# Onshore-offshore prolongation of structures between Campos and Santos Basins from aeromagnetic data

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**Abstract (Font: Arial Bold, 9)**

Tectono-structural studies have showed the high spatial variability observed along other passive margins, with the occurrence of laterally distinct rift structures ,that seem to be related to (or to reflect) the different evolutionary stages of rifting through time and differential amount of magma addition. The region between Santos and Campos Basins exhibits distinctive magnetic character, with short and long wavelength anomalies revealing potential magmatic sources at or close to the surface and at depth. The onshore-offshore continuation of the magnetic lineaments and the observed geometrical relationship between the magnetic data and the continental structures suggest that the source of the offshore anomalies is probably related to the magmatism the resulted in the onshore dykes. We propose that the more superficial features like dykes and their correlated lineaments are linked at depth with intra or subcrustal magmatic bodies. The accommodation of de deformation by a combination of dyking / faulting could resulted in a positive feedback between deformation and magmatism.

## Introduction

To investigate the tectonic evolution of a continental margin it is necessary to understand the correlation between continental and oceanic features, since most of its formation process, from extension to break up, involves the preexisting basemen (Tommasi et al., 2001; Manatschal et al., 2013)

The Southeastern Brazilian Margin exhibits a structural configuration that reflects its tectonic evolution during Mesozoic breakup of Gondwana supercontinent. The offshore structures are mainly NE-SW oriented, subparallel to the adjacent basement (The Ribeira Belt) framework orientation. Exceptionally along some marginal segments the expected pattern of basement-parallel structures is absent and E-W and NW-SE trends are observed. The accomodation of the diferential deformation between adjacent but reologically distinct crustal segments and the proximity to the South Atlantic Fracture Zones (Stanton et al., 2014) have been envisaged to explain the observed structural pattern.

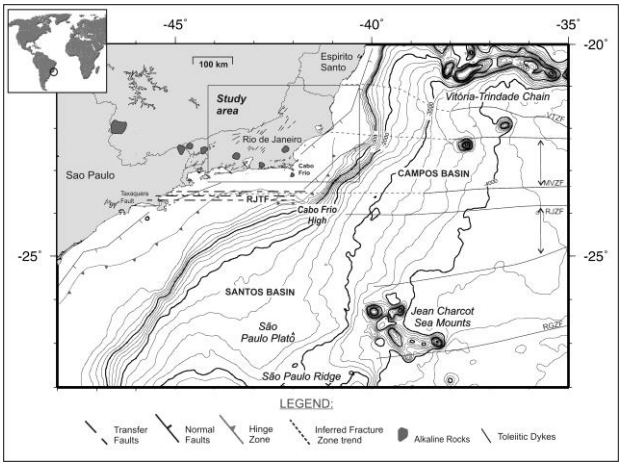


Figure 1- Location map showing the study area and the main regional structures of the margin (Stanton et al. (2010)

At Santos Basin, for example the crustal blocks NE-SW oriented are separated by E-W transfer zones, (Stanton et al., 2014), which are parallel to the flowlines of the plates and orthogonal to the main rifting structural direction. From previous studies of rifted margins it is well established that an intimate relationship exists between preexisting lithospheric weakness zones, the rate and direction of extension, the thermal state of the lithosphere pre and syn-rift and magma availability, to the rifting architecture. Some of these parameters involved in a rifted margin's formation can be accessed by investigating its continental crust; providing valuable information on the initial rift stage, existence of polyphase deformation, magmatism and the final evolution.

In the present work we investigate the crustal architecture through an integration of geophysical and geological data and show evidence of deformation and magmatism during rifting at proximal Santos and Campos basins. A new high resolution aeromagnetic grid, is presented compiled from different aerosurveys which enabled us to map in detail the area between Santos and

Campos basins, highlighting the prolongation of the continental basement structures towards offshore and the interrelation between rifting tectonics and preexisting continental structures during the initial stages of margin formation.

## Method

We combined onshore and offshore aeromagnetic data and onshore structural data for the State of Rio de Janeiro (onshore province) and the offshore proximal southern Campos and northern Santos Basins (Fig. 2).

The offshore aeromagnetic surveys were taken during 2002 by Fugro, the flight height was 150 meters with 1 km of line spacing, with a NW-SE direction. The onshore data corresponds to an old survey acquired by CPRM (Geological Survey of Brazil) in 1978. This latter corresponds to a 150 m height aero survey, with 1 km of line spacing and 10 km control line spacing but with N-S orientation. In order to build a unique final grid, with high resolution, the data treatment consisted of:

(1) The correction for the Regional Field was firstly done by subtracting the IGRF for each survey individually, due to the grids different epochs. The difference between the regional field at different epochs was then subtracted from the unified grid, once the regional filed is decreasing with time, the older survey displayed higher values for the superposed area, which needed to be corrected. When the computed IGRF did not account for complete removal of the total regional field leaving, we calculated a low degree polynomial surface, using the least mean square method (Miranda et al., 1989). We applied transformations on the total magnetic anomaly map in order to enhance the lateral and vertical variations of the crustal magnetic anomalies.

(2) The upward continuation of the total field to 10 km (Fig. 4) provided a deeper view of the crustal magnetic anomalies and the presence of intruded source bodies within or at the base of the crust.

## Results

Regionally the continental structures like main Ribeira Belt shear zones, Mesozoic faults and dyke swarms are represented by short wavelength NE-SW magnetic anomaly lineaments. The terrane boundaries like the Central Tectonic Limit and the Cabo Frio Tectonic Limit (Fig. 2) display negative magnetic signal, with a curvilinear anomaly along the CFTL. These limits do not show a good correlation with the long-wavelength anomalies observed on the upward continuation of the magnetic anomaly field at 10 km altitude. The magnetic signature associated with the Cabo Frio Tectonic Limit on this portion of the continent comprises a high positive anomaly reaching 200 nT at the surface and between 150-170 nT at 5 km depth. This anomaly represents a strong magneto-lithological contrast.

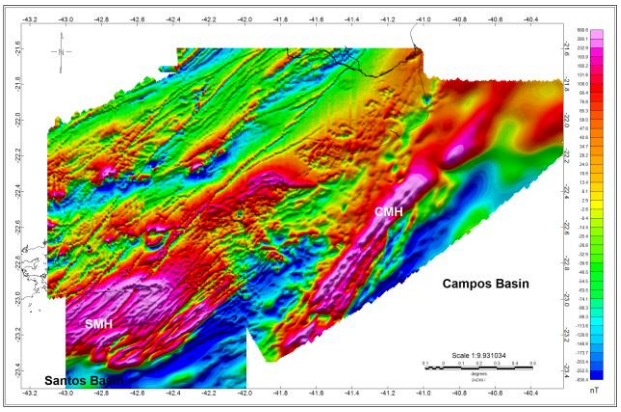


Figure 2- Aeromagnetic anomaly map of the study area. CMH- Campos Magnetic High; SMH- Santos Magnetic High.

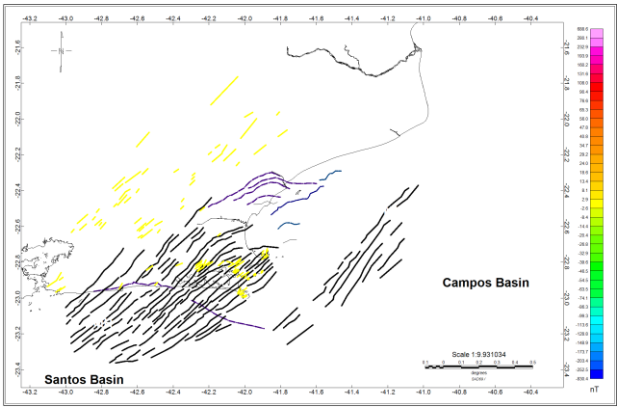


Figure 3- previous map interpreted. Black lines- magnetic lineaments; yellow lines- onshore mapped dykes (Valente et al. 2005). CMH- Campos Magnetic High; SMH- Santos Magnetic High.

Therefore the short-wavelength anomalies onshore likely reflect the upper crust structures, while the latter correspond to deeper crustal structures, represented by thrust faults and major lithologic boundaries. The spatial correlation between magnetic lineament and continental structures is shown in Figure 3. The magnetic lineaments seem to be correlated to rifting-related dikes from the Serra do Mar and Rio de Janeiro dyke swarms (Valente et al., 2007). These structures and their associated anomalies can be observed along the Cabo Frio Tectonic Domain (CFTD) and the Oriental Terrane, though the CFTD exhibits widespread volcanic structures and higher magnetic lineaments density. These terranes exhibit distinct structural characteristics and composition: the CFTD is characterized by NW-SE preexisting basement

structures and allocated NE-SW faults and dykes related to the rifting deformation. This observation rises the question of what is the role of basement reactivation during margin's formation?

The offshore areas at Campos and Santos display long lineaments of short-wavelength (10-30km) and higher amplitude (200-700nT) when compared to the onshore area (Fig. 2), related to superficial sources. A strong magnetic high, 100's kms witdh can be observed at the continental shelf of Santos, which shows a clear connexion with the onshore region, denominated Santos Magnetic High. This important feature shows similarities with the Campos Magnetic High (Stanton et al. 2010) in terms of amplitude and wavelength, though it corresponds to the highest magnetic anomaly of the southeastern Brazilian margin. The rectilinear and relative homogeneity of the lineaments geometry indicates sources closely spaced, probably like tabular bodies, highly magnetized. An impressive feature is the continuous prolongation between the continental and the offshore magnetic lineaments along the continental shelf of Santos Basin. However, the Santos Magnetic High reveals higher amplitude magnetic anomalies, despite the fact that it is located at greater depths.

The close geometric relationship between the magnetic lineaments and the mapped dykes onshore (Fig. 3) suggests that the observed anomalies are probably related to the faulting and magmatism associated to the initial rifting. A correlation with onshore structural data and magnetic profiles (Riguetti et al., 2011) showed that source of the magnetic lineaments are mainly related to subsuperficial structures. Long wavelength magnetic anomalies (Fig. x) show a positive correlation with the lineaments, indicating the existence of deep sources for the superficial anomalies and associated structures.

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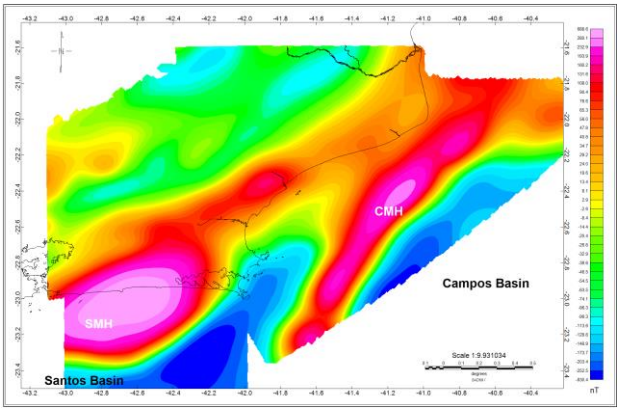


Figure 4- magnetic anomaly field upward continued at 10 km height.

The observed magnetic pattern may be associated with focused extrusion, which could have been facilitated by the lateral variation in crustal rheology represented by the existence of the alloochtonous CFTD. An excess of magmatism and related faulting would result in the formation of the Campos and Santos Magnetic Highs. As superficial magmatic features are likely related to sources at depth, the continental magmatic structures that intruded the crust in response to the Mesozoic extension, are probably linked to deeper source within and/or under the crust.

The results presented here suggest the possibility of mafic crustal additions and/or underplating, as responsible for the strong magnetic anomaly observed

An extension associated with a combination of dyking / faulting in the upper crust facilitates the rifting evolution. According to Corti (2009) and Ebinger (2005) the stress needed to get extensional separation of two lithospheric blocks is largely smaller if magmatism is involved in the process. Magma distribution at depth can control the evolution and structural pattern of transfer zones.

## Conclusions

We describe the magnetic anomalies observed at the onshore region of Rio de Janeiro, between the Santos and Campos basins and along the corresponding offshore area. The magnetic anomaly pattern observed onshore shows a clear continuation towards offshore, with continental magnetic lineaments connecting with offshore anomalies. Short and long wavelength anomalies are present, with high amplitude and are associated with: 1) subsuperficial structures related to the initial rifting of the Gondwana at this portion of the southeastern Brazilian margin; and 2) the longer wavelength anomalies may be atributed to deep seated mafic intrusions. On the continental area, due to their geometry and vertical extension within the crust, curvilinear anomalies may be attributed to a tectonic nappe (*lasca tectonica*) of the CFTD, or the CFTL, which was preserved during the extensional deformation associated with the rifting phase

The extension during the early phase seem to have been accommodated by a combination of dyking / faulting in the upper crust. As exemplified from previous works, the magma distribution at depth can control the structural pattern of transfer zones and thus influence the segmentation pattern of the margin (Corti, 2009).

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