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The Quaternary sedimentary deposits in the States of Paraná and Santa Catarina coastal plains

ABSTRACT

A detailed study, based on the interpretation of aerial photos, field surveys, radiocarbon dating and previous experience in Quaternary coastal researches along the States of São Paulo, Rio de Janeiro, Espírito Santo, Bahia, Sergipe and Alagôas, allowed us to distinguish two generations of sandy terraces associated with two periods of sea-levels higher than today. The more internal deposits are related to a period when the relative sea-level reached a maximum of 8 m above the present level by about 120,000 years BP. Numerous radiocarbon ages made possible to correlate the more external deposits to the final part of the last great transgressive period, when the relative sea-level reached a maximum of 2.5 to 3.5 m above the present level by about 5,100 years BP.

In the southern half of the State of Santa Catarina coastal plain, these sandy deposits have superficially been reworked by winds, giving rise to several generations of eolian dunes.

The evolutionary scheme previously established for the State of Bahia may be suitably applied to the States of Paraná and Santa Catarina coastal plains.

RESUMO

Um estudo detalhado, baseado na interpretação de fotos aéreas, levantamentos de campo, datações ao radiocarbono e experiência previa em pesquisas do Quaternário Costeiro ao longos dos Estados de São Paulo, Rio de Janeiro, Espírito Santo, Bahia, Sergipe e Alagoas, nos permitiu distinguir duas gerações de terraços arenosos associados a dois períodos de níveis marinhos mais altos que o atual. Os depósitos mais internos estão relacionados a um período quando o nível relativo do mar atingiu um máximo de 8 m acima do atual cerca de 120.000 anos passados. Numerosas datações ao radiocarbono permitiram

correlacionar os depósitos mais externos à parte final do último grande período transgressivo, quando o nível relativo do mar chegou a um máximo de 2,5 a 3,5 m acima do atual há aproximadamente 5.100 anos passados.

Na metade sul da planície costeira do Estado de Santa Catarina, esses depósitos arenosos foram superficialmente retrabalhados pelo vento dando origem a várias gerações de dunas eólicas.

O esquema evolutivo anteriormente estabelecido para o Estado da Bahia pode ser adequadamente aplicado às planícies costeiras dos Estados de Paraná e Santa Catarina.

INTRODUCTION

The studied area is comprised between the southern extremity of Ilha do Cardoso (southern limit of the State of São Paulo = 25°13'S) and the town of Torres (northern limit of the State of Rio Grande do Sul = 29°20'S), as it is shown in Figure 1. Between Paranaguá and the town of Laguna, the coastline has a N-S direction which changes to NE-SW direction southward. In some places, as in Paranaguá area, the coastal plain is about 60 km wide but in other parts, Precambrian crystalline rock headlands or Paraná Basin Paleozoic or Mesozoic sedimentary rocks reach the ocean.

1 GEOLOGY OF THE COASTAL REGION

In the States of Paraná and Santa Catarina the coastal region is represented by an elongated strip of lowlands, limited eastward by the Atlantic Ocean and westward by the Serra do Mar and Serra Geral. Serra do Mar is usually composed of Precambrian crystalline rocks (gneisses and other metamorphic rocks, granites, etc) intruded by Mesozoic diabase dikes. The crystalline escarpment of Serra do Mar disappears in the south of Laguna (State of Santa Catarina), being replaced by the Serra Geral composed mostly of Mesozoic basaltic lava flows.

Remnants of continental Neocenoic deposits (Tertiary?) are widespread in these states, being characterized by the general afossiliferous nature and lack of key-beds. They are represented in the State of Paraná by Alexandra Formation (Bigarella et al., 1959), and in the State of Santa Catarina by Iquererim Formation (Bigarella et al., 1961), Canhanduva sequence (Bigarella and Salamuni, 1961), and Cachoeira layers (Bigarella, 1975).

Quaternary deposits of the coastal region of these states are more or less directly related to submergence and emergence periods of Upper Pleistocene and Holocene. Among them, sandy ridges are widespread reaching a width of about 15 to 20 km, but they are discussed in more detail elsewhere.

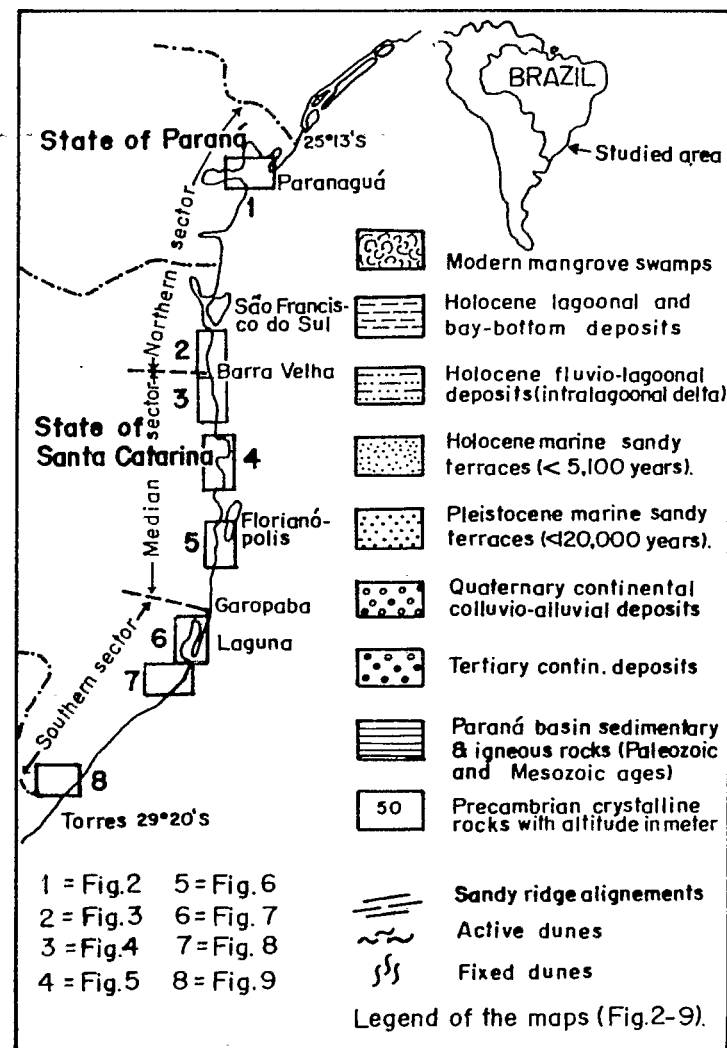


Figure 1. Location map of the studied area and legend of the maps (Figures 2-6).

2 PHYSIOGRAPHY OF THE COASTAL PLAINS

As a function of the physiography, it is possible to divide the coastal region of the States of Paraná and Santa Catarina into three sectors (Figure 1):

a) Northern sector - This sector goes from Ilha do Cardoso (25°13'S) to the town of Barra Velha (26°40'S), which is characterized by the occurrence of three great bays: Paranaguá, Guaratuba and São Francisco. The coastal plain situated at the foot of the Serra do Mar escarpment presents its greatest development within this sector.

b) Median sector - This sector is limited between the town of Barra Velha and Garopaba area (28°00'S). This portion of the coastline is characterized by the presence of Precambrian crystalline rocks interrupting Quaternary coastal plains. This sector is also characterized by the Santa Catarina Island, where, for the first time, eolian dunes fields become important.

c) Southern sector - This sector is comprised between Garopaba area and the town of Torres (29°29'S), which is characterized by vast coastal plains with extensive lagoons and paleolagoons. This area is also characterized by frequent and important eolian deposits belonging to several generations of dunes.

3 CLIMATE OF THE COASTAL PLAINS

The States of Paraná and Santa Catarina coastal regions are almost entirely characterized by a subtropical climate, with cold winter and warm summer. While mean annual temperatures are higher than 20°C in most of the Brazilian territory, in these states they are less than 18°C. The mountainous areas of the Serra do Mar and Serra Geral present the highest precipitation values of Brazil, reaching frequently to maximum precipitation higher than 5,000 mm/year in many places.

MARINE AND LAGOONAL DEPOSITS

A detailed study, based on the interpretation of aerial photos and field surveys, supported by radiocarbon ages and previous experience obtained studying coastal areas of the States of São Paulo, Rio de Janeiro, Espírito Santo, Bahia, Sergipe and Alagoas (Dominguez, 1983; Dominguez et al., 1981a, 1981b, 1982, 1983; Bittencourt et al., 1979a, 1979b, 1982a, 1982b; Martin and Suguio, 1975, 1976; Martin et al., 1978, 1979a, 1979b, 1980, 1981, 1982, 1983, 1984b, 1985, 1986; Suguio and Martin, 1976a, 1976b, 1978a, 1978b, 1982a, 1982b; Suguio et al., 1980, 1982, 1984a) allowed us to distinguish two generations of coastal sandy deposits associated with two periods of high sea-levels. The inner deposits began their sedimentation when relative

sea-level was about 8 m above the present level. Wood fragments sampled from argillaceous deposits at the base of these sands have a minimum age of 35,000 years BP (Duarte, 1981). Though not any dating has been done, we think to be logical to assign an age of about 120,000 years BP to this high sea-level in comparison with the corals dated in the State of Bahia. In fact, sandy terraces to which is assignable the high sea-level of 120,000 years BP occur almost continuously from the State of Paraíba to Rio Grande do Sul. Thanks to several radiocarbon ages it was possible to assign the outer deposits to the final portion of the last great transgressive episode, whose maximum level has been attained about 5,100 years BP (Martin et al., this volume). There are also some marine gravel deposits which can be probably correlated with 120,000 years BP sandy terraces.

1 PROPERTIES AND DISTRIBUTION OF PLEISTOCENE MARINE TERRACES

Presently these sandy terraces are whitish on the surface and brownish to blackish in the depth. The dark colours can be attributed to the presence of epigenetic organic matter which is impregnating the grains. Shallow marine origin of these deposits can be assured by the presence of *Callichirus* burrows, which can be attributed to marine arthropods whose life zone is the infratidal zone (Suguio and Martin, 1976b; Suguio et al., 1984; Rodrigues et al., 1984). This origin is also ensured by syngenetic sedimentary structures, like low-angle and herringbone cross-beddings. On the surface of the terraces it is possible to distinguish vestiges of alignments of ancient sandy ridges, which are much more dissipated than upon the Holocene terraces. This difference can be easily recognized on aerial photos (Martin et al., 1981). At the innermost portions of the coastal plains, the altitude of these terraces reach about 9.5 m, and oceanward, it declines until about 2.5 m, as in the Paranaguá area near the contact with the Holocene terraces.

Within the northern sector (Ilha do Cardoso - Barra Velha) the Pleistocene marine terraces are very well developed forming about 20 km wide band as in Paranaguá and Joinville regions (Figures 2 and 3).

They are much less developed within the median sector (Barra Velha - Garopaba), when they are found only in the protected area at backside of massives of Precambrian crystalline rocks (Figures 4, 5 and 6).

These terraces are once again developed within the southern sector (Garopaba - Torres), giving origin to 8 to 10 km wide band as in Sombrio area (Figure 9). In this sector they have superficially been reworked by wind and important fossil dune fields exist as in Laguna and Jaguaruna areas (Figures 4 and 5). On the other hand, in the Araranguá and Sombrio regions it is

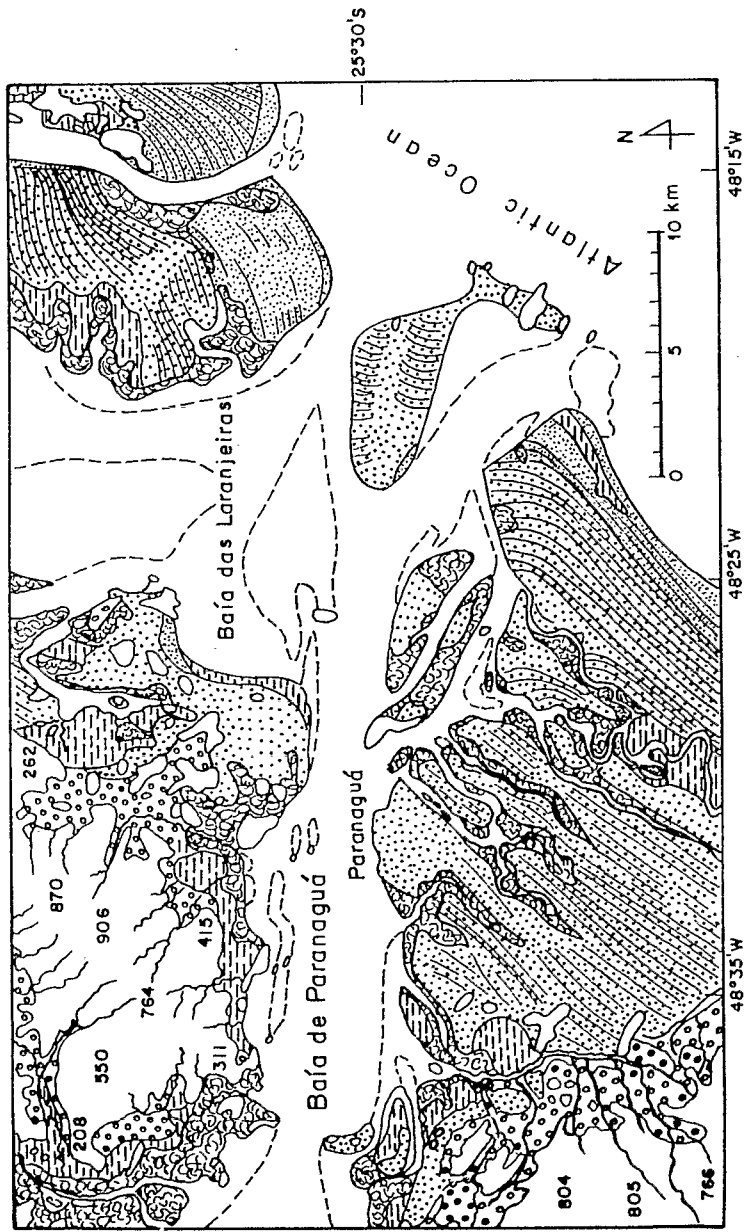


Figure 2. Geological map of Baía de Paranaguá area (State of Paraná).

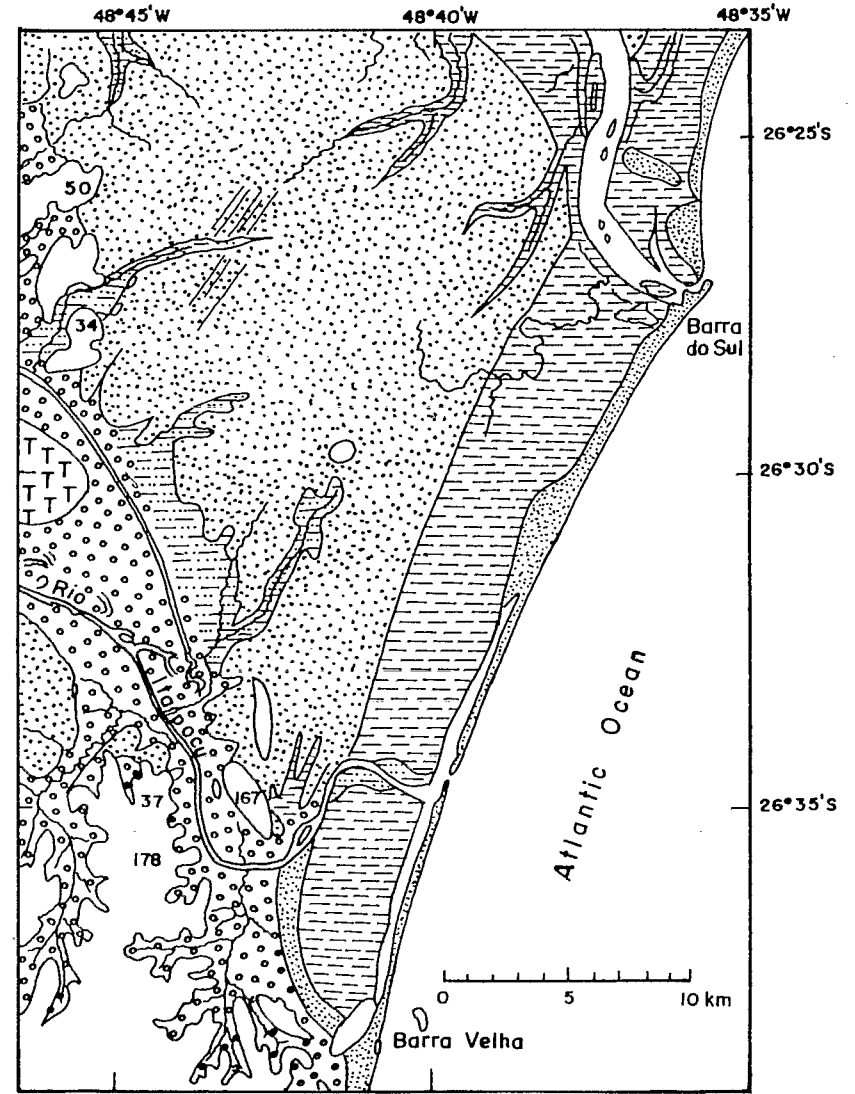


Figure 3. Geologic map of Barra Velha region (State of Santa Catarina).

possible to distinguish clearly the alignments of ancient sandy ridges (Figure 9).

2 PROPERTIES AND DISTRIBUTION OF ANCIENT MARINE GRAVEL DEPOSITS

In several places along the coastal plains of the States of Paraná and Santa Catarina, there are some remnants of ancient marine gravel deposits. They represent ancient sea-levels clearly higher than it is today and they are older than the Holocene. There are no absolute ages for these deposits but it seems that most of them could be attributed to high sea-level of 120,000 years BP.

a) Morro do Sambaqui

In Matinhos area (southern part of the State of Paraná), between the Morro do Escalvado and Morro do Sambaqui, there is a restricted outcrop of an ancient marine gravel deposit which was probably originated through incipient reworking of a colluvial deposit by the waves. This deposit is situated between 12 and 13 m above the present sea-level and was described by Bigarella and Freire (1960). If the reconstruction of ancient sea-level done by Bigarella (1975) is correct, this level is higher than that of 120,000 years BP. However, until a more detailed study about this problem we prefer to correlate this deposit with the Pleistocene sandy terrace of 120,000 years BP.

b) Porto da Passagem

At the backside of the late Club de Caiobá (State of Paraná), there is also a gravel deposit formed through incipient reworking of a colluvial deposit (Bigarella, 1975). This deposit is recording an ancient sea-level about 8 m above the present level, so it is in agreement with the altitude of 120,000 years BP sea-level. Perhaps, the difference of altitude between the Morro do Sambaqui and Porto da Passagem gravel deposits could be explained by differences in wave energies in these places.

c) Morro de Itajubá

Between Barra Velha and Picarras, in northern portion of Morro de Itajubá, there is a gravel terrace originated by partial reworking of a regolith. Also in this case, the gravel deposit could record an ancient sea-level about 8 m above the present level (Bigarella, 1975).

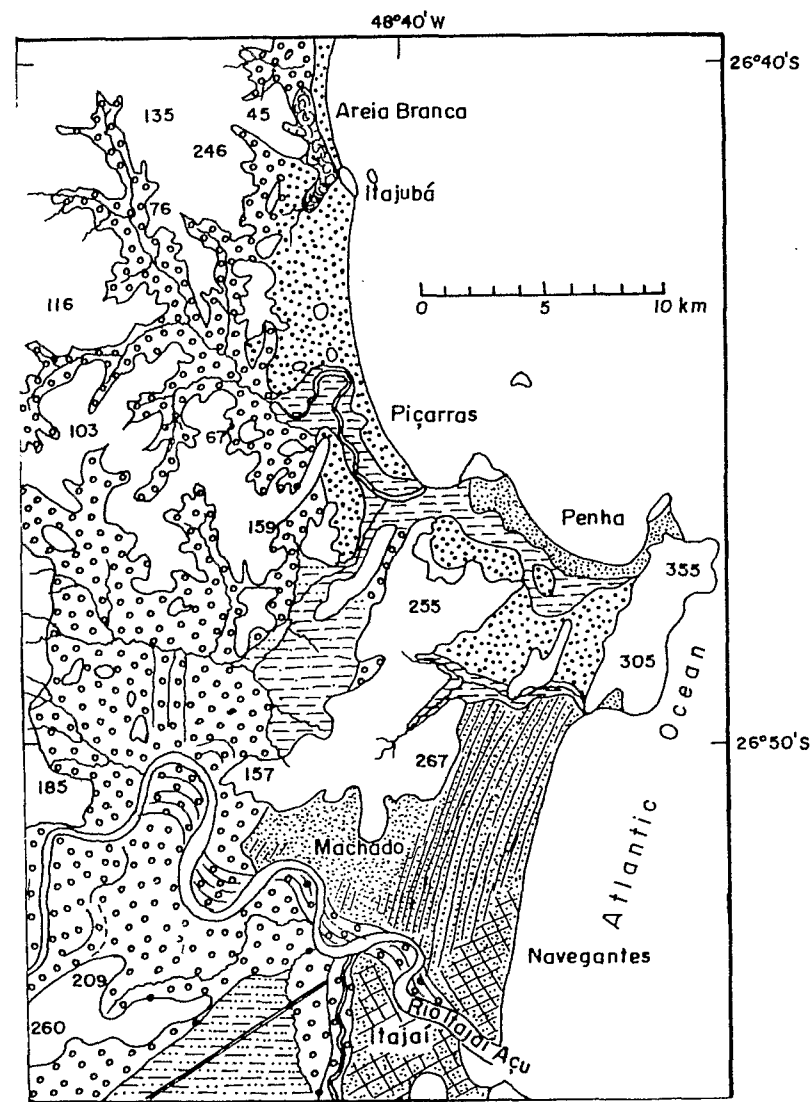


Figure 4. Geologic map of Picarras - Itajaí region (State of Santa Catarina).

3 PROPERTIES AND DISTRIBUTION OF HOLOCENE MARINE AND LAGOONAL DEPOSITS

a) Sandy deposits

In the outer side of the Pleistocene marine terraces, and very frequently separated from them by swampy lowlands, there are lower sandy terraces commonly containing abundant mollusc shells which can be dated by ^{14}C method and, under favourable conditions can give positions of ancient sea-levels. Differently from the Pleistocene marine terraces, these deposits are not in general impregnated by secondary organic matter. Alignments of sandy ridges are very conspicuously visible on aerial photos, mostly in northern and median sectors of the coastal plains, but intensive wind reworking affected the surfaces of the terraces in the southern sector.

In the northern sector the Holocene marine terraces are much less developed than Pleistocene terraces. They are only 2 to 3 km wide and can frequently be reduced to a narrow band as in the region between Ubatuba (Ilha de São Francisco) and the town of Barra Velha (Figure 3). They can be completely absent as in the Picarras area (Figure 4).

The Holocene marine terraces are very discontinuous within the median sector but locally, they can be very well developed like in the Rio Itajaí-Açu valley (about 7 km wide), Tijucas region (about 5 km wide) and Enseada da Pinheira (Figures 4, 5 and 6).

In the southern sector they have little development up to Morro dos Conventos, but they become more important with 5 to 6 km near the town of Sombrio (Figure 9).

b) Clayey and/or silty deposits

Around the bays of the northern sector (Paranaguá, Guaratuba and São Francisco), as well as in the periphery of lagoons, southward from Ilha de Santa Catarina, there are more or less sandy clayey and/or silty deposits formed during the high sea-levels when the lagoonal extent was greater than today. They very frequently contain mollusc shells, which are sometimes so abundant, like in Laguna area, and economically exploitable. Similarly, related to the occurrence of paleo-lagoons and paleobays there are numerous shell-middens, some of them of huge dimensions (about 50 m high).

CHARACTERISTICS AND DISTRIBUTION OF MANGROVES AND COASTAL MARSHES

Around protected margins of tidal channels and bays, where the tidal action is very conspicuous, there are mangroves and coastal marshes constituted dominantly by clayey silty

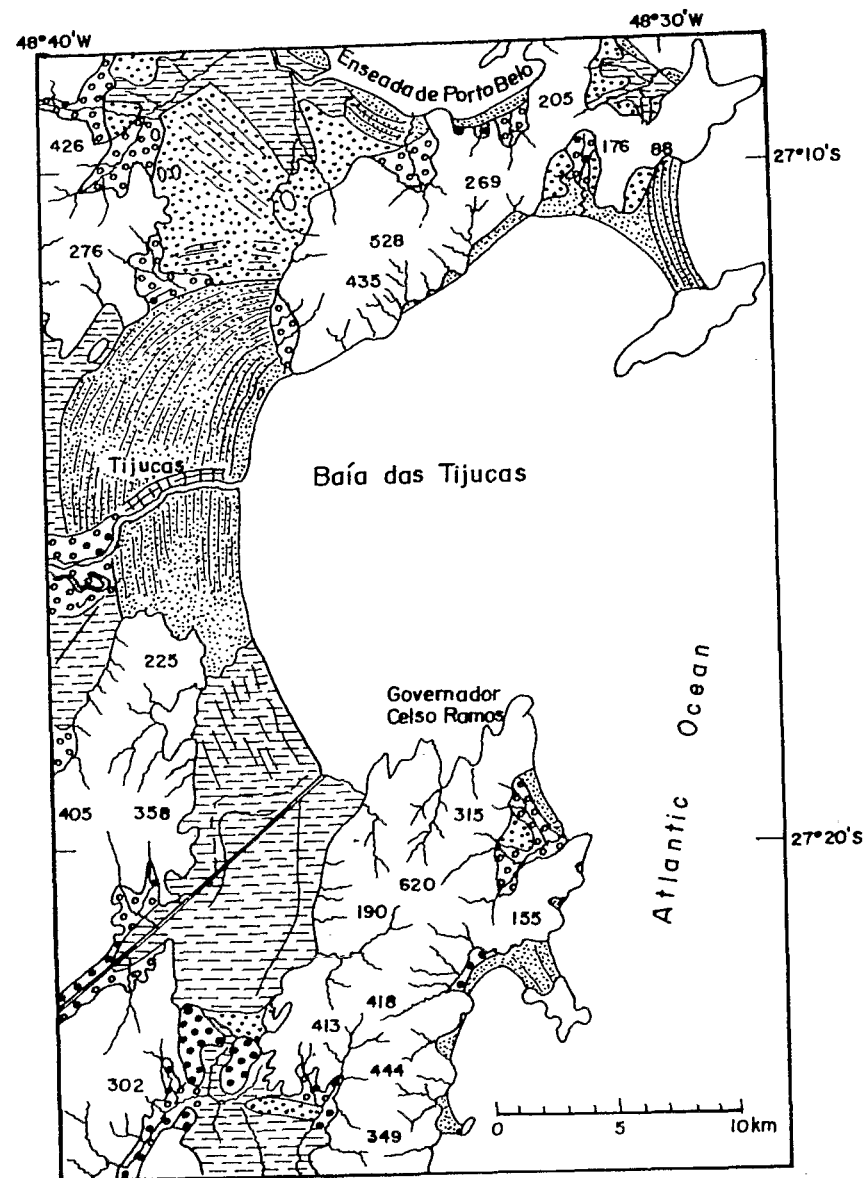


Figure 5. Geologic map of Tijucas region (State of Santa Catarina).

sediments very rich in organic matter.

The southernmost limit of occurrence of mangrove swamps along the Brazilian coast is located at the southern extremity of the Ilha de Santa Catarina (Figure 6). There are more or less developed mangroves northward of this point, at the margins of the baías de Paranaguá, Guaratuba and São Francisco and around the Ilha de Santa Catarina. Southward, the typical mangrove trees are almost entirely replaced by grasses like *Spartina*.

QUATERNARY CONTINENTAL DEPOSITS OF THE STATES OF PARANÁ AND SANTA CATARINA COASTAL PLAINS

1 COLLUVIO-ALLUVIAL DEPOSITS

The States of Paraná and Santa Catarina coastal plains are also characterized by extensive continental deposits, essentially terrigenous of different origin and age. At the foot of the Serra do Mar escarpment there are colluvial ramps representing episodes of generalized mass-movement phenomena. The alluvial deposits are formed of gravels and clayey-silty sediments. In general, the coarse alluvial deposits are older than the fine alluvial deposits. Former deposits correspond to semiarid paleoclimatic conditions while the latter have been formed under present conditions. In certain areas, like Garuva, Joinville, Turvo and Praia Grande, these colluvio-alluvial deposits are particularly well developed and may be more ancient than the Quaternary.

2 EOLIAN DEPOSITS

The coastal dunes are very well developed within the southern half of the State of Santa Catarina, mostly from the Ilha de Santa Catarina southward. It is possible to distinguish at least three generations of coastal dunes: a) ancient dunes, b) Holocene dunes fixed by vegetation and c) active dunes (Figure 7).

a) Ancient dunes - They are mostly constituted by reddish coloured sands, covered by more or less dense vegetation and subjected to intensive pedogenetic processes. In some places it is possible to recognize the nature of the substrate, formed of Pleistocene marine sands. Obviously, they are more recent than 120,000 years BP. In other places, it is possible to lower than today. Then, they are older than 7,000 years BP.

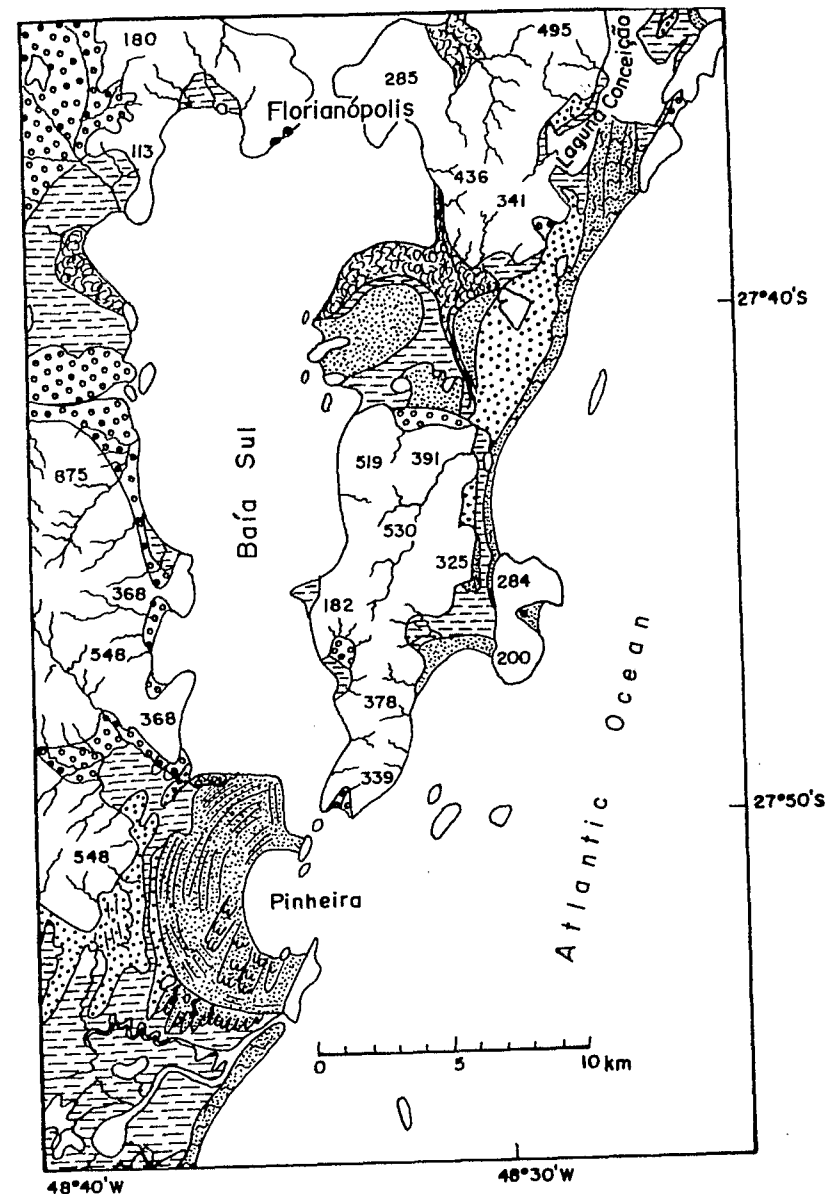


Figure 6. Geologic map of Ilha de Santa Catarina (southern portion) area (State of Santa Catarina).

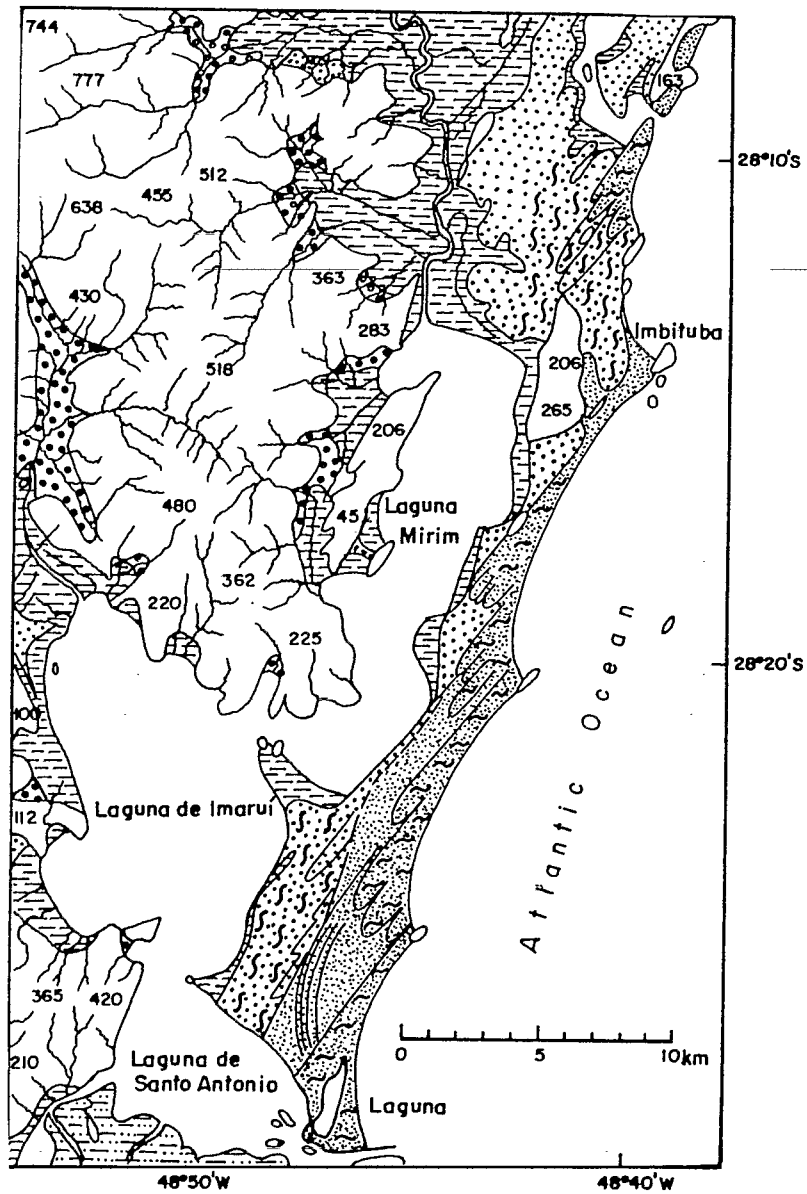


Figure 7. Geologic map of Imbituba/Laguna area (State of Santa Catarina).

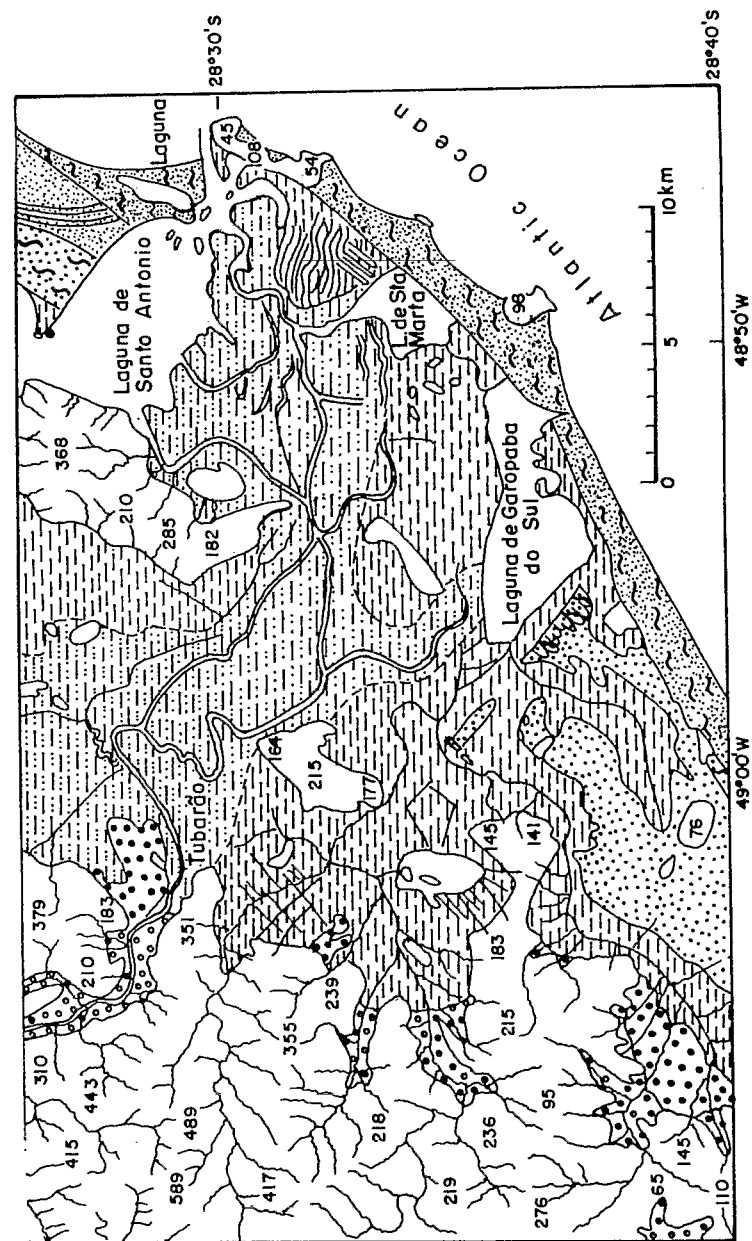


Figure 8. Geologic map of Laguna/Tubarão area (State of Santa Catarina).

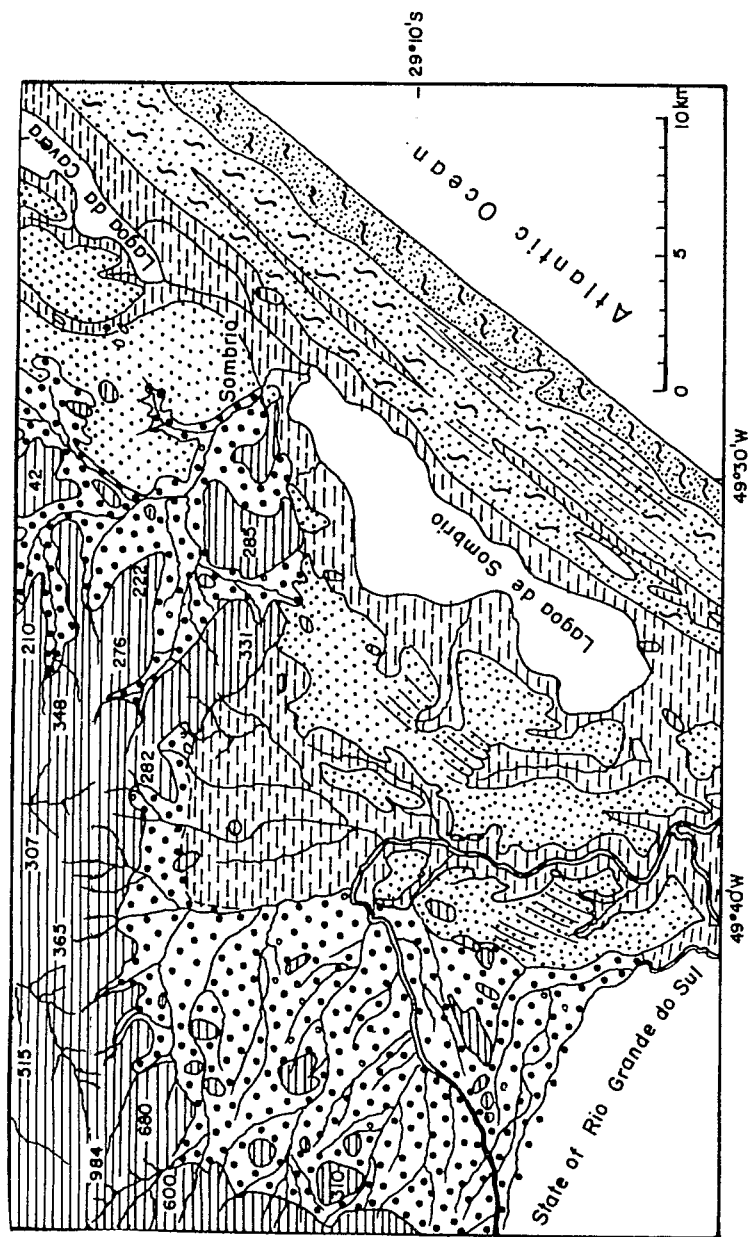


Figure 9. Geologic map of Sombrio area (State of Santa Catarina).

b) Holocene dunes fixed by vegetation - These sands are composed of whitish to yellowish coloured sands. They rest upon Pleistocene or Holocene marine terraces, ancient dunes and ancient lagoonal deposits as, for example, in Laguna da Conceição, Paulo Lopes and Garopaba do Sul areas. They are covered by vegetation and their migration stopped but they can be reactivated by antropic influence.

c) Active dunes - They are formed only of whitish coloured sands and represent the outermost band of eolian deposits existing in the coastal plains.

3 FLUVIO-LAGOONAL DEPOSITS

When a river flows into a lagoon, the fluvial sediments form an intralagoonal delta. Thus, during the past thousands of years, the Rio Tubarão constructed an intralagoonal delta with a considerable area, which partially filled the vast lagoon situated at south of Laguna (State of Santa Catarina). This delta is still active (Figure 8).

4 PEAT DEPOSITS

Total or partial desiccation of ancient lagoonal areas as a consequence of relative sea-level drop gave origin to swampy lowlands favourable to form peat deposits. Similarly, some badly drained lowlands gave origin to peat deposits. Neither of them resulted in thick deposits because vertical movements are practically null within Holocene time scale in these areas. Between Joinville and Itapocu, for example, there are extensive peat deposits presently covered by forest (Figure 3).

EVOLUTION OF THE STATES OF PARANA AND SANTA CATARINA COASTAL PLAINS DURING THE QUATERNARY

The evolutive scheme developed for the State of Bahia littoral zone and valid for most of the eastern and southeastern coastal plains of Brazil, was scheduled with a great precision by Martin et al. (1983 and this volume). This model is constituted by eight stages:

- a) Sedimentation of Pliocene continental deposits (Barreiras Formation);
- b) Maximum of the Ancient Transgression (older than 120,000 years BP);
- c) Sedimentation of the post-Barreiras continental deposits;
- d) Maximum of the Penultimate Transgression (about 120,000 years BP);
- e) Construction of the Pleistocene marine terraces;

- f) Maximum of the Holocene Transgression (about 5,100 years BP);
- g) Construction of intralagoonal deltas at the mouth of the most important rivers;
- h) Construction of the Holocene marine terraces.

This model remains almost entirely valid for the States of Paraná and Santa Catarina coastal plains.

Stage 1 - Several continental deposits, locally named Alexandra, Cachoeira, Canhanduva and Iquererim (Bigarella, 1975), probably Tertiary in age, have been deposited under semiarid conditions (*bajada* environment).

Stage 2 - There are not dated evidences of the Ancient Transgression in the area. However, the remnant of an ancient sandy marine terrace situated in Itapema could be related to the Ancient Transgression, as well as the ancient marine gravel deposits of Matinhos (State of Paraná), whose summits are situated about 13 m above the present sea-level according to Bigarella (1975). This idea is reinforced by occurrence of sandy marine terraces older than 120,000 years in the State of Rio Grande do Sul (Villwock et al., this volume).

Stage 3 - Continental deposits formed after the Tertiary and before the 120,000 years BP. Marine terraces are not still known in this area. However, probably the undifferentiated Quaternary deposits could be, at least in part, included within this stage.

Stage 4 - During the maximum of the Penultimate Transgression (about 8 m above the present level), the previous continental deposits have been partially eroded and the sea reached the foot of the Precambrian rock escarpments.

Stage 5 - Extensive sandy terraces have been formed after the maximum of the Penultimate Transgression along the States of Paraná and Santa Catarina littoral zones. These deposits were superficially reworked by winds giving origin to huge eolian dune fields.

Stage 6 - During the maximum of the Holocene Transgression, deeply eroded Pleistocene terraces were invaded by the sea with formation of many estuaries, bays and lagoons. Then, barrier island/lagoonal systems have been developed and paleoindians constructed many shell-middens at the border of these shallow-water bodies.

Stage 7 - When the barrier-islands isolated the lagoons from the open sea, the rivers flowing into these lagoons constructed intralagoonal deltas. With exception of Rio Tubarao, which formed an intralagoonal delta filling up, in

part, the lagoonal system of the Laguna area (Figure 8), there are not any other extensive intralagoonal deltas in this area.

Stage 8 - The maximum of the Last Transgression was followed by formation of sandy marine terraces. In southern half of this coastal plain the sandy deposits were superficially reworked by winds giving rise to important eolian dune fields. Some of dunes became completely inactive after being fixed by vegetation but others are still active.

CONCLUSIONS

Like in the most part of the previously studied Brazilian littoral zones, the coastal plains of the States of Paraná and Santa Catarina were also formed as a consequence of relative sea-level changes and paleoclimatic fluctuations during the Quaternary.

Extensive sandy terraces record the regressive phases which followed the maximum levels of the two last transgressive episodes (120,000 and 5,100 years BP). While the maximum height of the Pleistocene Transgression was similar in the most of the studied Brazilian littoral zones (about 8 m), the altitude of the relative sea-level during the Holocene was clearly lower in these states than in other sectors.

The southern half of the State of Santa Catarina is characterized by important eolian dune fields, where it is possible to recognize at least three generations of dunes. The oldest of them were deposited between 120,000 and 7,000 years BP. The second generation is constituted by dunes formed after 5,000 years BP, which is inactive because it is fixed by vegetation. These dunes are locally covered by still active dunes.

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