# TECTONIC MODELING IN THE BARREIRAS GROUP, SOUTH COAST OF THE STATE OF BAHIA, BRAZIL, BASED ON HYPSOMETRIC DIGITAL MAP.

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## RESUMO
The Barreiras Group in northeast of Brazil, constitutes a sedimentary deposit originated by continental geological processes. In spite of the tectonic activity in Barreiras Group, previous studies reveal that Barreiras sediments have evidenced displacement as well as recorded joints and faults. This work aims to discuss about tectonic activity in modeling tablelands composed by sediments of the Barreiras Group in south coast of the State of Bahia, Brazil, based on digital hypsometric map. Three structural blocks were chosen in that region and the contour lines present in each block were transformed in points. The punctual data were interpolated, making possible the creation of continuous surfaces, a Digital Elevation Models (DEM). After then it was created an aspect map, with the reclassification for the directions N, NE, E, SE, S, SW, W and NW. For the three studied blocks some refinements have showed a conjugated pattern that, for the knowledge of the area, it defines the walls of the river valleys. In the block 1, this pattern appear in the NW and SE quadrants, while in the blocks 2 and 3 the conjugated pattern are observed in the NE and SW quadrants. Considering that the disposition of the drainages is perpendicular to the aspect of those quadrants, river valleys are oriented to NE in the block 1. The results have showed that main drainages in block 2 are to SE, predominating streams oriented between 91° and 120°. Main river valleys observed in block 3 have revealed that orientation between 121° and 150° predominates. Data obtained from elaboration of the aspect maps for the analyzed structural blocks, indicate that the last movement of the Barreiras Group did not occur in a homogeneous way. The strong influence of the neotectonics in the development of the observed relief has occurred during Pleistocene when basement faults were reactivated. As markers of this influence are the origin and tilting of the studied structural blocks. This tectonic tilting occasioned the divergence of the drainage directions observed in that blocks.

Key Words: Barreiras Group, neotectonics, aspect map.

## INTRODUCTION

The Barreiras Group outcrop along almost all Brazilian coastal line, from states of Rio de Janeiro to state of Amapá (Suguio & Nogueira 1999) and, in northeast of Brazil, constitutes a sedimentary deposit originated by continental geological processes (Mabesoone et al. 1972, Bigarella 1975). The Age of this unit varies from Miocene to Pleistocene (Suguio et al. 1986, Arai 1997). In spite of the tectonic activity in Barreiras Group, previous studies reveal that Barreiras sediments have evidenced tectonic displacement (Bezerra et al 2001, Lima & Vilas Boas 2004), as well as recorded joints and faults (Lima 2002). This work aims to discuss about tectonic activity in modeling tablelands consisting of sediments of the Barreiras Group in south coast of the State of Bahia, Brazil, based on digital hypsometric map.

## STUDY AREA

The studied area is located along the eastern Brazilian coast, south of the state of Bahia and is limited to the north by the João de Tiba River and to the south, by the Caraíva River (Fig. 1). In that area there are tens of kilometers of sea cliffs composed by the Barreiras sediments that constitute the edge of coastal tablelands. The studied area was segmented by Lima & Vilas Boas (2004) in three structural blocks, separated by fluvial valleys (Fig. 2).

## METHODOLOGY

It was used hypsometric map digitalized from the Costa do Descobrimento Project (2000). As used by Lima & Vilas Boas (2004), three structural blocks were chosen, with delimitations given by quadrilateral, what modified, partly, the dimensions of the study area for each block. The contour lines present in each block were transformed in points. The punctual data were interpolated, making possible the creation of continuous surfaces, a Digital Elevation Models (DEM). This is necessary because, most of the time, research in Geographical Information System (GIS) presupposes the origin of continuous surfaces starting from the disposed data. The analysis of those surfaces is made in a situation where the attributes are quantitative and they vary continually in the space (Eastman 1999). The generation of such surfaces is very useful in the understanding of the distribution of the space data and in the representation of the real world (Silva 1999).

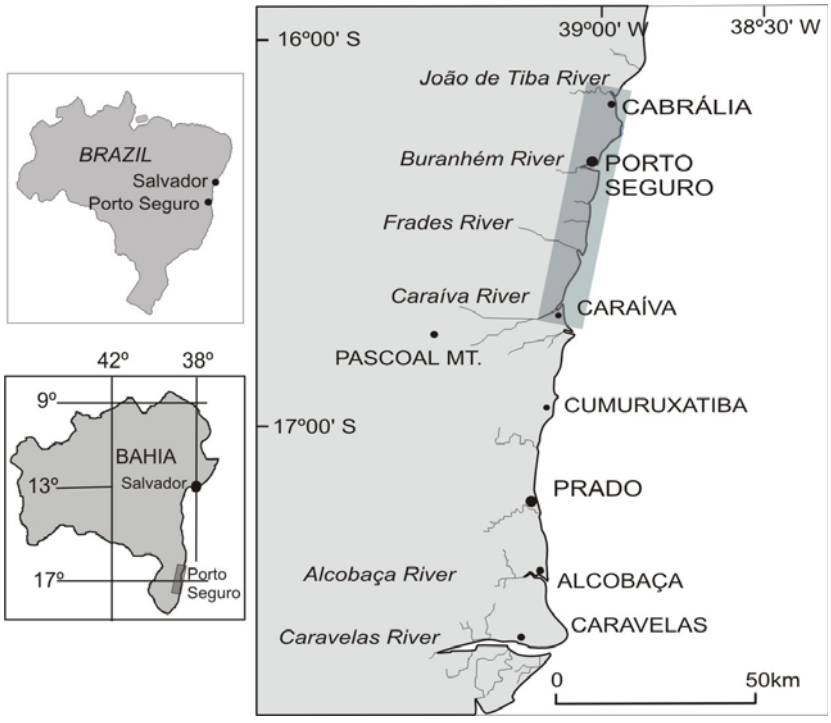


Figure 1 – Situation and localization map of the studied area.

A spacing of 100m was used for the points obtained from the contours with the coordinates being transformed in UTM (Universal Transverse of Mercartor) in the reference system WGS84. Utilizing the Idrisi® software, it was made a map of points in the vectorial format. After then, a raster generation of those information was made, so that, would possible from interpolated data, generate digital elevation model and aspect maps of each studied block. After the composition of the aspect map, that shows the direction where the surfaces of the land are faced, it was made a reclassification for the directions N, NE, E, SE, S, SW, W and NW. Other refinements were tried to improve the understanding and interpretation of observed data.

**RESULTS FOR THE BLOCK 1**

For the block 1 the DEM has showed, two horizontal plane areas differentiated by the altitude, with some reentrance of the lowest area, provoked visibly by the incision of rivers valleys in the highest area. The observed valleys however, did not show the whole extension of the drainages observed in the map of points and in the raster model. Except for the great structural lows that limit this block, the other canyons are NE in direction. This observation is also confirmed in the slope map, where the limits of those valleys are pointed out, since the prevalence of this block is horizontal areas or with very low slope.

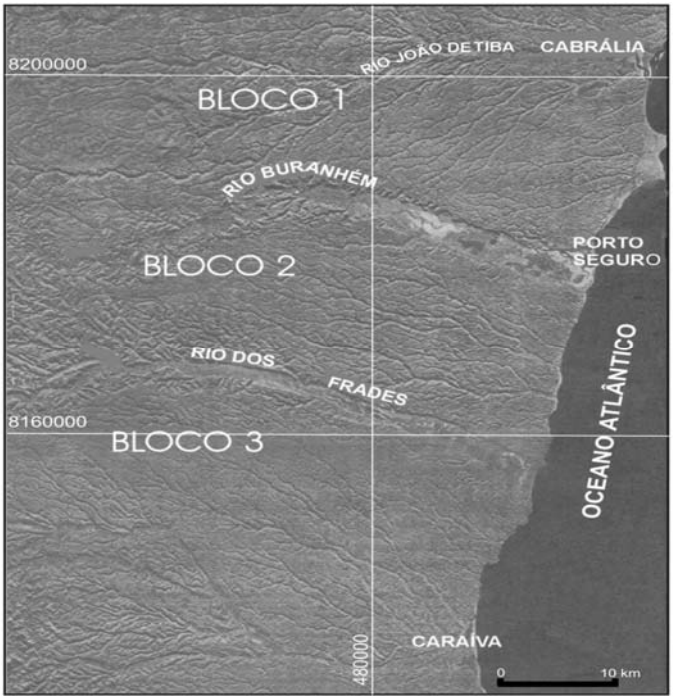


Figure 2 – Radar image of the three studied structural blocks.

The aspect map (Fig. 3a) shows more clearly that no horizontal surfaces ponder along valleys of present rivers, besides the sea cliffs along the coast. For a quantitative verification, the dimension of the horizontal plane areas was calculated and totaled 537.1 km$^2$. In relation to non-horizontal surfaces the total area is 97.1 km$^2$. Surfaces non-horizontal faced to SE obtained larger percentage with 22.9%; NW surfaces totalize 18% and those faced to NE amount 16.9%. Aspect maps were elaborated for each quadrant, with the intention of refining the information about of the orientation of the fluvial valleys present in the block 1. Two of those maps, get the attention, for having a distribution more or less continuous, and that visually possesses prolonged distribution in the direction NE-SW. One of them is the map of aspect only for the quadrant NW, that is, between N271º and N359º in relation to the true north and, the other is the map for the quadrant SE (between N91º and N179º). It is observed in that last one that a significant strip of the cliffs related to that block is faced to SE.

The union of the two quadrants in a unique map makes clear that, at least far away from the sea cliffs, the surfaces faced to NW and SE appear conjugated (Fig. 3b), forming a pattern that, for the knowledge of the area, it defines the walls of the river valleys that run for NE. The sum of the areas that constitute the surfaces faced to NW and SE is 40.9%, while for NE and SW the sum amount 28.1%. When influence of the sea cliffs is removed, it is observed that the sum of superficial areas faced to NW and SE arises to 47.1% of the total and that the conjugated pattern of the inclination of those quadrants is more evident. In that case, the quadrant SE totaled 23.1% while the quadrant NW is 24%.

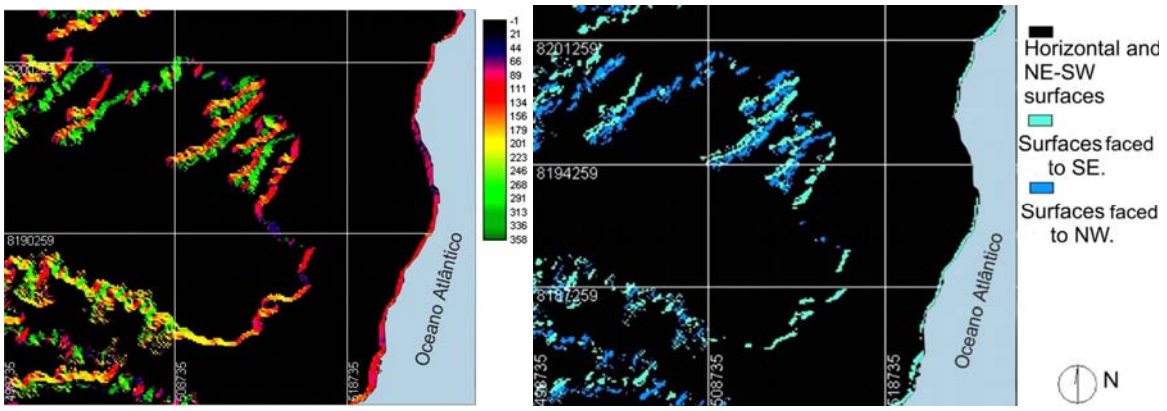


Figure 3 – (a) Aspect map of the block 1; (b) conjugated pattern showed by surfaces faced to NW and SE in block 1.

## RESULTS FOR THE BLOCK 2

Two interpolations were made for the block 2, one of them for the whole block and the other for a portion of the same that river valleys walls that limit the block and sea cliffs influences could be removed. Block 2 has an area 670.6 km$^2$. The digital model of elevation have showed three domains, where the reentrances are present again, between the two lowest blocks. In this case, however, the drainages, as already shown by Lima & Vilas Boas (2004), concentrate a SE and not a NE direction as in the previous block. Reclassifications from the aspect map (Fig. 4a) were made intended to observe the disposition of the horizontal and non horizontal surfaces. The horizontal surfaces also prevail in this block, with 542.5 km², while the surfaces that compose the rivers valleys and the sea cliffs totalize 128.1 km². The inclined surfaces are faced mainly to NE (24.7%), SW (19%) and SE (17.1%).

In the block 2 the conjugated pattern turn to appear among the two quadrants of larger percentile, that is, the quadrants NE and SW that define the walls of the rivers valleys rivers in this block (Fig. 4b), besides of the rivers valleys that limit it to north and south. The surfaces faced to NE and SW is 43.7% of the total non horizontal area. Eliminating the sea cliffs and the structural lows influence, the area totalizes 187.2 km$^2$, showing an increase in the percentile of the surfaces faced to NE (27.1%) and SW (22.1%). The sum of the two reaches 49.2%, while the areas tilted for the quadrant SE also increased, although not so much, to 17.3%.

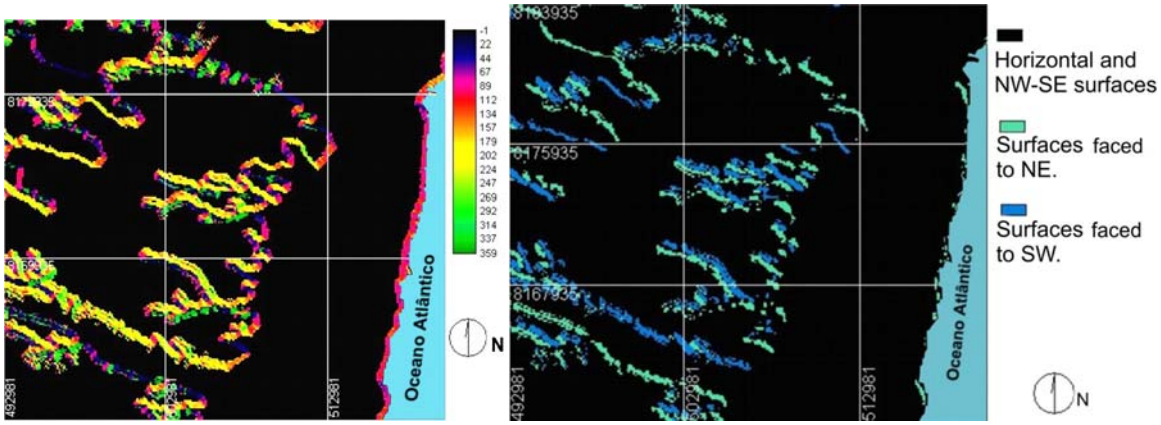


Figure 4 – (a) Aspect map of block 2, (b) conjugated pattern showed by surfaces faced to NE and SW in block 2.

## RESULTS FOR THE BLOCK 3

Following the same criteria for the previous blocks, two interpolations were made for the block 3. The total area of that block is 809.2 km$^2$ while, for the second interpolation the

area is 301.9 km$^2$. The DEM shows an area divided in two horizontal plans of different elevations, and there is a prevalence of the drainage pattern to the SE direction. The horizontal area showed in the aspect map totalizes 740.2 km², while the tilted areas are 68.9 km² (Fig. 5a). The larger percentage of the tilted area is distributed among quadrants NE with 24.2%, SW with 21.2% and the SE with 18.7%. The sum of the surfaces faced to the quadrants NE and SW is 45.4%. As in the block 2 the conjugated pattern turns to appear for those quadrants (Fig. 5b). In the Second interpolation the influences of the sea cliffs and of the valley walls that limit the blocks were removed. In his case, the sum of the areas faced to NE with those addressed for SW arises for 57 %.

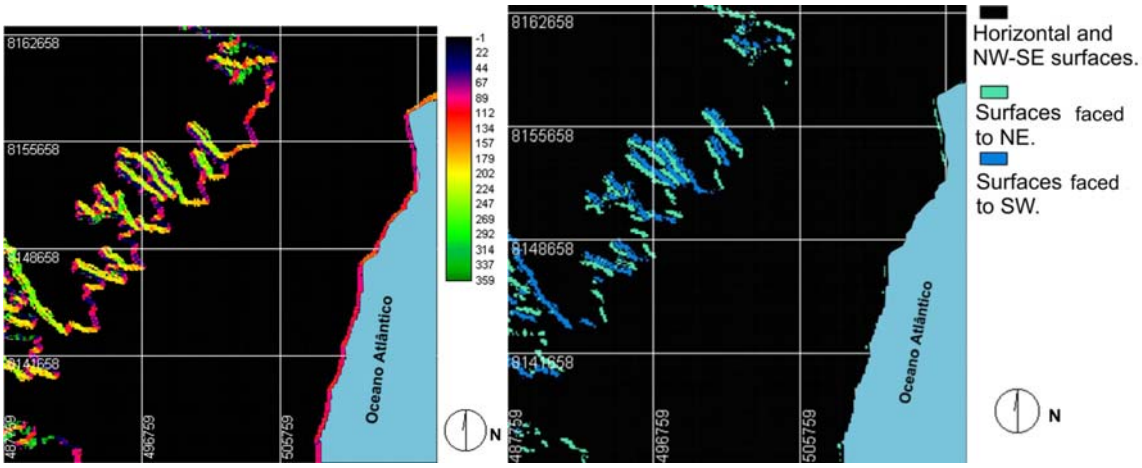


Figure 5 – (a) aspect map of block 3, (b) conjugated pattern showed by surfaces turned to NE and SW in block 3.

## DISCUSSION

Considering the prevalence of horizontal terrains in the studied area, there is not as affirming, at first, the tilting of the observed blocks under the influence of neotectonics. However, the digital elevation models and aspect maps have revealed some differences among the studied blocks, mainly concerning the main direction of river valleys presents in the same ones.

For the block 1, for instance, the walls of the river valleys indicate that the lines of larger steepness (drainage) are oriented to NE. To the interpolation elaborated for that block, removing the effects of the cliffs and of the scarps that limit it from structural lows, the sum of the surfaces faced to the quadrants NW and SE is 53.4%. Considering that the disposition of the drainages is perpendicular to the aspect of those quadrants, we can conclude that the percentage of the fluvial courses oriented to NE predominates. Between 1° and 30° percentage reaches 20.5%, between 31° and 60° is 44.3% and between 61° and

89° it is of 35.2%. These results were obtained take into account the aspect map. For the quadrant SE, the aspect revealed the following percentages for the orientation of the streams: 28.2% between 1° and 30°, 43.6% between 31° and 60°, and 28.2% between 61° to 89°. In spite of the results be different, the prevalence of the currents for the obtained data is in both cases between 31° and 60°.

The same systematic was used to blocks 2 and 3.The results have showed that main drainages in block 2 are to SE, predominating streams oriented between 91° and 120°. Main river valleys observed in block 3 have revealed that orientation between 121° and 150° predominates. In both situations, effects of sea cliffs and structural lows have been eliminated.

Except for the block 1, the analysis of the aspect maps are totally concordant with the results reached in the use of the method of the small squares for radar images (Lima & Vilas Boas 2004). In a general way, even for the block 1, the results obtained between the two above-mentioned methods can be considered similar. The difference observed between the methods should result of the limitation of the aspect maps, for areas where the surface of the land possesses an almost horizontal disposition and the interval of contour lines is relatively spaced (40m in this case). In this topographic terrain aspect maps do not show all the present drainages in the block, in other words, where the unevenness of the walls of the drainage pattern are not significant, the areas are considered by the program used as being horizontal. In spite of that limitation for lands of soft steepness, the elaboration of the aspect maps for the studied area, confirms the change in the orientation of the drainages considering the different studied blocks. This interpretation agrees with the information obtained from the method of the small squares on radar images propagated by Lima & Vilas Boas (2004).

## CONCLUSIONS

According to Lima (2002) the observed joints and the movement of structural blocks possess a character post depositional, since those features don't disturb the primary sedimentary structures. This fact, points a Quaternary age for the movement of the blocks studied in the present work.

Data obtained from field studies by (Lima 2002), analysis of radar images developed by (Lima & Vilas Boas 2004) besides the elaboration of the aspect maps for the analyzed structural blocks in present research, indicate that the last movement of the Barreiras Group did not occur in a homogeneous way as mentioned by Silva & Tricart (1980). The

strong influence of the neotectonics in the development of the observed relief has occurred during Pleistocene when basement faults were reactivated. As markers of this influence are the structural blocks, separate by valleys (structural lows). The origin of these blocks occasioned the divergence of the drainage directions in the several studied blocks.

Ratifying the observation made by Mendes et al. (1987), the block 1 suffered a tilting for northeast, causing a redirection of the main currents that end in João of Tiba River, although, the smaller ones, present in the southeast part of that block are orientated directly into the sea. The block block 2 did not suffer significant movement from Pleistocene to Recent age. In this situation river have maintained the original positioning, ending in the sea, with an approximate direction of E-SE. Lima & Vilas Boas (2004) observed a strong structural control evidenced by the abrupt deviation of some of the main currents, followed by straight domains indicating a control for lines of weakness orientated NW-SE.

The observed difference between the blocks 2 and 3 in relation to orientation of the drainage pattern shows a significant movement of the last one, with a deviation about 23º for the rivers of the block 2, evidencing a clear tilting for SE on the block 3.

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