Discovery Coast: The Brazilian Landscape First Sighted by Europeans

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Abstract

The Discovery Coast was the first landscape sighted by Portuguese explorers when they arrived in Brazil in 1500. This region's geomorphology is marked by the predominance of coastal tablelands, sustained by Miocene sediments of the Barreiras Formation, which were primarily deposited in tidal plains, tidal channels, and braided river systems. These tablelands are cut by wide, flat-bottomed river valleys and form sea cliffs when they reach the coastline. This last feature was presented in detail in the letter to the king of Portugal that communicated the discovery of Brazil and first described the physical aspects of the Brazilian territory. To the west of the tablelands, there is a mountainous relief sustained by a Precambrian basement, marked by an intricate system of fractures and dominated by siliceous metamorphic rocks. Other geomorphological domain of the Discovery Coast includes the Quaternary plains, which develop locally, beach rocks, and coral reefs. The predominance of flat relief in the tablelands, which is associated with weakness zones and represented by joints and faults related to Quaternary tectonics, promoted a morphogenesis in which tectonic forces tilted structural blocks. This morphogenesis changed the direction of the currents and the drainage pattern that develops along the Discovery Coast.

Keywords

Coastal tablelands • Barreiras formation • Sea cliffs • Quaternary plains • Quaternary tectonics

5.1 Introduction

The Discovery Coast (Fig. 5.1) has unique relevance for Brazil because it is included in the first geomorphological description of the South American continent made by the Portuguese sailors who arrived there in 1500 under the command of Pedro Álvares Cabral. The region has a hot climate with no dry season, an annual rainfall of approximately 2,000 mm Projeto Costa do Descobrimento 2000 (Discovery Coast Project 2000) and a mean annual temperature above 20 °C, which reaches a maximum above 30 °C in summer. Rainfall is concentrated between April and June and is influenced by cold fronts from the south.

Coastal tablelands predominate in the coastal zone (Fig. 5.2). These tablelands are sustained by Miocene sediments (Barreiras Formation), cut by U-shaped river valleys with flat bottoms and steep walls, and separated by horizontal interfluves. The tablelands reach the coastline, forming red and white sea cliffs, which are characteristic of the region. The Quaternary plain is discontinuous and narrow as a result of decreased sediment input to the region. Coral reefs occur along the entire section as do beach rocks.

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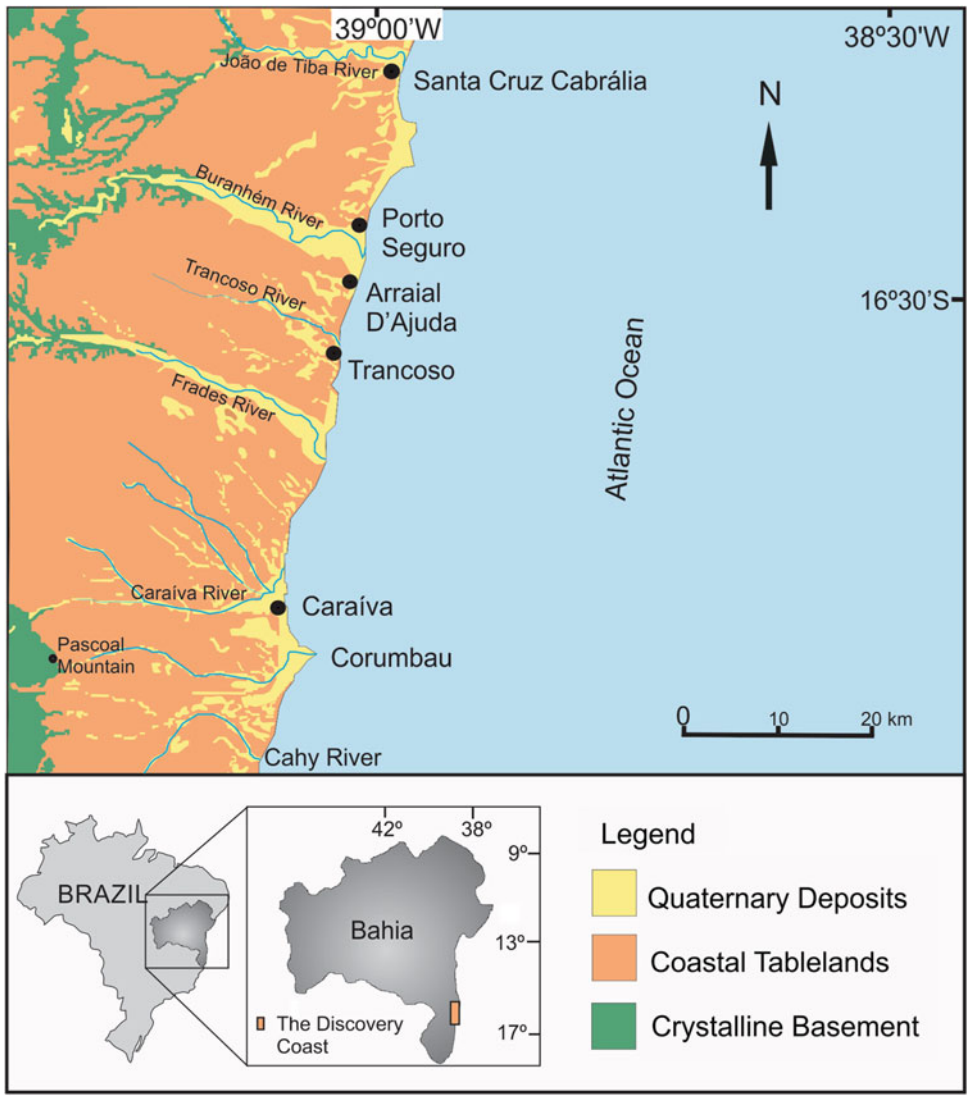

Fig. 5.1 The Discovery Coast. The map shows geomorphological domains with predominant coastal tablelands. The mountainous relief is sustained by crystalline bedrock in the west. Sediments of the Quaternary plains appear along the coastline. The Discovery Coast is located on the southern coast of Bahia State, Brazil

In the more internal coastal zone, a hilly and mountainous relief appears with peaks that are occasionally sharp. The hills and mountains are sustained by the high-grade metamorphic rocks of the crystalline basement (Fig. 5.2). One of these hills is known as Monte Pascoal (586 m a.s.l.) and was the first feature sighted by the Portuguese. These morphological attributes, which are associated with the historical and cultural value of this landscape, attract thousands of tourists to the region annually.

5.2 Historical Aspects of the Discovery Coast

The region known as the Discovery Coast, which is located on the southern coast of Bahia State, Brazil, was the first landscape sighted by the Portuguese explorers when they arrived in Brazil. The letter prepared by the onboard scribe, Pero Vaz de Caminha, and sent to the king of Portugal, reported the discovery of a new land, among other things, and faithfully described the region's geomorphology: "And so we continued our way through this sea until Tuesday the eighth day of the Easter, which were twenty-one days of April, said island being distant 660 leagues, according to what the pilots said, we came across some signs of land, which consisted of very many long seaweeds, that the navigators call 'botelho', and others that they named 'rabo-de-asno'. And next Wednesday morning, we came across the birds that they named 'fura-buxos'….On this day, in the evening, we made sight of land! First of a large mountain, very tall and round; and of other lower hills to the south of it; and low land, with large groves: the captain named the tall mountain Monte Pascoal, and the land, the Terra da Vera Cruz."

The coastal tablelands are described in substantial detail in another section of the letter: "This land, sir, from the southernmost point to the northernmost point, which we

Fig. 5.2 **a** Overview of the Discovery Coast with the coastal tablelands (foreground). The tablelands are cut by river valleys and exhibit cliffs along the coastline. In the background, the mountainous relief sustained by the lithologies of the crystalline basement can be observed; **b** The development of cliffs over several kilometers long marks areas where the coastal tablelands meet the coastline. The cliffs consist of Barreiras formation sediments that date from the Miocene

have seen since the port, is such that it will be as so twenty or twenty-five leagues of coast. Throughout the sea, in some parts, there are major red or white barriers; and the land on the top is low and full of large groves. From end to end, it's all beach-palm, very low and very beautiful."

After this historic letter, only in 1902 did American geologist John Casper Branner describe the geological–geomorphological coastal tablelands. Branner used the term "barriers," which occurs in the letter by Pero Vaz de Caminha, to designate the Barreiras Formation. This formation sustains the relief of these tablelands (quoted in Mendes et al. 1987).

The historical value of the Discovery Coast, which is associated with the presence of remnants of the Atlantic Rainforest, was decisive for the Brazilian government in creating the Monte Pascoal National Park in 1961. In addition, two other national parks were created: Discovery National Park and Pau Brasil National Park. These parks, in addition to a state park, integrate the conservation units present along the Discovery Coast.

5.3 Geological–Geomorphological Units of the Discovery Coast

5.3.1 Mountainous Relief—Crystalline Basement

The hills and sierras that form the crystalline basement on the Discovery Coast (Fig. 5.2) integrate the Eastern Pegmatite

Province of Brazil (Neves et al. 1986). The origin of these rocks is associated with the reworking of Archean rocks during the Transamazonian (920 Ma) and Brasiliano (570–540 Ma) tectonic cycles. The main lithologies that constitute the basement along the Discovery Coast are gneisses, granitoids, schists, calcosilicate rocks, and quartzites.

Morphologically, the crystalline basement consists of hills and sierras with a maximum altitude of approximately 600 m and topographical unevenness that can reach more than 200 m. The relief that makes up the high residuals of the basement is significantly dissected, with a drainage density that ranges from fine to medium. This intense dissection is related to the humid climate and its influence on rocks that possess an intricate system of fractures in the NE–SW and NW–SE directions, exerting strong structural control on the landscape.

In certain locations, structural features are revealed by straight river waterways or abrupt changes in valley orientation, although the drainage pattern is predominantly dendritic to sub-dendritic (Fig. 5.3). Where the coastal tablelands meet the residual elevations of the basement, sharp edges or ridgelines are formed, as exemplified by Monte Pascoal (Fig. 5.3b).

5.3.2 Coastal Tablelands—Barreiras Formation

The Barreiras Formation has practically continuous extension along the Brazilian coast, from Rio de Janeiro State to Amapá State (Suguio and Nogueira 1999). The age of these sediments has been attributed to the Miocene (Arai 2006; Rossetti et al. 2013), although many authors have found ages that range from the Miocene to the Pleistocene (Mabesoone et al. 1972; Bigarella 1975; Suguio et al. 1986). Regarding the source of the sediments that constitute the Barreiras Formation, Bigarella (1975) states that the lithology observed depends on the nature of the source area located near the sedimentation zone.

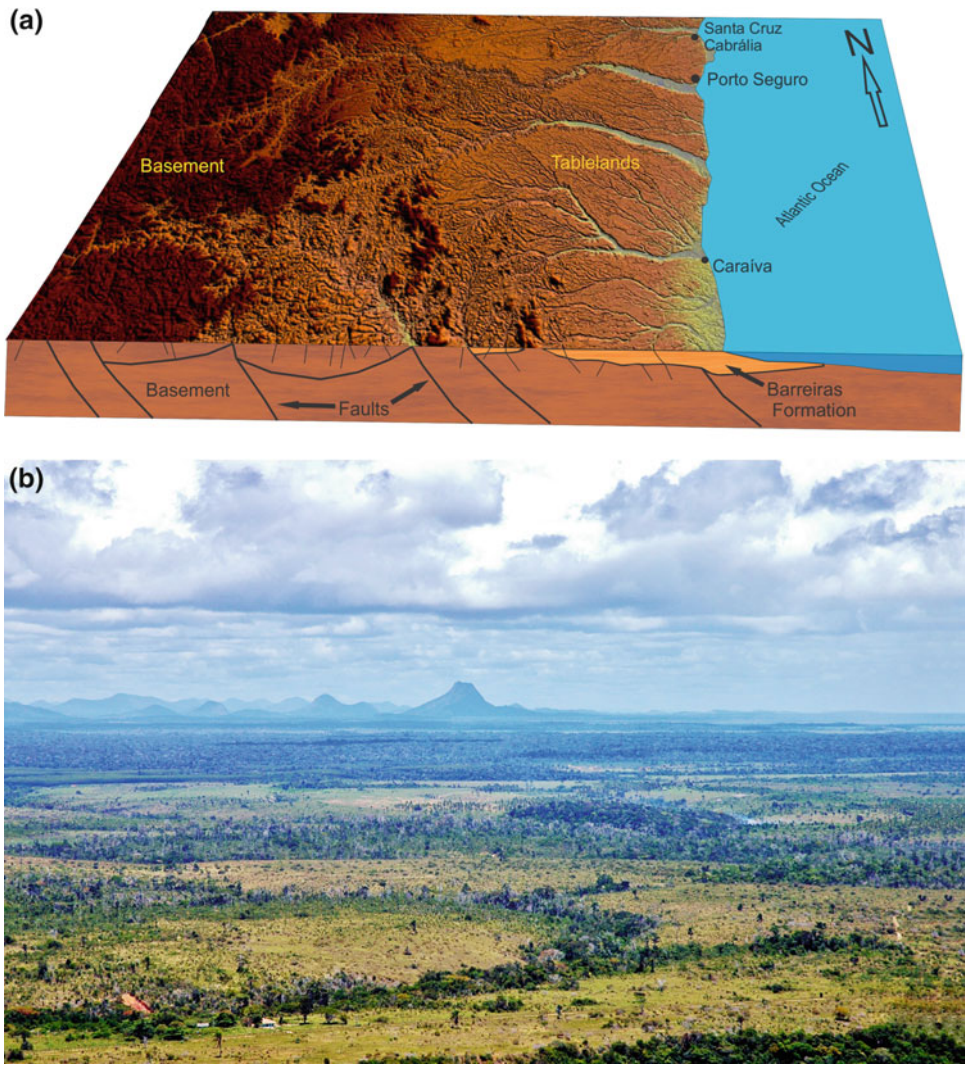

Fig. 5.3 **a** Schematic outline of the Discovery Coast showing coastal tablelands and high points of the basement. Note that the drainage appears with a dendritic to sub-dendritic pattern and occasionally accompanies the lineament; **b** Monte Pascoal, a rise in the crystalline basement that has substantial historical value because it was the first feature sighted by Portuguese explorers in the Brazilian territory

For the Discovery Coast, Lima (2002) documented the presence of black tourmaline and garnet in arcosic sandstones with angular and poorly sorted grains. These mineralogical characteristics indicate little chemical change and short transport before deposition. The presence of garnet, which is an unstable mineral, reinforces the idea of little reworking and the direct origin from the basement.

Lima et al. (2006) documented the facies diversity within the Barreiras Formation and found predominantly sandy and muddy sediments, with conglomeratic facies occurring locally. The sediments are texturally immature, dominated by sub-angular and more rarely sub-rounded grains. Mineralogically, there was an increase in the mineral maturity of the sediment from the bottom to the top.

Classically, the Barreiras Formation has been considered to be of continental origin (Mabesoone et al. 1972; Bigarella 1975; Lima 2002; Lima et al. 2006). However, several studies have identified sediments of marine origin in the coastal Pará (Arai 2006) and Maranhão States (Rossetti 2006). For the sediments of the Barreiras Formation on the Discovery Coast, Lima (2002) identified several channelized features that may coalesce, giving rise to thick sandstone packets that are 4 m or thicker. Several of these channeled bodies exhibit evidence of lateral migration, which corroborates the interpretation that the sediments were deposited in a braided fluvial plain (Lima et al. 2006).

More recently, Rossetti and Dominguez (2012) conducted a study on the Barreiras Formation throughout the coastal area of Bahia State and found diagnostic sedimentary structures of tidal processes and various ichnological associations representing coastal/transitional environments, similar to those documented for Brazil's northern region. These authors organized the sedimentary deposits of the Barreiras Formation in ten facies associations, which are predominantly marine-transitional. Among the most common lithofacies associations are mouth bars and tidal channels, which are associated with a deltaic structure. In addition, according to Rossetti and Dominguez (2012), the Barreiras Formation was deposited in onlap on older rocks of the Precambrian and Mesozoic, which occurred in association with a high sea level during the middle and lower Miocene.

The coastal tablelandstablelands on the Discovery Coast vary in width between 20 and 100 km and exhibit flat terrain with a slight gradient toward the sea. When the tablelands reach the coastline, they form active cliffs that are several kilometers long and reach up to 40 m high (Fig. 5.2b). In certain sections, inactive cliffs covered with vegetation mark the boundary between the tablelands and the Quaternary plain, or occur where the beaches are wider (Fig. 5.4). Wide, flat-bottom valleys, flanked by steep walls and associated with major rivers flowing into the region, cut the flat surface of the tablelands.

Fig. 5.4 Partially vegetated cliffs appear in areas in which the beaches are wider, which indicates little erosive action at these sites

The lithological homogeneity and flat surface favor the development of a dendritic drainage pattern on the tablelands. However, their slight slope toward the sea and, in several cases, to the northeast and southeast ultimately causes the local appearance of a sub-parallel pattern. In addition, several sections of rivers are embedded in fault zones, and some of these waterways abruptly change their orientation, which suggests a structural control on the regional drainage pattern (Lima et al. 2006).

The morphodynamics of coastal tablelands is linked to drainage density that ranges from medium to high and promotes uniform dissection of the relief, with shallow valleys that deepen toward the coast and are bordered by slightly curved convex slopes. In locations at which the sedimentary packet is thin or where the basement crops out, the dissection becomes, controlled by rocky substrate and fractures present in these rocks. Heavy rainfall has a significant influence on the morphodynamic processes, with the superficial runoff creating rills and gullies in the slopes of interfluves (Mendes et al. 1987).

5.3.3 The Quaternary Plain

Because of the decreased input of fluvial sediments to the coastal zone, a well-developed Quaternary plain is only present in the localities of Corumbau and the section between Porto Seguro and Cabrália (Fig. 5.5, see Fig. 5.1 for location), where protection provided by reef structures positioned beyond the coast favored accumulation of beach sediments in a process similar to that resulting in the formation of tombolos and salients. In these two Quaternary plains, there are beach deposits that have accumulated in association with the high sea levels of the Marine Isotope Stage 5e (123,000 years BP) and Marine Isotope Stage 1 (current). Other features of the Quaternary age and characteristic of the coastal zone are beach rocks and coral reefs.

The beach rocks represent ancient deposits of the surf zone cemented by calcium carbonate, later exhumed by coastline erosion. The cementing is typically superficial and extends up to 3–4 m thick. The ages reported for these sandstones are always less than the 7,000 cal years BP

Fig. 5.5 Aspects of the Quaternary plain on the Discovery Coast near the municipality of Santa Cruz Cabrália, Brazil. This small Quaternary plain was formed at the rear of a set of reef structures, also shown in the *photograph*

(Martin et al. 1999). The predominant sedimentary structures are cross-bedding stratifications, which formed under the action of longitudinal currents in the surf zone. Many occurrences of beach rocks on the Discovery Coast are associated with the mouths of large valleys that cut the coastal tablelands (Fig. 5.6) and are the testimony to the falling relative sea level during the Holocene.

The numerous reef structures on the Discovery Coast are found away from the coastline and form reef banks that occasionally reach several kilometers wide (Fig. 5.7). Their sides above the seafloor range from approximately 10 to over 20 m. Although located away from the coast, these reefs significantly interfere with the coastal dynamics by causing salients and tombolos. The flat top of these reefs has generally been attributed to a falling relative sea level of approximately 3–4 m, which has affected Brazil's eastern coast over the past 5,000 years.

5.4 Morphotectonics and Evolution of the Relief

Several morphotectonic features present on the Discovery Coast have been emphasized since 1980s. For example, Tricart and Silva (1968) drew attention to the gentle tilting of the coastal tablelands to the southeast, which would continue throughout the continental shelf. Additionally, various alignments of valleys and depressed areas are targeted according to the orientations of Precambrian basement faults, which may represent a recent reactivation of these weakness lines. Moreover, according to Tricart and Silva (1968), several evidences in coastal deposits suggest tectonic movements. Among these movements is the right-angle form of the tributaries of the Trancoso River (see Fig. 5.1 for location), which also suggests reactivation of Precambrian lineaments.

Fig. 5.6 Mouth of the Buranhém River in the city of Porto Seguro, Brazil. It is partially blocked by beach rocks, such as the one shown in the *photograph*. These rocks represent ancient beach deposits cemented by calcium carbonate and later exhumed by the erosive retreat of the coastline

Fig. 5.7 Recife de Fora near the city of Porto Seguro, Brazil. This is a typical example of a reef whose top was flattened due to reworking by waves

For the section between Porto Seguro and Santa Cruz Cabrália, Mendes et al. (1987) and Bittencourt et al. (1999) suggested a clear tilting of the coastal tablelands to the NE, which is evidenced by the alignment of the drainage pattern in the block located north of the Buranhém river valley, where the river borders a fault plane (Fig. 5.8).

Lima et al. (2006) noted the existence of three high blocks separated by structural lows, which correspond to the valleys of the region's main rivers, between the cities of Cabrália and Caraíva (Fig. 5.8a). The drainage patterns observed on the surface of these blocks suggest their differential tilting. The homogeneity of the sediments that support the coastal tablelands in the region theoretically favors the development of a dendritic drainage pattern.

In block 1, located between the structural lows represented by the João de Tiba (Fig. 5.8b) and Buranhém river valleys (Fig. 5.8c), the longest river courses tend to be parallel and flow NE (N70°), and most of the tributaries display this pattern. For block 2, which is bordered to the north by the Buranhém River and to the south by the Frades River (Fig. 5.8d), the river courses are directed E–SE (N106°). Certain drainage anomalies observed in this block are related to fractures, indicating structural control in certain sections of the rivers. In block 3, which is bordered to the north by the Frades River and to the south by the Caraíva River, the average direction of drainage is N129°, with the primary courses flowing into the Caraíva River, indicating that the block tilts to the SE (Fig. 5.8). One of the longest tributaries of the Caraíva River has a straight NW–SE course, which suggests that the river is controlled by a fault zone.

These observations suggest post-sedimentation tectonic reactivation with sufficient intensity to promote the tilting of blocks, thus modifying the drainage pattern. Lima and Vilas Boas (2004) suggested that the regional drainage pattern, originally dendritic, was reshaped by the tilting of blocks during the Quaternary.

Faults were observed by Lima (2002) and Lima et al. (2006) to affect the Barreiras Formation sediments and associated Quaternary deposits, indicating tectonic reactivation during the Quaternary. This reactivation helped shape the relief currently observed. In addition to the faults, these authors found conjugated systems of neotectonic joints in the directions NE–SW and NW–SE. Statistical analyses of

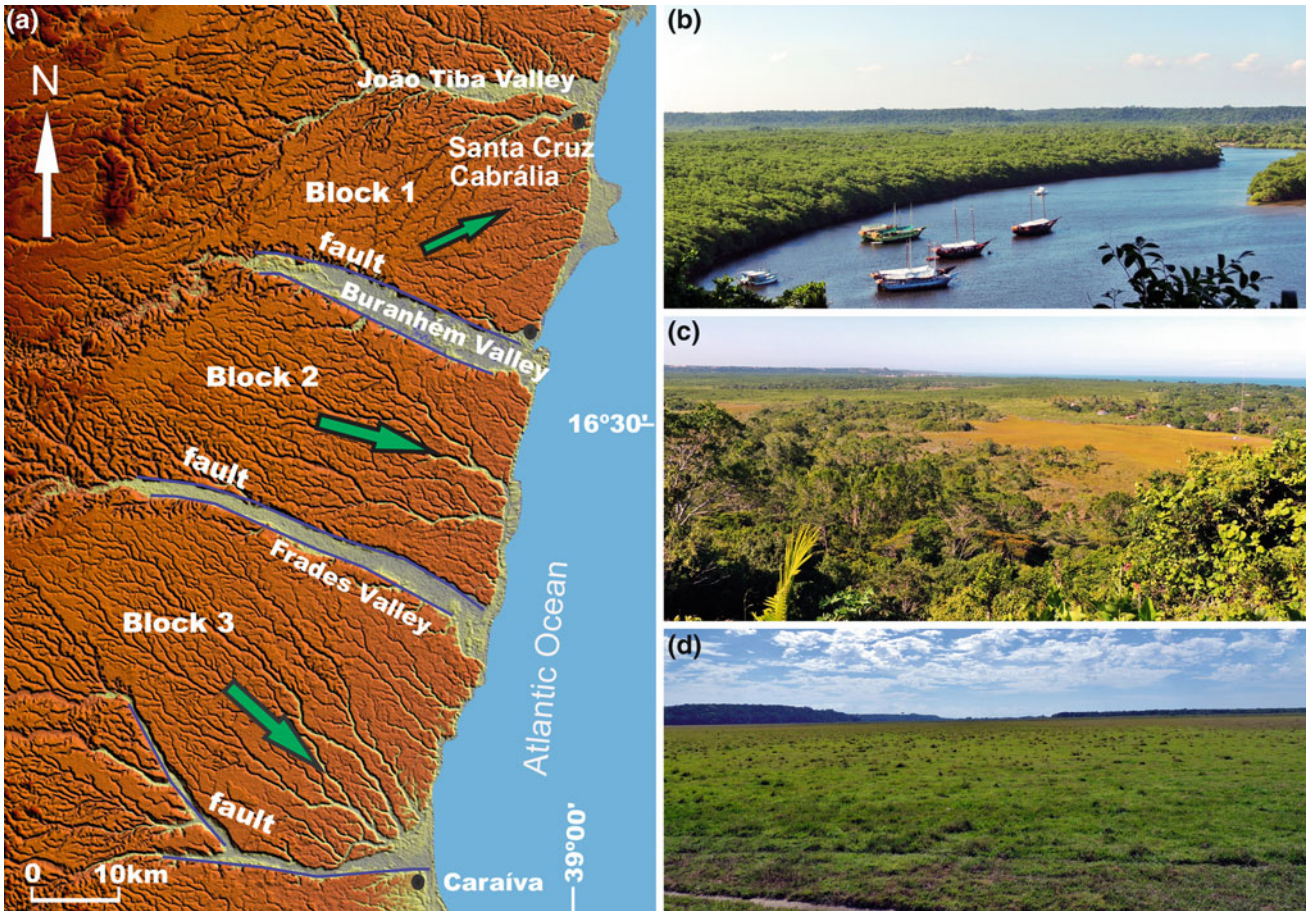

Fig. 5.8 **a** Structural blocks bordered by faults between the municipalities of Santa Cruz and Cabrália Caraíva, Brazil. Hypsometric map showing the three structural blocks. *Arrows* indicate the general direction of drainage for these three blocks (modified from Lima 2002; Lima and Vilas Boas 2004; Lima et al. 2006); **b** João de Tiba river valley; **c** Buranhém river valley; **d** Frades river valley

the joints by Lima et al. (2006) revealed that the maximum compression, which is currently experienced by the sediment that sustains the tablelands, has a NW direction, forming a 25° angle with the coastal zone's overall orientation.

5.5 Conclusions

The geomorphology of the Discovery Coast is represented by three domains. The first consists of a hilly to mountainous relief, which is substantially dissected, marked by sharp edges or ridgelines, and sustained by a crystalline basement. However, the most representative geomorphological domain consists of the coastal tablelands. These tablelands are flat, horizontal, or exhibit a gentle slope toward the coast and are cut by broad river valleys with flat bottoms and steep walls. Along the coastline, Quaternary plains have developed in certain locations, which are represented by beach deposits that have accumulated as a result of the high sea levels that occurred during the Quaternary. The development of the relief along the Discovery Coast was significantly influenced by Quaternary tectonics, which was responsible for the origin of faults and joints. These faults and joints are the result of paleotensions in the NW–SE direction. Several of these faults promoted the tilting of structural blocks, which induced changes in river flow direction and altered the drainage pattern that developed on the structural blocks of the coastal tablelands.

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