Norte Brasileira Ridge System, an example of natural component or natural prolongation of the Brazilian Continental Margin?

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Abstract

The anomalous morphology of the seafloor is evidence which provide a clear idea of how dynamic the underwater world is and how often changes occur in geologic time scale. So, volcanic underwater chains linear or not appear as a common and sometimes distinctive submarine features. Additionally, tectonic and sedimentary processes, in conjunction or isolated, are responsible for the continental margin building and morphology.

The UNCLOS in Article 76 mentioned the underwater features and Scientific and Technical Guidelines (STG) present details regarding the types of features cited on UNCLOS. The STG presents three types of underwater features: oceanic ridge, submarine ridge and submarine elevation and also introduce the approach of natural prolongation and natural component in which these features may be entitled.

The Norte Brasileira (NBR) and Fernando de Noronha (FNR) ridges are two conspicuous submarine features in the Equatorial Brazilian Continental Margin (EBCM). Both ridges present segments parallels and orthogonal to the coastline and this geometry associated with tectonics and sedimentary process observed since South American and Africa plates break up affected and shaped the margin in these region and provided special role in its building. This study will deal with this issue in a combination of events which may be better understood if considering the Norte Brasileira Ridge and inner seabed surrounded by it as an integrated system.

In conclusion, we suggest that the Norte Brasileira Ridge (NBR) System, supported by geomorphologic and geophysics data and scientific bibliography may be, at least, entitled as a natural prolongation of the EBCM.

1 - Introduction

The Norte Brasileira and Fernando de Noronha Ridges are two conspicuous features of Brazilian Equatorial Continental Margin. The current paper will focus on the Norte Brasileira Ridge as a feature and its role in the building of adjacent portion of the margin. Also, it will try to develop a view of closed system focused on the Norte Brasileira Ridge feature *per se* and its role as structural barrier confining continental sediments behind it.

The public domain scientific bibliography provides many works on this field (Hayes & Ewing 1970, Gorini 1977, and Gorini 1981) supported by a great range of data, such as: bathymetry, gravity, magnetic, seismic, piston core, heat flow, sonobuoys and bottom photographs and even nowadays they may be considered updated.

Considerations will be done in order to characterize the system applying geomorphologic, geological and geophysical data and pieces of information combined with scientific bibliography available and then provide a discussion regarding its entitlement in accordance to UNCLOS Article 76 and the Scientific and Technical Guideline in order to conclude in which type of ridge or elevation the Norte Brasileira Ridge System may be better fitted.

2 - Brazilian Equatorial Continental Margin (BECM)

The Brazilian Continental Margin evolution has begun around 200 million years when occurs the fragmentation of the supercontinent Gondwana resulting in the separation of Africa and South America continents (Asmus & Porto, 1972; Viro at all, 1985). This process is described by Thomaz Filho at all (2000) based on 380 K/Ar dating performed in basics and alkaline magmatic rocks.

Geo-chronological, micropalaeontological, sedimentological and geochemical data suggest that the final break up between Brazil and Africa occurred in vicinity of Cumuruxatiba/Mucuri and Pernambuco basins around 90 million years ago (Thomaz Filho at all, 2000) and magmatics rocks from this region are the link that Heilbron & Valeriano (1993) describe as the second distentional event in Eocretaceous/Paleocene.

Although the Brazilian Continental Margin (BCM) is classified as the type Atlantic or passive this classification do not means that the margin is a monotonous place along its almost 8500km coastline length. Deep sea submarine fan in Northern and Southern, plateaus, ridges, fracture zones, sedimentary basins (Figure 1), may be cited as example of some features which are responsible for the margin geomorphologic complexity and an idea of how often changes are performed in the seafloor regarding geologic time scale.

The BCM in its portion Equatorial (BECM) from Calcanhar Cape presents a change in the coastline direction from SW-NE to ESE-WNW and the margin acquires transcurrent characteristics until the vicinity of Amazonas Deep Sea Fan, where the coastline direction change one more time, to SE-NW.

Mohriak (2000) describes the BECM as characterized by a few aborted rift along continental shelf in the on shore region and by some sedimentary basins that are characterized by an extensional phase followed by transcurrent movements associated with wrench tectonics and transform faults, forming compressional structures, as (e.g., along the western part of Ceará basin).

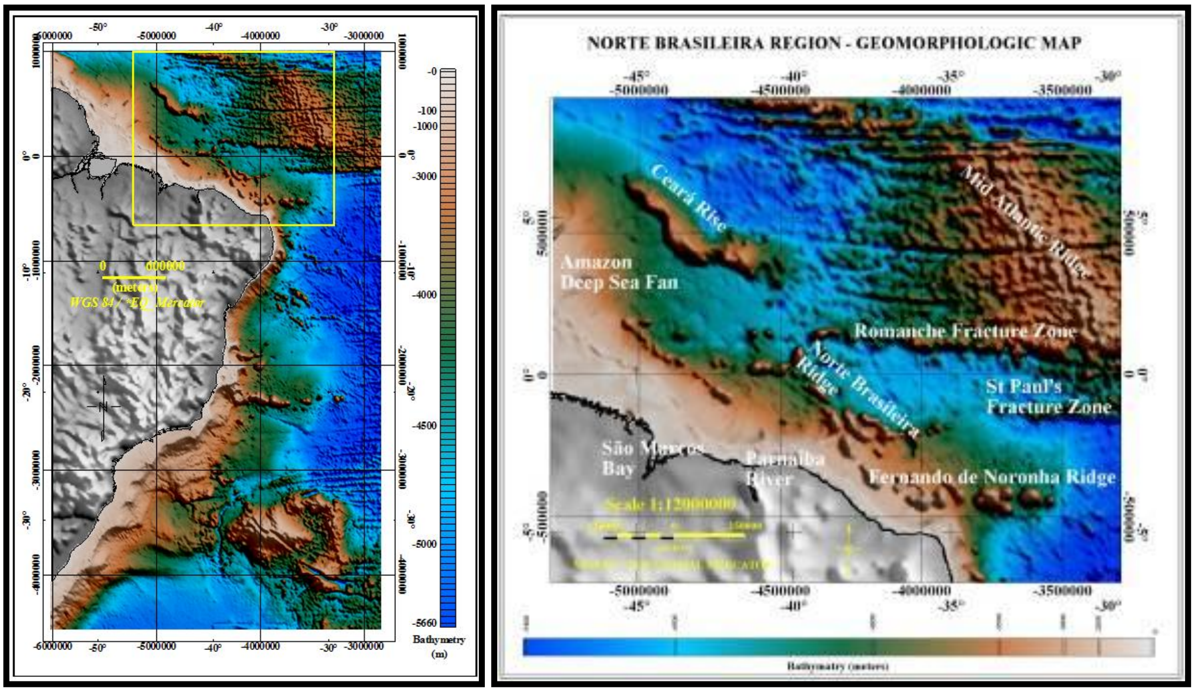

Figure 1 – Geomorphologic Map showing the Brazilian Continental Margin and its submarine features. In the right side it is displayed the study area (yellow square) in details emphasizing the most important features.

The Norte Brasileira and Fernando de Noronha Ridges divide the BECM influencing its physiographiy by confining of part of terriginous sedimentation between the rectilinear portions of the Norte Brasileira Ridge and between the Southern segment of the Norte Brasileira and the Fernando de Noronha ridges. The Norte Brasileira Ridge runs parallel to the coastline with 1,300km in length and its seabed relief level inner and outer varies from 300m to 400m (Hayes and Ewing, 1970). It forms an alignment of continuous seamounts portraying a geographic pattern where alterning E-W segments are controlled by the St Paul's and Romanche fracture zones; NW-SE is aligned parallel to the coastline. The genesis of the Norte Brasileira Ridge is related to the tectonic and volcanic activities originated from shearing stress caused by the separation of the South American and Africa continents in the equatorial region that formed structural highs. These structural highs on the continental shelf propagated towards the currently ocean in the same way as transversal of the mid-ocean Romanche and St Paul's fracture zones were formed (Gorini, 1977 and 1981), however this process occur in the continental crust domain. The second compartment of the Brazilian Equatorial Margin corresponds to the Fernando de Noronha Basin, limited to the north by the southern segment of the Norte Brasileira Ridge and to the south by the Fernando de Noronha Ridge. The sediment of the Fernando de Noronha Basin is originated basically from the Barreirinhas-Piaui and Ceará basins, following a W-E dispersion pattern.

3 – Methodology and Data

Since 1986 Brazilian Continental Outer Limit Project (LEPLAC) carried out more than 150,000km of seismic multichannel and bathymetric (single-beam and multi-beam) data in the BCM to establish the outer limits of continental shelf, according to the United Nation Convention on the Law of the Sea (UNCLOS) and Scientific and Technical Guidelines published by the Commission of the Limits of the Continental Shelf. The maps presented in the current paper are result of the integration of bathymetric, gravimetric, multi-channel seismic profile data and age of oceanic crust data. The bathymetric data and maps followed the same methodology as described in (Torres & Villena, 2007). Free-air gravity data were downloaded from public domain (Smith & Sandwell, 1997) in WGS-84 datum and 2 miles of sample distance spacing. The data of age of the oceanic crust were obtained at the National Geophysical Data Center (NGDC, 2010). Preliminary field seismic multichannel and bathymetric data acquired by LEPLAC project in the current year were used in this paper. Usually data (except seismic data) were submitted on GEOSOFT Oasis Montaj 7.2 software, in which were done procedures of quality control, gridding and mapping.

A consistent scientific bibliographic research was conduct in order to have a better comprehension of the study area and its relation with the vicinity.

4 – Legal Support

The current paper will focus on the United Nations Convention on the Law of the Sea (UNCLOS) and the Scientific and Technical Guidelines (STG) basic publications regarding the process to the establishment of the outer limit of continental shelf by a coastal State.

The STG is a document edited by the Commission on the Limits of the Continental Shelf (CLCS) and form the basis for the Commission to make recommendations with respect to submissions prepared by States according to article 76. Its purpose is providing direction to coastal States which intend to submit data and other material concerning the outer limits of the continental shelf in areas where those limits extend beyond 200 miles from the baselines. Additionally, the STG helps the CLCS to clarify its interpretation of scientific, technical and legal terms contained in the UNCLOS. Clarification is required in particular because the UNCLOS uses scientific terms in a legal context which at times depart significantly from accepted scientific definitions and terminology.

Special attention will be given to the Article 76 of UNCLOS and to the STG paragraphs concerning submarine features.

5 – Results and Discussion

This part of the paper will be developed trying to join the legal aspects with results and bibliographic research. This discussion will be developed over two large approaches: analyze of CNB System as a natural prolongation of the Brazilian Equatorial Continental Margin and analyze of CNB System as a natural component of the Brazilian Equatorial Continental Margin.

5.1 – CNB System as a natural prolongation of the Brazilian Equatorial Continental Margin

The UNCLOS, in its Article 76, paragraph 1 and 3, introduces the concept of natural prolongation of the land mass over the sea and provides the concept of continental margin and its essentials components:

"Paragraph 1 - The continental shelf of a coastal State comprises the seabed and subsoil of the submarine areas that extend beyond its territorial sea throughout the natural prolongation of its land territory to the outer edge of the continental margin, or to a distance of 200 nautical miles from the baselines from which the breadth of the territorial sea is measured where the outer edge of the continental margin does not extend up to that distance."

“Paragraph 3 - The continental margin comprises the submerged prolongation of the land mass of the coastal State, and consists of the seabed and subsoil of the shelf, the slope and the rise. It does not include the deep ocean floor with its oceanic ridges or the subsoil thereof.”

The CLPS defines in the STG paragraph 2.2.2 the test of Appurtenance which is designed to determine the legal entitlement of a coastal State to delineate the outer limits of the continental shelf throughout the natural prolongation its land territory to the outer edge of the continental margin, or to a distance of 200 nautical miles from the baselines from which the breadth of the territorial sea is measured where the outer edge of the continental margin does not extend up to that distance.

“Paragraph 2.2.2. - The Commission defines the term “test of the appurtenance” as the process by means of which the above provision is examined. The test of appurtenance is designed to determine the legal entitlement of a coastal State to delineate the outer limits of the continental shelf throughout the natural prolongation its land territory to the outer edge of the continental margin, or to a distance of 200 nautical miles from the baselines from which the breadth of the territorial sea is measured where the outer edge of the continental margin does not extend up to that distance.”

In order to submit the CNB System to the provisions presented above and then to reach the entitlement of the system as a natural prolongation over the continental margin will be adopt two different ways, although both related .

The first one, showing the progradation and distribution of the sediments in the margin and the role the CNB Ridge as a structural barrier to the sedimentation, characterizing distinctive standards inside and outside of the feature. This is shown by the distribution and peculiar inflections of isobaths as demonstrate in the Geomorphologic Map (figure 2). The 4300m isobath (red line) may be understood as a roughly reference to the outer limit of the Amazon Deep Sea Fan, CNB Ridge and Fernando de Noronha Ridge and 3000m isobath understood as the inner limit of the same features. Regarding the CNB Ridge, the yellow isobaths displacement is the geomorphologic evidence of the progradation of the continental sedimentation in the seaward.

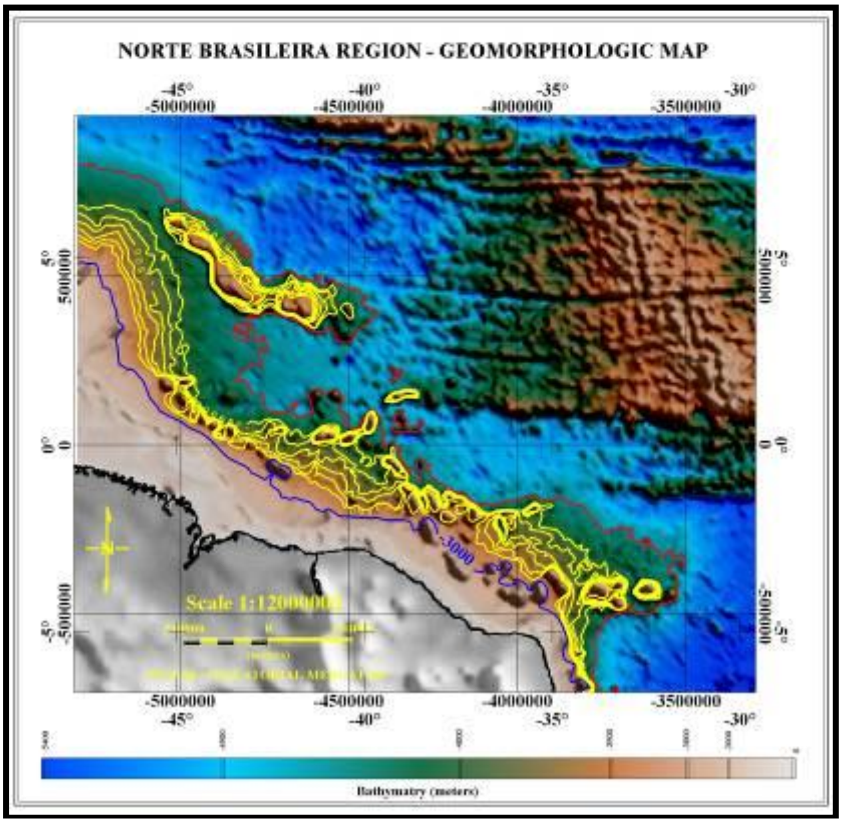

Figure 2 - Bathymetric map of the area of NBR indicating the isobaths from -3000 (blue line) to -4300 (red line) (modified from Torres & Villena, 2007). The isobaths (yellow lines inside the CNB Ridge) are roughly parallel to the coastline and present an almost regular departs between each one which provides to the region a smooth morphology.

The Norte Brasileira Ridge modifies the morphology of the Brazilian Equatorial Continental Margin by confining the sedimentation and forming a vast terrace that widens the continental slope. The first compartment, generated by the sediment accumulation behind the Norte Brasileira Ridge, corresponds to the Para-Maranhão Basin that evolved between the north and NW-SE segments of the Norte Brasileira Ridge and the continental shelf along the states of Para, Maranhão, Piauí and Ceará. The physiographic characteristics of this compartment are a result of the sediment propagation within a location restricted by the high relief segments of the Norte Brasileira Ridge. The terriginous sedimentation progradation originated essentially from the continental shelf along the state of Para and from the western part of the State of Maranhão. After the infill of the basin at the pedestal levels of the Norte Brasileira Ridge, the terriginous sedimentation flowed towards the Ceará Abyssal Plain isolating a few seamounts of the Norte Brasileira Ridge.

In the Southern portion of the Amazonas Deep Fan, the bathymetric contours are displaced considerably to the east around the E-W segments of the Norte Brasileira Ridge. This displacement on the bathymetric lines shows the importance of the ridge as an expressive geomorphologic boundary on the BECM. The ridge works on as a topographic barrier to the sediments transported towards the oceanic basin from the coast of states of Para, Maranhão, Piauí, Ceará, and part of Rio Grande do Norte. The structural barrier imposed by the ridge to the sedimentation into the oceanic basin caused a differentiated sediment accumulation along that part of the margin (Damuth and Kumar, 1970). This action results in a noted difference in the sediment thickness and a relief displacement between the inner and outer parts of the ridge. Only in some segments between the seamounts, isolated by the present sedimentation level, sediments are transferred to the oceanic basin thus contributing to the eastern extension of the Ceará Abyssal Plain.

The Northern of CNB shows (Figure 2) a great gap between 4300m (red line) isobath and the other yellow ones in contrast with the Eastern, which presents a sharp bathymetric difference. This regional morphology, as showed in Figures 3 and 4, characterizes the quasi-plateau feature composed by the flat part (inner CNB and sediment progradation), CNB per se (escarpment) and deep ocean floor.

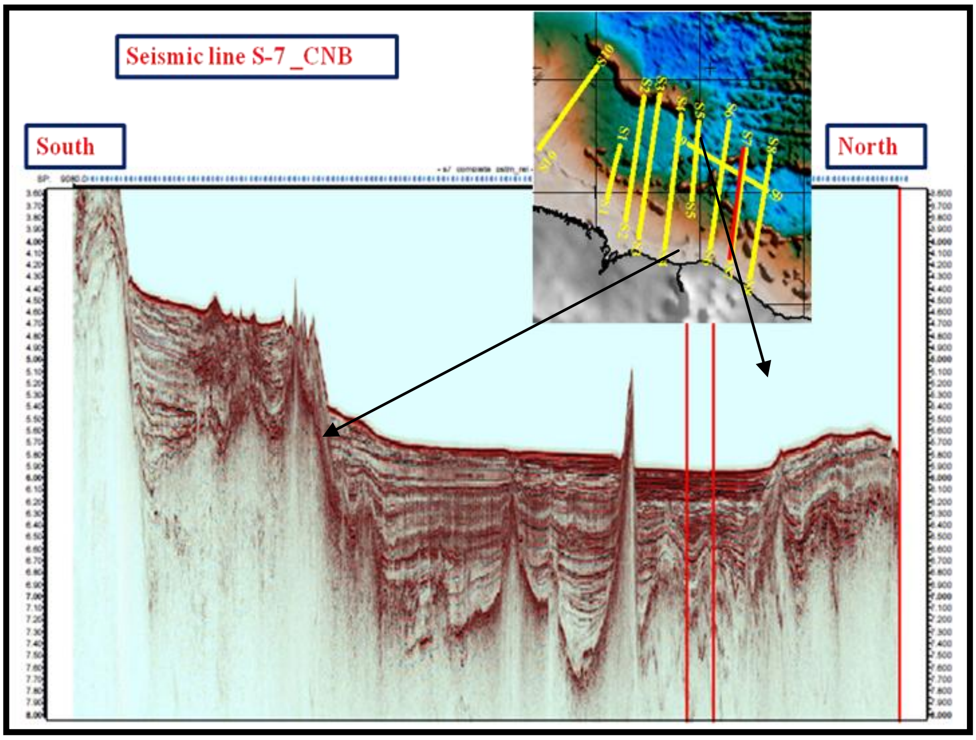

Figure 3 – Seismic multichannel line S7 (undefined vertical exaggeration). The CNB Ridge seamounts work on as a structural barrier, an escarpment that confines the terriginous sedimentation and provide to the region geomorphologic characteristics of a plateau.

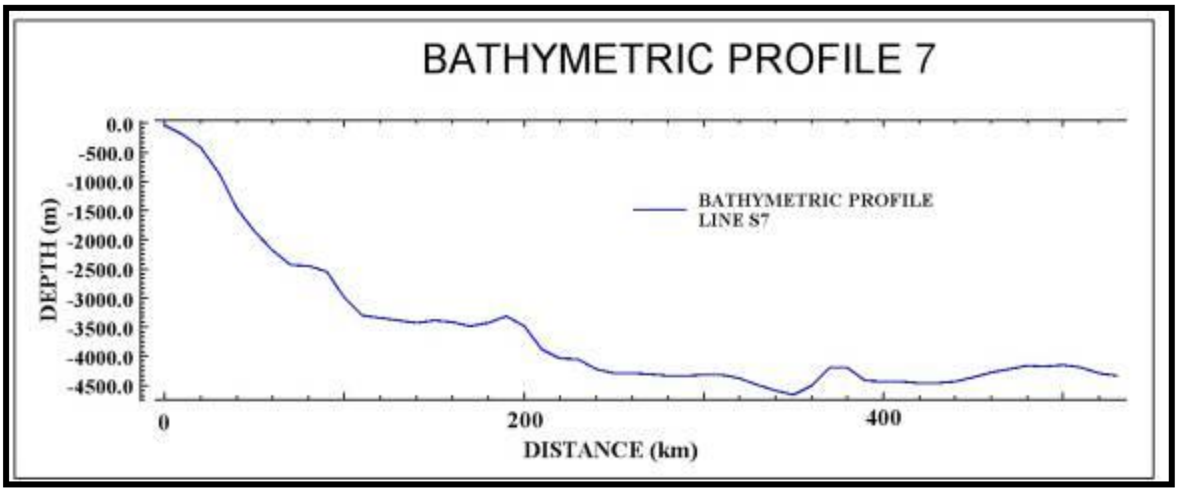

Figure 4 – Synthetic bathymetric profile extract from de bathymetric grid (Torres & Villena, 2007) over de seismic line S7. The bathymetric contrast inside and outside of CNB may be viewed around 4000m. The synthetic bathymetric profile in conjunction with the seismic line emphasizes the quasi-plateau approach.

The role of the NBR as structural barrier and its consequence in the geomorphology of the margin was presented above. Then, the second way of prove, or, emphasize the NBR *per se* as a natural prolongation will be discussed as follow. The construction of the support argumentation will take into account the continuity of the ridge and its link to the continent. Hayes and Ewing 1970, call attention to the ridge as a continuous feature which was also supported by Gorini 1977 and Gorini 1981. The geomorphology of the region is affected by features in subsurface and a Bouguer anomaly gravity map (Figure 5) appears as an important tool in this issue. The fracture zones (from North to South, Romanche, Saint Paul and Fernando de Noronha) are best noted from CNB to deep sea floor direction. The CNB appears as an alignment (red) of seamounts linked divided in three segments (NW-SE and two W-E). The difference of standard of the anomaly inside NBR (orange) to the outside (blue and green) is an important indicative of the continuity of the ridge (red). The blue regions in the vicinity of the CNB are related to difference in the sedimentation or fracture zone limits, and indicative of the role of the NBR continuity as a feature which individualizes part of the BECM. Other important point is the continuity of the ridge in the direction to the continent following the trend of the fracture zones, or at least the suggestion of this continuity, although the huge sedimentation makes this visualization not easy. The scenario of CNB Ridge continuity was expected because in continent break up process the embryonary fracture zone was developed in continental crust domain over some weakness region.

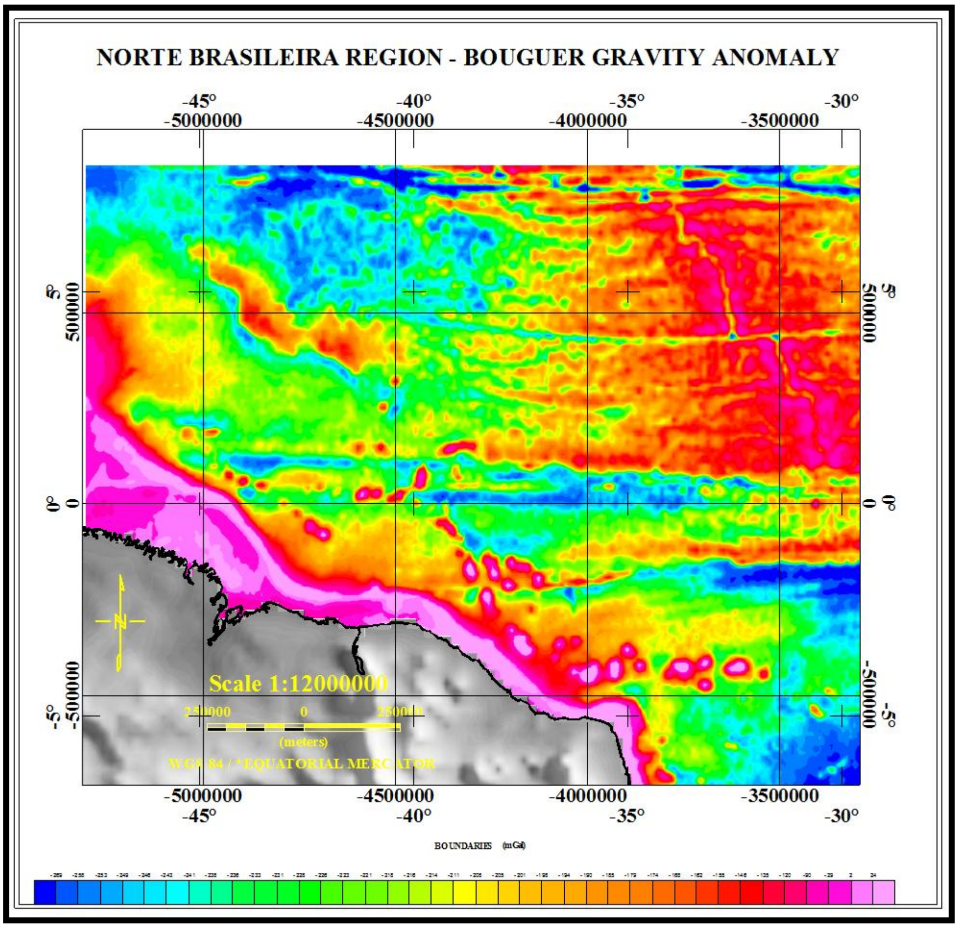

Figure 5 – Bouguer gravity anomaly map emphasizing the major features in subsurface of the study area. The alignments (red) of the seamounts which form the ridge are strong evidence in order to support the continuity of CNB and FNR ridges.

Although the Bouguer anomaly data provide important pieces of information regarding the features in subsurface, the derivative of this anomaly will emphasize the limits of this features, mainly the shallowest ones. Then, the map presented in the Figure 6 may introduce some important additional evidences. In Figure 6 the seamounts alignments appear most linked emphasizing the barrier continuity, as may be observed in the NBR ridge and in FNR ridges.

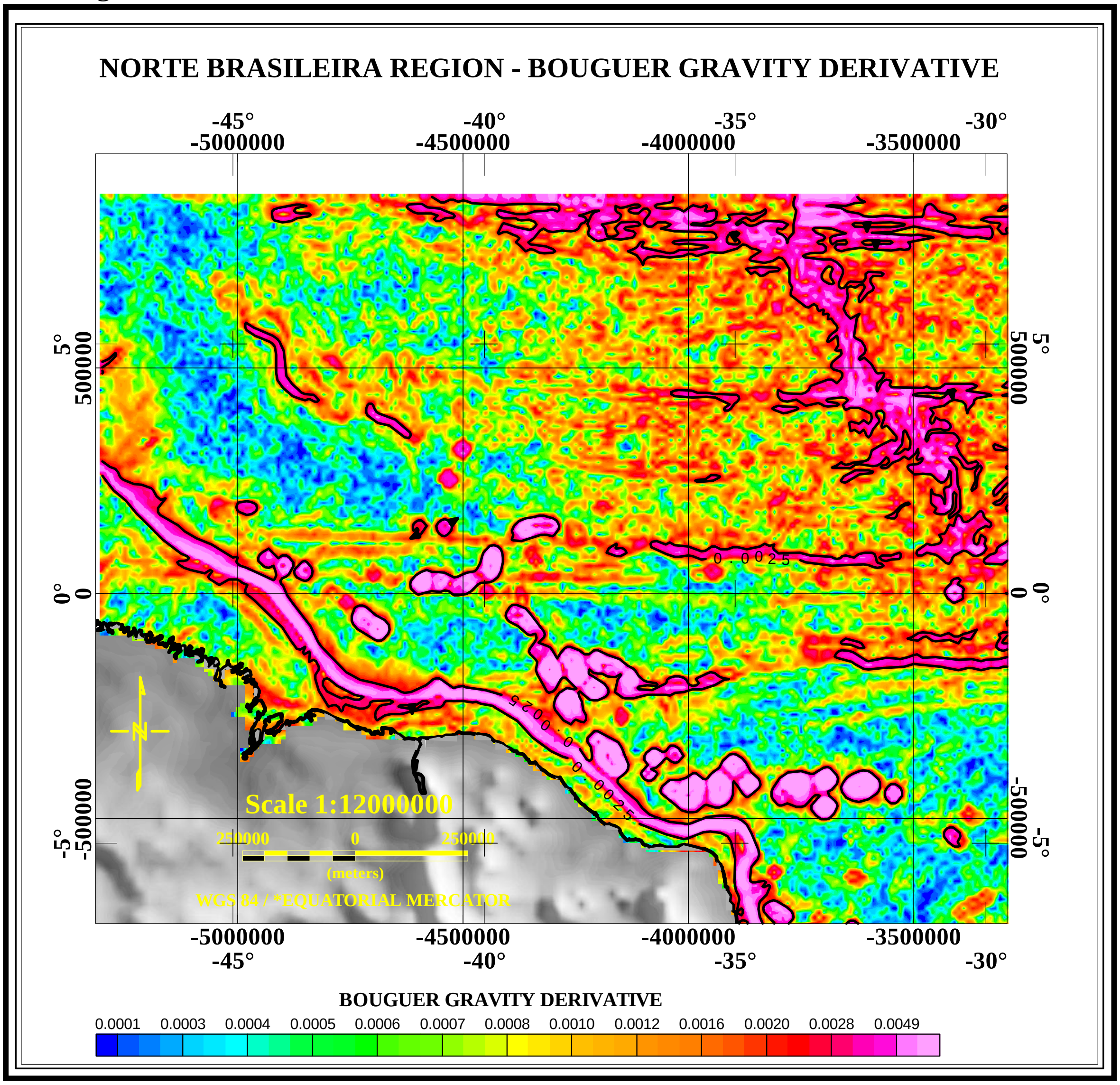

Figure 6 – Bouguer anomaly gravity first derivative map.

The interpretation of Bouguer anomaly gravity results is usually an indicative of the location of the crust limits. In the current paper we identified three domains of values in synthetic profiles extracted from Bouguer anomaly gravity grid. Each domains was associated to a kind of crust: continental, transitional and oceanic. It was represented (Figure 7 sumarizes the results of the application of the described proccess) by the limits between continental/transitional and oceanic pure crusts.

It is important to enphasize that it is not the intention of the authors to discuss in this paper how to determine the points of the foot of the slope. The crust limits discussed here are not viewed as a suggestion that evidence to the contrary to the general rule may be invoked in the region.

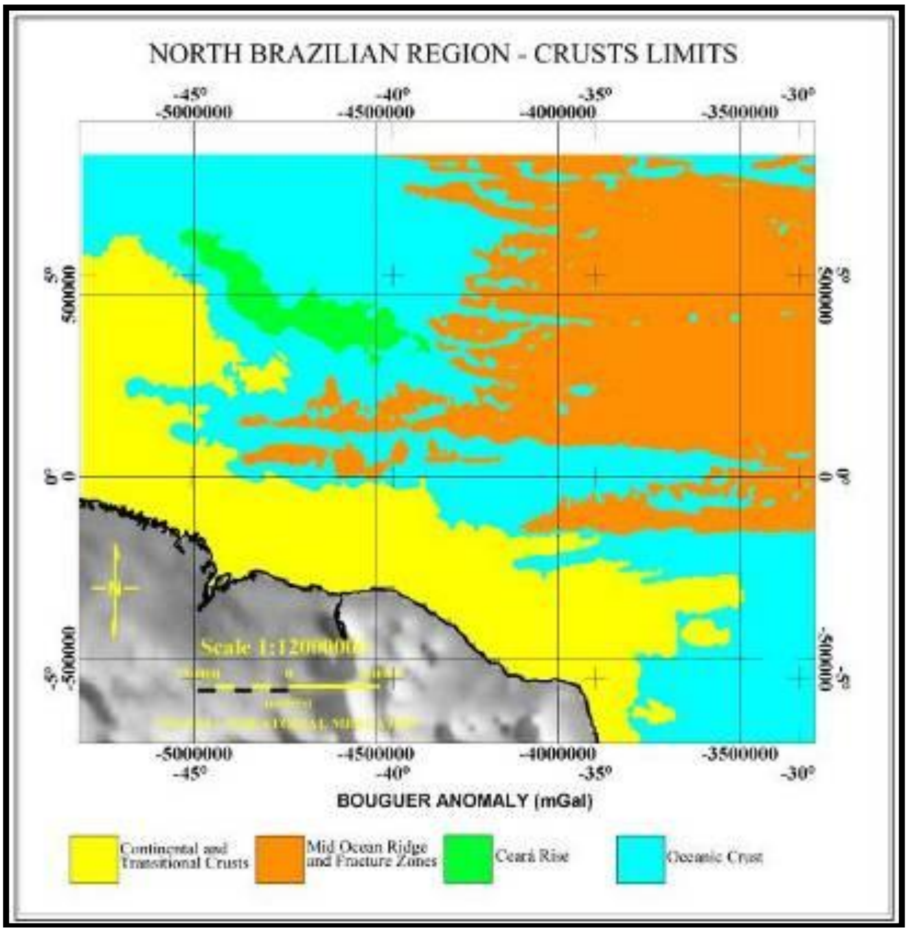

Figure 7 – Crusts Limits Map . The region concerning the CNB is completely inserted inside of area that represents the the limit of continental and transitional crusts.

The application of the seismic multichannel method provides an additional way to visualize the continuity of the ridge and its role as a structural barrier providing different domains inside and outside of the ridge. Figure 8 shows a detail of the seismic line S6 in the vacinity of the CNB seamounts and may be employed as an example of the ridge's action in the development of the margin in this region.

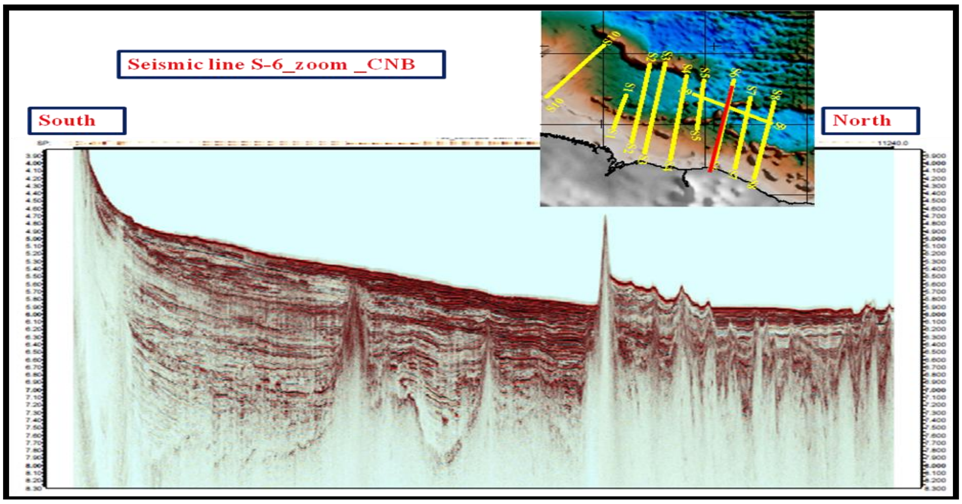

Figure 8 – Muitichannel Seismic profile S6 detail in the vicinity of the CNB. Note de difference between the seabed level, the seismic reflectors and basement inside and outside of the CNB feature.

5.2 – CNB System as a natural component of the Brazilian Equatorial Continental Margin

Volcanic or sedimentary, linear or not, rises, chains or ridge, appear as a common and sometimes distinctive submarine features in the passive continental margins. Paragraph 6 contemplates two types of submarine features in the continental margin, submarine ridge and submarine elevation, and introduces the concept of natural component:

"Paragraph 6 - Notwithstanding the provisions of paragraph 5, on submarine ridges, the outer limit of the continental shelf shall not exceed 350 nautical miles from the baselines from which the breadth of the territorial sea is measured. This paragraph does not apply to submarine elevations that are natural components of the continental margin, such as its plateaux, rises, caps, banks and spurs."

The expression: such as, in the list describing the features which may be classified as natural components, suggests that this one is not complete. The STG in paragraph 7.1.2 mentions three types of sea floor highs: oceanic ridges of the deep ocean floor, submarine ridges and submarine elevations; paragraph 7.1.3 admits that these terms are not precisely defined. Regarding NBR System, despite of what was previously showed like a natural prolongation of the continental margin, just a rapid comparison between the distance of NW-SE segment to the coastline (around 150 nautical miles) and the distance to the mid ocean spreading center (around 900 nautical miles) is an absolute evidence that the system can be not entitled as Oceanic Ridge. The System is linked to the continental margin and, as consequence, completely independent of mid ocean ridge feature process.

"Paragraph 7.1.2 - Article 76 mentions three types of sea floor highs:

- Oceanic ridges of the deep ocean floor (para. 3);
- Submarine ridges (para. 3);
- Submarine elevations (para. 6)."

"Paragraph 7.1.3 - None of these terms is precisely defined. It seems that the term "ridges" is used on purposes, but the link between the "oceanic ridges" of paragraph 3 and the "submarine ridges" of paragraph 6 is unclear. Both terms are distinct from the term "submarine elevations" of paragraph 6."

The STG in paragraph 7.1.8 mentions that distinction between "submarine ridges" and "submarine elevations" shall not be based on the name that the features are known in public domain but on basis of scientific evidence as presented in the own STG. Regarding NBR System (Jinno & Souza, 1999) the following names may be available: the complete feature "Cadeia Norte Brasileira (IHO-SCUFN Gazetteer); only the North part of the feature, "Cadeia Belem" (IHO-SCUFN Gazetteer) and only the South part of the feature "Parnaíba Chain" (ACUF – USA Advisory Committee on Undersea Features).

"Paragraph 7.1.8 - The distinction between the "submarine elevations" and "submarine ridges" or "oceanic ridges" shall not be based on their geographical denominations and names used so far in the preparation of the published maps and charts and other relevant literature. Such a distinction for the purpose of article 76 shall be made on the basis of scientific evidence taking into account the appropriate provisions on these Guidelines".

The STG paragraph 7.2.1 shows a list not complete (as mentioned in STG paragraph 7.2.2) of geological process that form oceanic and submarine ridges. The CNB System is contemplated only in the last option related rifting process that culminated with the break up between South American and Africa plates (Hayes & Ewing 1970, Gorini 1977, and Gorini 1981). This entitlement will be improved taking into account the provision of paragraph 7.2.4 once the CNB Ridge performed an important role in the development and growth of BECM.

> "Paragraph 7.2.1. - Ridges under the sea may be formed in a variety of geological processes, including:
>
> - Ridges formed by the sea-floor spreading and associated volcanic-magmatic processes;
> - Ridges formed along transform faults and created as an inherent part of the sea-floor spreading process;
> - Ridges formed by later tectonic activity resulting in uplift of oceanic crust;
> - Ridges formed by volcanic activity related to the movement of crust over a hot spot. These ridges are commonly composed of coalescing volcanic features or seamounts and generally occur on oceanic crust;
> - Ridges formed by interaction of oceanic crustal plates;
> - Ridges formed by regional excessive volcanism related to plumes of anomalously hot mantle;
> - Ridges associated with active plate boundaries and the formation of island arc systems. They could occur as active and inactive (remnant) volcanic arcs, and forearc and back-arc ridges. Such ridges commonly reflect different stages in the progressive development of island arc system and may result from variations in factors such as the rate and direction of convergence, and from the nature of the plate being subducted;
> - Ridges formed by rifting (extension and thinning) of continental crust. This process commonly forms broader features, such as marginal plateau and rises, but some times creates elongated slivers of continental crust separated by oceanic or highly extended continental crust."

"Paragraph 7.2.2. - This categorization of ridges is not exhaustive and complete owing to the variety of tectonic settings of the sea floor."

"Paragraph 7.2.4.- Some ridges located within the continental margins have been present since the early evolution of the margin and have influenced it since then. Because of their presence, sediment dispersal and thickness and the morphology of the sea floor may have acquired a unique configuration and individualization within the regional context."

The STG in paragraph 7.2.9 treats about the application of geological type of crust as qualifier to the classification of submarine ridge and submarine elevation although the CLCS admits that the criteria do not be the sole one. Regarding NBR System, as showed in the current paper as Crusts Limits Map (Figure 7), is completely outside of the region denominated exclusively by oceanic crust. The NBR System is inserted in the polygon which contours the region that delimited the continental and transitional crusts domain. This may be understood as important argument in order to entitle the NBR system at least as submarine ridge.

"Paragraph 7.2.9. - Article 76 makes no systematic reference to the different types of the earth's crust. Instead it only makes reference to the two terms:" the natural prolongation of

… land territory” and “the submerged prolongation of the land mass” of coastal States as opposed to oceanic ridges of the deep ocean floor. The terms “land mass” and “land territory” are both neutral terms with regard to crustal types in the geological sense. Therefore, the Commission feels that geological crust types cannot be the sole qualifier in the classification of ridges and elevations of the sea floor into the legal categories of paragraph 6 of article76, even in the case of island States.”

The STG 7.3.1 presents a not complete list of highs, suggesting the possibility of other types of “highs” may be included in the mentioned list and comments that the listed elevations are classified as “natural components” of the continental margin. Additionally, once that the feature is a natural component is important to consider the processes responsible by the development of the continental margin and the continent. As the geological processes has and had relevant role in the present continents shape they must be considered in the classification of a feature as submarine elevation. In the item b, of same paragraph, is presented considerations of Commission regarding passive continental margins.

“Paragraph 7.3.1. - The term “submarine elevations” in paragraph 6 includes a selection of highs: “such as plateau, rises, caps, banks and spurs”. The phrase “such as” implies that the list is not complete. Common to all these elevations is that they are natural components of the continental margin. This makes it relevant to consider the processes that form the continental margins and how continents grow. The growth of present continents is and/or was primarily caused by geological processes along the continental margins (e.g., Rudnick, 1995). Consequently, the Commission will base its views on “submarine elevations” mainly on the following considerations:

(a) ...

(b) In the passive margins, the natural process by which a continent breaks up prior to the separation by sea floor spreading involves thinning, extension and rifting of the continental crust and extensive intrusion of magma into and extensive extrusion of magma through that crust. This process adds to the growth of the continents. Therefore, sea floor highs that are formed by this break up process should be regarded as natural components of the continental margin where such highs constitute an integral part of the prolongation of the land mass.”

Concerning the adjustment of the CNB System to the STG provision on 7.3.1 the CNB System age, Hayes and Ewing (1970) proposed it around 100 My. As during the survey it was not dredged fresh rocks the age was not supported by means of rocks isotopic age. Combining crustal ages available in public domain database (NGDC, 2010) with bathymetric data (Torres & Villena, 2007) was generated a map (Figure 9) which shows that all CNB System age ranging between 80 and 100 My. Thomaz Filho at all (2000) suggest that the final break up between Brazil and Africa occurred in vicinity of Cumuruxatiba/Mucuri and Pernambuco basins around 90 My, coinciding with the second distentional event in the Brazilian Continental Margin described by Heilbron & Valeriano (1993). The LEPLAC Project carried out in the current year 17 fresh rocks sample in the CNB Seamounts. It is expected that laboratorial isotopic dating results of this sample will provide any contribution in order to clarify CNB age.

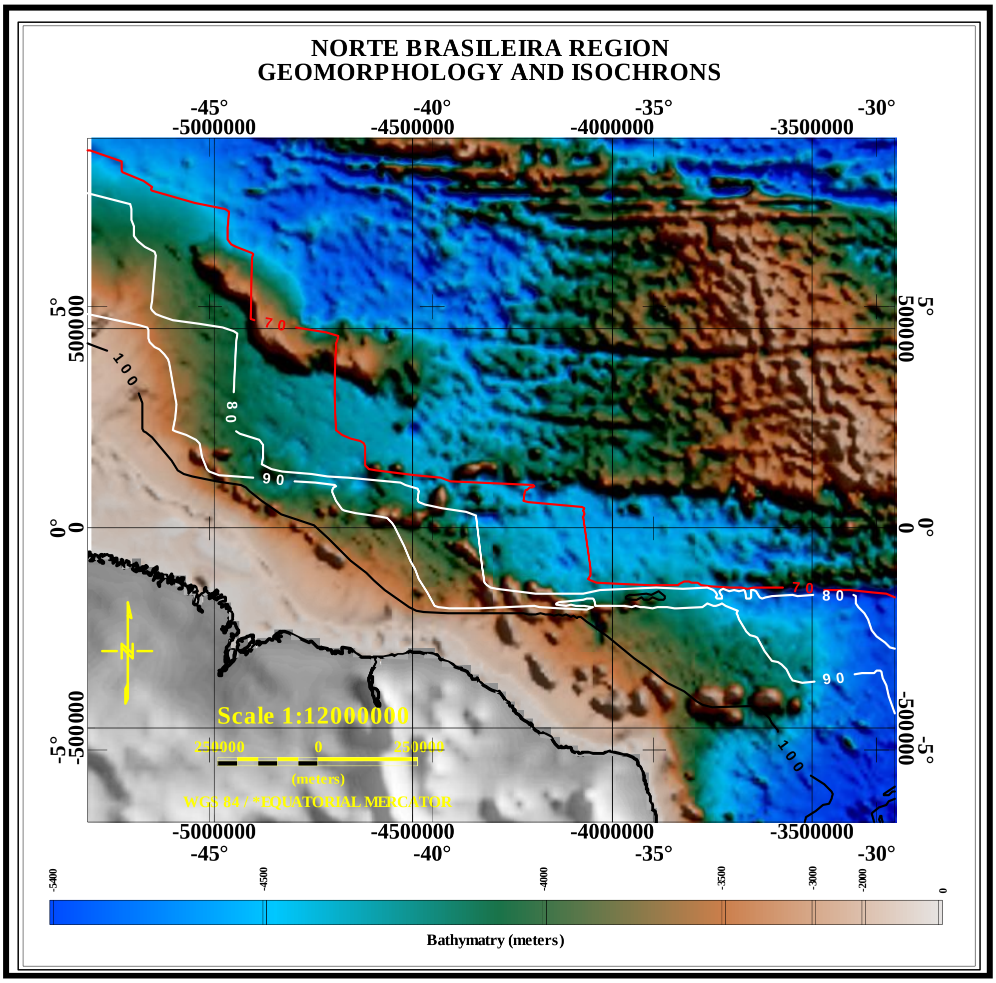

Figure 9 – Map combining geomorphology with isochrones of 70, 80 and 90 My.

Although there is some doubt regarding CNB age its importance in the development of BECM is clear. Figure 10 combines geomorphology with basement thickness depth which supports some remarkable considerations. The continuity of the CNB is highlighted by the red/pink zone superposing the CNB seamounts. This continuity is attributed to the feature characteristics of structural barrier. As consequence, two distinctive domains are created, inside and outside of the feature.

The sediment thickness depth is different inside and outside of the ridge as showed by the predominance of orange color outside contrasting with the green and blue colors inside.

Hayes & Ewing (1970) and Damuth and Kumar (1970) discuss the sedimentation pattern of the region and point out the Amazon River as the principal source of continental terriginous sediment. This southward sedimentation is conditioned by the Northern CNB and in the map is clear two routes. Part of the sediments pass outside of the CNB (green and orange zones) and the other part pass through the CNB Northern segment and deposit in its domain, as showed by the (orange, green and blue colors distribution) and in conjunction with the ones from Sao Marcos Bay and Parnaiba River.

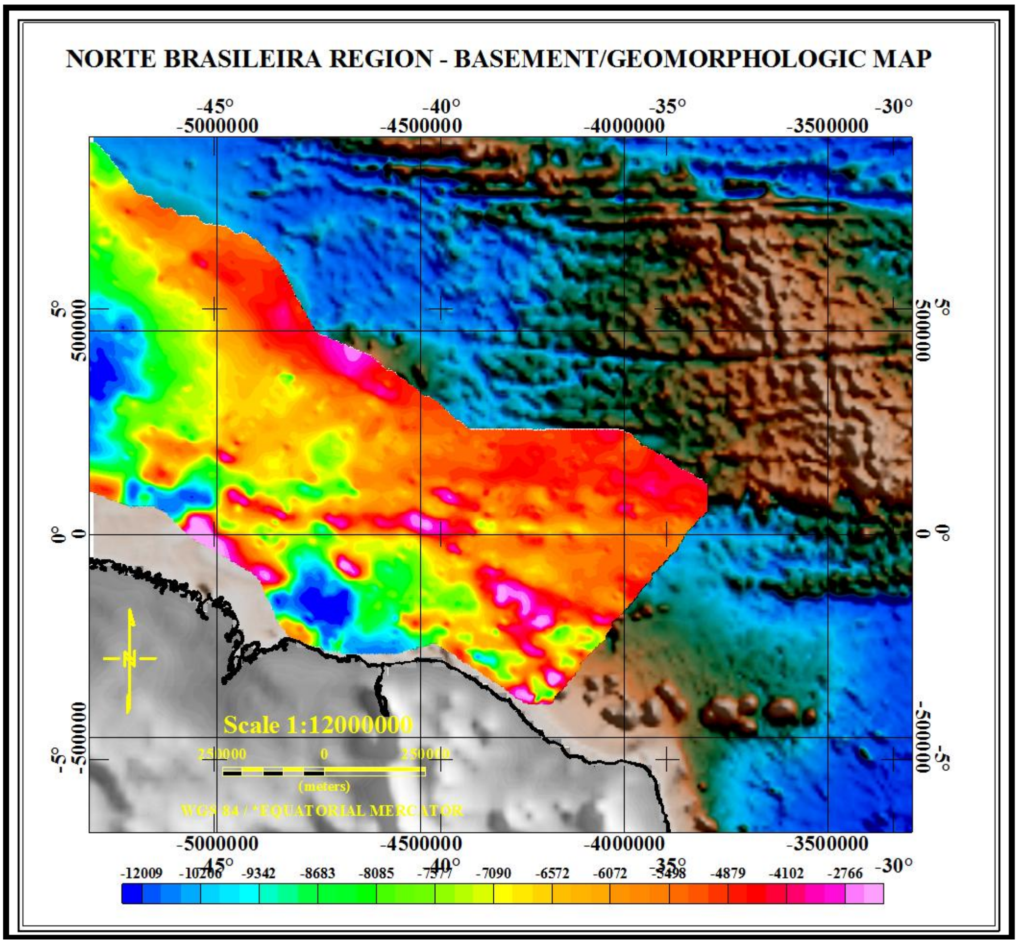

Figure 10 – Geomorphologic and basement map (CIRM, 2006).

As discussed in this paper the CNB has an important role in the development of the BECM. The morphology of the region was strongly conditioned by its presence. The system formed by the CNB per se and the confining continental sediments attributes to the region geomorphological characteristic similar to a plateau feature.

5 – Final Remarks

The UNCLOS and STG mention how difficult it is to classify a submarine feature as natural prolongation or natural component of the continental margin and shall not be based on the name that the features are known in public domain but on basis of scientific evidence as presented in the own STG.

As result of the recognized role performed in the development and in the growth of the Brazilian Equatorial Continental Margin, the Norte Brasileira Ridge System, composed by the Norte Brasileira Ridge *per se* and the confining continental sedimentation trapped by the structural barrier represented by the ridge since of its formation during the separation process between South American and Africa continents confirms that the system can be entitled as a natural component of the Brazilian Continental Margin.

The discussions and results showed in this paper, supported by scientific, legal and technical evidences, confirm that the Norte Brasileira Ridge *per se* can be entitled, at least, as a natural prolongation of the Brazilian Continental Margin.

Fernando de Noronha Ridge presents some geomorphologic, geophysical and geological similarities with Norte Brasileira Ridge and FNR also has a important role in the development of continental margin in its vicinity, so, the methodology applied in this paper if used in FNR may presents results concerning entitlement of the feature, very closer to the results discussed in the current paper regarding NBR.

The views in this paper are the authors' personal observations and do not necessarily reflect the official views of the Brazilian government.

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