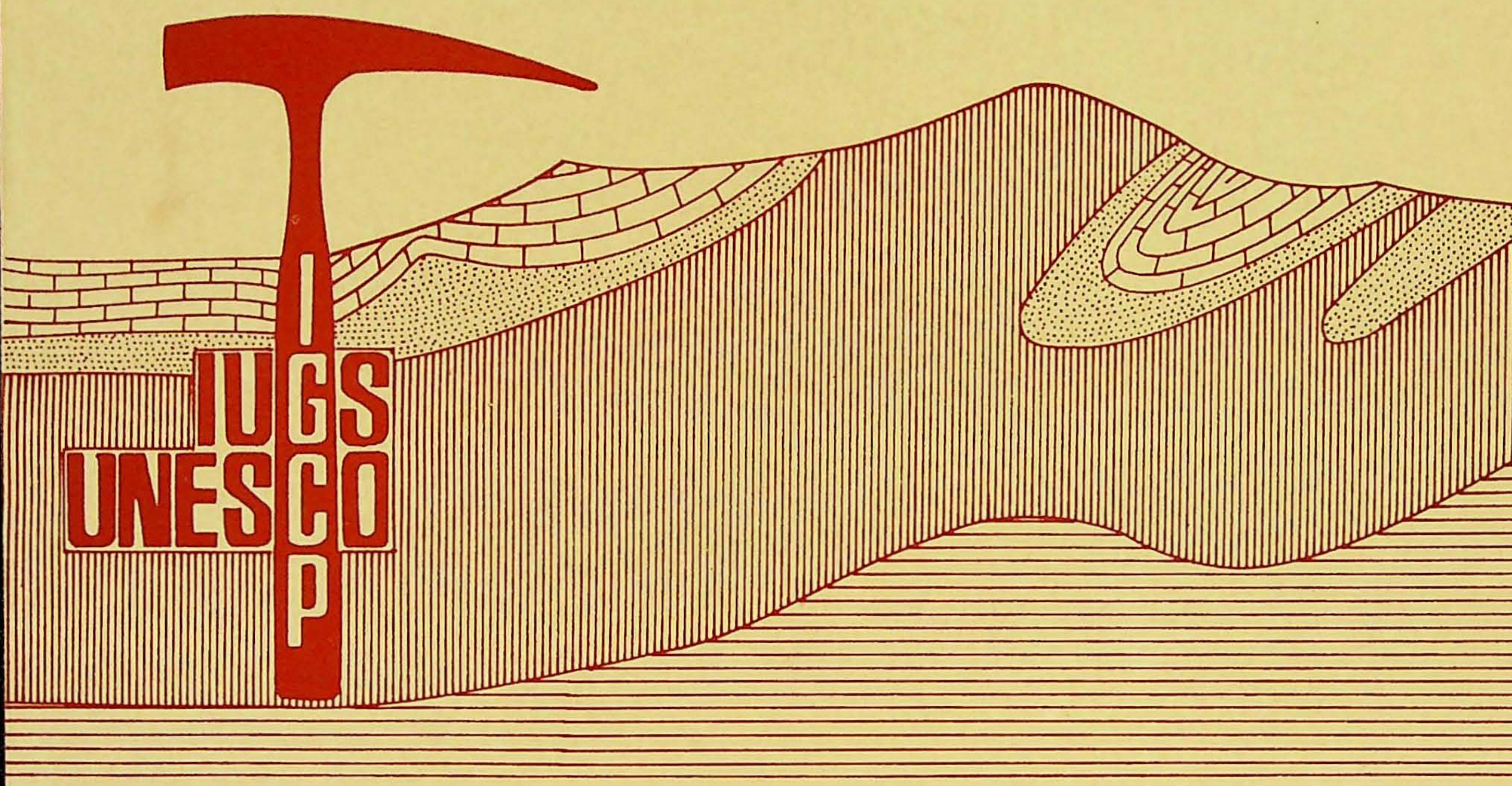
1978 INTERNATIONAL SYMPOSIUM ON COASTAL EVOLUTION IN THE QUATERNARY

SEPTEMBER 11 - 18, 1978



SPECIAL PUBLICATION N.o 2

EXCURSION ROUTE ALONG THE COASTLINE BETWEEN THE TOWN OF CANANÉIA (STATE OF SÃO PAULO) AND GUARATIBA OUTLET (STATE OF RIO DE JANEIRO)

The Brazilian National Working Group for the IGCP-Project 61

Instituto de Geociências, USP

Sociedade Brasileira de Geologia - SBG

São Paulo - Brasil

- 1978 -

THE BRAZILIAN NATIONAL WORKING GROUP FOR THE IGCP - PROJECT 61
IN COOPERATION WITH

Holocene Commission of INQUA
Shoreline Commission of INQUA
Neotectonic Commission of INQUA
Quaternary Commission of the Sociedade Brasileira de Geologia
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EXCURSION ROUTE ALONG THE COASTLINE BETWEEN THE TOWN OF CANANÉIA (STATE OF SÃO PAULO) AND GUARATIBA OUTLET (STATE OF R. DE JANEIRO)

by

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GENERAL OUTLINE OF BRAZILIAN GEOLOGY

1. GENERAL

North to south Brazil extends between latitudes 5° 16' N and 33° 45' S over a distance of about 4,319 km. East to west, it extends over 4,326 km between longitudes 73° 59' W and 34° 49' W. Brazil has an area of 8,511,965 km^2 which represents almost 50% of South America. Most of its territory is located in the intertropical zone (the Tropic of Capricorn passes slightly north of the city of São Paulo). The Brazilian territory is characterized by moderate altitudes, ranging from 0 to 3,000 m (Pico da Neblina, near the Venezuela frontier reaches 3,014 m); 40% of the country is 0 to 200 m high; 45% between 200 and 600 m, and only 15% is higher than 600 m.

2. PRECAMBRIAN BASEMENT

Precambrian rocks cover an area of almost 5 million km^2.

They have been subjected to more or less strong metamorphism and in general have been intruded by plutonic rocks. These Precambrian rocks were rejuvenated during the Brazilian Folding Cycle (900 to 550 m.y.), which represents the end of geosynclinal-type tectonic evolution in Brazilian territory.

The Brazilian portion of the South American Platform (Fig. 1) underwent a geocratic period with a rather prolonged tectonic calm from the end of the Precambrian to the end of the Jurassic (ALMEIDA, 1967).

3. INTRACRATONIC BASINS

3.1 - PRE-SILURIAN BASINS

3.1.1 - São Francisco basin

This is formed of limestones, schists and meta-arenites with a maximum thickness of 1,000 m. Radiometric datings indicated a minimum age of about 600 m.y.

3.1.2 - Corumbá-Cuiabá basin

Its central portion is covered by Cenozoic sediments of the Pantanal Matogrossense.

3.1.3 - Itajaí basin

Is formed by afossiliferous clastic sediments with a thickness of about 1,000 m.

3.1.4 - Camaquã basin

Formed by afossiliferous detrital deposits intensively intruded by andesitic and quartz-porphyric rocks.

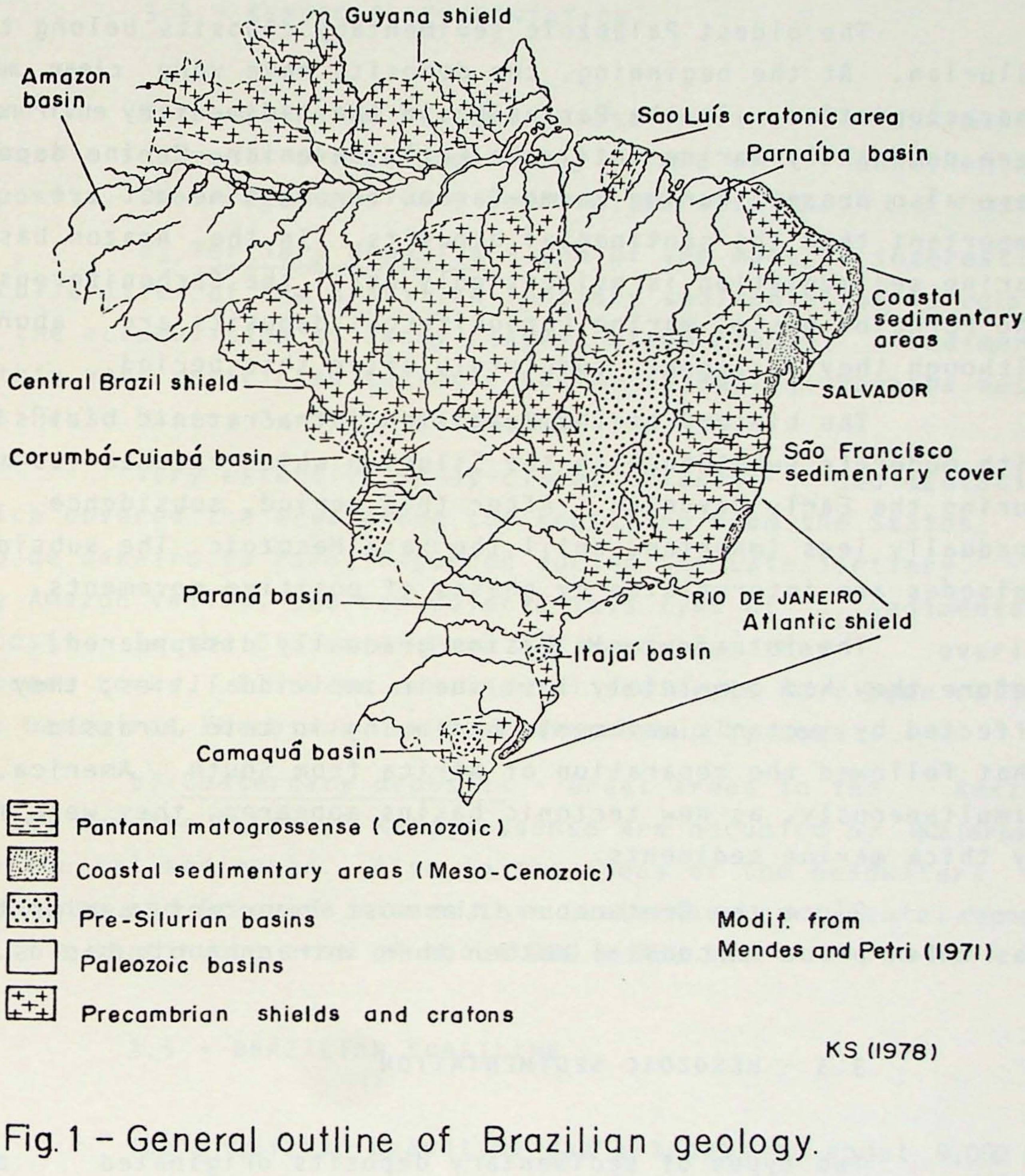


Fig. 1 – General outline of Brazilian geology.

3.2 - GREAT PALEOZOIC BASINS

There are three large Paleozoic intracratonic basins: the Amazon, Parnaība and Paranā basins.

The oldest Paleozoic sedimentary deposits belong to the Silurian. At the beginning, the deposits have very clear marine characteristics. In the Paranā basin the sedimentary environments were dominantly marine until the Early Devonian. Marine deposits were also present during Permo-Carboniferous time but are less important than the continental deposits. In the Amazon basin, marine sedimentation is evident only until the Carboniferous. In the Parnaība basin, marine Carboniferous deposits are abundant although they disappear completely after this period.

The history of the Brazilian intracratonic basins began with moderate subsidence in the Silurian which reached its maximum during the Early Devonian. After this period, subsidence was gradually less important until the Late Mesozoic. The subsidence episodes are intercalated by phases of positive movements.

The intracratonic basins gradually disappeared, but before they had completely lost their individualities, they were affected by tectonic movements beginning in Late Jurassic time, that followed the separation of Africa from South America. Simultaneously, as new tectonic basins appeared, they were filled by thick marine sediments.

Since the Cretaceous, the most important sedimentation has taken place in coastal rather than intracratonic basins.

3.3 - MESOZOIC SEDIMENTATION

Two types of sedimentary deposits originated during the Mesozoic: coastal formations and inland formations.

a) Coastal formations were deposited in tectonic depressions. They consist of marine and non-marine sedimentary sequences that began in the Late Jurassic and ended in the Early Tertiary.

b) Inland formations are distributed in the interior of the country and are typically continental deposits.

3.4 - CENOZOIC SEDIMENTATION

With exclusion of some coastal marine sediments, Cenozoic sediments are predominantly formed of continental deposits. Their ages are very doubtful because they lack fossils.

a) Tertiary deposits - One of the most interesting peculiarities of the Brazilian Tertiary sedimentation is related to the accumulation of sandy-clayey, often pebbly, sediments within very restricted tectonic basins (Examples: Paraĩba basin, São Paulo basin, Curitiba basin, etc.).

Very extensive sandy-clayey, clastic sedimentation, which covered the area along the coastline from the States of Rio de Janeiro to Pará, occurred during the Late Tertiary. In the Amazon valley, one can observe this type of sedimentary deposit. In the States of Pará and Maranhão, they overlie Miocene rocks. Pliocene continental sediments have been called the Barreiras Formation, or Barreiras Group by some.

b) Quaternary deposits - Great areas in the Amazon valley and the Pantanal Matogrossense are occupied by Quaternary continental sediments. Also in the areas of the headwaters of the Xingu and Araguaia rivers thin Quaternary continental deposits cover a continuous area of about 750 x 750 km.

3.5 - BRAZILIAN COASTLINE

The Brazilian coastline has a length of about 9,000 km. The distribution of sedimentary deposits along this coast is typically related to geologic structures and features on the continent.

SILVEIRA (1964) divided Brazilian coastline into five sectors:

a) Amazonic or Equatorial coastline - This sector is 1,500 km long and may be several hundred kilometers wide, mostly consisting of frequently flooded lowlands. Behind these lowlands, there is a low plateau (5 to 15 m) of older sediments (Tertiary to Quaternary) that is never covered by the waters. In several localities this plateau may reach the ocean and thus can form small cliffs. This situation is more common in the eastern portion of the Amazonic coastline.

b) Northeastern or Barreiras cliff coastline - The common feature observed from the Parnaíba delta to the city of Salvador is the presence of the Barreiras Formation. For the greatest part, these sediments overlie peneplaned Precambrian crystalline rocks, but in some places they are situated on Cretaceous sediments.

In the Cape of São Roque area, the coastline trend changes abruptly by forming an "elbow" separating a northern and a southern coastline. The northern part has a semi-arid climate, in which dunes are actively forming behind the beaches, while the southern part is humid.

One of the peculiarities of the northeastern coastline is the existence of beach-rocks.

c) Eastern coastline - This portion of the Brazilian coastline extends from Salvador to southern State of Espírito Santo. From Salvador to Itacaré the coastline is situated along the southern side of the Recôncavo Cretaceous sedimentary basin. Quaternary sedimentary deposits are well developed except at the margins of the Baía de Todos os Santos.

From Itacaré to Ilhéus, excluding the small Almada basin area, the coastline is cliffy with several outcrops of crystalline basement. Southward, the coastline is characterized by extensive bands of Barreiras Formation situated between Precambrian rocks and the sea, with marine Quaternary plains, often related to small streams (small deltas), being found in small embayments in this formation. In this part of the coastline there are many lineations of reefs. Coral reefs are also observed in southern State of Bahia, mostly in the Abrolhos area.

d) Crystalline coastline - From southern Espírito Santo to the Cape of Santa Marta (State of Santa Catarina), the coastline delineates a long concave line, whose most inland point is the bay of Paranaguá. Just as the northeastern coastline is characterized by the Barreiras Formation, the crystalline coastline is characterized by rocks of the Brazilian Complex. From Guanabara bay to the State of Paraná, coastal plains and beaches are frequently absent, and the coastline is abruptly intercepted by the eastern margin of the often more than 800-m-high, Brazilian Atlantic Plateau. Headlands oblique to the coastline reach the sea in many places thereby delineating small bays. Some of these bays have been more or less filled up by Quaternary marine sediments. One of the characteristics of this part of the Brazilian coastline is that the great majority of the nearby rivers flows toward the interior of the continent rather than into the sea.

e) Southern coastline - South of Laguna (State of Santa Catarina), the coastline is essentially low and sandy. Very well developed beach-ridge plains have governed the formation of lagoonal systems, some of which cover considerable areas, such as Patos lagoon (10,000 km^2) and Mirim lagoon. Unconsolidated fine sands have been frequently reworked by eolian action, and very high sand dunes have been formed.

MARINE QUATERNARY DEPOSITS OF THE BRAZILIAN COASTLINE BETWEEN THE TOWN OF CANANÉIA (SP) AND GUARATIBA OUTLET (RJ)

1. INTRODUCTION

The portion of the Brazilian coastline studied here is elongated in a NE-SW direction and is located between 44° and 48° W longitude. It covers the entire extent of the State of São Paulo's coastline as well as the southern half of the coast of the State of Rio de Janeiro. This corresponds, in a straight line, to about 550 km of the Brazilian coast (Fig. 2). This portion of the coastline is included in the crystalline coastline of SILVEIRA'S classification (*op. cit.*), which is characterized by the presence of the Serra do Mar (Coastal Ranges).

From a geomorphological viewpoint, this region is characterized by a submergent morphology in the north and an emergent morphology in the south (MARTIN and SUGUIO, 1975, 1976). In fact, in the north, the crystalline basement reaches the sea almost continuously, except along small plains made up inland by continental deposits and seaward by marine sediments. In the south, very extensive sedimentary plains are found, mostly formed by Quaternary marine and lagoonal deposits, and separated from each other by headlands of crystalline Precambrian, rocks. Taking into consideration the limits of the Precambrian basement, five morphological units may be recognized from south to north: Cananéia-Iguape unit, Itanhaém-Santos unit, Bertioga-Ilha de São Sebastião unit, São Sebastião-Serra do Parati unit and the Baía de Ilha Grande unit.

The first of these is completely filled by Quaternary deposits, and the strandline is practically straight. Northward, these plains are less and less filled, until finally, in the Ilha Grande bay area, only a few Quaternary marine deposits occur. Discounting the presence of the sedimentary deposits in the south,

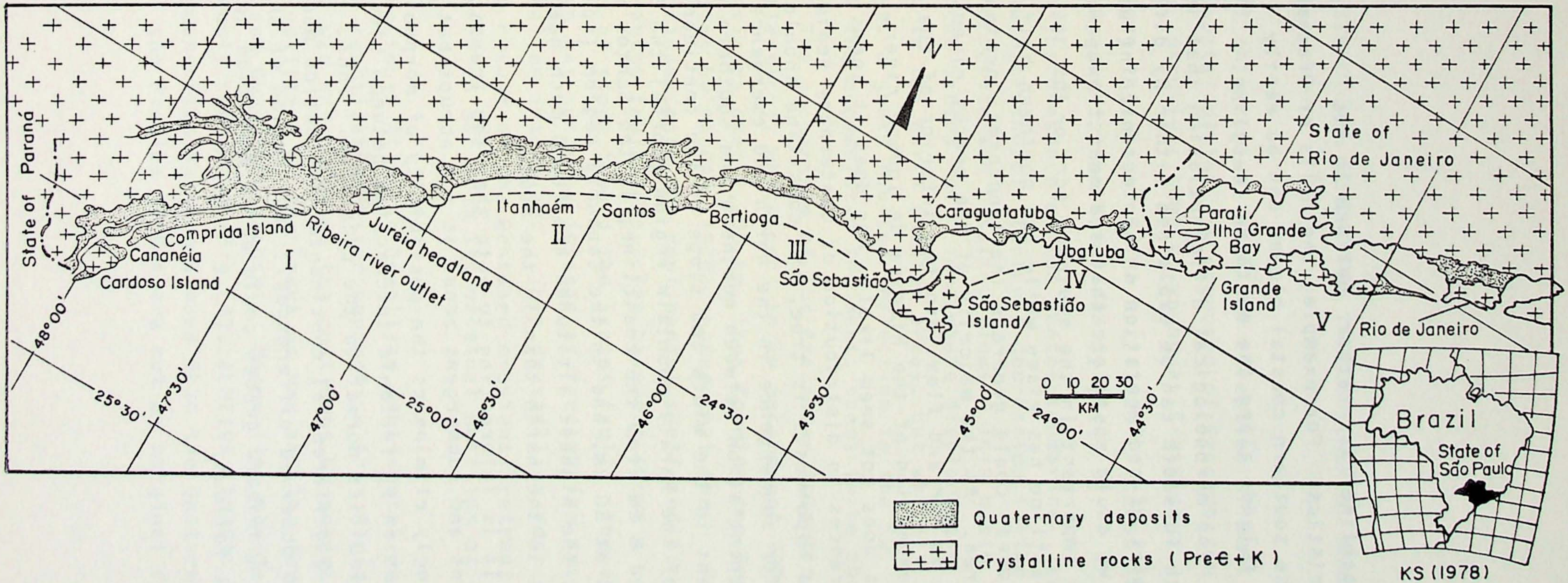


Fig.2 – Quaternary deposits on the coastal plains of states of São Paulo and southern Rio de Janeiro.

this coastline is rather uniform in its morphological characteristics. For example, the hills of Precambrian rocks within the southern coastal plains can be easily correlated with the islands along the northern coastline.

The morphological differentiation that is observable from north to south can be explained either by differences in the dynamics of sedimentation or by tectonic influences. For example, we could postulate that sediment transport could have been more important in the southern part,or that the southern half of the coastline has risen while the northern half has sunk; either process could generate the landforms presently evident in this area. As the majority of the nearby rivers begin in the Serra do Mar and flow into the interior of the continent, with the exception of the Ribeira de Iguape river, the former hypothesis does not seem likely, nor does it seems to explain the differences in distribution of Quaternary sediments. If the second hypothesis is true, the coastline should show a tendency for submergence in the north and emergence in the south. This differentiation between northern and southern provinces is also evident in the width and slope of the continental shelf. In front of the Parati mountain region (north) the 50 m isobath is situated 8 km from the coastline; in the Santos region, it is located at 30 km, and in the Cananéia region (south)at 50 km. Similarly, the highest altitudes are found much nearer the strandline in the north than in the south.

It is interesting to note that the transition between the emergent and submergent zones is not abrupt but gradual. This seemingly eliminates the possibility of morphological differentiation by tectonic interaction between blocks separated by discontinuities normal to the coastline. Thus, it is necessary to look to a differential continental inflection mechanism to explain the observed differences. The section of the coastline cut by the Guanabara graben could be an exception to the general scheme that follows.

2. STRUCTURAL SCHEME FOR THE CONTINENTAL MARGIN

All this region, with the exception of small sedimentary basins and coastal plains, is composed of Precambrian metamorphic rocks cut by intrusives some as young as Cretaceous.

Along this part of the Brazilian coastline, the continental margin is characterized by (Fig. 3):

a) The presence of the Santos submarine sedimentary basin, a Mesozoic-Cenozoic tectonic depression filled by sedimentary deposits and basaltic flows. This basin is limited landward by the Santos fault zone whose displacement is more than 3,000 m in the north (Santos area), but which passes gradually into a great faulted inflection to the SW. The maximum thickness of the accumulated sediments seems to be about 8,000 m.

b) The occurrence of the Brazilian Atlantic Plateau (Planalto Atlântico), which ends in an escarpment 900 to 2,000m high and continues over 1,200 km, thus forming the Serra do Mar. Seismic studies by BACCAR (1970) showed that the Precambrian basement continues onto the continental shelf and is inclined toward the Santos fault zone. The basement shows a rapid accentuation of slope toward the Santos fault. The area under consideration has numerous islands of Precambrian rocks and Senonian alkaline intrusives. This crystalline rock surface is supposedly a result of the westward erosional retreat of the ancestral Serra do Mar from its original position at the Santos fault margin.

The South Atlantic Brazilian continental margin was subjected to reactivation after separation from Africa. This reactivation was reflected on the continent by several events such as the uplifting of the Serra do Mar and the formation of the Paraība and Guanabara grabens. Meanwhile, the Santos basin was continuously subsiding (Fig. 4), ALMEIDA (1975). It appears that these mechanisms have continued into the Quaternary, as sediments of the Paraība graben are cut by marginal faults

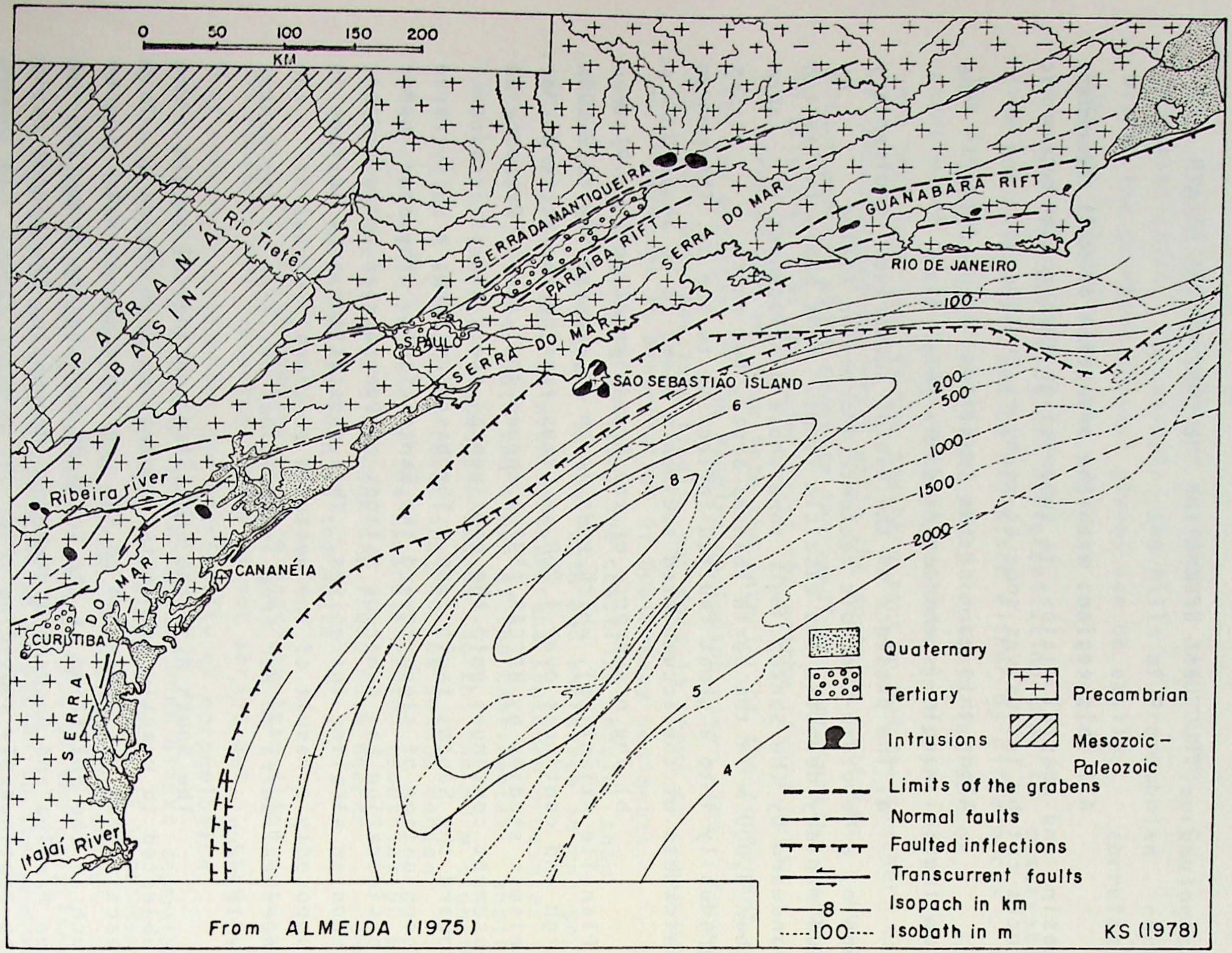


Fig. 3 — Structural framework of the continental margin at southeastern Brazil.

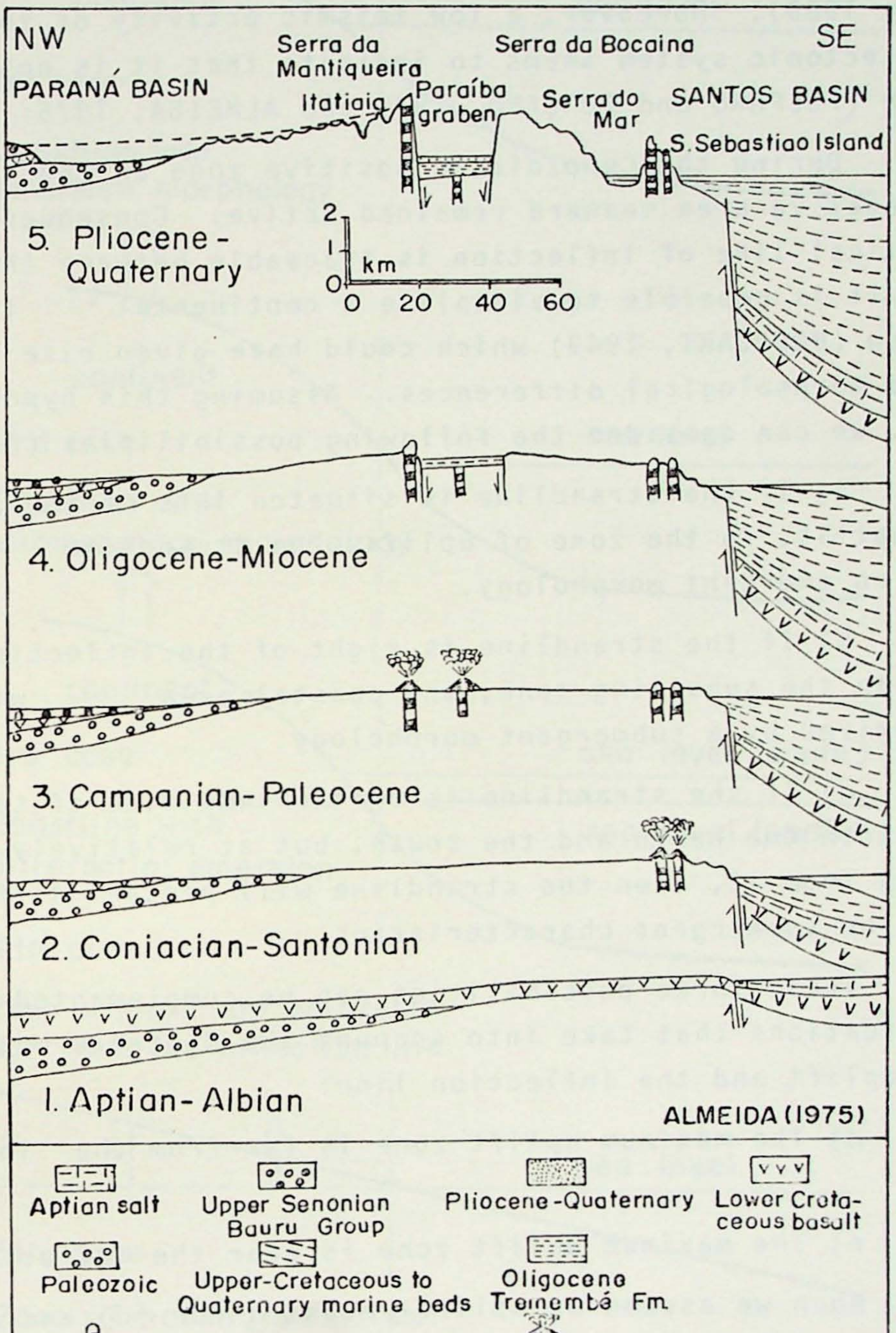


Fig. 4 – Possible tectono-magmatic evolution of the continental border of the Santos basin.

KS(1978)

(SUGUIO, 1969). Moreover, a low seismic activity of the Serra do Mar tectonic system seems to indicate that it is not entirely inactive (FULFARO and PONÇANO, 1974 and ALMEIDA, 1975: 24).

During the Cenozoic, a positive zone on the continent and a negative area seaward remained active. Consequently, a hypothetical line of inflection is traceable between the two areas. It is possible to visualize a continental inflection mechanism (BOURCART, 1949) which could have given rise to the observed morphological differences. Assuming this hypothesis to be true, we can consider the following possibilities (Fig. 5):

a) If the strandline is situated left of the inflection line, that is, in the zone of uplift, the strandline will exhibit an emergent morphology.

b) If the strandline is right of the inflection line, that is in the subsiding zone, the coastal area will be characterized by a submergent morphology.

c) If the strandline is on the same side of the inflection line in both the north and the south, but at relatively different distances from it, then the strandline will present differential emergent or submergent characteristics.

These three possibilities can be complemented by two other situations that take into account the distance between the maximum uplift and the inflection line:

d) The maximum uplift zone is far from the inflection line.

e) The maximum uplift zone is near the inflection line.

When we assume an uplift height h for (d) and (e),equal in both cases, the surface affected by the phenomenon will be more extensive in case (d) than in case (e). Thus, if we consider two points, A and B, separated by a distance d from the inflection line, the uplift height will be greater in the fifth case than in the fourth.

In reality, the maximum uplift zone is observed nearer

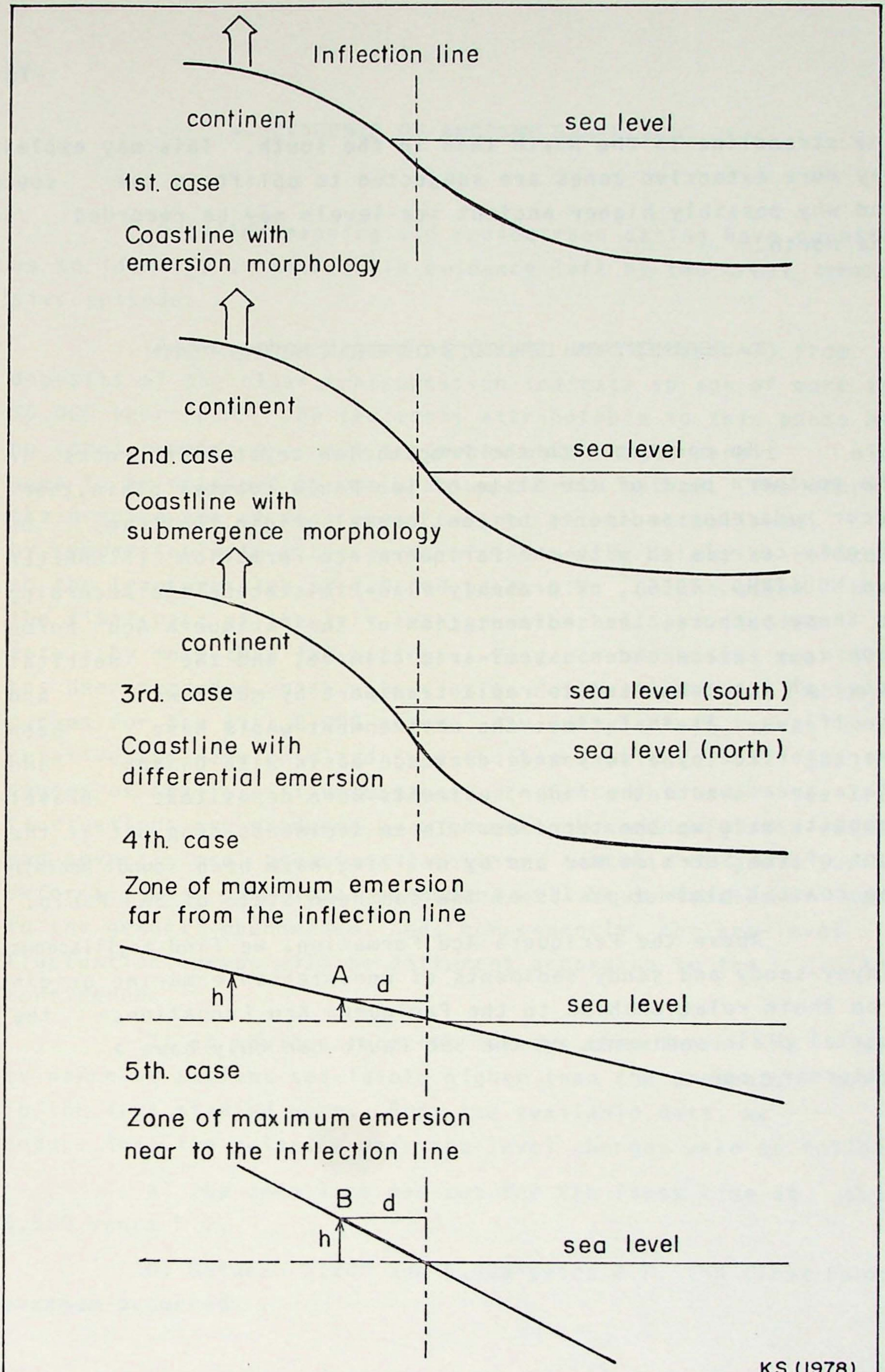


Fig. 5— Scheme of differentiation into emergent and submergent coast by continental inflection mechanism

the strandline in the north than in the south. This may explain why more extensive zones are subjected to uplift in the south and why possibly higher ancient sea-levels may be recorded in the north.

3. SEDIMENTARY DEPOSITS OF THE COASTAL PLAIN

In contact with the Precambrian crystalline rocks in the southern part of the State of São Paulo coastal plain, there occur rudaceous sediments of continental origin that can be roughly correlated with the Pariquera Açu Formation (BIGARELLA and MOUSINHO, 1965), of probably Plio-Pleistocene age. According to these authors, the sedimentation of the Pariquera Açu Formation took place under a semi-arid climate, and the detrital material was submitted to rapid transport by mudflows and sheetflows. At that time, the environment would have been characterized by a very wide drainage basin with bajada and playa areas where the finer sediments were deposited. Gravel deposits made up the terraces. These sediments crop out at the foot of the Serra do Mar and by drilling have been found beneath the coastal plain deposits of the southern State of São Paulo.

Above the Pariquera Açu Formation, we find argillaceous, clayey-sandy and sandy sediments of uncontestable marine origin. From their relationships to the Pariquera Açu Formation, the coastal plain sediments of the São Paulo can only have a Quaternary age.

4. EVIDENCE OF ANCIENT SEA-LEVELS

Detailed mapping and radiocarbon dating have permitted us to identify uncontestable evidence left by two great transgressive episodes.

Radiocarbon dating of fossil wood (charcoal) from the deposits of the older transgression indicate an age of more than 30,000 years B.P. The sediments attributable to this phase have no coral remains or shell fragments which might permit older ages to be obtained by the uranium-thorium method. Therefore, the precise age of this event can not yet be established, but by comparison with other parts of the world, it may be related to the transgression of 120,000 years B.P. On the other hand, the final part of the last transgression has been studied in detail by more than 120 datings. Evidence of ancient sea-levels has been recorded which allows us to outline sea-level fluctuation curves for the last 8,000 years. Obviously, these curves are relative and have resulted from the integration of all possible causes of sea-level fluctuations. In fact, relative sea-level fluctuations are produced by a general phenomenon(glacio-eustasy) and several local phenomena (isostasy, tectonic or geoid surface deformations). The local phenomena will be subtracted or added to the general phenomenon, and, consequently, the sea-level fluctuation curves will be different according to the area considered.

It is obvious from our surveys that there is much evidence of ancient sea-levels higher than the present, mostly in the area studied here. From the available data, we can deduce that the relative mean sea-level changes were as follow:

a) The zero line was cut for the first time at about 6,500 years B.P.

b) Between 5,200 and 5,000 years B.P. the first Holocene maximum occurred.

c) About 3,800 years B.P. the relative mean sea-level may have been equal to or slightly lower than the present level.

d) About 3,500 years B.P. the relative sea-level would have been at a second Holocene maximum.

Before comparing the sea-level change curves for different portions of the coastline, let us look at the distribution of the different Quaternary deposits left by the two great transgressive periods: the Cananéia transgression (Pleistocene) and the Santos transgression (Holocene).

5. SEDIMENTARY DEPOSITS LEFT BY THE QUATERNARY TRANSGRESSIONS

5.1 - UNIT I: CANANÉIA-IGUAPE COASTAL PLAIN

5.1.1 - General characteristics

The Cananéia-Iguape sedimentary plain forms an extensive crescent almost 130 x 40 km, covering about 2,500 km^2. It is limited in the SW and NE by headlands of crystalline basement that reach the sea. Lagoonal channel systems affected by tidal fluctuations drain its seaward side. Four islands are separated by several lagoonal branches (known as "mar" = sea):

Cardoso island - This island, located in the southern part of the area, is formed essentially of Precambrian rocks with Quaternary deposits only along its periphery. It is separated from the continent by a natural channel (Ararapira channel).

Comprida island - Excluding the small alkaline intrusive that forms Morrete hill in the south of the island, this 3- to 5-km wide, 70-km long barrier-island is essentially sandy. It is separated from the continent by the Mar Pequeno lagoonal channel which varies between 400 and 1,200 m in width. Southward, this channel divides into two branches around Cananéia island, thus giving origin to the Mar de Cubatão and Mar de Cananéia.

Cananéia island - This is also an essentially sandy island, except for São João hill near Cananéia, which is also formed of alkaline intrusive rocks but much larger than Morrete hill.

Iguape island - Iguape island, located in the central part of the coastal plain, is artificial, having originated during the past century by the opening of a channel connecting the Mar Pequeno to the Ribeira de Iguape river. This hilly island is predominantly formed of Precambrian rocks surrounded by Quaternary deposits.

The central portion of the Cananéia-Iguape plain is drained by the Ribeira de Iguape river, which is the most voluminous river of this part of the coastal plain. Several small interconnected rivers (Peroupava, Una de Aldeia, Pedras and Comprido) originate in the plain and are essentially responsible for its drainage. Thus, the Peroupava and Una de Aldeia rivers are connected by the Pequeno river and the Una de Aldeia and Comprido rivers by the Pedras river. The lagoons and the rivers in this region are connected to the sea by several outlets that are known, from south to north, as Ararapira, Cananéia, Icapara, Ribeira and Una outlets.

Another characteristic of this region is the abundance of shell-middens, which in Brazil are known as "sambaquis". Already by 1893, LÖFGREN had found 96 of these shell-middens. Obviously, the mollusk shells from the shell-middens are not the best materials for dating ancient strandlines. In fact, the relationship between the substrate of a shell-midden and the mean sea-level at the beginning of its construction is frequently unknown. However, the fact that high-tide level could not have been above shell-midden's substrate during its construction is obvious. We must assume, as a postulate, that the mollusks whose shells make up the shell-middens were not transported from very great distances by the Indians. From this assumption, it follows that the shell-middens on the Pleistocene formation at distances as far as 40 km from the present strandline can only be explained as indicative of an ancient sea-level higher than present. This idea seems to be logical, especially since the retreat of the strandline can not be explained by sedimentary progradation.

5.1.2 - Quaternary formations of marine and lagoonal origin

a) Sedimentary deposits related to the Cananéia transgression - Directly above the Pariquera Açu Formation is a formation, the Cananéia Formation (SUGUIO and PETRI, 1973), that is argillaceous in its basal part and sandy at its top. Its altitude ranges from 5 to 6 m seaward and 9 to 10 m near the crystalline basement rocks (Fig. 6). From the study of its microfossils, PETRI and SUGUIO (1973) showed that the basal argillaceous unit was deposited in a brackish water environment transitional between an earlier continental and a later salt-water environment, and thus helps characterize a transgressive episode. In the sandy sequence, it is possible to find fossil *Callianassa* burrows. *Callianassa* at present inhabits the lower part of the intertidal beach. Hence, the occurrence of these fossil burrows is indicative of a sedimentary deposit formed in the lower part of the beach (SUGUIO and MARTIN, 1976). Above the top of the sandy formation, several centimeters of argillaceous beds with mudcracks are found, a feature also characteristic of sedimentary deposits of the littoral zone. In certain regions, we can see very clear structures of old beach-ridges on aerial photos that testify to the beginning of the regressive phase. The lower part of the Cananéia Formation has transgressive characteristics whereas the upper part has regressive characteristics.

The first radiocarbon dating of a fossil wood fragment

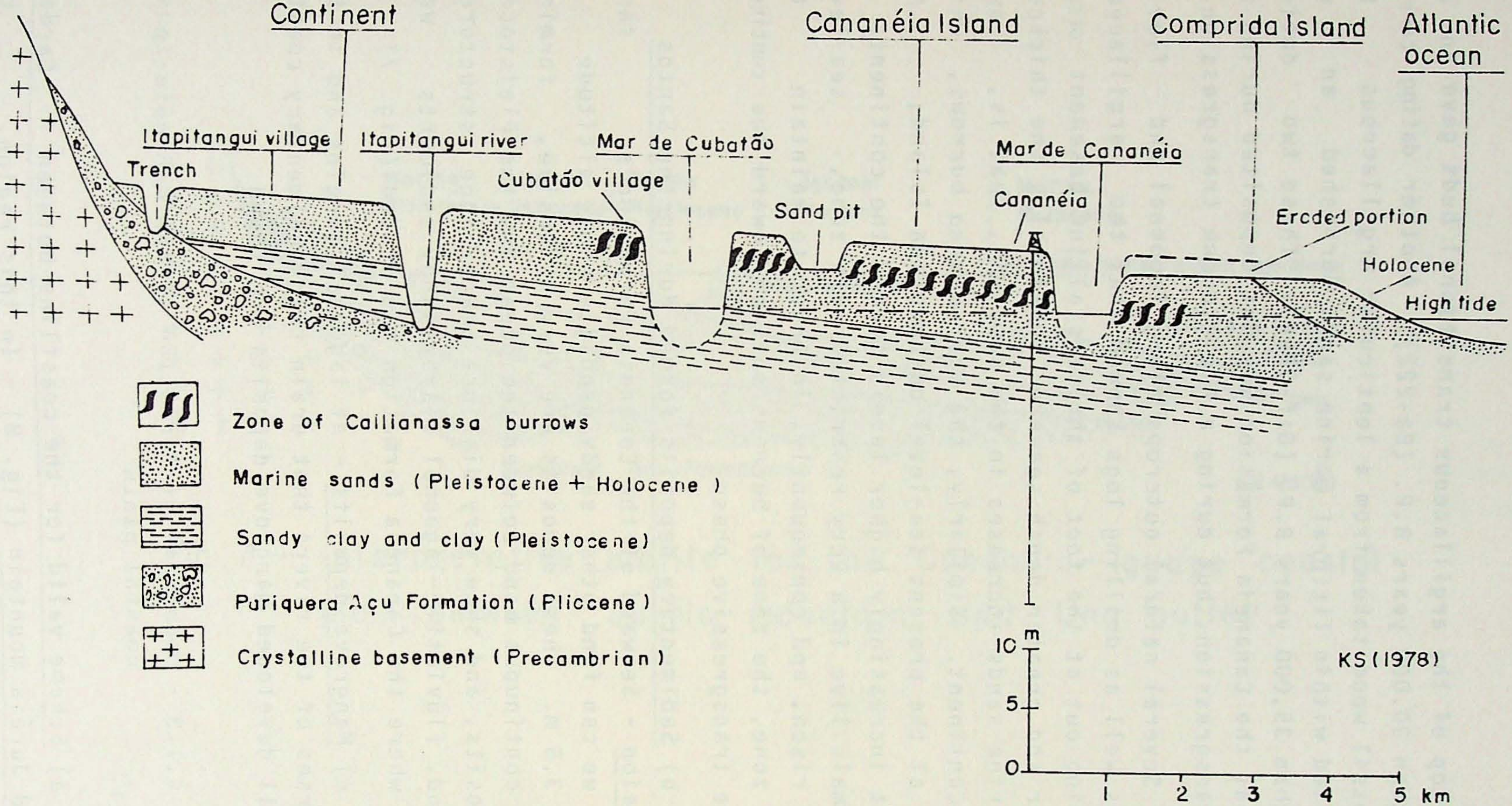


Fig. 6 – Interpretative profile across sedimentary deposits of Cananéia area.

from the top of the argillaceous transitional beds gave an age of more than 30,000 years B.P. (Ba-222). Another dating carried out on fossil wood taken from a lenticular argillaceous bed intercalated within littoral marine sands furnished an age greater than 35,000 years B.P. (Gif-3844). These two datings showed that the Cananéia Formation was not deposited during the Santos transgression, but during a Pleistocene transgression.

Several natural outcrops along lagoonal and fluvial margins as well as drilling logs showed that the argillaceous bed cropping out at the foot of the crystalline basement occurs at greater and greater depth seaward. Obviously, the thickness of the marine sands increases in the same way, that is, away from the continent. Similarly, the *Callianassa* burrows, which today are at the present sea-level on Comprida Island, are located at increasingly higher levels toward the continent. As these animals live in a very restricted life zone, sea-level must have risen, and consequently, in order to maintain the same life zone, the zone of burrows shifted toward the continent during the transgressive phase.

b) Sedimentary deposits formed during the Santos transgression - Seaward of the Cananéia Formation's sandy deposits, we can find other sandy deposits whose altitude is less than 3.5 m. These deposits are very extensive, forming an almost continuous band between the ocean and the Pleistocene sandy deposits, and show very distinct beach-ridge structures. More inland, fluviatile-lagoonal clayey-sandy sediments were deposited where the Cananéia Formation was eroded (Fig. 7).

c) Mangrove deposits - At lagoonal margins and in the lower courses of the rivers that drain this sedimentary coastal plain, well developed mangrove deposits are found.

5.1.3 - Mechanism of formation of the Cananéia-Iguape coastal plain

a) Scheme valid for the coastline between Cardoso island and Juréia mountain (Fig. 8) - In this region, the

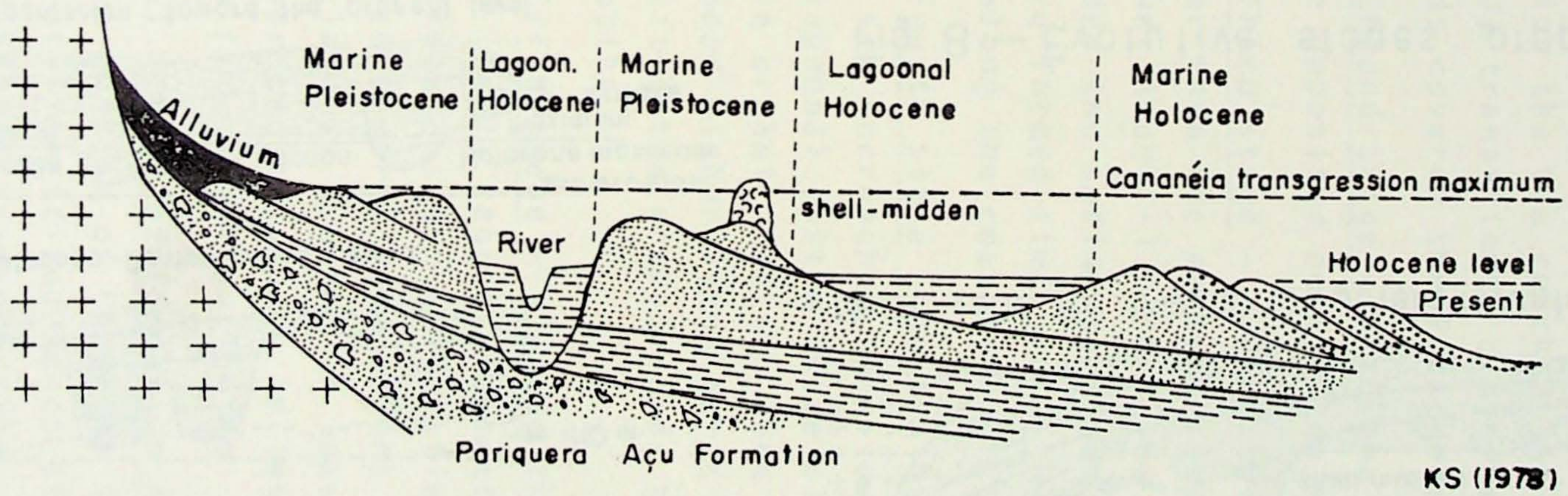
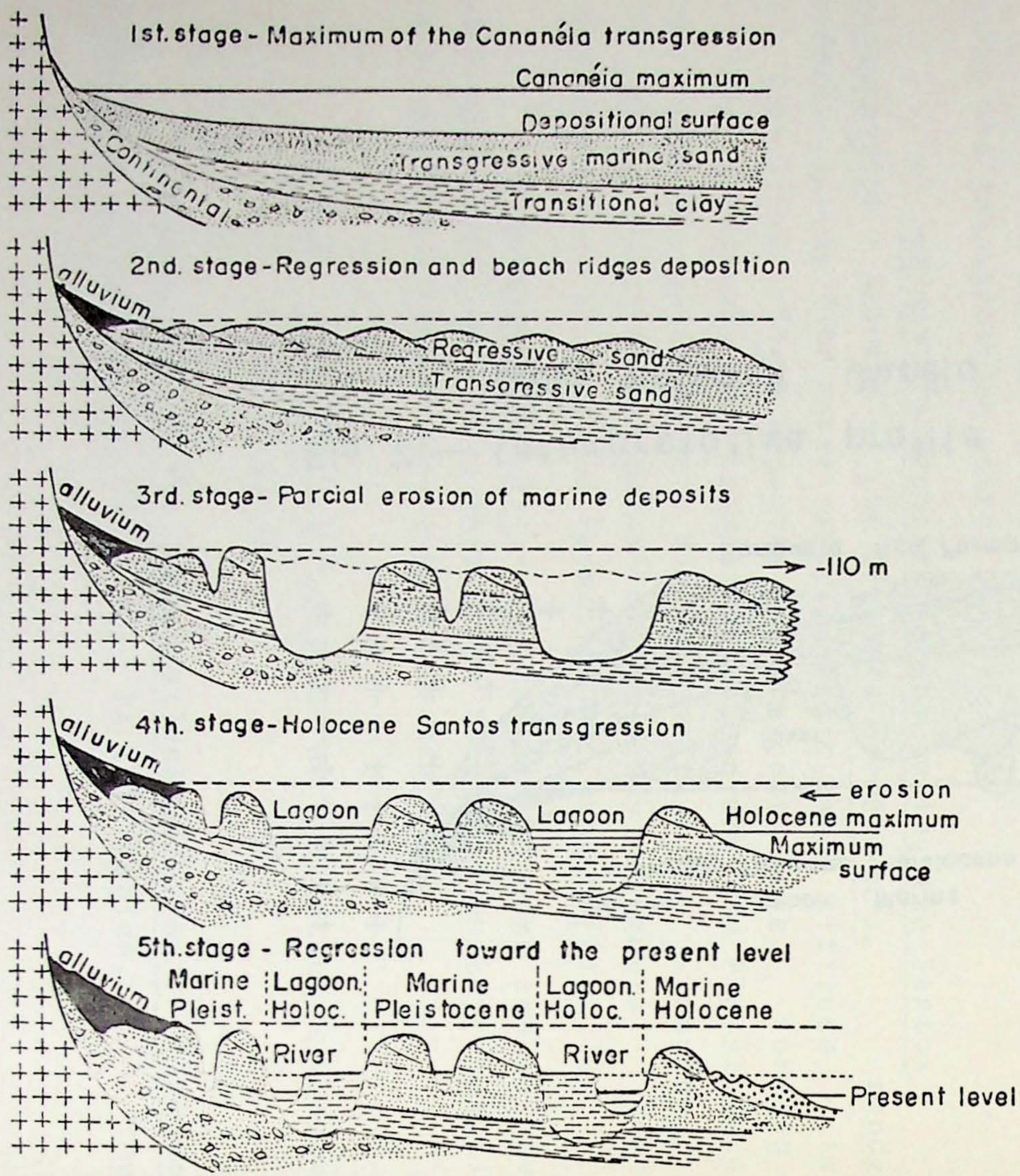
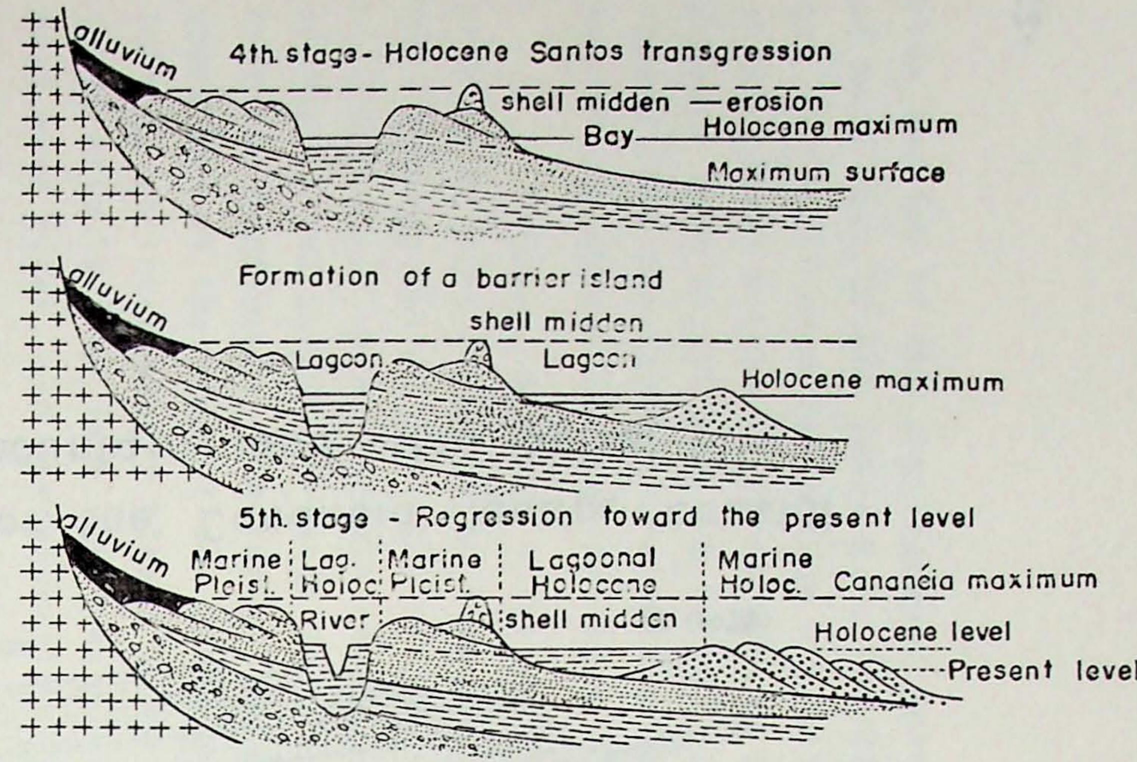


Fig. 7 — Interpretative profile for the Cananéia—Iguape coastal plain between Juréia mountain and Una outlet



Model valid between Cananéia and Juréia mountain



Model valid for the portion Juréia mountain - Una outlet

Fig. 8 — Evolutive stages proposed to explain the origin of the Cananéia — Iguape coastal plain.

KS (1978)

development of the Quaternary coastal plain may best be understood by means of a scheme showing its evolutionary sequence:

First stage - During the maximum of the Cananéia transgression the sea reached the foot of the Serra do Mar. In this period, transitional clayey-sandy sediments and transgressive marine sands covered the Pariquera Açu Formation.

Second stage - With the regressive phase,beach-ridges began to be deposited on the top of sandy sediments.

Third stage - During this phase the sea-level was always lower than the present (about 17,000 years B.P. the sea-level was about -110 m below present level), and the rivers deeply eroded the sedimentary deposits of the Cananéia Formation. Valleys were formed similar to those observed in the Barreiras Formation along the coastline of the State of Bahia.

Fourth stage - At the beginning of the last transgressive period the sea encroached upon lower areas, thereby forming an extensive lagoonal system where clayey-sandy deposits, frequently very rich in organic matter, were deposited. In the meantime, the sea eroded higher-lying parts of the Cananéia Formation and redeposited the eroded sands to form the Holocene sandy marine deposits.

Fifth stage - During the return of sea-level toward its present level, regressive beach-ridges were formed. Sea-level fluctuations during the final part of the last transgression produced several generations of beach-ridges. Thus, on Comprida island we can see at least two generations of beach-ridges separated by a more or less swampy, low-lying zone that can be followed about 50 km.

b) Scheme of formation of Comprida island - The southernmost portion of Comprida island, on the lagoonal side, is made up of limonitized sands of the Cananéia Formation. During the maximum Santos transgression, the southern extremity of the island was submerged (Fig. 9). After the first maximum (5,100 years B.P.), the island "grew" northward in the direction of

Iguape. The curved beach-ridges, easily visible on aerial photos, confirm this mode of formation. As the island grew longer northeastwardly, it enlarged laterally by the addition of beach--ridges parallel to the present strandline. During the minor transgression that took place prior to the second maximum (3,500 years B.P.), these beach-ridges were partially eroded. In actuality, the boundary of the sea during the second maximum is marked by a low terrace about 100 m wide, found over the greater part of the island. Southward, near Boguaçu river, there is a shell-midden on the first ridge between the low-terrace and the sea. This shell-midden has been dated at 3,220 ± 90 years B.P. (Ba-307) and 3,090 ± 110 years B.P. (Gif-3645). Abundant whale bones found in this shell-midden are suggestive of its construction near the ocean, that is, at the beginning of formation of the external beach-ridges. This very nicely proves that the part of the island between the low terrace and the ocean was entirely formed after the second maximum (3,500 years B.P.).

c) Scheme valid for the coastline between Juréia mountain and Una outlet - The first three stages developed in the same way as in the previous part, but the two last stages were different:

Fourth stage - During the Holocene transgression the sea greatly encroached upon the area between Juréia mountain and Una outlet, thus forming a great bay. This situation is attested to by the presence of shell-middens made up of *Anomalocardia brasiliana*, whose habitat is commonly related to salt-water bay and lagoonal bottoms.

Fifth stage - During the minor regression that followed one of the high sea-level periods, a barrier-island formed between Juréia mountain and Barra do Una mountain. This sand bar closed the bay thereby transformed it into a lagoon. Later, regressive beach-ridges were added to the original bar. A shell--midden made up of *Anomalocardia brasiliana* and situated on the Cananéia Formation at the paleobay margin was dated as 3,790 ± 110 years old (Gif-3642) and 3,840 ± 60 years old (Ba-306),

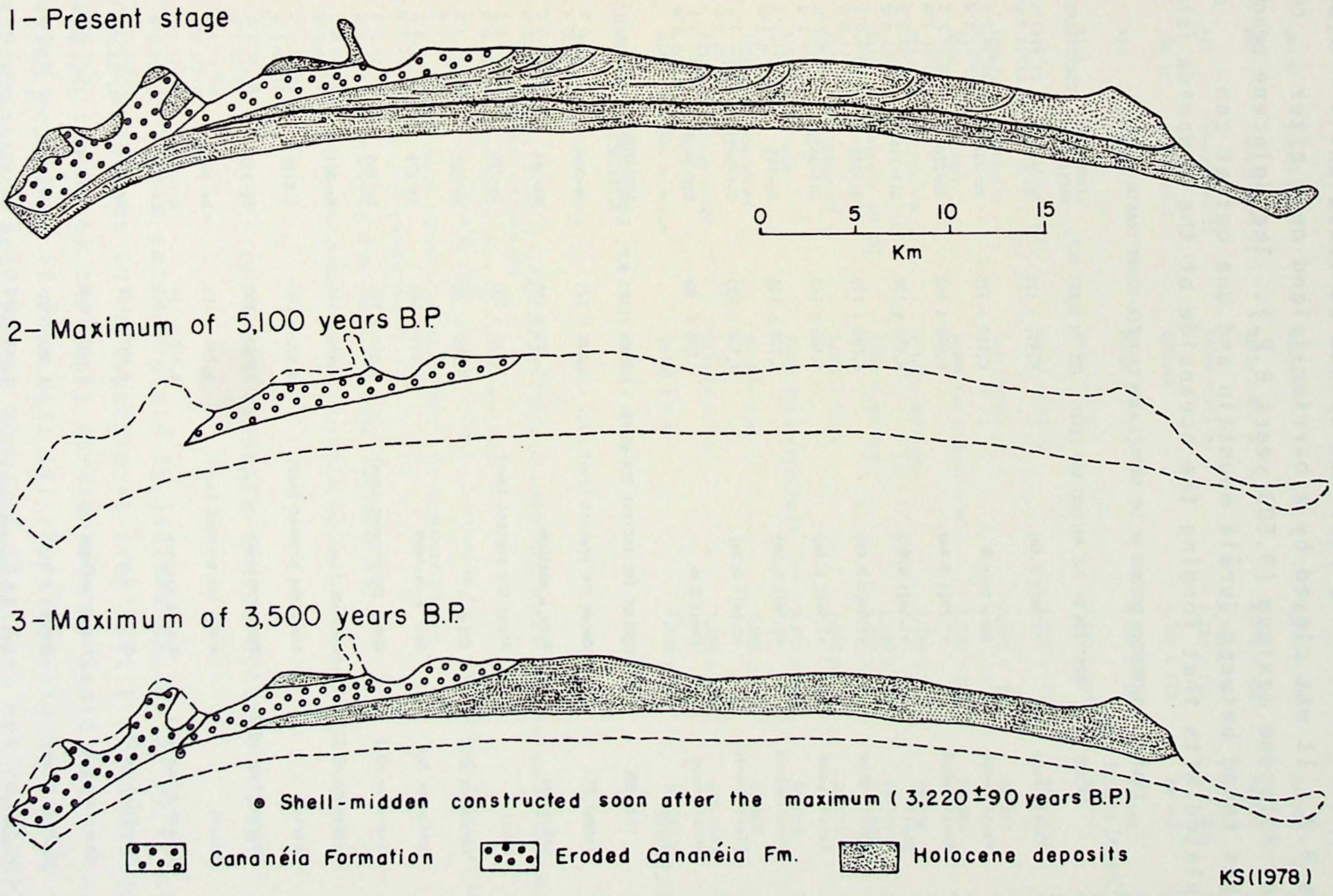


Fig. 9 – Evolutive scheme of Comprida Island during the Holocene.

indicating that this bay remained opened at least until 3,800 years B.P. It was closed by a barrier-island only after the second Holocene maximum (3,500 years B.P.). The Holocene beach-ridges found between Juréia mountain and Una outlet can be correlated with that forming the oceanside of the Comprida island.

TABLE 1 - RADIOCARBON DATINGS OF THE SAMPLES FROM CANANÉIA-IGUAPE COASTAL PLAIN

a) Geological samples

SAMPLE	NATURE	POSITION OF THE ANCIENT SEA-LEVEL	AGE IN YEARS B.P.	LABORATORY REFERENCE	COORDINATES
A93	Fossil wood	-0.8m(± 0.4m)	6,450 ± 170	Ba-230	24°59.7'S 47°53.7'W
A138	Fossil wood	More than 0	6,190 ± 175	Ba-231	24°39.7'S 47°43.0'W
A55	Fossil wood	+1.2m(± 0.4m)	6,000 ± 160	Ba-226	25°12.7'S 48°01.7'W
A89	Shell	+1.5m(± 0.4m)	5,410 ± 120	Gif-3444	25°00.0'S 47°53.8'W
A90	Fossil wood	+1.5m(± 0.4m)	5,290 ± 110	Ba-229	25°00.0'S 47°53.8'W
A28	Fossil wood	+1.5m(± 0.4m)	4,400 ± 110	Gif-3439	25°09.2'S 47°02.1'W
A131	Plant debris	+0.5m(± 0.3m)	3,710 ± 140	Ba-445	24°51.3'S 47°28.5'W
A37	Plant debris	+0.5m(± 0.3m)	3,370 ± 100	Gif-3430	24°51.3'S 47°28.5'W
A23	Fossil wood	About 0 m	690 ± 90	Gif-3438	25°01.9'S 47°55.0'W

b) Shell-middens

SAMPLE	NAME	POSITION OF THE ANCIENT SEA-LEVEL	AGE IN YEARS B.P.	LABORATORY REFERENCE	COORDINATES
IPH.7*	Itapoã III	Above the present level	5,245 ± 125	Ba-365	24°53.0'S 47°53.0'W
A.137	Jataituba	Near a maximum	5,240 ± 150	Ba-346	24°38.0'S 47°42.8'W
IPH.1*	Guaxixi	Above the present level	5,110 ± 100	Ba-370	24°55.0'S 47°52.0'W
IPH.4*	Vapumaúva nº I	Unknown	5,080 ± 60	Ba-366	24°52.9'S 47°53.8'W
A140	Pariquera Açu	Near a maximum	5,035 ± 140	Ba-295	24°37.6'S 47°43.5'W
IPH.9*	Juruvaúva nº I	Above the present level	5,010 ± 115	Ba-359	24°56.0'S 47°50.0'W
IPH.11*	Juruvaúva nº III	Unknown	4,970 ± 110	Ba-361	24°56.0'S 47°50.0'W
A30	Batatal	Above the present level	4,920 ± 100	I.9186	25°02.7'S 47°58.2'W
A123	Pedras river nº II	Near a maximum	4,860 ± 100	Ba-343	24°28.1'S 47°23.1'W
A44	Momuna	Above the present level	4,790 ± 115	Ba-308	24°41.5'S 47°37.5'W
A121	Pedras river nº I	Near a maximum	4,750 ± 110 4,710 ± 145	Gif-3641 Ba-300	24°30.0'S 47°28.0'W
IPH.8*	Vapumaúva nº II	Below + 3 m	4,680 ± 110	Ba-362	24°53.0'S 47°53.6'W
A175	Comprido river	Near a maximum	4,560 ± 110	Gif-3646	24°27.8'S 47°13.4'W
E91	Nóbrega river	Below + 3 m	4,380 ± 160	SPC-21	25°00.0'S 47°55.5'W
A3	Cananéia	Above the present level	4,340 ± 110 4,300 ± 140	Gif-3435 Ba-302	25°01.5'S 48°03.5'W
IPH.10*	Juruvaúva nº II	Above the present level	4,305 ± 140	Ba-360	24°56.0'S 47°50.0'W

TABLE 1 - Continuation

SAMPLE	NAME	POSITION OF THE ANCIENT SEA-LEVEL	AGE IN YEARS B.P.	LABORATORY REFERENCE*	COORDINATES
IPH.6	Itapoã nº II	Unknown	4,215 ± 140	Ba-364	24°52.0'S 47°53.0'W
A50	Ararapira nº II	Below + 0.7 m	4,175 ± 100	Ba-290	25°01.5'S 48°03.5'W
A16	Boguaçu nº II	Below + 1.5 m	4,160 ± 95 4,120 ± 110	Ba-303 Gif-3436	24°59.0'S 47°53.0'W
IPH.5*	Itapoã nº I	Unknown	4,100 ± 110	Ba-365	24°12.0'S 47°59.0'W
A58	Tapera	Below + 1.5 m	4,010 ± 110	Ba-291	25°12.0'S 47°59.0'W
A115	Ubatuba	Below + 2 m	3,870 ± 100	Ba-294	24°51.5'S 47°45.3'W
A29	Ararapira nº II	Equal or below	3,790 ± 110	Gif-3437	25°08.2'S 48°02.1'W
IPH.3	Estaleiro	Indifferent	3,690 ± 80	Ba-367	25°03.0'S 48°03.0'W
A47	Fosfasa	Above the present level	3,350 ± 135	Ba-340	25°01.5'S 48°03.5'W
A25	Pereirinha	After a maximum	3,330 ± 125	Ba-286	25°05.0'S 48°01.0'W
A149	Boguaçu nº III	After a maximum	3,220 ± 90 3,090 ± 110	Ba-307 Gif-3645	24°58.4'S 47°51.7'W
A11	Boguaçu nº II	Below + 2.5 m	3,080 ± 55	Ba-285	24°58.6'S 47°53.4'W
A154	Pindu	Above the present level	3,090 ± 120	Ba-348	24°39.0'S 47°29.0'W
IPH.2	Guarapari	Below + 1 m	2,285 ± 45	Ba-368	25°03.0'S 48°01.0'W
A81	Minas river	Below + 0.5 m	1,850 ± 100	Gif-3643	25°01.5'S 48°02.2'W
A144	São Bernardo	Below + 4 m	1,840 ± 150	Ba-347	24°47.0'S 47°40.0'W
A65	Sambaquinho	Below + 0.5 m	1,500 ± 120	Ba-292	25°04.0'S 48°02.0'W
A69	Itapitangui	Below + 1.5 m	1,490 ± 120	Ba-293	25°00.7'S 48°00.0'W

(*) = Samples collected by CAIO DEL RIO GARCIA and DORATH PINTO UCHOA of the Instituto de Pré-História - Universidade de São Paulo

Laboratory references where the datings were made:

Ba - Laboratório de Física Nuclear Aplicada - Instituto de Física - Universidade Federal da Bahia

Gif- Laboratoire du Radiocarbone (CNRS) - Gif-sur-Yvette (France)

I - Isotopes (United States)

LJ - University of California - La Jolla - California (USA)

SPC- Laboratório de Radiocarbono - Instituto de Geociências - Universidade de São Paulo.

5.2 - UNIT II: ITANHAÉM-SANTOS COASTAL PLAIN

This coastal plain is limited on the SW by Precambrian rocky headlands which separate it from Unit I (Cananéia-Iguape) and on the NE by the rocky portion of the Santo Amaro island which separates it from Unit III (Bertioga-São Sebastião island). A Precambrian headland at Mongaguá that does not reach the sea divides the Itanhaém-Santos coastal plain into two sub-units.

5.2.1 - Itanhaém coastal plain

a) General characteristics - This coastal plain extends about 40 km from Peruíbe to Mongaguá and is about 15 km wide in its widest place. The Peruíbe region is drained by the Branco and Preto rivers, while the central part is drained by the Itanhaém river and its tributaries, the Preto, Branco and Aguapeú rivers. There are several shell-middens near these rivers located very far from the present strandline, suggesting that their construction would have been possible only on lagoonal margins when the sea-level was higher than at present.

b) Quaternary formations of marine and lagoonal origin: Sedimentary deposits related to the Cananéia transgression - Between Peruíbe and Itanhaém, there is an extensive sandy region (probably covered by eolian dunes) that does not reach the foot of the Serra do Mar. It is separated from the Serra do Mar by a more or less marshy zone drained by the Preto river (Itanhaém river). As natural outcrops are lacking, it was not possible to characterize this formation adequately. However, the deposition of these sands during the Cananéia transgression seems to be confirmed by the age of 5,275 ± 125 years B.P.(Ba-349) obtained for fossil wood from a lagoonal clayey-sandy deposit. Field surveys showed that this deposit was laid down in low-lying places eroded in the marine sands during a transgressive period. Thus, the marine sands could only have been deposited during a transgression older than the most recent one. Their altitudes are inconsistent with sedimentation associated with the Santos transgression. The marine origin of these sands is confirmed by the presence of beach-ridge structures clearly visible on aerial photos.

In the northeastern part of this coastal plain these sands occur between hills of Precambrian rocks. The typical lineations of beach-ridges observed on aerial photos are also indicative of their shallow marine origin. They are morphologically clearly distinguishable from more recent littoral deposits.

<u>Sedimentary deposits of the Santos transgression</u> - Sandy deposits lower than the ones mentioned above occur between the ocean and the Pleistocene marine deposits and are probably Holocene in age. When observed on aerial photos, beach-ridge lineations are also very clear.

In lower zones presently drained by the Preto and Branco rivers in Peruībe and by the Preto, Branco and Aguapeū rivers in Itanhaēm, there are lagoonal clayey-sandy deposits. This type of sedimentary deposit is not very well developed in the Peruībe area. On the other hand, in the central and northeastern parts of this coastal plain, they comprise the great majority of the Quaternary sedimentary deposits. The occurrence of this ancient lagoonal zone is suggested by the shell-middens on Araraū hill, at Mundo Novo, and on Pleistocene sands. These shell-middens consist of oyster shells, *Anomalocardia brasiliana*, *Lucina jamaicensis*, and *Azara prisca*. The presence of *Anomalocardia brasiliana* and *Lucina jamaicensis* is related to the ancient salt-water lagoon of a period of sea-level higher than the present. In the headwaters of the Branco river, on a small hill of Precambrian rocks, there is a shell-midden 90% comprised by oysters and 10% by *Anomalocardia brasiliana*. LÖFGREN (*op.cit.*)described another shell-midden with the same composition, situated 20 km farther inland on this same river. As above, *Anomalocardia brasiliana* and *Lucina jamaicensis* indicate the presence of a salt-water lagoon, in the Branco river valley. LÖFGREN also described a shell-midden located 18 km from the Itanhaēm river mouth, on the left margin of the Aguapeū river. The shell-midden is situated about 800 m from the river on a small elevation surrounded by a marshy zone. It is 80% oysters, the rest being *Anomalocardia brasiliana* and *Lucina jamaicensis*. LÖFGREN further described a shell-midden situated practically at the foot of the Serra do Mar, on the left margin of the Preto river, a little above the port of Coatinga. It is situated on a hill surrounded by marsh and is also formed of oysters, *Anomalocardia brasiliana*, *Lucina jamaicensis* and *Azara prisca*. In the Peruībe region,he described a small shell-midden formed entirely of *Anomalocardia brasiliana*, 5 km from the Branco river mouth, on a high Pleistocene sandy area, on the left margin of the river.

Mangrove deposits - There are no lagoons in this area, and the mangroves are little developed, being limited to the lower courses of the rivers in the area of Peruíbe and Itanhaém.

c) Mechanism of formation of the Itanhaém coastal plain - The scheme of formation of this coastal plain is very similar to that for the Cananéia-Iguape coastal plain (Fig. 10).

During the Cananéia transgression, the sea came up to the foot of the Serra do Mar and the Pariquera Açu type of continental formation was covered initially by transitional clayey-sandy deposits, followed by transgressive sands. Beach-ridges on transgressive sands were formed during the regression. It seems that these beach-ridges abutted against a sand bar formed between hills of Precambrian rocks located in front of the Serra do Mar. Probably at this time there was a lagoon at the foot of the Serra do Mar. When the sea-level was lower than at present, older deposits were more-or-less deeply eroded. During the last transgression the sea encroached more-or-less rapidly into the low-lying eroded zones. Meanwhile, the higher portions were being eroded, and the sands from this erosion went to form the Holocene sedimentary deposits. A shell-midden on the Branco river, situated about 13 km from the sea, was dated as 5,970 ± 140 years old (Ba-297). The datings of shell-middens from the Araraú mountain indicated an age of 4,630 ± 140 years B.P. (Ba-296), Mundo Novo 4,575 ± 110 years B.P. (Ba-446) and Preto river 4.640 ± 100 years B.P. (Ba-331), showing that this lagoon was maintained at least until this period.

It was not possible to recognize the existence of multiple generations of Holocene beach-ridges in this region.

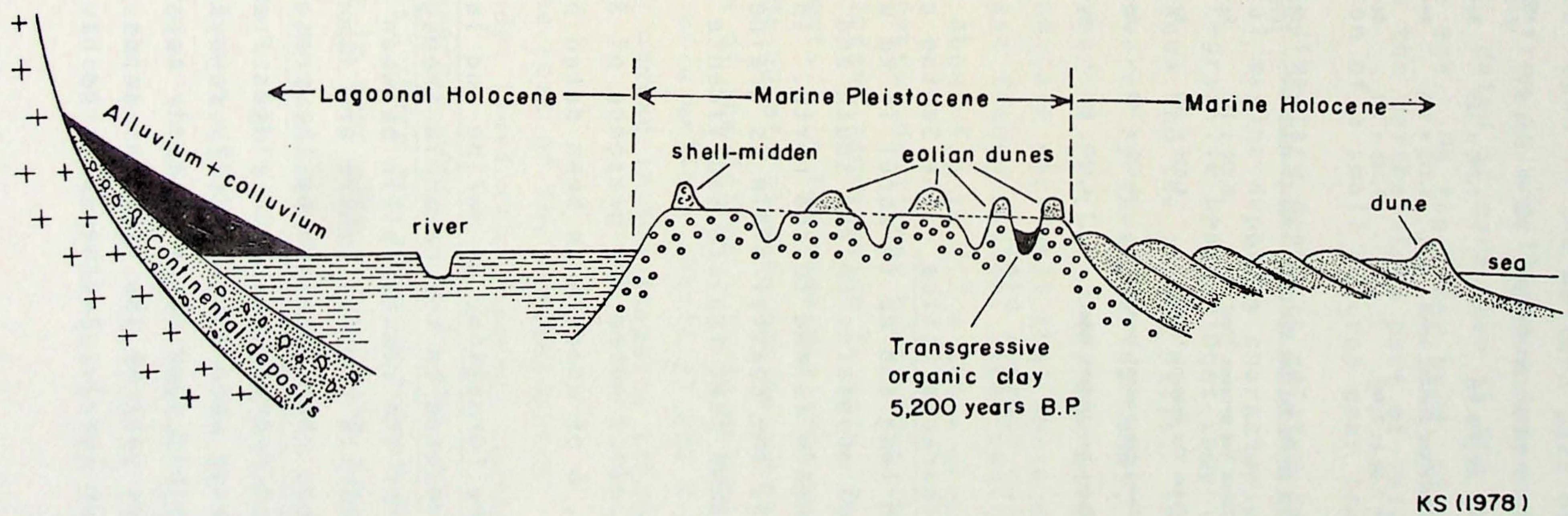


Fig. 10 — Interpretative scheme of the Itanhaém coastal plain.

TABLE 2 - RADIOCARBON DATINGS OF THE SAMPLES FROM ITANHAÉM COASTAL PLAIN

a) Geological samples

SAMPLE	NATURE	POSITION OF THE ANCIENT SEA-LEVEL	AGE IN YEARS B.P.	LABORATORY REFERENCE	COORDINATES
A205	Vermetidae	+ 1.3m (± 0.4m)	6,280 ± 135	Ba-350	24°12.0'S 46°48.6'W
A186	Fossil wood	Above the present level	5,275 ± 135	Ba-349	24°12.5'S 46°26.2'W
A203	Vermetidae	+ 1.6m (± 0.4m)	1,105 ± 115	Ba-325	24°12.0'S 46°48.6'W

b) Shell-middens

SAMPLE	NAME	POSITION OF THE ANCIENT SEA-LEVEL	AGE IN YEARS B.P.	LABORATORY REFERENCE	COORDINATES
A170	Branco river	Above the present level	5,970 ± 140	Ba-297	24°04.3'S 46°48.0'W
A196	Preto river	Above the present level	4,635 ± 100	Ba-331	24°08.9'S 46°54.0'W
A169	Araraú	Above the present level	4,630 ± 140	Ba-296	24°03.3'S 46°55.8'W
A269	Mundo Novo	Above the present level	4,575 ± 110	Ba-446	24°08.1'S 46°57.1'W

5.2.2 - Santos coastal plain

a) General characteristics - The Santos coastal plain forms a crescent 40 km long and up to about 15 km wide, that is limited by the Mongaguá mountains to the south and the rocky portion of the Santo Amaro island to the north. In the central and northeastern parts, the coastal plain is drained by lagoonal and tidal channel systems that isolate São Vicente and Santo Amaro islands.

LÖFGREN (*op.cit.*) noted the presence of 30 shell-middens on this coastal plain, 6 of which have been dated by the radiocarbon method.

b) Quaternary formations of marine and lagoonal origin: Sedimentary deposits related to the Cananéia transgression - In the southwestern part of the coastal plain between the Piaçabuçu and Branco rivers (Samaritá region), there are important outcrops of littoral marine sands characterized by the presence of *Callianassa* burrows and regressive beach-ridges. Frequently, these sedimentary deposits have been superficially reworked by eolian processes and thus exhibit sand dunes on their tops. Along the Mariana river the upper part of the littoral sands is about 7 m above present high-tide level. Another outcrop of the Cananéia

Formation is found in the western part of the São Vicente island. Fossil wood from an argillaceous intercalation near the top of these sands, dated at more than 35,000 years B.P., confirms their Pleistocene age. On the other hand, similar deposits are not observed in the northeastern part of this coastal plain, with the exclusion of a small outcrop near Tombo beach (Guarujá).

Sedimentary deposits related to the Santos transgression - Sandy littoral marine deposits characterized by *Callianassa* burrows and regressive beach-ridges comprise a continuous band between Mongaguá and the Itaipu hills. Tree trunks in life positions, covered by these marine sands, have been dated at 6,250 ± 130 years B.P. (Gif-3845) and 6,480 ± 75 years B.P.(Ba-327). These ages indicate very well that these deposits were formed during the last transgression. The summits of these marine sandy deposits are about 4.5 to 4.7 m above present high-tide level.

Several drillings have shown that the city of Santos lies upon Holocene sands which in turn lie upon lagoonal clayey-sandy sediments. In the same way, the sea-front of Santo Amaro island is made up of Holocene marine sands abutting against the rocky portion of the island. Their Holocene age is confirmed by dating of *in situ* mollusk shells (4,210 ± 145 years B.P.: Ba-353) from a trench opened in the Acapulco allotment behind Pernambuco beach.

The rest of the coastal plain essentially consists of clayey-sandy, fluviatile-lagoonal sedimentary deposits.

Mangrove deposits - At the lagoonal margins and in the tidal channels, there are very important developments of mangrove swamps, which in some places reach the foot of the Serra do Mar.

c) Mechanism of formation of the Santos coastal plain - At the maximum of the Cananéia transgression, as elsewhere, the sea also reached the foot of the Serra do Mar in this area. Drilling profiles which we have studied suggest that transitional clayey-sandy sediments were laid down on continental deposits probably equivalent to the Pariquera Açu Formation which in turn rests upon Precambrian crystalline rocks (Fig. 11). Transgressive sands were deposited on the argillaceous sediments, and during regression, beach-ridges and eolian dunes were formed. Probably the southwestern part of the coastal plain was not covered by these regressive sands. During the last great regression, when the sea-level was -110m in relation to the present level, the older deposits were partially eroded, and in places even the crystalline basement was eroded down to -50 m. When the Santos transgression occurred, the sea entered these low-lying zones and established lagoonal systems in which argillaceous sediments with shell debris and plant fragments were actively deposited. Several drillings have shown that these lagoonal deposits may be about 50 m thick in certain areas of the coastal plain. At the same time, higher parts of the Pleistocene marine deposits were eroded, thereby providing materials for deposition as transgressive Holocene sands. Behind these deposits an extensive lagoon formed which was filled in by sediments and invaded by mangrove vegetation during the return of the sea-level to its present position. Till now, it has not been possible to recognize the occurrence of multiple generations of Holocene beach-ridges. However, the minimum sea-level at 3,800 years B.P. seems to be confirmed by the shells of the Maratuã shell-midden dated at 3,865 ± 95 years B.P. (I.9185), according to GARCIA (1977), and 3,934 ± 140 years B.P. (Ba-382). In fact, the shell-midden substrate is below the present high-tide level (EMPERAIRE and LAMING, 1956). Even if the shell-midden substrate has been subjected to some sinking, this must have been negligible. Thus, it is reasonable to admit that about 3,800 years ago sea-level was near or even below the present level. Vermetidae samples dated at 3,625 ± 100 years old (Ba-352) indicate an ancient sea-level of + 2.5 m. This date seems to corroborate the occurrence of a second maximum at about 3,500 years B.P. (Fig. 12).

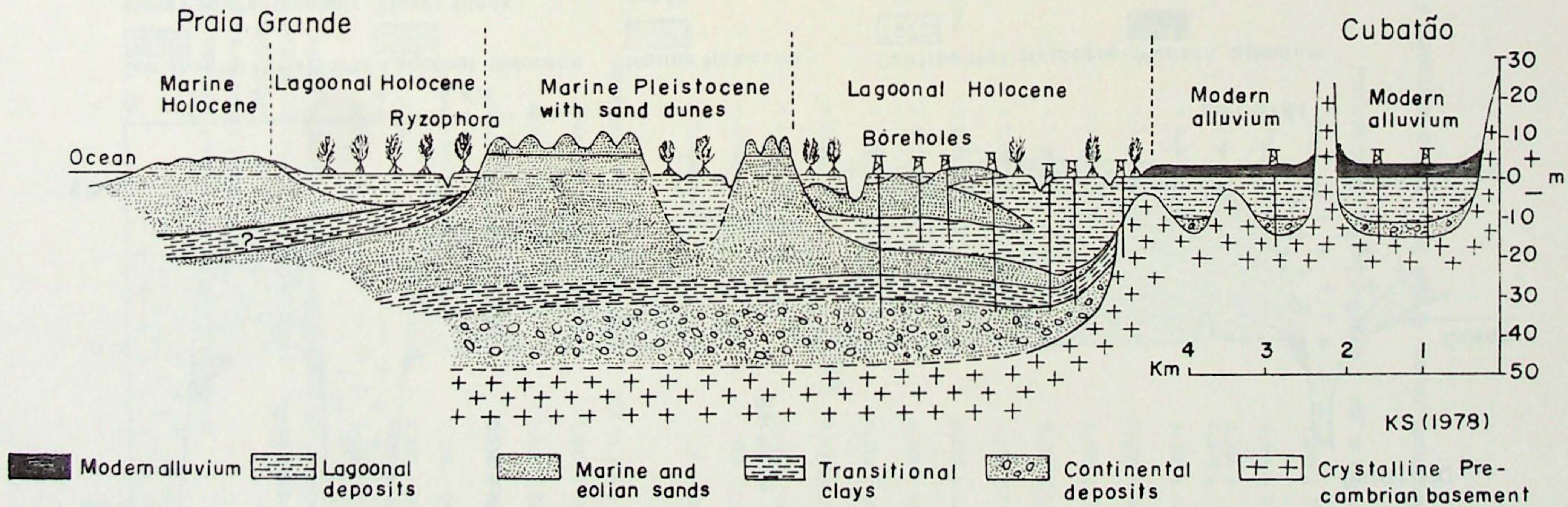


Fig. II– Interpretative profile of sedimentary deposits in Santos coastal plain.

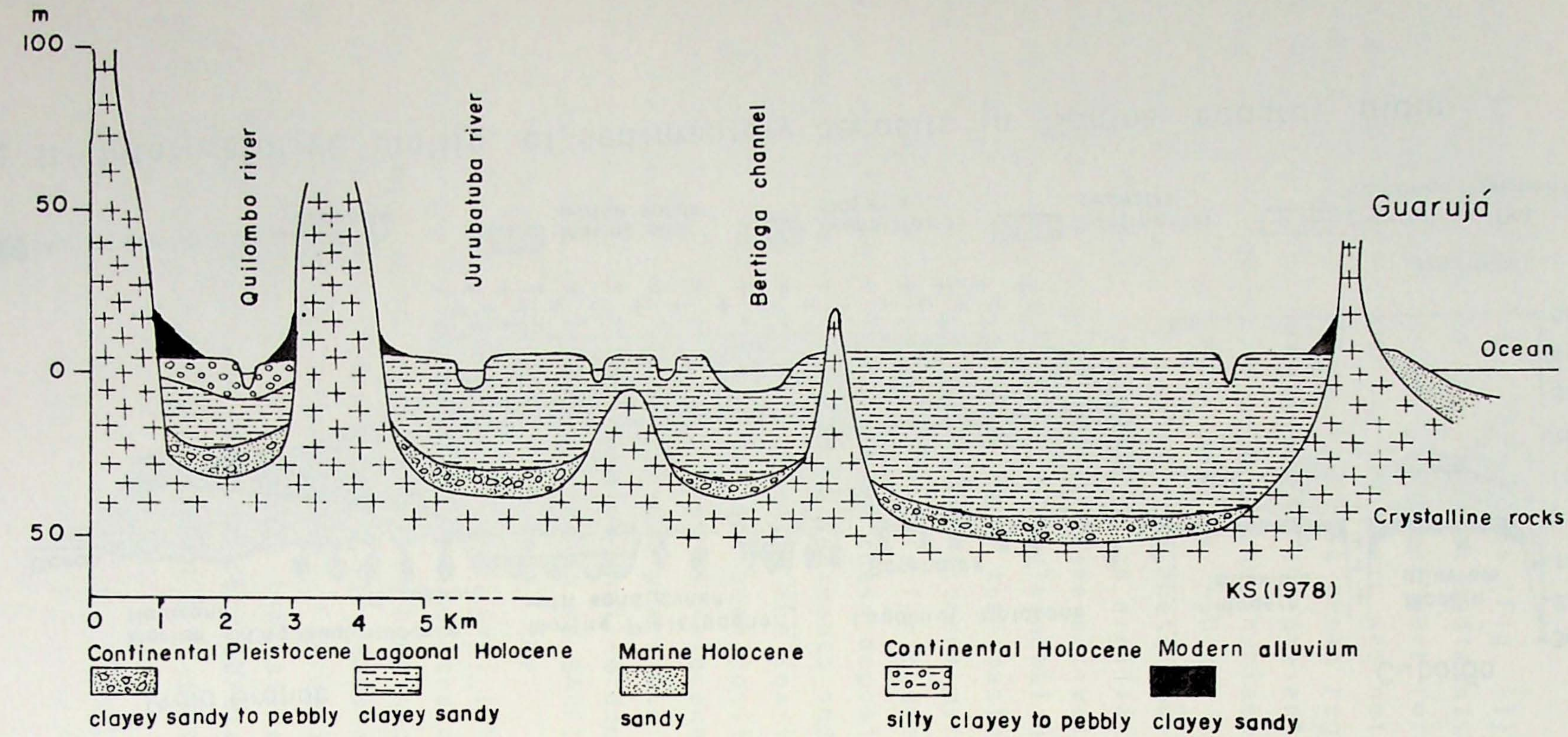


Fig. 12 – Interpretative profile of the southwestern Santos coastal plain between Serra do Mar and Guarujá (Santo Amaro island).

TABLE 3 - RADIOCARBON DATINGS OF THE SAMPLES FROM THE SANTOS COASTAL PLAIN

a) Geological samples

SAMPLE	NATURE	POSITION OF THE ANCIENT SEA-LEVEL	AGE IN YEARS B.P.	LABORATORY REFERENCE	COORDINATES
A988	Fossil wood	-11m(± 1m)	7,550 ± 170	Ba-233	23°52.7'S 46°26.1'W
A272	Fossil wood	+ 1m(± 0.4m)	6,565 ± 115	Ba-449	24°00.8'S 46°23.3'W
A234	Fossil wood	Below + 2m	6,480 ± 75 6,250 ± 130	Ba-327 Gif-3845	24°00.8'S 46°23.3'W
A238	Fossil wood	+ 0.8m(± 0.4m)	6,280 ± 130	Gif-3646	23°57.2'S 46°26.3'W
A271	Fossil wood	+ 1.2m(± 0.4m)	6,220 ± 125	Ba-448	24°00.8'S 46°23.3'W
A237	Shell	+ 1.3m(± 0.4m)	6,200 ± 165	Ba-329	24°00.8'S 46°23.3'W
A273	Fossil wood	+ 1.7m(± 0.4m)	5,795 ± 125	Ba-450	24°00.8'S 46°23.3'W
A232	Fossil wood	+ 2.4m(± 0.4m)	5,455 ± 170	Ba-326	24°00.1'S 46°26.3'W
A254	Vermitidae+algae	+ 3.4m(± 0.4m)	5,010 ± 120	Ba-354	23°52.3'S 46°50.8'W
Lab.I*	Vermetidae	+ 3.0m(± 0.4m)	4,480 ± 180	Gif-2147	23°55.0'S 46°14.0'W
A247	Shell	+ 2,5m(± 0.5m)	4,210 ± 145	Ba-353	23°57.8'S 46°12.3'W
A239	Fossil wood	+ 2.8m(± 0.4m)	4,100 ± 110	Gif-3847	23°57.2'S 46°26.4'W
A244	Vermetidae	+ 2.6m(± 0.4m)	3,625 ± 100	Ba-352	24°00.9'S 46°17.7'W
A249	Vermetidae	+ 1.4m(± 0.4m)	790 ± 90	Gif-3848	23°58.4'S 46°11.3'W
A270	Fossil wood	+ 0.4m(± 0.4m)	530 ± 80	Ba-354	24°00.8'S 46°23.3'W

b) Shell-middens

NAME	POSITION OF THE ANCIENT SEA-LEVEL	AGE IN YEARS B.P.	LABORATORY REFERENCE	COORDINATES
Piaçagüera(1)	Above the presente level	4,930 ± 110	I.4481	23°51.8'S 46°22.1'W
Mar Casado(2)	Below + 3m	4,400 ± 130	Gif-1194	23°57.9'S 46°11.5'W
A229	Below + 3.5m(After a maximum)	4,520 ± 150	Ba-328	24°00.1'S 46°26.2'W
Casqueirinho(3)	Not indicative	4,300 ± 180	SPC-15	23°53.0'S 46°23.0'W
Maratuã(4)	Below	3,935 ± 145 3,865 ± 95	Ba-382 I.9185	23°57.0'S 46°15.0'W
A219	Below + 1m	545 ± 90	Ba-330	23°55.8'S 46°24.8'W

(*) - Sample collected by J.LABOREL - Station Marine D'Endoume-Marseille (France)

(1) - Sample collected by CAIO DEL RIO GARCIA and DORATH P.UCHOA - Instituto de Pré-História - Univ.de S.Paulo

(2) - Sample collected by PAULO DUARTE

(3) - Sample collected by J.A.de MORAES PASSOS

(4) - Sample collected by J.EMPERAIRE and redated by CAIO DEL RIO GARCIA

5.3 - UNIT III: BERTIOGA AND SÃO SEBASTIÃO ISLAND

Based on morphology, this part of the coastal region may be divided into two distinct portions, with very different characteristics: the Bertioga coastal plain and the rocky and cliffy portion between Una outlet and São Sebastião island.

5.3.1 - Bertioga coastal plain

a) General characteristics - The Bertioga sedimentary plain, northeast of the Santos coastal plain, from which it is separated by the Bertioga channel, is about 45 km long and 7 to 8 km wide. There are no lagoons in this region, but three rivers (Itapanhaū, Itaguarē and Guaratuba) drain lowlands made up of ancient lagoonal sediments deposited when the sea-level was higher than present. In front of the Serra do Mar on the coastal plain are several hills of crystalline rocks recently connected to the continent by "tombolos".

Shell-middens have not been found in this region, which may be related to the very restricted development of lagoonal areas.

b) Quaternary formations of marine and lagoonal origin: Sedimentary deposits related to the Cananēia transgression - Between the town of Bertioga and the Itapanhaū river, a limonitized sandy formation is found that is morphologically distinct from other deposits of the coastal plain. Its top is situated at least 5.5 m above presente high-tide level. The age of 6,020 ± 130 years B.P. (Gif-3850) for a fossil wood fragment collected from an argillaceous sediment covered by marine sands suggests that the limonitized sandy deposits are older than 6,000 years B.P. and probably were deposited during the Cananēia transgression.

One can cross the coastal plain from Enseada hill as far as the Itaguarē and Una outlets without finding any trace of the Pleistocene marine formation. Nevertheless, it is possible that it may be represented northeast of Itaguā hill.

Sedimentary deposits related to the Santos transgression- The majority of the coastal plain is formed of sandy deposits that originated during the last transgressive phase. The above mentioned age of 6,020 ± 130 years B.P. shows that these sands were partially deposited during the first positive fluctuation of the sea-level. Another dating, made on a wood fragment also collected from argillaceous sediments covered by sand, gave an age of 3,250 ± 130 years B.P. (Ba-498). These clays and sands abut against the older formation deposited during the first fluctuation and thus would have been deposited during the second positive sea-level fluctuation.

Mangrove deposits - As lagoons are almost absent in the area, mangroves are also little developed and restricted to the lower courses of the rivers.

c) Mechanism of formation of the Bertioga coastal plain- In general features, the scheme of formation of this plain is almost the same as those for the previous coastal plains (Fig.13). During the maximum of the Cananéia transgression, the sea reached the foot of the Serra do Mar, and transgressive sands were deposited. During the regression these sands were covered by beach-ridges. When the sea-level was lower than the present level, these sands were more-or-less eroded. The rest of the sandy deposits were practically destroyed during the last transgressive phase. Pleistocene sands found near Bertioga have been protected from erosive wave action by the extremity of Santo Amaro island.

During the first Holocene maximum, the sea twice reached the foot of the Serra do Mar depositing marine littoral sands each time. When a minor regression occurred, these deposits were covered by beach-ridges. With the second Holocene transgressive episode, the sea encroached upon low-lying zones, depositing clays rich in organic remains and simultaneously destroying part of the previous deposits. The beach-ridges so clearly seen on aerial photos, mostly along the external part of the coastal plain, must have formed during the retreat of the sea towards its present

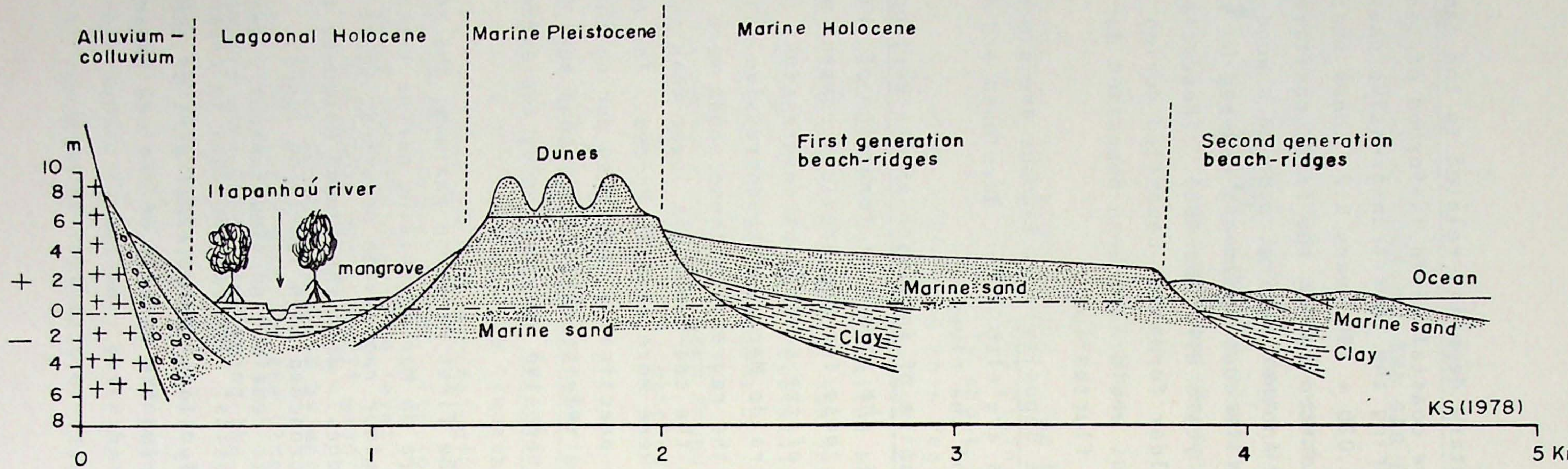


Fig. 13 — Interpretative profile of the Bertioga coastal plain.

level. The Enseada, São Lourenço, Itaguá anda Juréia hills may have been connected to the continent during the Santos transgression. Near the foot of the Serra do Mar modern alluvium and colluvium covered the marine sediments.

TABLE 4 - RADIOCARBON DATINGS OF THE GEOLOGICAL SAMPLES FROM THE BERTIOGA COASTAL PLAIN

SAMPLE	NATURE	POSITION OF THE ANCIENT SEA-LEVEL	AGE IN YEARS B.P.	LABORATORY REFERENCE	COORDINATES
A256	Fossil wood	+ 1m (± 0.5m)	6,020 ± 130	Gif-3850	23°50.5'S 46°08.6'W
A274	Fossil wood	+ 2.5m (± 0.5m)	3,520 ± 130	Ba-498	23°49.8'S 46°08.1'W
A263	Beach rock	+ 4m (± 0.5m)	3,480 ± 70	Ba-355	23°49.1'S 46°02.2'W
A266	Vermetidae	+ 1.6m (± 0.4m)	2,240 ± 90	Ba-357	23°47.8'S 45°59.7'W
A267	Vermetidae	+ 1.5m (± 0.4m)	1,985 ± 120	Ba-358	23°45.9'S 45°48.1'W
A264	Vermetidae	+ 1m (± 0.4m)	1,270 ± 130	Ba-356	23°49.2'S 46°02.2'W

5.3.2 - Coastal region between the Una outlet and São Sebastião island

In this part of the coastal area, only small sedimentary plains have developed, that are, from W to E: the Juqueī, Saī, Baleia, Camburi, Boioçucanga, Maresia, Paúba, Toque-Toque Pequeno, Toque-Toque, Guaecá and Baraqueçaba plains.

Practically without exception, these plains consist of continental sediments in their inland portion and marine sediments in their seaward portion. Sedimentary deposits related to the Cananéia transgression have not been observed. Field observations permit the recognition of two types of coastal plains, which are best represented by the Juqueī and Boioçucanga plains.

a) Juqueī-type coastal plain

In this type, the majority of the plain consists of a lower zone of clayey-sandy sediments that are separated from the sea by a clearly more elevated sandy marine belt (Fig. 14).

The origin of this type of coastal plain can be understood in the following way. After a higher sea-level period, a sand bar, abutting against two Precambrian headlands, was formed, which closed an ancient bay occupying the position of the present coastal plain. Behind the sand bar a lagoon formed where clayey-sandy sediments were deposited. When the sea-level returned to its present position, the original sand bar was subjected to enlargement by the lateral addition of beach-ridges. Simultaneously, the lagoon showed a greater and greater tendency for filling and drying up. After the disappearence of the lagoon, the lagoonal sediments were partially covered by continental deposits. Some of the coastal plains that formed in this way are those of Baleia and Camburi.

b) <u>Boioçucanga-type coastal plain</u>

In this type, the marine sediments are directly in contact with continental sediments at the foot of the Serra do Mar (Fig. 15). The reason why the formation of this type of coastal plain is not related to a sand bar separating a lagoon can probably be explained by differences in wave and current energy and morphology of that part of the coastal plain. The coastal plains of this type are those of Maresia, Paũba, Toque-Toque, Guaecã and Baraqueçaba.

5.4 - UNIT IV: COASTAL REGION BETWEEN SÃO SEBASTIÃO ISLAND AND THE PARATI MOUNTAINS

This part of the coastal region embraces the Caraguatatuba, Ubatuba and Parati regions, which is about 100 km long in a straight line, and is characterized by very restricted marine sedimentary deposits. Only the Caraguatatuba coastal plain has significant sedimentary deposits.

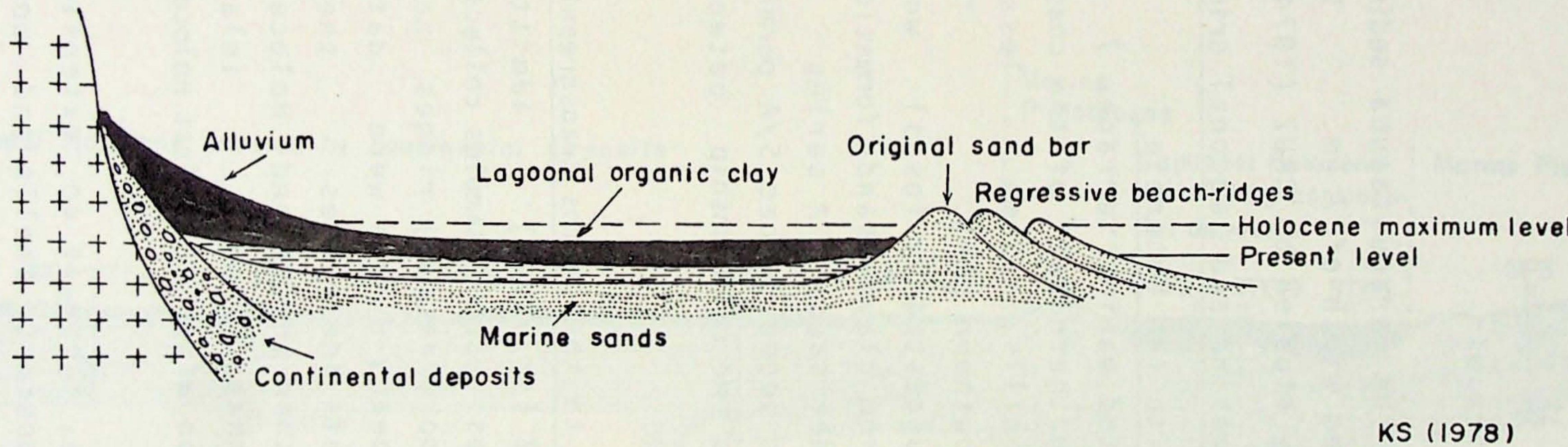


Fig. 14 — Interpretative profile of the Juqueí coastal plain.

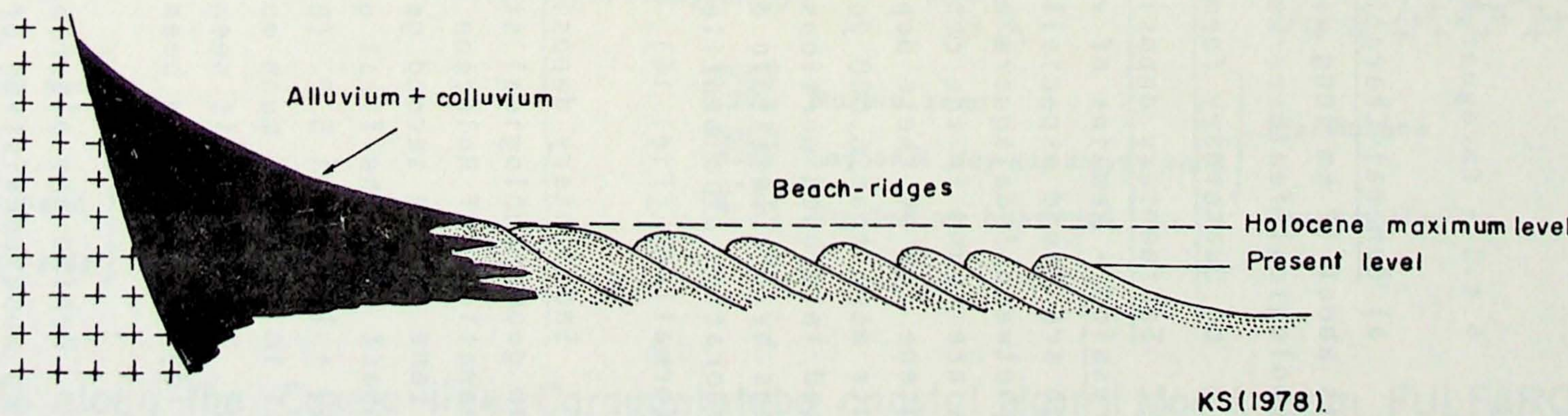


Fig. 15—Interpretative profile of the Boioçucanga coastal plain.

5.4.1 - Caraguatatuba coastal plain

a) General Characteristics - The Caraguatatuba sedimentary plain is about 12 km long with a maximum width of 7 km. The geomorphological features were recently studied by CRUZ (1974).

b) Quaternary formations of marine and lagoonal origin

Sedimentary deposits related to the Cananéia transgression - Remains of very dissected marine terraces 7 to 8 m high are found especially in the northern part of the coastal plain (between Indaiaquara and Empresa hills). Some lesser records are found in the central and southern part. The Pleistocene age of these deposits is suggested by fossil wood fragments more than 6,000 years old, from clayey-sandy formations deposited in eroded portions of the older sands. A series of drillings by the Instituto de Pesquisas Tecnológicas S/A permitted the elaboration of a profile that shows the relationship between these formations (Fig. 16).

Sedimentary deposits related to the Santos transgression - Based on geomorphological studies, CRUZ (*op. cit.*) admitted two generations of Holocene beach-ridges. Shell samples collected in the zone of the second generation (more recent) ridges near the contact with the first generation beach-ridges were dated at 2,750 ± 130 years B.P. (Ba-452). This age places these deposits in a period much more recent than the second Holocene maximum. Therefore, it seems logical that the more inland beach-ridges would have been formed soon after the first Holocene maximum.

Behind the older beach-ridges, there is an extensive low-lying zone consisting of clayey deposits. Shells and wood fragments collected from the clays 15 m below the present sea-level indicate ages ranging from 8,030 ± 150 years B.P. (Gif-3434) to 4,400 ± 110 years B.P. (near the surface). Thus, these clay

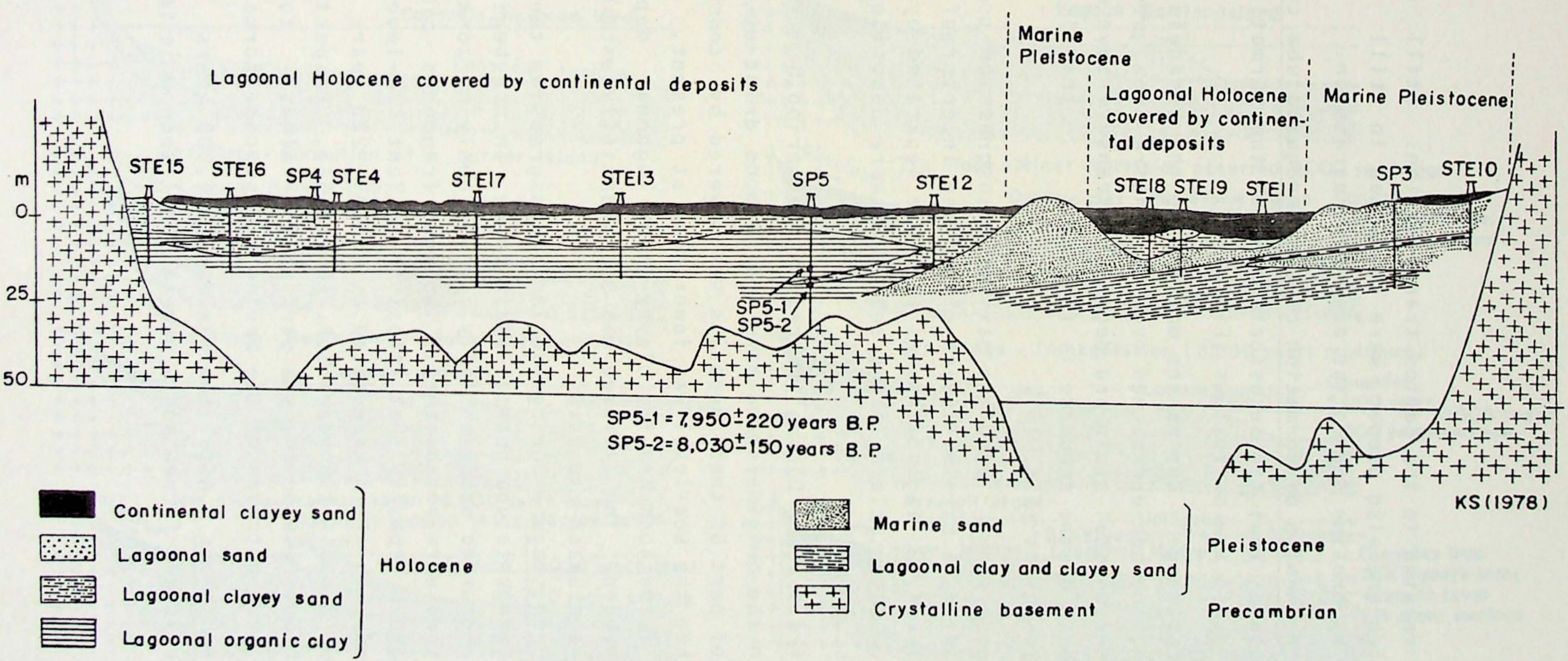


Fig. 16 — Profile along the Caxeta line, Caraguatatuba coastal plain (Modif. from FULFARO et al., 1976).

deposits are related to the Santos transgression. Still older deposits, which are also deeper, were deposited in still lower areas formed by erosion during the previous regression.

c) Mechanism of formation of the Caraguatatuba coastal plain - The stages that can be associated with the formation of this coastal plain are as follows (Fig. 17):

First stage - During the maximum of the Cananéia transgression, the sea encroached over the entire area presently occupied by the coastal plain and deposited transgressive marine sands. The base of the sequence is formed by transitional argillaceous deposits (Fig. 16).

Second stage - When the maximum transgression occurred, or a little after, a barrier-island closed the interior of the bay, and isolated two lagoonal zones that are separated by the Camburu hill. Later, clayey-sandy sediments were deposited in these lagoons.

Third stage - During the regressive period,beach-ridges were added to the original sand bar, the lagoons dried up, and the surface of part of these deposits was covered by continental deposits. When the sea-level was lower than at present, the sandy marine formations and the clayey-sandy lagoonal deposits were deeply eroded. The drainage was preferentially established in zones between beach-ridges.

Fourth stage - During the last transgression the sea invaded the Caraguatatuba coastal plain twice. In the beginning the invasion occurred preferentially across low-lying zones,and lagoonal systems were established. Two wood fragments collected from old mangrove deposits that attest to ancient sea-levels at -12.5 ± 1 m and -16 ± 1 m were dated as 7,950 ± 220 years B.P. (Gif-3433) and 8,030 ± 150 years B.P. (Gif-3434), respectively. During this transgression the sea partially or almost totally eroded the higher outcrops of the marine Pleistocene formations.

Fifth stage - After the maximum at 5,000 years B.P., a new barrier-island formed and a new lagoonal zone was established.

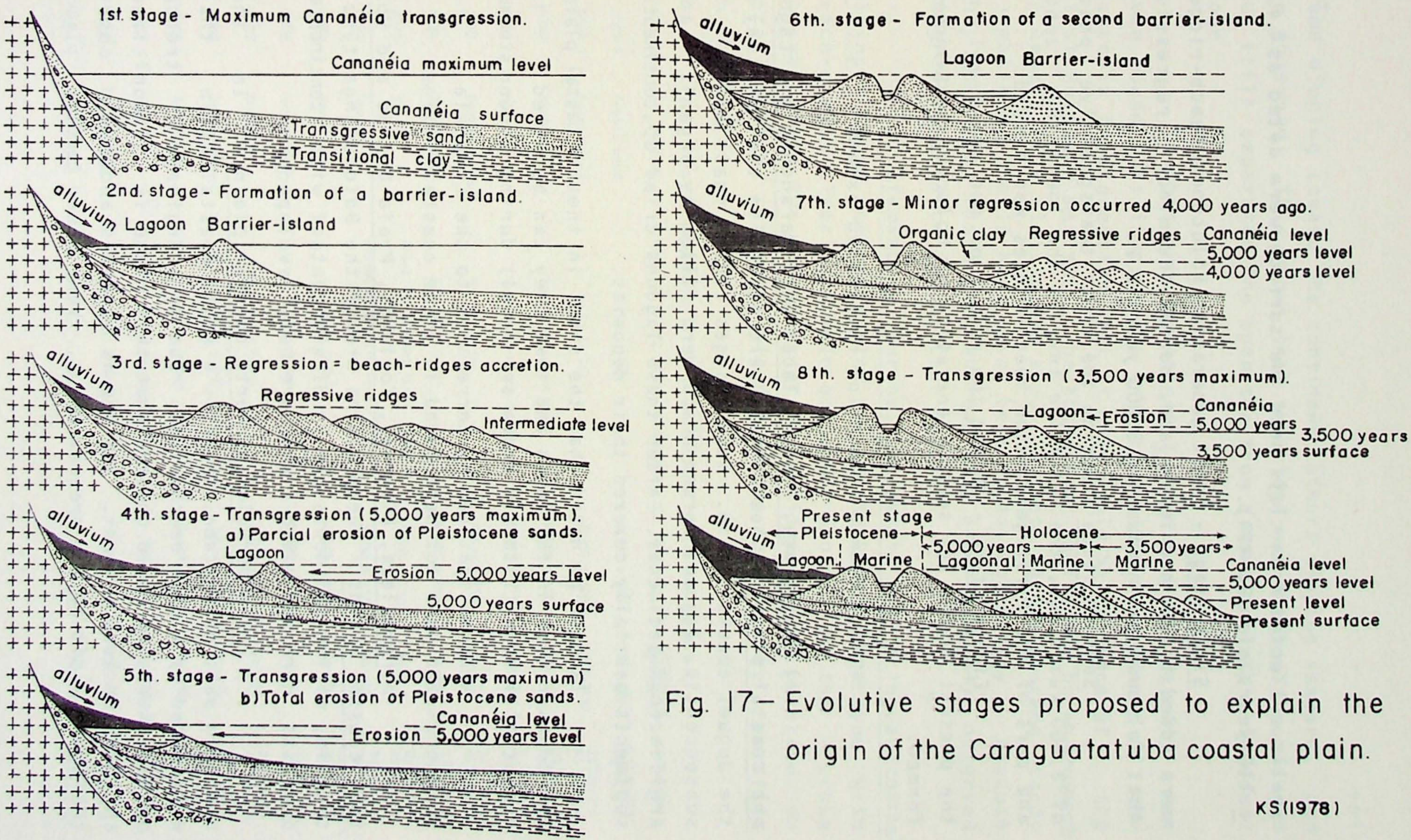


Fig. 17 – Evolutive stages proposed to explain the origin of the Caraguatatuba coastal plain.

KS(1978)

Shells collected from clays near the surface were dated as 4,400 ± 110 years old (Ba-454).

Sixth stage - First generation Holocene beach-ridges were added to the barrier-island, during the minor regression that followed the maximum at 5,000 years B.P.

Seventh stage - During the minor transgressive phase of 3,500 years ago, the sea twice invaded the low-lying zones and part of the first generation beach-ridges was eroded.

Eighth stage - During the return of the sea-level to the present level, the second generation of Holocene beach-ridges formed.

5.4.2 - Coastal plains of restricted extent

a) Massaguaçu, Mococa, Tabatinga, Maranduba and Lagoinha coastal plains - These plains were formed in the same way as the Juqueí coastal plain. Sandy ridges closed small bays; subsequently, lagoons formed which were filled by organic and argillaceous sediments. After these lagoons dried up, continental sediments partially covered their deposits.

It must be noted that the sands in these coastal plains are coarser than in the south and that they can be piled to higher altitudes (5 to 6 m above sea-level) during strong storms.

Records that can be correlated to the Cananéia transgression have not been found in these coastal plains.

b) Fortaleza, Flamengo, Toninhas, Praia Grande and Ubatuba coastal plains - These plains are of the Boioçucanga type; that is, marine sediments are in direct contact with continental deposits. Here the beach-ridges are well developed.

c) Praia Vermelha do Norte coastal plain - In the northern part of Ubatuba, there is a small coastal plain that was closed by a high beach-ridge. Due to a drainage trench opened there, we could observe that this ridge is limonitized and more or less ancient. Its top is situated about 4 m above the upper limit of the present beach. Very clear bedding planes, some dipping toward the continent, others dipping seaward, can be observed. This shows that the ridge was shallowly submerged but still separated the open sea from a more-or-less lagoonal zone.

In this area no material which could be dated has been found. It is possible that this ridge is evidence of the Cananéia transgression, but it also could be evidence of the first Holocene maximum. The absence of shells may be an argument on behalf of a Pleistocene age. In fact, in Pleistocene sandy formations, shells have never been found, apparently because they have been dissolved, whereas they are frequently observed in great abundance in Holocene deposits.

d) <u>Itamambuca, Puruba, Ubatumirim and Picinguaba coastal plains</u> - These coastal plains are of the Boioçucanga type with beach-ridges clearly visible on aerial photos. On the Puruba coastal plain two varieties of beach-ridges may be observed on aerial photos, although this difference could not be verified in the field.

TABLE 5 - RADIOCARBON DATINGS OF THE GEOLOGICAL SAMPLES FROM THE UNIT IV

SAMPLE	NATURE	POSITION OF THE ANCIENT SEA-LEVEL	AGE IN YEARS B.P.	LABORATORY REFERENCE	COORDINATES
SP05-2	Fossil wood	- 16.5m (± 1m)	8,030 ± 150	Gif-3434	23°39.3'S 45°29.0'W
SP05-1	Fossil wood	- 12.5m (± 1m)	7,950 ± 220	Gif-3433	23°39.3'S 45°29.0'W
A300	Shell	Near the present level	6,905 ± 185	Ba-455	23°40.6'S 45°28.6'W
A302	Shell	Near the present level	6,890 ± 175	Ba-456	23°41.3'S 45°28.8'W
A282	Oyster in situ	Above + 1.6m	4,605 ± 150	Ba-462	23°44.9'S 45°28.8'W
A281	Vermetidae	+ 1.9m (0.4m)	4,455 ± 145	Ba-461	23°44.9'S 45°20.8'W
A293	Shell	Above the present level. After a maximum	4,405 ± 110	Ba-454	23°38.8'S 45°27.2'W
A290	Shell	Above the present level. After 2nd. maximum	2,750 ± 130	Ba-452	23°38.5'S 45°26.1'W
A280	Vermetidae	+ 0.8m (± 0.4m)	2,665 ± 130	Ba-460	23°44.9'S 45°20.8'W
A309	Vermetidae	+ 1.2m (± 0.4m)	2,530 ± 130	Ba-469	23°29.6'S 45°05.9'W
A307	Shell	+ 1.5m (± 0.4m)	2,085 ± 140	Ba-457	23°34.4'S 45°17.5'W
A308	Vermetidae	+ 1.2m (± 0.4m)	1,840 ± 120	Ba-468	23°30.0'S 45°08.5'W
A325	Vermetidae	+ 1.0m (± 0.4m)	1,490 ± 80	Ba-482	23°14.8'S 44°37.6'W
A291	Shell	Above the present level	885 ± 115	Ba-453	23°38.5'S 45°26.1'W
A305	Vermetidae	+ 1.0m (± 0.4m)	865 ± 90	Ba-463	23°37.9'S 45°23.4'W
A312	Vermetidae	+ 0.4m (± 0.4m)	620 ± 120	Ba-487	23°22.6'S 45°50.4'W

5.5 - UNIT V: ILHA GRANDE BAY REGION

Based on geomorphological and structural features, due to the presence of the Guanabara graben, this unit can be divided into three parts.

5.5.1 - Part of the coastal region between Parati and Mangaratiba

This portion is situated at the western side of the Guanabara graben. Quaternary sedimentary deposits are very little developed. This region exhibits an irregular coastline which is characterized by a typical submersion morphology with several "rias", mostly in the Parati region (Saco de Mamanguã and Saco de Parati Mirim). There are several islands of Precambrian rocks and the coastline is very indented. Sedimentary deposits related to the Cananéia transgressive phase have not been observed. There are several vermetidae and oyster incrustations on the rocky surfaces above the present life zones of these animals. CURRAY (Oral communication) has dated *in situ* oysters 4.8 m above present sea-level as 5,200 ± 200 years old (LJ-1364). It was not possible to find the place of CURRAY's sample, which was collected during the construction of the BR-101 highway.

5.5.2 - Part of the coastal region at the southern extremity of the Guanabara graben

In this part, the coastal plain is low-lying, but marine sediments have not been verified in surface outcrops. Possible lagoonal deposits with shell debris found by drillings were mentioned by PONÇANO (1976).

5.5.3 - Part of the coastal region east of Sepetiba

Marine deposits situated above present sea-level are again observed when we leave the Guanabara graben. Near the place named Pedra there is about 20-cm-thick shell bed lying on a weathered crystalline surface. These shells indicate an ancient sea-level at least 2.5 m above the present level. Between Pedra and Guaratiba, a very flat low-lying sedimentary plain, superficially similar to that of the graben area, extends between the crystalline rocks and the ocean. However, in this case we have a sandy-clayey deposit very rich in shell beds.

A strong contrast is noted between the last two above-mentioned parts, even though they are morphologically similar. At the surface in the area of the graben, only continental deposits are observed, while eastern of Sepetiba well-developed marine sediments occur above present sea-level. Thus, sedimentary deposits related to ancient sea-levels higher than present are evident on both sides of the Guanabara graben, although they are absent in the interior of the graben. However, before postulating any Quaternary graben activity to explain this features it will be necessary to make datings of shell samples from the lagoonal deposits mentioned by PONÇANO (*op. cit.*), in order both to define their position in space and time and to correlate their ages with sedimentary deposits located outside the graben area.

TABLE 6 - RADIOCARBON DATINGS OF THE GEOLOGICAL SAMPLES FROM THE ILHA GRANDE BAY REGION

SAMPLE	NATURE	POSITION OF THE ANCIENT SEA-LEVEL	AGE IN YEARS B.P.	LABORATORY REFERENCE	COORDINATES
Curray I	Oyster in situ	+ 4.8m (± ?)	5,200 ± 200	LJ-1364	22°57.0'S 44°25.6'W
A333	Shell	Above or present level	4,900 ± 120	Ba-492	23°01.0'S 43°36.0'W
Curray II	Oyster in situ	+ 4.8m(± ?)	4,800 ± 200	LJ-970	22°57.0'S 44°25.6'W
A340	Shell	More than + 1.8m	4,395 ± 140	Ba-631	22°58.7'S 44°27.0'W
A332	Shell	Above + 2.5m	3,550 ± 105	Ba-492	22°59.8'S 43°39.0'W
Laborel II	Vermetidae	+ 3.0m (±0.4m)	3,420 ± 110	Gif-1059	23°00.0'S 45°00.0'W
A327	Vermetidae	+ 1.7m (± 0.4m)	3,255 ± 100	Ba-472	22°57.8'S 44°02.6'W
A330	Oyster in situ	More than + 1.6m	3,055 ± 140	Ba-474	22°55.7'S 43°50.6'W
A321	Vermetidae	+ 1.5m (± 0.4m)	2,695 ± 130	Ba-465	22°58.7'S 44°26.3'W
A329	Vermetidae	+ 1.6m (± 0.4m)	2,595 ± 132	Ba-473	22°55.7'S 43°50.6'W
A322	Oyster in situ	More than + 1.5m	2,510 ± 125	Ba-466	22°58.7'S 44°26.3'W
A178	Shell	More than + 1.5m	2,390 ± 100	Gif-3647	23°08.2'S 44°42.3'W
A316	Vermetidae	+ 1.4m (± 0.4m)	2,300 ± 85	Ba-470	23°09.2'S 43°41.8'W
A315	Oyster in situ	+ 1.7m	2,300 ± 95	Ba-464	23°14.0'S 44°42.0'W
A320	Vermetidae	+ 1.5m	1,840 ± 90	Ba-471	23°09.2'S 42°41.8'W
Laborel III	Vermetidae	+ 1.5m (± 0.4m)	1,670 ± 100	Gif-1060	23°00.0'S 45°00.0'W
A328	Vermetidae	+ 0.8m (± 0.4m)	1,630 ± 65	Ba-499	22°58.2'S 44°02.8'W
A318	Vermetidae	+ 0.7m (± 0.4m)	975 ± 80	Ba-478	23°02.9'S 47°36.7'W
A314	Oyster in situ	More than + 0.9m	960 ± 110	Ba-467	23°14.4'S 44°37.9'W
Laborel IV	Vermetidae	+ 0.5m (± 0.4m)	380 ± 90	Gif-1061	23°00.0'S 45°00.0'W
A326	Vermetidae	+ 0.5m (± 0.4m)	230 ± 60	Ba-483	23°01.0'S 44°13.3'W

The samples Curray I and Curray II were collected by F.DANCIGER (DER-Rio de Janeiro) and dated by J.CURRAY.

The samples Laborel II, III and IV were collected by J.LABOREL (Station Marine d'Endoume-France).

6. COMPARISON OF RELATIVE MEAN SEA-LEVEL FLUCTUATION CURVES FOR COASTAL MORPHOLOGICAL UNITS

As we have seen above, relative mean sea-level fluctuations are produced by a general phenomenon (glacio-eustasy) and several local phenomena (isostasy, tectonic or geoid surface deformations). The local phenomena will be subtracted from or added to the general phenomenon, and, consequently, the sea-level fluctuation curves will be different for each area considered. These differences will be most apparent when the component due to the general phenomenon is very weak, that is, during the maximum transgression and maximum regression.

In order to obtain a homogeneous curve, that is, a curve equally affected by the local phenomena, it is best to use samples collected along a restricted part of the coastline. In fact, the area of the coastline under consideration here are not more than several kilometers long each; it is possible, therefore, to assume that the isostatic and/or tectonic phenomena have been the same and that geoid surface deformations will be irrelevant for each area.

Frequently, we are presented with the following dilemma:

a) Either to construct an accurate curve from a lot of data, a task which frequently could involve a relatively flat portion of the coastal plain, where the local phenomena probably have not been the same at all points;

b) Or to consider only a very limited portion of the coastline, which will provide only a few data; consequently the curve will have little precision.

We have decided to take an intermediate path and to consider the smallest sections of the coastline for which enough data exist to allow us to delineate relatively precise curves.

6.1 - RELATIVE MEAN SEA-LEVEL CHANGE CURVE FOR THE COASTLINE BETWEEN CANANÉIA AND IGUAPE

Radiocarbon dating of several samples of fossil wood and shell debris from marine and lagoonal deposits, together with the study of depositional environments of these sediments, permitted us to recognize the position and the trend of variance of mean sea-level at different depositional phases. The morphological characteristics of the deposits (heights of the wave-built and wave-cut terraces) and the datings of shell-middens allowed us to delineate the curve (Fig. 18), that shows the following:

a) The zero line was cut for the first time at about 6,400 years B.P.

b) About 5,100 years B.P. the relative mean sea-level would have been at a maximum at 3.5 m higher than present.

c) About 3,800 years B.P. the relative mean sea-level may have been equal to or slightly lower than present level.

d) About 3,500 years B.P. the relative mean sea-level would have been at a second maximum situated 3.0 m above present level.

e) Since then, our accuracy diminishes; however, thanks to shell-midden datings, we know that about 3,100 years B.P. sea--level would not have been higher than + 2.3 m in relation to the present level. The relative mean sea-level evolved progressively toward the present level, and about 1,800 years B.P. the mean sea-level could not have been greater than + 0.5 m.

6.2 - RELATIVE MEAN SEA-LEVEL CHANGE CURVE FOR THE COASTLINE BETWEEN PRAIA GRANDE (SANTOS) AND JURÉIA MOUNTAIN (BERTIOGA)

Several datings carried out on shells and wood fragments from uplifted lagoonal deposits as well as on vermetidae and shell debris from a beach-rock, together with data on wave-built terrace heights, allow us to outline the sea-level changes for this area (Fig. 19).

It is possible to see the same fluctuations in this curve as in the previous one (Fig. 18), although their amplitudes are different. Thus, the maximum level of 5,100 years B.P. seems to have been situated at + 4.5 m and that of 3,500 years B.P. at + 4.0 m. About 2,000 years B.P. the level may have been between 1.5 and 2.0 m above present, while in the Cananéia-Iguape coastal plain it could not have been higher than +0.5 m. Moreover, it seems that the zero line was crossed earlier (about 6,700 years B.P.).

6.3 - RELATIVE MEAN SEA-LEVEL CHANGE CURVE FOR THE COASTLINE BETWEEN SÃO SEBASTIÃO AND UBATUBA

The entire curve for this area has not been delineated because of insufficient data. However, the final portion of the curve (after the second maximum) is well defined and looks like the previous curves (Fig. 20). Two samples related to ancient sea-levels situated at -12.0 and -16.0 m (± 1 m) and two others related to a level near the present have been dated and allow us to outline the portion of the curve between -16 and 0 m. It seems that the zero line was crossed in this region for the first time a little earlier than in the Santos area. This could indicate that the 5,100 - 5,200 years B.P. maximum had attained a relative height slightly superior to that in Santos. Two vermetidae samples from the west coast of São Sebastião island seem to indicate ancient sea-levels more elevated than on the continent.

6.4 - RELATIVE MEAN SEA-LEVEL CHANGE CURVE FOR THE COASTLINE BETWEEN PARATI AND ANGRA DOS REIS

As in the previous case, only the final part of the curve has been outlined (Fig. 21), and this shows characteristics similar to the previous three curves. A sample of oysters

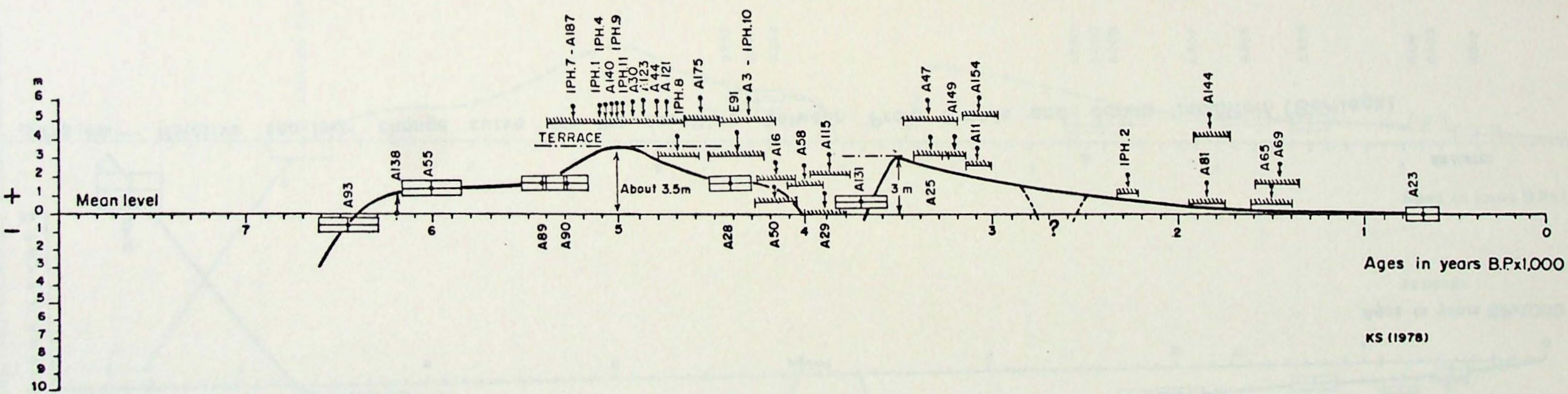


Fig. 18 — Relative sea-level change curve for the Cananéia - Iguape coastal plain.

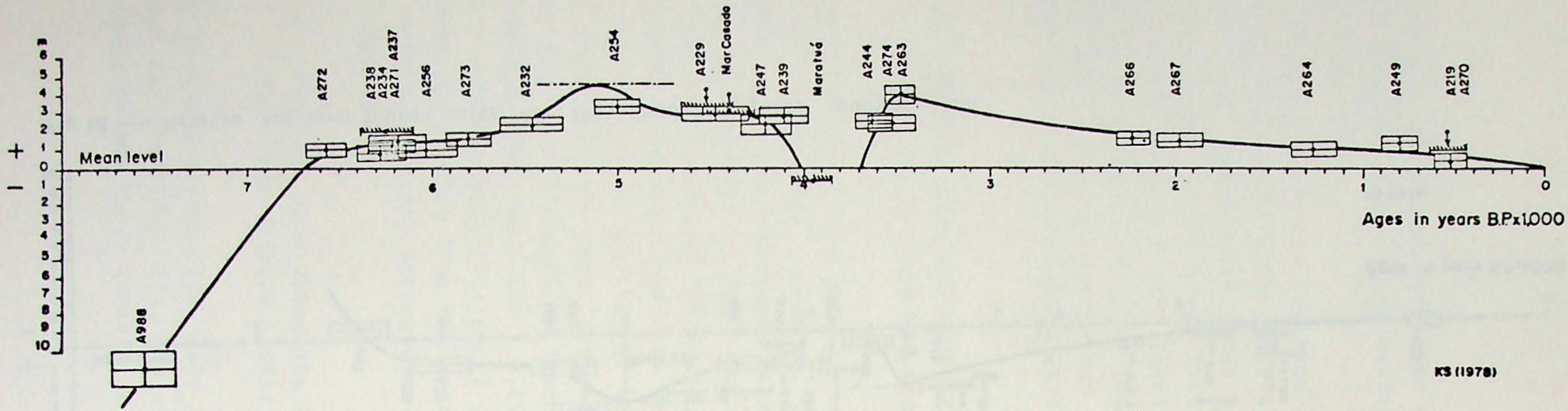


Fig. 19 — Relative sea-level change curve for the coastline between Praia Grande and Juréia mountain (Bertioga).

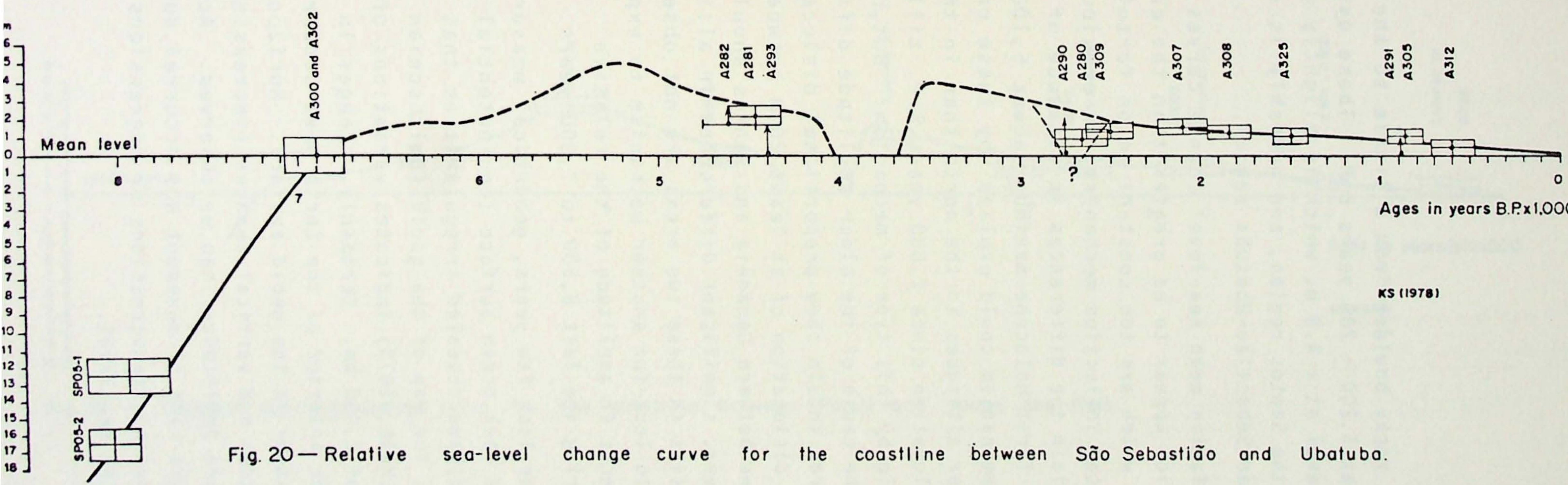


Fig. 20 — Relative sea-level change curve for the coastline between São Sebastião and Ubatuba.

collected from a rocky boulder from a little to the east was dated by CURRAY at 5,200 ± 200 years B.P. These oysters indicate an ancient sea-level at + 4.8 m, which is slightly greater than the maximum for the Santos region, and probably is equivalent to that of the São Sebastião-Ubatuba region.

The relative mean sea-level change curves show differences of amplitudes which appear to be greater than the errors of measurements and which are too constant to be fortuitous (Fig. 22). A continental inflection mechanism, as previously described, could easily explain the differences in altitude of the records belonging to the first Holocene maximum (about 5,100 years ago). Similarly, this mechanism could explain why these records are situated at higher altitudes in the north than in the south. However, the dislocation since 2,000 years B.P. till today is hardly explainable by this type of mechanism. But,if continental inflection was the cause of the older amplitude differences,the Pleistocene records should show proportional dislocations along the coast, and a dislocation of at least 20 m between the tops of the Pleistocene between Cananéia and Santos should be evident. In reality, however, significant differences in altitude of the Pleistocene deposits in these two areas are not observed. Thus, it is necessary to look for another mechanism to explain the observed differences in amplitude of the relative sea-level change curves during the last 6,500 to 7,000 years.

Over the last few years, geodetical measurements by satellites of the real ocean surface (equipotential surface of the gravity field)have revealed irregularities that are not negligible. Thus, the map of the geoid (Smithsonian Standard Earth III, GUPOSCHKIN, 1973) indicates variations of about 180m over a distance of 2,000 km. Certainly, changes in the distribution of the mass in the interior of the Earth have occurred through time, causing changes in the geoid surface. Horizontal changes (relief dislocation) and vertical changes (increasing or diminishing hump and depression amplitudes) can be observed. According to MÖRNER (1976), this kind of movement has occurred during the Holocene, thus causing transgressions or regressions by relative dislocations of the sea-level.

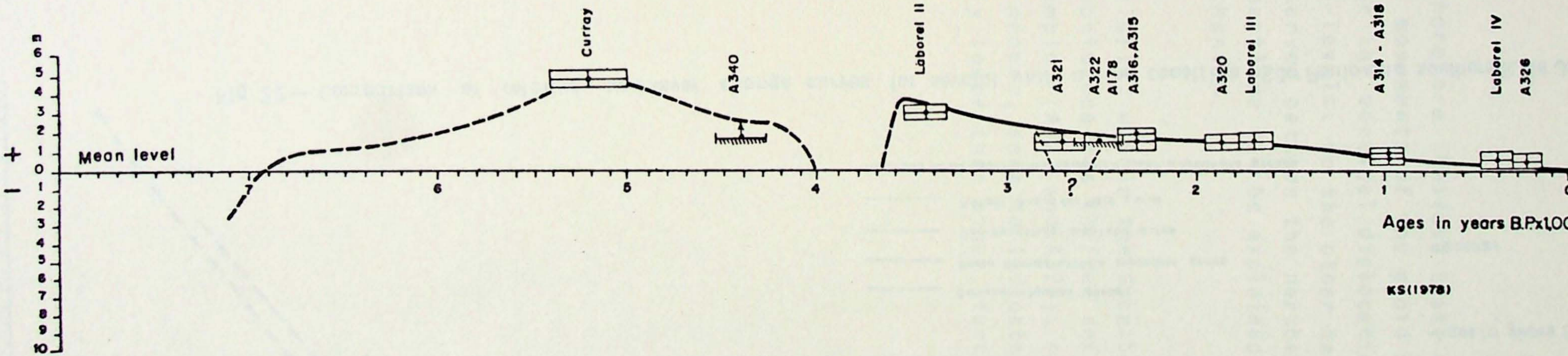


Fig. 21 — Relative sea-level change curve for the coastline between Parati and Angra dos Reis.

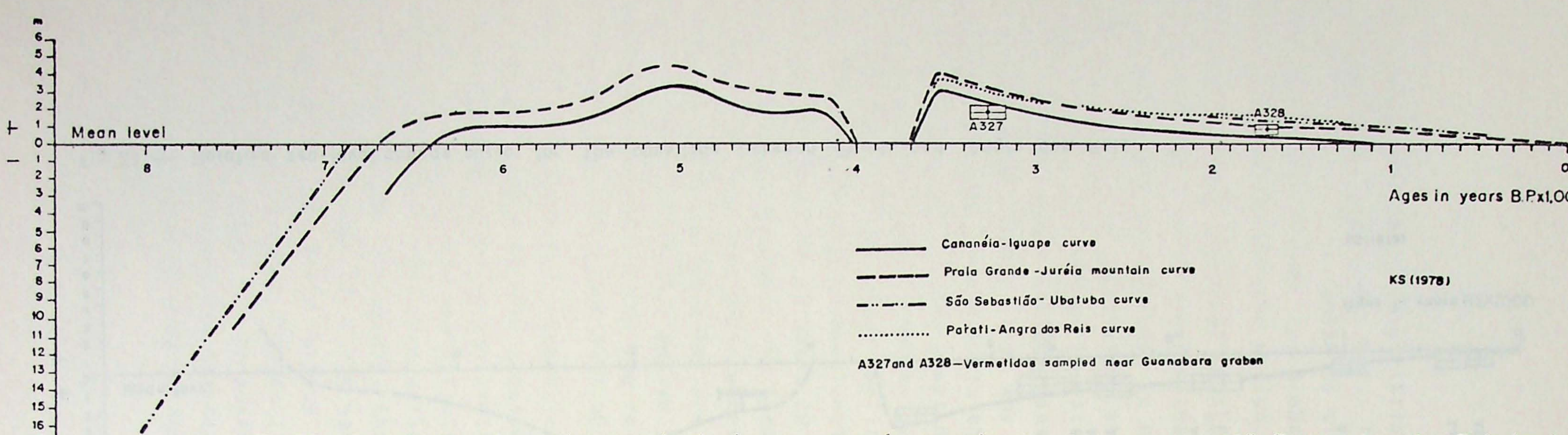


Fig. 22— Comparison of relative sea-level change curves for several units of the coastline (São Paulo and southern R. de Janeiro).

We therefore believe that, in the present stage of our knowledge, movements of the geoid surface provide the best explanation for the vertical dislocation observed for the records of ancient sea-levels. On the other hand, the differences in morphology observed between the northern and southern parts of São Paulo's coastline can be explained by the differential inflection mechanism.

Similarly, within the Guanabara graben region,it seems that recent subsidence has shifted ancient shorelines. In this manner, two samples (A327 and A328), collected west of the Guanabara graben proper, seem to indicate an ancient relative sea-level slightly lower than other, further westward records.

EXCURSION ROUTE

1. SUMMARY (FIG. 23)

First day: São Paulo to Cananéia

Second day: Cananéia to Peruíbe

Third day: Peruíbe to São Sebastião

Fourth day: São Sebastião to Rio de Janeiro

Fifth day: Rio de Janeiro

2. ROUTE

2.1 - FIRST DAY - SEPTEMBER 14th - DEPARTURE: 07:00 A.M.

2.1.1 - On the itinerary (Fig. 24)

From São Paulo to Cananéia, we shall travel by BR-116 and SP-226 highways. There is no stop between São Paulo and the town of Pariquera Açu. Geologically, this part is formed of Precambrian crystalline rocks, and only near Registro can we see some outcrops of Plio-Pleistocene continental deposits of the Pariquera Açu Formation. Between the town of Pariquera Açu and Cananéia we will enter the Cananéia-Iguape Quaternary sedimentary plain.

a) STOP 1: 10 minutes

Place: Between km 40 and 39 of SP-226 highway (near the town of Pariquera Açu).

Subject: One of the most representative outcrops of the Pariquera Açu Formation. This formation can be correlated

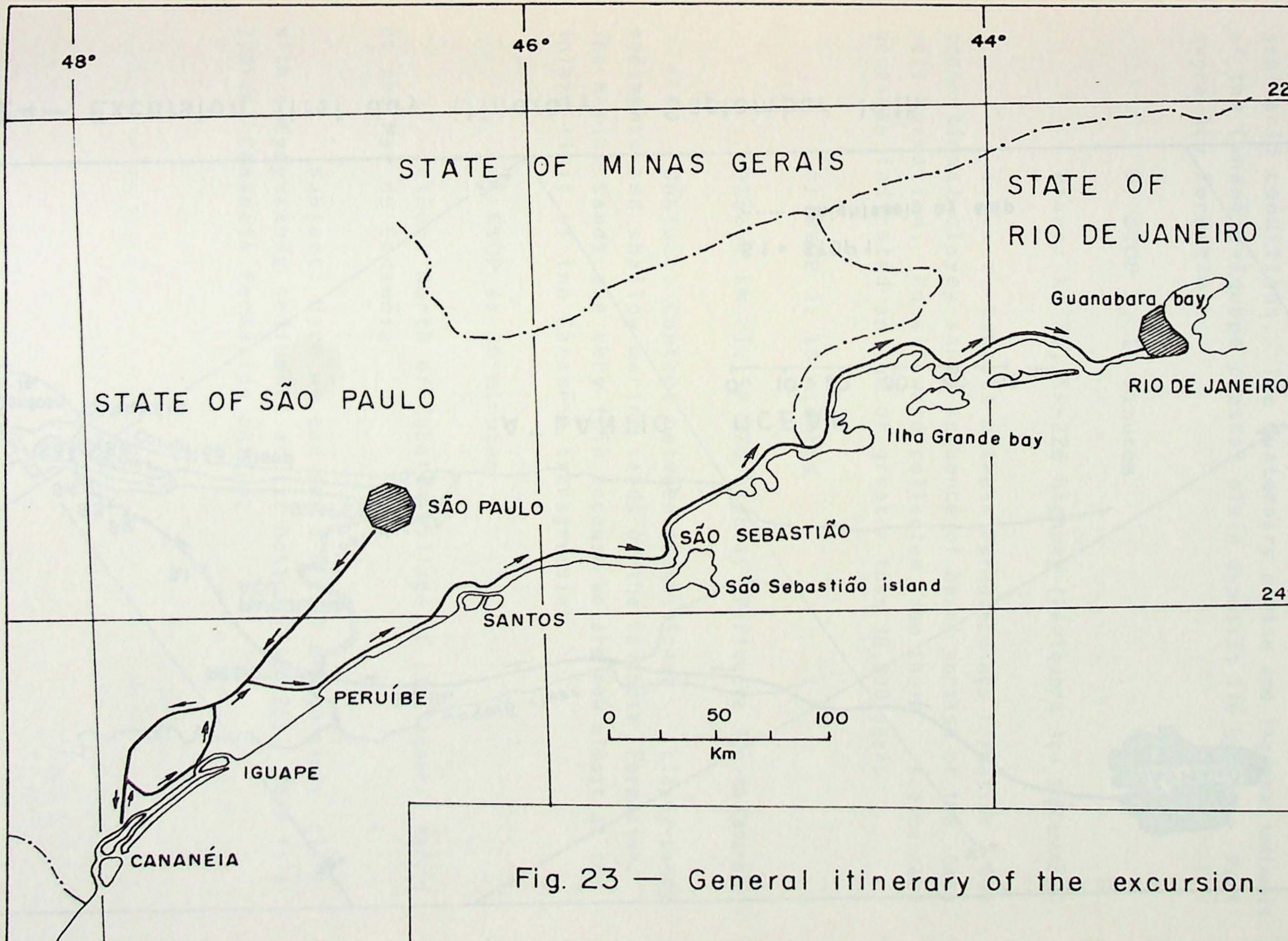


Fig. 23 — General itinerary of the excursion.

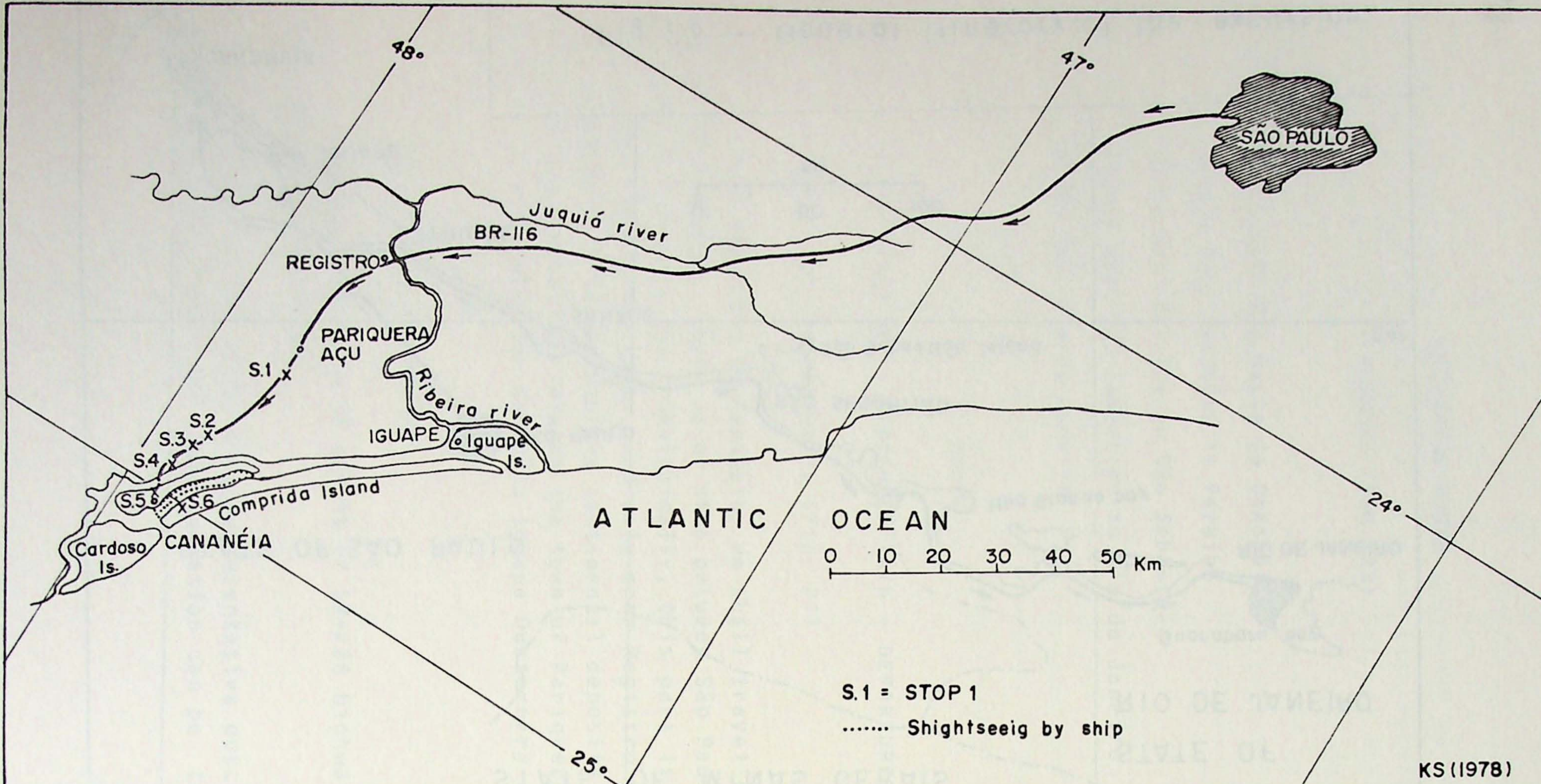


Fig. 24 — Excursion first day itinerary — September 14th.

with the Barreiras Formation that occurs in the north, beginning in the State of Rio de Janeiro. It was probably deposited under semi-arid conditions. The Quaternary marine and lagoonal sediments of the Cananéia-Iguape coastal plain deposits lie upon the Pariquera Açu Formation.

b) STOP 2: 10 minutes

Place: km 23, SP-226 highway (Pariquera Açu to Cananéia).

Subject: Contact between Pariquera Açu Formation and transitional clayey-sandy sequence of basal portion of the Cananéia Formation. Fossil wood collected from these sedimentary deposits indicated an age of greater than 30,000 years.

c) STOP 3: 10 minutes

Place: Km 21, SP-226 highway (Pariquera Açu to Cananéia).

Subject: Contact between transitional clayey-sandy sediments and shallow marine sands of the Cananéia Formation. The marine sands are very thin because we are now almost at the inland limit of the Cananéia transgression.

d) STOP 4: 30 minutes

Place: North of Cubatão village at the lagoonal margin of the Mar de Cananéia.

Subject: Here we can see a-6 to 7 m-high sandy cliff with clayey-sandy sediments at its bottom (Fig. 25). This is a typical Cananéia Formation outcrop.

e) STOP 5: 20 minutes

Place: Cananéia island, between Mar de Cananéia ferry-boat pier and the town of Cananéia; a sand spit.

Subject: Detailed features of the top of the Cananéia Formation can be observed here (Fig. 26):

- *Callianassa* burrows
- Mud-cracked clay beds
- Thin plant debris layers
- Horizontal parallel stratification of marine sands

At Cananéia, the day will be partially dedicated to a trip along the Mar de Cananéia lagoonal area. We shall travel along the Comprida island margin, where we can observe, in the following order:

- Lower terraced Cananéia Formation (eroded)
- Holocene lagoonal deposits
- Ancient mangrove deposits with shell bed within clayey-sandy deposits
- Lower terraced Cananéia Formation (eroded)
- Higher normal Cananéia Formation

The shells from the shell bed (Fig. 27) have been dated at 5,410 $\pm$ 110 years B.P. (Ba-229). They indicate an ancient sea-level at + 1.5 $\pm$ 0.5 m.

Fossil wood from ancient mangrove deposits (Fig. 28), collected near present low-tide, was dated at 6,455 $\pm$ 170 years B.P. (Ba-230), which attests to an ancient sea-level at -0.8 $\pm$ 0.4 m.

Returning, we shall follow the Cananéia island margin, where we can observe, in order:

- Higher normal Cananéia Formation
- Eroded zones within Cananéia Formation where Holocene clayey-sandy sediments have been deposited.

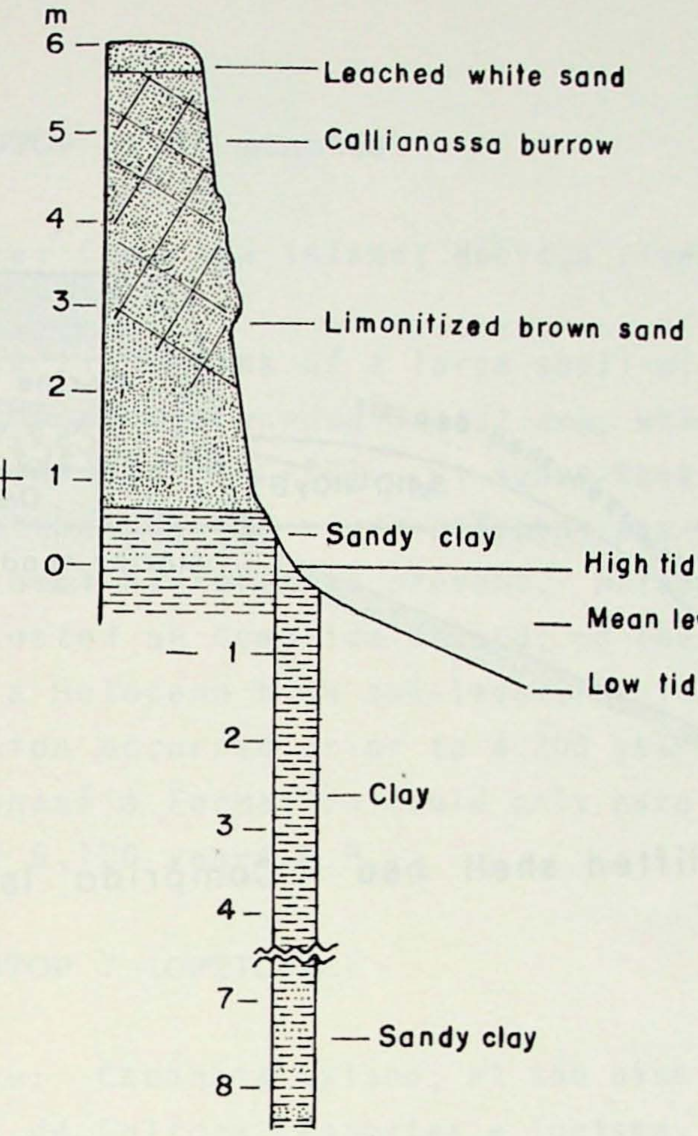


Fig. 25 – Cananéia Formation at Cubatão

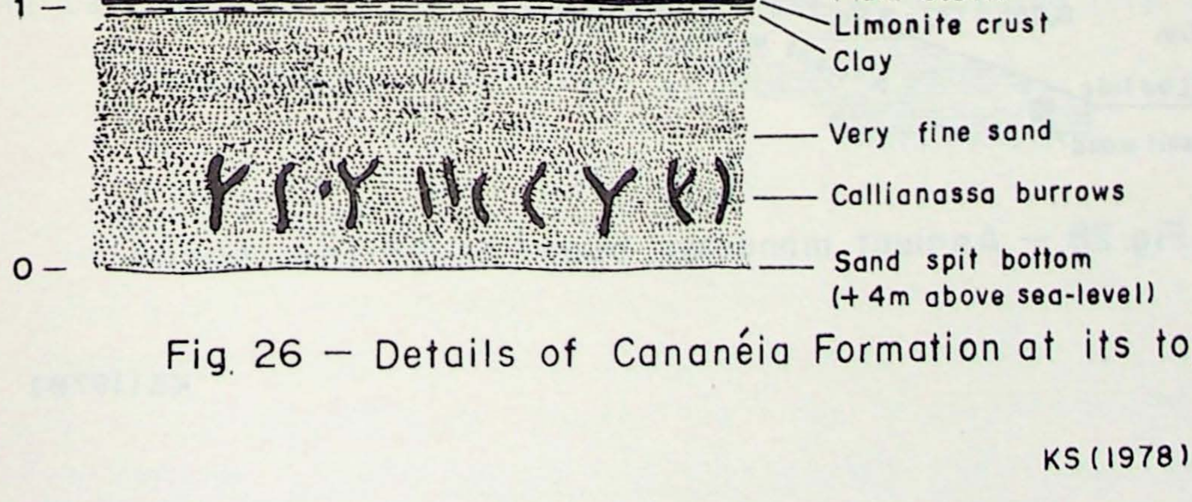


Fig. 26 – Details of Cananéia Formation at its top.

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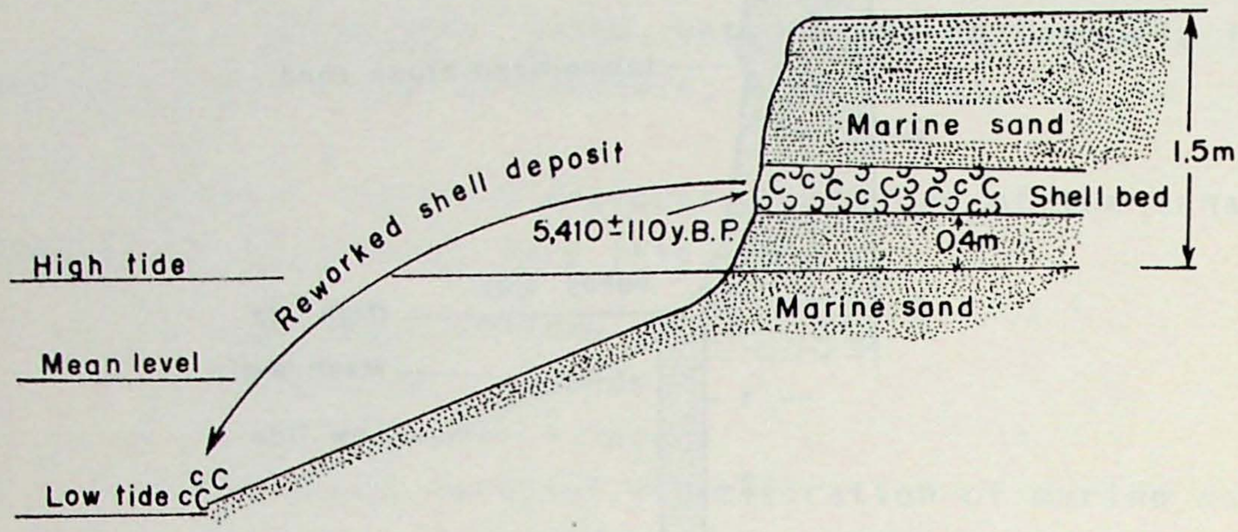

Fig. 27 — Uplifted shell bed (Comprida Island).

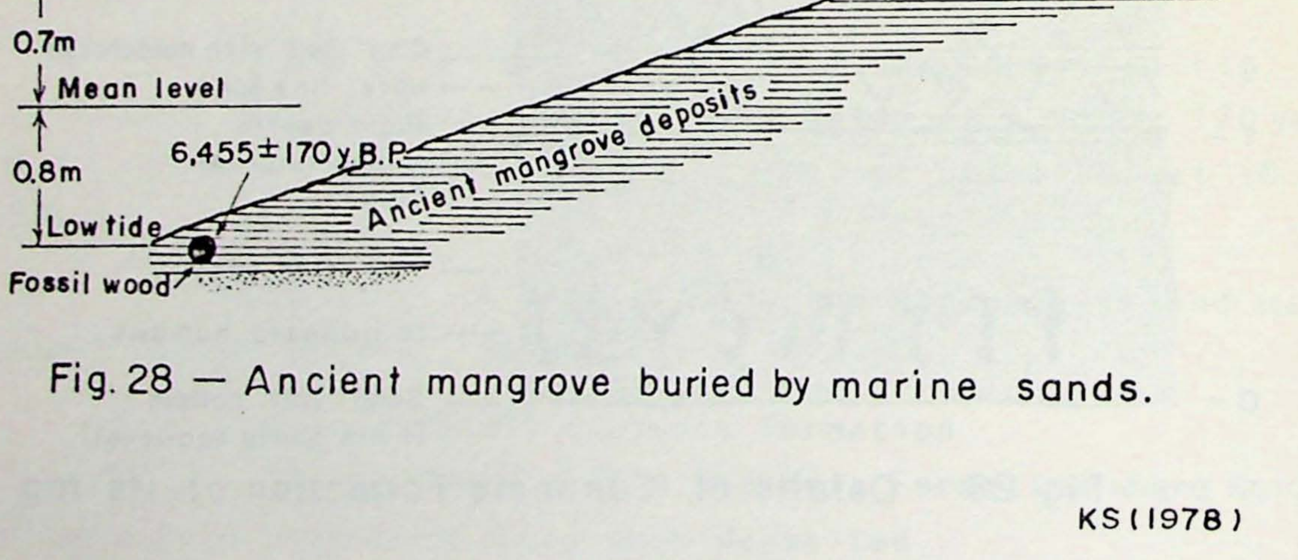

Fig. 28 — Ancient mangrove buried by marine sands.

KS (1978)

f) STOP 6: 60 minutes

Place: Comprida island; Nóbrega river paleobay bottom.

Subject: Remains of a large shell-midden formed predominantly of *Anomalocardia brasiliana*, which was dated as 4,210 ± 160 years old (SPC-22). It seems that the shell-midden was built when the Nóbrega river paleobay was flooded, that is during a sea-level higher than present. Moreover, as the shell-midden is situated on Comprida island, on the Cananéia Formation eroded during a Holocene high sea-level, it is logical to admit that this erosion occurred prior to 4,200 years ago. Thus, this part of the Cananéia Formation could only have been eroded during the maximum of 5,100 years B.P.

g) STOP 7 (OPTIONAL)

Place: Cananéia island; at the base of the hotel of the Secretaria de Cultura, Esportes e Turismo.

Subject: Cananéia Formation outcrop which shows the following details:

- *Callianassa* burrows (observe the level with the highest concentration)
- Thin layers of plant debris
- Thin clay beds

At this place the transitional clayey-sandy sequence of the Cananéia Formation is observed only by drilling (Fig. 29).

First night - Cananéia

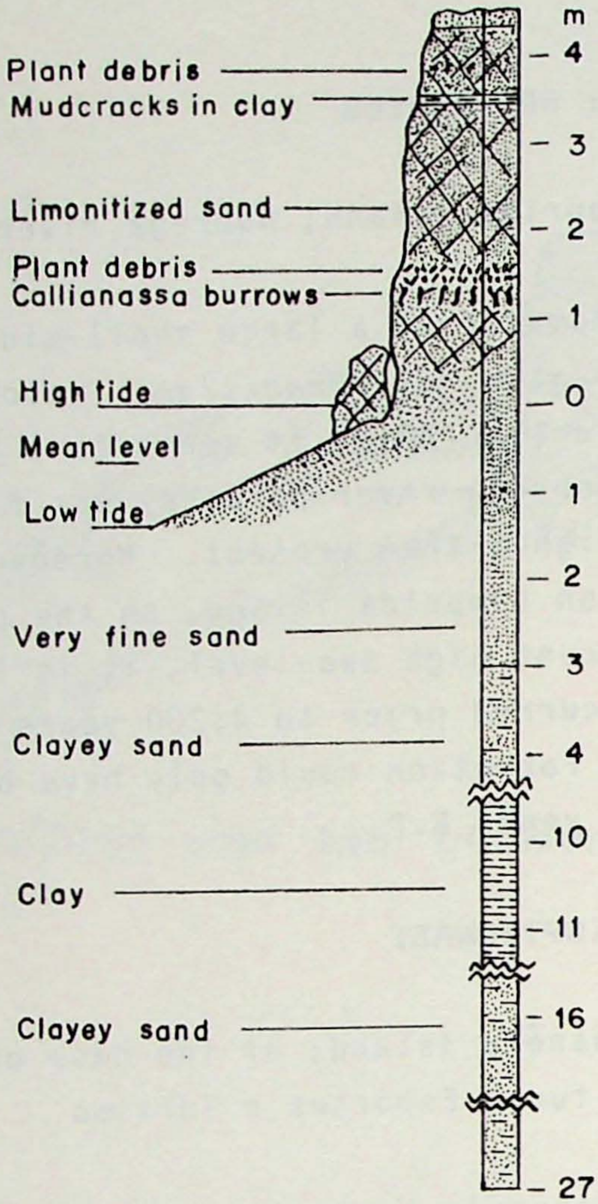

Fig. 29 — Cananéia Formation at the base of the hotel (FUMEST); Cananéia Island.

KS (1978)

2.2 - SECOND DAY - SEPTEMBER 15th-DEPARTURE: 07:00 A.M.

2.2.1 - On the itinerary (Fig. 30)

Returning to Pariquera Açu, our route will be the same as the first day. From Pariquera Açu we will travel along the SP-222 road toward the town of Iguape, which is also situated on the Quaternary Cananéia-Iguape coastal plain. Departing from Iguape toward Biguã (BR-116 highway), we will go by SP-222, at last leaving the Cananéia-Iguape coastal plain. At Pedro de Barros we will enter SP-165 highway toward Peruībe.

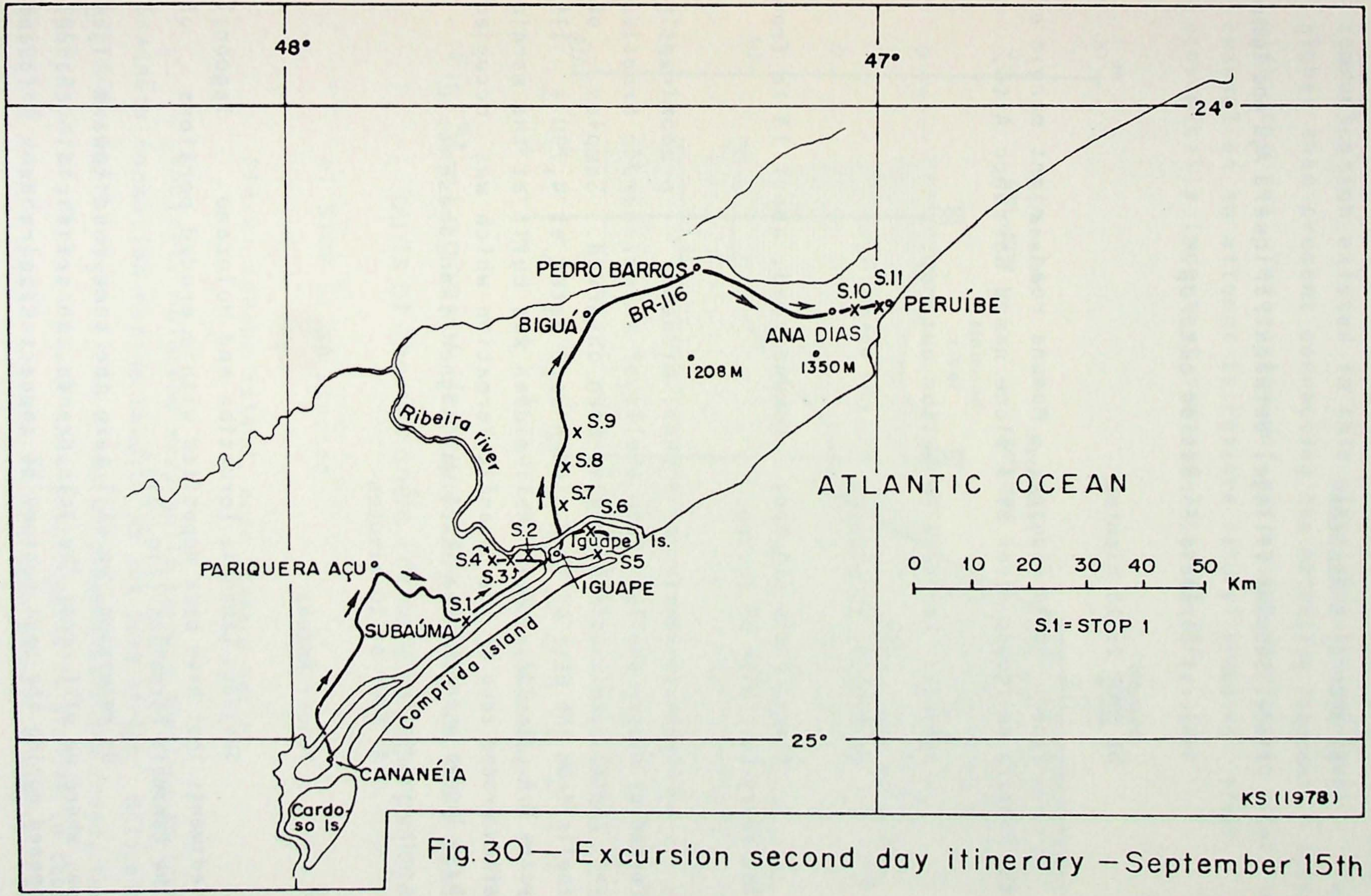

Fig. 30 — Excursion second day itinerary — September 15th

a) STOP 1: 5 minutes

Place: Subaūma village, between Pariquera Açu and Iguape.

Subject: Cananéia Formation outcrop.

b) STOP 2: 15 minutes

Place: Rocio (Iguape) - Momuna road, right margin of the Ribeira de Iguape river at a place named Barranco Alto.

Subject: Cananéia Formation outcrop.

c) STOP 3: 10 minutes

Place: Rocio (Iguape) - Momuna road, about 13 km from the ferry-boat pier of Iguape.

Subject: Remains of a shell-midden predominantly formed of oyster shells. Some shells of *Anomalocardia brasiliana* and *Lucina jamaicensis* have also been observed. Samples of shells from the base of this midden were dated at 4,790 $\pm$ 115 years B.P. (Ba-308). This shell-midden was built at the margin of an eroded zone of the Cananéia Formation which was occupied by a lagoon when the sea-level was higher than present.

d) STOP 4: 10 minutes

Place: Momuna

Subject: Cananéia Formation and Holocene lagoonal sediments that have been deposited within eroded portions of the Cananéia Formation (Fig. 31).

On returning, we will take the same road toward Iguape, where we will cross the Valo Grande, an artificial channel opened during the past century to connect Ribeira de Iguape river to Mar Pequeno (lagoonal zone). Probably a natural communication existed in this place when the sea-level was higher than present connecting the extensive lagoonal system with the sea. The government has announced plans to close this channel as an attempt to restore natural breeding areas of economically important sea and lagoonal life.

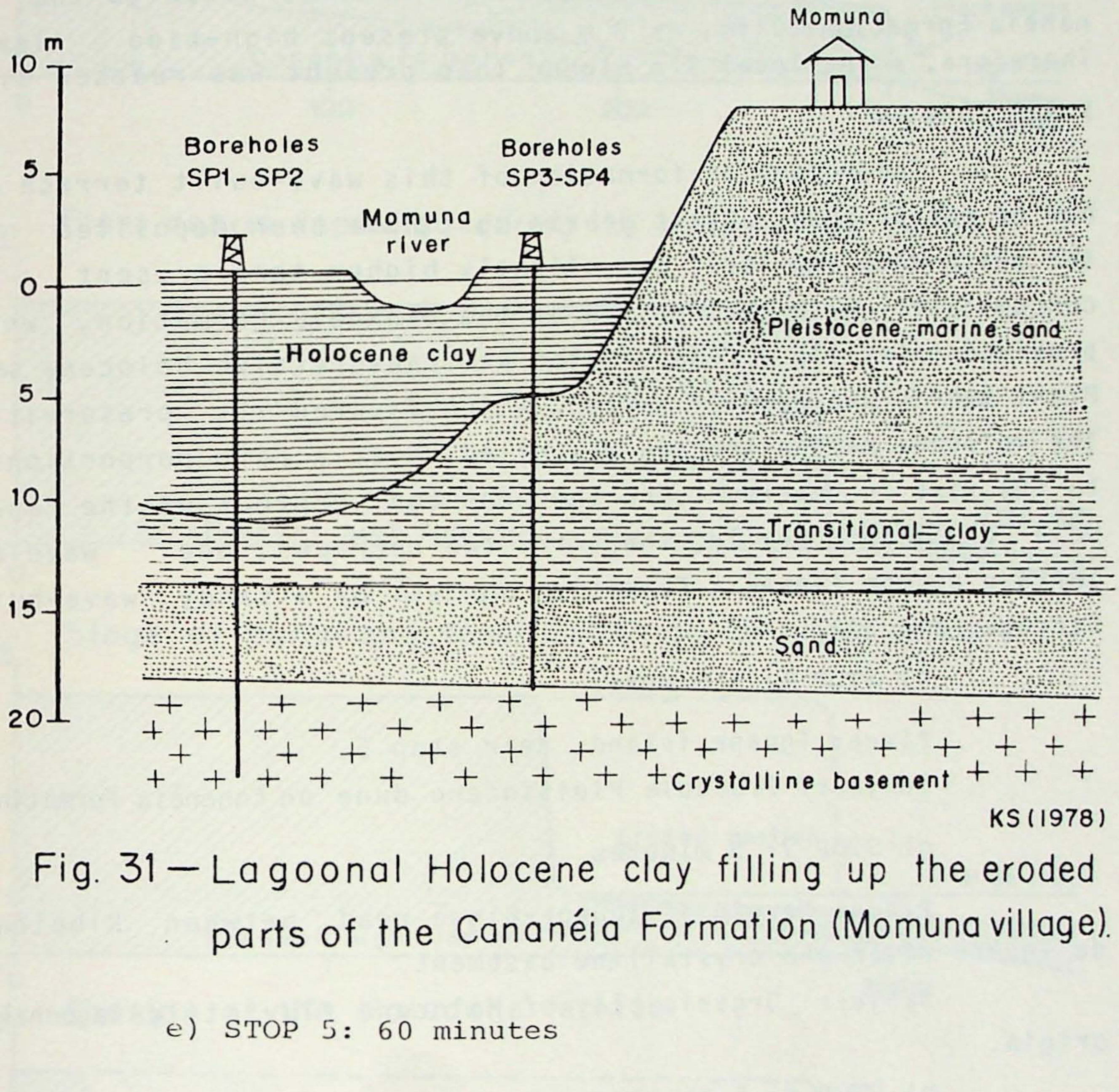

Fig. 31 — Lagoonal Holocene clay filling up the eroded parts of the Cananéia Formation (Momuna village).

e) STOP 5: 60 minutes

Place: Iguape island, near Icapara outlet.

Subject: Holocene wave-built terrace abutting against Cananéia Formation marine sands. At the base of the Holocene terrace, thin layers (1 to 2 cm) of plant debris are found. The mechanism of deposition of this plant debris is similar to that observed on the present beach in the same place. A sample of this plant debris from a layer 0.2 m above present high-tide level was dated at 3,370 ± 100 years B.P. (Gif-3430). A second sample collected only a few meters away from the first one was dated at 3,700 ± 140 years B.P. (Ba-445). These plant remains are covered by almost 2.5 m of marine sands, suggesting that they were deposited in a transgressive phase. Altimetric measurements have shown that the Holocene terrace's summit, close to the Cananéia Formation cliff, is 3 m above present high-tide level. Therefore, a sea-level 3 m higher than present was reached 3,700 years ago.

The scheme of formation of this wave-built terrace can now be established. Plant debris must have been deposited on the beach when sea-level was slightly higher than present and concomitantly with the erosion of the Cananéia Formation, which provided materials for deposition as transgressive Holocene sands. Plant debris was rapidly buried, which favored its preservation. The Holocene marine terrace was piled up at a rate porportional to the rise in sea-level and the erosional retreat of the Cananéia Formation. Really, there are two terraces, one wave-cut terrace on the Cananéia Formation overlain by a sandy, wave-built terrace (Fig. 32).

f) STOP 6: 5 minutes

Place: Iguape island, near stop 5.

Subject: Probable Pleistocene dune on Cananéia Formation.

g) STOP 7: 5 minutes

Place: Margin of Iguape-Biguã road, between Ribeira de Iguape river and crystalline basement.

Subject: Organic clay of Holocene fluviatile-lagoonal origin.

h) STOP 8: 5 minutes

Place: Margin of Iguape-Biguã road, near the foot of the Serra do Mar.

Subject: Small Cananéia Formation outcrop.

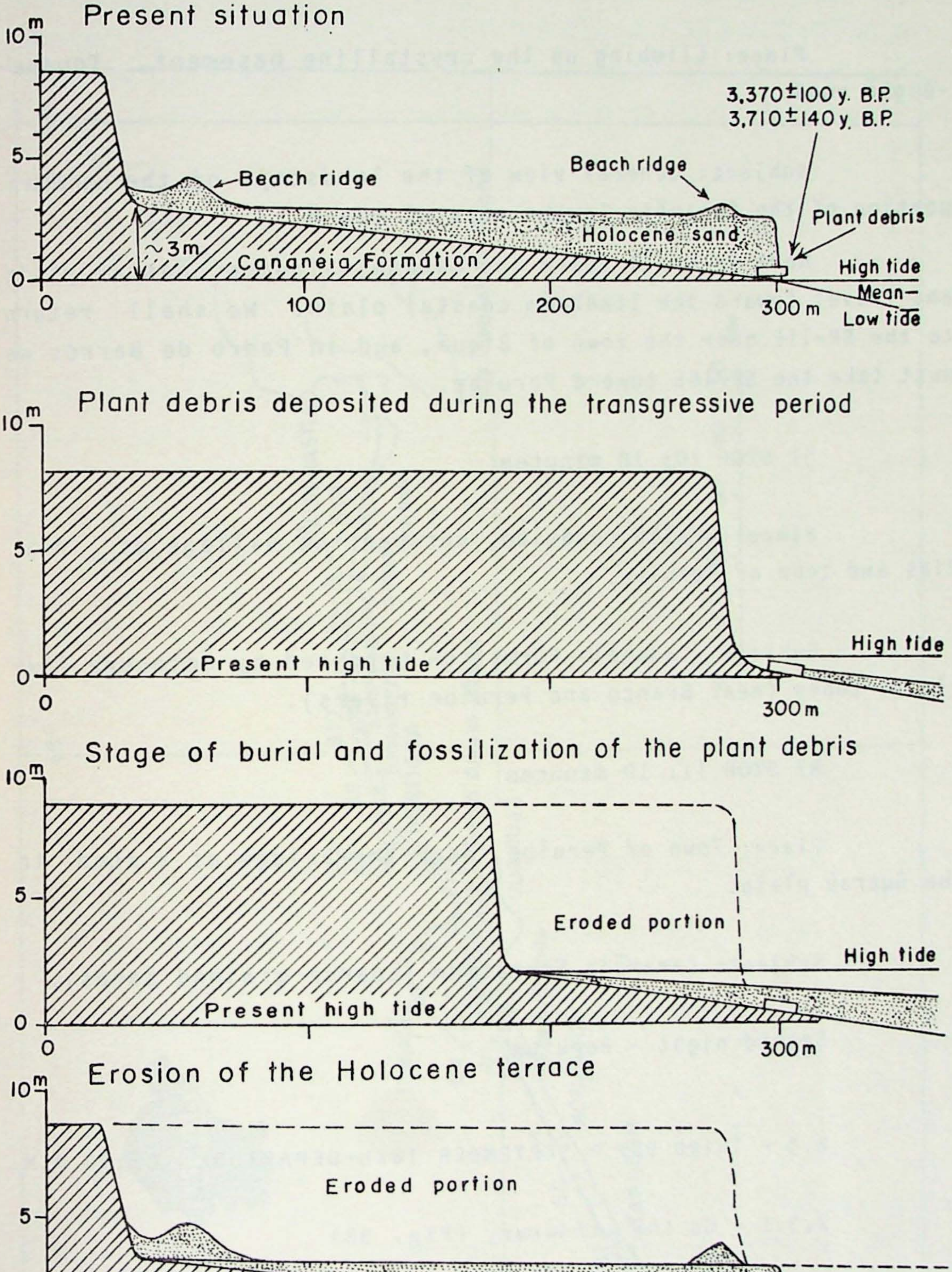

Fig. 32 — Evolutive scheme of the Icapara outlet Holocene wave-built terrace (Iguape island).

i) STOP 9: 5 minutes

Place: Climbing up the crystalline basement, Iguape--Biguã road.

Subject: General view of the landscape of the northern portion of the Cananéia-Iguape coastal plain.

Here we shall leave the Cananéia-Iguape coastal plain and travel toward the Itanhaém coastal plain. We shall return to the BR-116 near the town of Biguã, and in Pedro de Barros we must take the SP-165 toward Peruíbe.

j) STOP 10: 10 minutes

Place: SP-165 roadside, between the village of Ana Dias and town of Peruíbe.

Subject: Cananéia Formation bordered by Holocene low--lying zones (near Branco and Peruíbe rivers).

k) STOP 11: 10 minutes

Place: Town of Peruíbe, near the bridge of a road to the Guaraú plain.

Subject: Cananéia Formation (coarse-grained sands).

Second night - Peruíbe

2.3 - THIRD DAY - SEPTEMBER 16th-DEPARTURE: 07:00 A.M.

2.3.1 - On the itinerary (Fig. 33)

From Peruíbe to Mongaguá we shall travel over the Itanhaém coastal plain. From Mongaguá to Praia Grande and then from

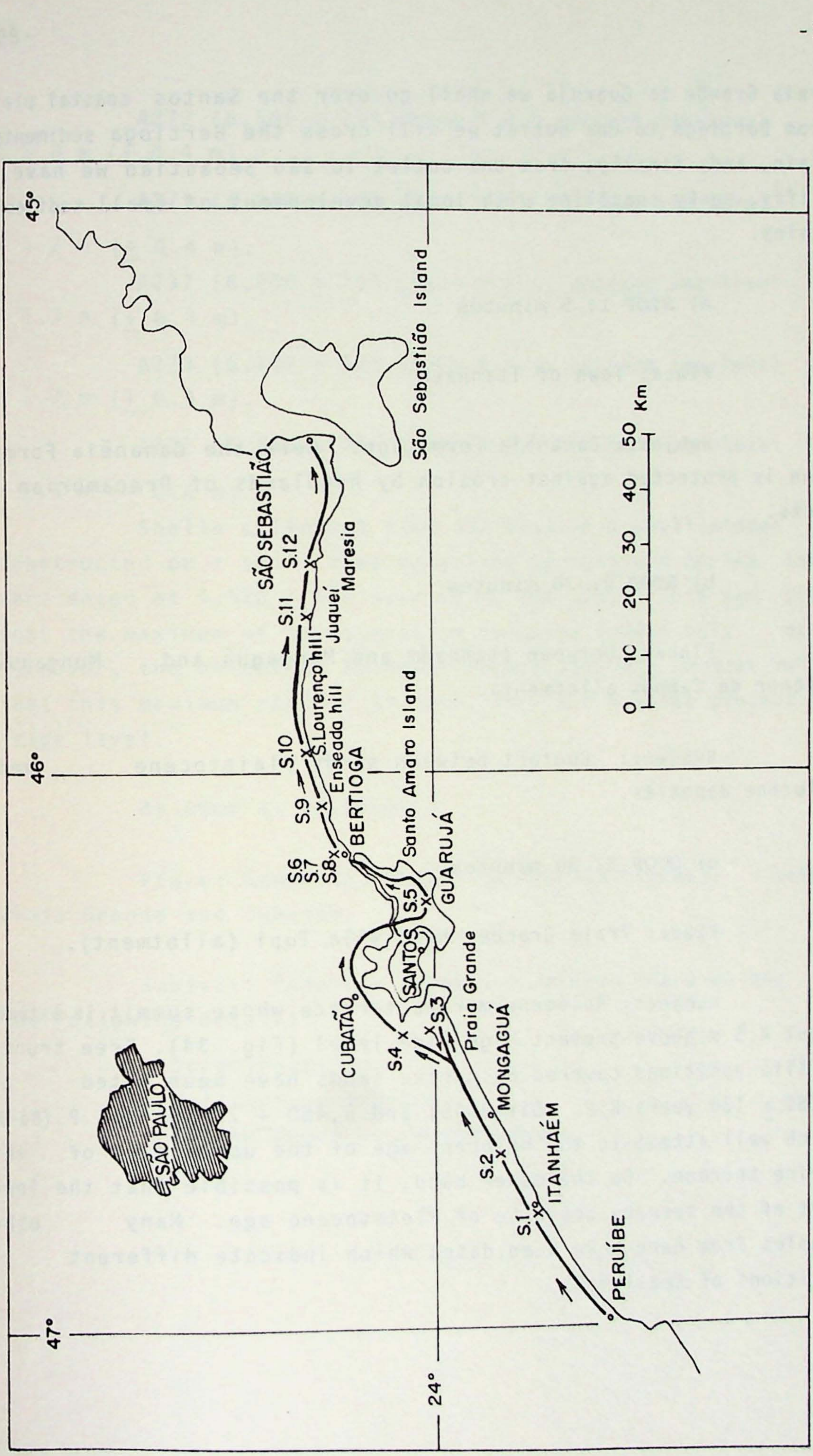

Fig. 33 — Excursion third day itinerary — September 16th.

Praia Grande to Guarujá we shall go over the Santos coastal plain. From Bertioga to Una outlet we will cross the Bertioga sedimentary plain, and, finally, from Una outlet to São Sebastião we have a cliffy, rocky coastline with local development of small sedimentary plains.

a) STOP 1: 5 minutes

Place: Town of Itanhaém

Subject: Cananéia Formation. Here the Cananéia Formation is protected against erosion by headlands of Precambrian rocks.

b) STOP 2: 20 minutes

Place: Between Itanhaém and Mongaguá and Mongaguá (Agenor de Campos allotment).

Subject: Contact between sandy Pleistocene and Holocene deposits.

c) STOP 3: 30 minutes

Place: Praia Grande, near Vila Tupi (allotment).

Subject: Holocene marine terrace whose summit is situated about 4.5 m above present high-tide level (Fig. 34). Tree trunks in life positions covered by marine sands have been dated at 6,250 ± 130 years B.P. (Gif-3845) and 6,480 ± 75 years B.P.(Ba-327), which well attest to the Holocene age of the upper part of this marine terrace. On the other hand, it is possible that the lower part of the terrace could be of Pleistocene age. Many other samples from here have been dated which indicate different positions of sea-level:

A272 (6,565 ± 115 years B.P.), ancient sea-level at + 1.0 m (± 0.4 m).

A271 (6,220 ± 125 years B.P.), ancient sea-level at + 1.2 m (± 0.4 m).

A237 (6,200 ± 165 years B.P.), ancient sea-level at + 1.3 m (± 0.4 m).

A273 (5,795 ± 125 years B.P.), ancient sea-level at + 1.7 m (± 0.4 m).

A232 (5,455 ± 170 years B.P.), ancient sea-level at + 2.4 m (± 0.4 m).

Shells collected from the base of a shell-midden constructed on a small dune underlain by Holocene marine sands were dated at 4,520 ± 150 years B.P. (Ba-326). This age shows that the maximum of transgression occurred before this date. Moreover, the height of Holocene marine sediment terraces indicates that this maximum reached at least to + 4.5 m above present high-tide level.

d) STOP 4: 10 minutes

Place: Samaritã; Manuel da Nóbrega highway, between Praia Grande and Cubatão.

Subject: Cananéia Formation outcrop where we can see the following details:

- Stratification
- *Callianassa* burrows
- Eolian dunes on marine sands

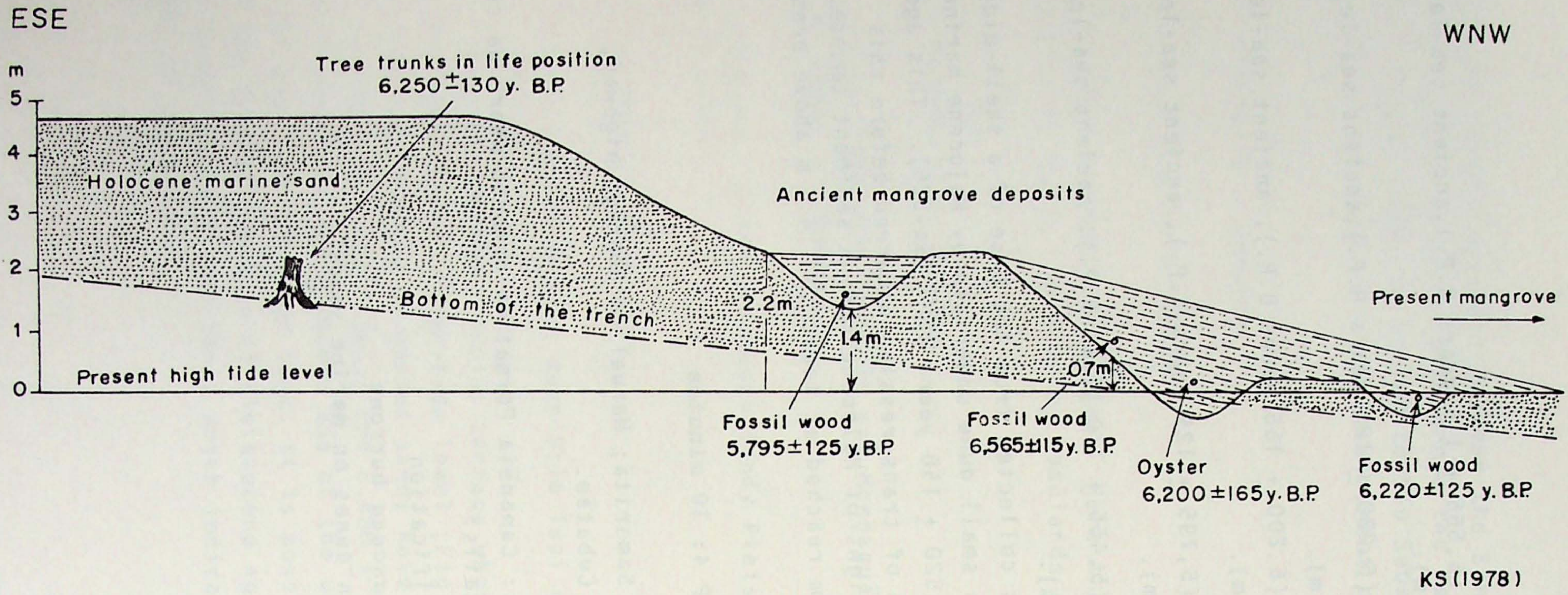

Fig. 34 — Schematic profile of the Balneário Tupiri Holocene terrace (Praia Grande).

e) STOP 5: 10 minutes

Place: Acapulco allotment, near Pernambuco beach (Santo Amaro island).

Subject: Holocene marine sands with shells (Fig. 35). During the maximum of the Holocene transgression, the sea reached the foot of the rocky portion of Santo Amaro island. Shortly after this maximum, a "tombolo" abutted against the rocky portion of Santo Amaro island and Tortuga Club hill. Later, sandy ridges closed the Pernambuco beach and formed a deep bay open toward the present Perequê beach. The Mar Casado shell-midden dated at 4.400 ± 130 years B.P. (Gif-1194) shows that this closing must have occurred before this date. Shells sampled from beach--ridges closing the paleobay site have been dated as 4,210 ± 145 years old (Ba-353), which shows that this bay still existed at this time. The paleobay surface diminished as the sea retreated. The beach-ridge lineations, very clearly distinguished in the paleobay area, confirm this scheme.

f) STOP 6: 15 minutes

Place: Bertioga, left margin of the Itapanhaū river.

Subject: Holocene lagoonal clayey deposit with fossil wood and shell fragments covered by marine sands (Fig. 36). Shells collected from the clay deposits were dated at 6,020 ± 130 years B.P. (Gif-3850). 2.7 m-thick marine sands covering this clay show that this date represents a transgressive phase and that these sands can be related to the first Holocene maximum.

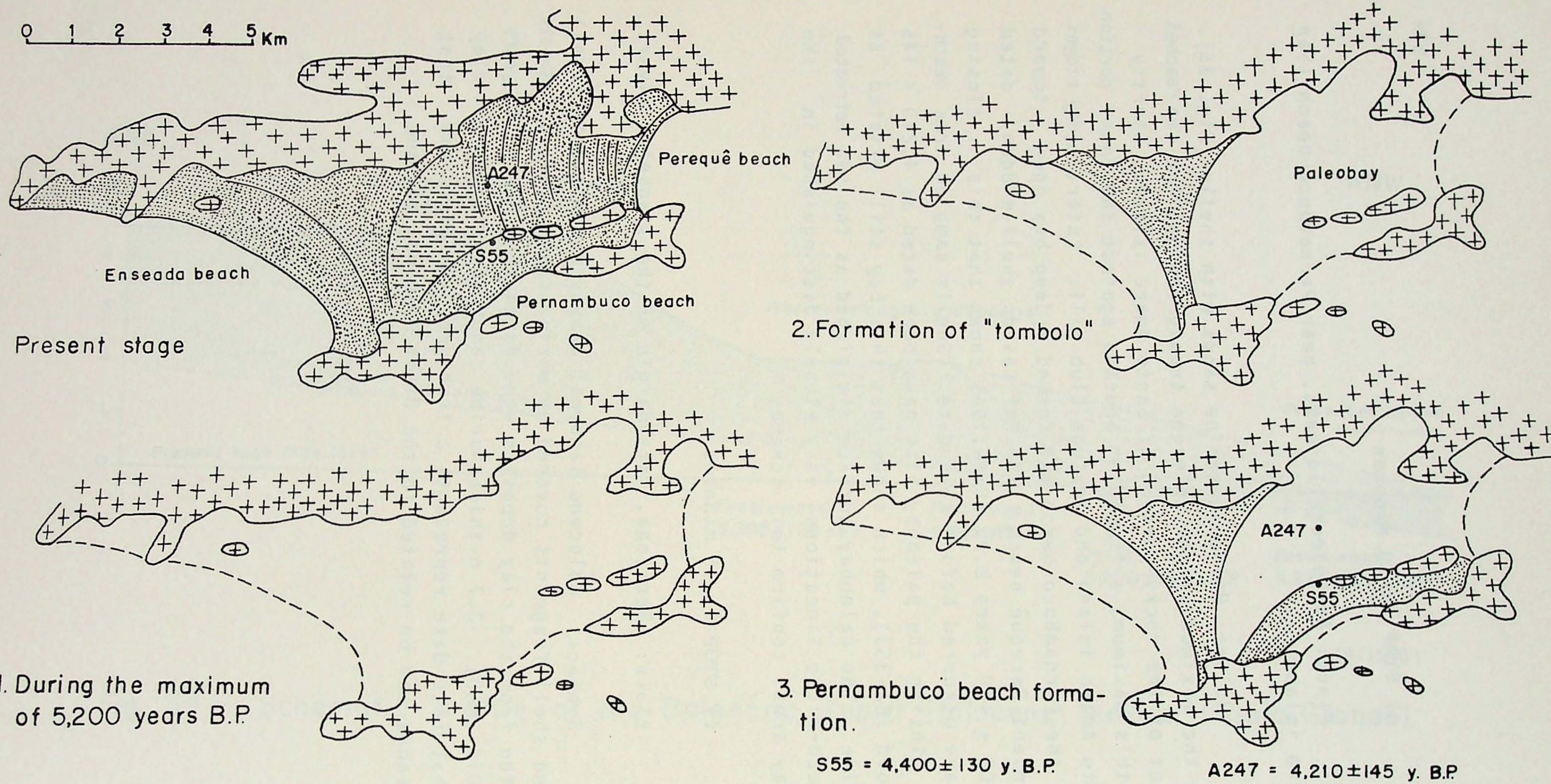

Fig. 35 — Evolutive scheme of the coastal plain among Enseada, Pernambuco and Perequê beaches.

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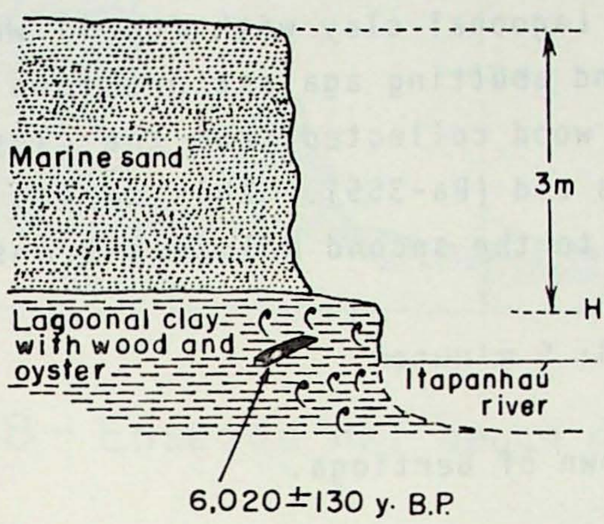

Fig. 36 — Holocene deposit at Itapanhaú rivermargin.

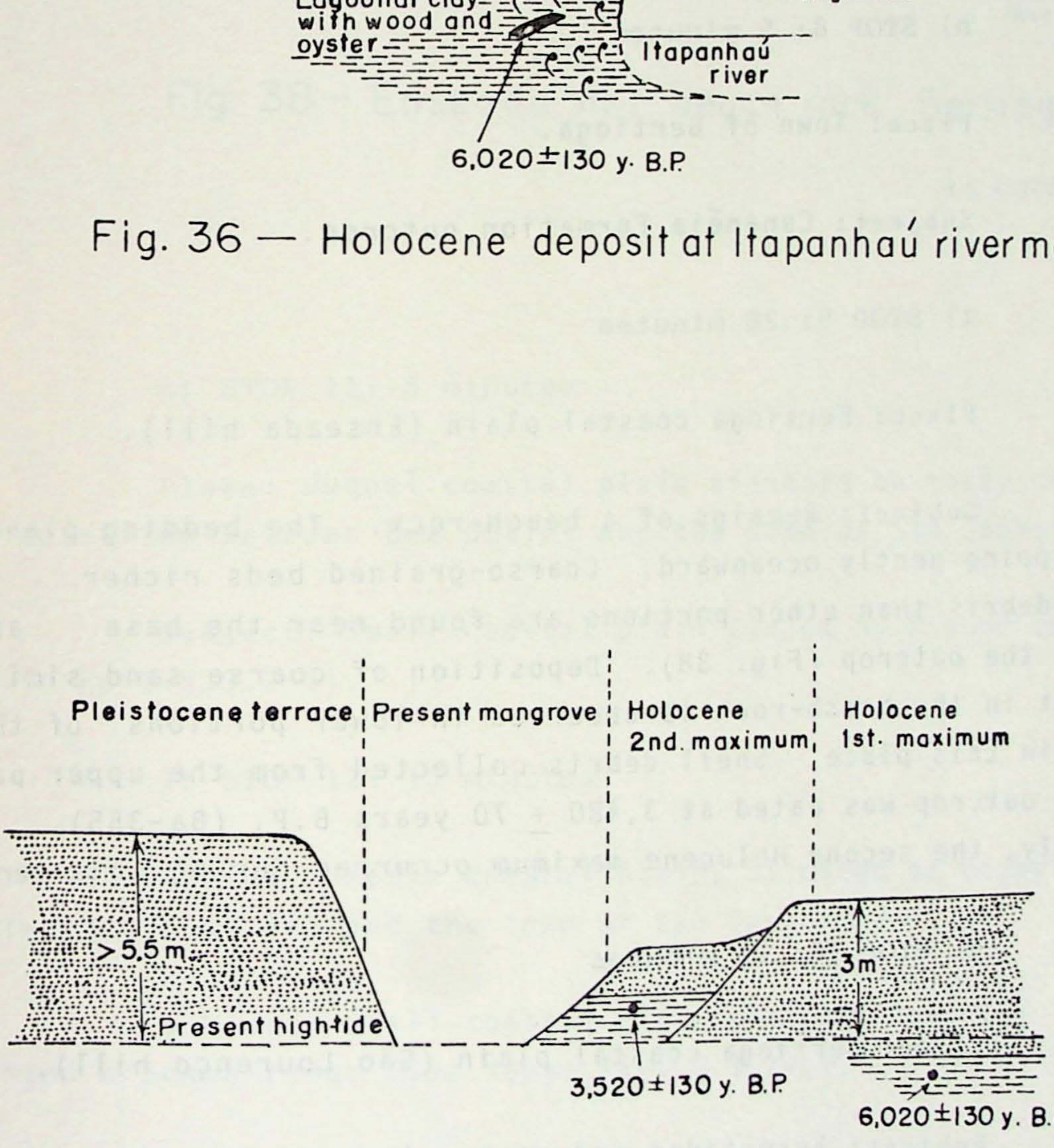

Fig. 37 — Holocene marine terraces and their relation-
to Pleistocene terrace at Bertioga coastal plain.

g) STOP 7: 10 minutes

Place: Town of Bertioga.

Subject: Lagoonal clay with fossil wood covered by Holocene marine sand abutting against previous (Stop 6)deposits (Fig. 37). Fossil wood collected from the clay has been dated as 3,480 ± 70 years old (Ba-355). This dating shows that this deposit is related to the second Holocene transgression.

h) STOP 8: 5 minutes

Place: Town of Bertioga.

Subject: Cananéia Formation outcrop.

i) STOP 9: 20 minutes

Place: Bertioga coastal plain (Enseada hill).

Subject: Remains of a beach-rock. The bedding planes are dipping gently oceanward. Coarse-grained beds richer in shell debris than other portions are found near the base and top of the outcrop (Fig. 38). Deposition of coarse sand similar to that in the beach-rock is observed in lower portions of the beach in this place. Shell debris collected from the upper part of the outcrop was dated at 3,480 ± 70 years B.P. (Ba-355). Probably, the second Holocene maximum occurred during this period.

j) STOP 10: 15 minutes

Place: Bertioga coastal plain (São Lourenço hill).

Subject: Vermetidae and oyster incrustations on protected Precambrian rocky surface. A dated sample indicated an ancient sea-level at + 1.6 m (± 0.4 m) at 2,240 ± 90 years B.P. (Ba-357).

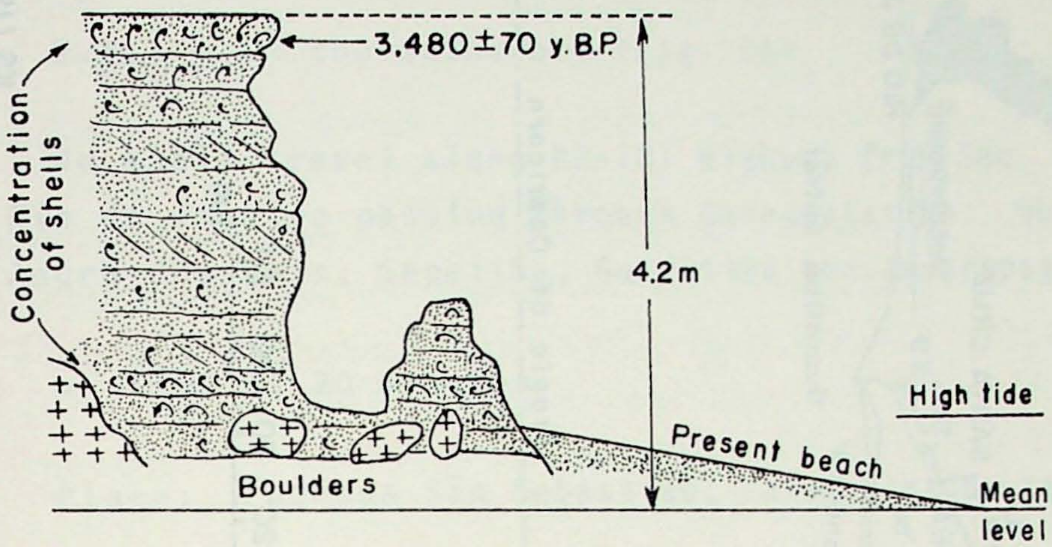

Fig. 38 – Enseada hill beach rock, Bertioga.

KS (1978)

k) STOP 11: 5 minutes

Place: Juqueí coastal plain situated on rocky crystalline coastline between Una outlet and the town of São Sebastião.

Subject: Small coastal plain closed by a sand bar (See text: Part 5.3.2-a).

l) STOP 12: 10 minutes

Place: Maresia coastal plain, situated on rocky coastline between Una outlet and the town of São Sebastião.

Subject: Small coastal plain without low-lying zone behind a beach-ridge (See text: Part 5.3.2-b).

Third night - São Sebastião

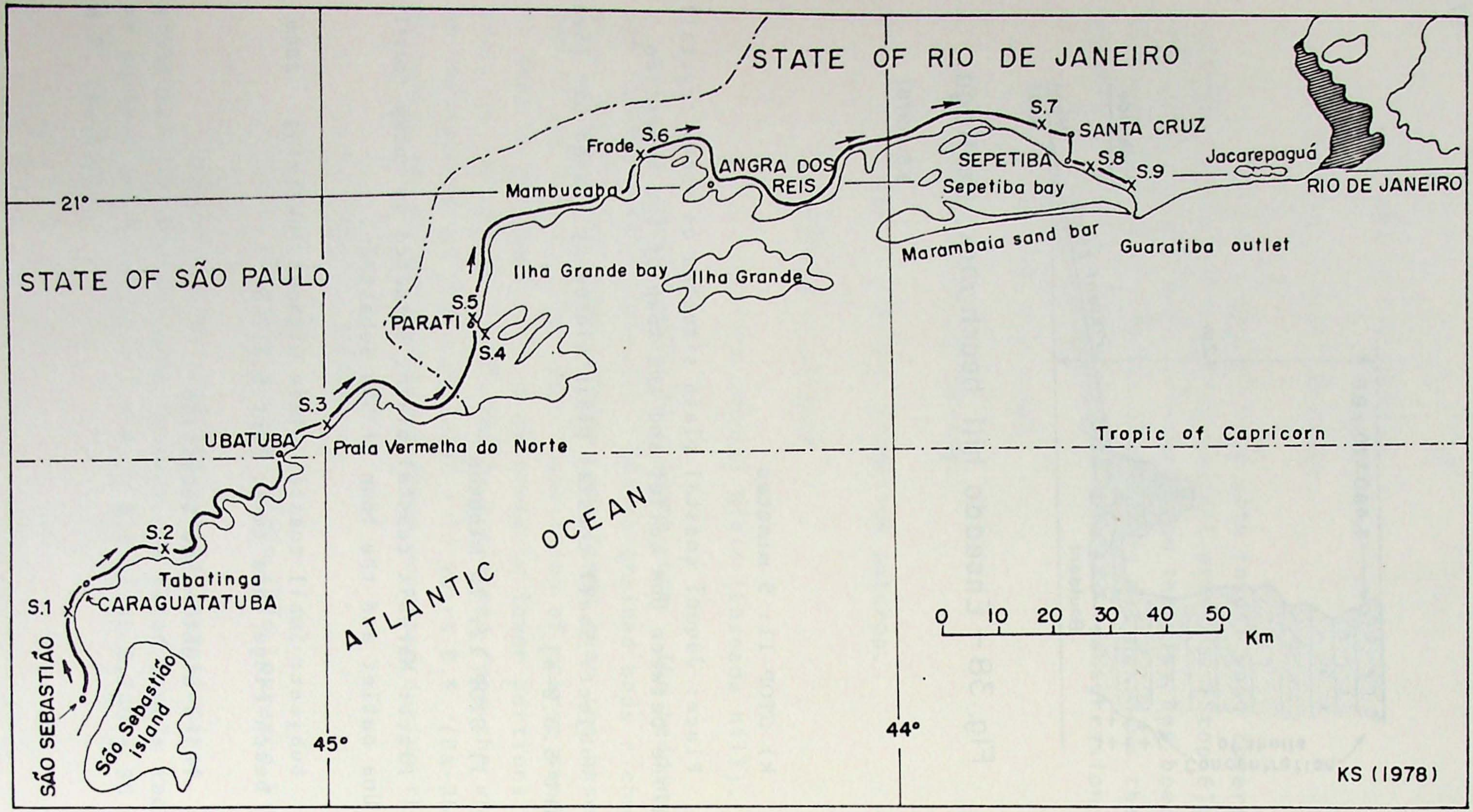

Fig. 39 — Excursion fourth day itinerary – September 17th.

2.4 - FOURTH DAY - SEPTEMBER 17th-DEPARTURE: 07:00 A.M.

2.4.1 - On the itinerary (Fig. 39)

We shall travel along BR-101 highway from São Sebastião to Rio de Janeiro passing through Caraguatatuba, Ubatuba, Parati, Angra dos Reis, Sepetiba, Guaratiba and Jacarepaguá.

a) STOP 1: 20 minutes

Place: Fazenda São Sebastião, Caraguatatuba coastal plain.

Subject: Coarse-grained Pleistocene marine sands, Holocene beach-ridges probably in two phase of generation, and Holocene lagoonal clayey-sandy deposits.

b) STOP 2: 20 minutes

Place: Tabatinga beach between Caraguatatuba and Ubatuba.

Subject: Uplifted beach with shell debris; partially covered by colluvial deposits. Shells have been dated at 2,085 ± 140 years B.P. (Ba-457); this age must indicate an ancient sea-level at + 1.5 m above present level (Fig. 40).

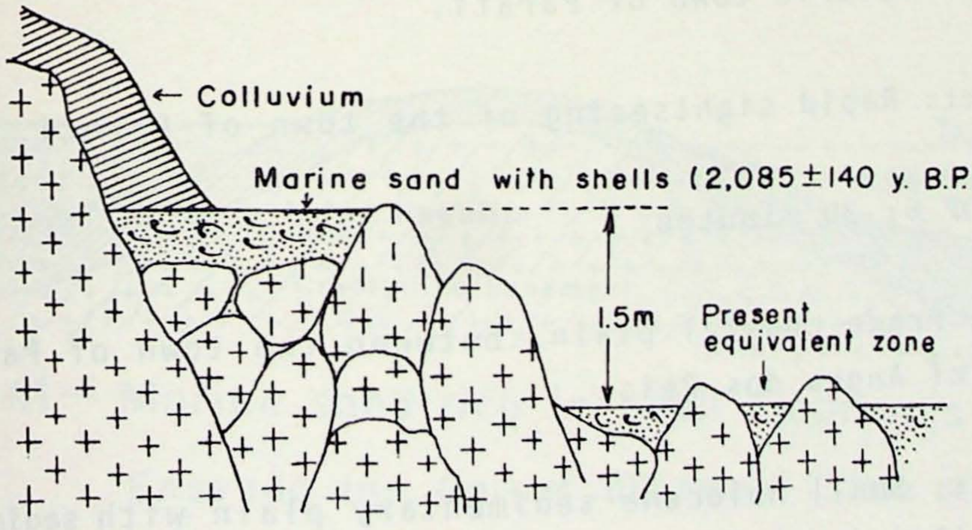

Fig. 40 — Ancient uplifted beach of Tabatinga.

KS (1978).

c) STOP 3: 15 minutes

Place: Praia Vermelha do Norte, N of Ubatuba.

Subject: Limonitized ancient beach-ridge with bedding planes dipping toward the continent as well as oceanward. This shows that the ridge was shallowly submerged and that it still separated the open sea from a more-or-less lagoonal zone. Its top is about 4 m above the upper limit of the present beach. It has not been dated; however, it is probably Pleistocene in age.

d) STOP 4: 30 minutes

Place: BR-101, beneath a viewpoint near the town of Parati.

Subject: Oyster shell incrustation on rocky surface. The top of the incrustation zone is situated about 1.7 m above the present life zone of living oysters at this place. These shells were dated at 2,300 $\pm$ 95 years B.P. (Ba-464).

e) STOP 5: 30 minutes

Place: Historic town of Parati.

Subject: Rapid sightseeing of the town of Parati.

f) STOP 6: 30 minutes

Place: Frade coastal plain, between the town of Parati and the city of Angra dos Reis.

Subject: Small Holocene sedimentary plain with sediments very rich in shell beds.

Vermetidae and oyster samples indicate an ancient sea--level at + 1.5 m at about 2,695 ± 130 years B.P. (Ba-465) and 2,510 ± 125 years B.P. (Ba-466), respectively. From this region J. CURRAY has dated oysters indicating an ancient sea-level at + 4.8 m at about 5,200 and 4,800 years B.P. (LJ-1364 and LJ-970).

g) STOP 7: 10 minutes

Place: Guanabara graben (rift valley).

Subject: Sedimentary plain formed of continental deposits superficially. Marine sedimentary deposits have been found only by drilling.

h) STOP 8: 30 minutes

Place: Enseada das Garças allotment, between the town of Sepetiba and a locality of Pedra.

Subject: Shell bed upon weathered crystalline rock (Fig. 41). Sampled shells indicate an ancient sea-level at least + 2.5 m at 3,550 ± 105 years B.P. (Ba-492).

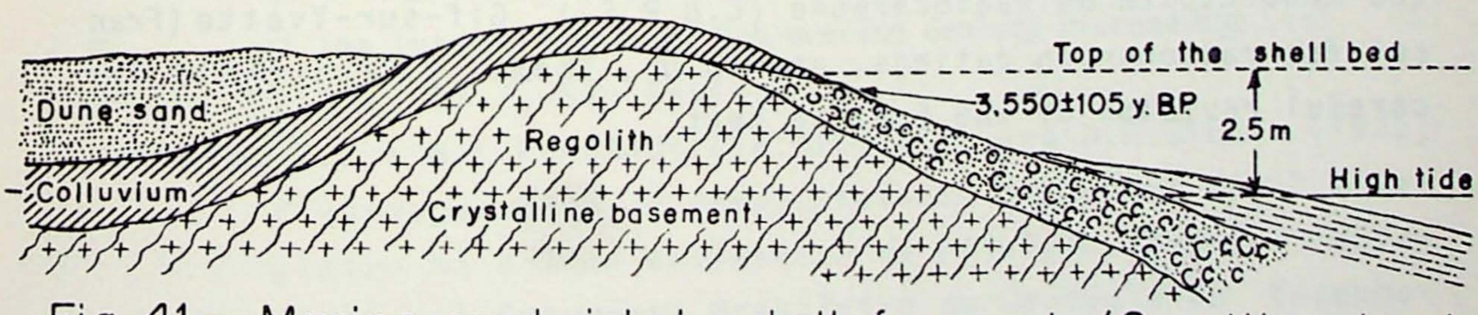

Fig. 41— Marine sand rich in shell fragments (Sepetiba bay) Enseada das Garças allotment (State of Rio de Janeiro).

KS (1978)

i) STOP 9: 10 minutes

Place: Between Pedra and Guaratiba outlet.

Subject: Sedimentary plain very rich in shell beds. Sampled shells indicate an age of 4,900 ± 120 years B.P.(Ba-493).

Fourth night - Rio de Janeiro

2.5 - FIFTH DAY - SEPTEMBER 18th (morning)

Jacarepaguã coastal plain, studied by CENPES (PETROBRÃS).

ACKNOWLEDGEMENTS

The authors wish to express their thanks to the Fundação de Amparo ã Pesquisa do Estado de São Paulo (FAPESP) for financial support for field surveys (Processo 08-Geologia 74/ /284), to the Instituto Oceanogrãfico (University of São Paulo) for the utilization of boats and other facilities at its Cananẽia base, to Geotẽcnica S/A for drilling logs, to Dr. Jean-Marie Flexor of the Laboratõrio de Fĩsica Nuclear Aplicada (Federal University of Bahia, Brazil) and Dr. G. Delibrias of the Laboratoire de Radiocarbone (C.N.R.S.), Gif-sur-Yvette (France) for radiocarbon datings, and to Dr. Thomas R. Fairchild for careful revision of the English text.

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GEOLOGICAL EXCURSION TO JACAREPAGUÁ COASTAL PLAIN AND SEPETIBA BAY (RJ)

by

Hélio Roncarati and A.N. Bandeira Jr.
(CENPES - PETROBRÁS; RIO DE JANEIRO)

September 18th, 1978

07:00 h - Preliminary remarks on the excursion route (At the hall of the hotel).

07:30 h - Departure from the hotel toward south of the city of Rio de Janeiro, passing through Copacabana, Ipanema, Leblon and São Conrado beaches. We can see some outcrops of Precambrian crystalline rocks (... and some "tangas" walking along the beaches!).

STOP 1: 10 minutes

Panoramic view of the Jacarepaguá coastal plain observed from its eastern flank. This Holocene sedimentary plain is limited on the north by Tijuca and Pedra Branca mountains (crystalline Precambrian rocks). It is possible to observe one of the residual lagoons forming the present Lagoa da Tijuca.

On the way toward the next stop we will follow the inner restinga (sand bar).

STOP 2: 10 minutes

Road 11 and BR-101 crossing. Here, to the north, we can see the remnants of an inner old lagoon represented by the present Lagoas of Jacarepaguá, Camorim and Tijuca. At the south, we can see the present Lagoa de Marapendi, which is a residual lake of the external lagoon, more important in the past. It is separated from the open-sea by a restinga. From here we will also continue on the inner restinga.

STOP 3: 10 minutes

Bridge on Sernambetiba channel. Here we can observe the restingas of the type "broken half-moon ridges" (cordão meia-lua de arrombamento) and, to the north, ancient swampy zones filled up by peat deposits in certain portions of the inner lagoon.
From here to the next stop we will continue on peat deposits.

STOP 4: 10 minutes

From this point, we can observe evidence of ancient shorelines delineating the maximum of the Flandrian transgression in the area.
From here to stop 6 we will go along the crystalline basement.

STOP 5: 10 minutes

Panoramic view of the Jacarepaguá coastal plain observed from its western flank.

STOP 6: 10 minutes

Eastern flank of Sepetiba bay, an area being studied presently by a team of geologists and sedimentologists of CENPES (PETROBRÁS). We can observe a great part of this bay, limited on the south by the restinga do Marambaia, which exhibits well-developed eolian dunes, though partially covered by vegetation, and limited on the north by the extensive muddy sedimentary plains, Holocene in age. At the back, the escarpment of the Brazilian South Atlantic Plateau forms the Serra do Mar.

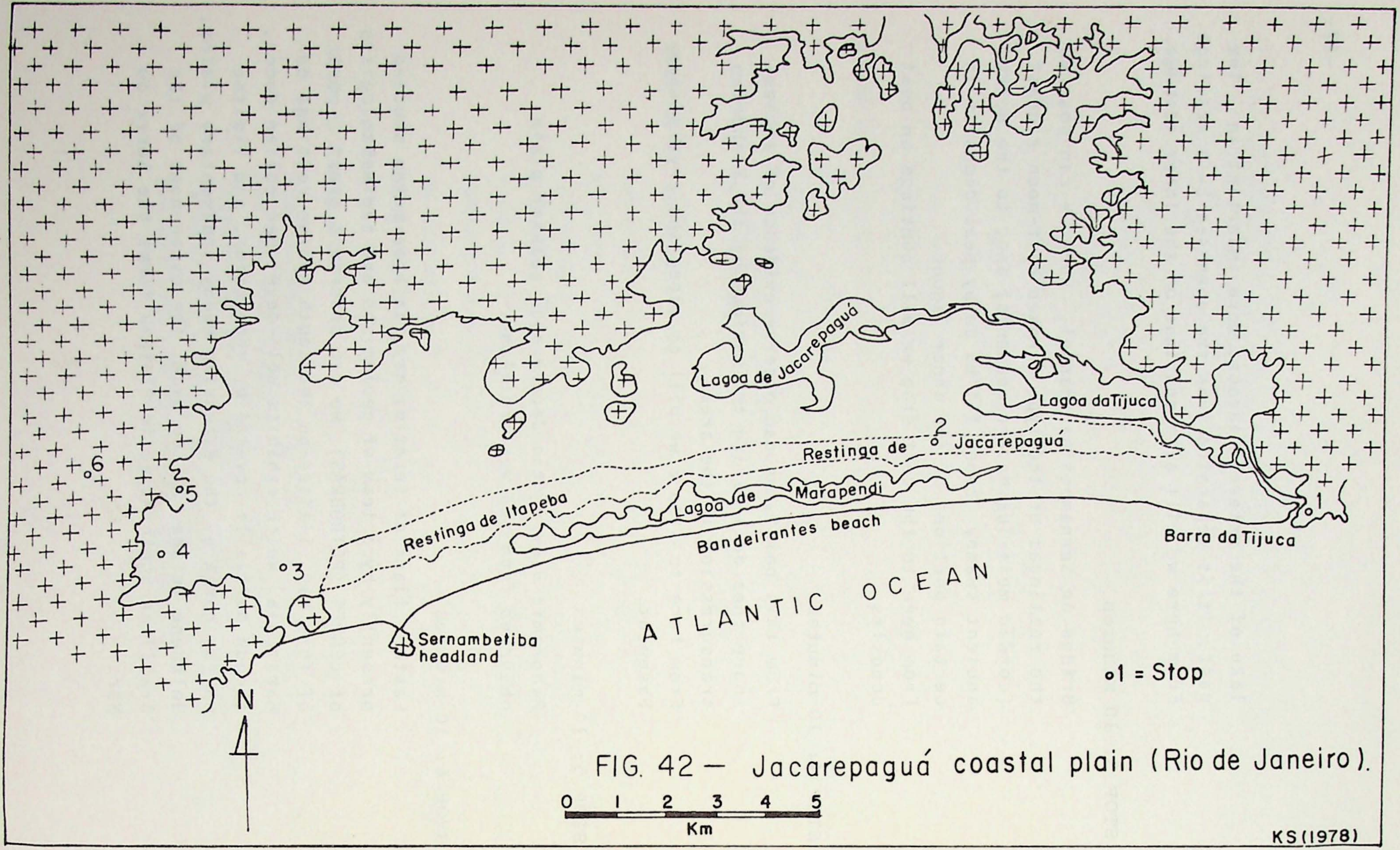

FIG. 42 — Jacarepaguá coastal plain (Rio de Janeiro).