Gravimetry of the Tapira Alkaline Complex (MG) - Method and Interpretation

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Abstract

The Tapira Alkaline Complex in the Alto da Parnaíba region (MG, Brasil) is the southernmost among the intrusions in that area containing carbonatites. For this work a gravity survey was performed over the Complex and adjacent areas. The Bouguer anomaly was obtained from the measured data. The regional component was calculated in order to isolate the gravity contribution of the body.

To separate the gravity contribution of the body three different numerical methods were used: omission, upward continuation and robust polynomial. Once isolated the gravity anomaly, due to the alkaline body, two profiles were modeled using a 2,5D and a 3D geometry.

Key-Word: alkaline complex, Tapira, gravimetry, 2,5D Model, 3D Model.

Geology

According to Silva et al. (2006), in the Tapira area, the Brasilia Fold Belt shows four different lithotectonic domains, which are thrust faulted and interlayered. The lower and upper layers were interpreted as derived from rocks originated in a distal continental platform, having sediments from the San Francisco Craton of paleoproterozoic age as their main source. Rocks from the upper layer originated from deposits of a continental slope or flat oceanic floor environment, with the Craton of San Francisco´s sediments being the source with paleo- and mesoproterozoic age. The overall metamorphism was not synchronous; which is expected for an overthrust system.

The Tapira Alkaline Complex has an elliptical shape, and is composed by several intrusions of silicate plutonic-rocks and carbonatites in a lesser amount, (figure 1).

According to Brod et al. (2005), two units of ultramafic rocks can be recognized in the Complex: B1 and B2. In the northern part an intrusion of syenites of average granulation (S) is observed.

Brod et al. (2005) identified five episodes of carbonatite activity. The most recent intrusion (C1) occurs in B1 region. The carbonatites of C2 are mainly associated to the syenites (S). C3 and C4 are lesser calcium-carbonatites intrusions. Dolomite-rich carbonatites are recurrent in the late-stage dykes (C5).

The primitive magma of the Alkaline Complex of Tapira is ultrapotassic and has strong affinity with kamafugites.

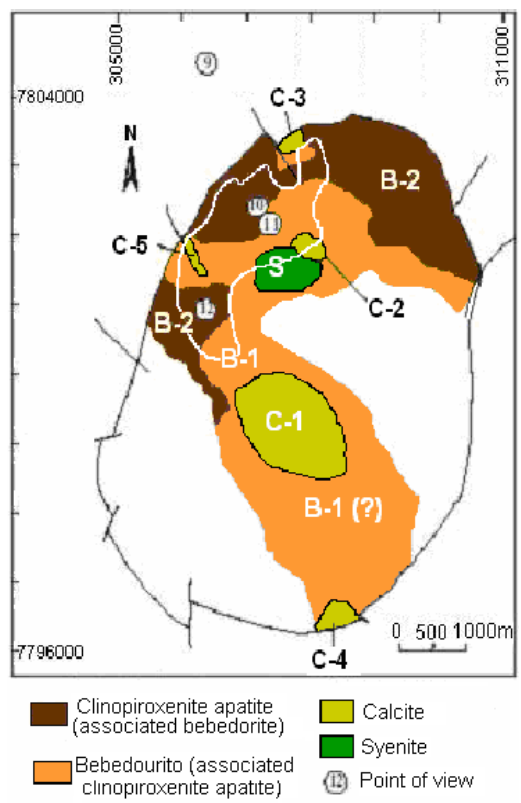

Figure 1: Geological sketch of the Tapira complex. Modified from Brod, 2005.

Methodology

To obtain the geometry, and study the geophysical characteristics of the Tapira Alkaline Complex, a gravity ground survey was performed. This method allows to laterally delimit the source of the gravity anomaly due to the density contrast between the intrusion and the host rock. When density contrast exists, this is the best method to study magmatic intrusions, even if compared to seismic methods (Vigneresse, 1995).

Gravity Survey

Over the dome, the gravity stations were measured along profiles, with a distance between two measurements of about 1km. In the adjacent areas (away from the center of the anomaly), the measurements were performed at 2km from each other, and further at 4km (figure 2), in order to obtain a larger area to calculate the regional field.

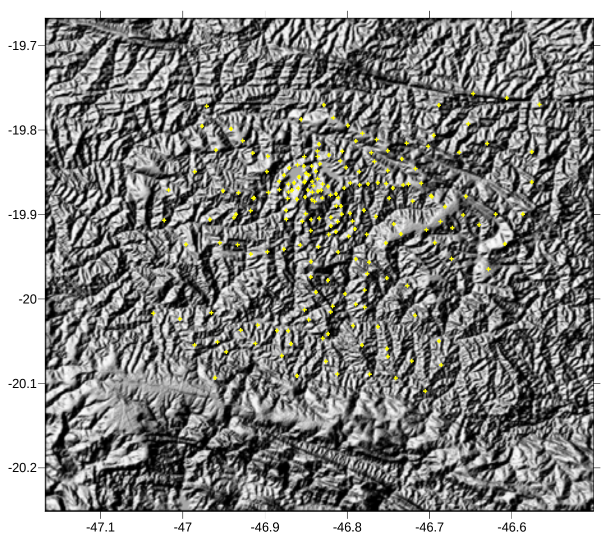

Figure 2: 3D Map of topography on the studied area; the yellow crosses are the site of gravimetrical stations. The map was obtained from the SRTM - NASA/ USGS public data base (www2.jpl.nasa.gov/srtm).

Data Reduction

Data processing included the analysis for the choice of the best mathematical method to interpolate the obtained Bouger anomaly data. Residues for two methods of interpolation (minimum curvature and kriging) are shown in (figure 3): for the used data set, kriging is considered to be the better interpolator.

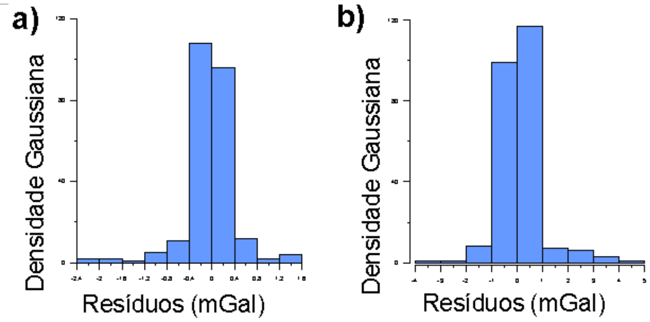

Figure 3: Histogram of the residues obtained by interpolating the Bouger anomaly, using (a) Kriging and (b) Minimum Curvature methods.

Once the data were interpolated, the Complete Bouger Anomaly map for the study area was obtained (Figure 4).

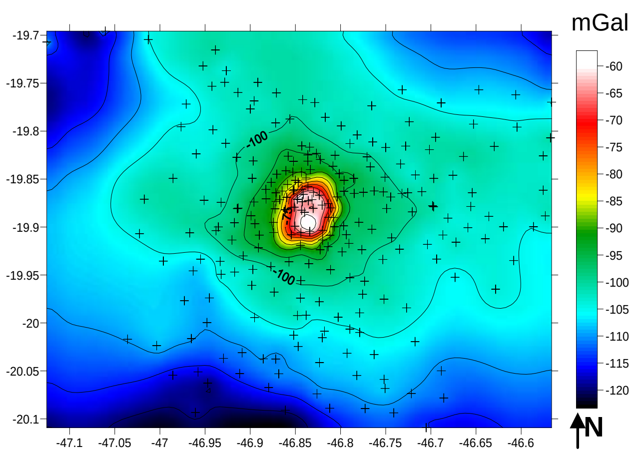

Figure 4: Bouger Anomaly obtained for the region using kriging as interpolator. Crosses correspond to the gravity stations.

To estimate the residual gravimetric anomaly, three different methods were compared: omission, upward continuation and robust polynomial. To select the best method, an analysis along the profile that crosses the anomaly center (figure 5) was performed, subtracting the observed Bouguer anomaly from the regional field calculated by each of the four cited methods. The 1st degree polynomial presented the best result (figure 6).

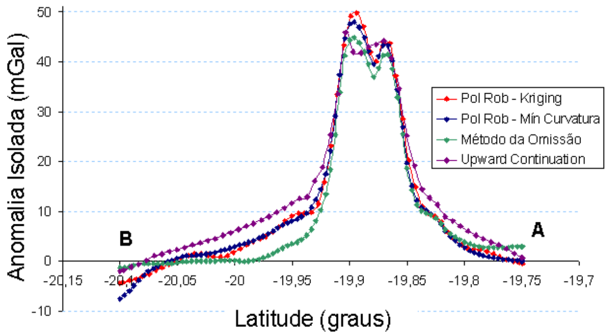

Figure 5: Graph of obtained values from the A-B profile for each of the used methods.

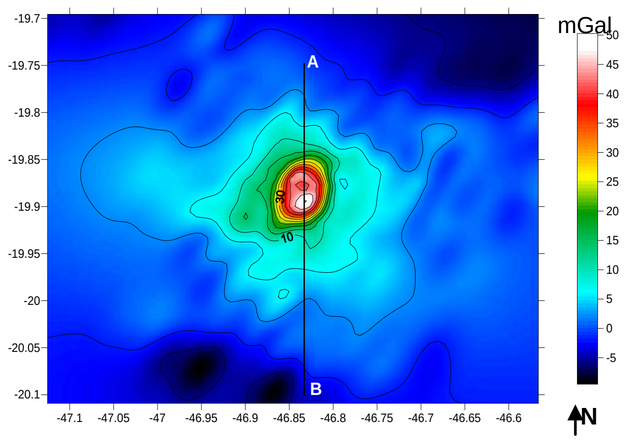

Figure 6: Component of Residual Bouger anomaly isolated by robust polynomial of degree 1, interpolated by Kriging.

2,5D Interpretation and modelling

The 2,5D gravimetric modeling was performed with the “GRAVMAG” software (Pedley et al. 1993), throughout the section shown in figure 6. The maximum depth along the AB profile was 5km, considering a 3.17g/cm^3 density for the intrusion, and 2.67g/cm^3 for the bedrock.

For the host rock (figure 7), the density value of the intrusion matches the average value of pyroxenites (3.00 to 3.33 g/cm^3). A body of lower density within the alkaline, associated to carbonatite (2.5 g/cm^3), was modeled as well. At the anomaly´s sides, the calculated curve (red line), doesn’t completely match with the observed data due the presence of diverse lithologies with variable densities around of the body.

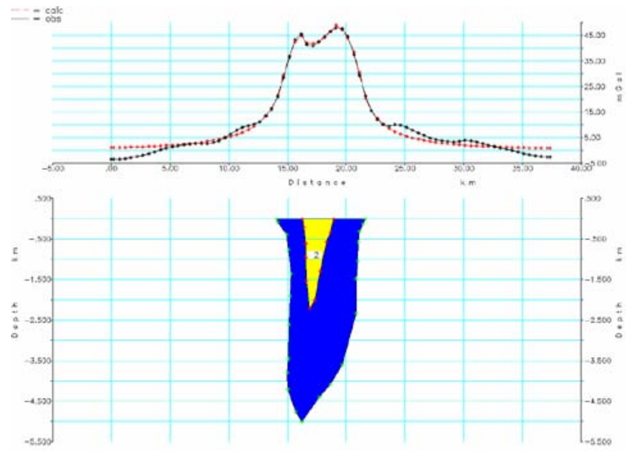

Figure 7: 2,5D gravimetrical model obtained from the A-B section, traced over the isolated anomaly by the robust polynomial interpolated by kriging. The black line represents the observed anomaly in mGal, and the red line refers to the anomaly created by the model.

3D Interpretation and modelling

To perform the 3D modeling we used the GRAV3D (2002) Version 2.0 program, developed by Li and Oldenburg (1996, 1998). The program assigns the region of the model as a set of rectangular cells, where each cell has a constant density. To invert the gravimetrical data, we used a mesh of 0.5km cells in the x, y and z axis.

The 3D model of density distribution obtained with this inversion is shown in figure 8. For the visualization of the internal part of the model developed for the alkaline, we did one diagonal cut (figure 9), and a North-South cut as well (figure 10).

The maximum depth reached by the model for the alkaline was 9.5km, and 2.5km for the carbonatite.

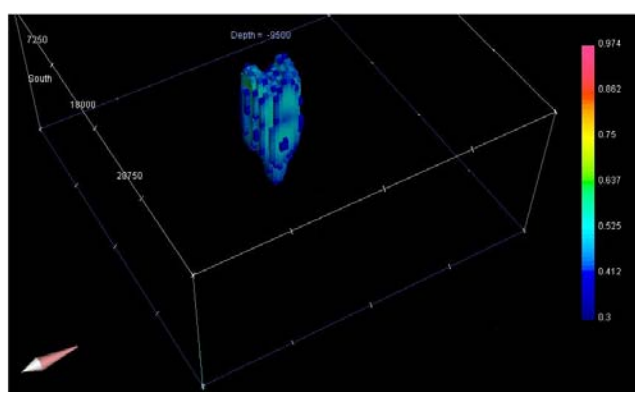

Figure 8: 3-D model generated by the GRAV3D program.

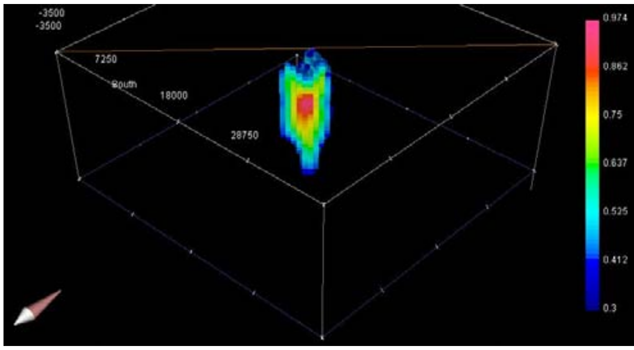

Figure 9: Diagonal cut of the 3D model generated by GRAV3D.

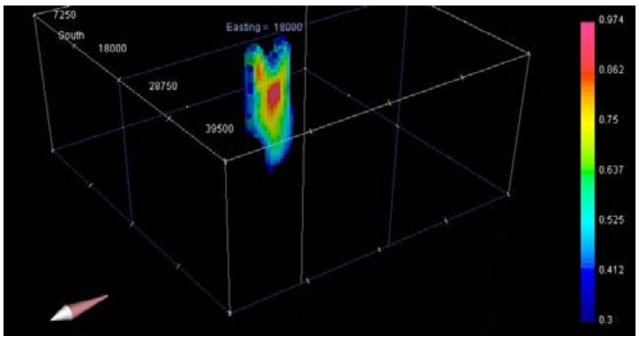

Figure 10: North-South cut of the 3D model generated by GRAV3D.

For validation purposes, the map of the observed residual gravimetrical field (figure 11) was compared to the map obtained from the calculated gravimetrical data of the generated model (figure 12).

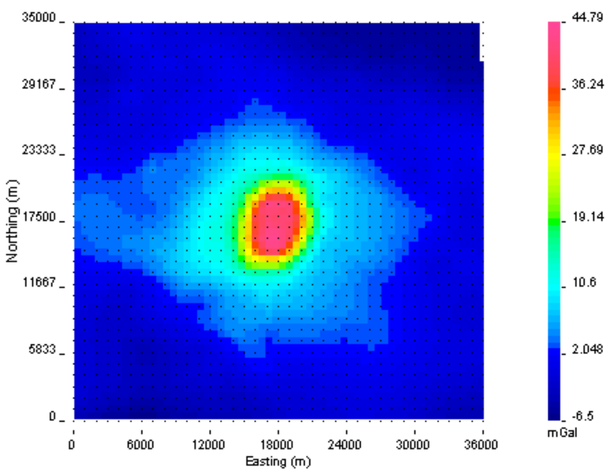

Figure 11: Map of residual Bouger anomaly observed for the studied region.

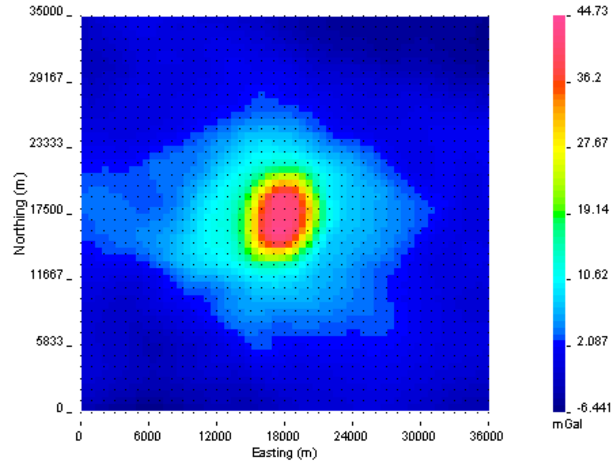

Figure 12: Map of the residual Bouger anomaly obtained from the 3D model generated by GRAV3D.

Conclusions

Through the comparison between the obtained residues, we noticed that the best interpolation was obtained using kriging, supplying the least errors associated with the interpolated data.

On low ends of the profiles obtained for the three separation methods, we noticed that the omission and "upward continuation" methods presented an attenuation of the residual anomaly values, which can be explained by the fact that these two methods did not completely isolate the regional component of the residual.

The profiles generated by the robust polynomial method presented higher peaks, without distortion in both end of the graph (Figure 5). These indicate that this method had optimal isolation of the anomaly. It is interesting to point that the results obtained using both the interpolated profile for the minimum curvature and kriging presented a similar behavior. The observed differences in the maximum values of the residual anomaly profile are in accordance with the expected from the analyses of the residues (Figure 3).

The adjustment of the 2,5D geometry shows an approach of the structure of the body in subsurface. The outcrop points of the body were adopted based on the map coordinates of the alkaline (Figure 1). For the volumetric analysis of the intrusion, the 3D method using the kriging interpolation associated with the robust polynomial was used.

Comparing the observed residual Bouger anomaly with the program generated one, a strong correlation can be seen, validating the experimental modeling.

Acknowledgments

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