Unconventional shale exploration in the Sergipe Basin. Major and subtle faults mapping using gravity data.

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Abstract

In the present work we interpret gravity data to provide a high-resolution structural framework for Sergipe Basin. We applied a multiscale edge method to the Bouguer anomaly data and defined several major and subtle gravimetric lineaments within Japaratuba Low.

Our results will serve as guidelines to the next step of the ongoing work: a detailed structural interpretation of available 2-D and 3-D seismic data. One goal of this subsequent interpretation is the search of sweet-spots in unconventional shale reservoirs.

Introduction

Hydrocarbon exploration of unconventional plays, the so-called "shale gas/oil", represents a new challenge for the global petroleum industry. USA is the major global producer, currently the unconventional gas corresponds to 45% of the total production. In 2025, the forecast is that it will respond to 60 % of the total.

The main challenge in unconventional reservoirs production is the fact that these hydrocarbon accumulations in the source rock (usually shale) are difficult to be characterized and produced by conventional exploration and production technologies. Consequently, we need complex geological and petrophysical systems to describe these unconventional reservoirs in addition to heterogeneities at all scales similar to conventional systems.

Because of the low to ultra-low permeability of these unconventional systems, the integration of horizontal drilling and well stimulation operations (e.g., single or multi-stage hydraulic fracturing, etc.) are required to establish production from the formations at commercial rates. The a priori knowledge of the content of total organic carbon (TOC), and mainly the presence of the natural fractures in the reservoir can positively impact the production.

Brazil has a high potential for the development of unconventional resources in onshore basins. However, the geological knowledge of the prospects to define sweet-spots for exploration must be improved. ANP (Brazilian Petroleum National Agency) described Sergipe Basin as a potential target area for unconventional research. This is due to several factors: be a mature basin with hundreds of drilled wells; installed infrastructure; and most important, abundance of geological and geophysical available data.

In the present paper, we present the preliminary results of a long-term project of unconventional reservoir characterization at Sergipe Basin (Figure 1). At this point, we are concerned to better define the structural framework of the studied area. More specifically, we are particularly interested in mapping both major and subtle faults that may have influenced both sedimentation and fracturing of the shale source rocks of the basin.

To that end, we applied a multiscale edge detection method (Hornby et al., 1999) to available gravity data. Following that approach, we were able to define a structural framework to the northern part of the Sergipe Basin. We identified not only the major NE-SW trending fault system, but also NW-SE trending transfer fault system. This last, separates the main internal graben highs and lows. The faults herein interpreted will we used, in a near future, to guide the subsequent 2-D and detailed 3-D seismic interpretation in the studied area.

Geologic framework

The Sergipe Basin is located in the northeast Brazilian continental margin (Figure 1). The basin extends over 350 km and fills an area of 45,760 km2, including onshore and offshore portions (Aquino and Lana et al.,1990). It is bounded to the north by the Pernambuco-Paraiba Basin, to the south by the Jacuípe Basin and to the west by crystalline basement rocks of the Sergipano Belt (Feijó, 1994).

The basement consists of gneissic-migmatitic of the Pernambuco-Alagoas Massif and Neoproterozoic metamorphic rocks of the Sergipano Belt (Figure 1). The tectonic style of Sergipe basin is associated to the separation of Africa and South America plates, and to the development of the Rift of the South Atlantic in upper Neojurassic-Eocretaceous.

The structural framework of the half-graben Sergipe basin is controlled by an NE-SW trending fault system. This synthetic and antithetic normal fault systems controls the subsidence and sedimentation within the basin, forming internal highs and lows distributed along a standard en-echelon pattern (Ojeda and Fugita, 1976). The subsidiary NW-SE trending faults system is interpreted as a transfer strike-slip fault system as it shows slickenlines geometry indicating sinistral transtension (Destro, 1995).

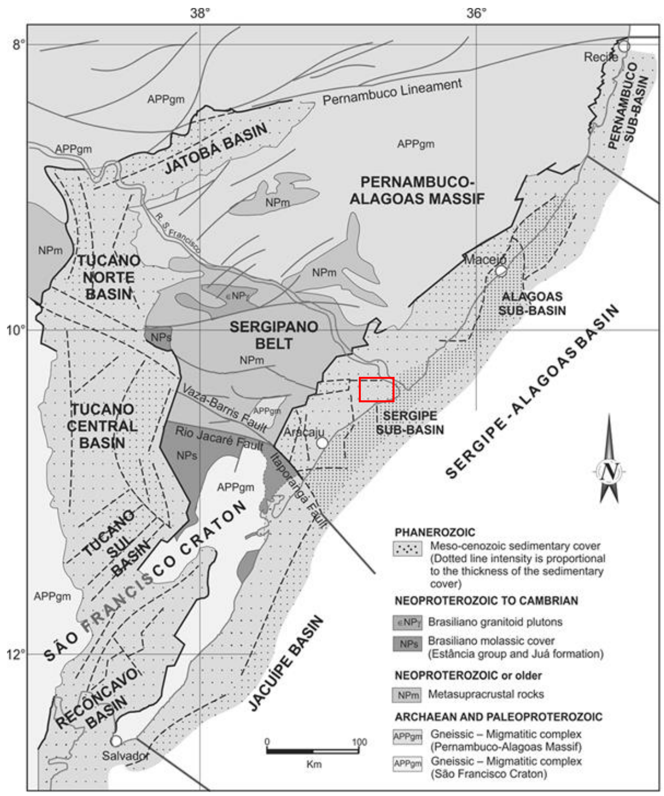

Figure 1. Geological Map of regional Basin Sergipe-Alagoas (modified from Lana, 1990). Red rectangle indicate the studied area.

Gravity dataset

The gravity data herein interpreted is a subset (Figure 2), comprising the Sergipe-Alagoas basin, of the onshore Debardenest dataset made available by Brazilian Petroleum Agency (ANP). Debardenest dataset assembles gravity data of several coastal surveys collected by Petrobras in the sedimentary basins of the northeast Brazilian margin. Data were collected with two different site spacing (see Figure 2): regular grids with 500 m spacing and irregularly spaced sites along available roads. ANP provided a processed database in ASCII format. The database has five main channels for each gravity station: latitude, longitude, bathymetry, free-air anomaly, and Bouguer anomaly (calculated with a 2.2g/cm^3 density correction).

Figure 3 shows the Bouguer gravity anomaly map gridded at 350 x 350 m cells. The Bouguer anomalies have a remarkable correlation with the structural knowledge of Sergipe Basin. Well-known geological features like Japaratuba and Ilha das Flores lows show negative anomalies (Figure 3); while Alagamar High shows a positive Bouguer anomaly.

Fault Mapping and Discussions

Usually, potential-fields fault and structural interpretations are conducted semiquantitatively by processing methods applied to gridded data (Lourenço et al. 2014). Quantitative methods are also available (e.g. Barbosa et al., 2007, Adriano et al. 2014), but as it deals with inversion procedures, they may not give quick responses as the gridding techniques.

In the present paper, we apply a multiscale edge detection method, often assigned as worming (Hornby et al., 1999), to the Bouguer anomaly map (Figure 3).

The whole process contains several control parameters that the interpreter must adjust before running the routine. We used 16 upward continuation levels from 100 up to 9000 m. At each level, we calculated the first vertical derivative as any cross-cutting worms tend to be better solved (Boschetti, 2005). We specified a maximum scanning distance of 5000 m between edge points, and a minimum of 15 consecutive points as necessary to create a worm employing the Canny's(1986) approach. This procedure minimizes the effect of creating worms around the boundaries of the input grid (Lourenço et al., 2014).

The worming method has a quite simple theory. It consists of estimating the horizontal gradient of gravimetric data and picking any found peaks (points of maximum slope) as they correspond approximately to geologic boundaries (Blakely and Simpson, 1986). The gravimetric grid is upward continued to different levels, and the peaks are determined at each level (Holden et al., 2000). Finally, the connected points of the peaks at all continuation levels provide a pseudo-3D plot and a set of shape (vectors) files.

The interpreted worms (solid black lines) are shown in figure 4 superimposed on the Bouguer anomaly grid. Several NE–SW and NW-SE worms (lineaments) were mapped in the study area providing a high-resolution image of the structural framework of Sergipe and Alagoas basins. The known major faults were recovered and also several subtle faults within the Japaratuba Low. In detail scale, the Japaratuba Low shows a complex structural framework that may have influenced the deposition of the source rocks in the basin and can also have played an important role in defining high porosity zones within these rocks. As the next step, we will integrate our results to structural interpretation of 2-D and 3D seismic data at Japaratuba Low the main goal of this upcoming interpretation is the identification of possible sweet-spots in the shale source rocks of the basin.

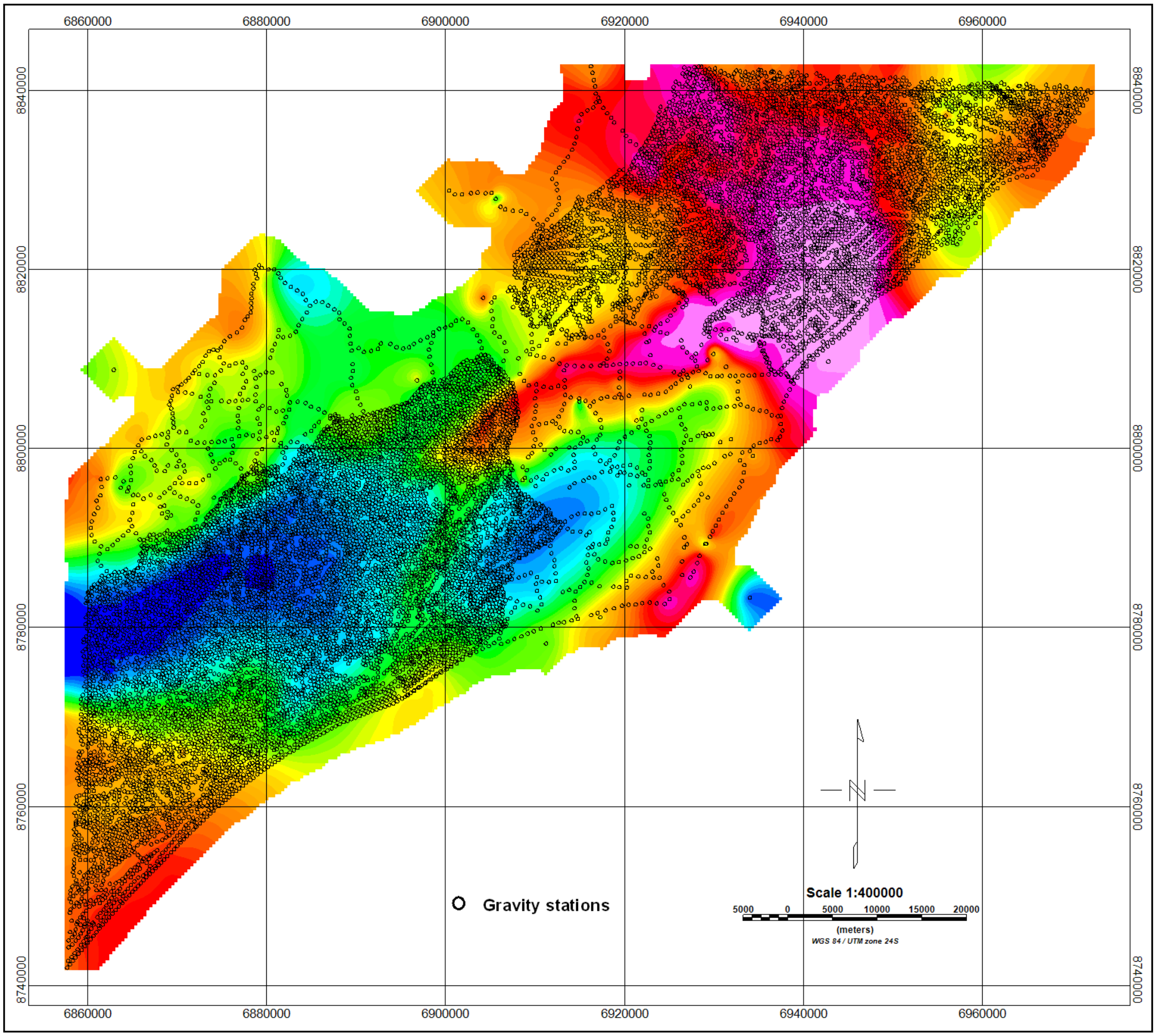

Figure 2. Map showing the distributions of gravity stations used to build the Bouguer anomaly map of Figure 3.

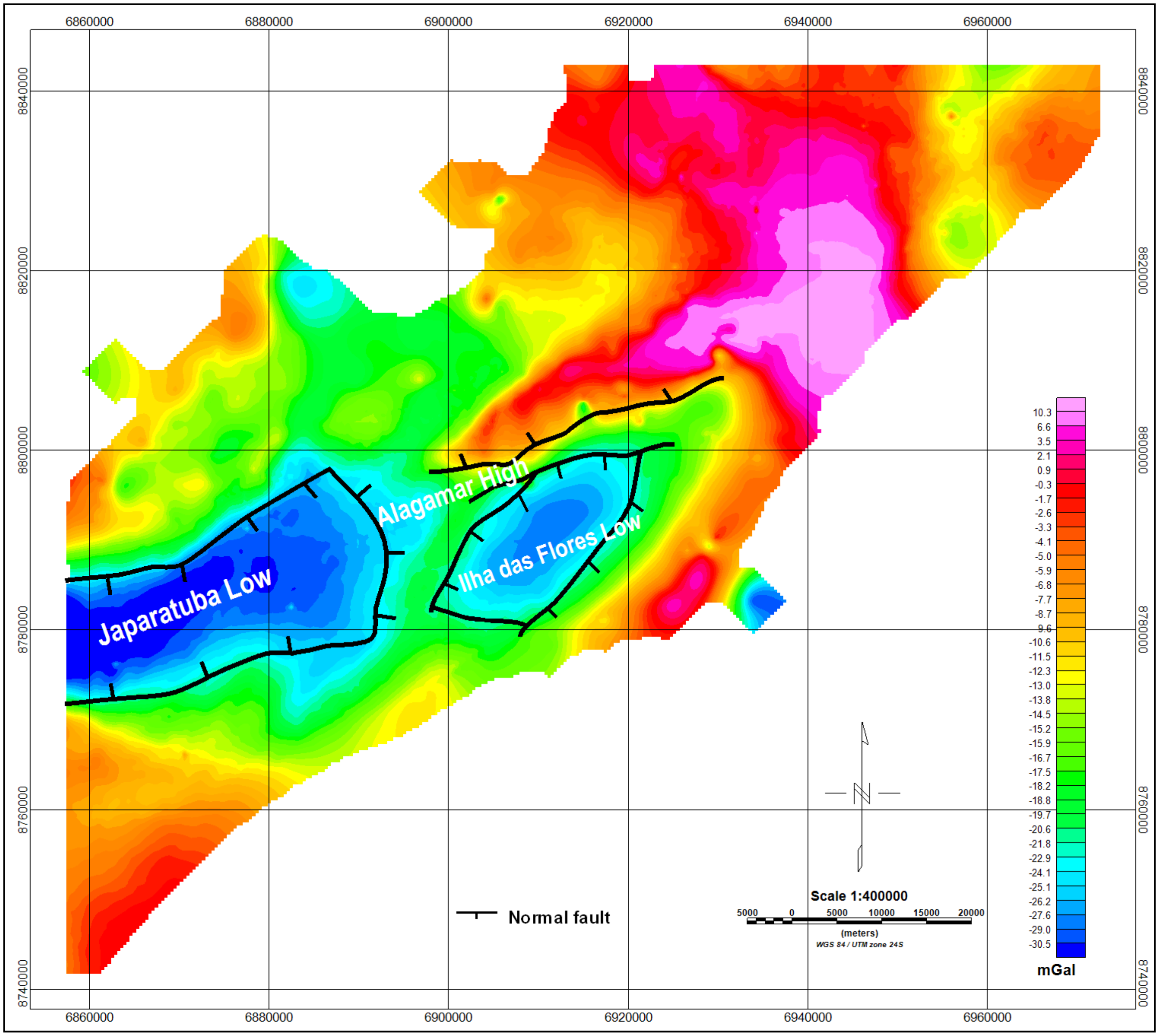

Figure 3. Bouguer anomaly map of Sergipe and Alagoas basin with main geological features: Japaratuba Low, Alagamar High and Ilha das Flores Low.

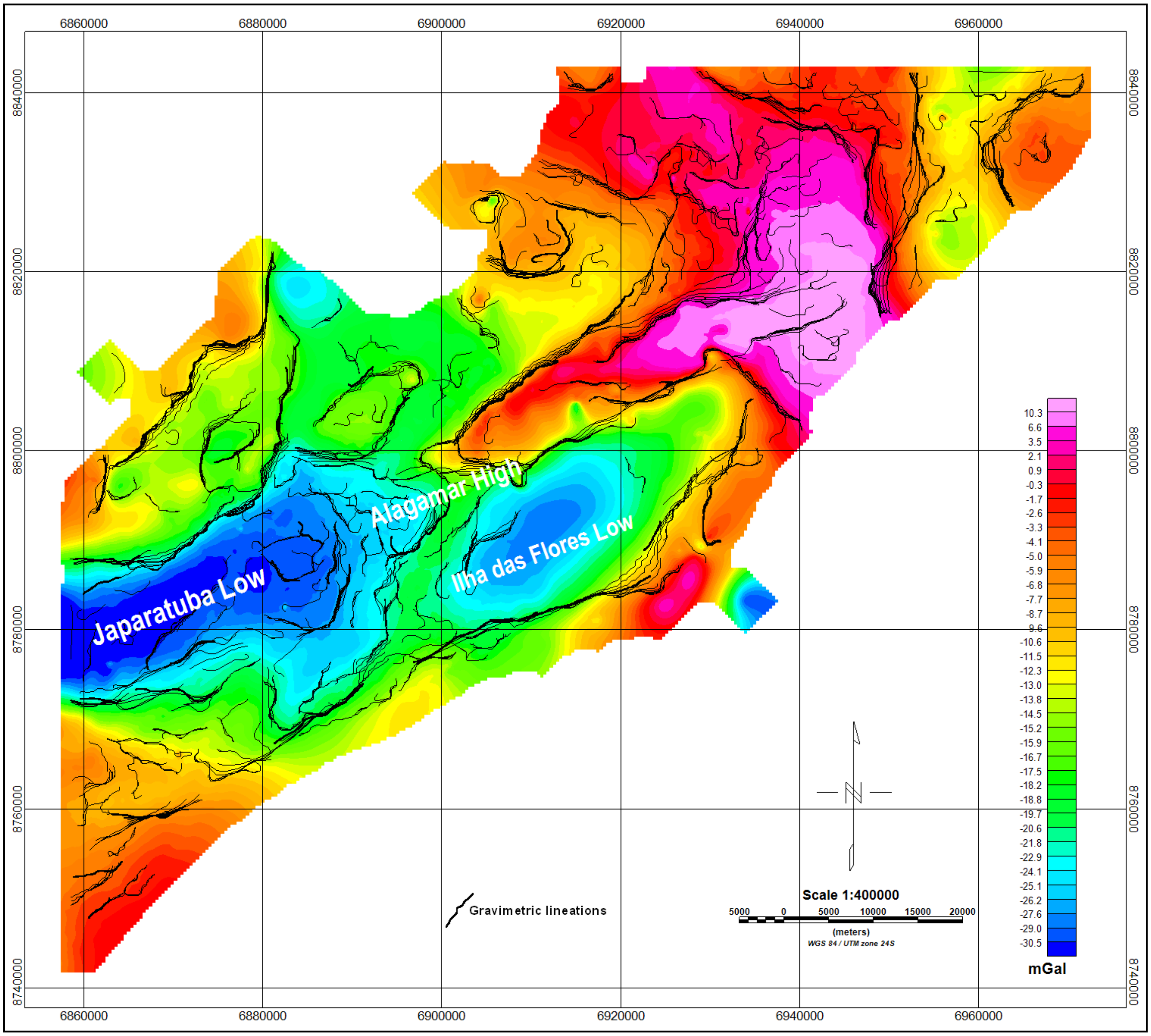

Figura 4. Interpreted Gravimetric lineations (black solid lines) superimposed on Bouguer anomaly map of the study area. Main geological features: Japaratuba Low, Alagamar High and Ilha das Flores Low.

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