Refining Structural Interpretation by Using the Composite Map of the Vertical Derivatives of Aeromagnetic Anomaly Data

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Abstract

The present study implemented aeromagnetic data processing as a complementary tool for improving structural interpretation of the poorly-solved Araripe Basin, northeast Brazil. Here, two Araripe sub-basins were studied. The structural analysis through seismic section, digital elevation model (SRTM), and vertical derivatives of aeromagnetic anomalies maps compared to the previous interpretations demonstrated that the structural trend changes according to the tool analyzed due to its range, and also shows their effectiveness to improve the structural interpretation in the area of study.

Introduction

The Araripe Basin encompasses a near-continuous, 400-1400 m thick, Paleozoic-Early/Middle Cretaceous sedimentary succession mainly controlled by the multi-episodic deformational pulses associated with the break-up of Gondwana and opening of the South Atlantic Ocean (Silva, 1983; Ponte & Ponte-Filho, 1996). Although conventionally interpreted as an interior rift system (e.g. Ponte & Ponte-Filho, 1996; Assine, 2007), the Araripe Basin has its structural framework development poorly constrained due to the dearth and low-quality of subsurface data coverage. Despite recent efforts to use combined aeromagnetometric data to identify the deep-structure of the basin (Camacho *et al*., 2017), structural interpretations are still mostly conditioned to low-quality geophysical data, and field- and remote sensing based geologic mapping.

Since little is known concerning Araripe Basin deep structure, much yet regarding its forming processes and structural framework remains unclear and controversial. Silva (1983) and Miranda *et al*. (2012) argue that the physiographic aspects of Araripe Basin are better explained by the transtensional pull-apart basin model. Another feature of importance lies in understanding the role of intra-basement structure on modulating rift-related normal fault arrays growth. The problems here are: (i) how to refine structural interpretation where subsurface geophysical data are at low resolution or scarce? (ii) In which extent should geological mapping (field-based and remote sensing methods) be used to provide information on basin forming processes and structural framework?

This study aims to examine the applicability of aeromagnetic data processing, i.e. composite of the vertical derivatives, as a tool for refining structural interpretation of sedimentary basins where subsurface data available are limited and/or at poor- quality resolution.

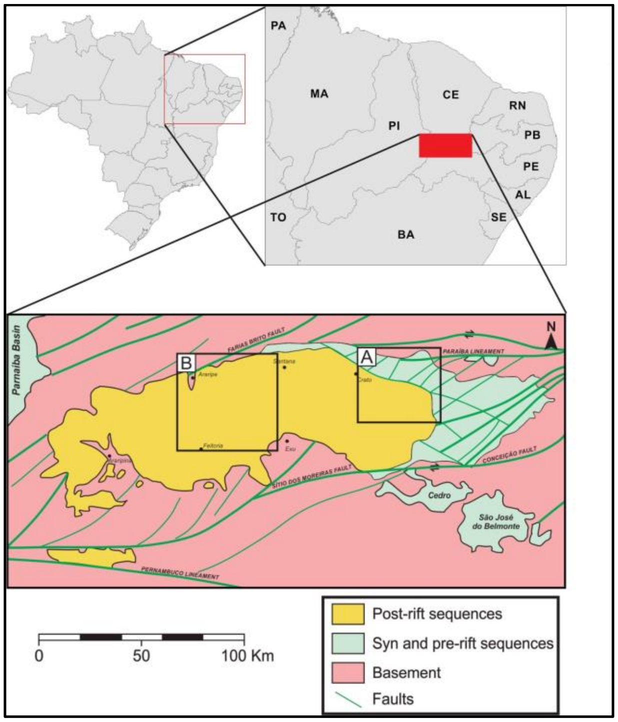

Figure 1 – *Location map of the Araripe Basin in Brazil with indication of the two studied areas of (A) Cariri and (B) Feira Nova sub-basins. (Modified from Ponte & Ponte-Filho, 1996).*

Methods

Aeromagnetic data acquisition and processing

The magnetic data used in this study are publicly available on www.geosb.cprm.gov.br. The data were collected using cesium vapour magnetometers installed in especially adapted small aircraft, at 10 samples/second rate along N-S oriented lines, spaced 500 m. The average speed of the aircraft was 273 km/h with samples spaced 7.6 m, on average, along the lines. The flying height was 100 m above terrain, whenever possible. Three surveys were reprocessed and merged to fully cover the Araripe Basin (CPRM 2006, 2010a, b). The reprocessing consisted in re-applying the parallax and diurnal variation corrections, International Geomagnetic Field reduction, tie-line levelling, micro leveling and leveling the three surveys to each other, using the procedures described in Reeves (2005). In order to enhance the features of interest, vertical derivatives of 0.75, 1.0 and 1.25 orders were calculated and presented as a ternary composition image (Cooper & Cowan, 2003).

Seismic data acquisition and processing

The source energy used in the seismic acquisition was explosive charges. The 36 geophones were positioned linearly by each station, covering 150 m, the distance between each station was 50 m, and presenting 2.400% of fold. The seismic sections were processed, stacked and filtered in Calgary by Seiscom Delta United. Refraction profiles were obtained every two kilometers to the low seismic velocity determination and weathering correction. The datum used for the lines in the valley was 400 m and for the plateau was 850 m. The stacking velocities were determined at each interval of 3 km. The stacked seismic lines present maximum time of seismic signal penetration of 2 s in two-way time and sample interval of 4 ms (Miranda et al., 1986).

Structural analysis

In order to investigate basement control on rift-related normal fault arrays, the geometry and distribution of intra-basement and rift-related lineaments were compared in two distinct locations, Cariri and Feira Nova sub-basins (Fig. 1). The Composite map displaying the vertical derivatives of magnetic data has been used to interpret the geometry and distribution of intra-basement lineaments of Cariri and Feira Nova sub-basins.

Cariri Sub-Basin

Rift-related structures were interpreted based on the seismic reflection profile of a 2-D seismic line RL-0141-0007 modified from Miranda *et al*. (1986) and from a digital elevation model (SRTM) maps (Figures 2 and 3 respectively).

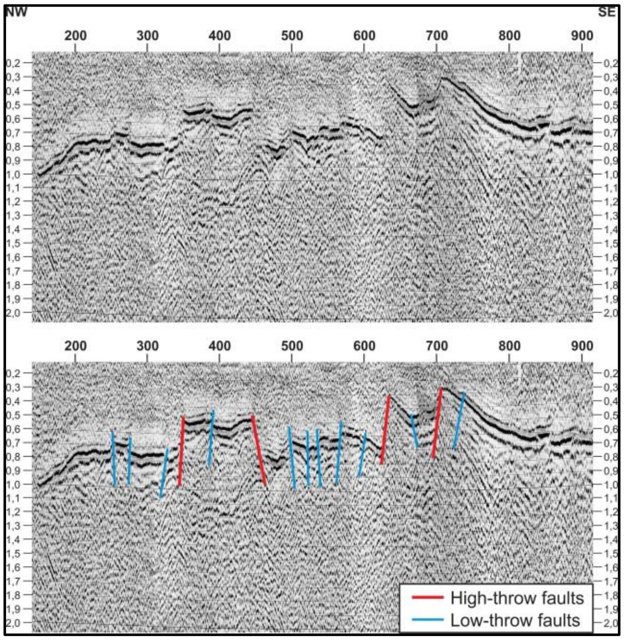

Figure 2 – *NW-SE seismic reflection profile of a 2-D seismic line (Araripe-RL-0141-0007, see Fig. 3 for location) that crosses the Cariri sub-basin. Interpretation of seismic line illustrates the occurrence of two fault populations, represented by high- (red) and low-throw (light blue) faults. Modified from Miranda et al. (1986).*

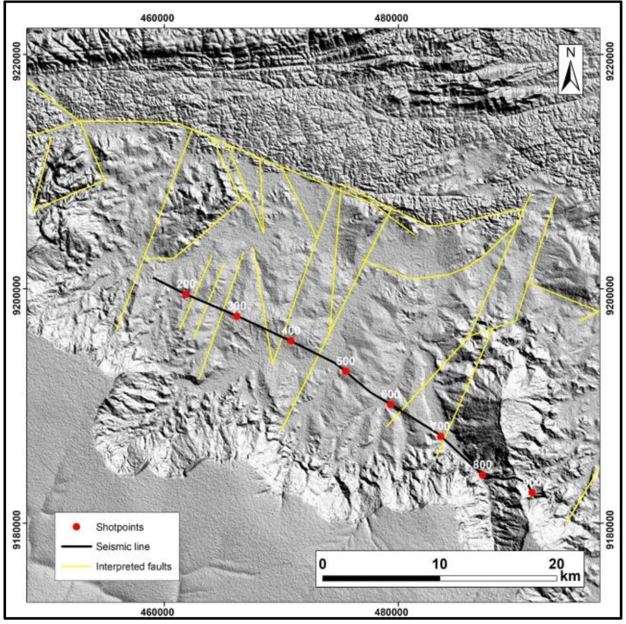

Figure 3 – *Digital elevation model of the Cariri sub-basin (SRTM) showing interpreted faults (yellow) and the location of a 2-D seismic line (Araripe-RL-0141-0007 seismic line).*

Feira Nova Sub-Basin

Data on rift-related structures compiled from Ponte & Ponte-Filho (1996), who interpreted faults based on both field- and remote sensing analyses.

Results

Structural interpretation of a seismic reflection profile superimposed with the composite aeromagnetic and digital elevation SRTM maps from Cariri sub-basin demonstrates that:

(i) The composite map of the vertical derivatives of aeromagnetic anomaly data highlighted the NE-SW trending basement structures underneath sedimentary layers, as previously documented by Ponte and Ponte-Filho (1996), (Red and blue lines in Figure 4).

(ii) SRTM-defined faults have different directions when compared to structures mapped with the other methods. (Yellow lines in Figure 4)

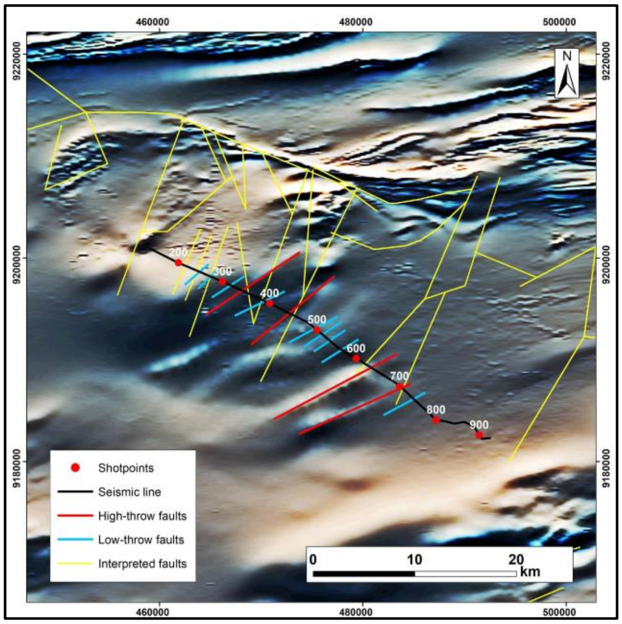

Figure 4 – *Composite map of the vertical derivatives of aeromagnetic anomaly data superimposed by rift-related structures interpreted from 2-D seismic reflection profile (faults are traced in red and blue, see Fig. 2) and digital elevation model, SRTM (lineaments are traced in yellow, see Fig. 3). Cariri sub-basin**.***

The seismic lines 141-RL-09 and 141-RL-10 along the Feira Nova sub-basin have limited usefulness for structural characterization due to the sub-basin location and dearth of data. By comparing the composite aeromagnetic anomaly map with the structural data interpreted by Ponte & Ponte-Filho (1996), it is possible to observe that the lineaments interpreted by the authors are better defined by using magnetometric data as presented in Figure 5.

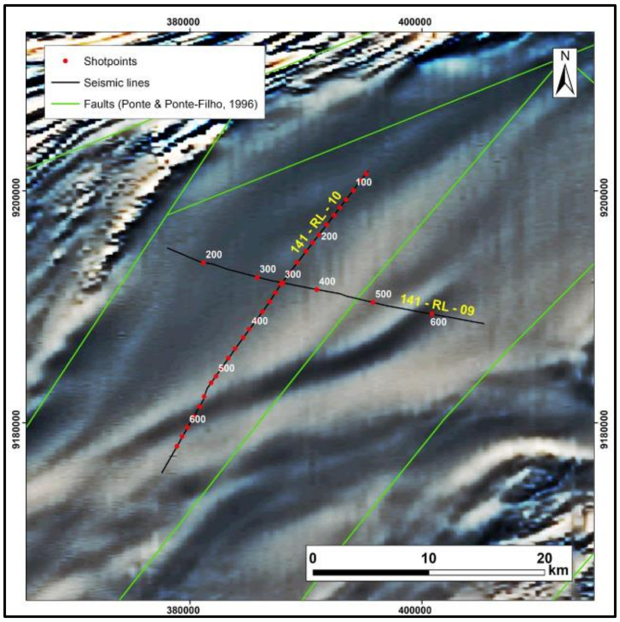

Figure 5 – *Feira Nova sub-basin. Composite map of the vertical aeromagnetic anomaly data superimposed by 141-RL-09 and 10 seismic lines and the faults proposed by Ponte & Ponte-Filho (1996). The remote sensing interpretation of the authors fails to identify major and minor structures, leading to incorrect delineation of the blocks due to the surface dependence of the analysis.*

Conclusion

The present study combined data from literature with structural interpretation of digital elevation model (SRTM) and composite aeromagnetic maps from Cariri and Feira Nova sub-basins. Some key observations of what came out from this work are highlighted as follows:

(1) The composite map of the vertical derivatives of aeromagnetic anomaly data has significantly improved the imaging of the Araripe Basin deep-structure. Such map not only improved but also added new information to the visualization of the geometry and distribution of basement structures underneath sedimentary layers. Such aeromagnetic data processing method has therefore proven to represent a powerful tool for refining structural interpretation of sedimentary basins where subsurface geophysical data are scarce or of poor resolution.

(2) The structural framework of the Araripe Basin has been conventionally interpreted by means of poor resolution quality seismic and gravimetric data of limited spatial coverage, as well as by field-based and remote sensing geological mapping. In most cases, surface interpreted rift-related faults (i.e. field-based and remote sensing mapped) were interpreted as basement-inherited structures. Rift-related surface faults compiled from literature and also the ones interpreted from digital elevation maps, however, display different orientation (~ 30º) in relation to the basement structures interpreted on the composite aeromagnetic map. The latter suggests that the

association between rift-related normal fault arrays and basement structures may not be as straightforward as previously established.

(3) At last, the higher-resolution visualization provided by the processed aeromagnetic map also indicates that differential subsidence between blocks and depocenters was more prominent/pervasive than previously thought in the Araripe Basin. It implies that further studies should be addressed to better constrain structural segmentation within structural domains (i.e. sub-basins, grabens and horsts etc.). The latter would not only bring information on how basin physiography controlled sedimentary depositional systems, but would also elucidate the preferential routes in which sediment were dispersed and grain size partitioning trends on both space and time.

Acknowledgments

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