the eastern portion of the Az 125° (to the east of the Transbrasiliano Lineament), where its geophysical features are well defined, the estimated depths to the top of the magnetic sources are around 1 km or less. To the west of the Transbrasiliano Lineament, for the area that is supposed to be the segment of the Az 125° Lineament to Rondônia, the Euler solutions show estimated depths about 5 km (Fig. 3).

4.2. Curie Surface

Spontaneous magnetization disappears at the Curie temperature by raising the temperature of a magnetic material (Lowrie 2007). The crust Curie depth refers to the isotherm of 580° C, marked as the point of demagnetization of the magnetite (Frost and Shive 1986). In this way, an indicator of the extent of the magnetic signal is given by the depth associated with this temperature.

It is known that the temperature, mainly, controls the rheology of solids. Thus, to understand the mechanical behavior of lithosphere and asthenosphere, it is essential to know its thermal structures (Turcotte and Schubert 2002). Volcanism, intrusion, earthquakes, mountain uplifts, and metamorphism are processes controlled by the generation and transfer of heat on Earth (Fowler 2005). The Az 125° Lineament is composed of a series of intrusions throughout its tectonic provinces and is expected, due to the complexities and specificities of each province, that the contrasts in the thermal properties become different.

In this work, we applied a method that uses the spectral analysis proposed by Spector and Grant (1970), in which the mathematical model is based on random samples of systematic distribution of prisms with constant magnetization. The technique is applied in two steps because of the high complexity in calculating the depth of the base. Thus, the depth of the center and the depth of the top are calculated separately (Okubo et al. 1985; Tanaka et al. 1999).

The window was selected according to the average crustal thickness of the region (40 km), considering that the Curie surface generally has a positive correlation with the Mohorovicic discontinuity and that the spectrum shows information up to the depth of L/2π, where L is the window size. In this way, to reach depths around 40 km, the window of 250x250 km was selected.

The calculated depth is considered to refer to the center of the window. Then, the study area was divided into windows of 250x250 km, and its centers were spaced apart 50 km.

The depths were interpolated using the method of minimum curvature, with a cell size of 12.5 km to avoid aliasing. The study area presents an average of 42 km to the Curie surface, a value that is close to Mohorovicic discontinuity in the area (Fig. 4).

5. Results and Discussion

One objective of this work is defining, if the Az 125° occurs from its limits with the TB to the state of Rondônia based on magnetic data. After the analysis of the geophysical data of the area, by combining a few techniques to create images that enhance features that could be related to the Az 125°, we found no evidence that this lineament goes through the Mato Grosso State reaching the Rondônia State.

The geophysical images show that the lineament extends to the limit of the Goiás and Mato Grosso states (Fig. 5).

The magnetic data allowed us to identify the features related to the Az 125° as well as to distinguish some of its characteristics. Based on our magnetic data, there is no evidence that the Az 125° Lineament extends far beyond to the west of the TB (Fig. 6).

5.1. The Azimuth 125° dikes emplacement

It is not unanimity the dikes propagation and how far they can move. The arrangements of dike width, dike length, and lava extrusion suggest that the propagation of the dike is controlled by tectonic stresses. Magma pressures are strongly linked to the dike opening and these processes can change with each event of dike intrusion (Buck et al. 2006).

For the lateral propagation of the dikes over the magma chamber, a quantitative model was developed by Buck et al. (2006). They consider that the propagation of the dike begins at the moment when the driving pressure corresponds to the pressure of breakout needed to impulse the magma out of the chamber, and it stops when a minimum value is reached by the driving pressure. Besides the breakout and stopping pressures, the initial distribution of tectonic stress and the thickness of the lithosphere cut by a dike will influence directly on the propagation distance.

Despite along strike rheological variability, as the Az 125° dikes change from one geological province to the next, they show slight deviation in their direction. The lineaments are almost perfectly linear in an NW-SE trend, from the southeastern portion of the area until the region of Santa Bárbara Intrusive Suite, in Goiás state. At this point, the lineaments undergo a slight rotation and are arranged to be in an almost E-W orientation.

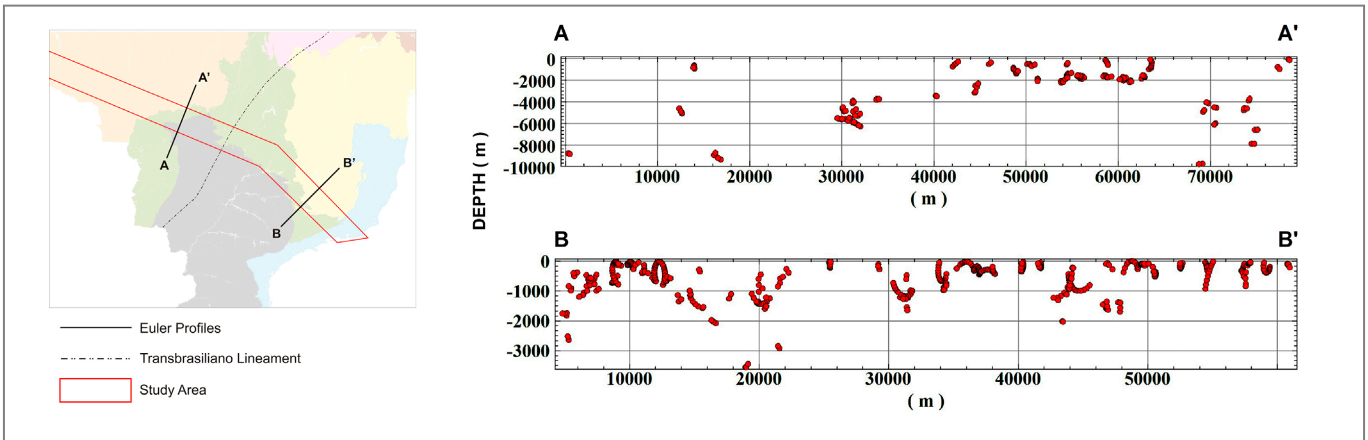

FIGURE 3 – Example of two SED(Standard Euler Deconvolution) profiles along the area of study: A-A' profile to the west of the Transbrasiliano Lineament (TB) shows depths to the top of the magnetic sources around 5 km; B-B' profile displays depths about 1 km for the segment to the east of TB.

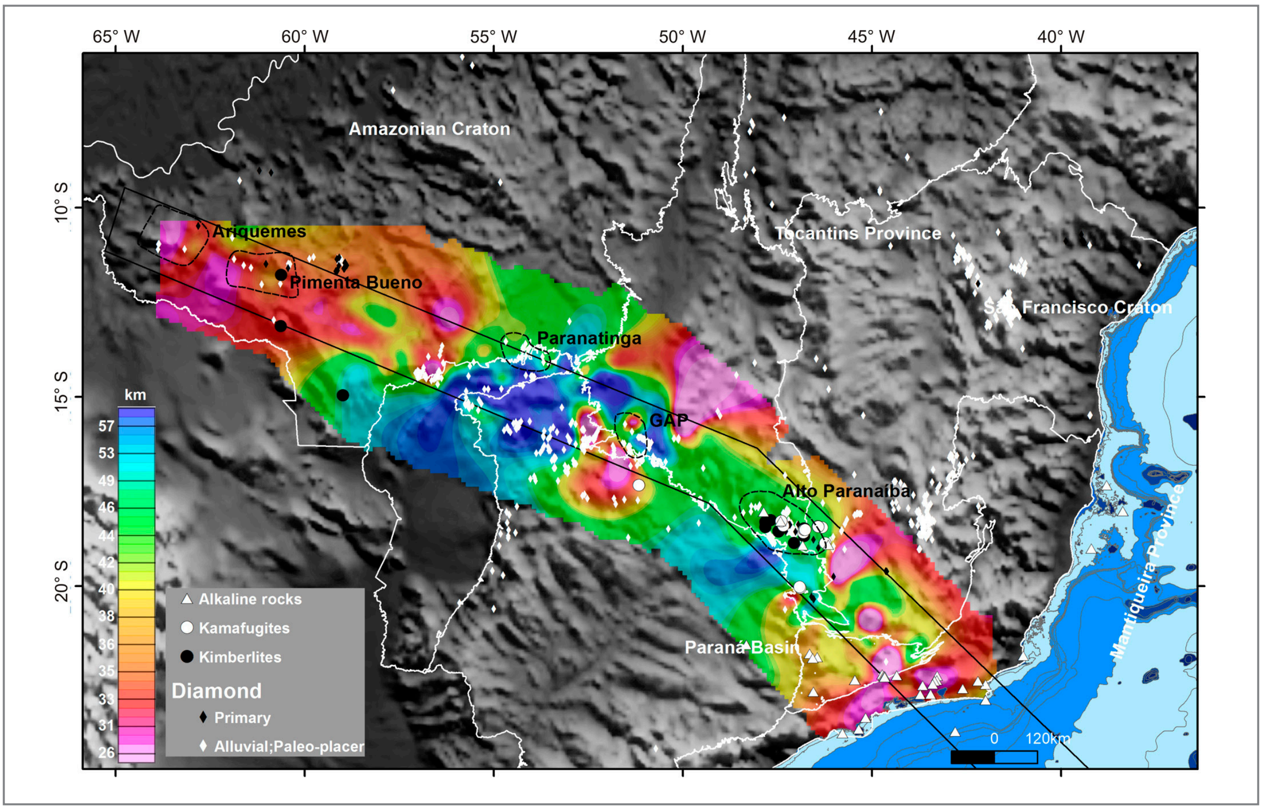

FIGURE 4 – Map of Curie depths. The kimberlitic provinces of Paranatinga and Alto Paranaíba are located in Curie depths points deeper than 45 km and Ariquemes and Pimenta Bueno provinces are in a region of curie depths of less than 35 km. On the other hand, the GAP is located in the middle of two regions of narrow curie depth.

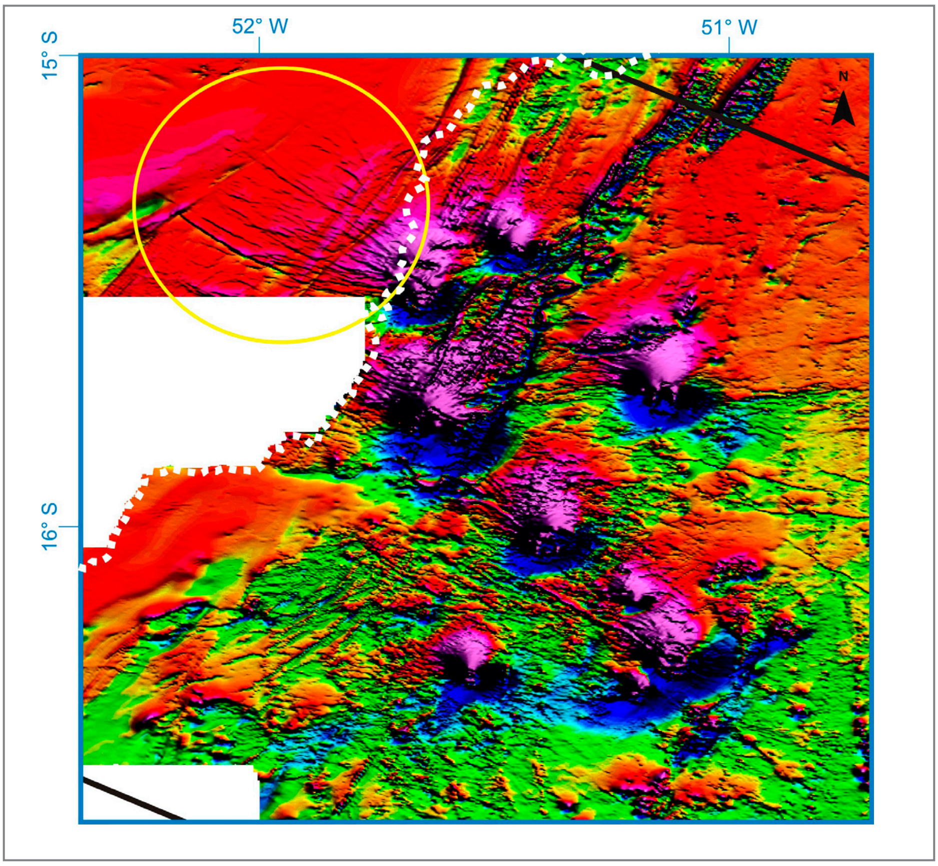

FIGURE 5 – Map of the AMF(Anomalous Magnetic Field) in the region of the Goiás Alkaline Province (GAP). The yellow circle shows that the Az 125° Lineament continues to the west of GAP and Transbrasiliano magnetic signatures, and they fade as they continue to NW. The white dashed line displays the limit between the Brazilian states of Minas Gerais (to the right) and Mato Grosso (to the left).

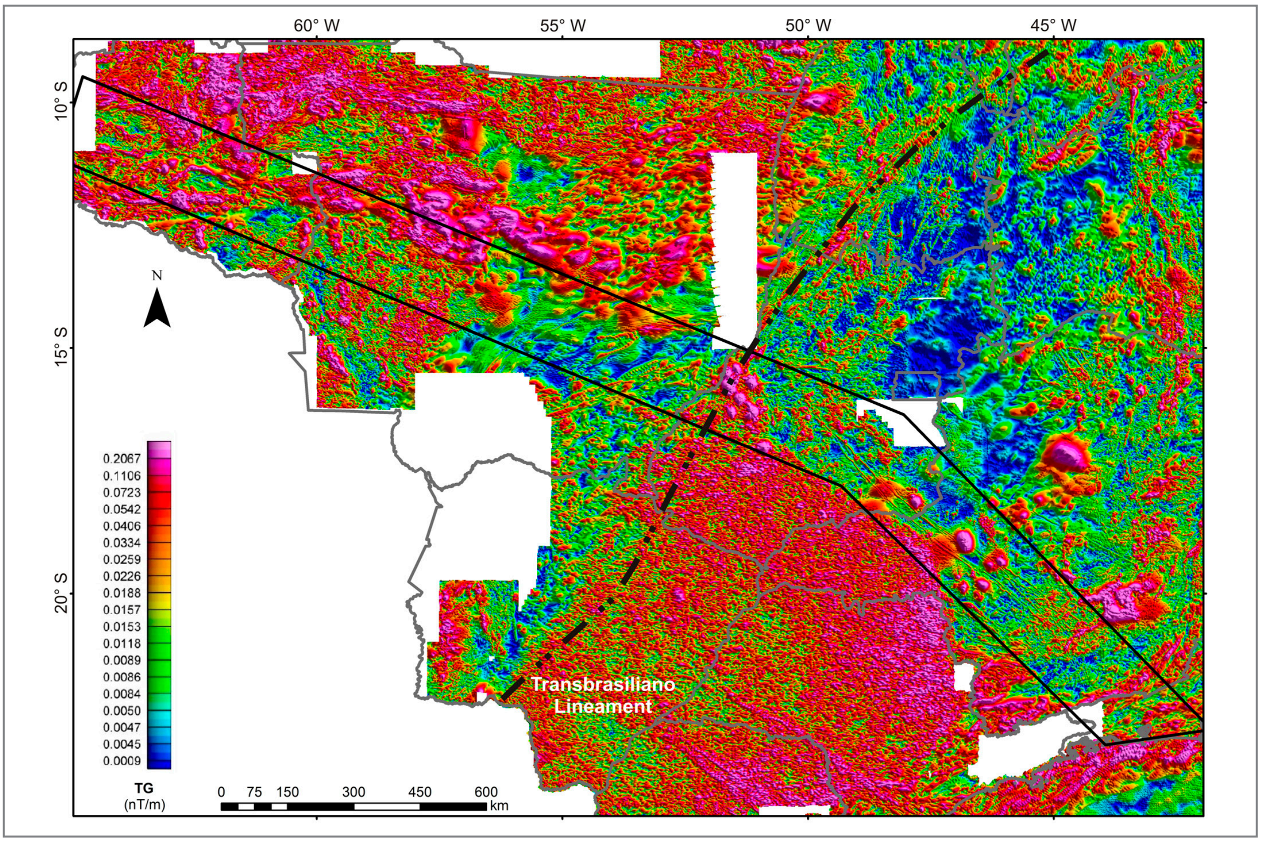

FIGURE 6 – Map of the Total Gradient with the entire area of study (black polygon). This map shows that there is no magnetic evidence that the Az 125° Lineaments extends far beyond to the west of the Transbrasiliano Lineament (shown in the map in black dashed and dotted line).

Understanding the emplacement of giant dike swarms such as the Mackenzie, in Canadá (>2000 km), Okavango, in Botswana (~1500 km), and Az 125° (~1000 km) is still limited, due to the absence of exposure, and also due to the generalization of the mechanisms of propagation of the dikes. In this way, it is important to know how magma could spread for hundreds or even thousands of kilometers within a heterogeneous and cold continental lithosphere.

Is the emplacement of the Az 125° dikes associated with rifting processes? For this proposal, and disregarding if it was a rift zone that has failed or proceeded to continental breakup, some geophysical definable characteristics must be present on these lithospheric-scale weakness zones (Le Pera 2014), such as i) an anomalous thin crust, hence a shallow Mohorovicic Discontinuity depths; ii) an elevated Curie Point Depth; iii) the presence of positive gravity anomaly.

i) An anomalous thin crust, hence a shallow Mohorovicic Discontinuity depths: In the lithospheric model (Fig. 7) presented by Moraes Rocha et al. (2015) and updated in this study for the central portion of Az 125° Lineament, the crustal thickness is about ~40 km, with an average of 35 km (Assumpção et al. 2013). These authors detected, for the whole area, crustal thicknesses between 30 and 50 km. In the central segment of the Az 125° (CK, Fig. 1), we observed the thickest values, ranging from 35 to 50 km (Fig. 7). Geophysical investigations of rift systems such as the Muglad basin (Fairhead et al. 2012) and the Rio Grande rift (Olsen et al. 1987) have indicated the presence of a domed Mohorovicic discontinuity below the axis of the rift, at depths varying from 22 to 33 km. The average 40 km Mohorovicic Discontinuity for the central portion of Az 125° (Fig. 7) suggests that the upper lithosphere was not expressively affected. This fact can, consequently, decrease or eliminate the probability that underplating exists below the Az 125° region. Accordingly, the dikes that form the Az 125° Lineament, probably, were not formed in association with the evolution of a rift system.

ii) An elevated Curie Point Depth: Moraes Rocha et al. (2015) estimated, for the southeastern portion of the Azimuth 125° Lineament, Curie depths reaching up to 40 km. In this work, we calculated, for the whole project area, Curie depths about 42 km (Fig. 4). Given this, and provided the fact that the Mohorovicic discontinuity for the area extends to a depth of approximately 35 km (Assumpção et al. 2013) based on seismic datasets (receiver function, deep refraction, and surface-wave dispersion velocities). We noticed that Curie point depths are controlled mainly due to the geological setting of the end of Neoproterozoic rather than the thermal field signature that could be registered by the Cretaceous magmatism. The Mantiqueira Province, São Francisco Craton, Tocantins Province, and Amazonian Craton have each a particular signature (Fig. 4). Therefore, the Cambrian magmatism did not leave evidence of a disturbance in the curie depths points, as well as in the crustal thickness. Thus, the long wavelength variation Curie point is associated with the depth to the magnetic bottom layer, which depends mainly on the composition of the crust, instead of the thermal field. Shorter variations (wavelength smaller than 100 km) are due to crustal heterogeneities. The Euler Deconvolution estimates depths to the top of the magnetic sources around 1 km in the eastern portion of the Az 125° Lineament. It suggests that the dikes of the Az 125° were probably set within the upper 5 km of the crust.

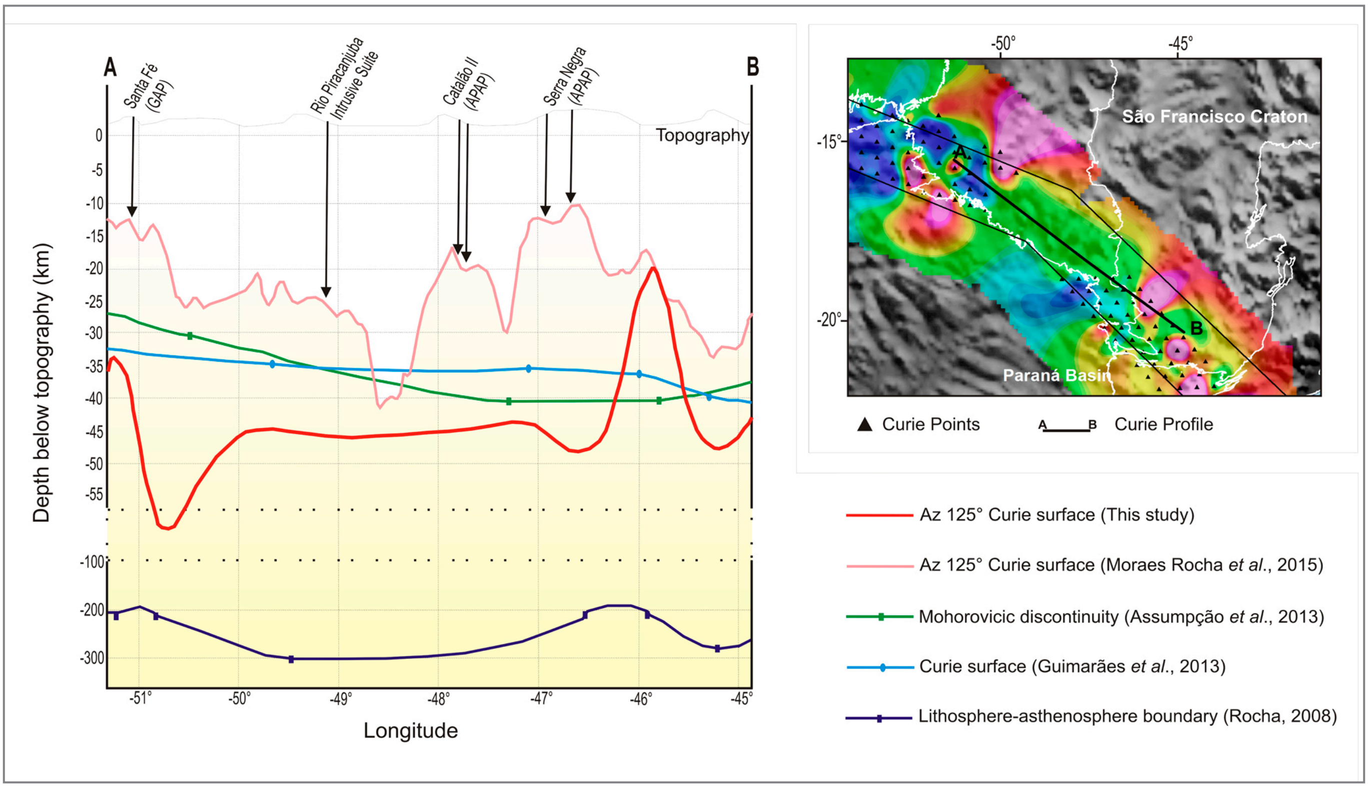

FIGURE 7 – A-B profile along the central portion of Az 125°: indicating the main crustal discontinuities and the Curie surface defined in different studies

The shallow Curie depths found along the Az 125° extension are probably related to the high susceptibility circular magnetic anomalies. These anomalies are directly associated with the alkaline intrusive bodies (such as Catalão, Serra Negra, and Salitre). We propose them as ancient magma feeder chambers, whose shapes, sizes, and position were controlled by crustal weakness zones and terrain heterogeneities. Assuming that crustal thickness is negatively correlated with thermal gradient as shown by Correa et al. (2016a), the geophysical data shows distinct depth to the magnetic bottom along the Az 125° area and, based on our interpretations, the Az 125° dikes emplacement is incompatible with the typical thermal system below failed rift systems, once in this environment is expected constant shallow depth to the magnetic bottom.

iii) The presence of positive gravity anomaly: In rift zones, increased sedimentation at the time of the subsidence of the surface usually produces a negative Bouguer anomaly (Ebbing et al. 2007).

Figure 8 presents the Bouguer anomaly for the studied area with crustal thickness information. The high gradients are located, mainly, in the limits of the major provinces, as occurs in the limits between the São Francisco Craton and Mantiqueira Province. There is a crustal-scale discontinuity in the central portion of Tocantins Province, and a high gradient between the Tocantins Province and the Amazonian Craton. Besides, regions related to high density corroborate with the low depth to the magnetic bottom, except for the midwest portion of the Tocantins Province. In this part, the calculated depths are elevated, which probably indicates the presence of serpentinized minerals (magnetic) in the upper mantle. This signature is, usually, related to Neoproterozoic orogens, as in the Borborema Province (Correa et al. 2016a). Thus, the signatures of Curie surface and Bouguer anomaly can reflect the end of the Neoproterozoic configuration that culminated in the formation of the Gondwana Supercontinent.

Due to the lack of typical rift features related to the Az 125°, and based on the high-resolution magnetic data, we suggest that the Az 125° was emplaced along a zone of lithosphere weakness. The propagation of the Az 125° dikes was aided over the 1000 km distance by the occurrence of a sequence of magma feeder chambers. The semi-rounded and high magnetic anomalies imaged along the Az125°, related to the Alto Paranaíba and Goiás Alkaline Provinces, maybe represent the solidified form of these feeder magma chambers (Fig. 9). Great magma chambers can be responsible for the propagation of the dikes to a long distance. Buck et al. (2006) speculate that chambers related to great gabbroic intrusions, which are found close to the axis of some enormous igneous provinces, could fill dikes spreading thousands of kilometers.

Even so, how could magma propagate over such a long distance before solidification? Theoretical models studied by Lister and Kerr (1991) show that dikes as thin as 10 meters could spread for thousands of kilometers. Also, Rubin (1993) proposed that certain characteristics of the basaltic magma, like viscosity and initial pressure, could be responsible for the propagation of the dike to infinity without solidification.

5.2. The normal and reversed polarization Azimuth 125° dikes

As suggested by Moraes Rocha et al. (2014) and as described above, the Az 125° Lineament is composed by, at least, three sets of dikes with specific geophysical characteristics. We

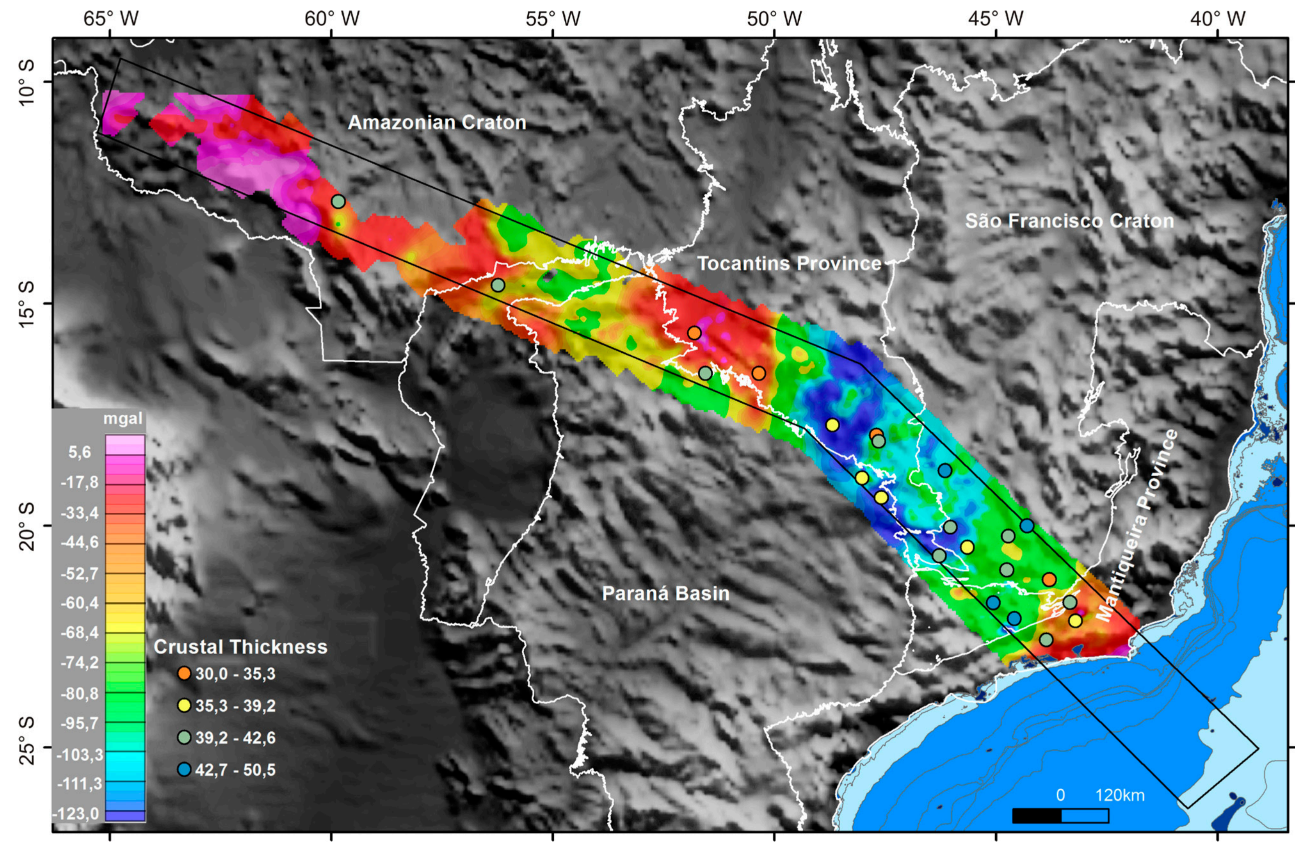

FIGURE 8 – Map of the Bouguer Anomaly. Filled colored circles represent the crustal thickness (Assumpção et al. 2013). Gravity data is provided by the National Gravity Database controlled by ANP (Agência Nacional do Petróleo).

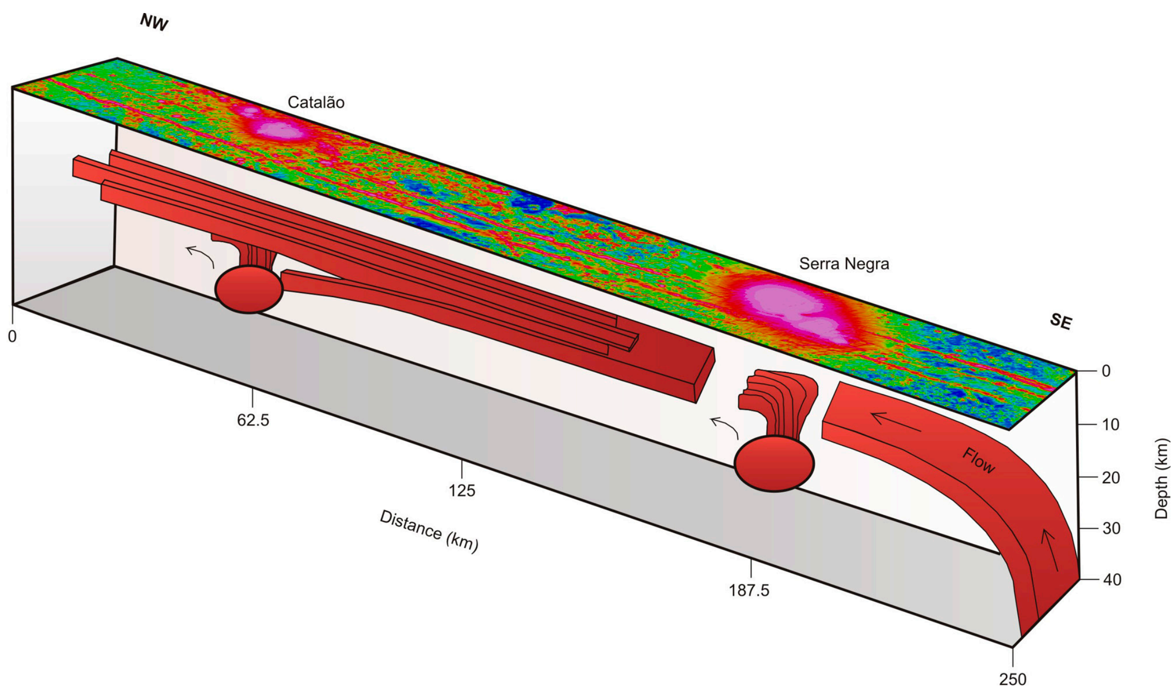

FIGURE 9 – Azimuth 125° dikes emplacement model. The swarm was probably fed into the vertical flow. The alkaline bodies (Serra Negra and Catalão, for example) may have acted as along-strike magma chambers that supplied extra magma volume to support, for at least, three dike systems to propagate along 250 km (emplacement model based on Le Pera 2014).

notice that one of these dikes exhibits reversed polarity (Fig. 10). But, what explains the difference of polarization once the set of dikes are so close to each other? The cause of this alternating polarity is not known. Two hypotheses can explain it: self-reversal of magnetization or field reversal.

The works of Néel (1948, 1951) and Nagata et al. (1952) are references for understanding self-reversal processes. The term self-reversal means that the magnetization of ferromagnetic minerals is conducted antiparallel to the magnetizing field (Liebke et al. 2012). The self-reversal magnetization is due to some intrinsic property of the magnetic minerals in the rocks such that the rocks acquire a remanence that is antiparallel to (or reverse of) the Earth's field (Lawson 1989). When some igneous rocks and the ferromagnetic minerals detached from their primary rocks are cooled in a weak magnetic field, they can get the remanent magnetization whose direction is contrary to that of the magnetic field during cooling (Nagata et al. 1952).

Dikes can be multiphase intrusions emplaced over time. In the work of Preston (1967) a variety of dolerite types in the Fermanagh Doraville Dike are interpreted as having crystallized from discrete magmatic pulses over time. Gibson et al. (2009) propose that a comparable process may have happened in the Cuilcagh Dike and that different sections of the dike cooled and solidified under different field polarities and at different times. This unique situation may reflect the rare chance of capturing dike injection during a magnetic polarity switch. This hypothesis is likely for the Az 125° Lineament dikes, and the alternating polarity could suggest local re-magnetization of the dike at some time after its intrusion.

6. Conclusions

This study was relevant for understanding the regional manifestation of the Az 125° Lineament. It was important to explain the expression of such great continental-scale dike swarms and to show the efficiency of geophysical methods for mapping areas of dike swarms where they are set in the subsurface.

Many studies describe the Az 125° as a geological feature that follows from Rondônia to Rio de Janeiro states. Based on our data, we found no relevant geophysical evidence that this lineament occurs between the states of Mato Grosso and Rondônia. Also, the cross-cutting relationships between the Az 125° and the Transbrasiliano (TB) lineaments are not well defined by the geophysical data, and we notice that the Az 125° does not extend far beyond the TB to the west.

Based on the high-resolution magnetic data and the absence of common rift features associated with the Az 125°, we suggest that the Az 125° was set along a zone of weakness of the lithosphere.

The alternating polarity of the Az 125° Lineament dikes can be explained by local re-magnetization at some time after its intrusion.

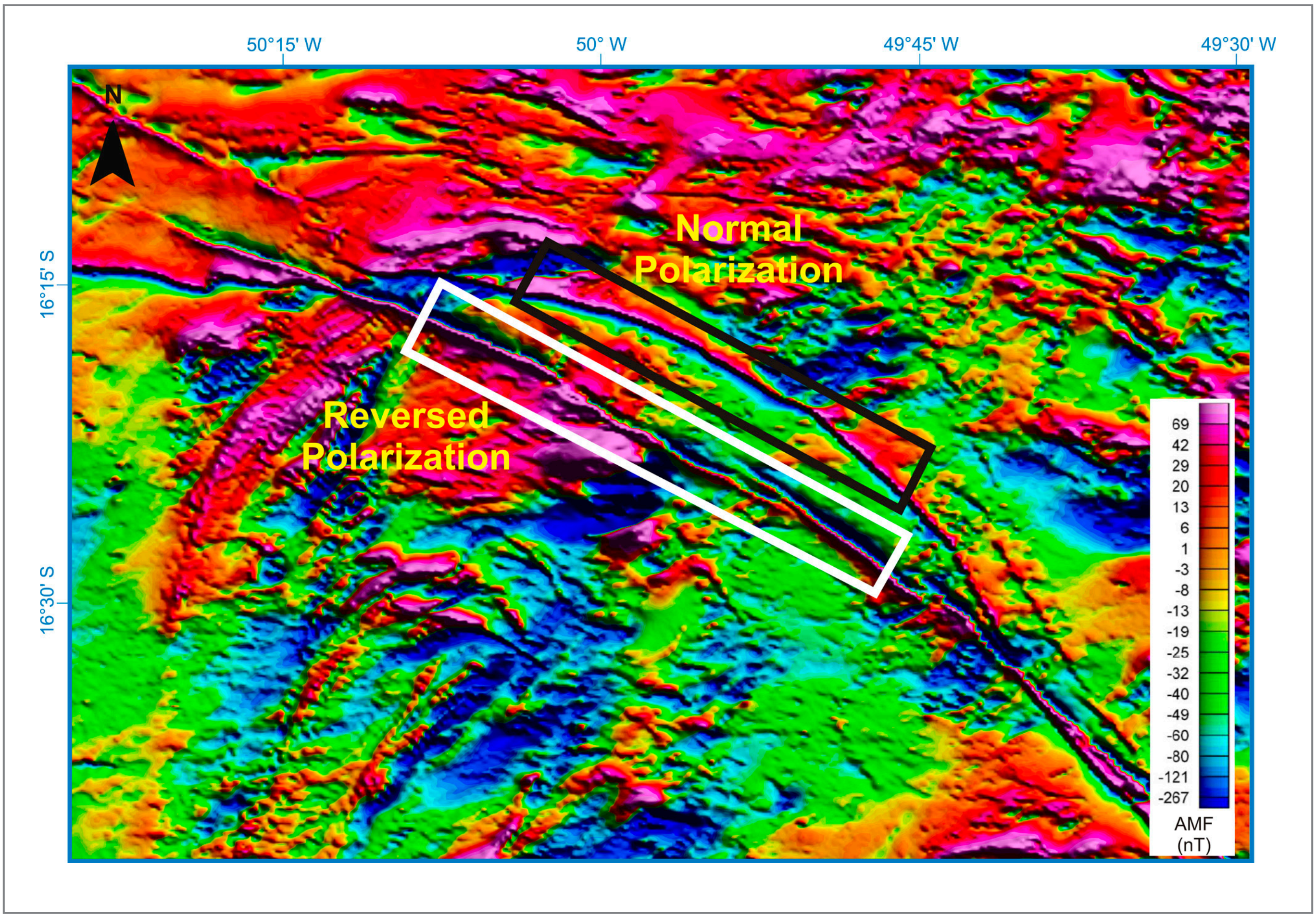

FIGURE 10 – Map of the Anomalous Magnetic Field presenting two dike systems with distinct polarization characteristics. Black box indicates a dike magnetic signature with normal polarization; white box emphasizes a dike magnetic signature with reversed polarization.

We propose that the propagation of the Az 125° dikes were facilitated over a 1000 km distance because of the occurrence of a sequence of magma feeder chambers. The semirounded and high magnetic anomalies imaged along the Az125°, related to the Alto Paranaíba and Goiás Alkaline Provinces, maybe represent the solidified form of these feeder magma chambers.

We suggest the geochronological dating of the Az 125° dikes samples to limit their ages more precisely, and also to determine the age of other magmatic events related to the lineament. We also recommend the acquisition and processing of deeper geophysical data, such as magnetotelluric and seismic, in order to realize the in-depth behavior of the Az 125° and the processes occurred in the subcontinental lithospheric mantle along the area.

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