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Volcanic Evolution of the North Brazilian Ridge and Fernando de Noronha Ridge: Insights from Seismic Stratigraphy

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Introduction

The North Brazilian Ridge (NBR) and Fernando de Noronha Ridge (FNR) are prominent submarine volcanic features that stretch offshore along the Brazilian Equatorial Margin (Fig. 1). While the FNR is usually linked to the Fernando de Noronha hotspot (O`Connor e Duncan, 1990; Almeida, 2006), the NBR's origin still remains debated, opened for distinct interpretations (Hayes & Ewing, 1970; Miura & Barboza, 1973; Le Pichon & Hayes, 1971). Hypotheses put forward vary from the suggestion that the NBR is the present expression of extinct spreading centers (Gorini, 1977; Azevedo, 1991). or the result of reactivation of segments of fracture zones (São Paulo Fracture Zone - northern segment, and the Romanche Fracture Zone - southern segment; Bonatti, 1978; Azevedo, 1991). Having this undefined evolution scenario for the NBR in perspective, this study addresses an evolution model based on integrated analyses by combining seismic stratigraphy, chronostratigraphy, and plate tectonic reconstructions in the attempt to unravel their magmatic evolution and tectonic controls.

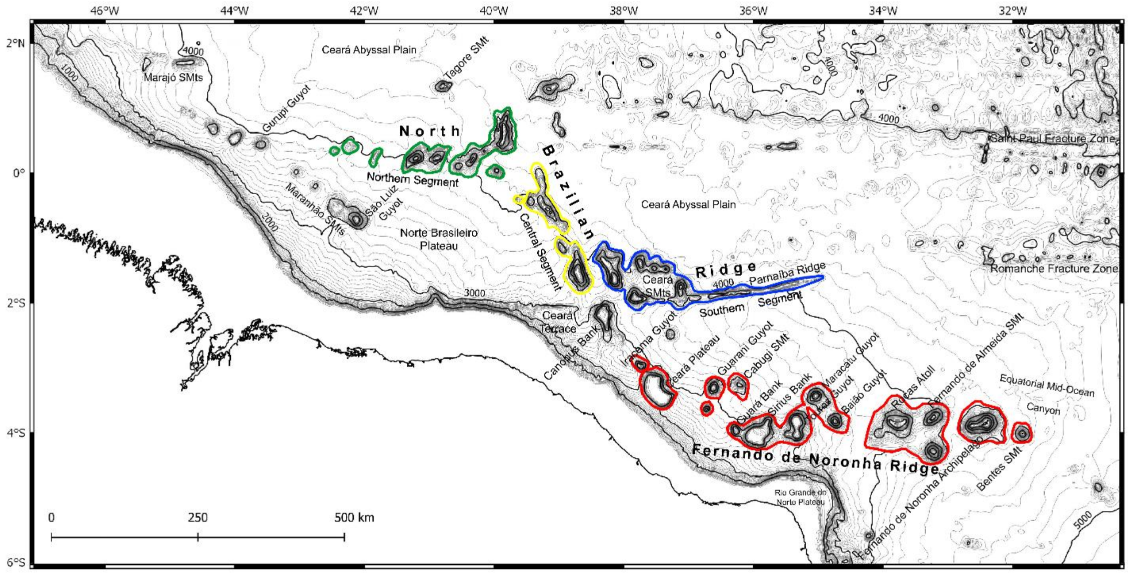

Figure 1: (a) The study area highlighting the North Brazilian Ridge, with its south (blue), central (yellow) and north (green) segments, and the Fernando de Noronha Ridge (red). Bathymetric map, LEPLAC 2019 base, presenting isobaths with 100 m intervals.

Method

The study is primarily based on seismic data from the LEPLAC Program (Plano de Levantamento da Plataforma Continental Brasileira) acquired between 1987–2009 made available by the Brazilian Navy. For the present study, 119 LEPLAC deep seismic sections (penetration up to 8-10 s) were analyzed, focusing on magmatic bodies identified by high-amplitude limiting reflectors, chaotic inner seismic facies, and onlap terminations of the sediment strata in contact with these magmatic bodies. The study also had access to chronostratigraphic horizons (horizons dated from 2 to 66 Ma) provided by the Brazilian National Petroleum and Gas Agency (ANP) and regional bathymetric maps compiled by the LEPLAC team (Alberoni et al., 2019). These data were used to perform stratigraphic correlations of volcanic phases of the seamounts ridges within the nearby marine sedimentary succession. Plate motion models (Seton et al., 2012) and gravimetric data (Müller et al., 2022) also allowed us to reconstruct a possible hotspot track and influence of specific fracture zone.

Results and Conclusions

The integration of seismic, geochemical, and plate reconstruction data provides a cohesive model for Equatorial Atlantic volcanism, linking mantle dynamics to inherited tectonic frameworks. These findings contribute to the long-standing debates on ridge origins and underscore the interplay between deep mantle processes and crustal inheritance.

The structural analysis highlights the alignment of the NBR's E-W segments with the Romanche and St. Paul fracture zones, while the FNR is aligned with the Chain Fracture Zone (Fig. 1). Such orientation is confirmed by linear gravimetric lows along the fracture zones (Fig. 2), strengthening the hypothesis that these listopheric faults served as primary magma conduits for the ridges' volcanism.

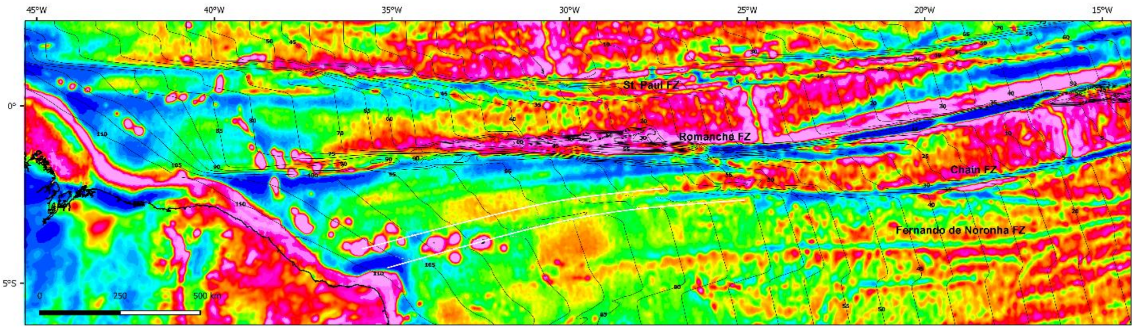

Figure 2: Free-air gravity map of the South American portion of the Equatorial Atlantic (Topex v29.1 data), displaying the continuity of oceanic fracture zones from the transform zone between the Mid-Atlantic Ridge axes to the flanks of the CNB (São Paulo Fracture Zone, adjacent to the northern segment, and Romanche Fracture Zone, connected to the southern segment) and the CFN (via the Chain Fracture Zone). These features are highlighted by gravity lows marked by white solid lines, and the inflection of crustal age isochrons (represented by thin black lines labeled in Ma, based on estimates by Müller et al., 2008).

Coupled seismic and chronostratigraphic analyses allowed us to identify that the ages of the magmatic activity decrease from ~80 Ma (the oldest NBR volcanism) to 2 Ma (the youngest FNR volcanism), which leads to a magmatic activity eastward migration at a rate of ~22.1 km/Ma. The chronological distribution of volcanic activity across seamount ridges is as follows (Fig. 3):

(i) **Pre 66 Ma**, volcanic bodies occur as thick, isolated flows (≤1.4 s twtt thick) located West of Marajó Seamounts;

(ii) **Between 66 - 38 Ma**, volcanic bodies occur as s parse flows (≤0.6 s twtt thick) distributed between the Gurupi Guyot and the Ceará Seamounts;

(iii) **Between 38 - 14.9 Ma**, the peak of volcanic activity (0.1–0.5 s twtt thick) occurs along the NBR's Central-South segments, with flows exceeding 1.5 s twtt thick;

(iv) Volcanic activity **<2 Ma** occurs as thin flow layers (0.05–0.1 s twtt thick) near the FNR. These ages are correlatable with the possible hotspot final stages.

The key hypothesis of this work is that the NBR and the FNR originated from prolonged volcanic activity similar to that of a typical hotspot (~85 Ma to present), along with an eastward-moving magmatic migration reflecting the South American Plate motion. In such a scenario, the NBR and the FNR evolutions reveal themselves to have been structurally controlled by preexisting fracture zones and pre-existing Mesozoic spreading centers (Gorini, 1977; Azevedo, 1991), emphasizing the important role of lithospheric weaknesses in focusing volcanic activity.

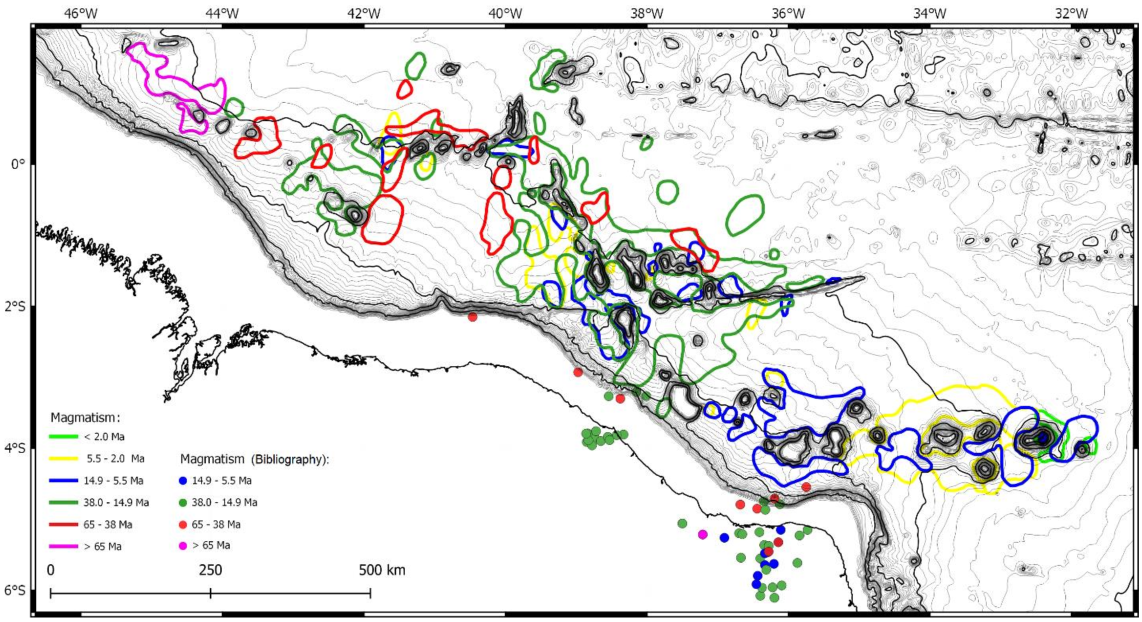

Figure 3: Correlation between the volcanic flows identified in this study and the ages of volcanic rocks described in the literature. Note the relationship between the mapped magmatic events (solid colored lines) and the radiometric dates obtained from bibliographic analysis (points, sourced from Guimarães et al., 2020; Perlingeiro et al., 2013; Misuzaki et al., 2002; Knesel et al., 2011; Sousa et al., 2013; and Silveira, 2006). Base morphological map: LEPLAC, 2019.

References

Alberoni, A. A. L.; Jeck, I. K.; Silva, C. G. ; Torres, L. C., 2019. The new Digital Terrain Model (DTM) of the Brazilian Continental Margin: detailed morphology and revised undersea feature names. Geo-Marine Letters , v. 1, p. 1-16.

Almeida, F.F.M., 2006. Ilhas oceânicas brasileiras e suas relações com a tectônica atlântica: Terrae Didatica, v. 2, p. 3-18.

Azevedo, R. 1991. Tectonic Evolution of Brazilian Equatorial Continental Margin Basins. Tese submetida para obtenção do título de Doctor of Phylosophy na Universidade de Londres.

Bonatti, E. 1978. Vertical tectonism in oceanic fracture zones. Earth and Planetary Science Letters, v. 37, n. 3, p. 369 – 379.

Gorini, M.A. 1977. The Tectonic Fabric Of The Equatorial Atlantic And Adjoining Continental Margins: Gulf Of Guinea To Northeastern Brazil. Doutorado (Thesis Submitted For The Degree Of Philosophy In The Faculty Of Pure Science)- Columbia University, EUA

Guimarães, A. R.; Fitton, J. G.; Kirstein, L. A.; Barfod, D. N., 2020. Contemporaneous intraplate magmatism on conjugate South Atlantic margins: A hotspot conundrum. Earth and Planetary Science Letters, v. 536, p. 1-8.

Hayes, D.E.; Ewing, M., 1970. North Brazilian Ridge and Adjacent Continental Margin. The American Association Petroleum Geologists Bulletin, v. 54, p. 2.120-2.150.

Knesel, K.M., Souza, Z.S., Vasconcelos, P.M., Cohen, B.E., Silveira, F.V., 2011. Young volcanism in the Borborema Province, NE Brazil, shows no evidence for a trace of the Fernando de Noronha plume on the continent. Earth Planet. Sci. Lett. 302, 38–50.

Le Pichon, X.; Hayes, D. E., 1971. Marginal Offsets, Fracture Zones and the Early Opening of the South Atlantic. Journal of Geophysical Research, v. 7626: p. 6283 – 6293.

Misuzaki, A.M.P.; Thomaz-Filho, A.; Milani, E.J.; Césero, P., 2002. Mesozoic and Cenozoic igneous activity and its tectonic control in the northeastern Brazil. Journal of South American Earth Sciences, 15, p. 183 – 198.

Miura, K., and Barbosa, J., 1973, Geology of the continental shelf off Maranhao, Piaui, Ceara, and Rio Grande do Norte states, north and northeast Brazil: Cong. Brasileiro de Geologia, Anais, 26th, p. 57—66.

Muller, R.D., Royer, J.Y., Lawver, L.A., 1993. Revised plate motions relative to the hotspot from combined Atlantic and Indian Ocean hotspot tracks; Geology, v. 21, p. 275 – 278.

O'Connor J.M.; Duncan, R.A., 1990. Evolution of the Walvis Ridge-Rio Grande Rise Hot Spot System: Implications for African and South American Plate Motions Over Plumes. Journal of Geophysical Research, v. 95, p. 17.475 – 17.502.

Perlingeiro, G., Vasconcelos, P.M., Knesel, K.M., Thiede, D.S., Cordani, U.G., 2013. 40Ar/39Ar geochronology of the Fernando de Noronha Archipelago and implications for the origin of alkaline volcanism in the NE Brazil. J. Volcanol. Geotherm. Res. 249, 140–154.

Seton, M.; Müller, R.D.; Zahirovic, S.; Gaina, C.; Torsvik, T.H.; Shephard, G.; Talsma, A.; Gurnis, M.; Turner, M.; Maus, S.; Chandler, M., 2012. Global continental and ocean basin reconstructions since 200 Ma, Earth-Science Reviews, v. 113, p. 212-270.

Silveira, F.V., 2006. Magmatismo cenozóico da porção central do Rio Grande do Norte, NE do Brasil. Tese de Doutorado em Geodinâmica, Universidade Federal do Rio Grande do Norte.

Souza, Z.S., Vasconcelos, P.M., Knesel, K.M., da Silveira Dias, L.G., Roesner, E.H., de Farias, P.R.C., de Morais Neto, J.M., 2013. The tectonic evolution of Cenozoic extensional basins, northeast Brazil: geochronological constraints from continental basalt 40Ar/39Ar ages. J. South Am. Earth Sci. 48, 159–172