Geophysical analysis of Cata Branca fault, Central-North Moeda Syncline, Quadrilátero Ferrífero, Minas Gerais

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Abstract

We present here the results of geophysical study conducted in the strike slip fault of Cata Branca, located in the central-north region of the synclinal Moeda, a structure of great interest in the Quadrilátero Ferrífero (QFe), located in the state of Minas Gerais. The QFe is a well-studied province due the occurrence of great mineral assets. The fault is located, more precisely, near the highway BR-356, 50 km from Belo Horizonte (MG), between the cities of Ouro Preto and Itabirito. In this paper, geophysics was used to show the continuity of the Cata Branca fault in depth, through qualitative and quantitative analyses of magnetometric and radiometric data, and also the 3D modeling of the structure using processed geophysical data.

Introduction

The Quadrilátero Ferrífero (QFe) is an important tectonic site located in the southern portion of the São Francisco Craton, surrounded by several brasilianos fold belts (ALMEIDA, 1967). Besides that, it presents a long history of research and mineral exploration.

The Synclinal Moeda has north-south vergence and eastern flank curved to west (DORR, 1969). The Synclinal tectonic evolution is characterized by three deformational events, one distensive and two compressive, being the compressive events responsible for the region main structure formation (SILVA, 1999).

The Cata Branca Fault was generated during compressional tectonics, which has a transcurrent character and is a shear zone structure where the contact occurs between the Rio das Velhas Supergroup and the Minas Supergroup. In the same region several gold deposits are described.

In this study, the use of geophysics makes it possible to obtain information on the continuity and on the behavior of the fault. Since the gold mineralization in this region has occurred in the shear zone, the in-depth study of the structure may indicate the possible continuity and gold mineralization extent.

Method

The methodology used in this paper relies on the stage of processing magnetometric and radiometric aerolevant data through the use of software for the generation of thematic maps on which qualitative analyses were performed, and later on a 3D visualization of the transcurrent fault by the data inversion method of the potential methods.

The aeromagnetic and aeroradiometric data are from the “Levantamento Aerogeofísico de Minas Gerais” project – Area 2, and the study region is located in the western block of area 2. The survey had N30E production lines, spaced at 250m, and N60W control lines, spaced at 2.500m.

The magnetometric thematic maps generated were: Anomalous Magnetic Field, Vertical Gradient of First and Second Order, Horizontal gradients in X and Y, analytical signal amplitude. The radiometric maps were: Channels of K, Th, U and Total Counting; Th/K, U/K, U/Th ratios; Ternary image; Parameter F. Those maps were produced from the software Oasis Montaj 7.0.1 of the GEOSOFT system. Later, the software ArcGis 10.3 was used to integrate the georeferenced maps to the geological data in a GIS environment, for the qualitative interpretation of the data. The qualitative interpretation of the magnetometric data was made mainly on the amplitude map of the Analytical Signal (AS), due to its monopolar characteristic.

The quantitative analysis uses the Euler Deconvolution, an interpretation method that estimates the position and depth of magnetic sources, using mathematical operations. Subsequently, the data are interpolated by kriging and a three-dimensional model of the area is created. Twenty-one 2D profiles were generated in the Euler 1.0 software on the AS map, with an N-S direction with spacing of 500 meters in an area of 50km^2. In the inversions, the parameters structural index 1.0 and window size 13 were used.

Results

The qualitative magnetometric analysis was mainly based on the analytical signal amplitude map, figure 1. It was made by a description of magnetometric facies specified according to the similar behavior of the anomalies. Three magnetometric facies were identified, as show in the figure 2. The magnetometric facies 1 are classified as low magnetization because they have values between 0.02488 to 0.19524 nT / m. It is located in the eastern domain and exhibits low amplitudes and high wave lengths. The magnetometric facies 2 presents intermediate magnetization with values ranging from 0,19524 to 0,71484 nT/m and located mainly in the western domain. Finally, occupying most of the western domain, the magnetometric facies 3 has high magnetization with values ranging from 0,714841 to 2,19697 nT/m. From the analytical signal amplitude map, were drawn magnetic lineaments and as a complement all the other maps were used as aid. In this way, the main orientation of the linearizations was determined, they are N-S and E-W directions.

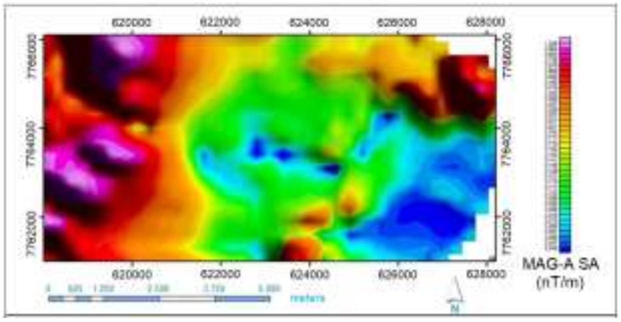

Figure 1 - *Map of Analytical signal amplitude. The blue and green tones indicate a local low magnetic, while the red and magenta tones are the high magnetic. In yellow and orange tones, the intermediates.*

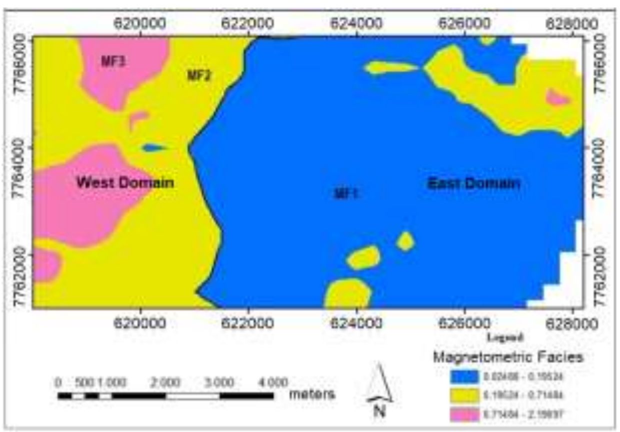

Figure 2 - *Determination of the east and west domains of the area and the magnetic facies present. MF1: magnetometric facies 1, MF2: magnetometric facies 2, MF3: magnetometric facies 3.*

Using the Thorium (Th) channel map (Figure 3) and the ternary image, three domains were determined. The eastern domain has the highest concentration of Th and relatively lower values of U and K. The central domain presents intermediate anomalies of Th, U and K. And the West domain has a low concentration of Th and high concentrations of U and K. The domains are represented in figure 4.

Linearizations were drawn using all the radiometric thematic maps, which indicated a preferential orientation E-W. The lineaments are presented overlapped on the Thorium channel map.

In the geophysical-geological integration the integration results between the thematic maps and the geological map of the region are presented. The relations between the geophysical signatures of the magnetic and radiometric anomalies and the lithologies, are made from the results.

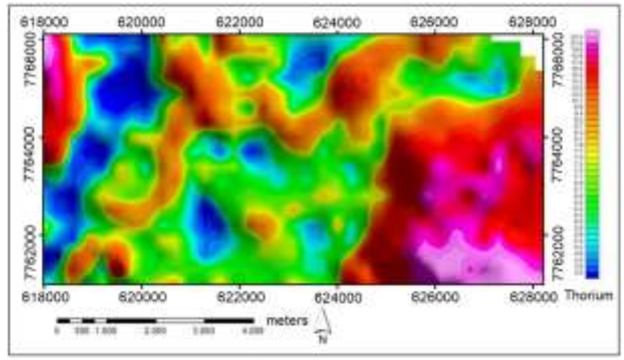

Figure 3 - *Radiometric map of the Thorium Channel.*

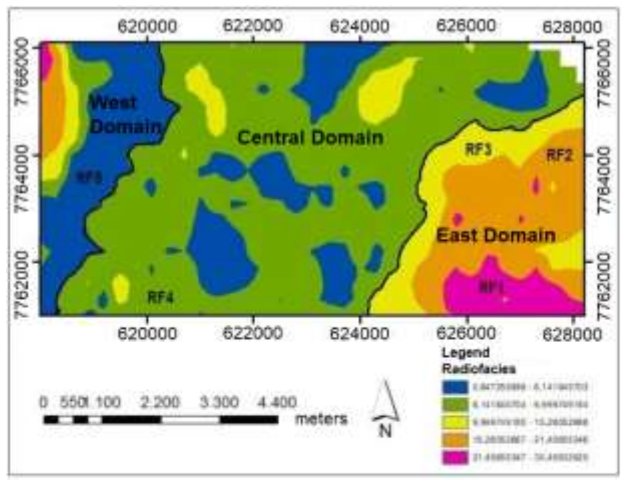

Figure 4 - *Description of the radiofacies and division of the domains present. RF1: radiofacies 1, RF2: radiofacies 2, RF3: radiofacies 3, RF4: radiofacies 4, RF5: radiofacies 5.*

The region is notably marked by rocks from Minas and Rio das Velhas Supergroups. Part of the Minas Supergroup, both hematite ore bodies and limonite (Cauê Formation) bodies, as well as dolomite itabirite and magnesian limestone (Gandarela Formation) are marked by high magnetic anomaly response. In the Rio das Velhas Supergroup, the magnetic anomalies response varies from intermediate to low. Given that the fault of Cata Branca puts the lithological units of these two Supergroups in contact, this will be used as a parameter to understand how it behaves on the surface.

While analyzing the monopolar character of the Analytical Signal Amplitude map with the aid of magnetofacies 3, it can be observed that, by overlapping these facies on the geological map of the region area of the greatest magnetic intensity signal response, the lithologies with the highest magnitude concentration of ferromagnetic minerals and those in eluvio-colluvial deposits, with presence of limonitic capping canga and iron formation boulders. Meanwhile, the magnetofacies 1 presents less response to the magnetic anomalies, corresponding lithologically to schist of the Rio das Velhas Supergroup and the Bação Complex.

The radiometric methods present a greater precision in delimiting lithological contacts of the units based on the thematic maps generated. From the map of the Th channel and the Ternary Image, it is possible to observe how the anomalies of Th correspond to the radiofacies specified above and how the Ternary Image, when superimposed on the geological map, explicitly specifies the layout of the lithological contacts.

The quantitative results, after the deconvolution of twenty-one profiles, were obtained in ArcScene 9.3 software and the data were interpolated by the kriging method to obtain the three-dimensional model of the target area. The subsurface behavior of the Cata Branca transcurrent sinistral fault with the 3D modeling was observed, thus the adjacent area in depth was understood. Thereby, in addition to providing in-depth structural analyses, one can also reproduce the origin and depth of rocks that have magnetic anomalies detectable by geophysical methods and presented on the thematic map.

The expressive anomalies of the area are expressed in three different regions, those that are more susceptible are concentrated in the western portion of the map, besides being related to outcrops of the area, consequently they count on the presence of ferromagnetic minerals. In the southern center portion these high susceptibility peaks are related to granada-staurolite schists in contact metamorphism aureole of the Nova Lima Group of the Rio das Velhas Supergroup. In the eastern portion in turn, the highest peaks of magnetic anomalies are also associated with the schists described previously, as well as by adjacent iron-forming metaconglomerates.

In the analysis of the 3D image (figure 5), it is noticed that whenever a high magnetic anomaly occurs, closely adjacent to it a significant increase of depth is observed. In depth it is possible to observe the continuity of the Cata Branca Fault, as well as the presence of other planar structures in the region.

Among the twenty-one profiles generated, the profiles 07, 08, 14 and 15 were selected because they favor the study of the fault geometry in depth.

In profile 07 (figure 6), the planar structures observed vary in a depth between 600 and 1800 meters. Also located in the western portion, the profile 08 in which the depth reached by the fault in this region is approximately 1250 meters.

Both profile 07 and profile 08 (figure 7) cross areas where magnetic anomalies are not so expressive, maintaining this trend throughout the central portion of the area.

Profiles 14 (figure 8) and 15 (figure 9) show, in common, a definite push fault that reaches a depth of approximately 600 meters. The Cata Branca fault intersects profile 14 in shallow depth compared to the other profiles analyzed. When analyzed in profile 15, the development of this fault does not appear. These profiles cross areas of low magnetic susceptibility anomalies.

Since the previously described profiles are selected to show a panorama of what is happening in the region, it is noted that the region is marked by deep planar structures, besides the Cata Branca Fault.

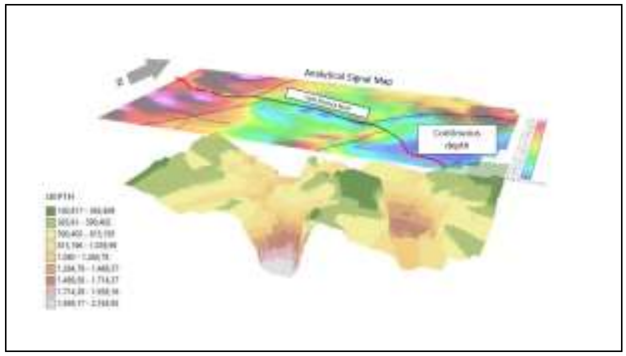

***Figure 5** - Depth profile of the area, with overlap of the Analytical Signal Amplitude map. The fault of Cata Branca appears as CB and its continuity in depth appears in red.*

Conclusions

From the achieved results it is possible to emphasize the importance of the geophysical approach in the understanding of geological structures, which allows advances in the academic environment and mineral exploration.

The sinistral and transcurrent fault of Cata Branca, because it is inserted in the context of the Moeda synclinal, is configured as an important geological structure, historically associated with the gold exploration in the region. The structure extends linearly for about 7 km, and from the approaches adopted, continuities of approximately 3 km to the west and 1 km to the east were identified.

From the data of magnetometry it was possible to delimit zones of greater concentration of minerals with high magnetic susceptibility, besides that these data were applied to determine the continuity of the structure in depth. The radiometry data were applied to aid in the understanding of the variation of lithology responses and to the construction of the F parameter map, used to visualize the hydrothermal responses. The execution of quantitative analysis by the deconvolution of Euler allowed a quick review with acceptable approximation to the depths of the structures. Depths were found between 420 and 1250 meters.

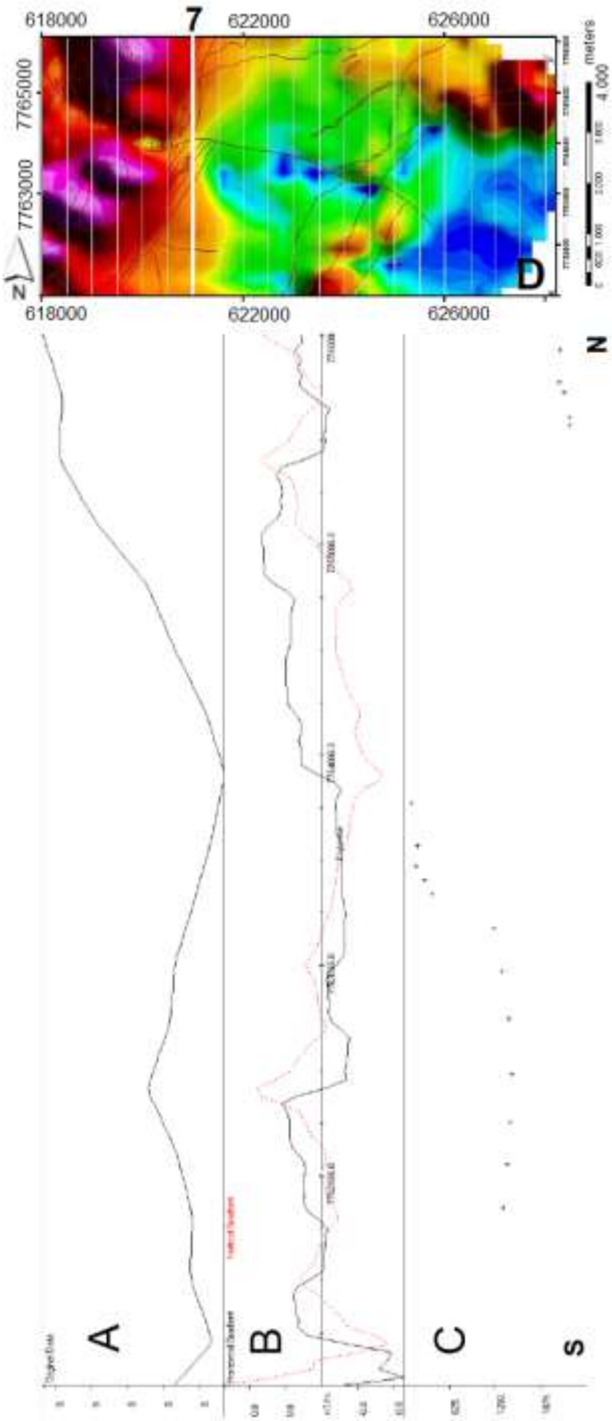

Figure 6 - *Euler's Deconvolution in profile 07. A) Displays the data generated on the Analytical Signal Amplitude map. B) Shows the vertical and horizontal gradients, in red and black, respectively. C) The estimated depth of the body that generated the detected anomaly. D) The Analytical Signal Amplitude Map, with the superimposed Deconvolution profiles mesh, can be seen profile 07 evidenced.*

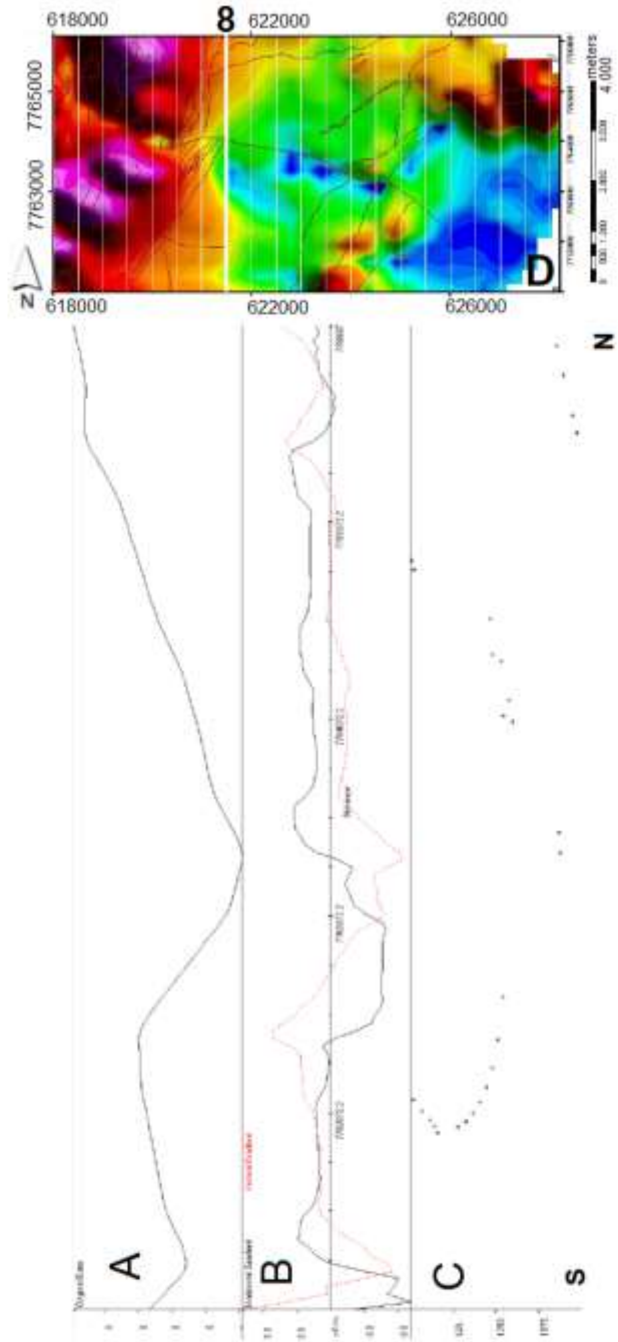

Figure 7 - *Euler's Deconvolution in profile 08. A) Displays the data generated on the Analytical Signal Amplitude map. B) Shows the vertical and horizontal gradients, in red and black, respectively. C) The estimated depth of the body that generated the detected anomaly. D) The Analytical Signal Amplitude Map, with the superimposed Deconvolution profiles mesh, can be seen profile 08 evidenced.*

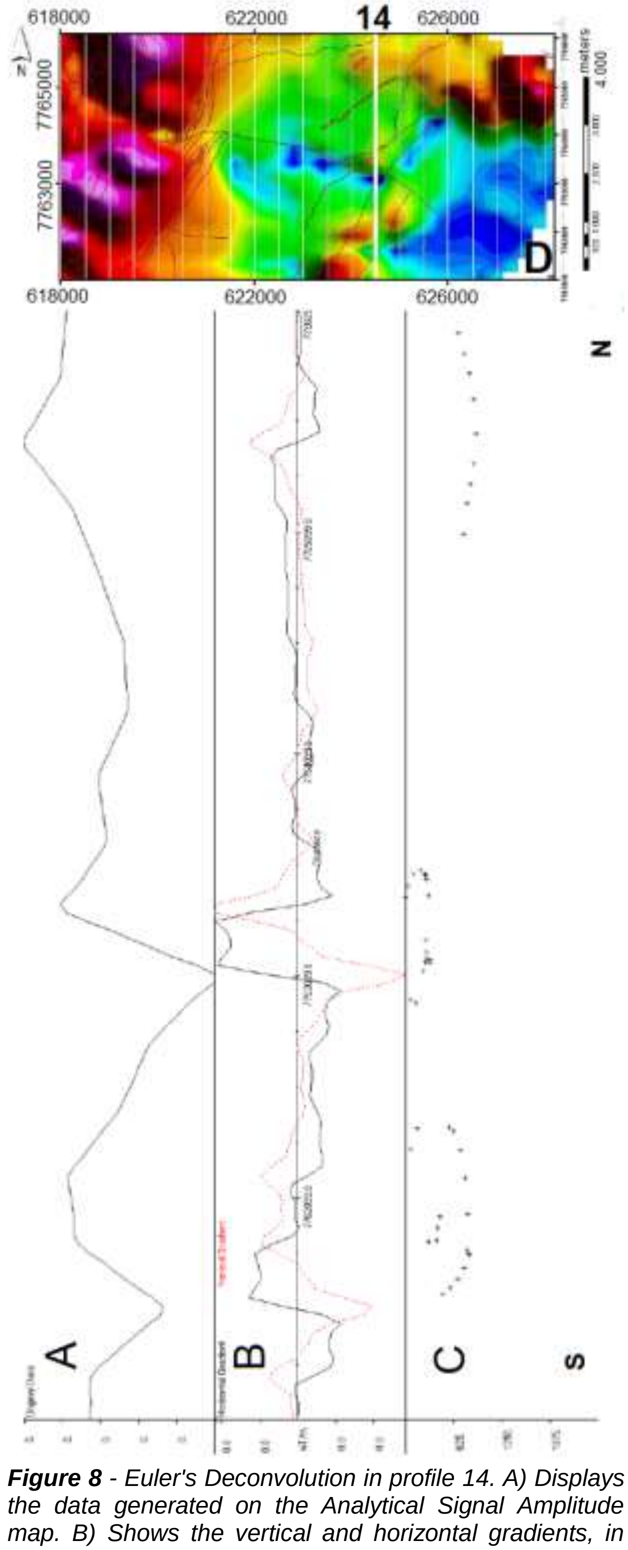

Figure 8 *- Euler's Deconvolution in profile 14. A) Displays the data generated on the Analytical Signal Amplitude map. B) Shows the vertical and horizontal gradients, in red and black, respectively. C) The estimated depth of the body that generated the detected anomaly. D) The Analytical Signal Amplitude Map, with the superimposed Deconvolution profiles mesh, can be seen profile 14 evidenced.*

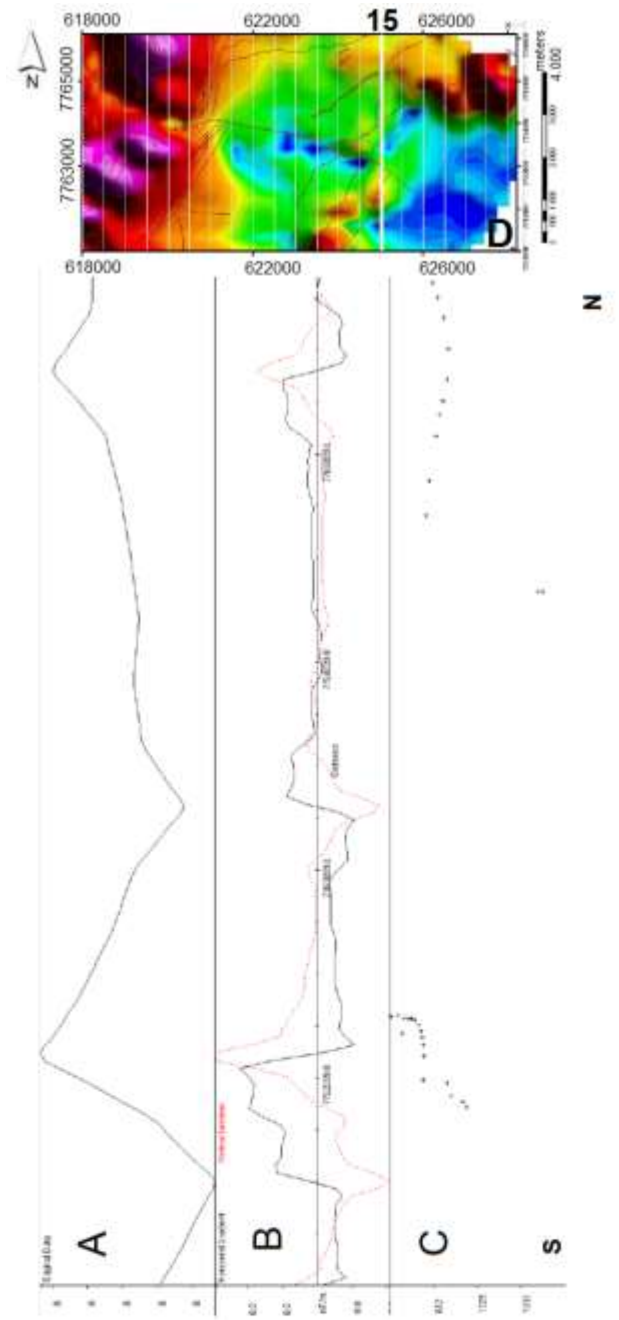

Figure 9 - *Euler's Deconvolution in profile 15. A) Displays the data generated on the Analytical Signal Amplitude map. B) Shows the vertical and horizontal gradients, in red and black, respectively. C) The estimated depth of the body that generated the detected anomaly. D) The Analytical Signal Amplitude Map, with the superimposed Deconvolution profiles mesh, can be seen profile 15 evidenced.*

Acknowledgments

- Society of Applied Geophysics (Sociedade de Geofísica Aplicada - SGA), University Federal of Ouro Preto.

References

ALMEIDA, F.F.M. Evolução tectônica do centro-oeste brasileiro no Proterozoico Superior. Annaes Academia Bras. Ciências, V 40, p. 285–295, 1967.

DORR, J.V.N. II. Physiographic, stratigraphic and structural development of the Quadrilátero Ferrıífero, Minas Gerais, Brazil. U.S. Geol. Surv. Prof. Paper 641-A. U.S. Geological Survey, 110p, 1969.

SILVA R. G. Análise Estrutural e modelagem tectônica da região centro-sul do Sinclinal da Moeda, Quadrilátero Ferrífero. DEGEO/EM/UFOP, Ouro Preto, Dissertação de Mestrado, 154 p, 1999