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Morphological Analysis of Submarine Ridges: Genetic Implications in the context of the Brazilian Equatorial Margin

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Introduction

Submarine seamounts are critical features for the understanding of ocean magmatic and tectonic processes. While seamounts are typically associated with tectonism or intraplate magmatism, their morphological diversity reflects variations in magma composition, eruption rates, and tectonic stresses. This study investigates the morphology and genesis of the North Brazilian (NBR) and the Fernando de Noronha Ridges (FNR) that stretch across the Brazilian Equatorial Margin (Figure 1). These volcanic ridges, extending offshore along the Barreirinhas and Potiguar marginal basins, exhibit rather distinct volcanic features structures, and reveal seamounts of different dimensions, shapes, and orientations. The NBR extends through two E-W trending segments, connected by an intermediate N30°W-oriented sector, while the FNR, with an E-W orientation, extends to the Fernando de Noronha Archipelago. Notably, the E-W segments of both the NBR and FNR align with the São Paulo Fracture Zone (northern segment), the Romanche Fracture Zone (southern segment), and the Chain Fracture Zone (FNR).

This work aims to correlate seamounts' morphometric parameters with the surrounding regional tectonic and magmatic evolution.

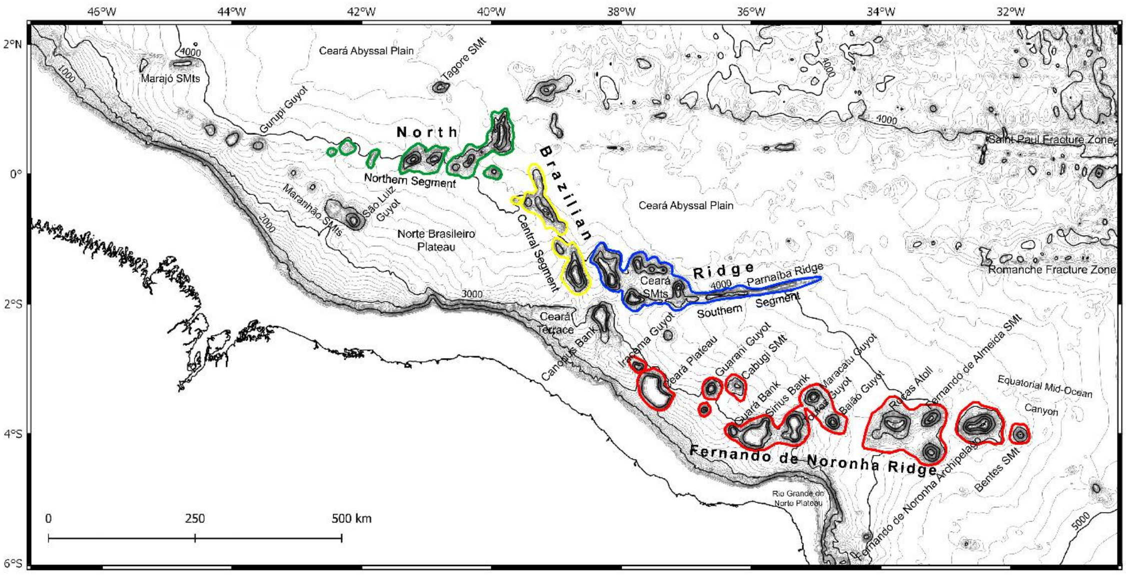

Figure 1: (a) The study area highlighting the North Brazilian Ridge, with its south (blue), central (yellow) and north (green) segments, and the Fernando de Noronha Ridge (red). Bathymetric map, LEPLAC 2019 base, presenting isobaths with 100 m intervals.

Method

The study method relies essentially on the morphometric analysis of bathymetric data from the LEPLAC project (1,500 m grid resolution). This data base allowed the morphometric classification of forty-seven seamounts, considering isolated topographic highs with steep gradients, and excluding those linked to mid-ocean ridges. Morphometric parameters were delimited using the deepest closed isobath that individualizes each individual seamount (applying 50 m isobath intervals) to minimize sediment influence, except in the NBR's southern segment (Figure 2). They include: (i) **Relative relief**: Depth difference between peak and surrounding seafloor; (ii) **Circularity**: ratio between the areas of a seamount and a circle with an equivalent perimeter, (iii) **Radius/height ratio**: Basal radius of a seamount divided by its height; (iv) **Orientation**: Major axis alignment of elongated seamounts, and (v) **Peaks number**: number of individualizable elevations of a seamount.

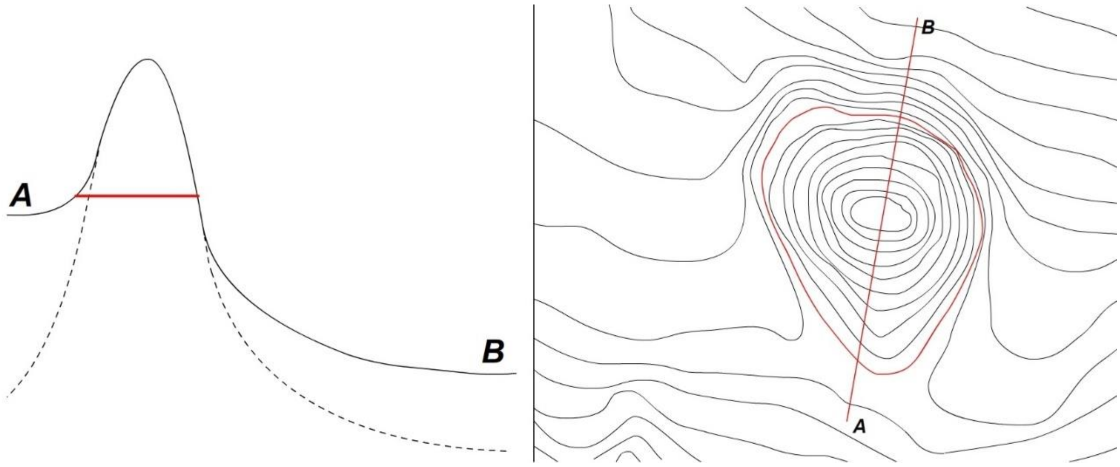

Figure 2: Methodology for mapping the dimensions of the seamount, represented in profile and plan view. In this study, seamounts were delineated using the deepest bathymetric contour line that encloses the feature, represented in this figure by the solid red line. In the image, the solid black line represents bathymetry (in the left profile and as contour lines on the right), while the dashed line represents the basement.

Results and Conclusion

Analytical results reveal that the NBR and the FNR exhibit rather contrasting morphologies and morphometric parameters:

(1) The **NBR** seamounts area segmented into a Southern (E-W), a Central (NW-SE), and a Northern (E-W) sectors. They exhibit low average circularity (0.503), usually multiple peaks (3–4) per seamount; and quite high relative relief (up to 3,250 m; Figure 3). These parameters reveal prolonged and multiphased-magmatism (Iyer et al., 2012; Chouldri & Nemcok, 2017; Mitchell, 2001, and; Vogt & Smoot, 1984) whose volcanism occurred via pre-existing lithospheric fractures;

(2) The **FNR** seamount are all aligned along a general E-W direction; they are quite circular seamounts (mean C=0.853); and each seamount exhibiting one single peak, as well as that much higher relative relief (e.g. 4,550 m high at the Fernando de Noronha island). This ansemble of morphometric parameter are compatible with seamount that evolved under the influence "monogenetic) volcanism.

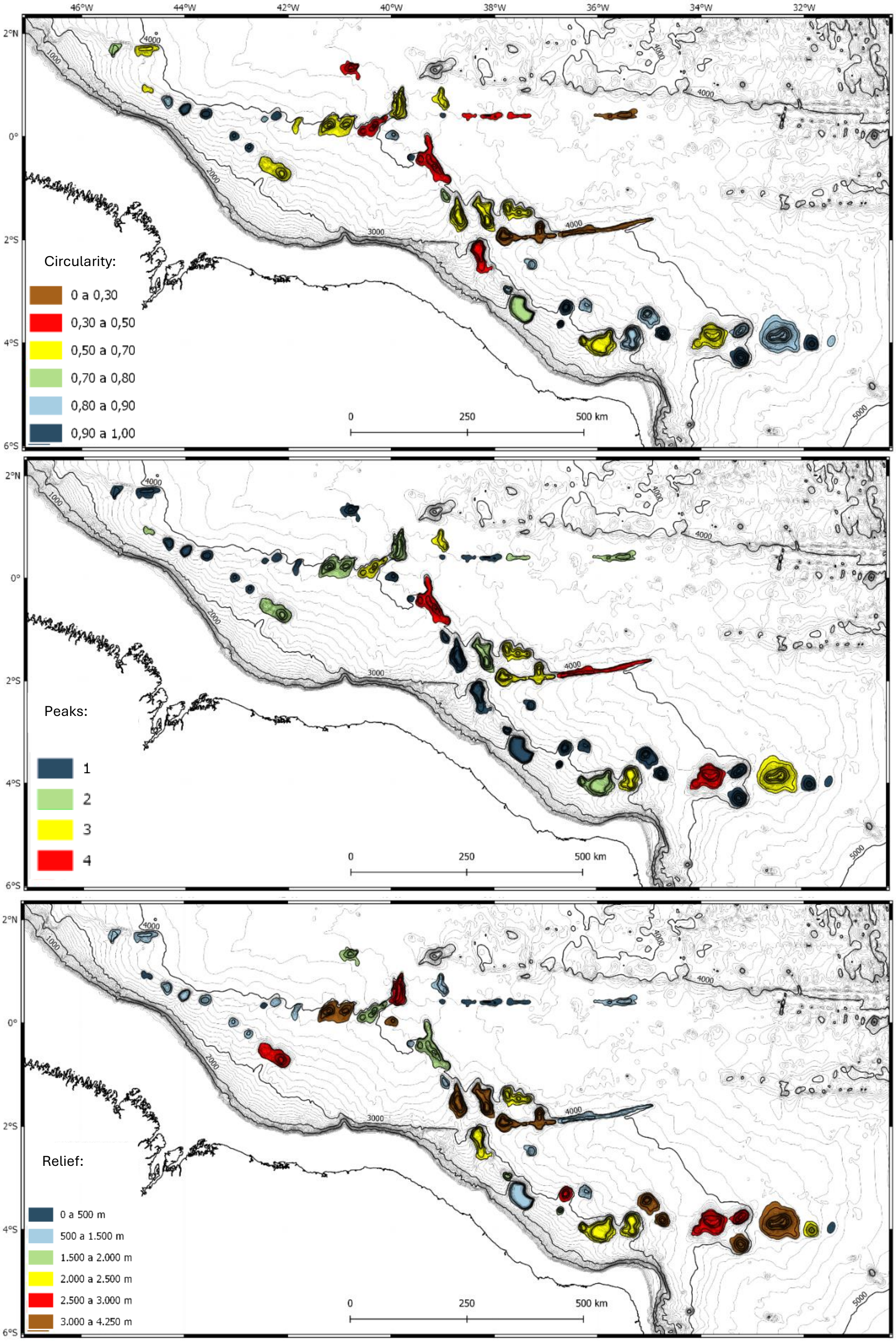

Figure 3: NBR and FNR Morphometric Analyses**. (a) circularity seamount map; (b) peak number and (c) relative relief.**

Results evidence the interplay between (i) tectonic stress, (ii) pre-existing structural framework (e.g., fractures acting as magma conduits), and (ii) magmatism, in shaping seamount morphology. The NBR morphometric complexity (Figure 3) suggests multi-stage magmatic phases, while the FNR's circularity points to a younger magmatic activity that occurred as a single magmatic phase. The main key findings are:

1. The NBR's E-W alignment correlates with the São Paul and Romanche fracture zones, highlighting transtensional stress as a magma conduit;

2. Radius/height ratios (<9 for the NBR *versus* ~11.5 for the FNR) reflect distinct growth phases for the NBR and the FNR evolution. Long-lasting multiphased volcanism across the NBR *versus* Continuous and more rapid eruptions across the FNR.

These results underscore the interplay between tectonic stress, pre-existing fractures as conduits, and magmatism in shaping seamount morphology. The NBR's complexity suggests multi-stage magmatism, while the FNR's circularity points to younger, and single activity.

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