Euler Deconvolution Applied to Potential Field Data from the Parnaíba Basin, Brazil

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Abstract

In this paper we discuss the results of the application of Euler deconvolution to determine the depth of the gravimetric and magnetic sources beneath the Parnaiba (Maranhão) Basin. As the Euler Deconvolution method is mathematically based only, some criteria are needed to select the viable solutions. One such criteria for gravity is the use of the kriging error, providing very good results. A variety of methods have been explored for magnetic data and the best results seem to come from the application of Located Euler Deconvolution. This technique first calculates the analytic signal and then searches solutions only on those points with high amplitude values.

Introduction

The Parnaiba Basin is an intracratonic inland basin in NE Brazil and its roughly ellipsoidal shape covers an area of about 600.000 km^2. The Parnaíba Basin is mainly Palaezoic in age and filled with siliciclastics of mostly continental origin deposited in five great depositional cycles from Upper Ordovician to the Cretaceous. The basin is bounded by fold belts and structural arches. These belts are made of low to high-grade metasediments formed or reworked during the Brasiliano Cycle (700-500 Ma).

Figure 1 – Location of the Parnaiba Basin.

De Sousa (1996) proposed a regional gravity interpretation for this basin explaining the lack of correlation between the geologic and Bouguer maps through the existence of a slightly denser anomalous crust resulting from extensional tectonics. In this paper we use another technique, namely Euler deconvolution, to estimate the depth of the regional gravimetric and magnetic sources beneath the Parnaiba Basin.

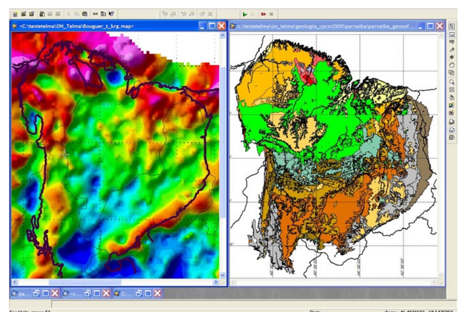

Figure 2 – Lack of correlation between the Bouguer map (left) and the geology (right).

The gravimetric dataset is composed of 21432 onshore stations and 19438 offshore stations and is maintained by ON. Its very heterogeneous sampling pattern poses a first challenge concerning the appropriate interpolated grid. The best grid for the entire basin was obtained using Universal Kriging with a cell size of 15 km, in accordance with the optimum value obtained by De Souza (2002). We used an spherical model with a nugget value of 0, a sill value of 530 and range of 180. This method also generates an error grid showing model deviations. The latter clearly points out large errors due to undersampled areas and regions with no data.

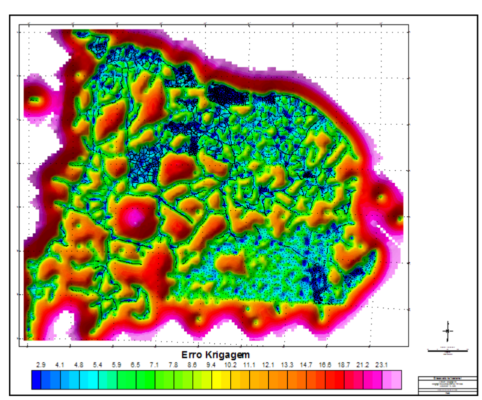

Figure 3 – Distribution of gravimetric stations displayed over the error grid resulting from kriging.

The magnetic dataset used in this work is composed of three airborne surveys, namely the South and West blocks of the Maranhão Basin and the South Border of the Parnaíba Basin as shown in Figure 4.

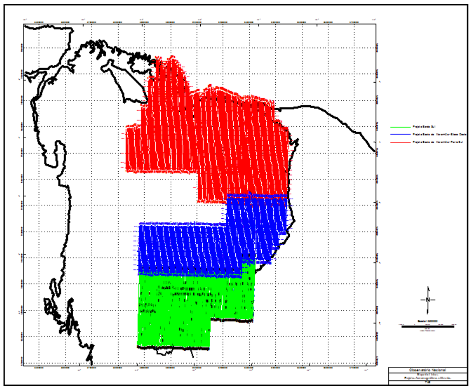

Figure 4 – Distribution of magnetic stations, in red the west block of Maranhão Basin, in blue the south block of Maranhão Basin and in green the south border of Parnaíba Basin.

As the survey parameters differ, *e.g.* the flight heights, they were processed separately, although the results are displayed in a single map.

Method

The Euler deconvolution method allows for automatic estimation of depths of potential field sources and it has attracted the attention of many researchers *e.g.* Thompson (1982), Barbosa *el al.* (1999), Reid *et al.* (1990), Mikhailov *et al.* (2003), Mushayandebvu *et al.* (2001) and Keating (1998), either considering aeromagnetic or gravimetric datasets.

In a Cartesian coordinate system, a function *T(x,y,z)* is said to be homogeneous of degree *n*, if

$$T(tx,ty,tz)=t^{n}T(x,y,z) \qquad (1)$$

This function can be written in terms of the Euler homogeneity equation as

$$x\frac{\partial T}{\partial x}+y\frac{\partial T}{\partial y}+z\frac{\partial T}{\partial z}=nT \qquad (2)$$

Considering the observation plane $z=0$, equation (2) can be rewritten as

$$(x-x_0)\frac{\partial g}{\partial x}+(y-y_0)\frac{\partial g}{\partial y}-z_0\frac{\partial g}{\partial z}=-Ng(x,y,0) \qquad (3)$$

where *N* stands for the decay rate of the anomaly is called its Structural Index or SI.
Equation (3) can be analytically solved for simple geometries, with different structural indexes. For magnetic sources SI varies from 0 (magnetic contact) to 3 (point dipole), while for gravity it goes from 0 (sill, dyke, step) to 2 (sphere). As the real complex bodies can be thought as being assemblages of point sources, the structural index can vary from 0 - 3 for magnetic sources and from 0 – 2 for gravimetric sources.
Equation (2) is rearranged as a linear equation with unknown parameters x_0, y_0, z_0 and N.

$$x_0\frac{\partial g}{\partial x}+y_0\frac{\partial g}{\partial y}+z_0\frac{\partial g}{\partial z}-Ng=x\frac{\partial g}{\partial x}+y\frac{\partial g}{\partial y} \qquad (4)$$

Given a value for the structural index N, Equation (4) can be solved for three measured points using the measured or calculated gradients, what often leads to unstable solutions and inconsistent values. Euler deconvolution is usually implemented using least squares inversion to determine unknown parameters in sliding windows as described by Reid *et al.* (1990).
The main problem with the method is the difficulty in interpreting results as too many solutions are usually found. Some kind of filtering is crucial to retain only the better solutions. Traditionally, errors on position and depth are applied as filtering criteria but this problem has been recently addressed in different ways. Keating (1998) used weights proportional to station accuracy and interstation distances for irregular gravimetric grids, while Mikhailov *et al.* (2003) proposed a cluster analysis to select the appropriate solutions. Barbosa *et al.* (1999) proposed a criterion to determine the structural index based on the correlation between the magnetic total-field and the estimates of an unknown base level.
In this study, for gravimetric data, filtering was based on the standard deviation of the kriging process at each grid point. For aeromagnetic data we tested the traditional methods and also the located Euler Deconvolution that uses the Blakely method to find peaks in a grid.

Results

Since this is a regional interpretation work, where it is expected to find many sources with different geometries, we have calculated the results for the gravimetric grid shown in Figure 2 for different SI,: 0, 0.5, 1, 1.5 and 2. Figure 5 shows the results obtained for SI = 2 .

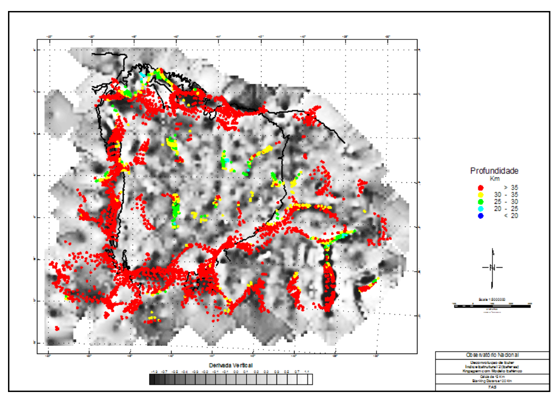

Figure 5 – Depth solutions for the Bouguer anomaly grid using SI = 2 over the vertical derivative grid.

Retaining solutions for which the standard deviation σ of the kriging error is less than 10, we obtain the result shown in Figure 6.

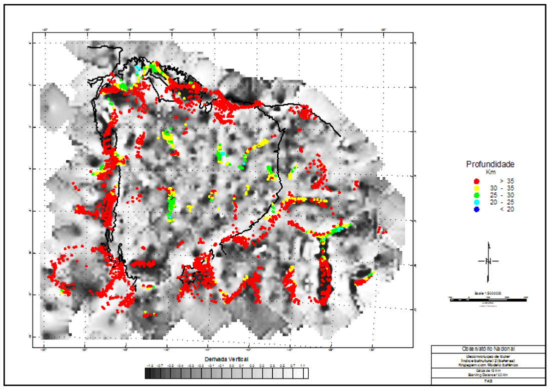

Figure 6 – Filtered solutions based on the kriging error of the Bouguer Anomaly for SI = 2 over the vertical derivative grid.

For aeromagnetic data, due to the regular sampling and better resolution, it is even more difficult to find an optimum filtering criterion, as the number of solutions is too high. Grids of the west and south blocks of Maranhão Basin have cell sizes of 750 while for the south border of the Parnaíba Basin Project the cell size is 450 m. In Figure 7 we present the results for SI = 2 after removing solutions with errors in positioning greater than 30 m and errors in depth greater than 10%.

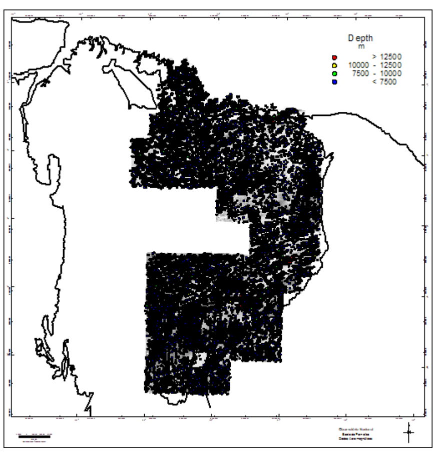

Figure 7 – Solutions based on the magnetic fields for SI = 2 over the vertical derivative grid.

Further restriction on the depth ranges helps dealing with the large number of solutions to be examined. Since a deep crustal model beneath the basin is sought after, in Figure 8 we present the solutions only for depths greater than 5 km.

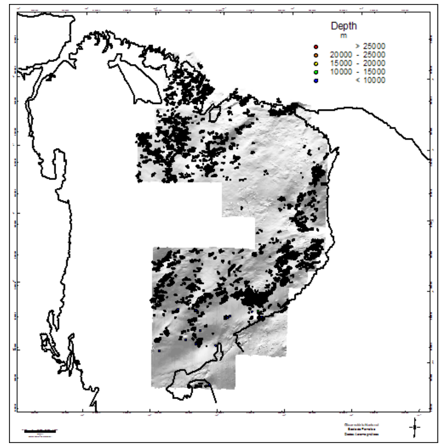

Figure 8 – Solutions deeper than 5 km based on the magnetic fields for SI = 2 over the vertical derivative grid.

Use of located Euler deconvolution enables the interpreter to use results directly. Interpretation in this case is not based on clustering solutions, but rather assumes that the algorithm generates only acceptable solutions. In Figure 9 we present the result for the same structural index (SI = 2) shown in Figures 7 and 8.

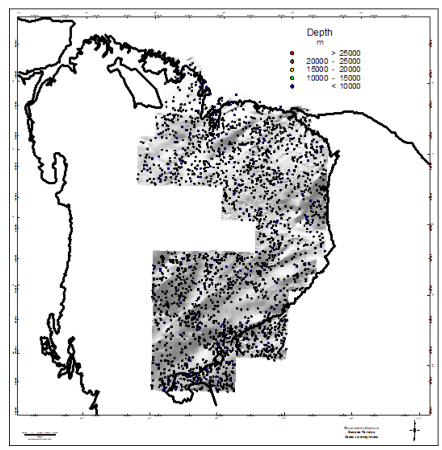

Figure 9 – Located solutions deeper than 5 km based on the magnetic fields for SI=2 over the vertical derivative grid.

Still using the located Euler deconvolution technique, a test was devised to determine the optimum structural index for a particular location, based on the minimum error in location positioning. For better comparison of all methods used, Figure 10 presents a zoomed image with the solutions generated for structural index 1.5.

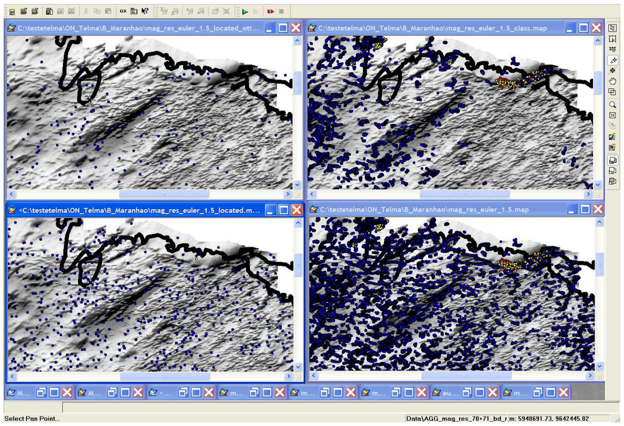

Figure 10 – Comparison of the solutions generated using: (top left) located optimum solutions for SI = 1.5, (bottom left) located solutions for SI = 1.5, (top right) standard Euler deconvolution solutions deeper than 5 km for SI = 1.5, and (bottom right) standard Euler deconvolution solutions for SI = 1.5.

Conclusions

The Euler deconvolution is an useful automatic technique to determine source depths but realistic interpretation demands filtering of the solutions set. For random and aligned random datasets as is usually the case of gravity surveys (Eckstein, 1989), good results were obtained generating an input grid using universal kriging and applying the error grid based on the standard deviation to discard meaningless solutions.

For aeromagnetic surveys the number of generated solutions is too high and a promising filtering technique seems to be the located Euler deconvolution. This is a subject that requires further investigation and testing.

Acknowledgments

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