Tectonic Framework of Parecis Basin: a Seismic-Gravity Integrated Interpretation

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Abstract

The Parecis Basin is one of the largest Brazilian intracratonic basins. In spite of its size, it continues practically unexplored, since only five wildcat wells were drilled. To date, no commercial discovery have been proclaimed.

Past regional studies propose a Paleozoic sedimentation, while more recent ones indicate a Neoproterozoic fill. Nevertheless, no tectonic model to adequately describe the basin's development, nor a structural map for the whole basin has been published already. Furthermore, the explanation of the breakup or agglutination of the supercontinents Rodinia and Gondwana, the crystalline basement below the basin, is still a subject of debate.

In the present work, we present a new structural map of Parecis Basin based on an integrated interpretation of seismic, well and gravimetric data. Our analysis relies on a four-step work flow. In the first step, we converted the available 2-D seismic lines to depth domain. The second step comprised the estimation of a residual Bouguer anomaly, where the calculated anomalies should be linked with the basin's basement. The third step comprised the 2D forward modeling of the gravimetric anomalies employing the geological information supplied by the 2-D seismic interpretation as a constraint; and finally, all the interpreted faults were compiled in the structural map.

Our map reveals the top of the basement extending to 6km depths forming a complex framework of E-W trending highs, grabens, and hemigrabens. Normal faults are predominant, however, thrust and transcurrent (with positive flower structures) faults were also observed.

Beyond these results, we were able to recognize thick high-density bodies within the crystalline basement. These bodies may be defined as Orosian-Calimian (1.8-1.6 Ga) ophiolites or as a consequence of a magmatism originated from the continental opening process.

Introduction

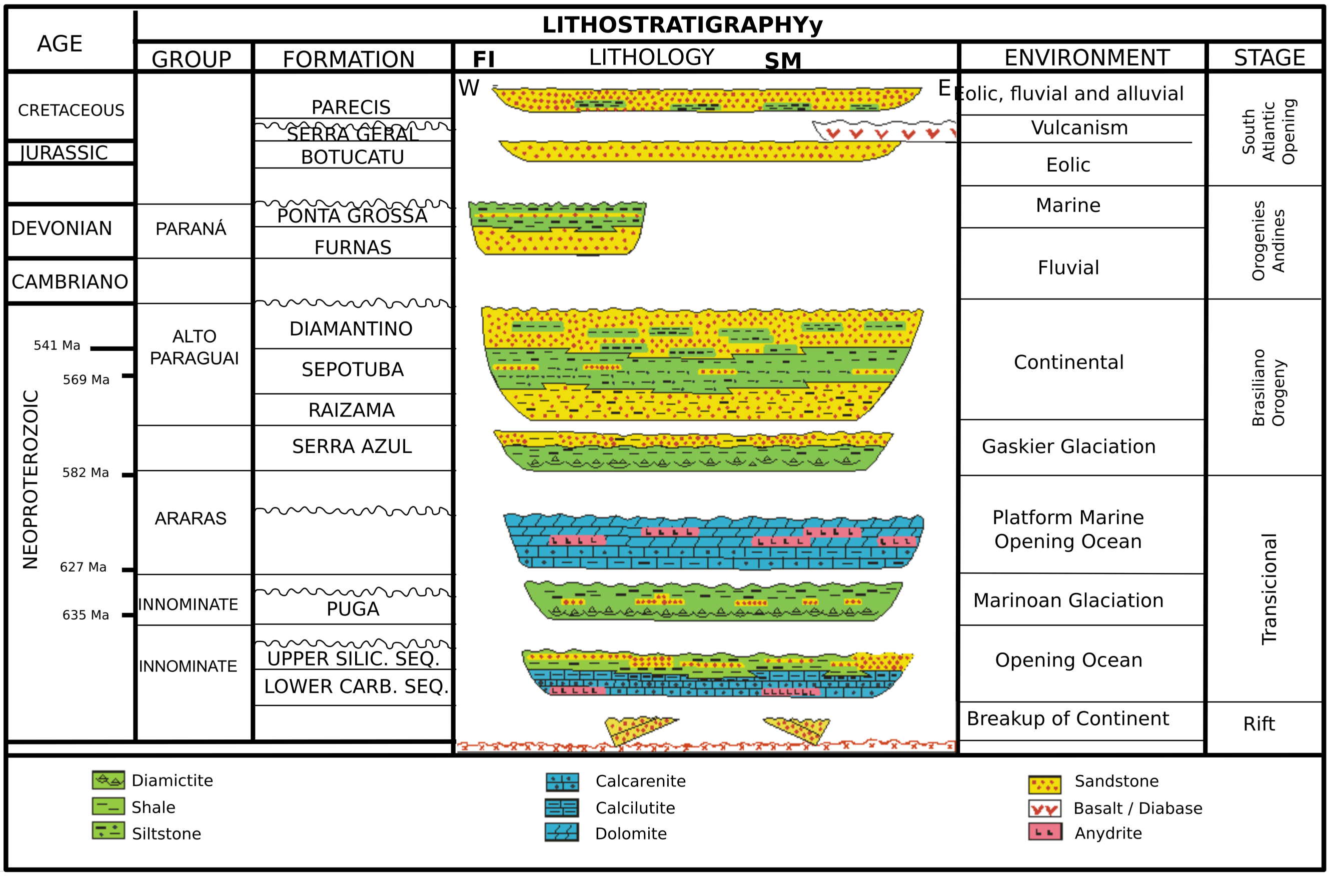
The Parecis is one of the largest of the Brazilian onshore basin and its mesozoic cover extends over an area of 356,376 km^2. It has a rectangular and elongated shape in the W-E direction, occupying practically the entire central-north portion of the Mato Grosso State and partially, the Rondônia State. It is bordered to the south by the Alto Xingu and, to the west, by the Rio Guaporé Arches; to the north by the rocks of the Ventuari-Tapajós and Rio Negro-Solimões Provinces and to the east by the Bananal Basin.

The hydrocarbon exploration in the Parecis Basin has challenged geoscientists. One of the principal reasons is the scarcity of data; until now, there are only five exploratory wells drilled for hydrocarbon studies, few regional surveys of potential methods and seismic data are limited to less than a hundred two-dimensional lines. As result, there are no commercial discoveries reported. Because of that and due to the high investment risk it represents, the Parecis Basin is classified as an exploratory frontier.

Concerning the geological knowledge, the Parecis Basin started to be studied for hydrocarbon prospecting by Siqueira (1989), who proposed the tectonostratigraphic correlation between the paleozoic basins of South America and that of the Parecis. In addition, the data of shallow wells (depths less than 1,000 m), surface mapping and gravimetry were used to generate the geological and structural map. Also, the basalts of the Anarí Formation were identified and dated, designated as Cretaceous by analogy with adjacent areas (Pinto Filho et al., 1977).

Next, Bahia et al. (2006) added to the previous study the information of the two stratigraphic wells, 2FI0001MT and 2SM0001MT, both of them drilled in 1993 and 1995 respectively. In this analysis, another stratigraphic chart was presented, based on the previous one. The following year, Bahia et al. (2007) presented a new proposition of tectono-sedimentary evolution and these two works represented the solidification of the understanding that most of the sediments were considered of Paleozoic age. Siqueira (1989) and Bahia et al. (2007) subdivided the Parecis Basin into three sub-basins: Alto do Xingu, Juruena and Rondônia, which are separated by Serra Formosa and Vilhena Arches respectively.

Recently, Haeser et al. (2014) have suggested that the tectonic evolution of the Parecis Basin occurred from the Neoproterozoic to the Quaternary period, predominating the existence of a huge package of neoproterozoic sedimentary rocks. Thus, a new stratigraphic chart was proposed and adopted in this study (Figure 1). In this article, the applied geophysical data consisted in two-dimensional seismic data, gravimetric data and two wells. From the integrated geophysical data, it was possible to obtain a new structural map of the Parecis Basin.



Modified from Haeser et al.(2014).

Figure 1: Stratigraphy chart modified

Methods

The methodology used was schematized by Figure 2 and consisted of an integrated interpretation of seismic and gravimetric data, using the geological control provided by well information. This approach is different from those presented so far because it allows the construction of a tectonic model that satisfies the different data used. At the beginning, the main time horizons were interpreted according to the well tie process, tops of formations or groups identified in the wells. Then, the time to depth conversion of the seismic lines and interpreted horizons was performed.

The faults and horizons in depth were used as input in the gravimetric data modeling step, which consisted in validating the seismic interpretation, considering the gravimetric response of the mapped features/units. The modeling consisted of producing geological models, with the aid of deep seismic, to reproduce the same result as in the observed gravimetric signal. The seismic lines converted in depth were used in the modeling and the surfaces interpreted in the seismic were fixed. On the other hand, non-imaged surfaces and bodies, such as the top of the crystalline basement (Amazon Craton) and shallower intrusive rocks, are determined in the geological model until they are adjusted to the best results (minor model error). It is important to emphasize that there are infinite solutions for modeling and it was necessary to reflect the geology of the region. par Regarding the parameters, the sediment densities were estimated by calculating the arithmetic mean of the curve data (RHOB). The well 2SM0001MT had the value calculated at 2.42 g/cm^3 and this value was considered to model mesozoic and neoproterozoic sediments. The well 2FI0002MT, which was drilled in the portion containing igneous rocks and older than those of the well 2SM0001MT, had a mean density of 2.52 g/cm^3 and was applied to the economic basement, that is, igneous rocks which have no commercial interest in the exploitation for hydrocarbons. The crystalline basement was modeled considering the density of 2.67 g/cm^3, value used for granitic rocks, and the variation from 2.70 to 2.77 g/cm^3, for intrusive rocks and spills.

From the result of this process, it was possible to refine the original seismic interpretation with the calibration of an auxiliary geophysical methodology. Finally, a new structural map for the Parecis Basin was produced.

Results

As final results, the resulting interpretations of the seismic lines can be discussed. In the line 0259-0001 (Figure 3), the eastern portion has different seismic facies from the western portion. However, the modeling considered the existence of a large threshold that could have attenuated the seismic signal, since an intrusive rock of the Tapirapuã Formation emerges to the south of the Basin, composed

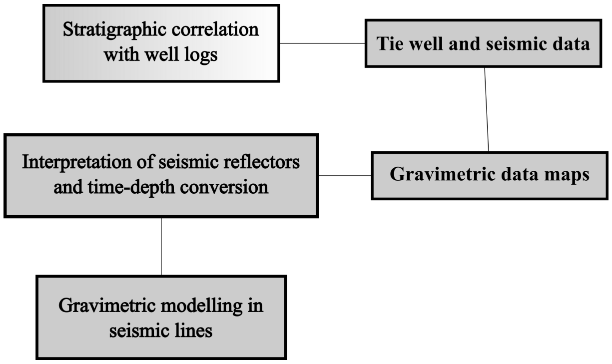


Figure 2: Workflow used in the study.

by basalts and diabase (Lacerda Filho et al., 2004).

Additionally, there is the presence of a more dense body, ranging from 2.70 to 2.77 g/cm^3, which was mapped in some of the lines 0295-0001 and 0295-0002 (shown in Figures 3 and 4). The body was interpreted as a probable density variation in the crystalline basement itself, and may be an ophiolite resulting from a process of obduction or magmatism that occurred in the opening of an ancient continent, possibly the Rodinia.

The modeling also revealed that, in line 0295-0005 (Figure 5), in particular, the crystalline basement could have two domains: one to the north, with density 2.66 g/cm^3, and the other with 2.67 g/cm^3 to the south. In addition to the basement, another value used for the adjustment was 2.32 g/cm^3 in the northern portion of the line. An important assumption of low density may be due to the existence of a mesoproterozoic basin to the north of the line. There are basins of several ages adjacent to the Parecis Basin, with Mesoproterozoic sediments, such as the Dardanelos Basin, of the Caiabis Group, dated to 1.3 Ga (Lacerda Filho et al., 2004), and the Gorotire Basin, formed by paleoproterozoic metassedimentary rocks (Barbosa, 1966).

After that, the seismic data were reinterpreted in the seismic and a structural map of the crystalline basement was generated. The map details some interpreted faults and allows to observe that, besides the already delimited Grabens, there is a great structural low mapped. Next, the Bouguer Residual Anomaly and structural map were overlapped (Figure 6).

Finally, a structural map of the Parecis Basin was generated from previous knowledge Siqueira (1989) and Bahia et al. (2006, 2007) integrated with the seismic and gravimetric interpretations of this study. This new map was superimposed on that of Bouguer Anomaly and six new grabens were defined, considering that the gravimetric lows are related to low densities. The grabens were named as follows: Juína, Buritis, Juara, Campo Novo dos Parecis, Salto Magessi, Teles Pires and Cáceres Graben, from west to east respectively. The names of the Pimenta Bueno and Colorado Grabens were kept only for the two outcroppings in the state of Rondônia. The deep grabens underlying the Parecis Basin were renamed (Figure 7).

According to the data observed in this project, most of the faults, mapped by the seismic and gravimetric interpretations, are normal and extend from the basement to the Araras Group. Others were reactivated at later compressive events and extended to the top of the Neoproterozoic.

Therefore, they are all large and tailings, being mostly normal almost vertical, some thrust by the compression movement and others by pushing. Positive flower structures can be observed.

The compressive structures of Brasilian Orogeny are observed in the shallower proterozoic layers and many of them form several large anticlines. After these phases, the Basin suffered subsidence related to two tectonic pulses that occurred in the Paleozoic during Andean Orogenies.

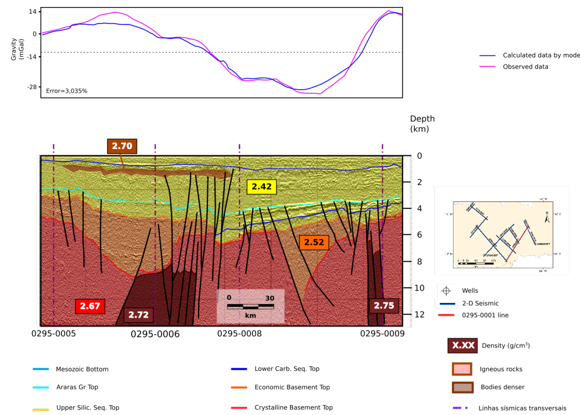


Figure 3: Gravimetric modelling integrated to seismic interpretation on the 0295-0001 line.

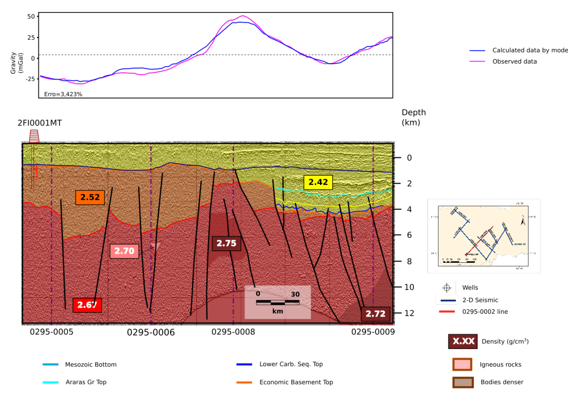


Figure 4: Gravimetric modelling integrated to seismic interpretation on the 0295-0002 line.

Summary and Conclusions

Finally, this study suggests that sedimentation of the Basin occurred associated with several continental-scale tectonic processes, such as the rupture of the Rodinia and the Brasiliana (Neoproterozoic 550 to 500 Ma) and Andean (Paleozoic) Orogenies. The basin filling was possibly controlled by high structural and grabens of kilometer scale, following the preferred W-E trend. Another hypothesis suggested is that there is a mesoproterozoic basin in the central-west region of the Juruena Sub-basin. It is noteworthy that there are basins with sediments of the same age adjacent to the Parecis Basin.

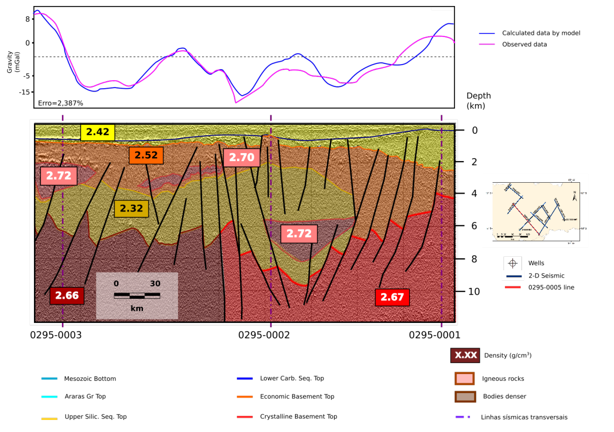


Figure 5: Gravimetric modelling integrated to seismic interpretation on the 0295-0005 line.

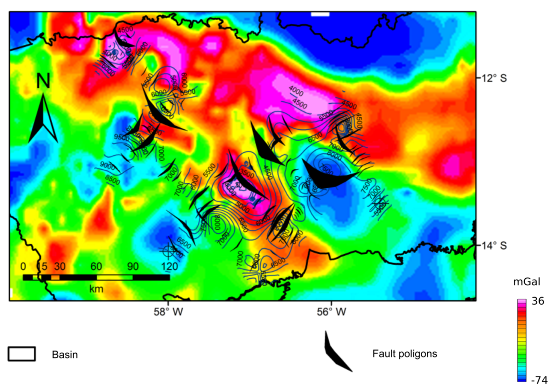


Figure 6: Structural map of the crystalline basement, obtained by the gravimetric modeling allied to the seismic interpretation, superimposed on the Bouguer residual anomaly map.

In addition, the modeling showed denser bodies that may be ophiolites generated in the process of continental or magmatic closure related to the continental opening that occurred in the Precambrian.

In relation to the next research, it should be remembered that this model was obtained through a workflow that used the integration of geophysical methods: seismic, gravimetry and well logs. The integration of data, geophysical methods, and geological information can be a strong ally in exploratory frontier basin studies and may continue to be employed in the Parecis Basin. In order to do so, there are more data that could be used, such as ancient aerial magnetometric data, three wells drilled in recent years, magnetotelluric data and more seismic lines.

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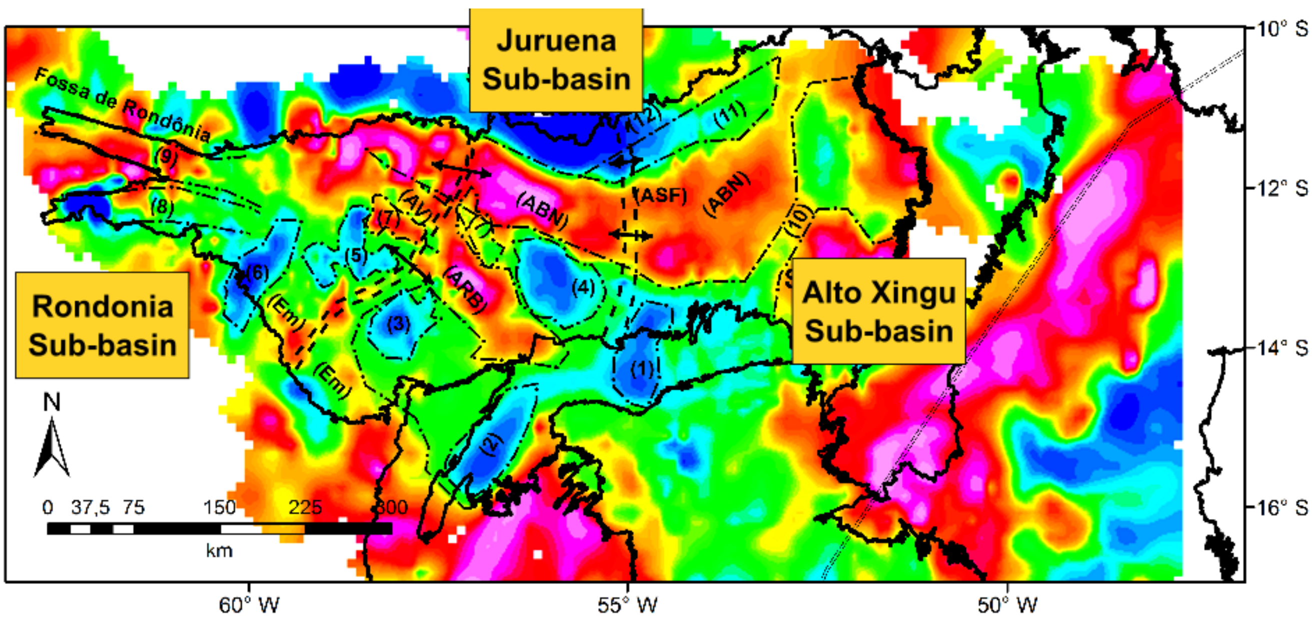

·—·—	Grabens	- - -	Arches	(Em)	Basement
------	Trans-Brazilian Lineament	⟷	Directions	(ARB)	Rio Branco High
·—·—	Structural highs	·—·—	Inferred fault	(ABN)	Brasnorte High
(1)	Teles Pires Graben	(7)	Juara Graben	(AV)	Vilhena Arch
(2)	Cáceres Graben	(8)	Colorado Graben	(ASF)	Serra Formosa Arch
(3)	Campo Novo dos Parecis Graben	(9)	Pimenta Bueno Graben		
(4)	Salto Magessi Graben	(10)	Xingu SW Graben		
(5)	Buritis Graben	(11)	Xingu NW Graben		
(6)	Juína Graben	(12)	Caiabis Graben		

Modified from Braga, L.; Siqueira, L., (1996), Bahia et al. (2007) Apud Siqueira (1989) and Curto et al. (2015)

Figure 7: Structural map of the crystalline basement superimposed on the Bouguer residual anomaly map.