Tectonic Framework of Barra de São João Graben, Campos Basin, Brazil

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Abstract

In the present work we interpret gravity data to propose a new structural map to the BSJG. The interpretation of the residual gravity data constrained by available seismic lines, magnetic data and well logs showed a more complex picture than previously know.

Introduction

The Barra de São João Graben (BSJG), located in the western shallow water portion of Campos Basin (Fig. 1), has been recognized as one of the several SW-NE grabens of the so-called Cenozoic Rift System (Zalán and Oliveira, 2005). This regional system runs parallel to Brazilian southeast continental margin and is segmented by SE-NW transfer faults reactivated in the Lower Cretaceous and Cenozoic. That tectonic event was followed by volcanism and thermal subsidence assigned to the lithosphere movement probably related to hot-spots (Cobbold et al, 2001).

The structural framework of BSJG has been previously studied by Mohriak and Barros (1990) using sparse 2D regional seismic lines and regional Bouguer gravity data. As result, Mohriak and Barros (1990) have defined a relatively complex internal structure with basement highs and lows mainly separated by SW-NE faults as shown in Fig. 1. They also estimated a sedimentary infilling of 700m to 1.000 m.

In the present work we present a more detailed structural framework of BSJG based on the interpretation of gravity data. Available high-resolution magnetic data, 2D seismic lines and the density log of a nearby well were used as constraints to our inverse modeling. Our interpretation workflow consists of:

(a) Separation of the Bouguer anomaly into its regional (Moho discontinuity) and residual (top of the basement surface) components (e.g. Leão et al. 1996, Barbosa et al. 2007);

(b) 2.5D forward modeling of the gravity residual component and magnetic data along a seismic line crossing the BSJG; and

(c) 3D inversion the residual anomaly aiming to recover the geometry of the basement topography.

Figure 1: Location map of Campos Basin and the Barra de São João Graben delimited by the green rectangle. Dots represent the seafloor gravity stations. Inset shows the distribution of available onshore, seafloor and satellite gravity data gathered in a regional database.

Gravity Dataset

The gravity data herein interpreted is part of the regional EG13 database available at ANP (Brazilian Petroleum Agency). The EG13 survey consists of shallow (0 – 200 m water depths) seafloor gravity stations collected, in the 1970 decade, for Petrobras. The survey extends along the Brazilian continental margin from Rio de Janeiro State to Alagoas State. The gravity data were collected along profiles with 4 km average spacing and 1 km site spacing within the profiles (Fig. 1). Data was provided by ANP as ASCII database with five main channels for each gravity station: latitude, longitude, bathymetry, Free-Air and Bouguer anomalies.

Each gravity station measures the sum of gravity effects of shallow and deep-seated sources. In Campos Basin, Mohriak et. al. (1987) described positive gravity anomalies over the main regional depocenters, where gravity lows (negative anomalies) would be expected. That happens due to the positive gravity effect of the moho uplift (crustal thinning) in the area mask the negative effect of the basement depocenters.

To separate the gravity effects of the basement relief from deep-seated anomalies produced by the crust-mantle interface, we applied the polynomial method of Beltrão et al. (1991) to the Bouguer anomaly of Figure 2. To better estimate the regional anomaly due to the Moho interface, we merged the seafloor data with available onshore gravity stations, satellite and marine data in the deep-water portions of Campos basin (see inset in Fig. 1) into a regional database.

In Beltrão's method the polynomial coefficients are calculated by a robust procedure so that reduces the influence of the residual component in the fitted regional. The program assumes that isolated anomalies are locally either positive or negative, but not both. A major advantage is that it can be applied directly to irregular spaced data (like our data distribution), as the polynomial coefficients are calculated in the actual gravity station position.

We calculated polynomial order from 1 to 9 (not shown her for the sake of brevity). The polynomial of fifth-order was chosen as the best because its residual anomaly (Fig. 3) shows the best correlation with the interpreted seismic faults of the BSJG (Mohriak and Barros, 1990), and the polynomials of higher order (sixth to ninth) show essentially the same features observed at order five, with the gravity anomalies only being smeared out.

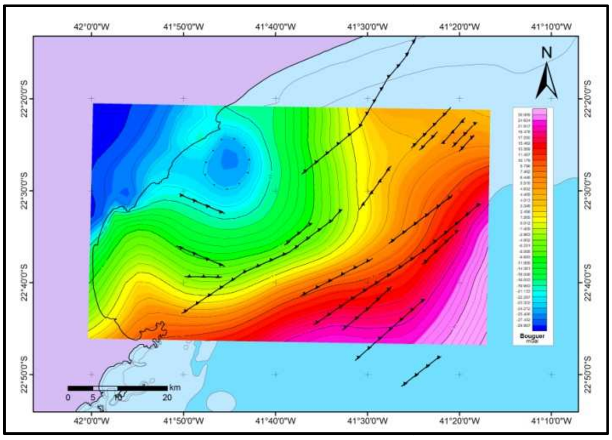

Figure 2 – Bouguer anomaly map of BSJG and adjacent region. The seismic faults defining the BSJG (Mohriak Barros, 1990) shown as black lines.

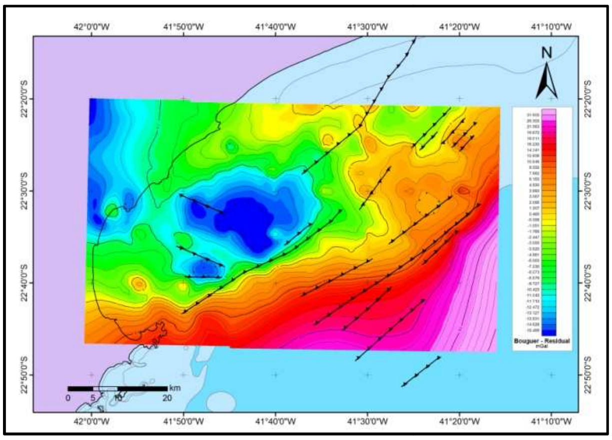

Figure 3 – Residual anomaly map of BSJG and adjacent region. The seismic faults defining the BSJG (Mohriak Barros, 1990) shown as black lines, compare with the Bouguer anomaly of Fig. 2.

2,5D Forward Modeling

The 2,5D inverse modeling is a powerful tool to estimate geometry and physical properties of geological features. In the present work we used the LCT software that is based on the Talwani `s (1965) method. A main advantage of LCT is to build geophysical models from seismic SEG-Y files allowing its integration with gravity and magnetic data. Seismic horizons and georeferenced images are also allowed for model building.

In the present study we modeled the seismic line L-028-64 following the interpretation of (Mohriak and Barros, 1990) (figure 4) depth-converted using available seismic velocity information at a nearby well 1-RJS-69. In our modeling exercise we kept fixed the basement topography as given by the seismic interpretation. We also used the well information to constrain the densities of the sedimentary section. The only free parameter to be modeled was the basement's density. Our first try was a uniform density for the whole section but we didn't got a satisfactory misfit. That was only achieved with the allowance of a heterogeneous basement with 3 different densities (Fig. 4), with a high density body in the southeastern portion of the model.

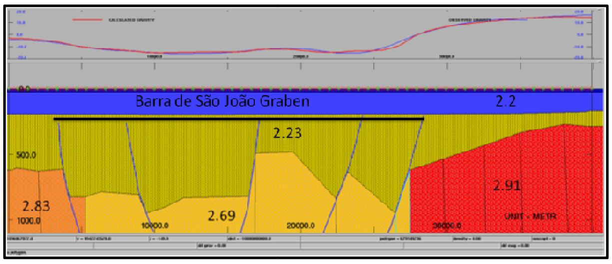

Figure 4: 2,5D model based in the seismic line L-028-64.

3D Inversion

The 3D inversions were performed using the 3D module of LCT. We built an initial model as a single density cube composed by four layers (Table 1). With the definition of the model, the densities for all the layers were applied in order to prepare all the steps for the structural inversion of the layer 3´s top representing the basement topography. Before the structural inversion, an inversion for the densities of the layer 3 was applied to reproduce the lithology's differentiation inside the layer.

Table 1: 3D Model Layers

	Top	Bottom	Density (g/cm^3)
Layer 1	Water	Sea Floor	2.2
Layer 2	Sea Floor	Layer 2 Top	2.23
Layer 3	Layer 2 Top	Layer 3 Top	2.69 - 2.91
Layer4	Layer 4 Top	Half Space	0

The final 3D model of the BSJG basement topography and proposed structural map of SJBG is shown in Figure

5 and the proposed structural. The comparison showing the good fitting between observed and calculated data is shown in Figure 6. We can observe in Figure 5 a complex structure with several internal highs and lows. We superpose the previously known structural map of Mohriak and Barros (1990). Our results confirm the previously known features and new ones were identified. The main structural trends observed in the basement´s top map are NW-SE and NE-SW, very similar to the structural pattern of the Taubaté Basin (Marques, 1990), one of the basin that composes the Cenozoic Rift systems.

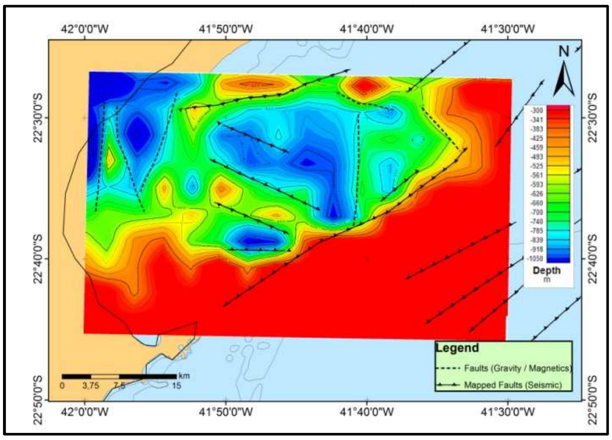

Figure 5: Map of the basement topography with old structural features (continuous lines) of Mohriak and Barros (1991) superimposed. New interpreted faults (dashed lines).

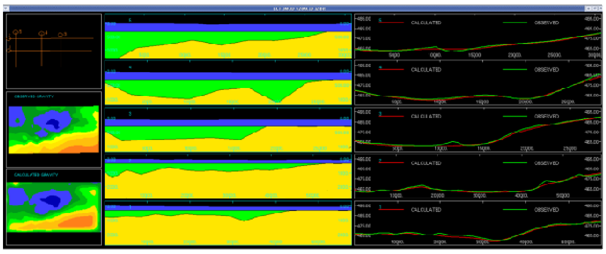

Figure 6: Screenshot of 3MOD software (CGG-GMS) showing the fitting between observed data (in green) and calculated data (in red).

Available magnetic data from can also be used to corroborate our interpretation as shown in Fig. 7, where exists a good match between the magnetic anomalies and the gravity structures herein interpreted.

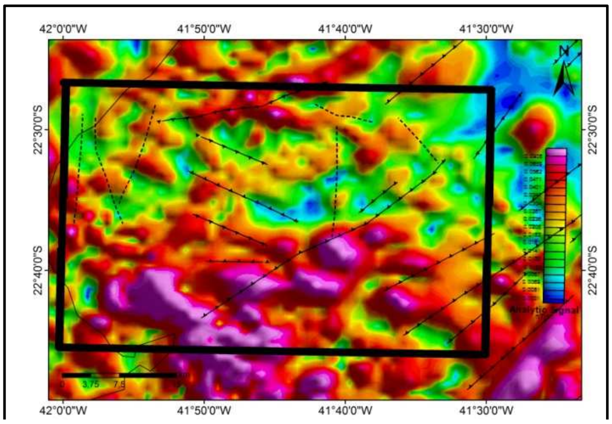

Figure 7: Analytic Signal of the total magnetic intensity data with the faults mapped in this study.

Conclusion

In the present work we used a three step gravity data interpretation strategy to propose a new structural map to the Barra the São João Graben . The first step was to separate the gravity effects from deep sources to shallow (residual anamlies) and interpreted the latter only. The second step was a 2.5D modeling based on seismic interpretation followed by 3D inversion for the top of the surface of the basement. Our interpretation strategy allowed a better definition of masked features in the BSJG structural framework.

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