South Atlantic Ridge Segmentation

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Abstract

The morphology of the South Atlantic Ridge is analyzed focusing on its large scale segmentation. Variation of the axial topography was correlated to Mantle Bouguer Anomaly in a way to infer the mantle processes governing the observed morphology. We observed three main topographic domains along the ridge axis, which are approximately around 10ºS, 20ºS and 35ºS. The first and the third domain exhibit shallower and smoother ridge topography, while the central one displays a deeper and segmented morphology. We noticed at least 20 tectonic segments, mainly defined by the continuity of the fracture zones towards the continental margins. Bathymetric and gravity correlation along the ridge axis showed that some segments are inflated with a high in the middle of the segment and lacking rift valley. This seems to be the result of focused and intense magmatism, especially near the Ascension and Tristan da Cunha regions. On the other hand, the central part of the South Atlantic is apparently dominated by a widespread and discontinuous magmatism.

Introduction

The mid-ocean ridge is a dominant feature on the floor of the oceans, extending from more than 70.000 km around the globe. Its morphology is profoundly segmented by a number of discontinuities, hierarchically related to mantle processes (Macdonad *et al*, 1988). The largest scale of segmentation is defined by long-lived tectonic corridors, which bathymetric signatures extend to both continental margins (Batiza, 1996). A smaller scale of segmentation, called first-order (Macdonad *et al*, 1988), are the transform faults, offsetting the mid-ocean ridge axis into smaller segments that may exhibit independent tectono and magmatic histories (Fox *et al*, 1991).

In the last decades many investigations on the morphology of the mid-ocean ridge system were developed, mainly on the North Atlantic Ridge and East Pacific Rise. In contrast, the Southern Mid-Atlantic Ridge (SMAR) remains relatively unknown. Kane and Hayes (1992) identified 8 tectonic corridors, and suggested a local and regional variation in mantle temperature as a possible cause. Some detailed investigations were developed in specific areas such as 7º-11ºS, 26-27ºS and 31-35ºS, based on multibeam data (Carbotte *et al*, 1991; Fox *et al*, 1991; Grindlay *et al* (1991); Weiland *et al*, 1996). Distinct tectonic styles were documented near Ascension at 7ºS (Brozena, 1986; Mello and Palma, 2001), and at 32ºS (Fox *et a*l, 1991), where the rift valley gives place to a subtle rise, typical of regions probably influenced by hot spots (Schilling *et al*, 1985; Brozena and White, 1990). Müller *et al* (1998) documented successive ridge jumps at around 30ºS toward Tristan da Cunha Hotspot, indicating a ridge-hotspot interaction.

The SMAR exhibits a clearly N-S morphological variation. Here we develop a regional investigation of the topography and gravity by using satellite data in conjunction with marine data. These data along with the Mantle Bouguer Anomaly model provides a good way to infer the role of lithospheric processes influencing the ridge morphology.

Data set and analysis

Our analysis was based on the predicted bathymetry derived from a combination of satellite gravity and shipborne bathymetric data (Smith and Sandwell, 1997). The Generic Mapping Tools – GMT (version 3.3.4) was used data for displaying maps and profiles (Wessel and Smith, 1998). The depth at the zero-age was obtained using the axial magnetic anomaly (Müller *et al*, 1997) and profiles of bathymetry and gravity along the ridge axis were filtered in 100 km in order to smooth out the rift valley.

Computed Mantle Bouguer Anomaly (MBA) was also used to characterise the crustal structure under the ridge (Kuo & Forsyth, 1988). The MBA was calculated subtracting the gravity effects of seafloor topography and crust/mantle boundary from the observed free-air anomaly. A constant crustal thickness of 6 km with a density of 2750 kg/m^3 was assumed for the oceanic crust. Therefore, the MBA reflects variations in crustal thickness and/or crustal/mantle densities.

Map and profiles were then used to investigate the variation of ridge axis topography and gravity. Fracture zones defined major tectonic segments, while the along ridge axis profiles at the zero-age showed the variability of the topography and gravity. Parameters such as similarity of the topography along the segment, ridge axis offset, and ridge axis depth and gravity anomaly variation were used to define the ridge segmentation.

Results

As a whole we identified 20 tectonic segments, mostly defined by the E-W continuity of the fracture zones towards the continental margins (fig. 1).

In a broad scale, the South Atlantic Ridge is gently oriented NW-SE, with a conspicuous rift valley, where depth increases from north to south. Its central part (around 20ºS) shows the greatest depths and minimum free-air gravity. The segments are very short; many non-rigid discontinuities are present and a deep rift valley as well. Between 30ºS and 35ºS the ridge changes its overall direction to a NE-SW orientation, and the entire morphology southward exhibits a distinct pattern. This region seems to correspond to a zone of an intense deformation, producing an abrupt change in the general morphology. Despite of recovering the NW-SE trend southern of 30º S, the topography becomes smother and shallower, with a more continuum axis, once less discontinuities are dichotomizing it. At the southern part of the ridge, we observe longer individual segments, which display wider ridge flanks with a high crestal topography, such as at 39º and 47ºS.

The along-axis depth variation shows a long-wavelength gradient of the topography southern of 30ºS, possibly related to an influence of the Tristan da Cunha magmatism. Two anomalously shallow segments are evident, one at north, between the Ascension and Bode Verde fracture zones, and another on the southern end of the Atlantic, at 47ºS. Particularly at 9ºS, there is a striking correlation between the axial depth and MBA profiles, indicating a less dense region, caused by an increase in crustal thickness and/or mantle temperature, probably due to its proximity to the Ascension Hotspot.

In general, all the studied area shows a good correlation between ridge segmentation and MBA variations, showing a strong dependence of the two parameters. The largest variations in MBA are found at the northern (-75 to 25 mGal) and southern (-50 to 25 mGal) end of the South Atlantic. The MBA map displays two regions of lower values, all of them located on the eastern flank of the ridge, at the African plate. The northern region corresponds to the ridge area around the Ascension Hotpot (7ºS), and a second one at 46ºS, near The Bouvet Hotspot.

The analysis of individual tectonic segments shows 6 segments with similar tectonic styles. At segments **E, G, N, Q, S** and **T** the ridge morphology shows an axial high on its central part instead of a typical Mid-Atlantic rift valley, indicating a dominant magmatic process under these regions. The MBA profile at these segments shows a minimum, evidencing thicker crust and/or less denser mantle in these regions, what is directly related to enhanced magmatism underneath. In general, the segments on south MAR display a central rift valley, with an average depth between 2500-3000 m. At the central South Atlantic, the deeper segments **J, K, L** and **M** are probably related to less pronounced magmatism, with a morphological style characteristic of tectonic process. This pattern may indicate a colder region in the central part of the South Atlantic Ridge, in contrast with hotter regions observed on its northern and southern

Conclusions

The South Atlantic Ridge is characterized by three main topographic domains. At the northern and southern ends of the South Atlantic, the ridge morphology is shallower and smoother, while its central part displays a deeper and rugged topography. Segments **E, G, N, Q, S** and **T** which exhibits a distinct morfostructure, more characteristic of hotter regions, are located close to the Ascension (**E, G**), Tristan da Cunha (**N, Q**) and Bouvet (**S**, **T**) hotspots. The central South Atlantic Ridge probably corresponds to a colder region, with less focused and intense magmatism.

The tectonic segmentation of the ridge showed a strong dependence with the Mantle Bouguer anomalies (MBA), which reflects variations in crustal thickness and/or crustal/mantle densities. The greatest along-axis variations were observed at the northern and southern ends of the South Atlantic Ridge, specifically at the segments **E, G, N, Q, S** and **T,** which display minimum values, as a result of thicker crust and/or less denser crust/mantle. This pattern, in conjunction with the distinct morphostructure observed on these regions suggests an enhanced magmatism and perhaps a hotspot influence.

A possible hotspot influence on specific ridge segments of the southern MAR requires further constrain. A correlation between basalts geochemical data and the morphological and gravity variation along the ridge is important.

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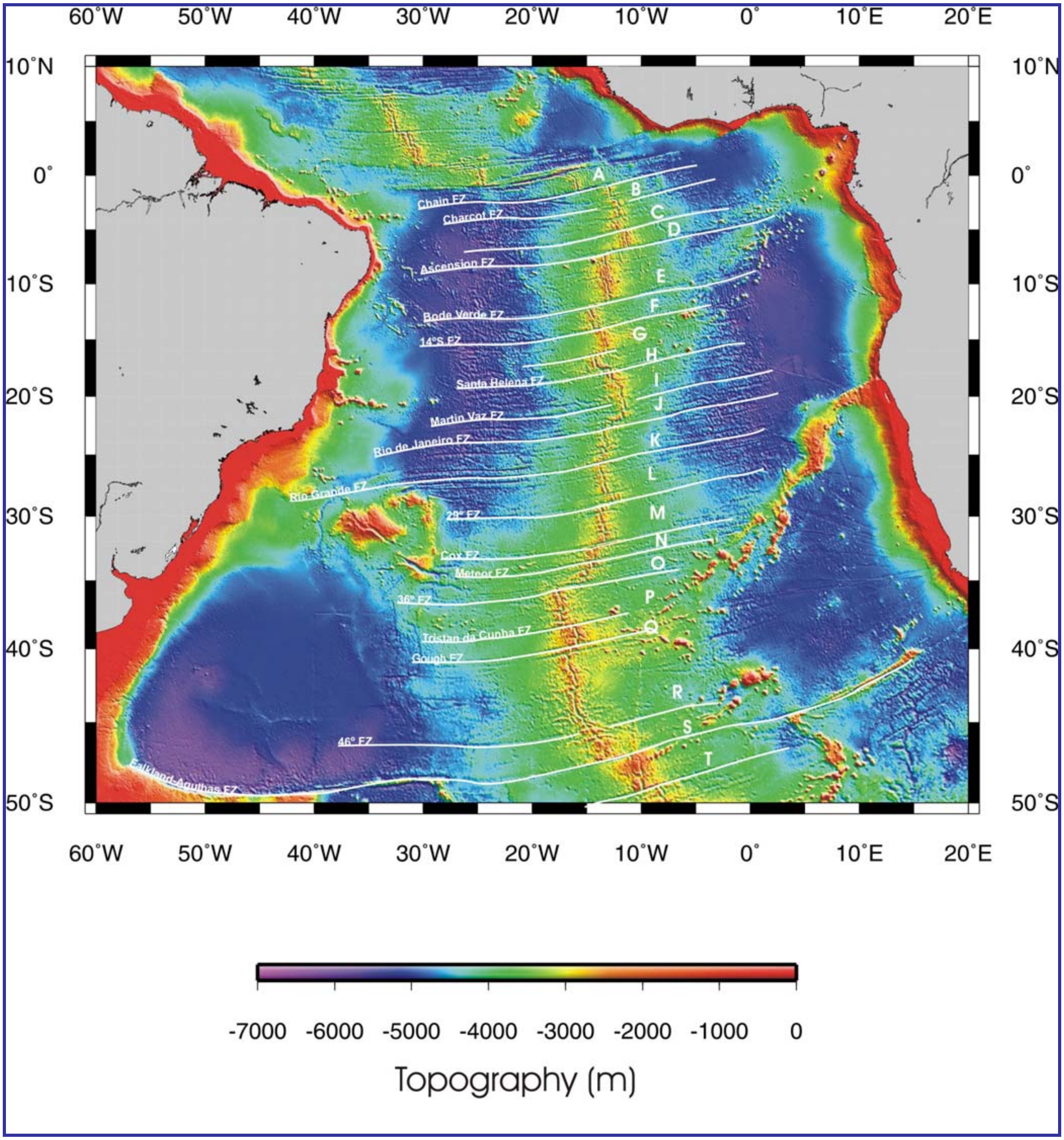

Figure 1- Predicted topographic map. White lines correspond to the fracture zones, and numbers correspond to the 20 tectonic segments, identified from A to T.

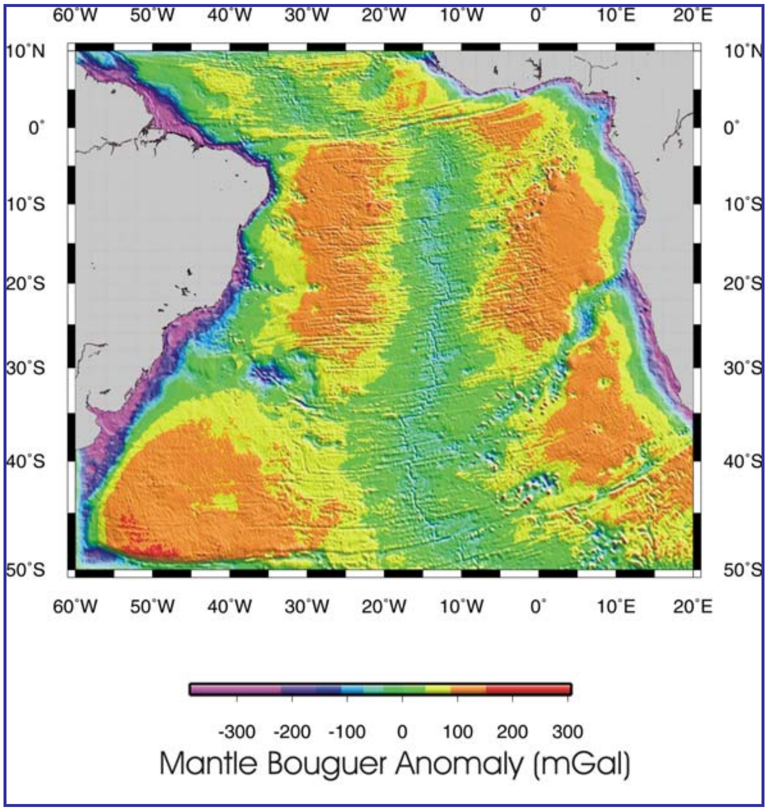

Figure 2- Mantle Bouguer Anomaly variation in the South Atlantic.

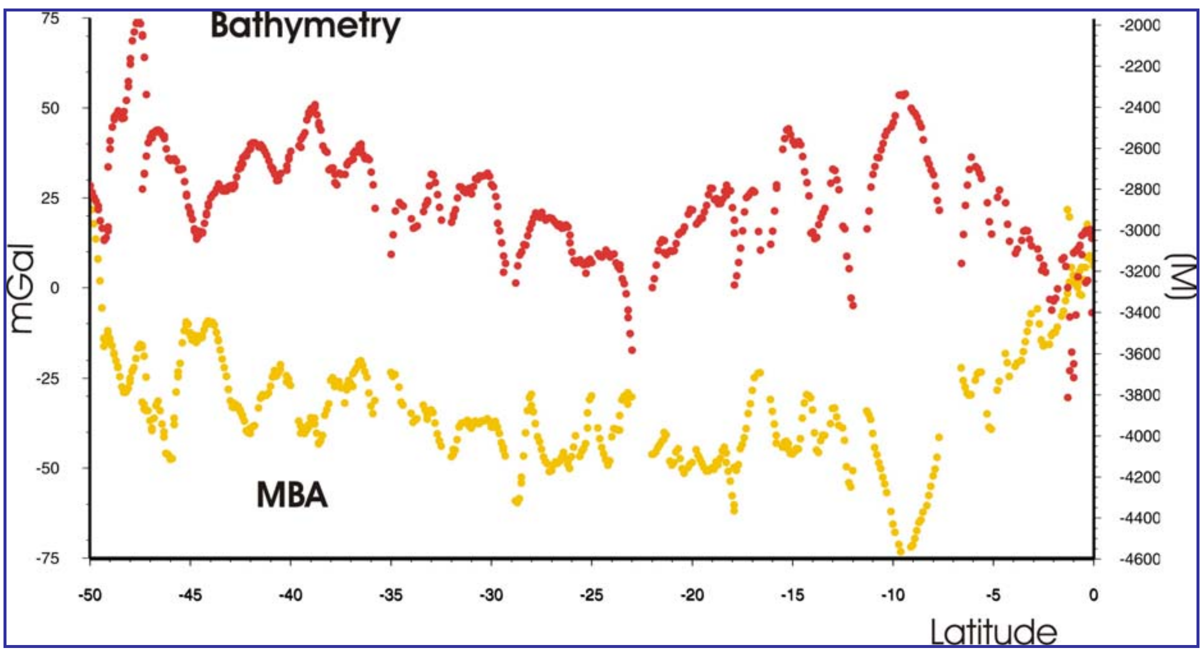

Figure 3- Along-axis depth and MBA variations along the South Atlantic Ridge.