

EVOLUTION OF THE GEOMORPHOLOGY OF THE COAST OF THE STATE OF PARA, BRAZIL

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Résumé

Entre l'embouchure de l'Amazone à l'ouest et celle du rio Gurupi à l'est, sur environ 600 km, il existe deux types physiographiques distincts de côtes sur la façade atlantique de l'Etat du Pará (Brésil), séparés par la baie de Marajó. A l'ouest de cette baie, une côte d'émergence, développée à partir de dépôts holocènes, forme la marge nord de l'île de Marajó. Parcourue par le bras sud de l'Amazone, cette portion de côte est rectiligne, contournée par de bas cordons sableux, avec quelques rares petits cours d'eau. A l'extrémité de l'île, entre la baie de Marajó et l'océan Atlantique, il existe des plaines de marées bien développées au cap Maguari. Ces plaines peuvent atteindre 30 km de long à marée basse.

A l'est de la baie de Marajó, la côte de submersion est continue jusqu'à la baie de São Marcos (Maranhão). Cette côte, très découpée, présente de nombreuses baies dans lesquelles viennent se jeter des rivières à larges embouchures à caractéristique de canaux de marées, limitées par des péninsules et par des îles s'avancant dans l'océan. Près de l'embouchure de la baie de Marajó, les falaises sont découpées dans les dépôts limoneux et sablo-argileux du groupe Barreiras datant du Mio-Pleistocène. Les affleurements de la formation Pirabas (Miocène) restent limités sur cette côte. Vers l'ouest, la formation Barreiras s'éloigne de la ligne de côte, remplacée par des îles et par des péninsules formées de sédiments modernes, avec de larges plaines de marées. Ces plaines sont occupées par de la mangrove et des marais dont les zones les plus éloignées sont limitées par des bancs de sable. Des cordons sableux de type "cheniers" apparaissent irrégulièrement, isolés par la mangrove et éloignés de l'actuelle ligne de rivage. Quatre types morphologiques ont été décrits pour cette côte: les falaises, les dépôts de mangrove, les plaines de marées et les cordons sableux. La carte géomorphologique de la région a été élaborée à partir des études d'images radar, d'interprétation de photographies aériennes et de contrôles sur le terrain.

Summary

Two different physiographic types of coast occur on the Atlantic border of the State of Pará. They extend about 600 km. between the mouth of the Amazon River on the west and the mouth of the Gurupi River on the east, abruptly divided by the Marajó Bay. In fact, to the

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west of this bay the shoreline of emergence, which develops in holocenic deposits, form the north coast of Marajó Island; the shoreline of submergence, to the east of the bay, is continuous until the São Marcos Bay (State of Maranhão).

The geomorphological features occurring on this coast described in this paper are: cliffs, mangrove deposits, tidal plains and beach ridges. The geomorphological map, which was produced by the interpretation of remote sensing (radar sheets and aerial photos) and field studies, shows the geographical distribution of these features on the coast. The north coastline of Marajó Island is smooth, continuous, broken only by rare, short tidal channels. On the contrary, the continental coastline is very irregular, showing a succession of small estuaries, forming bays bordered by peninsulas and islands extending into the Ocean.

The occurrence of these types of coast is related to the origin and evolution of this region during the last 6000 years. Some evidence shows that Marajó Island was a part of the continent at least until the Flandrian Transgression, enclosing a very large estuary of a big river that drained to the north-east. Some paleochannels occurring in the plains of Marajó Island, continuous also in the Caviana and Mexiana Island to the north of Marajó, indicate the original fluvial environment and the outlines of the paleogeography. Heavy minerals studies confirm the provenance of the sediments of the Tocantins-Amazon System. The very high rate of sedimentation found in the upper 6000 years sequence in the central part of the island indicates rapid subsidence. On the other hand, C14 data from the north-east region of the island indicates a very low rate of sedimentation showing that in this time this area operated like a hinge between the continent and the subsiding area of the island. There is some evidence that indicates that the continental coast and Marajó Bay had their origin influenced by tectonism. The modern beaches and beach ridges of this coast are made up of reworked sand of the pleistocenic Barreiras Formation according to some studies carried out on heavy minerals of this sediment.

Mots-clés : Ile de Marajó, côte Nord du Brésil, littoral de l'Etat du Pará, côte d'émergence, côte de submergence, géomorphologie, néotectonique

Keys-words: Marajó Island, north coast of Brazil, coast of the State of Pará, emergence and submergence shorelines, geomorphology, neotectonism.

I - GENERAL INTRODUCTION

Two types of coasts, differing from the physiographic point of view, occur on the Brazilian north Atlantic border. They extend about 600 km. from the south side of the estuary of the Amazon River in the NE part to São Marcos Bay in the

SE end. Marajó Bay - which is the large estuary of the Pará River, about 200 km. long and 50 km. wide - abruptly divides these two geographic features (fig.1).

Generally the geology and the geomorphology of Atlantic coastline of this region were considered with the regional geology of this area. In fact, we don't have any specific paper on the geomorphology of this region, in spite of the dimension of this coast and of the violent phenomena that take place there, owing to the influence of the discharge of the Amazon River. Some information about the geology of the north coast of Marajó Island can be found in the final report of the integrated studies of this island by the group for hydrological research of IDESP (1974) and in the RADAMBRASIL REPORT.(1974, V. 5).

The most important papers on the continental coast are the papers by AKERMAN (1969), FRANCISCO et al. (1971) and the report of the research developed for economical purposes by the geologists of CPRM, including the geological map of the region, in scale 1:100.000 (1977). FRANZINELLI, in a detailed paper (1982), presented the geomorphological map of a part of this coast, with emphasis on the occurrence of the modern environment of sedimentation and taking also into consideration some neotectonic problems that influenced the development of this coastline.

This paper aims to show some results obtained by the interpretation of remote sensing (radar sheets and aerial photos) and field work carried out along the coast of Marajó Island and the continental Atlantic coast.

Access to field work in the north coast of Marajó Island is very difficult. In fact, the demographic density is very low and only two small villages, in the western part, Afuá and Chaves are notable. Owing to the lack of roads it is only possible to reach these places by boat, circumnavigating the island, or by small plane, landing in an open field. More people live in the continental part of coast, where there are numerous small towns: Salinas, Curucá, Marudá, São João de Pirabas, Japerica and Quatipurú, that are in communication with the capital of Pará State, Belém, by paved roads.

According to TANCREDI AND SERRA (1986) the climate of Marajó island is tropical humid, corresponding to type AFI-AMI (Koppen), where the annual pluviocity is about 2700 mm/year, concentrated between January and June. On the continental coast, the pluviocity is less, according to LIMA et AL.(1977). Here the climate is similar to type AM, subtype AMW (Koppen). The winds

blow most frequently in the dry season from the NE direction. Very important is the influence of the tides on the coast, channels, rivers and in Marajó Bay. The greatest amplitude of the tides is 5.3 meters registered in Salinópolis.

II - REGIONAL GEOLOGICAL SETTING

SCHALLER et al. (1971), investigating the stratigraphy of the Amazon Cone sedimentary basin, gave the name of PARÁ GROUP to the clastic sediments occurring from the Late Miocene to the Holocene in the region of the Amazon mouth and extending above the north continental shelf from Amapá to Pará States.

The PARÁ GROUP is made up of clastic sediments deposited in fluvial to paralic environments on the continent and neritic environments on the shelf.

The set of this clastic group was separated into two stratigraphic units:

- on the bottom, the PIRARUCU Formation, mainly shale, that has a thickness of about 700 meters in its thickest portion and rapidly diminishes towards the continent.

- on the top is the TUCUNARE Formation, made up of medium to coarse quartz sand, poorly sorted. This Formation outcrops in the north region of Marajó island.

The BARREIRAS Formation, correlated to the Tucunaré Formation, consists of yellow and pink sandstones and red clays, deposited in a continental environment, in the Late Miocenic to Pliocene age (ARAI et al, 1988) or Plio-Pleistocenic age. (MORAES REGO, 1930). It is characterized by lateritic concretions that sometimes form ferruginous beds owing to the high degree of lateritisation. The Barreiras Formation outcrops in the southeast border of Marajó island, near the south side of the Paracauari River mouth where twelve meters high cliffs occur, engraved in this formation. In the north side of the Paracauari river mouth, along the coast and inland this formation decreases in height and quickly disappears covered by the modern sediments. The Barreiras Formation is continuous along the Atlantic continental coast, from the southeast edge of Marajó Bay, and it shows good outcrops in cliffs. Only in two places, Salinas and Ilha de Fortaleza (fig.2) does it lay above the PIRABAS Formation, which is marine, calcareous and Low Miocenic in age.

Modern sediments of the seashore are sand, silty sand and clays deposited by different hydrodynamic processes.

III - GENERAL STATEMENT OF THE COASTLINE GEOMORPHOLOGY

The distinctive processes of sedimentation in progression along the Brazilian coastline permit its subdivision into several parts or provinces. (MENDES, PETRI, 1971). According to these authors, the Atlantic coast lying between latitudes 4 degrees N to 2 degrees S and longitudes 52 degrees to 44 degrees W, belongs to the first province extending from the mouth of the Oyapoque River in Amapá State to the estuary of the Itapequirim River in Maranhão State. This province is characterized by flat, low coasts, with sediments composed mainly of clay deposited in mangrove swamps, the Quaternary sedimentation occupying a very wide area.

In reality, this coastal province, shows a great diversity of geomorphological aspects as a result of different geological setting, variable hydrodynamical processes along its length, and, the most important parameter, different responses to the neotectonic effects. In fact, the north coastline of Marajó Island is smooth and continuous broken only by short sandy ridges either near or at a distance from the coastline, maximum 4 meter high, that are backed by the swampy plain region of the island. Occasionally, short tidal channel occurs on this coast, except for the Tartaruga channel that links the Ararí Lake, located in the central part of the island, to the ocean. However, a part of this channel is artificial. Tidal flats, developed at Cabo Maguari, on the east end of the island, between the mouth of Marajó Bay and the Atlantic Ocean, are very wide and conspicuous. Extending a distance of more than 30 km they are completely submerged by the water during the high tides; they are made up by silty-sandy sediments and transversed by short tidal channels of different sizes.

To the east of Marajó Bay, the continental coastline belongs to the littoral of "rias" according to BARBOSA et al.(1973) and FARIA JR. (1987). This coastline is very irregular, showing a succession of small estuaries forming bays bordered by peninsulas and islands extending into the ocean. One can distinguish two primary geomorphological features on this coastline:

- the first one, from Marajó to Pirabas Bay (fig.7,8,9) is characterized by low terraces sculptured in the red plio-pleistocenic rocks, that reach the ocean, where they form cliffs. Mangrove deposits are present only along the rivers that penetrate into the continent.

- the second one, to the east, where the clastic tidal flats are very developed, consists of wide mangrove deposits bounded by white beach ridges on the seashore (fig.9,10). To the landside, the terrace of the red plio-pleistocenic rocks are lower and extend into the continent.

IV - COASTAL FEATURES

From geomorphological point of view, one can distinguish four different features all along the studied coast, which are ²:

- a - Cliffs
- b - Mangrove deposit
- c - Tidal plains
- d - Beach ridges.

A. The cliffs

Only in one place on the north coast of Marajó Island do cliffs exist, developed in the friable, coarse, badly sorted sand of the Tucunaré Formation. This cliff forms a north side of a terrace, about 5 meters high, that seems to be the remnant of a large paleo-channel formed during the last stage of sedimentation on Marajó Island. It is about 3 km long facing to the sea and gently drops at its ends to a low, dark, fine sediment, probably an ancient swampy deposit. This cliff - as are all on the north coast of Marajó Island - is terminated by very narrow sandy fringe, causing the outline of the foreshore to be very steep.

The Amazon south channel, which originates from a braching of the main channel of the Amazon at the west end of Marajó Island, bathes this coast. The erosion power of this stream is very strong and allied to the actions of waves and

(2) The geographical distribution of these features is show in the geomorphological map of this region (Fig. 4,5,6,7,8,9 and 10) and some details of the relationships can be observed in Fig. 11 and 12.

to the running water of the very abundant rain above the friable, coarse material of the cliff, causes its rapid collapse. In fact, the erosion rate is nearly one meter a year or more, in this place.

Also on the southeast side of Marajó Island abrupt cliffs occur along Marajó Bay, but like in the east border of this bay and in the continental coastline, the cliffs are always developed in the red, lateritic rocks of the Barreira Formation. The height of these cliffs varies between one to twenty meters (Fig. 2 and 3) and they are not continuous. In some places the cliffs reach the ocean and their bases are constantly swept by the waves, the erosion causing the accumulation of blocks and pebbles. In other places the cliffs were completely eroded and destroyed, leaving in the water low sharp floors of hard lateritic material covered by sand, or beaches shingles composed of ferruginous pebbles. This situation is common on the shelf near the east side of the mouth of Marajó Bay where large shallow shoals of this type exist. They are called "corôas" and are very dangerous to navigation. They show vestiges of ancient cliffs in the Barreiras Formation that existed in this place. However, cliffs reaching to the ocean occur in some isolated places, especially at the ends of peninsulas that protrude into the ocean, as well as in the deepest parts of the small bays.

PONÇANO (1985, in FARIA, 1987) related in this region, two levels of abrupt coast with cliffs: one, formed by modern and active cliffs on the coastline and the second inland, formed by "dead" cliffs, more ancient and lower. The second circumstance can be observed at the mouth of the Paracauari River at the east border of Marajó Island.

There, these two levels of cliffs are present; the "dead" on the north side and the active on the south side of the mouth of this river. Dead, abandoned cliffs are especially common in the east coast, from the Pirabas Bay, where they are aggregated to the wide, tidal plains toward to the ocean.

B - Mangrove deposits

Mangrove deposits form the most extensive modern sediments in the studied area. They are made up of very fine sediments, clayey silt or clay, grey to black in color, rich in organic material.

They occur in the low areas, periodically flooded by the tides and all along the rivers and channels that drain to the coast. These sediments are generally settled

by the typical vegetal association of *Rhizophora Mangle* and *Avicennia Sp.* sometimes with very tall trees. Mangrove deposits occur covering the rocks of the Barreiras Formation (Fig. 3) or modern sandy sediments. In some places, now occupied by sandy tidal flats, large lens shaped spots of clay are being eroded by the movement of the waves and covered by sand; in other places roots and stems "in situ" arising from the sand, show that this area was formerly occupied by mangrove. Sometimes, muddy gray sediments are accumulating above the sand, like at Maçarico beach near Salinas as demonstrate by FARIA et al.(1987).

The distribution of the area with mangroves varies from the northwest to southeast of the studied coast. Mangrove deposits exist only in the southeast region of Marajó Island, or on the coast of Marajó Bay. (Fig.6). In fact, the coast at the west end of the island is also covered by muddy sediments, but lacks the typical vegetal association of mangrove, owing to the immense fresh water of the Amazon River. On the contrary, in Marajó Bay, some salt water can be transported from the ocean inside of the bay by the high tides, especially in the dry seasons, permitting the sedimentation of brackish muddy sediments and in consequence the development of mangrove vegetation. So mangrove deposits are present close to the Paracauari River and all along it. To the north of this coast the mangrove deposits are progressively covered by the sand of the tidal flats.

To the east of Marajó Bay the mangrove deposits sometimes lie directly above the rocks of the Barreiras Formation and are sometimes developed above the modern sand or alternated with the fine sand of the tidal flats. They are restricted between the Barreiras Formation and the modern sand and enter into the continent forming strips following the rivers. To the east of Pirabas Bay (Fig.9,10) where the Barreiras Formation is a distance from the coast, mangrove deposits occupy large areas towards the ocean limited by beach ridges in the more distant places.

C - Tidal Flat deposits

The tidal flats of this coast are covered by fine to very fine sand and silt. Shells and shell fragments occur in accumulations or are randomly distributed in some places. Pebbles of grey clayey material are found in tidal flats formerly occupied by mangrove deposits.

Many types of depositional sedimentary structures occur in this material. The most frequent sedimentary structures are: symmetrical and asymmetrical wave ripples, undulatory megaripples, antidunes, rhomboedral ripples, swash marks and current ripples. These plains are frequently interrupted by sinuous tidal channels.

The most extensive tidal flat on this coast is located at Cabo Maguarí, at the east end of Marajó Island, between the Ocean and Marajó Bay. It is about 30 km wide and crossed by numerous temporary short tidal channels of different sizes. The height of the tides in the place is about five meters and this plain is completely submerged during the high tides.

The backshore zone, at Cabo Maguarí, is very reduced. To the south the width of this tidal flat decreases and near the mouth of the Paracauari River it gradually changes to mangrove (Fig.6). The backshore zone at Cabo Maguarí is formed by a low beach ridge that in the south where the tidal flat becomes narrower, the ridge bifurcates and the two beach ridges extend parallel to the coastline.

In the continental coastline the clastic tidal flats develop at the base of the cliffs. To the east of Marajó Bay they are less developed, limited among the cliffs or the mangrove deposits. In some places, like in a small plain on Agodoal Island (Fig. 11) a shingle, made up of ferruginous sandstone pebbles, limit the fine sediments in the upper part of plain. To the south the tidal plains are wider on the peninsulas and islands and made up of fine sand to silt and sometimes pebbles of grey clay. They also are limited by beach ridges in the backshore zone.

D - BEACH RIDGES

A beach ridge is a continuous linear mound of rather coarser sediments near the high water line (REINECK and SING, 1973). The sediments have been heaped up by waves during high waters beyond the mean high water line and storm tides.

By this context the sandy bodies of the north coastline of Marajó Island are not real beach ridges. They have irregular shapes and short lengths and are covered by some vegetation. Rather they are remains of the final stage of the

sedimentation processes on Marajó Island, probably reworked by the waves when the hydrodynamic conditions were different from the present situation.

Now, this coastline is undergoing continuous erosion by the action of the immense water mass of the Amazon River. These sandy bodies have a random distribution and are made up of average sized sand, poorly sorted, about two meters high. They form the limit of the internal plains of Marajó Island. Only at Cabo Maguari and on the east coast of Marajó Island, to the north of the Paracauari River, do authentic beach ridges occur. They are made up of fine sized sand, well sorted, 1.0 to 1.5 meters high. Internal sedimentary structures are fine horizontal laminations and cross laminations that are emphasized by very fine lines of black minerals.

In the continental coastline, beach ridges occur which are better developed in the eastern part. They generally form the ends of the islands and peninsulas, constituted by fine, very well sorted quartz sand. The beach ridges found at the bases of cliffs are composed of coarse sand. In some places we have more than one line of beach ridges. In the Quatipuru Point a series of three ridges occurs. (Fig. 12). They are separated from one another by zone of salt marsh with the characteristic vegetation of *Spartina* and *Salicornia*.

Some beach ridge of this type can be classified as chenier. Some cheniers exist to the east and some of them are located very far from the present coastline and also not parallel to the coastline, showing intense changes of the directing parameters during the transport and sedimentation processes. They exhibit variable length and width. The Furo Novo beach is the most important, 4 km long and 50 meters wide, NW-SE trend, isolated in the mangrove region, between Maiau and Quatipuru Bays. Generally they are made up of white, fine sand and 3 to 4 meters thick.

Other, not frequent features are dunes. They occur in some places not far from the mouth of Marajó Bay at Salinas and Algodual Island. They are about 7 meters high and constituted of fine, very good sorted sand.

VI - DISCUSSION

Present coastlines reflect the sum of all the influences which have operated on them since they were originally established. According to KIDSON (in FAIR-

BRIDGE, 1968) the sea-level reached its maximum about 6000 years ago. In this sense, all the world's coast are relatively new.

Analysing the features occurring on the State of Pará coast, it is easy to discern the differences taking place on this coast to the west side of Marajó Bay and to the east side, concluding that two different types of coast exist, on the Atlantic border of this region.

According to the shorelines classification of JOHNSON (in LOBECK, 1939) the north seashores of Marajó Island agrees exactly to a shoreline of emergence; on the contrary, the continental coast corresponds to a shoreline of submergence. The evolution of these shorelines is deeply related to the evolution of the regions now washed by the Ocean. Unhappily, we don't have enough systematic data to relate exactly the stages of the changes that occurred during the last 10.000 years. So we are only able to examine in general terms the processes that actuated in this region to reach the present outlines based only on geomorphological and sedimentological evidences. Besides the processes were different on the two sides of the emerged lands.

The Barreiras Formation, Plio-Pleistocenic in age, outcrops on the continental coast and also on the east border of Marajó Island, exhibiting good exposition in some cliffs. The continuity of this formation on the continent and on the island, having the same lithology, the same lateritisation degree and the same conditions of peneplanation inherited from the pleistocenic age suggests that this formation was continuous and that the island was integrated with the continent. Remnants of paleochannels are the best geomorphological features on Marajó; these features are continuous also on the islands to the north of Marajó, Caviana and Mexiana, showing also that these islands were united to Marajó and to the continent. In consequence, the south branch of the Amazon that contours the north coastline of Marajó originated recently, only after the formation of these superficial features.

Detailed investigations on the sediments of these paleochannel by BEMERGUY (1981) demonstrated that they were deposited in a fluvial environment by high to medium energy, coming from the Tocantins-Amazon System, as confirmed by heavy mineral studies. According to VITAL (1988) the Ararf Lake, in the central part of the Island, is the result of the last phase of sedimentation of a larger fluvial-lacustrine system. Data of Pb210 for the upper eleven meters of these sediments gave an age of 6000 years assuming a sedimentation rate of

1.8 mm/year. However, TANCREDI et al(1975) determined the age of 35.000 years obtained by the C14 analysis of the ten meters deep deposits of the east region of the island, that had functioned like a hinge between the continent and the large paleoestuary during this time³.

Recent researches by IGREJA et al.(1990) on the origin of the southeast portion of Marajó Bay, show that the coast and the associate islands of this region are made up of an assortment of rhomboid shaped blocks that were active since the Tertiary period. Consequently, the origin of this bay would be connected to the neotectonic of this region, rather than the simple water flood during the Flandrian Transgression.

IGREJA et al (1990) suggest that the neotectonic model expressed for the southeast region of Marajó Bay can be extended also to the north coast of Pará State. Therefore the drowned valleys that gave rise to the submerged coast and that are parallel to the cut of Marajó Bay, probably originated in the same age in which the incision of Marajó Bay was formed. The formation of this part of the continental coast was also affected by the tectonic tilting of some great blocks. In fact, a large block of the Barreira Formation, close to the mouth of the Bay, probably was moved by a positive dislocation and tilting, and the block to the east of Pirabas Bay underwent a negative deslocation. The first situation lead to the formation of the cliffs engraved in the Barreiras deposits facing towards the Atlantic Ocean.

According to FARIAS (1987, in FARIAS et al.) large offshore bars, close to littoral are remnants of some coastal dunes that were covered by water during the maximum transgression. These coastal dunes were formed by the reworking of the sediments of the Barreiras Formation during the last Pleistocene regression. Large shoals of ferruginous beds of the "Grés do Pará" forming the bottom of this sand on the external continental shelf, show that the Barreiras Formation in that time must have been more extensive expanding towards the Ocean.

Actually, some of these dune sands were displaced by waves and streams to form modern beach ridges. Heavy mineral studies in these sands by FERNANDES (1985) confirmed that their source area was the Barreiras Formation. The large block to the east of Pirabas Bay, had undergone a negative movement. For this reason the Barreiras Formation is found very far from the

(3) An outline of this region from 6000 years b.p. is show in figure 13.

Ocean, with lower "dead" cliffs. This situation precipitated the development of very large plains covered by fine sediments.

The hydrodynamic processes of transport and deposition of fine sediments in large plains may be investigated by an examination of chenier that occur there. The deposition took place by lateral progradation during stages as shown by dissimilar types of chenier that vary in size, in geographical position with respect to the shoreline and in shape. They are rather randomly scattered, occurring in bundles or individually. Sometime they are very short in relation to their width, giving the impression that they were partially destroyed. Their grain-size also changes, generally the sand that forms these bodies is coarser in the west becoming finer to the east. The most notable chenier of this region is called Furo Novo (Fig.10): it is an individual chenier, isolated in the mangrove deposit, about four km long and fifty meters wide, and links the Maiiau to the Quatipuru Bay at a distance of 10 km from the open ocean, lying in a NW/SE direction. It is made up of very fine, white sand.

A detailed analysis of these features could yield excellent results for the interpretation of the multiple changes that occurred in the last 6000 years during the formation of these plains that are associated with the submerged coast in the east border of Pará State.

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ORIENTATION MAP

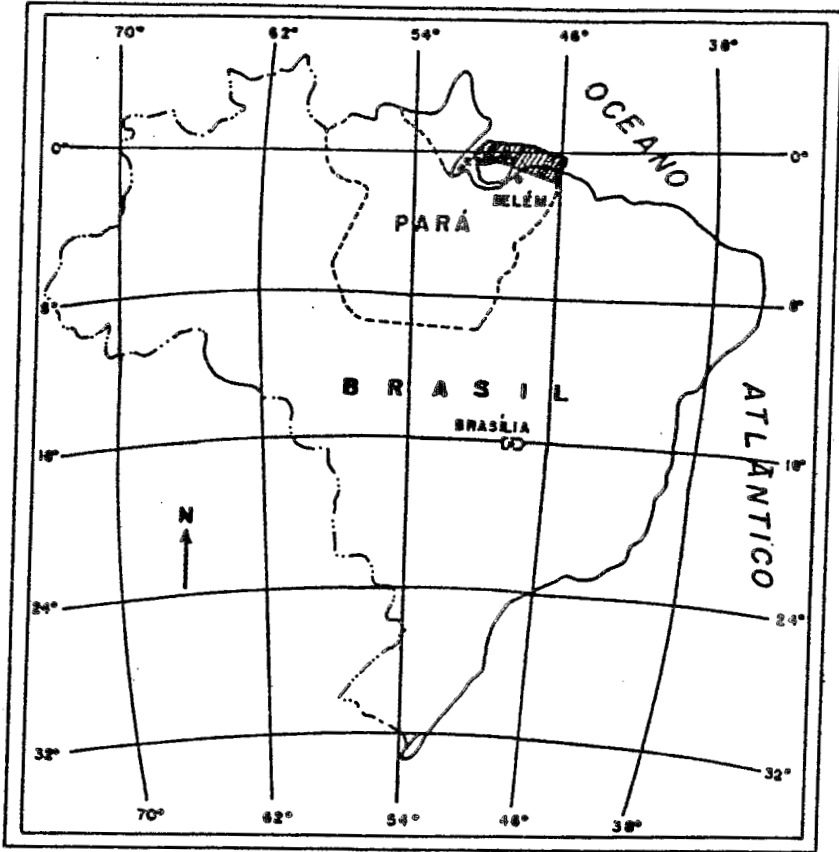
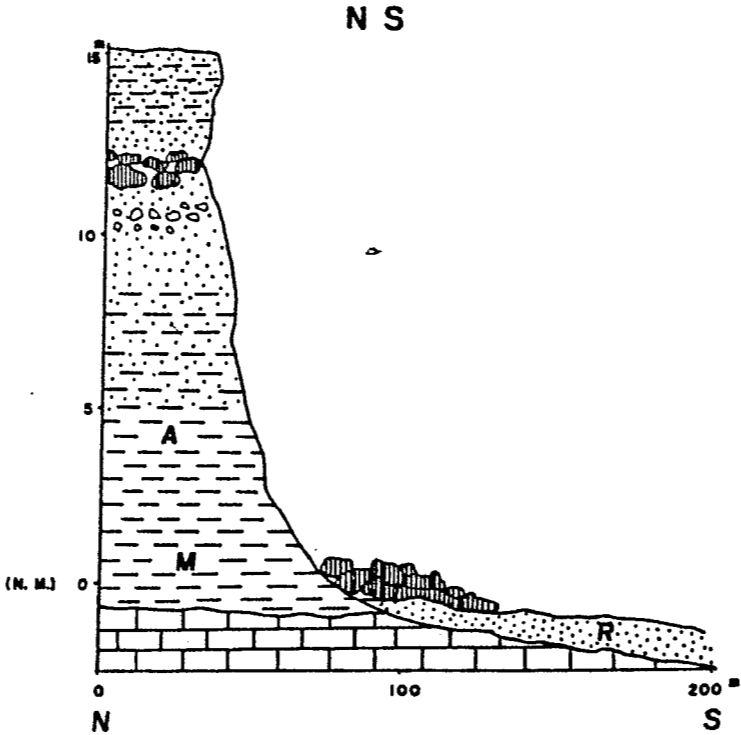


FIG. - 1

CLIFFS AT THE ATALAIA BEACH(SALINOPOLIS)



LEGEND




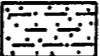
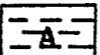
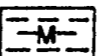
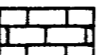
	- SAND	}	HOLOCEN
	- LIMONITIC CONCRETIONS		
	- CONGLOMERATIC SANDSTONE	}	BARREIRAS FORMATION
	- RED CLAYEY SANDSTONE		
	- CLAY		
	- CARBONATE CLAY	}	PIRABAS FORMATION
	- LIMESTONE		

FIG.- 2

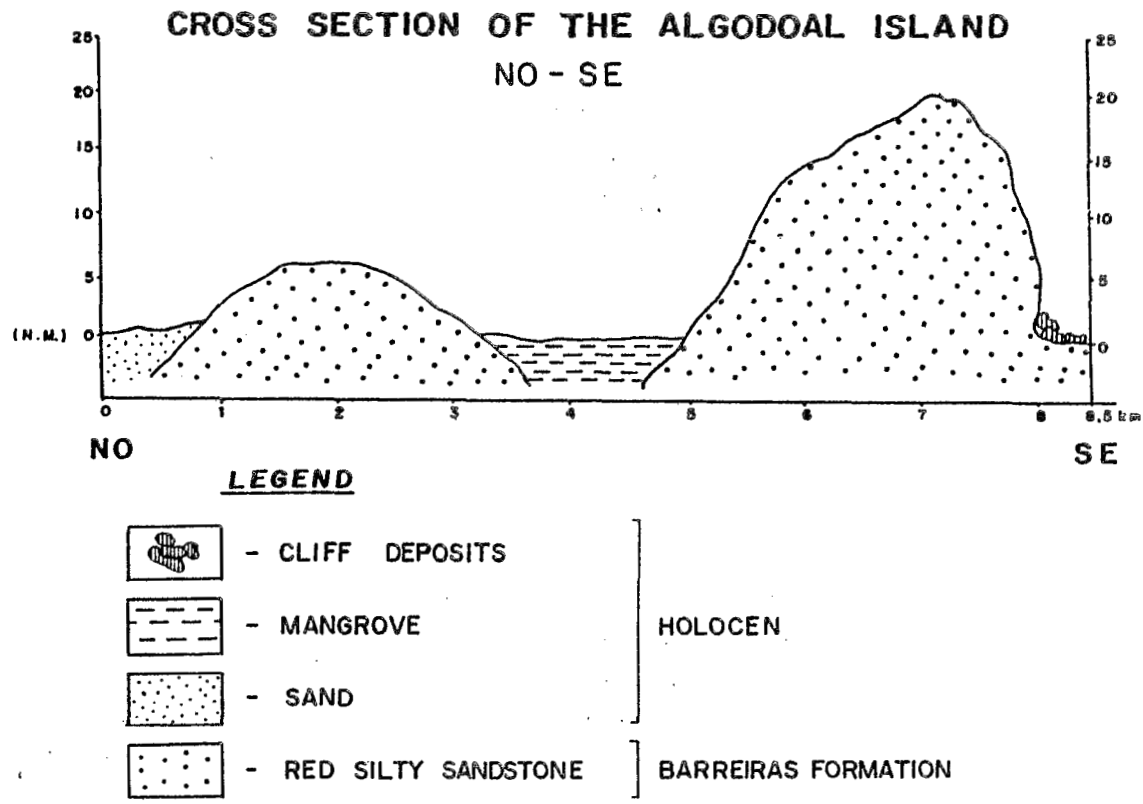
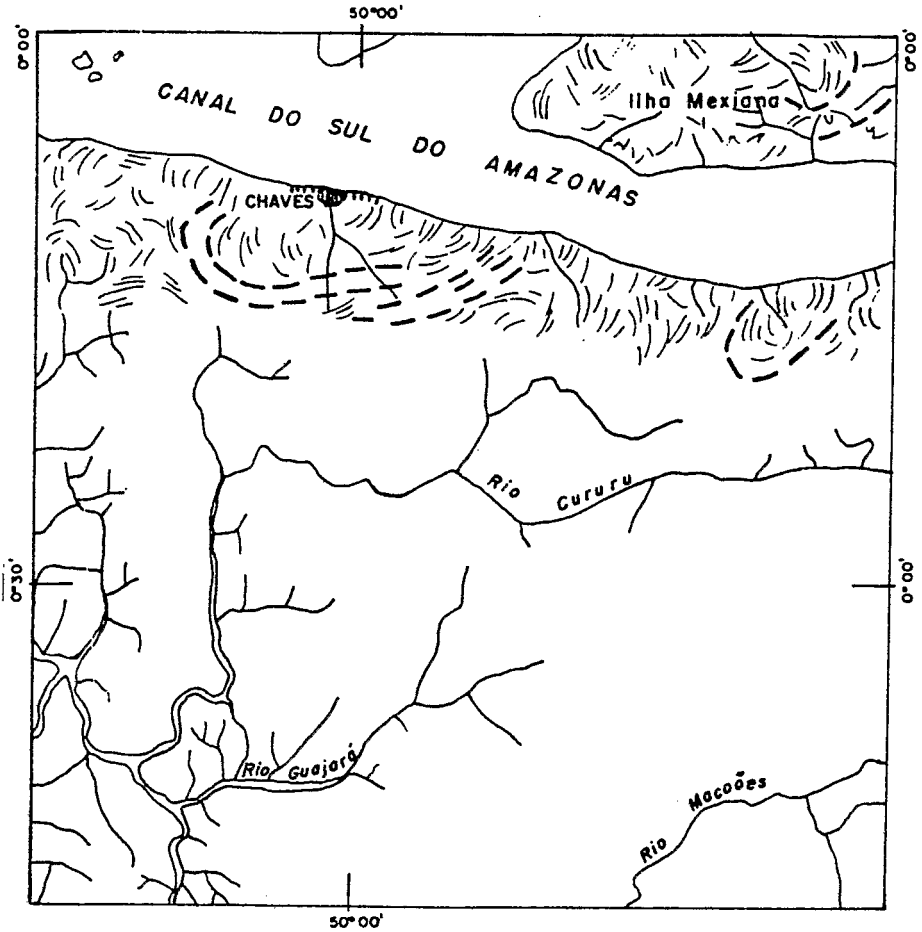


FIG. - 3



GEOMORPHOLOGICAL MAP OF THE COAST OF
THE STATE OF PARÁ, BRAZIL
MARAJÓ ISLAND (CHAVES)

LEGEND

- Mangrove deposits
- Tidal flat deposits
- Barreiras Group
- Lithologic Contact
- Cliffs
- Beach ridges
- Paleochannel
- Towns

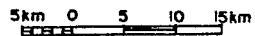
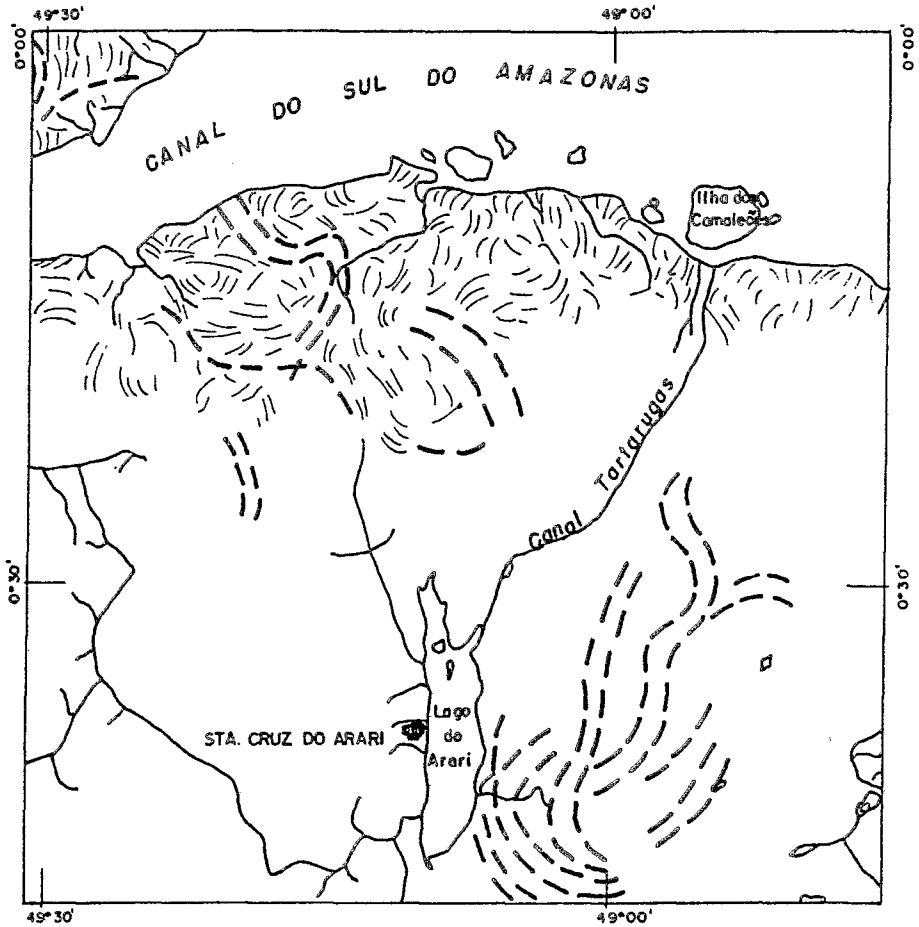










FIG. - 4



GEOMORPHOLOGICAL MAP OF THE COAST OF THE STATE OF PARÁ, BRAZIL
MARAJÓ ISLAND (LAGO DE ARARI)

LEGEND

-  - Mangrove deposits
-  - Tidal flat deposits
-  - Barreiras Group
-  - Lithologic Contact
-  - Cliffs
-  - Beach ridges
-  - Paleochannel
-  - Towns

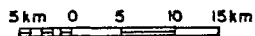
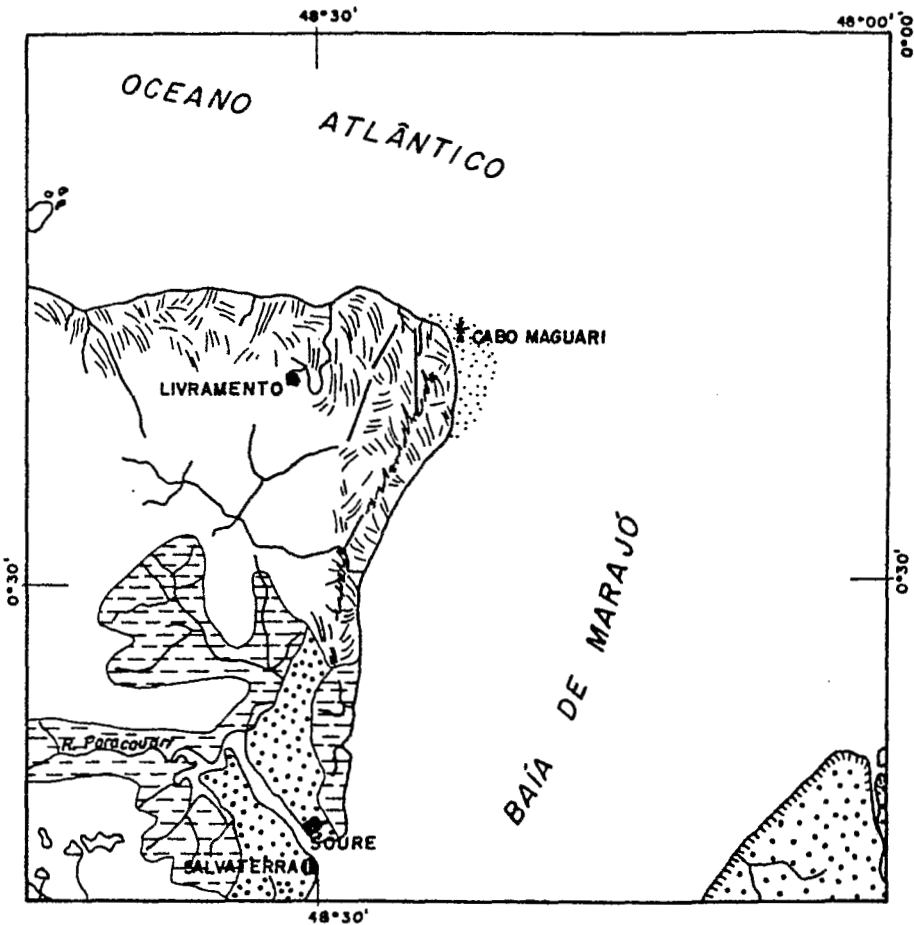


FIG.-5



GEOMORPHOLOGICAL MAP OF THE COAST OF THE STATE OF PARÁ, BRAZIL MARAJÓ ISLAND (CABO MAGUARI)

LEGEND









-  - Mangrove deposits
-  - Tidal flat deposits
-  - Barreiras Group
-  - Lithologic Contact
-  - Cliffs
-  - Beach ridges
-  - Paleochannel
-  - Towns





FIG. - 6



GEOMORPHOLOGICAL MAP OF THE COAST OF THE STATE OF PARÁ, BRAZIL (CORUÇA)

LEGEND

-  - Mangrove deposits
-  - Tidal flat deposits
-  - Barreiras Group
-  - Lithologic Contact
-  - Cliffs
-  - Beach ridges
-  - Paleochannel
-  - Towns

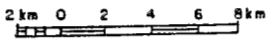
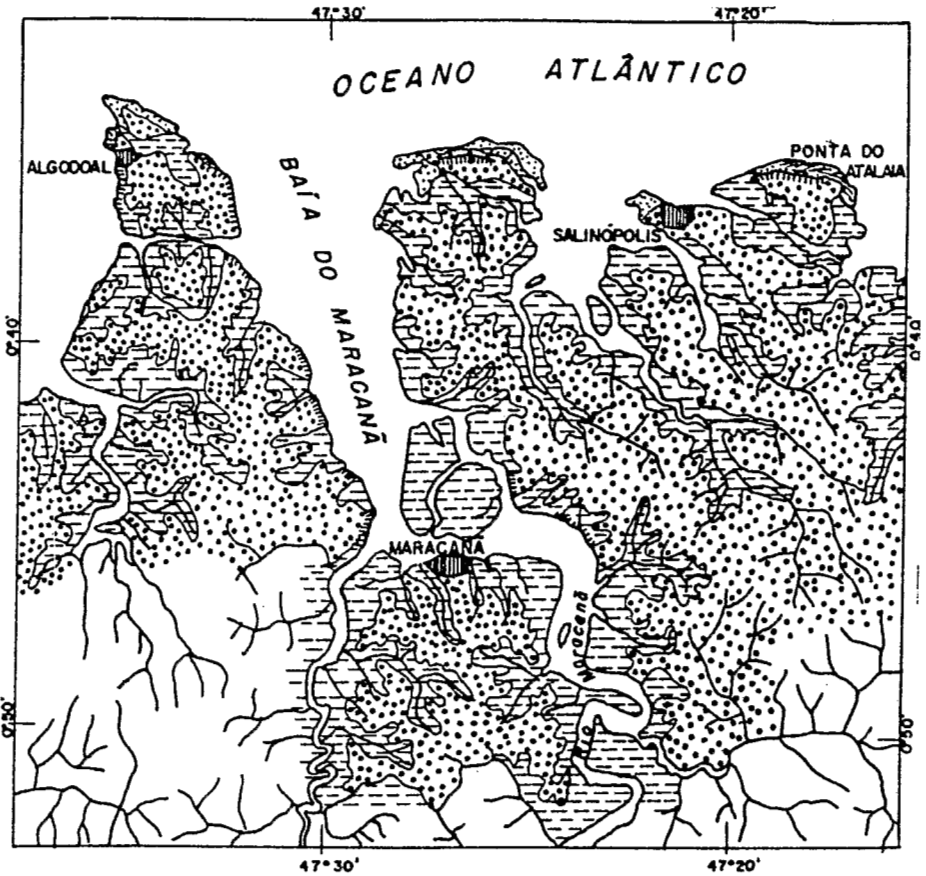







FIG. - 7



GEOMORPHOLOGICAL MAP OF THE COAST OF THE STATE OF PARÁ, BRAZIL (MARACANÃ)

LEGEND

-  - Mangrove deposits
-  - Tidal flat deposits
-  - Barreiras Group
-  - Lithologic Contact
-  - Cliffs
-  - Beach ridges
-  - Paleochannel
-  - Towns

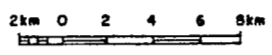
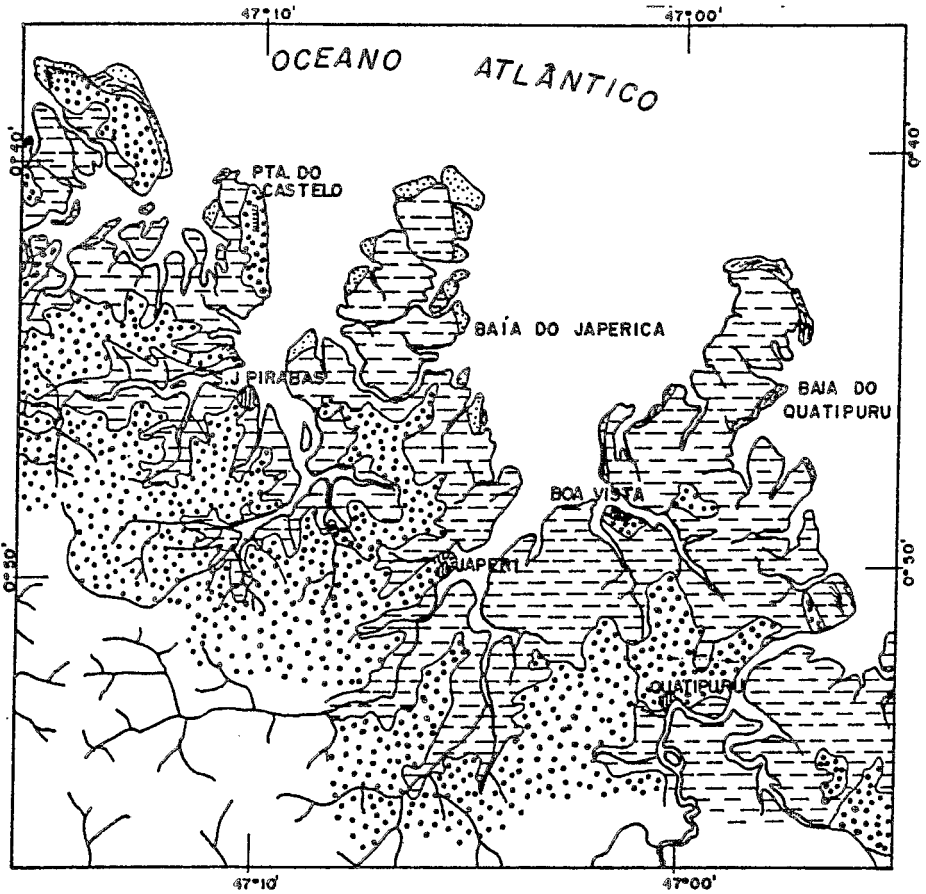








FIG. - 8



GEOMORPHOLOGICAL MAP OF THE COAST OF THE STATE OF PARÁ, BRAZIL

(S. J. PIRABAS)

LEGEND

-  - Mangrove deposits
-  - Tidal flat deposits
-  - Barreiras Group
-  - Lithologic Contact
-  - Cliffs
-  - Beach ridges
-  - Paleochannel
-  - Towns

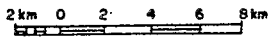
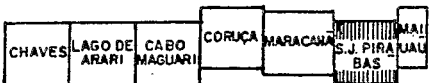


FIG.-9

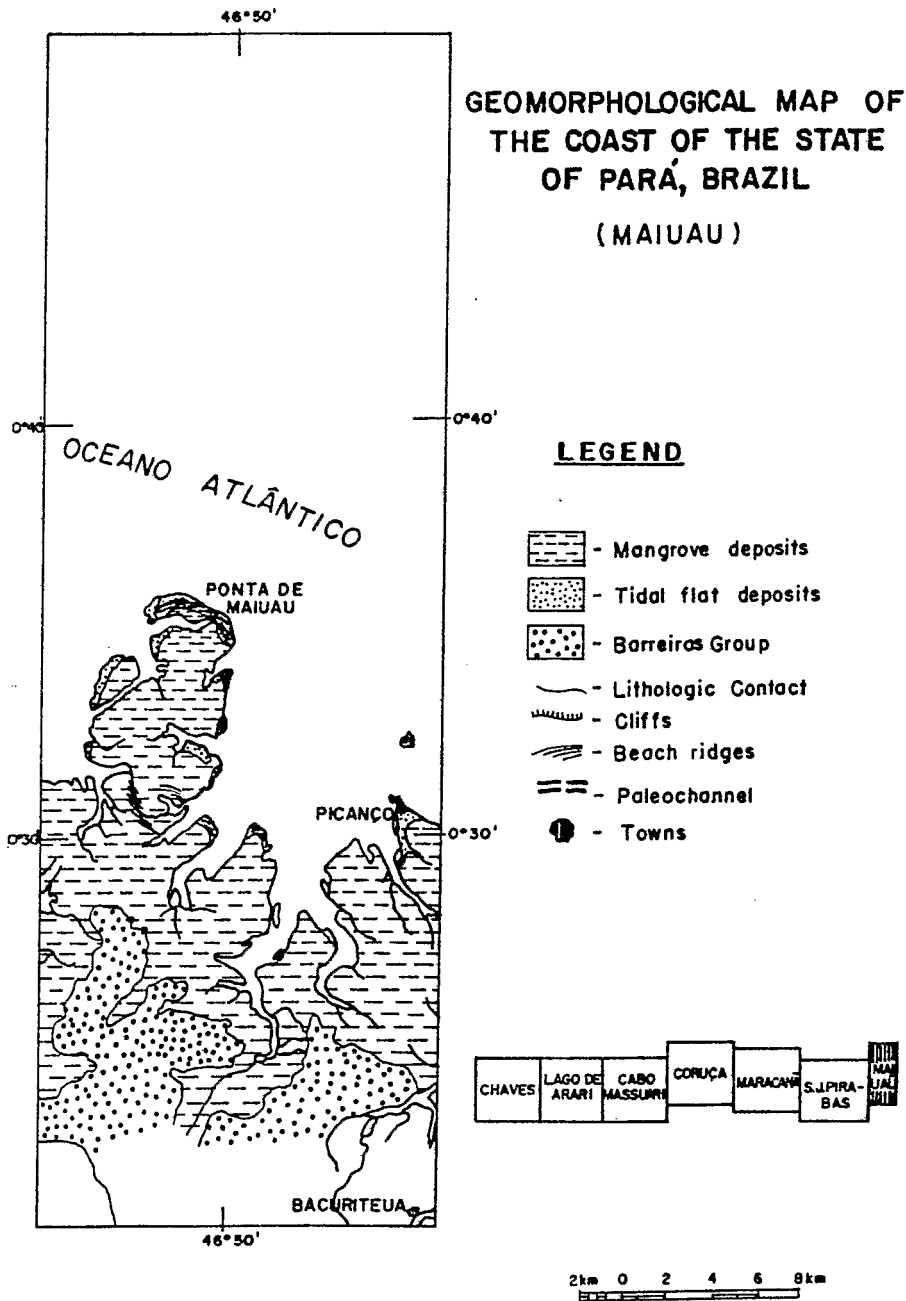


FIG. - 10

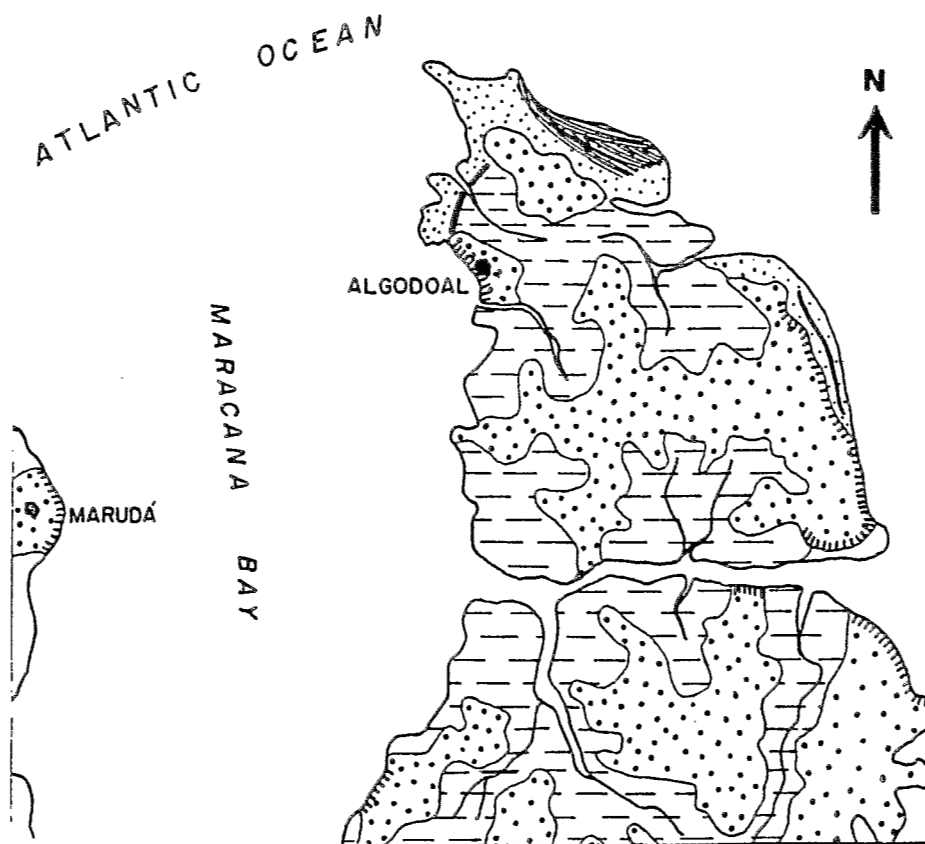


Fig. 11- ALGODOAL ISLAND, DETAIL OF FIGURE 8. ALL THE DESCRIBED FEATURES ARE PRESENT: CLIFFS, MANGROVE DEPOSITS, TIDAL FLATS AND BEACH RIDGES

LEGEND

- Tidal flat deposit
- Mangrove deposit
- Barreiras Formation
- Lithologic Contact
- Cliffs
- Tidal Channel
- Shingle
- Beach ridge
- Village

0 1 2 km

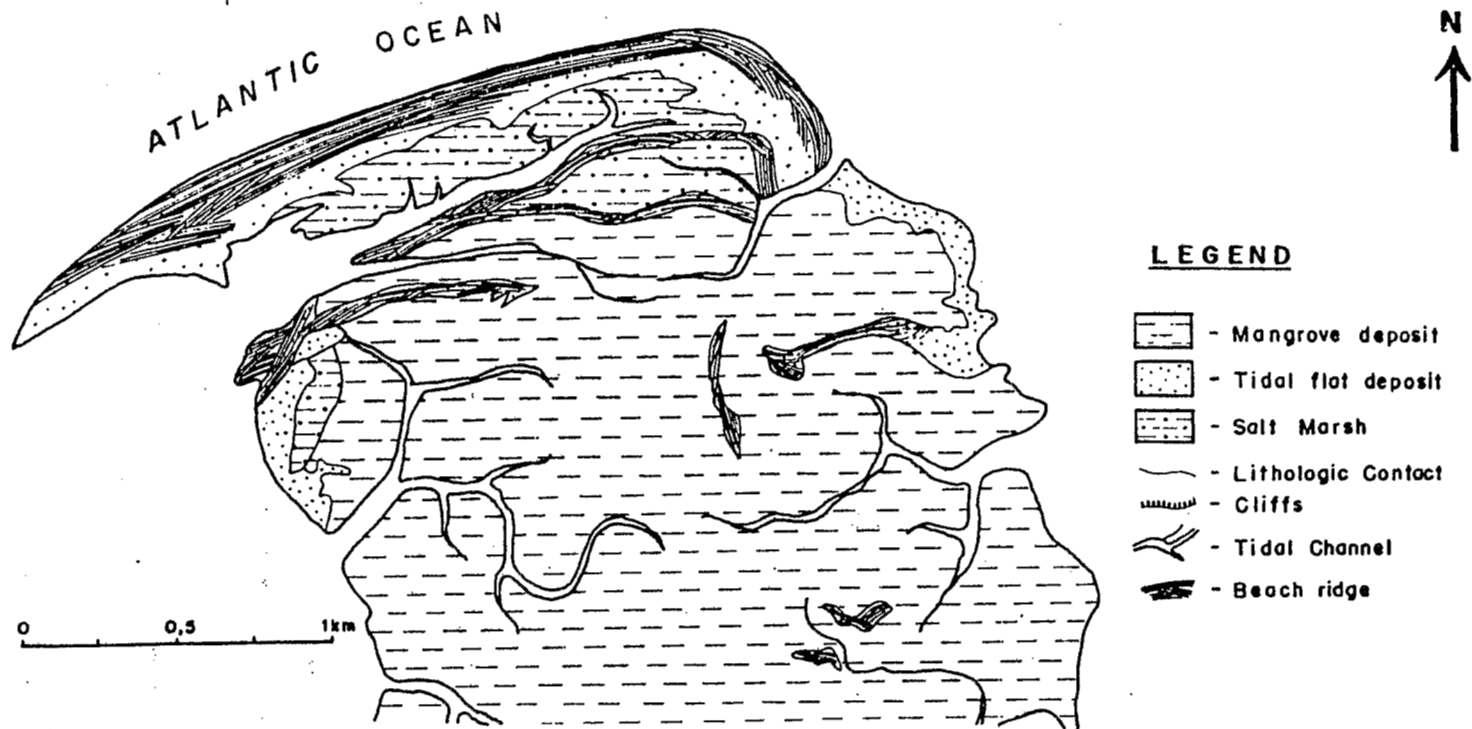


Fig.12- MAIAU POINT, CHENIERS IN BUNDLES, CLOSE TO THE BEACH, SEPARATED BY SALT MARSHES

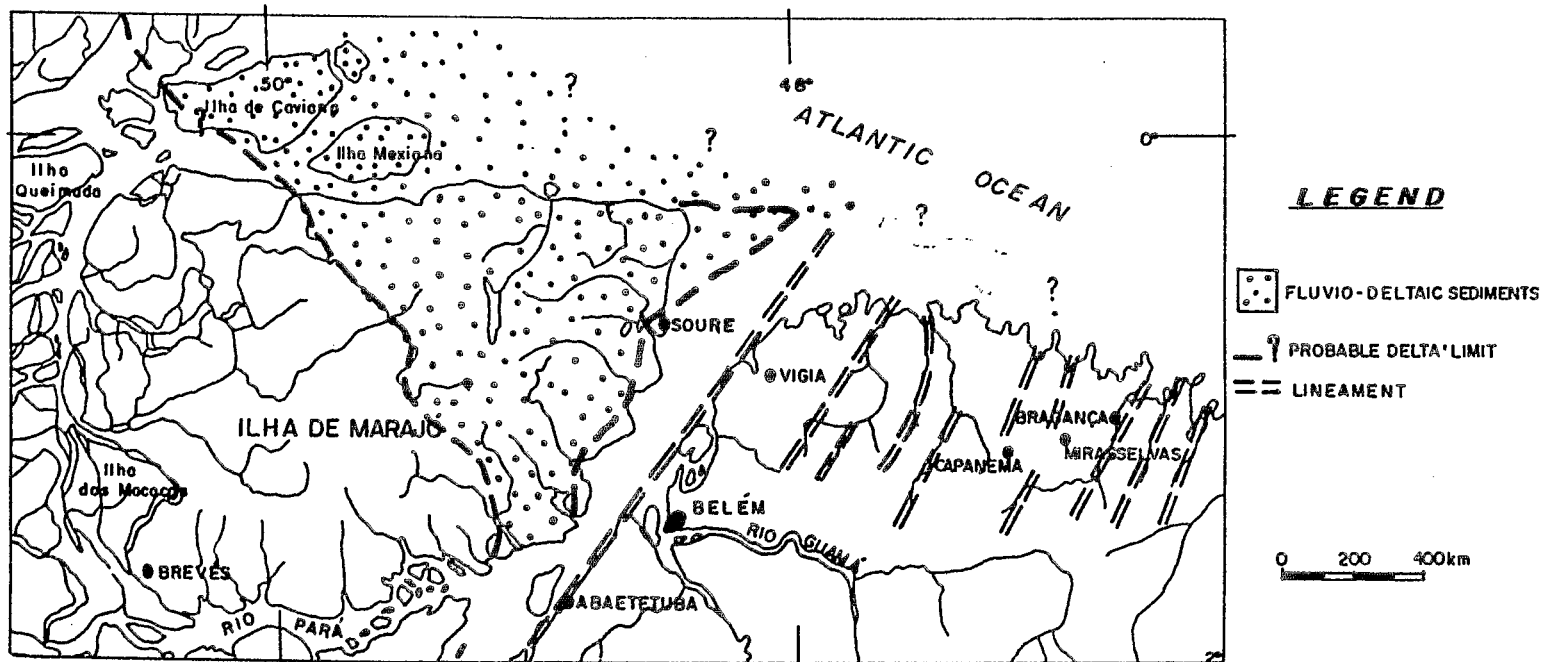


Fig. 13-OUTLINE OF THE PALEOGEOGRAPHY OF THE COASTAL REGION OF PARÁ STATE, BRAZIL, BEFORE THE LAST 6000 YEARS. THE EASTERN PART OF MARAJÓ ISLAND CONSISTED OF A LARGE DELTA, FORMING THE EMERGENCE COAST WITH THE FLANDRIAN TRANSgression. THE TECTONIC LINEAMENTS THAT CAUSED MARAJÓ BAY, ACTIVE FROM THE TERTIARY AGE, ARE PARALLEL TO THE PROBABLY CONTEMPORARY LINEAMENTS THAT FORMED THE SUNKEN VALLEYS THAT ORIGINATED THE SUBMERGENCE SHORELINES OF THE CONTINENTAL COAST.