THE STATE OF SÃO PAULO COASTAL MARINE QUATERNARY GEOLOGY
— THE ANCIENT STRANDLINES —

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1. INTRODUCTION

1.1. THE OBJECTIVES OF THE WORK

This paper is the first summary of the State of São Paulo marine Quaternary systematic research.

Several references to the marine terraces and other features along the littoral are found in the brazilian geologic and geographic literature. However, they are either strictly local or specific and so many questions still persist about the coastal plain regional geology, because there are no systematic surveys on the subject.

Bigarella dealed with problems of Cenozoic sedimentation in 1946 and with the brazilian Quaternary sea level changes in 1965. Bigarella **et al.** (1966) studied the State of São Paulo recent beach sands.

Silveira (1952) published a regional geomorphological study about the Ribeira de Iguape River valley and its coastal environments.

The State of São Paulo littoral geomorphology and its evolution were discussed by Ab'Sáber (1955 and 1965).

Freitas (1951a), for the first time, tried to demonstrate the recent tectonic influence in the brazilian geology, with special emphasis to the coastal zones.

The mineralogical composition and the geological significance of the State of São Paulo beach sands were analysed by Freitas (1951b, 1951c, 1951d, 1951e e 1960) in several papers. Recently, in 1972, this subject was again studied by Fúlfaro and Coimbra.

The Geobrás report (1965) concerned with a first integrated outlook of the Cananéia-Iguape lagoonal region which would be valuable for a general planning problems directed to the regional development.

Suguio & Petri (1973) and Petri & Suguio (1973) published a comprehensive geological research entitled "Stratigraphy of the Iguape-Cananéia Lagoonal Region Sedimentary Deposits", when the stratigraphy of these Cenozoic deposits was for the first time considered.

The Caraguatatuba area geomorphology was recently dealed with in a paper by Cruz (1974).

Nevertheless, a coastal plain geology of the State of São Paulo based on a systematic field work and absolute dating was not tried before.

The main purpose of this paper is to survey and map the several Quaternary formations and to make out a certain number of level altitudes and ages to try to outline sea level changing curves. The establishment of a changing curve of each zone of the littoral would be the ideal. Those curves would be the integration of all the eustatic, tectonic and astronomic agents that gave rise to the sea level fluctuations. The comparison of the curves so established for several littoral zones would permit to get to the eustatic com-

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ponent and verify if there is a residue superior to the measurement precision.

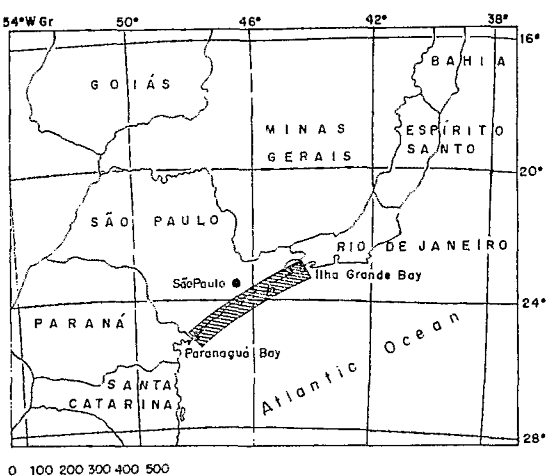
The curves of relative changes were constructed using the recommendations of Gill (1969), President of the Pacific Strandlines Subcommission of the INQUA.

The ages were plotted in X-axis, being 1 cm equal to 1,000 years and the altitudes along the Y-axis, 1 cm corresponding to 1 m. The present time (1950 for the C^{14} method) was plotted at the right side of the diagram. Each sample will be represented by one point in correspondence to its leveling altitude relative to more probable sea level in the sampling moment. Downward directed vectors will indicate above sea level samples and upward ones, below sea level samples. At last, radiometric age uncertainty interval bar will appear horizontally. The rectangle limited in this way will furnish a zone in which the sea level changing curve will cross.

1.2. GENERAL CONSIDERATIONS

The State of São Paulo littoral is directed nearly NE-SW and limited by the 23 and 25 southern parallels and by the 43 and 45 western meridians (Fig. 1).

This coast presents a mixed emersion and submersion morphological craracteristics, being the Boracéia Point (Bertioga plain northern extreme) the natural limit of different behavior zones. At the northern part the Precambrian Basement frequently reaches the sea, with exception of little recent marine



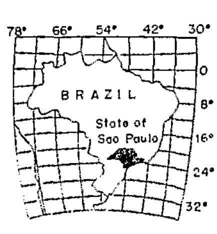


FIGURE 1 — INDEX MAP OF THE STUDIED AREA
The State of São Paulo Coastal Plain

deposition plains at the Caraguatatuba and Ubatuba coastal plains. In the southern part of the São Sebastião Island several well developed Quaternary sedimentary plains are separated by Precambrian rocks. In the State of São Paulo the Quaternary plain areas increase in a very regular way from northeast to southwest (See Map I).

In the Parati region (State of Rio de Janeiro) the marine Quaternary formations are very restricted and in the eastern part of Parati there is a true "ria". The littoral plain is very well developed in the Cananéia-Iguape. Similarly, the continental shelf width increases regularly from northeast to southwest.

The 50 m isobatic line is about 8 km offshore in front of Parati Range, in the Ubatuba region it is nearly 30 km, in the Santos region it is about 50 km and in the Cananéia-Iguape region it is almost 60 km.

These differences in the Quaternary sedimentation may be explained both by different deposition dynamics and by tectonics: the northeastern coastline with a negative trend and the southwestern one with a positive tendence.

It is also interesting to note the occurrence of numerous "sambaquis" (shell mounds) in the Santos, Itanhaem and Cananéia-Iguape coastal plains.

1.3. ACKNOWLEDGEMENTS

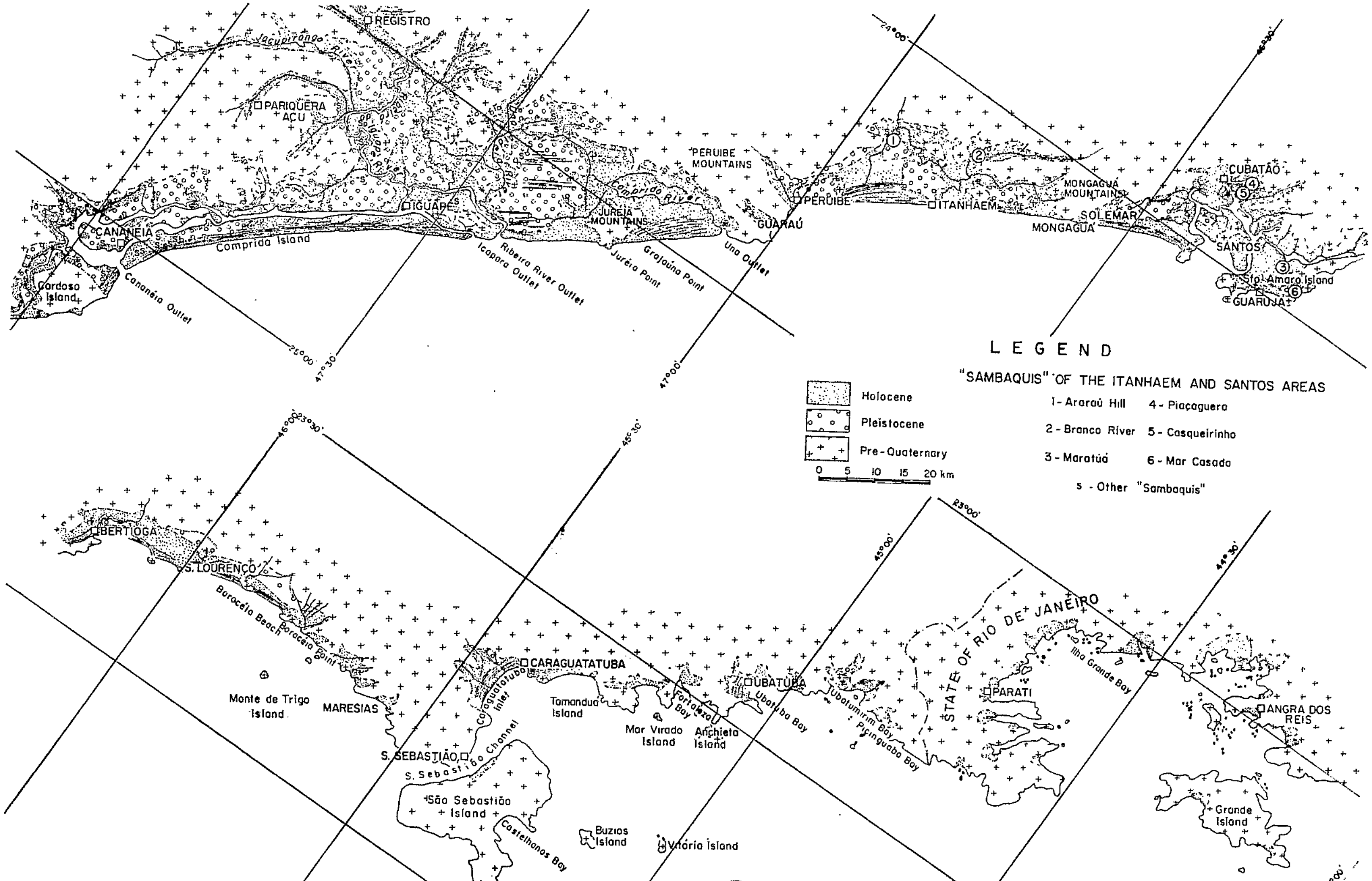
The authors wish to express their sincere acknowledgements particularly to the "Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP)", for the financial support and to the "Instituto Oceanográfico da Universidade de São Paulo (IOUSP)" and "Departamento de Águas e Energia Elétrica (DAEE)", for the travel facilities.

2. THE STATE OF SÃO PAULO QUATERNARY SEDIMENTATION ZONES

2.1. CANANÉIA-IGUAPE REGION

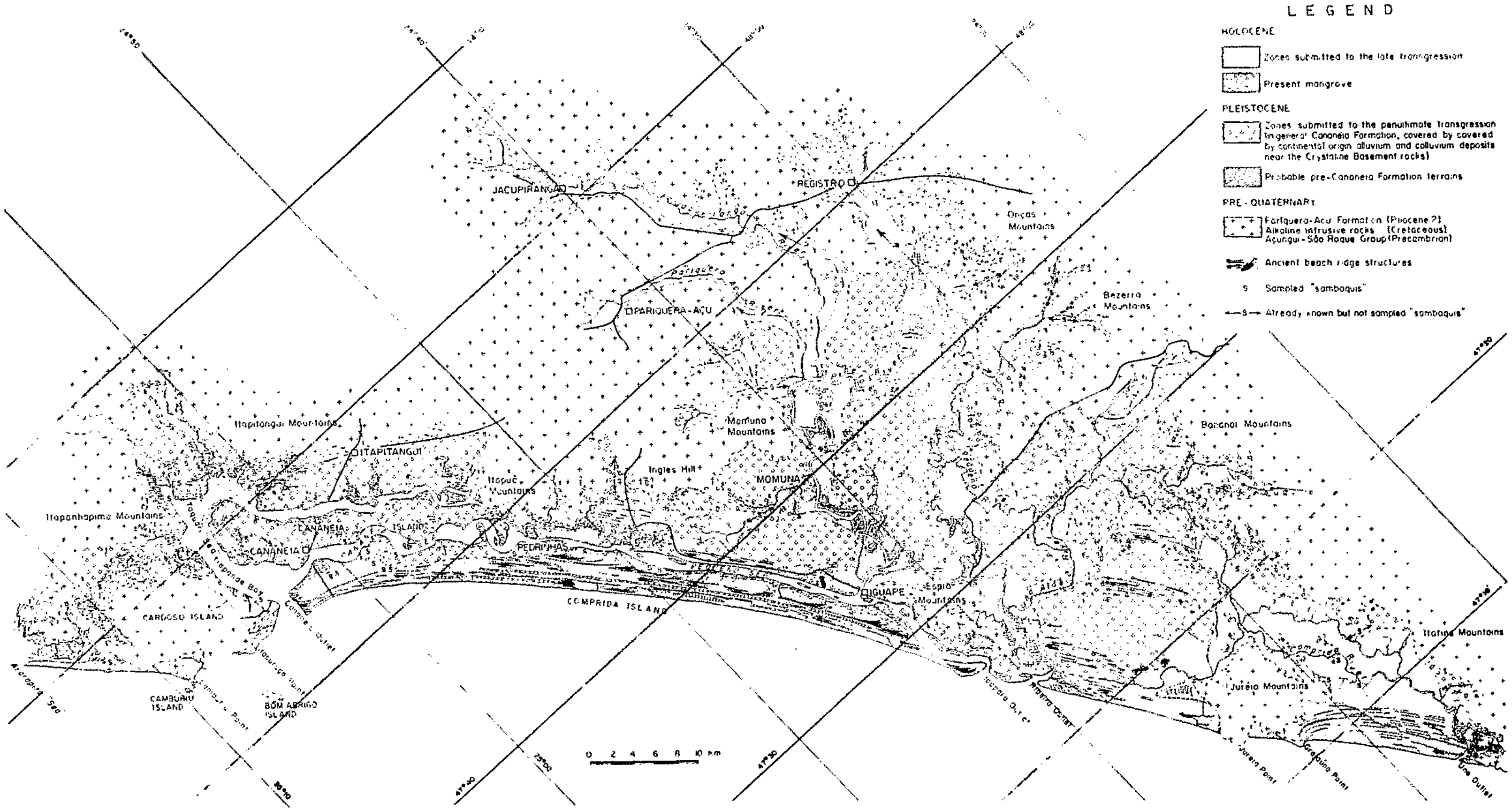
The Cananéia-Iguape plain was the only one studied rather detailly up to now; other northeastern coastal plains were surveyed in a preliminary stage (See Maps I and II).

The Cananéia-Iguape Quaternary sedimentation plain forms an extensive "crescent" more than 100 km long, limited northeastward and southwestward by Precambrian extensions reaching the sea. Its largest portion (about 40 km) is located in the Iguape region. This plain is essentially constituted by marine sandy formations, fluvial-lagoonal sandy-clayey formations and present mangrove swamps.



MAP 1 - COASTAL MARINE QUATERNARY GEOLOGY OF THE STATE OF SÃO PAULO

MAP II - DETAILED COASTAL MARINE QUATERNARY GEOLOGY OF THE CANANÉIA - IGUAPE REGION



Near the Crystalline Precambrian Complex the marine sands are partially and locally covered by the continental alluvium and colluvium. Most of the plain lies at 0 to about 10 m above the present sea level. There are several Precambrian Crystalline rocks "islands" isolated in the marine sedimentary plain.

The southern part of the region is formed by 4 great islands very near to the continent. The Comprida Island is a sandy island 70 km long and 3 to 5 km wide, separated from the continent by a sea channel called Pequeno "Sea", whose width ranges from 400 to 1,200 m. This channel is split southward into two branches by the Cananéia Island, called Cubatão "Sea" and Cananéia "Sea".

Southward of the Comprida Island is located the Cardoso Island, a great mountainous Precambrian island, separated from the Cananéia Island by the Trapandé Bay and from the continent by the Ararapira Channel. Northward lies the Iguape Island artificially born in the past century by the construction of the Valo Grande, a channel connecting the Ribeira de Iguape River to the Pequeno "Sea".

Four outlets link those sea channels with the ocean called, from the north to south: Ribeira Outlet, Icapara Outlet, Cananéia Outlet and Ararapira Outlet.

A detailed mapping allowed the separation of two groups of geological formations with different ages (See Map II).

2.1.1. Pleistocene Formations

2.1.1.1. Cananéia Formation

A Pleistocene formation, probably originated before the latest transgression, occupied great part of the region, reaching the Crystalline Basement Rocks, where it is partial and locally covered by more recent continental deposits. The "interior seas" margins are 6 to 7 m high excepting southern Comprida Island 2.5 to 3 m high and 9 to 10 m high near the Precambrian margin.

The composition of the Cananéia Formation as well as some hints on its depositional environment, were possible thanks to sea channel and river margins outcrops and bore holes.

a) **Comprida Island**

The 2.5 to 3 m high section of southern Comprida Island is formed by the Cananéia Formation (Fig. 2).

A Callianassid burrow zone referred to in the literature (De Windt, 1974 and others) indicates a beach or shallow water marine environment for the deposition of the Cananéia Formation.

b) **Cananéia cliff**
(Cananéia "Sea" margin).

From the top to bottom the following sequence is present:

0.5 m — Leached white, fine to very fine sand.

3.0 m — Very "limonitized" fine sand.

There is a thin, some millimeters thick, plant carbonized layer, after a thin mud crack layer, 1 m below the land surface. Callianassid burrow zone is present in a horizon 1 to 1.5 m above the high tide.

A partially "limonitized" fine sand with horizontal parallel stratification stressed by heavy mineral concentrations follows the sequence reaching the outcrop total thickness.

Several bore holes drilled during the construction of a hotel (Sports, Culture and Turism Secretary of the State of São Paulo) in Cananéia made possible the study of the Cananéia Formation down to a depth of 25 m (Fig. 3):

From the surface to 3 m — Fine sand.

3 to 10 m — Argillaceous sand.

10 to 16 m — Sandy clay.

16 to 25 m — Argillaceous sand.

c) **"Sand pit" in the Cananéia Island** (near ferry-boat pier to Cananéia town).

This outcrop located 2.5 km from Cananéia, at the left side of the road Cananéia to ferry-boat pier, is the same selected by Suguio & Petri (1973) as a section-type for the sands of the Cananéia Formation. From top to bottom the following sequence is observed:

0.60 m — Brownish fine to very fine sand with horizontal stratification.

0.003 to 0.004 m — "Limonite" crust.

0.03 to 0.04 m — Very light clay.

0.12 m — Brownish sand with horizontal stratification.

0.03 m — Plant root debris concentration with cross lamination unit at the top.

0.003 to 0.004 m — "Limonite" crust.

0.03 m — Very light clay.

1.00 m — Fine to very fine white sand with incipient stratification.

The "limonitized" plant root debris are found in two thin layers separated by a cross stratified sand bed and a thin clay layer. Near the pit bottom (1.5 to 2 m above the high tide level) a zone of Callianassid burrows occur (Fig. 4).

Another place in the same sand pit shows three thin clay layers and beautiful mud cracks.

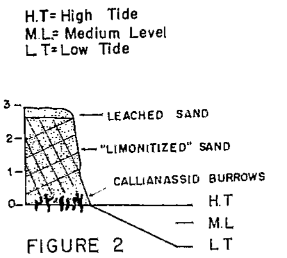
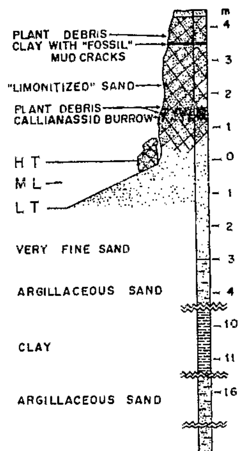


FIGURE 2



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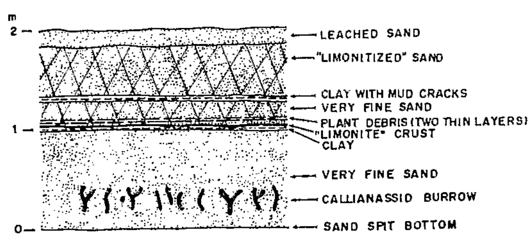


FIGURE 4

d) **Cliff near Cubatão "Sea"** (Cananéia Island).

In this locality there is a sequence formed by 5 m of more or less "limonitized" sand followed by a gray argillaceous layer interbedded by sand (Fig. 5).

e) **Cliff of the Cubatão Village** (Cubatão "Sea" margin).

The following sequence is present from top to bottom (Fig. 6):

6 m — Fine sand strongly cemented by "limonite".

0.3 m — Sandy clay of grayish color with plant debris.

The contact between sand and clay is situated 0.2 m above the high tide level.

A bore hole down to 8 m was drilled in that cliff base cutting the following sediments:

0 — 5 m Greenish-gray clay (very plastic).

5 — 8 m — Sandy clay.

f) **Bore hole of Itapitangui Village** (Continent).

We made a drilling beside the Cananéia — Pariquera Açu road down to 7.5 m cutting thick fine sand since the surface. Fine quartz pebbles were observed in the bottom.

g) **Itapitangui River cliff** (Continent).

A cliff near the Itapitangui mouth, at its right side margin, at the Cubatão "Sea" is formed, from top to bottom, by the following sequence (Fig. 7):

2 m — Fine sand.

1.4 m — Laminated sandy clay.

1.2 m — Plastic grayish clay with plant debris.

A progressive transition from clay to argillaceous sand with quartz pebbles 1 to 2 cm along their longest diameter, occurs at the high tide level.

h) **Iririaia Açu River cliff** (Continent).

From top to bottom we have (Fig. 8):

3 m — Fine, very well sorted sand.

4 m — Argillaceous sand with frequent rythmic sand-clay stratification and ripple drift cross laminations.

i) **Trench beside Cananéia — Pariquera Açu road** (Continent).

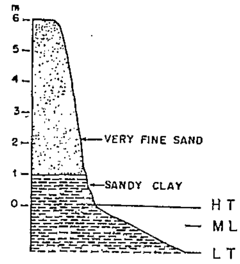
A trench opened beside this road, soon after Itapitangui village, showed absence of the argillaceous deposit indicating its pinching-out toward the Precambrian Crystalline Rocks (Fig. 9).

j) **Bore holes drilled by the "Instituto Geográfico e Geológico".**

The bore holes intended to study the Late Cenozoic sedimentation sequence in the area.

The first one was drilled in the continent, beside the Iguape-Subaúma road, about 10 km from Iguape (approximately latitude 20° 46' and longitude 47° 38'). The second one was drilled in the Comprida Island about 29 km from its southwestern tip at the ocean side (approximately latitude 24° 52' and longitude 47° 42').

According to Suguio & Petri (1973) four lithological sequences were cut through in these holes. The oldest beds of the Comprida Island hole are sandy and pebbly beds with subordinated sandy clay layers (sequence I), probably resting on the Precambrian Crystalline Basement. Above there are silty clays (sequence II) and sandy silt (sequence III). The uppermost beds are predominantly fine to very fine well sorted sands so loose that they were unsuitable for coring (sequence IV). The sediments of the last sequence cover most of the present coastal plain, sometimes weakly cemented by ferruginous matter as previously referred (Figs. 10 and 11).



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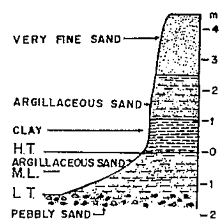

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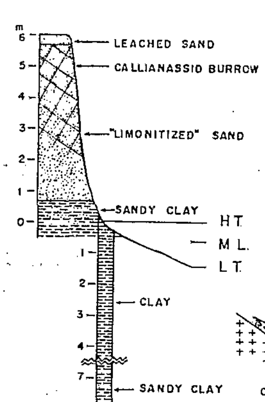

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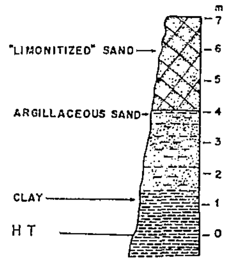

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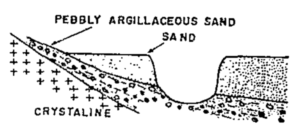

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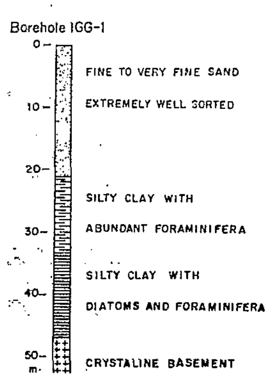


FIGURE 10

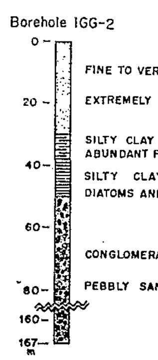


FIGURE 11

From: Suguio and Petri (1973)

2.1.1.2. Stratigraphic Interpretations

a) Sandy Formation

The appearence of the Callianassid burrows, rarely observed bivalve shell casts, and the sedimentary structures are indicative of its deposition in a beach or shallow marine environments. This conclusion is concordant with the previous interpretation given by Suguio & Petri (1973) that suggested a low energy sea, based on grain size analysis.

The increasing elevation of the Callianassid burrow zone toward the continent was interpreted as indicating that those animals migrated into the continent following the rising sea level (Fig. 12).

There are evidences of emersion periods in the upper part of the formation, constituted by clay layers containing mud cracks and plant debris acummulations separated by cross stratified sandy units. It is reasonable to assume that those structures are a consequence of sea level oscillations: emersion periods followed by repeated marine sedimentations.

Finally, a regressive phase came out and sandy beach ridges, still locally visible in the Cananéia Formation, were originated. This sandy deposit was denominated Cananéia Formation by Suguio & Petri (1973).

b) Argillaceous Formation

The Cananéia Formation rests on argillaceous beds very rich in plant debris. Syngenetic sedimentary structures as ripple drift cross laminations and sandy lenses are very common; no pure clay deposits are known indeed (Fig. 12).

Assuming that this sediment can be correlated with the sequences II and III of Petri & Suguio (1973), better described in the IGG bore holes (Figs. 10 and 11), we have the following situation:

Sequence II (Lower) — Fine sediment; silty clay with abundant diatoms and few foraminifera. The diatoms are mostly fitted to brackish water environment and the foraminifera belong to euryhaline and eurythermal species.

Sequence III (Upper) — Sandy silts resting on the sequence II. They were laid down in a marine environment as proved by the abundant and well preserved foraminifera.

The outcrops of these sediments are observed in several places: western part of the Cananéia Island (Fig. 5), Itapitangui River mouth on the continent (Fig. 7), Iririaia Açu River on the continent (Fig. 8), etc.

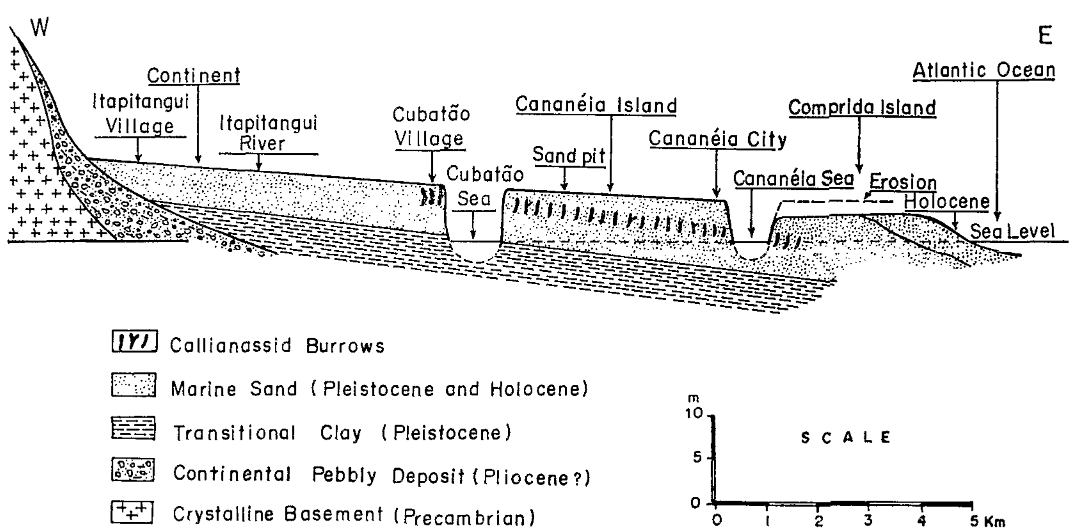
c) Pebbly Formation

The Cananéia Formation outcrop in the Itapitangui River mouth exhibits a pebbly sandy deposit situated above an argillaceous one (Fig. 7).

One of the IGG bore hole (Fig, 11) and a ground water drilling near Iguape presented likewise a pebbly lithology below the argillaceous sediments.

FIGURE 12 — INTERPRETATIVE PROFILE FROM THE OCEAN TO THE BASEMENT.

CANANÉIA REGION



As previously assumed by Fúlfaro & Suguio (1974), possibly these deposits can be correlated with the Pariquera Açu Formation, probably of Pliocene age, that near the coast would appear as valley fillings. These ancient valleys would be formed by differential erosion of the Crystalline Precambrian Basement rocks.

2.1.1.3. **Older Formation**

In the northern part of the Iguape Island, near Icapara village, there are evidences of sedimentary formations probably older than the Cananéia Formation, but a more detailed study about the subject is needed.

2.1.2. **Holocene Formations**

2.1.2.1. **Marine Formation**

This formation is located topographically below the Cananéia Formation outcrops. Lithologically it is formed by fine sand from the reworking of the Cananéia Formation. These sediments form extensive beach ridge accretionary deposits on the coastal plain. The Comprida Island is dominantly formed by this type of sand. Their extension is also considerable at the Una Outlet region (See Map II).

2.1.2.2. **Mangrove Sediments**

These mangrove sediments are found within ancient bays carved in the Cananéia Formation. Mangrove are scarce in the southern littoral of the State of São Paulo. The most expressive ones are those related to the Ribeira de Iguape River and its tributaries. They are developed also in the northern half of the Comprida Island besides Pequeno "Sea" and around the Cardoso Island.

Emerged mangrove formations, originated during times of higher sea levels were found in the Comprida Island.

2.1.2.3. **Fluvial-lagoonal Formation**

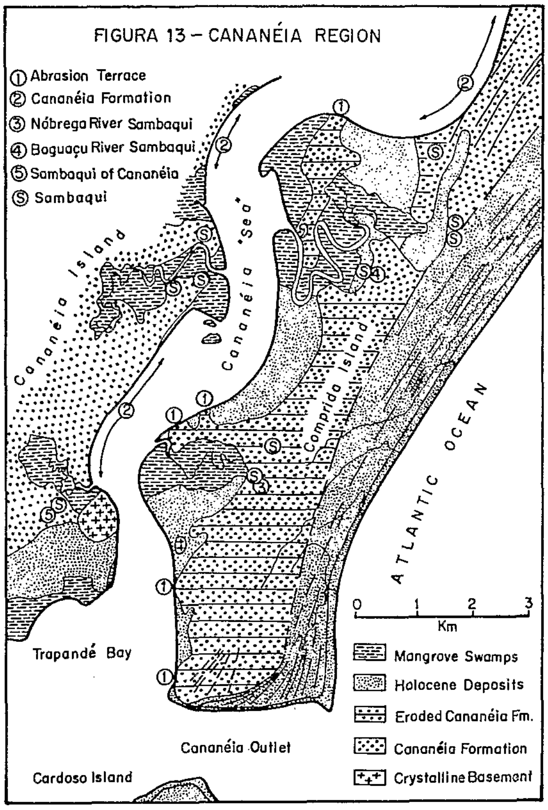
They are clayey-sandy sediments deposited by the Ribeira de Iguape River and its tributaries or by the lagoonal areas originated during higher sea levels. During those times the marine or lagoonal transgressions propitiated sedimentation on the lower parts of the Cananéia Formation. These sea level elevations would have propitiated also the erosion of the Cananéia Formation whose product formed the Holocene deposits.

3. PRELIMINARY SCHEME OF THE SEA LEVEL CHANGES IN THE CANANÉIA-IGUAPE REGION DURING THE LAST 6,000 YEARS.

3.1. SAMBAQUIS AS PROBABLE INDICATORS OF ANCIENT STRANDLINES

Shell mounds or sambaquis made by ancient Indian peoples are very frequent in the Cananéia-Iguape region (Fig. 13).

It is evident that the sambaqui shells are not an ideal material for the ancient strandlines dating, because it is not possible to know the relation between the sambaqui and the average sea level at the time of the sambaqui's buildings. However, sea levels could not be higher than the their basements.



Similarly, it is obvious that many indications can not be furnished by an isolated sambaqui dating. By the other hand, the sambaqui dating in a region in confront with other known data must bring very precious informations.

It was possible to observe in the Cananéia-Iguape region the occurrences of many sambaqui groups, according to their relative positions to the present sea level. Some are located above the Cananéia Formation. Those located in the present lagoonal margins are indicative of ancient strandlines. Moreover, the sambaquis situated in the interior must furnish much more informations. Considering their geographic situations it is difficult to explain their construction without assuming an ancient sea level higher than the present one. Thus, the age of these sambaquis must correspond to a period of higher sea level in the Holocene.

3.2. SEA LEVEL CHANGING EVIDENCES IN THE HOLOCENE

3.2.1. Wave cut terraces of the Comprida Island

As previously mentioned in this paper, the southern Comprida Island, beside Cananéia "Sea" exhibits 2.5 to 3 m high wave cut terraces of the Cananéia Formation (Fig. 12). A little to the north of the Comprida Island and in the Cananéia Island, the Cananéia Formation is 5 to 6 m high (Fig. 13).

This difference of altitude could be reasonably explained assuming a razing the Comprida Island southern extremity by the sea when its level was at least 3 m higher than present.

3.2.2. Sambaqui of the Nóbrega River (Comprida Island).

The dating of shells collected in the lower part of this sambaqui furnished 4,380 ± 340 years B.P. (SPC. 20, 1973)*. This sample was collected and submitted to dating by GUY COLLET. This sambaqui is mostly formed by "berbigões" (**Anomalocardia brasiliensis**), and situated at the back of a mangrove zone drained by the Nóbrega River (Fig. 14).

It is worthwhile noting that this sambaqui is located at the southern part of the Comprida Island, where the Cananéia Formation was razed by the sea during a higher level stage (Fig. 13). This shell mound could be built only after a lowering of the sea level.

It seems that at the sambaqui building time the present mangrove zone formed a little bay where the "berbigões" lived, whose shells supplied the sambaqui material. The sambaqui base would be situated near 2.5 m above the high tide level. It is bordered by a zone about 1 m lower than the mangrove swamp. Then, we can suppose that at this time the sea level was 1.5 to 2.5 m above the present one (Fig. 13).

3.2.3. Sambaqui near São João Mountain (Cananéia Island)

A sambaqui remainder located at the margin of a mangrove zone which spread between the Cananéia town and the São João Mountain (Fig. 13) was dated as 4,340 ± 110 years B.P. (Gif. 3435, 1975), through oyster shells. The sambaqui was laid down above the 5 m high sands of the Cananéia Formation.

The location of this sambaqui gave us too little informations about the sea level during its building time. It is possible to assume that the level was higher than the present one and that the mangrove zone was a little bay where the "berbigões" and oysters lived.

* (SPC. 20, 1973) = Laboratory symbol; number of the dating and year of the dating.

SPC = Radiocarbon Laboratory of the "Centro de Pesquisas Geocronológicas" of the University of São Paulo (Brazil).

3.2.4. Sambaqui of the Boguaçu River (Comprida Island)

This sambaqui was dated as 4,120 ± 110 years B.P. (Gif. 3436, 1975), through oyster shells near the base of it; as the sambaqui is untouched however, and sampling was not made in its basal part, this age would not be of the oldest portion of the sambaqui (Fig. 15).

This sambaqui is located in the interior of the Comprida Island near a mangrove zone now drained by the Boguaçu River (Fig. 13).

The altitude of the sambaqui base is very difficult to be measured because it is within a closed forest.

The sambaqui was built at the foot of a terrace 3 m high probably built on the Cananéia Formation. According to other data surveyed in the area it is possible that the sambaqui base is situated between 1.5 to 2 m above the present high tide level (2.1 to 2.6 m above the average tide level) (Fig. 15).

The position of the sambaqui seems to be indicative of a sea level higher than now during its construction time and with a tendence to regression.

3.2.5. Sambaqui of the Ararapira Channel

Two datings were realized on materials from this sambaqui. The first one made on the shells of the sambaqui base indicated an age of 3,790 ± 110 years B.P. (Gif. 3439, 1975). The second dating 4,400 ± 110 years B.P. (Gif. 3437, 1975) was made on wood carbonized debris collected from the argillaceus formation supporting the sambaqui (Fig. 16).

The basal formation is an argillaceous and sandy sediment containing several wood fragments and "ameijoa" **(Lucina jamaicensis)** shells. The upper part of this formation is now at the high tide level. In a preliminary examination this material looks like an ancient mangrove sediment, however as the wood fragments, mangrove plant stems and roots are not "in place", it is more logical to think of this sediment as deposited in a lagoonal bottom forming a mud very rich in wood fragments. The "ameijoa" could have lived on the lagoonal bottom on sandy and muddy shoals. The last hypothesis permit to assume a sea level higher than now at that time. The sambaqui, with 3,700 years B.P., constructed on that formation is indicative of an emersion time. Then, the time interval between 4,400 to 3,790 years B.P. characterized a regression phase.

The sambaqui base situated at the present high tide level seems to show that the sea level was slightly lower than now during the sambaqui construction.

FIGURE 14 – NÓBREGA RIVER SAMBAQUI

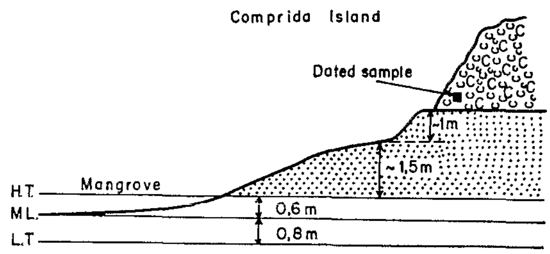


FIGURE 15 – BOGUAÇU RIVER SAMBAQUI

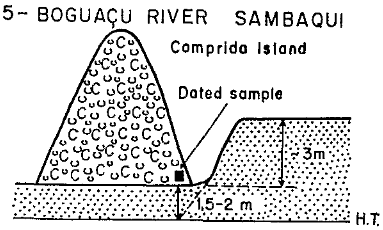
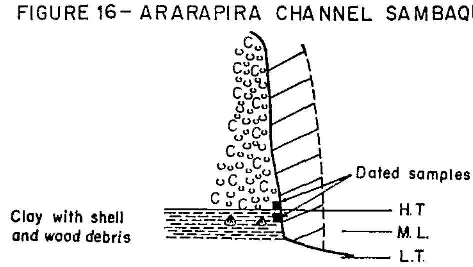


FIGURE 16 – ARARAPIRA CHANNEL SAMBAQUI



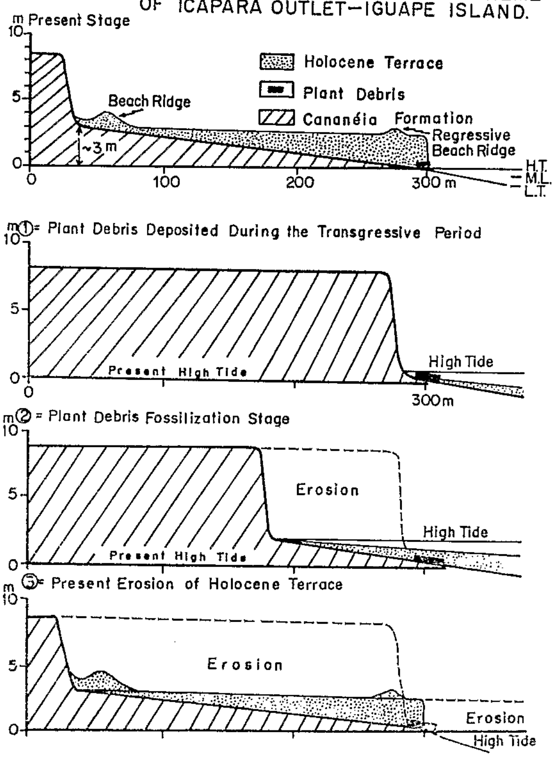
3.2.6. Fossil plant debris dated from Iguape Island, near Icapara Outlet.

Plant debris laid down as a thin 1-2 cm thick layer, 30 cm above present high tide level were found in the basal part of a wave built terrace leaned against Cananéia Formation. Similar plant debris concentrations are being formed on the present beaches of the area. The dated plant debris, indicating 3,370 ± 100 years B.P. (Gif. 3430, 1975), is covered by marine sands with beach sedimentary structures. This situation would represent a period of marine transgression. It can be assumed that the plant debris deposition took place in the foreshore, near the berm crest, when sea level was slightly higher than now and the Cananéia Formation was being eroded. The Cananéia Formation erosion products could quickly cover the plant debris, preserving them (Fig. 17).

In conclusion, while the sea level was rising the erosion and the consequent backward movement of the Cananéia Formation was active then building the terrace. Really, we have two kinds of terraces: a wave cut terrace carved in the Cananéia Formation and a wave built terrace covering the first one.

The transgression boundary is situated in the Cananéia Formation cliff foot, here representing the high tide level. At little distance from the cliff foot there is a beach ridge that probably traces the sea level stationary period. A small beach ridge above the wave built terrace characterizes the regression phase that followed the transgression. Presently the wave built terrace is being eroded to furnish the sedimentary matter to the northward growing up of the Comprida Island. The Icapara Outlet is being consequently drifted, giving the chance to the appearence of the dated plant debris layer.

FIGURE 17 — HOLOCENE TERRACE EVOLUTIVE SCHEME OF ICAPARA OUTLET–IGUAPE ISLAND.



3.2.7. The curve of the sea level changing.

In the presence of that preliminary dating results we can delineate the sea level changing curve from 6,000 years B.P. to the present. The changing curve values are relative, being valid only for the Cananéia-Iguape region.

The sea level might have been 3 m higher than now between 5,500 and 5,000 years B.P. It was followed by a regressive period between 3,900 and 3,300 years B.P., when the sea level was a little lower than now. Between 3,000 and 2,500 years B.P. occurred a second transgression, when the sea level was about 3 m higher than now (Fig. 18).

Several other datings, in process, on sambaquis and natural shell banks, ancient mangrove wood fragments, etc. will permit to check the curve.

The comparison of this curve to that obtained by Fairbridge (1961) and reproduced by Bigarella (1965) allowed to verify the abcence of correspondence in the high and low sea levels.

3.3. COMPARISON OF OUR DATA WITH SOME PARANAGUÁ BAY (STATE OF PARANÁ) SAMBAQUIS DATINGS

3.3.1. Sambaqui of Rosas Island

This sambaqui is very interesting because it is constituted by an alternating above sea level artificial shell deposits and subaqueous argillaceous matter (Fig. 19). This alternance is indicative of an oscillating sea level (A. Emperaire, 1975: Oral communication).

The first shelly bed is situated above the high tide level .The sea level at the time of the sambaqui building would be slightly below the present one. This layer indicated 3,150 ± 110 years B.P. (Gif. 1047). It is covered by a mangrove or lagoonal bottom sediment indicating a transgressive tendency. Above this clay layer there is a second shelly bed containing "human activity" products and the contact between them was dated as 2,480 ± 110 years B.P. (Gif. 1046). Then, a regressive time came on. A second argillaceous layer covers the shelly beds indicating a new transgressive period, and finally a last man deposited shelly bed suggests a renewed regressive tendency. Unfortunately the last shelly bed was not yet dated.

3.3.2. Sambaqui of Gomes (Rauth, 1968)

Through shells collected in the base of this sambaqui was reached an age of 4,887 ± 64 years B.P. (P. 916). This sambaqui is situated in a ancient mangrove zone margin above a sandy terrain that would be correlated with the Cananéia Formation. This situation suggests a sea level higher than now when the sambaqui was built. This level could correspond to the first maximum found in the Cananéia-Iguape region.

3.3.3. Sambaqui of Saquarema (Rauth, 1962)

The age of this sambaqui is 4,371 ± 69 years B.P. (P. 588). It is situated above an ancient mangrove spreading out in the foot of sandy terraces that can be correlated with the Cananéia Formation. The man occupation of the mangrove zone followed a regression time. The sambaqui must have been built when the sea level was lower than the settlement time of the sambaqui of Gomes. It is assumed, therefore, a regression time between 4,900 and 4,300 years B.P. This is in accordance with the changing trends in Cananéia.

3.3.4. **Sambaqui of Macedo** (Hurt & Blasi, 1960).

The dating of this sambaqui furnished 3,496 ± 56 years B.P. (P. 500). It is located above a sandy formation 1.6 m higher than the present sea level. The authors suggest its construction before the transgression period that is in accordance with the changing scheme for Cananéia.

4. OTHER QUATERNARY PLAINS OF THE STATE OF SÃO PAULO

4.1. ITANHAEM REGION

The Itanhaem Quaternary plain is elongated through 50 km and is limited by the Peruíbe Range at southwest and by the Mongaguá Range at the northeast. It is about 15 km in its widest portion (Map I).

The knowledge of this Quaternary plain is in a preliminary stage up to now, but it is possible to verify that the Cananéia Formation is well developed. This formation is found in the Peruíbe zone where it leans against two Crystalline Precambrian hills at the north. It is found also at the right margin of the Itanhaem and Preto Rivers supported by the Itanhaem region mountains.

Widespread Holocene marine sands cover great part of the Cananéia Formation. The Precambrian Crystalline piedmont was under the influence of this Holocene transgression where the sambaquis formed by oysters, **Azara prisca** and "ameijoas" **(Lucina jamaicensis)** were built, most of them found at the Araraú Mountain.

Remnants of the Cananéia Formation outcrop north of the main area of its development, supported by two Crystalline hills, are also found. The influence of this transgression was observed along the Aguapeú and Branco Rivers where several sambaquis were observed. We sampled one of that sambaquis situated at the Rio Branco River margin near the Crystalline.

In Itanhaem sea margin Crystalline outcrops there are wave cut terraces whose formation time is unknown. At least 2 m above present sea level "urchin burrows" are found in that terrace rocks.

4.2. SANTOS REGION

It is limited by the Mongaguá Range at the southwest and by the Santo Amaro Island Crystalline zone at the northeast. From northeast to southwest its elongation is of about 50 km and the maximum width is about 15 km.

The Cananéia Formation or its equivalent sandy terrains are quite developed in the southwestern part (Samaritá region), reaching São Vicente, Guarujá near Tombo Beach and probably between the Enseada and Pernambuco Beaches.

The Praia Grande region is formed by Holocene sediments. A wide extension of the region is constituted by mangrove formations.

The following sambaquis were dated in the Santos Region.

4.2.1. **Sambaqui of Maratuá** (Emperaire & Laming, 1956)

This sambaqui dated as 7,803 ± 1,300 years B.P. (Gif. 24) has its base below the present sea level. There are doubts about this datation and furthermore some people think the region sank after the building of the sambaqui.

4.2.2. **Sambaqui of Piaçaguera** (According to Caio Del Rio Garcia, 1975 — Oral Communication).

It was located on a hill flank very near the Crystalline beside the COSIPA (The State of São Paulo Ironworks). It is difficult to ascertain the altitude of its base because of the evidences of slumpings. It would be about 10 m high. This sambaqui was dated as 4,890 ± 100 years B.P. (I. 4480).

The topographic position agrees with a sea level higher than the present.

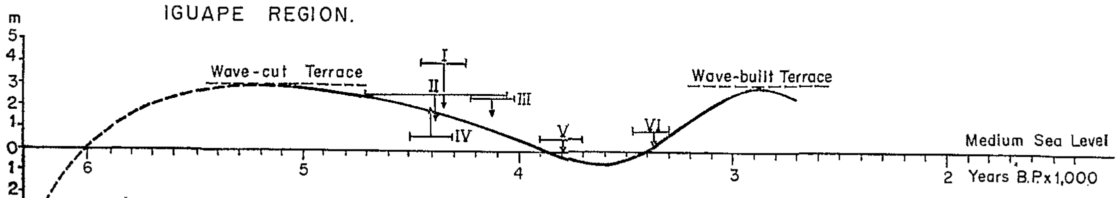
4.2.3. **Sambaqui of the Casqueirinho Island**

This sambaqui is located on the flank of a hill lower than the Piaçaguera Mountain. The sampling was made by J.A. de Moraes B. Passos and the dating furnished is 4,400 ± 180 years B.P. (SPC. 15, 1973).

4.2.4 **Sambaqui of the Mar Casado**

The dating of this sambaqui furnished an age of 4,400 ± 130 years B.P. (Gif. 1194). It is located in the Santo Amaro Island, near Pernambuco Beach with shells of bay, lagoon and open sea mollusks. Presently the sambaqui is completely destroyed by allotment activities. It could have been about 2.5

FIGURE 18 — SEA LEVEL CHANGING SCHEME FOR THE LAST 6,000 YEARS IN THE CANANÉIA IGUAPE REGION.



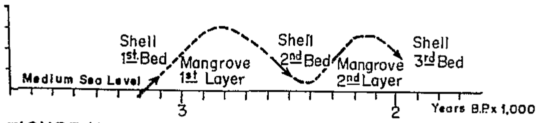


FIGURE 19 — SEA LEVEL CHANGING INDICATED BY THE ROSAS ISLAND SAMBAQUI (PARANAGUÁ BAY).

to 3 m above the present high tide level. Between this elevated zone and the Serra do Mar (Mar Range) there are ancient beach ridges lowlands where natural marine shell accumulations were found.

The positions and datings of these sambaquis agree with the sea level fluctuations proposed for the Cananéia Iguape region. Nevertheless, the changing amplitudes may have been different from the Cananéia — Iguape because the Santos region did not have the same tectonic evolution.

4.3. BERTIOGA REGION

It spreads from the Bertioga town to the Boracéia Point, over about 45 km with a maximum width of about 7 to 8 km (Map I). There are also very recent terrains formed by Holocene regressive beach ridges. A certain number of Crystalline hills, which were true islands during Holocene higher sea level episodes, were again joined to the continent through "tombolos".

Cananéia Formation terrains made up of very "limonitized" fine very well sorted sands are widespread in the Bertioga region. The transition between Pleistocene and Holocene formations contrary to the Cananéia — Iguape region takes place smoothly without any break in the relief.

4.4. NORTHERN LITTORAL

The São Paulo northern coastline is characterized by a general submergence morphology. The occurrences of the Quaternary formations are limited to small plains between Crystalline Basement rock heads. The same scheme is found in all these plains. During higher sea level episodes sand bars closed up incipient drainage systems forming lagoons later buried by transition environmental deposits and covered by colluvium and alluvium from the Crystalline Precambrian zones.

4.4.1. Caraguatatuba Region.

The largest Quaternary plains of the northern coast is here developed. It is 12 km long with maximum width of about 7 km. The geomorphological characteristics were recently studied in detail by Cruz (1974). A series of Holocene beach ridges are found. It seems that during the maximum of Holocene transgression various lagoons separated the beach ridges.

Older marine wave built terraces developed near the Crystalline, at the northern and southern parts of the plain. These terrains were dissicated by erosion resulting cliff reliefs 1.5 to 2m above the Holocene beach ridges present level.

The altitudes mentioned by Cruz (probably based on photo-interpretations) are exaggeratedly high. It is also necessary to emphasize that the beach ridges grain size in this region is coarser and consequently their altitudes are higher than in the south.

4.4.2. Ubatuba Region

The Ubatuba Quaternary sedimentation plain is constituted by Holocene marine deposits, covered by continental origin colluvium and alluvium near the Crystalline Basement. However, in the Vermelha do Norte Beach (northeast of Ubatuba) there are sandy formation testimonies indicating an age probably older than the Holocene. They would be old sand bars that shutted a little bay formed in the Quaternary plain, and must have been built during a transgression time, when the sea level was higher than now. The top of this formation is about 6 m above the present beach. The stratifications dipping in opposite directions and visible in both sides of the beach ridges indicate that it was then submerged by the waves.

In the Ilha Grande Bay (State of Rio de Janeiro) there are also little Quaternary built-in plains within the Crystalline. During the formation of these plains the sea level was thought to be slightly higher than now since marine shells from argillaceous beds lay above sea level. A precision levelling survey is necessary to know the altitude of that formation relative to the present sea level. However, it seems fair to assume a time of higher sea level during certain times of the Holocene eventhough its amplitude was not yet measured. The occurrence of Pleistocene marine formations in this zone is unknown.

5. CONCLUSIONS

The evidences at hand allowed to assume at least two phases of sea level higher than now (probably 3 m higher), during the Holocene in the Cananéia-Iguape region. These two phases occured about 5,000 and 3,000 years B.P., separated by a phase of sea level probably slightly lower than now.

An older transgressive phase, probably Pleistocene in age, was the responsible for the Cananéia Formation deposition, whose maximum altitude ranges from 9 to 10 m above the present sea level. The Holocene seas encroached upon low terrains through erosion that erased the upper part of the Cananéia Formation.

In Itanhaem, Santos and Bertioga regions there are Holocene terrains above the present sea level, and several Pleistocene terrain occurrences then can be correlated to the Cananéia Formation, probably related to the penultimate great transgression.

Holocene levels testimonies were also found in the northern littoral but it was not possible to demonstrate whether they are contemporaneous or not with the southern ones. In the Parati — Angra dos Reis region (State of Rio de Janeiro), which seems to be the most submerged zone, there are also Holocene terrains higher than the present level.

The tectonic movements have probably played a role in the differentiation of two kinds of coastline in the State of São Paulo during the Quaternary: submerged coast at the north and an emersion coast at the south. It is possible that the vertical movements had been very weak during the Holocene and stronger during the Pleistocene, causing the morphological differentiation of the littoral. The last transgression (Holocene) affected the northern part with negative tendency. The sea level changing curves as a function of the time for each littoral sector must permit to estimate the tectonic influence in the process. Possibly the variations must have the same directions, but with different amplitudes.

RESUMO

A zona costeira do Estado de São Paulo mostra dois diferentes aspectos, limitada pela parte norte da região de Bertioga. A metade sudoeste é formada por depósitos marinhos quaternários bem desenvolvidos com características de emersão e a metade nordeste com fortes características de submersão. Esta costa, não perfeitamente estável, foi provavelmente ativa tectonicamente durante o Quaternário, mas com influência menor na sedimentação quaternária do Holoceno.

Na região de Iguape-Cananéia (sudoeste) a planície costeira é principalmente constituída por depósitos de areia marinha transgressiva situados 5 a 10 m acima do nível atual do mar, denominada Formação Cananéia. Em muitos lugares esta formação foi escavada pela última transgressão marinha, provavelmente 3 m acima do presente nível do mar, originando um terraço de abrasão, localmente superimposto por um terraço de construção marinha de mesma altitude. Estes dois eventos ocorreram durante 5.000 e 3.000 anos A.P., separados por um período quando um nível do mar ligeiramente inferior ao atual deve ter existido. Abaixo da Formação Cananéia um depósito de argila arenosa de água salobra é encontrado. Depósitos fluviais conglomeráticos, que podem ser correlacionáveis à Formação Pariquera Açu (provavelmente de idade pliocênica), estão abaixo dos depósitos transicionais de água salobra acima mencionados.

Outras planícies quaternárias marinhas costeiras do Estado de São Paulo foram levantadas somente em um estágio preliminar de reconhecimento.

Esses testemunhos de eventos sedimentares foram mapeados com certo detalhe na região Cananéia-Iguape, onde foi possível construir até uma curva de variação do nível marinho nos últimos 6.000 anos. Em outras regiões, onde os trabalhos foram ainda insuficientes, somente um mapeamento preliminar foi executado.

ABSTRACT

The State of São Paulo coastal plains are yielded to a subdivision in two different sections limited by the Bertioga region. The southwestern half is characterized by well developed Quaternary marine formations with emergence features, and the northwestern half that has less developed sedimentary formations and strong submergence characteristics. This one, not absolutely stable, was probably tectonically active during the Quaternary, but with minor influence in Recent Quaternary sedimentation.

In the Cananéia-Iguape region (south-

west) the coastal plain is mainly constituted by a transgressive marine sandy deposits 5 to 10 m above the present sea level, denominated Cananéia Formation. In many places this formation was carved by the latest marine transgression, probably 3 m above the present sea level, originating a wave cut terrace, locally superimposed by a wave built terrace at the same altitude. These two events occurred during 5,000 and 3,000 years B.P., separated by a time when the sea level was slightly below the present one. Under the Cananéia Formation a brackish water sandy clay deposit is found. Conglomeratic fluviatile deposits, that may be correlated to the Pariquera Açu Formation (probably Pliocene in age), are below the above mentioned transitional brackish water deposits.

Other coastal marine Quaternary plains of the State of São Paulo were surveyed only in a preliminary recognizing stage.

These sedimentary events testimonies were mapped in detail in the Cananéia-Iguape region, where a sea level changing curve for the latest 6,000 years was performed. In other regions, where surveys were still insufficient, only a preliminary mapping was made.

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