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Magnetic and Gravimetric Study of Pratinha I Anomaly (MG)

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Abstract

The magnetic and gravimetric anomaly of Pratinha I (MG) is a probable response of an alkaline intrusion, so as many others in the southwest of Minas Gerais. This study aims to estimate the nature of the source body using different techniques.

Two different scenarios are designed based on the geological history of the region and on results from the applied techniques and inversions. The first one points to an intrusion marked by a significant magnetic remanence. The second one suggests an intrusion delimited by the Bocaina Shearing Zone, with no significant magnetic remanence. The common point observed between both the scenarios is a bulging in the eastern part of the Bocaina Shearing Zone, probably caused by the intrusion and subsequent faults at southeast of the body.

Introduction

The magnetometric and gammaspectrometric aerosurvey promoted by the Company of Economic Development of Minas Gerais (CODEMIG) in 2006 over the southwest region from the same state – named Area 7 – evidenced a magnetic anomaly centered at the coordinates (19°45'S, 46°10'W – Figure 1). This anomaly was denominated as Pratinha I.

The anomaly of Pratinha I does not present correlation with geological upwelling differently to the magnetic anomalies of the alkaline complexes of Tapira (at west) and Barreiro (in Araxá – at northwest), however it does present enough contrasts of density and susceptibility to allow a geophysical exploration through potential methods. By this way, it were utilized the gravimetric and magnetic methods allied to the local geology and geotectonic to obtain the necessary information to estimate the source-body of this anomaly.

The magnetic response of Pratinha I presents a tripole with 50km in its major axis (a) (Figure 2). At southwest (b) lies a second anomaly named Pratinha II.

The maps generated by the data of gravimetry and magnetometry were processed through various techniques and inverted with 3D geometry, in matter to estimate the shape, depth, average contrast and volume of the source-body.

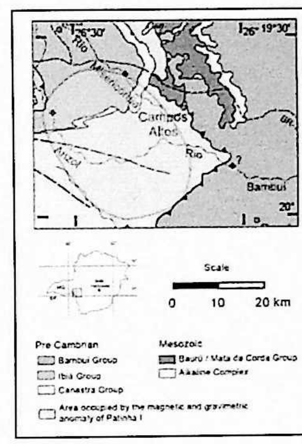


Figure 1. Geological map with the location of the Pratinha I and II anomalies. Modified from Heineck et al (2003).

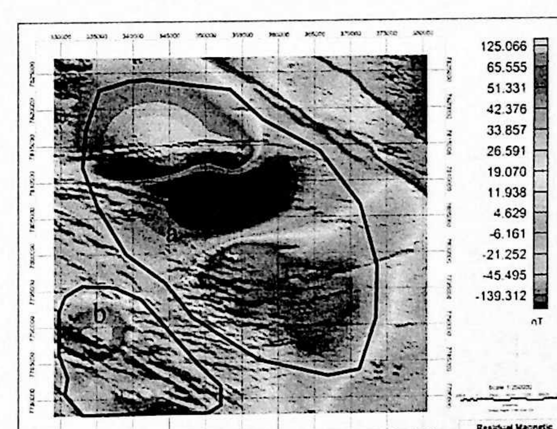


Figure 2. Residual Magnetic Field map of Pratinha I (a) and II (b)

Regional Geology

The Arch of the Alto do Paranaíba is an elongated structure in the NW-SE direction located between the borders northeast of the Paraná Basin and southwest of the São Francisco Basin, had a fundamental role in the independent tectono-stratigraphic development of both basins (BROD et al, 2004) and is the location of the Igneous Province of the Alto do Paranaíba (IPAP – GIBSON et. al, 1995). The IPAP is defined by the set of magmatic events of the Brasília Belt between the

Magnetismo (anomalias)
Gravimetria (anomalias)
Minas Gerais

coordinates (18°S, 48°W) and (20°S, 45°30'W). In sight of these events, Pratinha I is expected to be an igneous intrusion.

The anomalous source embeds in a metasedimentary environment defined by the Canastra Indiviso Group, with a superficial geology is characterized by meta-sandstones, pure and micaceous quartizites, graphite schists, sericite schists, quartz-muscovite schists, philites, graphite philites, chlorite phillites, meta-siltites, siltstone meta-argilites, marl, limestone and slate. Sm-Nd and U-Pb studies indicate an age younger than 1Gy (RODRIGUES, 2008).

Gravimetric Method

Gravimetric anomalies are caused by the influence of intrusive bodies with densities different to the mean of the region in which they are inserted or by variations of crustal thickness. Besides the contrast of density, the anomaly's shape depends on the geometry and position of the source in relation to the point of measurement.

The gravimetric method demands, for regions above the sea-level, corrections of altitude and mass (BLAKELY, 1995). In order to correct the altitude, it is used the Free-Air correction; to the mass, it is usually applied the Complete Bouguer correction once the local landscape is highly irregular.

The Bouguer Anomaly map, obtained after the two corrections, presented a regional trend of the magnetic field in NE-SW direction. For its removal and consequently isolation of the anomalous signal, it was performed a frequency filtering with a Robust Polynomial algorithm proposed by Beltrão (1991 – Figure 3).

Based in results of the robust polynomial filtering, it was designed the analytic signal map (AS - NABIGHIAN, 1979) to further comparison between the lateral limits obtained through the gravimetric and magnetic method.

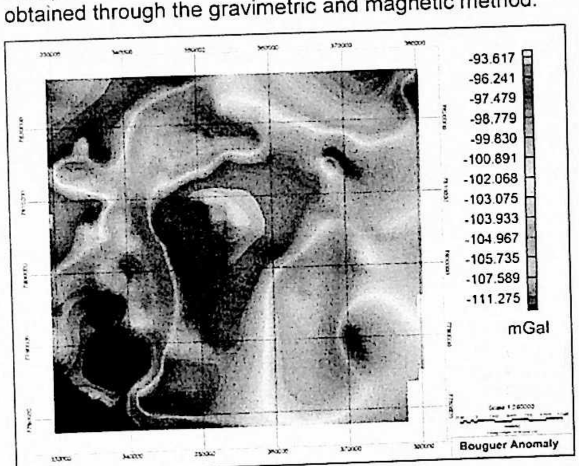


Figure 3. Complete Bouguer Anomaly map filtered with the robust polynomial algorithm (BELTRÃO, 1991).

Magnetic Method

The magnetization of a rock is calculated by the vectorial sum of the induced and remnant magnetizations (BLAKELY, 1995). The first one is obtained by the influence of the Earth's magnetic field of the day of the survey on the material; the remnant magnetization is a property of ferromagnetic materials that, when submitted to a magnetic field and subsequently deprived of it, tend to retain part of the original magnetization.

The magnetic data showed a regional trend in the NW-SE direction, which was successfully removed by a trend filter of first order (Figure 1). It was also calculated an analytic signal map to compare with the gravimetric AS.

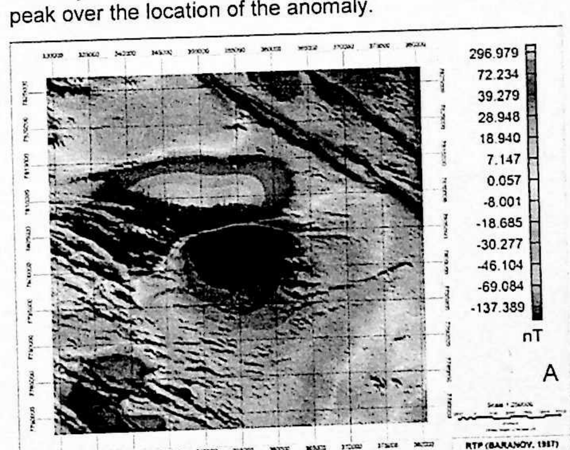
Composition of Magnetic and Geological Scenarios

Given the way that the anomaly of Pratinha I is presented, it is possible to compose different geological scenarios that could explain such behavior. In this study it was designed two cases in face of the geological /geotectonic characteristics of the region and the magnetic responses of well-known anomalies in the proximity.

First Scenario: Intrusion with significant remnant magnetization

The significance of the remnant magnetization may provoke mistaken interpretations if not taken into account. When the remnant magnetization vector has relevant module, the amplitude and/or the direction of the total magnetic field is deviated, producing a distorted direction of total magnetization.

This scenario was built based on the magnetic response of the Alkaline Complex of Tapira (RIBEIRO, 2011) – a magnetic quadrupole with significant remnant magnetization – in parallel with the solutions of the Reduction to the Magnetic Pole (RTP) filtering with the algorithms by Baranov (1957 – Figure 4a) and by Fedi et. al (1994 – Figure 4b). The expected solution for an ordinary RTP is a tridimensional surface with a positive peak over the location of the anomaly.



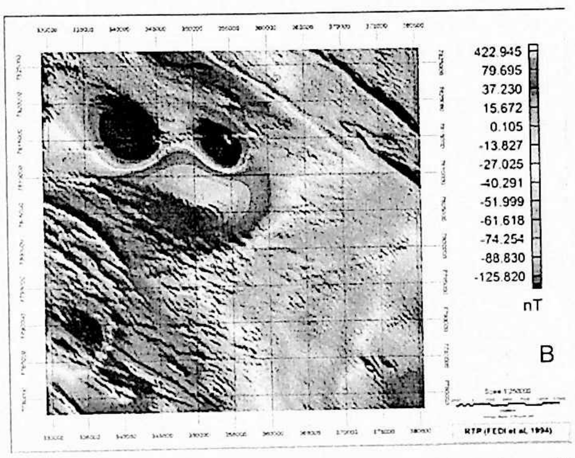


Figure 4. RTP maps designed by the algorithms from (A) Baranov (1957) and (B) Fedi et. al (1994)

Most of the known techniques for magnetic anomalies processing are not trustful when applied to cases with remanence, so as the RTP algorithm proposed by Baranov (1957), the TILT (MILLER and SINGH, 1994) and TILT-Depth (SALEM et. al, 2007), the inversion algorithm proposed – and used in this study – by Li and Oldenburg (2003), among others. The solution to this case was the use of techniques with little dependence on the direction of magnetization, as the RTP algorithm by Fedi et. al (1994) and the Amplitude of the Anomalous Magnetic Field (AAMF) proposed by Shearer (2005).

The RTP algorithm proposed by Fedi et. al (1994) executes a randomic filtering process in which each iteration will exclude the worst solution (the one that presents the most negative value in the map) in accordance with a pre-defined convergence criteria. The better solution to this filtering is shown in Figure 4B.

The AAMF (SHEARER, 2005) filters the map through the following function:

$$AAMF = \sqrt[2]{M_x^2 + M_y^2 + M_z^2} \quad (1)$$

Being M_x, M_y and M_z the components in each cartesian axis. The AAMF result is presented in the Figure 5.

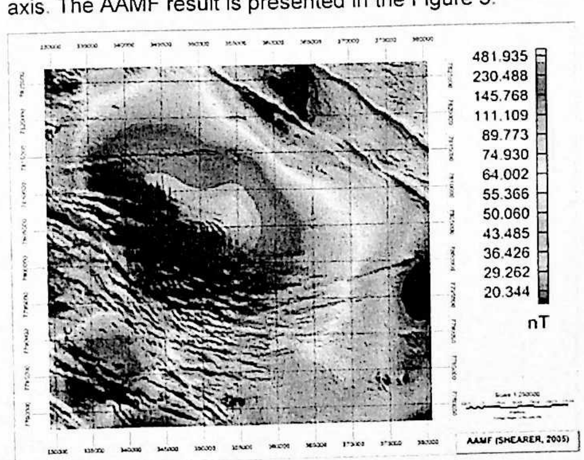


Figure 5. AAMF map.

Second Scenario: Intrusion without significant remnant magnetization

Following the first scenario's premise, the second hypothesis is based on the magnetic response of the Alkaline Complex of Barreiro, in Araxá (PEREIRA et. al, 2010), which does not present a significant remanence.

The assumption of a non-relevant remanence permits the use of many techniques to estimate the source body. It was used in this study the TILT-Depth (MILLER, 1991) technique to estimate the depth, in parallel with the AS (NABIGHIAN, 1984), allowing the presumption of the form of the source-body, subsequently modeled in 3D geometry (Figure 6).

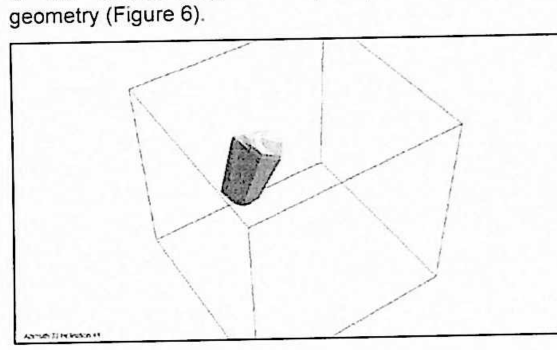


Figure 6. 3D synthetic model of the source-body based on the limits achieved by the analytic signal filter.

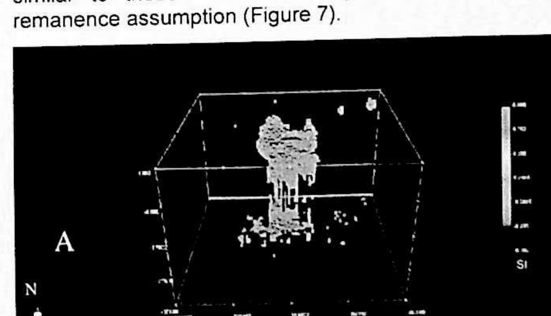
The synthetic model created was subjected to filtering processes as AS, RTP (BARANOV, 1957) and AAMF to further comparison with the results obtained from the real data.

3D Inversions

The results achieved from the gravimetric and from the magnetic methods were inverted with 3D geometry through the algorithm proposed by Li and Oldenburg (2003), in order to compare the form, depth and volume from different kind of data to achieve more trustful approaches of the nature of the source,

The two magnetic scenarios were compared through the inversion of the results of the AAMF and RTP's filtering for the first scenario, and the residual magnetic field (inverted using the synthetic model as initial reference), for the second case.

The gravimetric inversion model presented a shape more similar to those obtained through the non-significant remanence assumption (Figure 7).



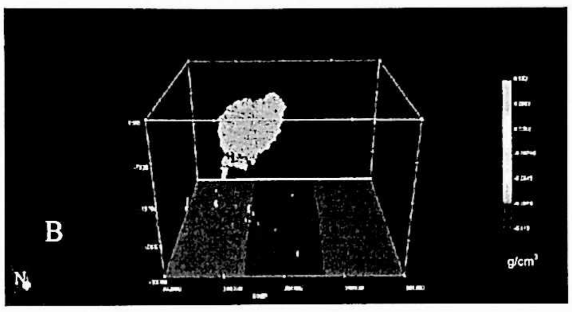


Figure 7. Comparison between the gravimetric (A) and the residual magnetic field inversions (B).

The models of residual magnetic field (RMF) with and without the use of the synthetic model as initial reference revealed very few differences with each other.

The inversion of the RTP data, by the algorithm of Baranov (1957) showed a remarkable resemblance with the inversions of the residual magnetic field data, and with the RMF inverted using the synthetic model as initial reference (Figure 8).

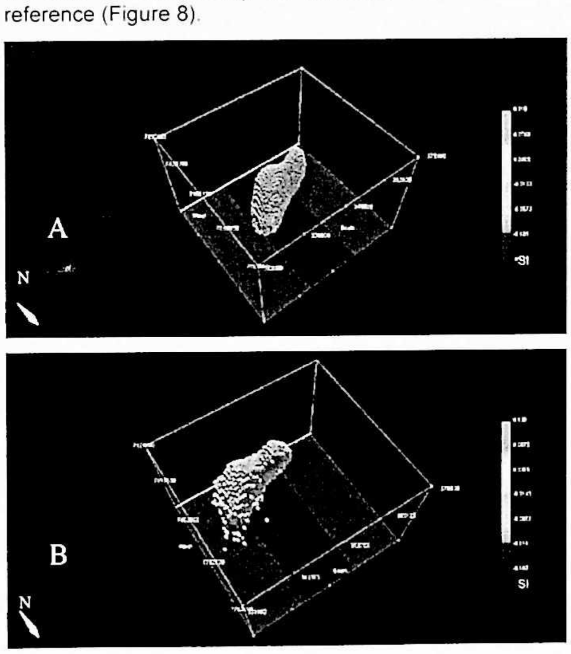


Figure 8. Comparison between the RTP (A) by Baranov (1957) and the RMF with initial model inversion (B).

The results of the inversions of the RTP, by Fedi et. al (1994), and the AAMF have a batholit-like shape and have they top at greater profundities than the other models (Figure 9).

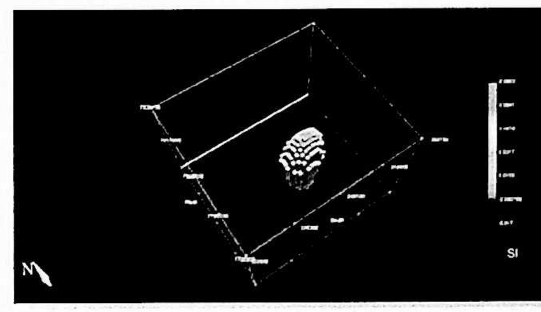


Figure 9. Result of the AAMF inversion. Depth to the top 3 km.

Discussion

Accordingly with the inversions, it is possible to correlate all models, gravimetric and magnetic, to the Bocaina Shearing Zone at north of the anomaly (Figure 10). It is also acceptable to affirm that the light bulging of the shearing zone in the N-S direction may be related to the intrusion of the source-body. Similarly, but in a minor magnitude, this bulging occurs in the relations of Tapira and Barreiro alkaline complexes with the same shearing zone. There are also several faults at south and southeast of the anomaly that may be linked to the mass displacement occurred by the intrusion of the source. These relationships, allied with the geotectonic information of the APIP, reinforce the expectation of an igneous alkaline intrusion as a possible explanation for Pratinha I anomaly.

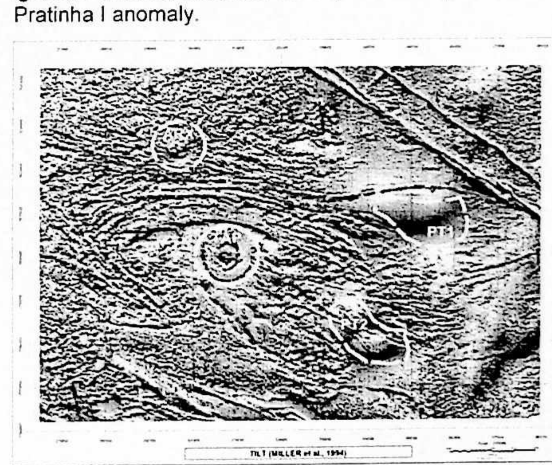


Figure 10. TILT filtering result on the Pratinha I region. The red-traced lines highlight the Bocaina Shearing Zone over the region. The yellow lines locate the intrusions of Pratinha I (PT1), Pratinha II (PT2), Tapira (TAP) and Araxá (ARX).

The magnetic inversions presented a susceptibility contrast which corroborates with an alkaline intrusion, even when it is taken into account a substantial presence of ferromagnetic minerals that would validate the first scenario. This case presents an intrusion with a significant remnant magnetization evidenced by the RTP's filtering results. The inversions for this scenario converged to an elliptic form, similar to batholits,. For this case it was not developed a synthetic model because there was not any stable technique that could permit to estimate the depth of the source, increasing the number of possible solutions in face of the ambiguity associated to potential methods.

The second scenario shows an elongated body in the E-W direction, with its northern border matching with the shape of the Bocaina Shearing Zone and at southwest with a set of faults. The synthetic model created to this hypothesis (Figure 6) was based in the AS and TILT-Depth techniques, and the inversion, initially referred to this model, presented a body of about 10 km (at E-W axis), 1800m of depth from the surface to the top of the body, 20 km height, and a volume of 900km^3 (Figure 8B). The AS filtering, for magnetic and gravimetric data, showed a correspondence with each other, what makes the AS a good criteria for the comparison for the inverted data.

Conclusions

This study allowed establishing different scenarios to justify and estimate the nature of the gravimetric and magnetic anomaly of Pratinha I. The first scenario shows the intrusion of a body with a significant remnant magnetization. This hypothesis is sustained by different algorithms of reduction to the pole filtering – once the expected response for such filtering would be a Gaussian surface, differently to the dipole (through Baranov's (1957) algorithm) and tripole (through Fedi's et al. (1994) algorithm), by the AAMF technique and by similar events so as the alkaline complex of Tapira. The second scenario presents an intrusion, delimited by the Bocaina Shearing Zone, fact sustained by the forward modeling, the analytic signal, the tilt-depth technique and the similarity of the inversions of the RTP - by the algorithm Baranov (1957) – and the RMF. There are also similar events of intrusion without significant remnant magnetization, so as the alkaline complex of Barreiro.

The principal attribute in common to the two scenarios is the presence of faults near the anomaly. The northern was originated in Pre-Cambrian period and reactivated in the D_3 phase of the Araxá Sinform (SEER, 1995) and it is visible the bulge exactly at north of the expected body of Pratinha I.

The gravimetric method allowed an inversion which exposed an intrusion of similar shape to the one obtained through the analytic signal; however the coarse number of data impeded to define which hypothesis approaches better to the reality. A refinement of gravimetric data, the use of a different method or – in an ideal case – a drilling could resolve the ambiguity of Pratinha I.

Acknowledgments

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