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Magnetic Framework of the Borborema Province, Northeast Brazil: an interpretation from digital data

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ABSTRACT

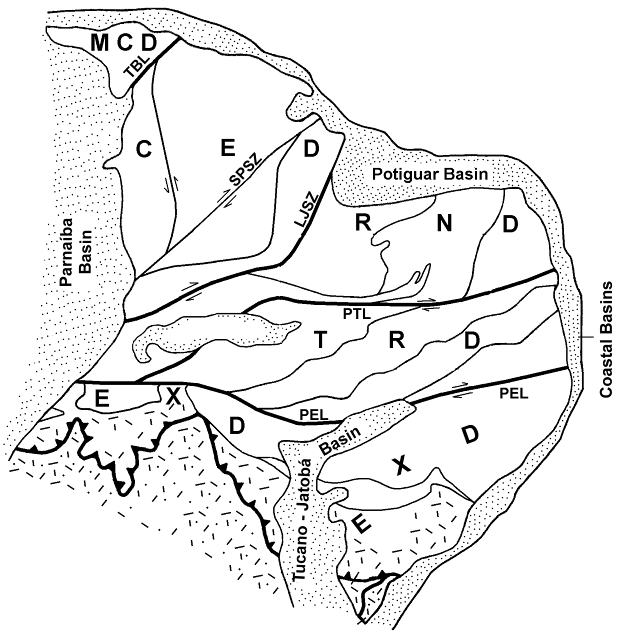
A total field anomaly - magnetic grid, available by South American Magnetic Mapping Project, was filtered in the Fourier Domain to separate shallow and deep crustal magnetic sources. The colorful - shaded maps were correlated with known geological data of the Borborema Province, Northeast Brazil. This correlation demonstrates that several shear zones, lithologic boundary and tectonostratigraphic terrane have strong affinity with magnetic patterns and lineaments. As a result of this integrate study a consistent magnetic framework of the Borborema Province was constructed, as a help to terrane analysis and metallogenic researches.

INTRODUCTION

Interpretation of regional magnetic - anomaly map can be an useful tool for new information about rock units and reveal shallow and deep structures, as well as, supply regional geologists with 3-dimensional shape of the bodies and tectonic compartments. Borborema Province has a very complex history, but up to now, few geophysical data have been used for geological - regional research. This work is an attempt to correlate magnetic - anomaly map with known geological data, to help in the construction of a very consistent geotectonic model.

GEOLOGICAL CONTEXT

The Borborema Province (Figure 1) is a Proterozoic fold belt spread between the São Luis - West Africa and São Francisco - Congo/Kasai cratons. Currently, after a geochronologic data increase (Van Schmus *et al*., 1995; Brito Neves *et al*., 1995), there is growing evidence that its evolution has occurred by a mechanism of terrane collage (Santos *et al*., 1999). This evolution model suggests that large crustal pieces were put together during Meso (Cariris Velhos) and Late - Proterozoic (Brasiliano) events, enlarging the crust by the arrival of the small crusts or by adding a new crust.



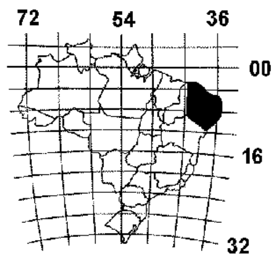


Figure 1 Sketch of the tectonostratigraphic domains and their boundaries in the Borborema Province. Domains: MCD-Médio Coreaú (NW Ceará); CED-Cearense (Central Ceará); RND-Rio Grande do Norte (Seridó); TRD-Transverse (Transversal Zone); EXD-External. Boundaries: TBL-Transbrasiliano Lineament; SPSZ-Senador Pompeu Shear Zone; LJSZ-Limoeiro-Jaguaribe Shear Zone; PTL-Patos Lineament; PEL-Pernambuco Lineament. CSF: São Francisco Craton (Santos *et al*., 1999)

The major tectonic features in the Borborema Province are long dextral shear zones (Figure 1). Those shear zones were corridors in the amalgamation and dispersion processes occurred during the late stage of the Brasiliano event. The

Patos lineament represent a first order boundary confirmed by geochronologic and geophysical data, separating two major crustal segments (Santos *et al*., 1999): a) the northern one composed largely by Archean-Paleoproterozoic reworked basement terranes, comprising three main tectonostratigrafic domains: the Médio Coreaú domain, an counterpart of the Trans-Sahaarian belt; the Cearense domain, a complex Neoproterozoic thrust-and-fold belt overthrusting Archean to Early Proterozoic terranes; and the Rio Grande do Norte domain, characterized by a Brasiliano belt, implanted over Archean-Early Proterozoic terranes; and b) the southern one composed mainly by Meso-Neoproterozoic meta-vulcanosedimentary terranes accreted to adjacent northern edge of the São Francisco craton. In this segment, separated by the Pernambuco lineament, Transverse and External domains are recognized. The Transverse domain is composed of Cariris Velhos complexes forming terranes and the External domain represents the near-marginal belt, including the Riacho do Pontal and Sergipano thrust-and-fold belts.

MAGNETIC DATA

The total field magnetic-anomaly map of the Borborema Province (Figure 2) consists in a piece of the digital grid constructed by South American Magnetic Mapping Project (SAMMP). This project resulted from the collaboration between GETECH and PGW, which produced a unified digital grid of available aeromagnetic and marine magnetic data for South America and its continental margins. In the Borborema Province and marginal basins, nearly 26 individual surveys conducted by CPRM, DNPM, NUCLEBRAS, CNEN and PETROBRAS, were used to construct the magnetic-anomaly map by SAMMP. The reader is referred to GETECH & PGW (1996) for detailed description of the technics and challenge required to solving scientific problems relating to integrating various individual surveys.

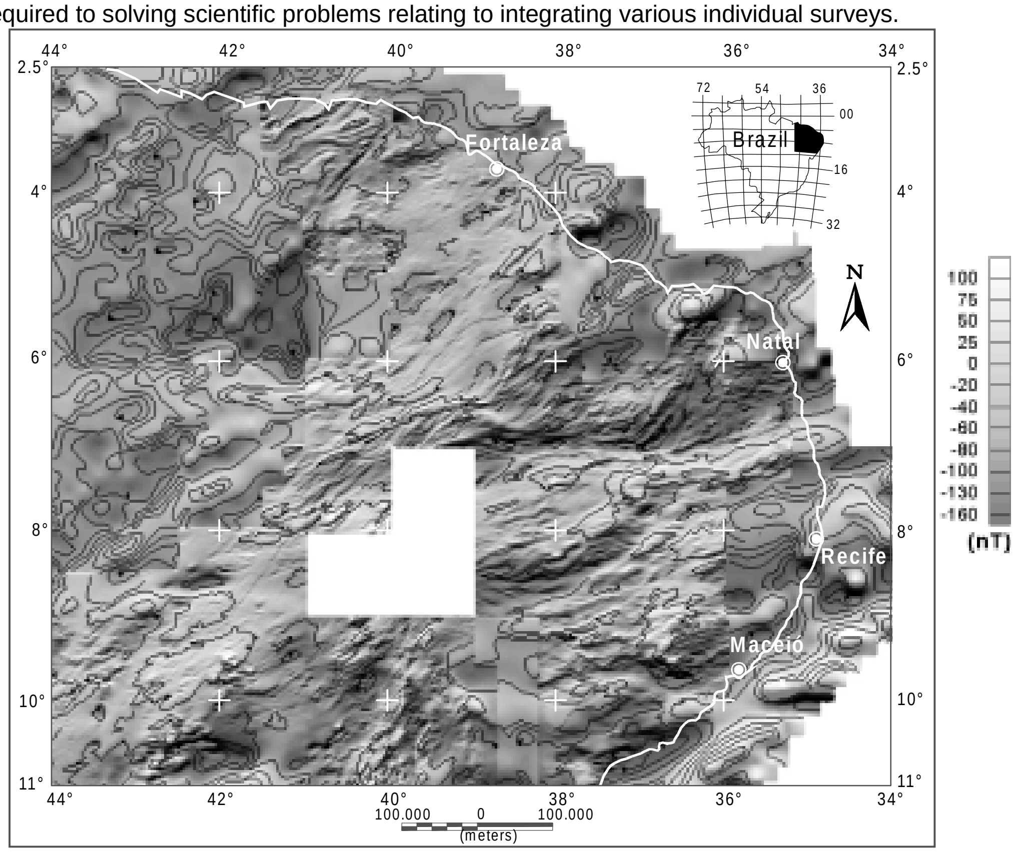


Figure 2 - Grayscale - shaded image of the total field magnetic-anomaly grid available by SAMMP. Shading was performed at an illumination azimuth of 0^0 and an elevation angle of 45^0.

Digital grid available by SAMMP, with 1km interval and 1 km terrain clearance, was obtained in various steps of a processing sequence (GETECH & PGW, 1996): compilation and digitalising of the various surveys; digital data set construction; filtering to avoid alias ambiguity; bi-direcional or minimum curvature gridding at 1 km interval; Definitive Geomagnetic Reference Field (DGRF) removal; Fourier Domain Processing; upward continuation at 1 km terrain clearance; linking grids together after the surveys were processed to common specifications; and drape on Magsat/Regional Crustal Field to avoid long wavelength distortion in the adjusting survey process.

MAGNETIC DATA RE-PROCESSING AND FILTERING

This processing was performed by MAGMAP System (Oasis montaj, version 4.1c, GEOSOFT 1996), which execute 2-dimensional filtering in the Fourier Domain. The operation, a well know approach to filtering gridded magnetic data, was executed in three steps:

a) Pre-processing - a trend was removed from the data, afterwards the grid was expanded to be square by a 2-dimensional maximum entropy technique and the dummy areas were replaced by reasonable interpolated values. Finally, the square and periodic grid was transformed to wavenumber domain by the application of a Winograd Fast Fourier Transform.
b) Filter Application - the primary step was to produce a radially averaged energy spectrum (power spectrum). The observation of this spectrum (Figure 3) demonstrates that it can be separated in two differents components. Shallow sources with wavenumber greater that 0.04 cycles/km, and fonts tops with depth minor that 10 km; and deep sources with wavenumber minor that 0.04 cycles/km and fonts tops with depth in the range 10 - 30 km.

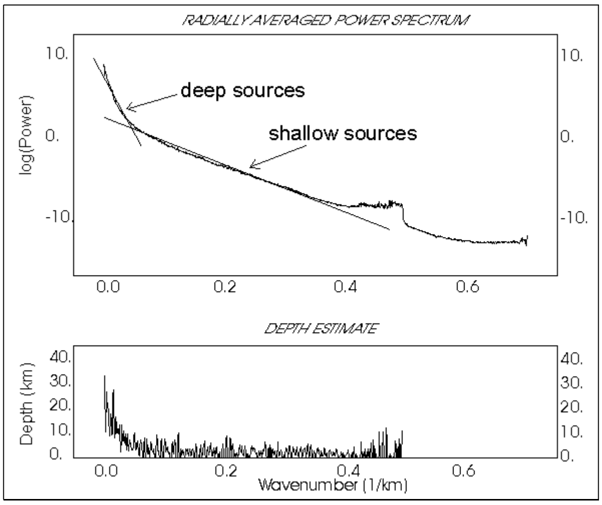


Figure 3 - Radially averaged energy spectrum of the anomaly-magnetic grid available by SAMMP.

Gaussian Filter - this is a smooth filter often used for low-pass and high-pass applications. The mathematical operator has the following expression:

$$L(r) = 1 - e^{-\left(\frac{r}{r_0}\right)^2} \text{..............................(1),}$$

where r_0 = 0.04 cycles/km is the standard deviation of the gaussian function.
The regional options, which passed frequencies below 0.04cycle/km, was performed for emphasize deep-seated, long wavelength magnetic sources within the crust. The residual options, which passed frequencies above 0.04 cycles/km, emphasize magnetic sources at or near the surface.
3D - Analytical Signal - this processing was performed with the objective of associate the magnetic-anomalies directly to underlying rocks. It avoids the complexity provided in original data and makes easy the magnetic-anomaly/geology correlation. This technique performed by MacLeod *et al*. (1993) is very useful in low latitudes regions, and avoids the noise problems introduced by reduction to the pole processing.
c) Post-processing - grid was transformed back to the space domain; dummy areas of the original grid were masked.
All magnetic-anomaly maps were artificially illuminated at azimuth of 0^0 and an elevation angle of 45^0 , to create a 3-dimensional shaded-relief maps and enhance preferential trends.

MAGNETIC-ANOMALY/GEOLOGY CORRELATION

The interpretation and data correlation were implemented by inspections of the geological units, terranes boundaries and magnetic maps. In the last, were emphasized magnetic patterns, boundaries of magnetic units and structures bounding affecting magnetic units. The comparison between regional (deep-seated anomalies) and residual (shallow-seated anomalies) was useful in the understanding of the 3-dimensional magnetic body shapes.
The most obvious features are the correlation between magnetic lineaments and shear zones (Figures 1 and 4). Shear zones are very important terrane boundaries, and in some cases are associated with gravity dipole anomalies, interpreted as due to abrupt changes in mean upper crustal density. The magnetic data show that Senador Pompeu and Transbrasiliano shear zones continues for a long distance under the sedimentary pile of the Parnaíba basin. The southeast Piauí magnetic lineament is a reflex of a concealed shear zone by sedimentary cover. These three faults are marked by an Eocambrian extensional regime. The resultant pull-apart rifts were filled up by a thick non-magnetic sedimentary pile. The Patos lineament is characterized by strong east-west magnetic alignment and steep gravity gradient. It has an important geochronologic and tectonic key in the Borborema Province evolution.
The tectonostratigraphic domains are terranes mosaic put together by shear zone mechanism. The Médio Coreaú and Cearense domains are characterized by a magnetic pattern dominated by linear and shallow-seated anomalous bodies. In the Cearense one, in addition to dominant pattern, there are non-magnetic supracrustais belts and highly granitized crusts. The Rio Grande do Norte domain is a more tectonically complex region. It has northeast-trending magnetic boundary that separates belts with sharp change in the magnetic property. Linear magnetic patterns are interlayed with non-magnetic and highly granitized terranes, deep-seated magnetic body and Archean-Paleoproterozoic crustal fragments.The Transverse domain also has northeast-trending boundaries, but the magnetic patterns are dominated by non-magnetic supracrustais and granites, with the exception of A-type magnetic granites and a narrow belt of Paleoproterozoic highly magnetic crust. The External domain has an east to southeast-trending boundaries between non-magnetic granitized crust and lens shaped of Archean highly magnetic crust. The limit between this domain and the basement craton is defined by an arched, wide and steep gradient gravity dipole, which has a typical collisional feature.

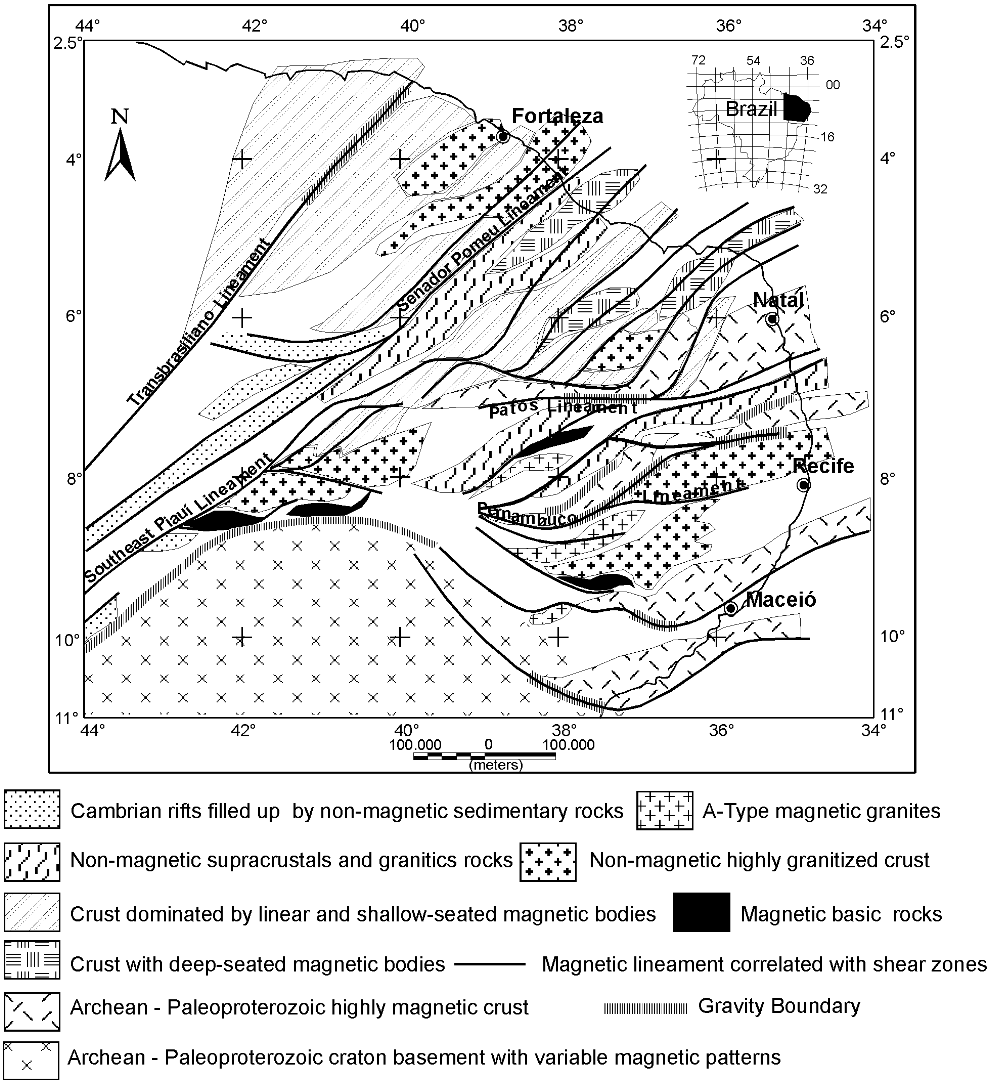


Figure 4 - Magnetic framework of the Borborema Province constructed from magnetic-anomaly/geology correlation.

CONCLUSIONS

Application of regional magnetic data to the regional framework of the Borborema Province, demonstrate to be a useful tool in the study of tectonic compartments and composition of the Precambrian crust. The magnetic patterns and alignments present a good correlation with known tectonostratigraphic terranes and faults boundaires. Moreover, it's possible to localise unknown terranes and shear zones. Consequently, the magnetic framework provide several clues that can be used to assist the outlining of a consistent tectonic model for the Borborema Province.

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