Magneto-Structural Imaging (MSI) and Regional Basement of the Santos Basin, Brazil.

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Abstract

In this paper we present the results of the integration of the various High Resolution Airborne Magnetic (HRAM) surveys that have been conducted by FUGRO-Lasa-Geomag in the Santos Basin since 1998. These surveys greatly differ from the old airborne and marine magnetic data that were acquired in the Santos Basin in the past. The high spatial resolution and high accuracy in the measurements of the amplitude and positioning of the magnetic anomalies characterize the present data. We present a variety of maps obtained through the use of Fourier filtering techniques and discuss their value to the magneto-structural imaging and the magnetic interpretation of the Santos Basin. We also present the depth-to-basement estimates that we obtained using the Multiple Source Werner Deconvolution technique to access quantitatively the structural framework of the Santos Basin.

Introduction

The Santos Basin is the largest petroleum province among the offshore Brazilian sedimentary basins. Since 1998 the airborne geophysical companies GEOMAG and LASA, which are now part of the FUGRO AIRBORNE SURVEYS group, have been collecting HRAM data in the Santos Basin. This basin is now almost entirely covered with HRAM data from the coastline to its deep-water limits (Figure 1). The total coverage includes approximately 0.5 million line-kilometers of flight lines flown at 150 meters constant altitude. The survey grid is 0.5 km x 2.5 km in the shallow water regions and 1.0 x 5.0 in the deep-water areas of the basin. The sampling of the magnetic field is 7 meters along the flight lines and the navigation with Differential GPS allows an accuracy of about 5 meters in the positioning of the measurements. The measurement of the magnetic field was carried out with cesium vapor magnetometers having a sensitivity of 0.001 nT. With filtering applied during the data processing phase, the mapped magnetic anomalies show an accuracy better then 0.1 nT and a spatial resolution in the range 125-250 meters (half- wavelength).

Magneto-Structural Imaging

Fourier filtering techniques have been applied over the Total Magnetic Intensity (TMI) data to produce a variety of maps where individual anomaly attributes are emphasized. Examples of these attributes are: the maximum total horizontal gradients that are related to the edge of the magnetic structures; the analytical signal that facilitates the identification of provinces characterized by differing degrees of magnetism; the phase of the analytical signal that balances the amplitude response of faults, fractures and lineations, producing a map rich of structural features. The magneto-structural imaging (MSI) obtained through the mapping of the phase of the analytical signal (Figure 2) reveals objectively a wealth of geologic structures of both detailed and regional scales devoid of any pre-judgement of an interpreter. The MSI of the Santos Basin shows the precise location of the hinge line with its various segments offset by transfer faults. In the Northeastern portion of the basin the edges of major normal faults with strikes NE-SW are very well imaged together with the associated lows and highs of the magnetic basement. Within this portion of the basin, a large magnetic province extending seaward from the hinge line shows a good correlation with the spatial distribution of diabase sills sampled in the exploratory wells. All these features shown together build the most comprehensive structural framework of the Santos Basin.

Regional Basement

A previous interpretation work carried out over the HRAM data of the first phase of this project (Braga, 2001) used spectral analyses to estimate depths to the magnetic basement (Spector and Grant, 1970; Okubo et al., 1985). The regional map of the basement then obtained has shown that the northeastern portion of the Santos Basin comprises a major sub-basin with the bottom of the rift sedimentary sequence located as deep as 10-12 km. Total sediment isopach was estimated to be as thick as 9-11 km. In this study we estimated depths to magnetic

basement using the Multiple Source Werner Deconvolution method (Hansen and Simmonds, 1993). We applied the Werner technique over the magnetic data selected from a set of regional flight lines aiming to access quantitatively the structural framework of the Santos Basin. The resulting depth-to-basement map (Figure 3) confirmed the geometry of the structural framework of the northeastern portion of the basin and it showed that the southwestern portion also comprises a second major sub-basin. In spite of their similar range of depths-to-basement, the southwestern sub-basin shows an average depth-to-basement approximately 2 km shallower than the average for the northeastern sub-basin. The regional basement high that divides the two sub-basins correlates well with the regional anomalies shown in the central areas of the TMI map of the Santos Basin. The NW-SE strike and the location of these anomalies suggest them to be the signatures of a major transfer zone. Typical depth-to-basement values in this zone are in the range 5 to 6 km seawards from the hinge line. The extension of this transfer zone northwestwards coincides with the northern limits of the Ponta Grossa Arch. In fact, the Ponta Grossa Arch hosting an extensive set of NW-SE dikes seems to be integral part of the tectonic history that built the present structural framework of the Southeastern Santos sub-basin. The southern border of this sub-basin is also well marked in the TMI map by a dominantly positive regional magnetic anomaly that inflects eastward from NE. This border of the basin known as the Florianópolis High shows steep gradients in the basement topography and shallow locations seawards from the hinge line at depths in the range 2 to 3 km.

Summary and Conclusions

Many oil companies are now using the present non-exclusive HRAM data available in the Santos Basin as part of their exploration studies. Among the various geological application of these data in the Brazilian basins we may highlight: mapping of the basement topography and corresponding location of the oil kitchens and favorable oil migration pathways, definition of the structural framework and location of its associated faults, mapping of depths and spatial distribution of mafic intrusions, basalt and diabase sills, identification of intra-sedimentary structures, identification of mini-basins originated by salt tectonics, and studies of the regional thermal gradients by means of the estimates of the depths to the Curie Surface. Modeling of subsurface structures integrating gravity, magnetic, seismic and well data has shown to be one of the most effective means to reduce ambiguity and uncertainties that usually affect the subsurface imaging and the knowledge of the nature of the imaged structures. The MSI (Magneto-Structural Imaging) tools and techniques that we applied over the HRAM data of the Santos Basin resulted in a set of maps where the structural framework of the basin can be visualized, for the first time, as a unique geological entity in the presence of all its individual structural components, i.e., petrofabric of the basement, hinge line segments, transfer zones, faults, dikes, grabens and horsts, volcanic provinces, depocenters, regional basement highs, etc. The MSI of the Santos Basin, obtained through the use of the available HRAM data, combined with our estimates of the depths to the regional basement , brings a set of new information very valuable to a better understanding of the tectonic evolution and structural framework of the Santos Basin, and may contribute to other studies on hydrocarbon formation, migration and accumulation in that basin.

References

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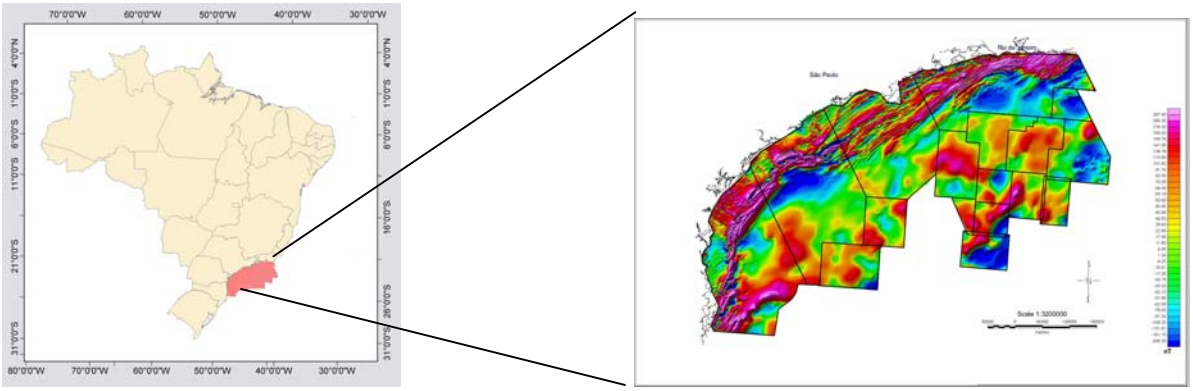

Figure 1: HRAM data window location and TMI color map.

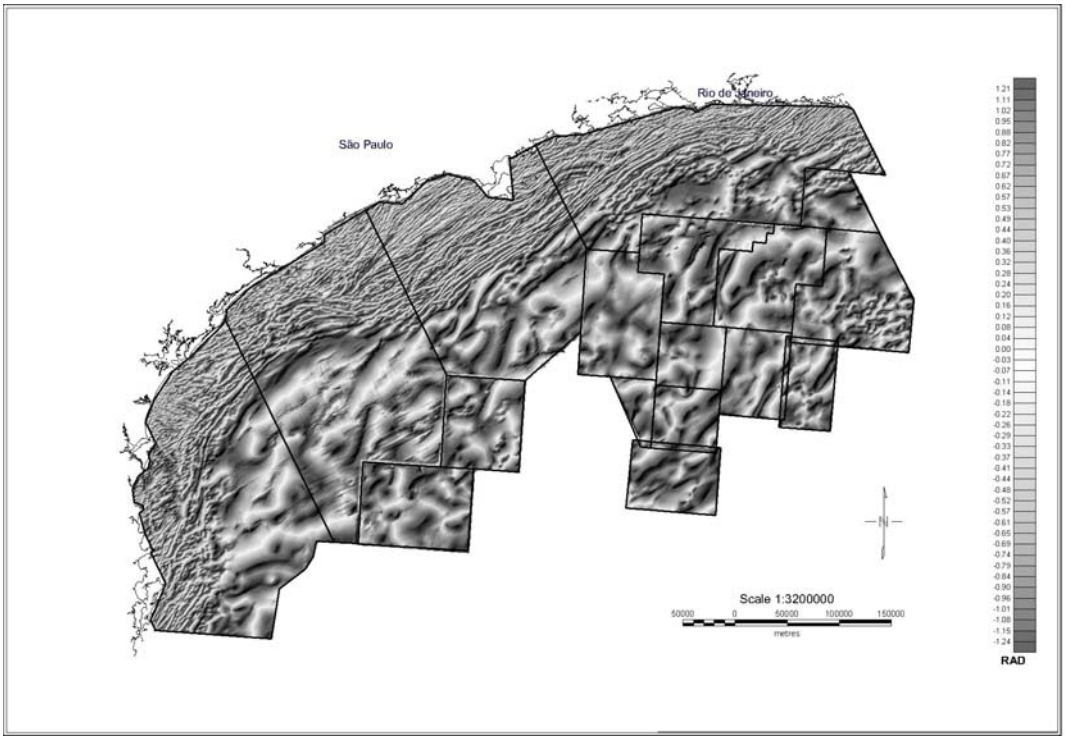

Figure 2: MSI of the Santos Basin – Phase of the Analytical Signal of the TMI

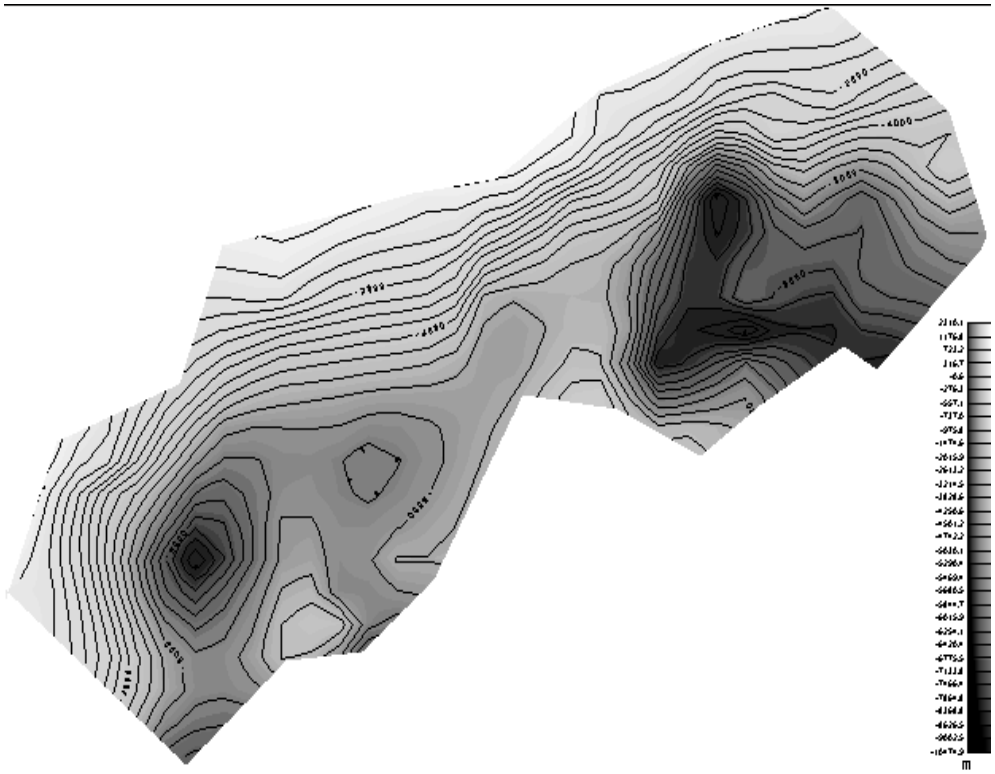

Figure 3: Santos Basin – Map of the Regional Basement (preliminary results) estimated using the HRAM data