NW-trending lineaments across Brazilian margin: a discussion upon their origin and implications for the Albian-Maastrichtian paleobiogeography and paleoecology of the South Atlantic

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Abstract

Increasing evidence has been collected favoring the idea that NW-trending bathymetric and topographic lineaments observed in the Brazilian margin and adjoining continent could be associated to hot spot tracks. The Tristão da Cunha hot could have been the southernmost boundary of Albian Tethys gulf.

Introduction

Since the eighties, several groups of NW-trending lineaments running from the coast up to the Mid Ocean Ridge have been recognized across the South Atlantic Brazilian margin from analyses of gravity SEASAT data (Bostrom, 1989). The direction of sea floor spreading has remained remarkably constant around a ENE-trending since 84 m.y B.P. (Nurnberg & Muller, 1991; Mello & Dias, 1996). Therefore, at least for the time elapsed between the Upper Cretaceous and the Present, these features can not be straightly attributed to the divergence between South America and Africa plate since they show remarkable cross cutting relation with the EW- trending fractures zones. In this paper we briefly discuss some ideas concerning the origin of such features and some implications for the Upper Cretaceous paleobiogeography and paleoecology of the South Atlantic.

Bathymetric and topographic NW-trending lineaments across Brazilian margin and adjoining continent

Bostrom (1989) noted that in front of the NE Brazilian coast, associated with the lineaments are some circular features resembling the surface expressions of mantle plumes elsewhere. Following him, the interpretation of images using a filter which is sensitive to structures aligned NW-SE suggested that the entire region between the lineaments was affected by left-lateral simple shear or by antecedent fractures zones.

In front of the NE Brazilian coast, 3 of such lineaments are related to 45 seamounts distributed along 3 chains (Bahia seamounts; fig. 1). These chains are separated by thick and weakly disturbed basins. The seamounts lie over a 100 m.y.–old crust and radiometric ages obtained from dredge samples from 2 of them display dates of origin of approximately 78 m.y B.P. (late Cretaceous). These seamounts were then considered to be a result of the movement of the South America plate over one or more now extinct hotspot(s), which died out in the early Tertiary and not later than the late Paleocene (Cherkis et al., 1992).

Lima (1999) showed that the bathymetric NW-trending lineaments discussed above actually continue across the continent for hundreds of kilometers, where they are associated with positive isostatic anomalies and seismicity. Actually, the most prominent of them is responsible for the sharp inflexion of the São Francisco river towards SE (fig. 1). North of that inflexion, fission track results have been interpreted as indicating a late Cretaceous (~60 – 80 m.y B.P) pulse of uplift (Harmann et al., 1998).

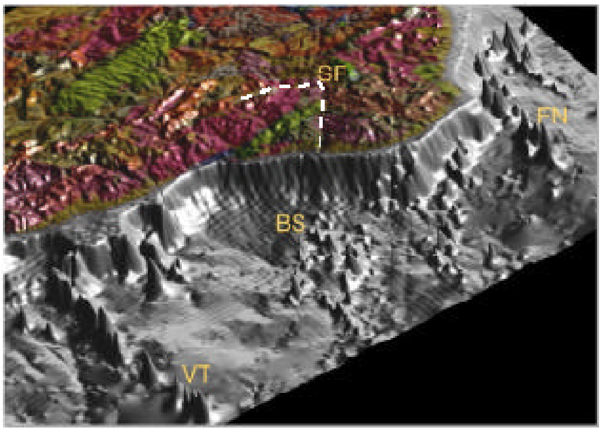

Figure 1. NW-trending bathymetric and topographic lineaments in NE Brazil and adjoining sea floor.

The figure shows a DEM of topography and bathymetry draped with the UNESCO Geological Map of South America. Greenish hues are Mesozoic basins; reddish hues indicate Precambrian basement. See the continuation of the NW-bathymetric lineaments as topographic lineaments. BS, FN and VT indicate the Bahia. the Fernando de Noronha and the Vitoria-Trindade- Martin Vaz seamounts; SF marks the inflexion of S. Francisco river towards SE. The final NW-SE-trend course of the river is aligned with NW-SE-trending Bahia seamounts (BS)

In front of the SE Brazilian coast, there are several NW-trending lineaments, the most prominent one passing through the Rio Grande Rise. This rise is a huge and complex feature that lies over crust older than 80 m.y B.P. and was affected by a widespread volcanism during the Eocene (about 45 m.y. B.P.; Gamboa & Rabinowitz, 1984; fig. 2).

On the basis of radiometric, petrologic, gravity and seismic data, this prominent NW-trending lineament has been interpreted as a major extensional intraplate deformation zone, named "Croix du Sud" by De Souza (1991) (fig. 2). Following this author, this deformation zone would have been a response to global changes in velocities and geometry of sea floor spreading during 84 to 50 m.y. B.P. This deformation zone also separates two major domains of the South Atlantic rifting, an older one (130 m.y. B.P. to the south, a younger one to the north (107 m.y).

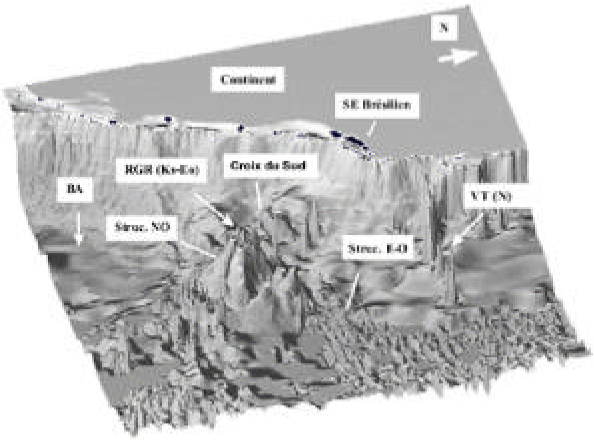

Figure 2. DEM of bathymetry in front of the SE Brazilian coast.

See the cross-cutting relation between a prominent NW-trending lineament (Struc. NO; Croix du Sud) and the EW-trending fracture zones (Struc. E-O). Other captions are: BA, the Argentinean basin; VT(N), the Vitória Trindade-Martin Vaz EWtrending alignment of seamounts, of possibly Neogene age. Modified form Lima (1999).

NW-trending lineaments and hot spot tracks

O'Connors & Duncan (1990) obtained the 40Ar / 39Ar crystallization ages along the Walvis Ridge and the Rio Grande Rise. According to these authors, the fundamentally age-progressive distribution of theses basement ages suggests a common hot spot source for volcanism on the island Tristão da Cunha, along the Walvis Ridge and Rio Grande Rise, and for the formation of the continental flooded basalts located in Brazil and Namibia. Nowadays the hot spot would be located under the Tristão da Cunha Island.

VanDeccar *et al*. (1995) supported this interpretation on the basis of their analyses of deepseated P- and S-wave velocities in SE Brazil. Following these authors, the observed negative anomalies would be indicative of a fossil plume. This feature would represent a piece detached from of the Tristão da Cunha plume, now traveling attached to the South America plate. Its melting would have originated the Parana basin flood basalts and those from Namibia as well.

On the basis of the ages found along the Walvis Ridge, O'Connors & Duncan (1990) have calculated the absolute motion of the African plate over the hotspot. Adding up the relative movement between Africa and South America, these authors have obtained the absolute motion of South America over the same hotspot frame (fig. 3).

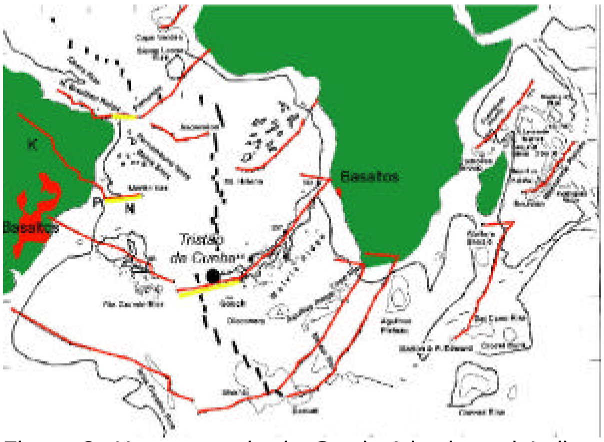

Figure 3. Hotspot tracks in South Atlantic and Indian Oceans

The South Atlanti c calculated tracks are EW-trending for the Neogene (N, yellow) and NW-trending for the Paleocene (P, red) and the Cretaceous (K). Modified from O'Connors & Duncan (1990) and Lima (1999).

The calculated trajectories of the absolute motion of the South America over South Atlantic hot spots are EW trending for the Neogene and NWtrending for older times (O'Connors & Duncan, 1990). They are markably coincident with some of those groups of seamounts (fig. 4). Moreover, the ages found along some of the calculated tracks for which radiometric ages are available (Mizusaki *et al*., 1996), are roughly consistent with expecting ages along them (Lima, 1999).

The Vitória Trindade- Martin Vaz alignment of seamouts (fig. 2 , 3 and 4) is one the these tracks. For that one, the isotopic signature has been interpreted as indicative of a mantle plume origin (Gibson *et al*., 1997). For the Martin Vaz island considered to be the active hot spot, the available radiometric ages are Quaternary – Pleistocene (>0.17- 3,6 m.y B.P) whereas to the west, Eocene ages (~45 m.y B.P.) are found near to the coast (fig. 4). In spite of these consistent results, it is important to note that Upper Cretaceous radiometric ages are also reported and therefore the evolution of these oceanic island is not still well understood.

Recently, Ar-Ar dating has been obtained for an ESE-trending line of alkali intrusions in SE Brazil, from Poços de Caldas near the Paraná basin to the Atlantic (Szatmari *et al*., 2000). This dating showed an age-progressive pattern consistent with a hot spot model. The radiometric ages available for the Brazilian Equatorial margin are also roughly consistent with a hot spot model (fig. 6; Lima, 1999)

The Tristão da Cunha hot spot: the southernmost boundary of an Aptian-Albian Tethys gulf

Paleontological, geochemical and sedimentological data have supported the hypothesis that an effective barrier existed southward to the Santos basin up until Aptian-Albian times. North of such a barrier, usually believed to be formed by the São Paulo Dorsal and the Florianópolis High, sea water was hipersaline, similar to that found in the modern Red Sea. Consistently, only in this northern South Atlantic evaporites are found (Azevedo, 2001).
Over large parts of the world there are Albian-Maastrichtian, open sea, fine-grained carbonates displaying a rich content of pithonellid calcispheres. These calcitic organisms, most commonly range in size between 40 and 100 µm, have been grouped in different taxonomic entities, and the discussions on their nature are still occuring. From a facies and climatic point of view, pithonellids have been associated with low energy carbonate deposits that accumulated in platform to shallow bathyal environments of the Mesoegée/Tethys ocean, a warm water belt surrounding the Cretaceous Earth (Dimas –Brito (2000).
Dimas Brito (2000) reviewing the global stratigraphy, paleobiogeography and paleoecology of Albian-Maastrichtian pithonellid calcispheres, greatly refined the definition the Tethys ocean. The global distribution of the pitonellids defines a Tethian realm occupying both hemispheres, approximately between latitudes 400N and S, in the Albian-Turonian interval (fig. 6). This Megatethys Ocean reached its maximum extension in the late Albian, when the northern South Atlantic, a remarkable late Aptian-Albian tropical carbonate ecosystem, was still a Tethyan gulf.
The comparison between this scenario with the hot spot tracks calculated by O'Connors & Duncan (1990) (fig. 5) leads to the idea that the Tristão da Cunha hot spot could be the southernmost boundary of this Tethys gulf.

Discussion and conclusion

Increasing evidence points out that the bathymetric and topographic NW-trending lineaments observed in the Brazilian margin and adjoining continent could be hot spot tracks. Nevertheless, to be supported, this interpretation still deserves refining radiometric dating and isotopic analyses. Other interpretations for those features include fracture zones older that than 84 m.y B.P. or intraplate deformation zones generated to accommodate global plate reorganizations. We believe that those ones do not exclude the hypothesis that, at their origin, these features could be the superficial manifestations of deep-seated mantle plumes, given the available radiometric dating evidence.
If so, the impact of considering the additional heat input due to the passage of the Brazilian marginal basins over mantle plumes on the creation of topography, intraplate deformation, and petroleum maturation should be comprehensively evaluated.
The calculated tracks exhibit a general EWtrending for Neogene times and NW trending for older times. These trends are consistent with at least some groups of seamounts, namely with those occurring along the Vitória-Trindade- Martin Vaz and the Fernando de Noronha trends. The calculated tracks imply that a major change in South America plate absolute motion did occur around 30 m.y B.P. Silver & Russo (1996) have used this information to support their so called flow-coupled interaction forceplate mode. Following this model, the asthenospheric drag should be the most important force responsible for plate tectonics, and as so, all plate interactions would be globally linked via the asthenospheric flux. With this model in mind, these authors have explained the observed change in the absolute motion of South America as being mostly the result of the interaction between Africa and Eurasia plates since Tertiary times. In the proposed scenario, the Africa's absolute movement to the north would have been progressively de-accelerated by its collision with Eurasia, which would have begun at 38 m.y B. P. and would have produced the Alpes. Putting into evidence that the divergence between Africa and South America has remained essentially constant since the Upper Cretaceous. Silver & Russo (1996) have proposed that South America would have been accelerated towards the west in response to the northwards Africa's obstruction.
The comparison between calculated South Atlantic host spot tracks with the Albian – Maastrichtian paleobiogeography and paleocology of South Atlantic leads to the idea that the Tristão da Cunha hot spot could have been the southernmost boundary of an Aptian-Albian tropical carbonate ecosystem existing in a Tethyan gulf.

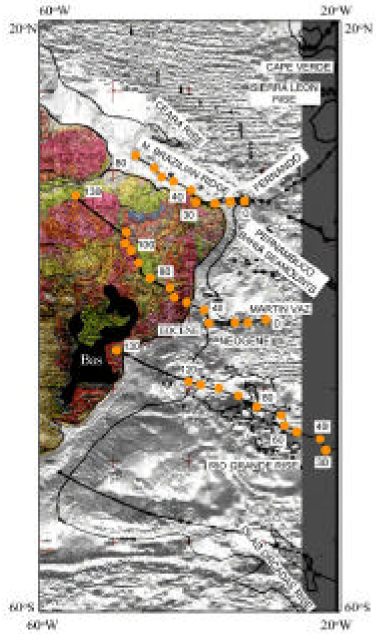

Figure 4. Overlay containing the tracks calculated by (O'Connors & Duncan, 1990) for the Fernando de Noronha, Martin Vaz and Tristão da Cunha hotspots.

Circles (orange) indicate 10 m.y. intervals along the tracks. Number in the white squares are ages B.P. (m.y). Accordingly, 130 m.y B.P., the Tristão da Cunha hotspot was under SE-Brazil, being responsible for the tholeitic basalts of the Parana basin (Bas). Modified from Lima (1999).

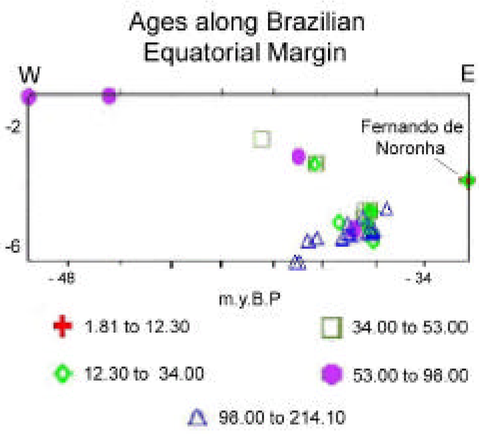

Figure 5. Radiometric ages along the Brazilian Equatorial Margin

The ages become progressively older west to Fernando de Noronha (the active hot spot?). Ages ranging from 98 to 214 m.y B.P. have been interpreted as been not related to the hot spot model. Ages from Mizusaki et al. (1996). Modified from Lima (1999).

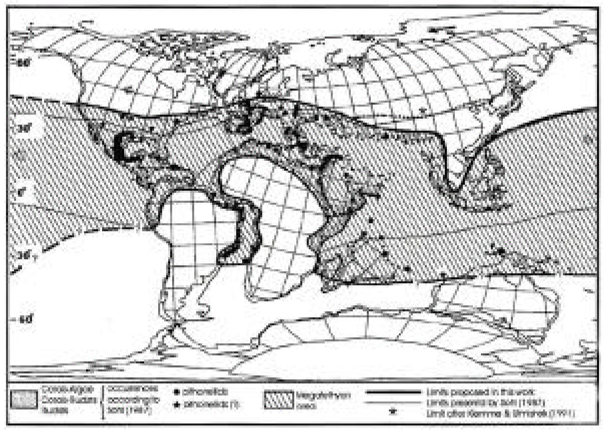

Figure 6. Mid Cretaceous Tethyan Realm, the Megatethys ocean as suggested by pithonellid data.

The map represents, to a large extent, the late Albian scenario. See how the proposed southernmost boundary of the Megatethys could be the Tristão da Cunha hot spot (figs. 4 and 5). Modified from Dias -Brito, 2000)

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