Geophysical Analysis of the Parecis basin.

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Abstract

A structural-geological mapping can help indication of possible preferred lineaments, however has limited scope in terms of depth, what makes geophysics an important tool in structural-geological subsurface prospecting, providing a qualitative and quantitative analysis of structures with advanced depths.

Geophysical analysis applied to the prevailing geological structures in the region of Parecis basin (Figure 1) in the states of Mato Grosso and Rondônia, in Brazil.

The study of regional geology and the geophysical analysis was mainly based on Bahia's (2007) doctoral thesis, while gravimetric databases were from space mission Topex/Poseidon and aeromagnetic survey from Petrobras. The geological database used in the integration is contained in the CPRM GEOBANK platform.

Initially the database was processed with the aid of Oasis Montaj 7.0.1 software generating a series of gravimetric and magnetic maps for qualitative interpretation. The application of filters in the generated maps stressed physical aspects of the structures and eliminated influences of unwanted sources.

The resulting data was used in inversions based in Euler deconvolution equations for identification of the structural behavior at depth. After integration and interpolation by the kriging method, it was possible to view the deep structures in 3D.

Introduction

The Parecis basin previously designated Parecis/Alto Xingu is located in the brazilian Midwest, occupying the southwest portion of Amazon Craton, between Rondônia and Guaporé shear bands corresponding to the Parecis Block from Hasuí *et al.* (1984).

Covering an area of 500.000km², lies between the Solimões, Alto Tapajós and Paraná basins, occupying the SW edge of the Amazonian Craton and considered as one of the largest intracratonic basins in Brazil.

The amazon region was affected during Paleozoic by an extensional event, which led to the deposition of Cacoal, Furnas, Ponta Grossa, Pimenta Bueno and Fazenda da Casa Branca Formations from the Ordovician to Eopermian. There is a gap from Permian to Triassic in the stratigraphic record of the Parecis basin.

During the Mesozoic era, the amazon region was again affected by an extensional event that led depressions to be filled by volcanic and sedimentary rocks. In the Parecis basin it was deposited during Jurassic, the Rio Ávila covered by the Anarí and Tapirapuã Formations. During Cretaceous, the Parecis Group deposited and kimberlite bodies cut the sediments in the northwest and southeast portions of the basin.

Covered discordantly by sediments deposited in a dismantled laterite crust. Since 1988, it became the target of research for hydrocarbons developed by Petrobras by means of aeromagnetic, seismic and gravimetric surveys whose results enabled the execution of two stratigraphic wells in 1993 and 1995 (Bahia, 2007).

It was revised all the available information, with updated geological survey, detailed stratigraphic analysis of the Paleozoic, Mesozoic and Cenozoic sections of the basin, its relationship with proterozoic sedimentation and its correlation with the other Brazilian proterozoic basins. Through the geophysical data, aims to elaborate a model of its evolution, definition of the tectonic-structural framework, interpreting the great lineaments that make up the basement and their importance in the tectonic-sedimentary evolution of the Parecis basin.

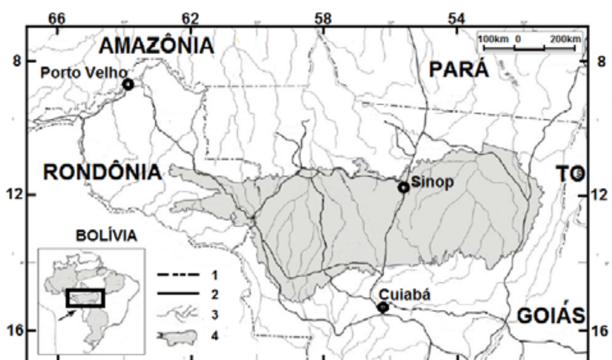

Figure 1: Location of the Parecis basin, 1: Interstate Limits, 2: Roads, 3: Rivers, 4: Parecis basin (Source: Bahia, 2007 modified)

Method

The first stage was the bibliographical research on sedimentology, stratigraphy and structural geology developed in the region.

Geophysical database obtained from Petrobras´ aerial geophysical survey program and the Topex/Poseidon spatial mission. These were processed through the software Oasis Montaj 7.0.1, for qualitative analysis.

Geophysical and geological analysis in a GIS environment using ArcGIS software highlighted structures at depth.

The quantitative analysis consisted in using the data obtained through the Analytic Signal, Bouguer anomaly and Euler 2D deconvolution, to estimate depths of the top of the anomalies in schematic profiles made in previous GIS environment analysis. The kriging method interpolated the surface in depth.

Qualitative and quantitative analysis were integrated for interpretation of observed geophysical anomalies in conformity with the structures.

Parecis Basin

According to Almeida (1983), the Parecis basin accumulates more than 6.000m of sediments, mainly siliciclastic, related to Paleozoic, Mesozoic and Cenozoic.

The stratigraphic nomenclature presented (Figure 2) follows, in part, that presented by Siqueira (1989), while the description and interpretation of the various lithostratigraphic units presented, are based on the data collected and treated by Bahia (2007).

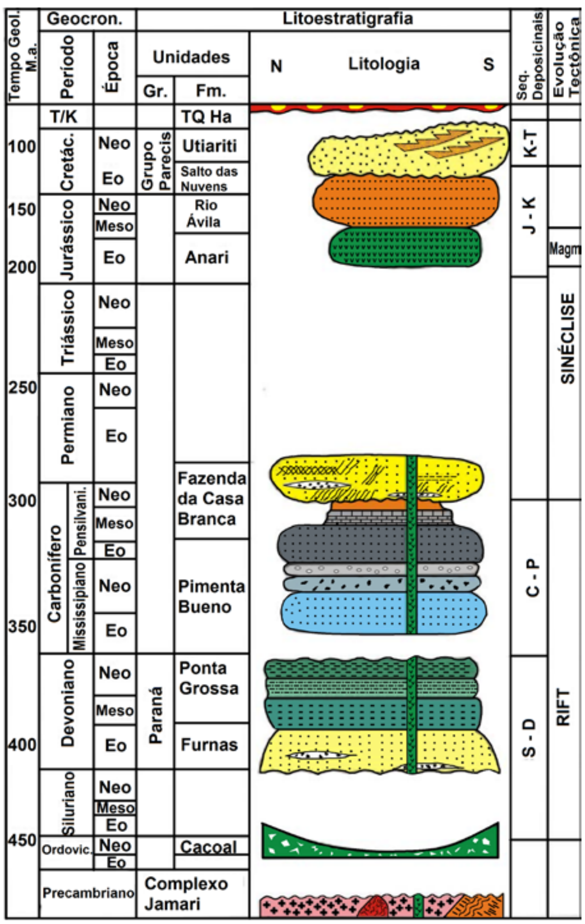

Figure 2: Lithostratigraphic column of the Parecis Basin. (Source: Bahia, 2007 modified)

The geological mapping at the level of recognition (scales 1: 250.000 and 1: 500.000) carried out by the National Department of Mineral Production – DNPM and conducted in the 1970´s by the Mineral Resources Research Company - CPRM (Figure 3). The Mato Grosso Central-West Project (Padilha *et al*., 1974) covered the central and northeast parts of the basin. The southwest portion Serra do Roncador Project (Costa *et al*., 1975), the west by the Sudeste of Rondônia Project (Pinto Filho *et al*. (1977) and the Southeast wedge of the basin by the Alto Guaporé and Serra Azul projects (Barros & Pastore Jr., 1974 and Ribeiro Filho *et al*., 1975, respectively).

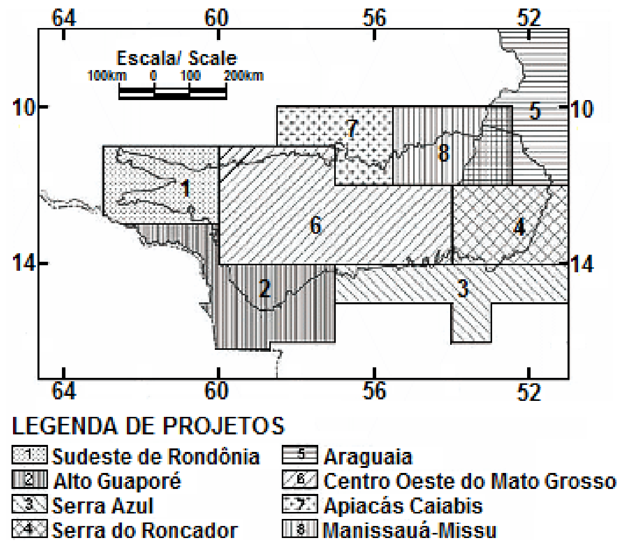

Figure 3: Projects developed by CPRM in the Parecis basin. Source: (Bahia, 2007 modified)

The west portion of the basement named Jamarí Complex (Isotta *et al*, 1978), is comprised of gneisses, migmatites, amphibolites and granitoids with medium to high grade metamorphism related to the Paleoproterozoic and gneisses, migmatites and granitoids of Xingu Complex (north and south of the basin) of archean and mesoproterozoic ages in the states of Mato Grosso and Goiás. Metavulcan-sedimentary rocks belonging to the Nova Brasilândia Group related to Mesoproterozoic, besides the Palmeiral Formation, a Neoproterozoic sedimentary cover. The basic and intrusive ultrabasic volcanic rocks are of the Mesozoic.

According to Siqueira (1989), the Parecis basin starts to fill in the Paleozoic, with conglomerates, sandstones, siltstones and shales respectively towards the center of the basin, with a certain contribution of carbonate and glacial sediments. This sedimentary package is composed from the base to the top by: the Cacoal, Pimenta Bueno and Fazenda da Casa Branca Formations in the western portion including Furnas and Ponta Grossa Formations in the eastern region.

In the Amazon region, there was a first extensional event in the Lower Paleozoic, when implanted a system of intracontinental rifts using previous weakness zones, which were filled, at least in part, by the Cacoal Formation during the Ordovician. The Cacoal, Furnas, Ponta Grossa, Pimenta Bueno, Fazenda da Casa Branca, Rio

Ávila Formations and also the Parecis Group deposited on the rift system from the Devonian to the Cretaceous (Costa *et al.*, 1975).

The Paleozoic sequence borders the Parecis basin at the west, southeast and southwest ends, while the Mesozoic sequence occupies the central and western portions of the basin and finally, the Cenozoic sequence is mainly concentrated in the Upper Xingu sub-basin, forming the already known "duster" of the Xingu River (Siqueira, 1989).

The Cenozoic is represented by the detrital-lateritic cover (Ronuro Formation), related to the Tertiary and the quaternary sediments of the Guaporé River Basin (Bahia, 2007).

Basic extrusive rocks (Anari/ Tapirapuã Formation) and ultrabasic intrusive (kimberlites) related to the Cretaceous occur in addition to these sedimentary sequences (Siqueira, 1989).

The Amazon region was affected by a second extensional event, related to the separation between South America and Africa during the Mesozoic (Juro-Cretaceous), when depressions filled by sedimentary and volcanic rocks. In the Parecis basin this event corresponds to the basaltic spills of the Anari and Tapirapuã formations (Pinto Filho et al., 1977), constituting the Jurassic sequence. On the basic volcanic rocks deposited sandstones of the Rio Ávila Formation, interpreted as being of eolian origin and correlated with the Botucatu Formation of the Paraná basin, forming the jurassic-cretaceous sequence (Siqueira, 1989).

The Cretaceous sequence is restricted to the Parecis Group of the Upper Cretaceous, composed of conglomerates and sandstones deposited in fluvial and eolian environments. (Oliveira, 1915).

The tectonosedimentary evolution of the basin, or parts of it, outlined in the works of Siqueira (1989), Bahia & Pedreira (1996) and Bahia *et al.* (1996). Bahia (2007) analyzed this evolution through in-depth study.

Bahia (2007) observed the continuation to the east of the Pimenta Bueno and Colorado grabens, disappearing below the Juruena and Alto Xingu sub-basins. This fact reinforced his idea of the evolution of the Parecis basin from intracontinental riftes to a thermal sineclisis. Subsequently, these depocentres were subdivided by the elevation of the structural horsts of NE-SW direction, reflecting a modifying tectonic caused by processes related to the elevation of the Andes Mountains.

This mountain range influenced the evolution of the Parecis basin, from the Mesozoic, resulting in the rise of the Rio Branco Arc in the west of the basin, separating Rondônia and Juruena sub-basins, isolating them from sub andine depression with which linked during the Paleozoic. This orogenesis associated with the opening of the Atlantic Ocean, results in collisions already proven in other Brazilian basins, such as strike-slip faults and the development of basic magmatism in the Solimões basin (Siqueira, 1989).

The qualitative geophysics analysis using Oasis Montaj 7.0.1 generated gravimetric and magnetic maps applying grind and image routine that interpolated the .gdb database by the minimum curvature method with pre-defined cell size originating grid files. Thematic maps generated through the colour-shaded grid routine.

The following flowchart (Figure 4) shows that, Bouguer, first order vertical gradient and horizontal gradients obtained by the application of filters in free-air anomaly map. The Total Magnetic Field map made viable the analytic signal (ASA), first order vertical gradient and horizontal gradients.

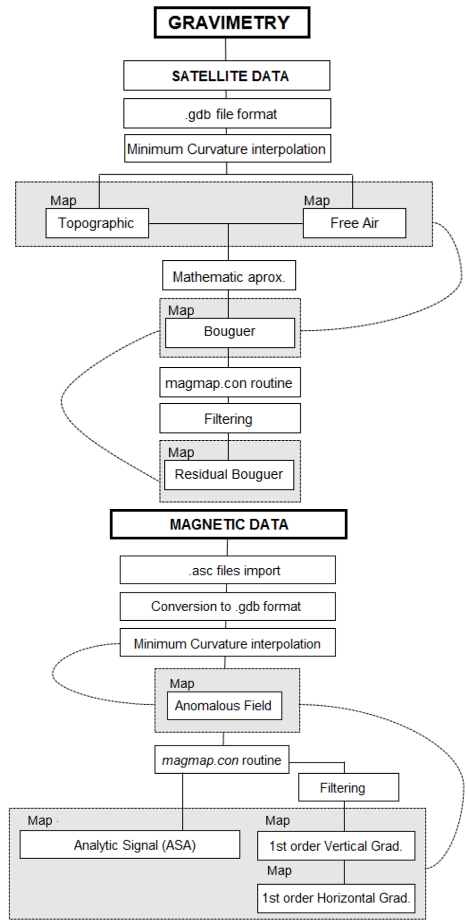

Figure 4: Flowchart of gravimetric and magnetic processing routine.

Thematic maps were first analyzed individually and geophysical-geological integration initially proceeded correlating only with maps of the same physic property. Magnetic and gravimetric database integrated to geologic features by ArcGIS 9.3 software.

In the Bouguer map of Figure 9 are present two gravimetric grabens on north and center-west parts of the basin, separated by a structural high with east-west direction, which confirm the regional trend of the structures. These gravimetric anomalies coincide with the continuation of the Pimenta Bueno and Colorado grabens below the Mesozoic sequence, related to the precursor rift phase of the Parecis basin proposed by Siqueira (1989).

They coincide with the Juruena sub basin, and the depocentres related to the Pimenta Bueno and Colorado grabens can be well defined, extending from the Rondônia sub basin until they disappear below the Juruena and Alto Xingu sub basins.

The arcs of Vilhena to the west and Serra Formosa to the east (Siqueira & Teixeira 1993) are not clear, as shown in Figure 10; however, the three tectono-sedimentary domains from west to east, proposed by Siqueira (1989) are evident.

The large NS-direction lineage present in the center-west portion of the map is a gravimetric response related to terrestrial mantle, due to the acquisition of the satellite data, a fact that better evidences smaller wavelength amplitude and consequently deeper structures.

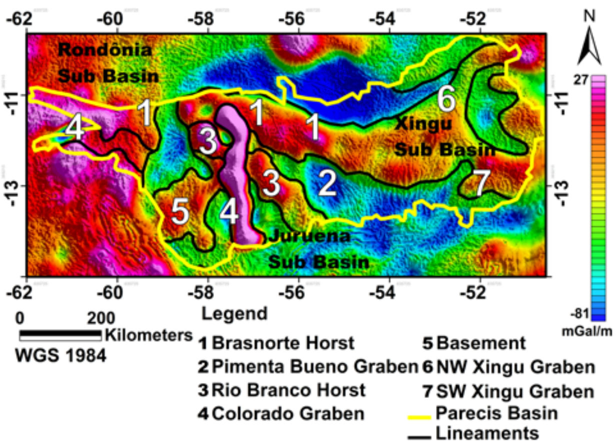

Figure 5: Bouguer map featured principal lineages.

The aeromagnetic data of the Parecis basin, presented in the Analytic Signal map (Figure 6), shows the continuation of the Pimenta Bueno and Colorado grabens to the east, separated by a horst called Rio Branco do Guaporé (Soeiro, 1981). Continuations that correspond the Rondônia graben presented by Siqueira (1989), as one of the three sedimentary tectonic domains proposed by this author separated by the arches of Vilhena and Serra Formosa, these as well as in gravimetric map, were not evident.

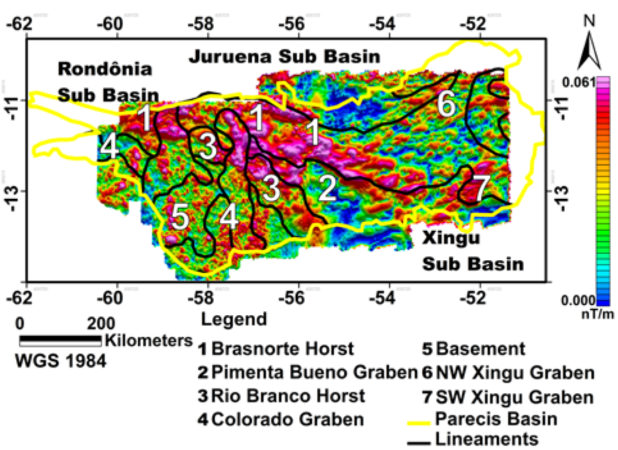

Figure 6: Analytic Signal map featured principal lineages.

The gravimetric designation related to the terrestrial mantle is not evident in the map of Figure 5, since the altitude of the survey is considerably smaller in relation to the satellite data, characterizing a survey with detail and superficial responses.

Gravimetric data of the geological structures and the fact that most of the magnetic maps illustrate the anomalies as a function of the magnetic dipoles allowed the study in subsurface. Therefore, analyzing the three-dimensionality of a magnetic dipole is not trivial and the centricity techniques allow the analysis of magnetofacies symmetrically centered in relation to the generating source. The conversion of the magnetic response into a magnitude proportional to the magnitude of the magnetic force generates an easy visualization of the anomaly.

In this work, two sets of geophysical data were used to infer the depth of the source through its anomalies. The first and largest of the sets to be worked was the satellite gravimetric data, the other used data from the aerial surveys of the Parecis basin.

The procedure begins with the creation of the georeferencing meshes in ArcGIS software (version 9.3). The meshes are directed north south, that is, perpendicular to the direction of the greater extension of the Parecis basin. A geo-positioning grid with one line spacing every 20 kilometers was created for the depth estimates using the aerial data.

Using the freely accessible on the internet software FREEWARE: Euler Deconvolution (version 1.0) developed in South Africa by the School of Geosciences, University of the Witwatersrand, among the work options offered by the software, the data type (gravimetric and analytical signal) to be manipulated was selected, reporting 1.000m as the flight height of the surveys (Figure 7). Knowing in a timely manner the ordered pair of surface position and physical magnitude (i.e., the anomaly itself), the software uses Euler deconvolutions to infer the depth of the emitting source. In this way, each linear profile infers the depth of the source as a slice and the union of numerous bidirectional profiles generates a three-dimensional surface (Figure 8).

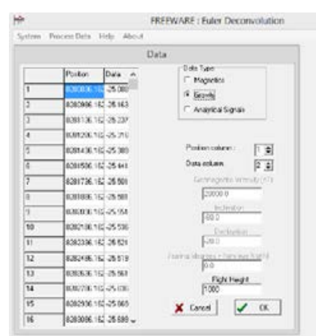

Figure 7: Euler 1.0 software interface showing position data, type of geophysical information (Gravity) and flight height (Flight Height).

For the inversion of the data in all profiles, the structural index was set at 1.0, window size equal to 11 and depth of 8.000m.

By the analysis of Figure 8, a sequence of structures positioned transversely to the profiles that have a continuity greater than 8.000m in depth can be observed.

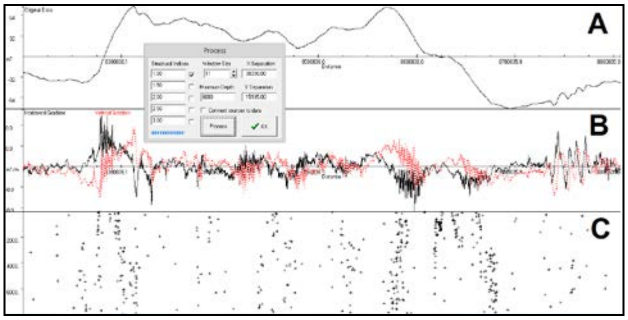

Figure 8: Result of the gravimetric inversion of a profile (example), visualizing the input data (A), the horizontal and vertical gradients (B) and the estimated depth (C).

These structures are better characterized in the Bouguer anomaly map profile, since their responses present larger wavelengths, emphasizing the presence of the Pimenta Bueno and Colorado grabens, separated by the Rio Branco do Guaporé horst (Siqueira, 1989). The high-amplitude (3D) circular anomalies located to the north and south of the profile are less deep, as can be seen in the analytical signal map profile.

The highlighted profiles in Figure 8 do not show the great gravimetric lineage related to the terrestrial mantle due to the maximum limit of 8.000m of admitted depth.

Results

The three-dimensional kriging interpolation routine in the ArcScene software (version 9.3) transformed the two-dimensional profiles into a three-dimensional surface, aiming at the arrangement of the structures present in the area of the Parecis basin. The results regarding gravimetric modeling are shown in Figure 9, as well as the magnetic modeling presented in Figure 10.

The 3D analysis of Figures 9 and 10 allows verifying signal sources that reach depths of the order of 1.000m to 6.000m. The first correspond to high frequency of the Brasnorte and Rio Branco do Guaporé horsts while the second are related to low frequency anomalies and correspond to the Pimenta Bueno, Colorado and Alto Xingu grabens, the latter subdivided by a horst in NW and SW Xingu grabens.

The low frequency magnetic anomalies are associated with depths of the order of 6.000m and corroborate the results of the gravimetric modeling, since these regions of deep anomalies are associated to the above-mentioned grabens.

The Juruena sub basin grabens lose evidence as they approach the SW limit of the Xingu sub basin and the arcs of Serra Formosa and Vilhena are not clear in these models.

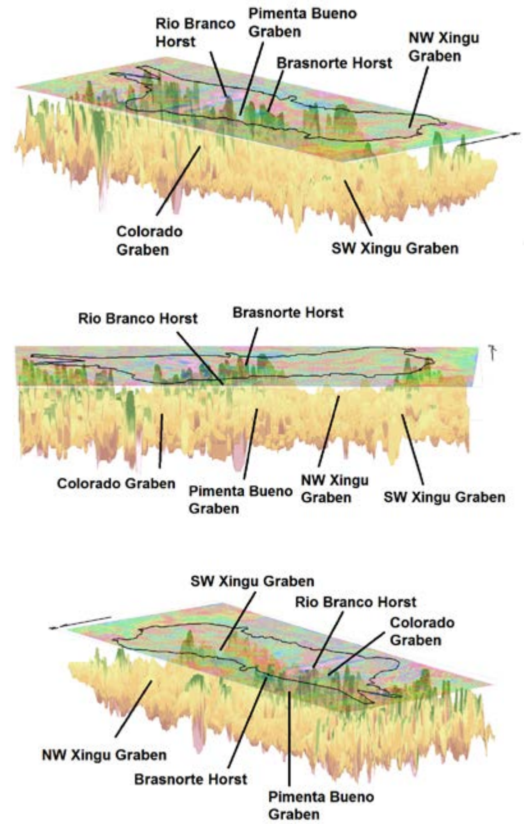

Figure 9: Different perspectives of gravimetric modeling.

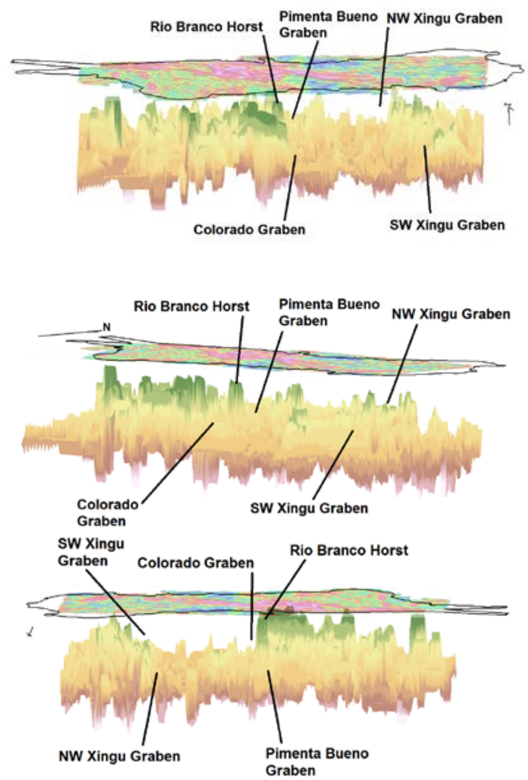

Figure 10: Different perspectives of magnetic modeling.

Conclusions

The analysis of the thematic maps made, identified structures of regional character and high depth, allowing a structural analysis of the Parecis basin in high resolution after the appropriate computational treatment presented in the evaluation of the results.

We must recognize the insufficiency of data, both from the basin and its basement, for a more precise and detailed definition of the structural framework and history of subsidence.

Comparing the modeling results of the Bouguer anomaly map and the analytic signal, it can be observed the presence of more intense crustal magnetic sources in the regions of the Pimenta Bueno graben and the Brasnorte and Rio Branco horsts, with depths varying from 1.000m to the deepest regions reaching 7.000m.

The three tectonic sedimentary domains from west to east, separated by the arcs of Vilhena to the west and the Serra Formosa to the east, are clearly perceived in gravimetric and magnetic maps, which does not occur for the mentioned arcs.

The gravimetric anomaly related to the terrestrial mantle was not evident in the modeling, since the Vertical Gradient map was used, highlighting the more superficial structures.

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