BRAZILIAN COASTLINE QUATERNARY FORMATIONS - THE STATES OF SÃO PAULO AND BAHIA LITTORAL ZONE EVOLUTIVE SCHEMES

KENITIRO SUGUIO

Instituto de Geociências - Universidade de São Paulo
Caixa Postal nº 20.899 - São Paulo - Brasil

LOUIS MARTIN

O.R.S.T.O.M. (Office de la Récherche Sciéntifique et Téchnique Outre-Mer) - France

ABSTRACT

The State of São Paulo coastline and part of the State of Bahia, the Salvador area, may be compared as Brazilian littoral evolutive scheme models during the Quaternary.

The Salvador coastal area, being a natural lengthening of the Recôncavo Sedimentary Basin, shows directly the tectonic behaviour of this «graben». Nevertheless, the presence of strong tectonic control evidences during the Quaternary, related to the continental inflection phenomenon, was verified in the State of São Paulo coastline.

DIFFERENT ZONES OF BRAZILIAN MARINE QUATERNARY GEOLOGY

Stretched out for 9,000 Km the Brazilian littoral shows several different characteristics. The differences in the continental structures are reflected in the Quaternary coastal deposit distribution (Fig. 1). In many places the Precambrian basement rocks touch the sea. Frequently, high relief is found near the coastline as a consequence of the tectonic phenomenon still active during the course of the Quaternary.

Some coastal plains, predominantly formed by Quaternary sediments, such as that of the State of São Paulo's littoral, are located in zones where the present day sedimentation rate is insignificant. These plains were formed through several transgressive cycles by successive reworking of the previous formations.

The Recent Quaternary marine deposits of other areas were influenced particularly by the sediments transported by the rivers, like the Paraíba do Sul River, the Doce River, the São Francisco River and the Amazon River.

In other areas, such as in the State of Bahia, few Quaternary deposits are found, but clear evidences of ancient strandlines are confirmed.

UTILIZATION OF THE ANCIENT STRANDLINES AS INDEX OF EVENTUAL TECTONIC ACTIVITY

Some transgressions and regressions occurred during the Quaternary. These sea level changes were a consequence of eustatic phenomena related to the glaciation events, tectonic activities and coastal dynamics. The eustatic changes had worldwide influence and the coastal dynamics and tectonic activities had only local influence. The eustatic changes have the same direction throughout the Earth's surface during a certain period. However, the tectonic changes and coas-

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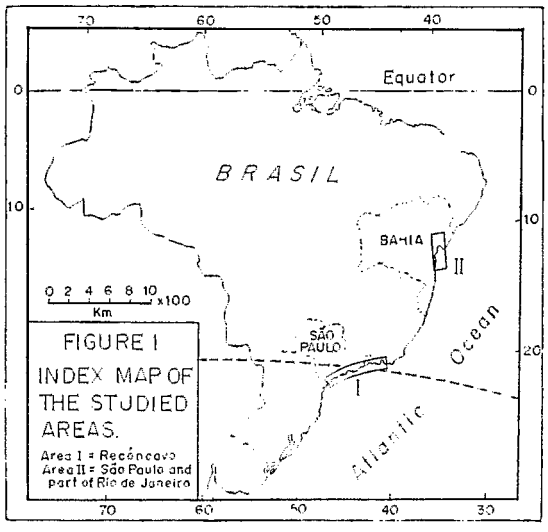
tal dynamics may increase or diminish the effects of the glaciation events.

It is on the last transgressive-regressive cycle that we have the most data. A certain number of sea level changing curves was outlined in several parts of the world. It may be concluded that those curves vary in details because the local phenomena are not the same.

Let us consider an example of a curve established at the Ivory Coast, Africa (Fig. 2), according to Martin (1973). It is verified that the sea level changed from — 60 to little more than — 110 m in relation to the present sea level, between 23,000 to 18,000 years B. P. As a consequence, a change of about 50 m in 5,000 years was verified. Similarly, between 17,000 and 7,000 years B. P. the sea level changed from — 110 to about — 10 m. The sea level changed, in this case, 100 m in 10,000 years. Nevertheless, during the last 6,000 years the sea level did not change more than some meters, and in some areas the sea levels were not higher than the present one.

The rapid sea level changes are related mostly to the eustatic phenomena. When the eustatic changes go toward zero, other changing factors become more emphasized, which explains why the upper parts of the curves are not the same in several parts of the Earth, where the local phenomena may be different and perhaps opposite in direction. During the rapid changes, it is very difficult to estimate the local phenomena values, because these values must be within the uncertainties involved in the altitude and absolute age measurements. On the other hand, during the eustatic quiet periods (maximum and minimum regressive-transgressive periods) other phenomena become relatively more important. As a consequence, it will be during these periods of eustatic quiet that we can try to estimate the tectonic influence. For example, we can try to verify if there are differences of levels of the ancient strandline during the last 6,000 years.



Two zones, in particular, of the brazilian coastline, where the geologic evolution during the Quaternary seems to have been affected by the tectonic movements, are here considered. These are the coastal regions of the States of Bahia and São Paulo.

THE EVOLUTION OF THE STATE OF BAHIA COASTLINE

This part of the brazilian coastline is geologically characterized by the presence of the Recôncavo Sedimentary Basin, which is a «graben» oriented according to a certain angle of the present coastline (Fig. 3).

If we make an observation about the position of the ancient strandlines, left outside and inside the Recôncavo Basin by the last transgression, we can note very great differences. On the beaches of the city of Salvador, situated on the northeastern part of the limiting accident eastward of the Recôncavo (Cristo Beach, Rio Vermelho Beach and Itapoã Beach), occurrences of several evidences (beach rocks, emerged sea-urchin burrows, etc.) testify to periods of sea levels higher than the present. In the Itaparica and Madre de Deus Islands, former higher sea levels can also be demonstrated.

However, on the other side of the fault zone, in the Todos os Santos Bay, evidences of sea levels higher than the present are not found. Neither are they found on the western edge of the Bay, nor in the Valença and Camamu regions, for the Holocene period. However, the same evidences are present when we cross the fault zone defining the western edge of the «graben». For example, beach rocks and emerged sea-urchin burrows exist in the Ilhéus regions.

The research developed by the oil exploration (Barnes and Leite, 1972) showed that the Recôncavo Basin was formed by a series of blocks dislocated in different degrees in the course of time. The Itaparica and Madre de Deus Islands are situated on a positive trend block or on a block with a negative trend higher than the other.

In this way the differences in elevation of the Holocene strandlines show that the Recôn-

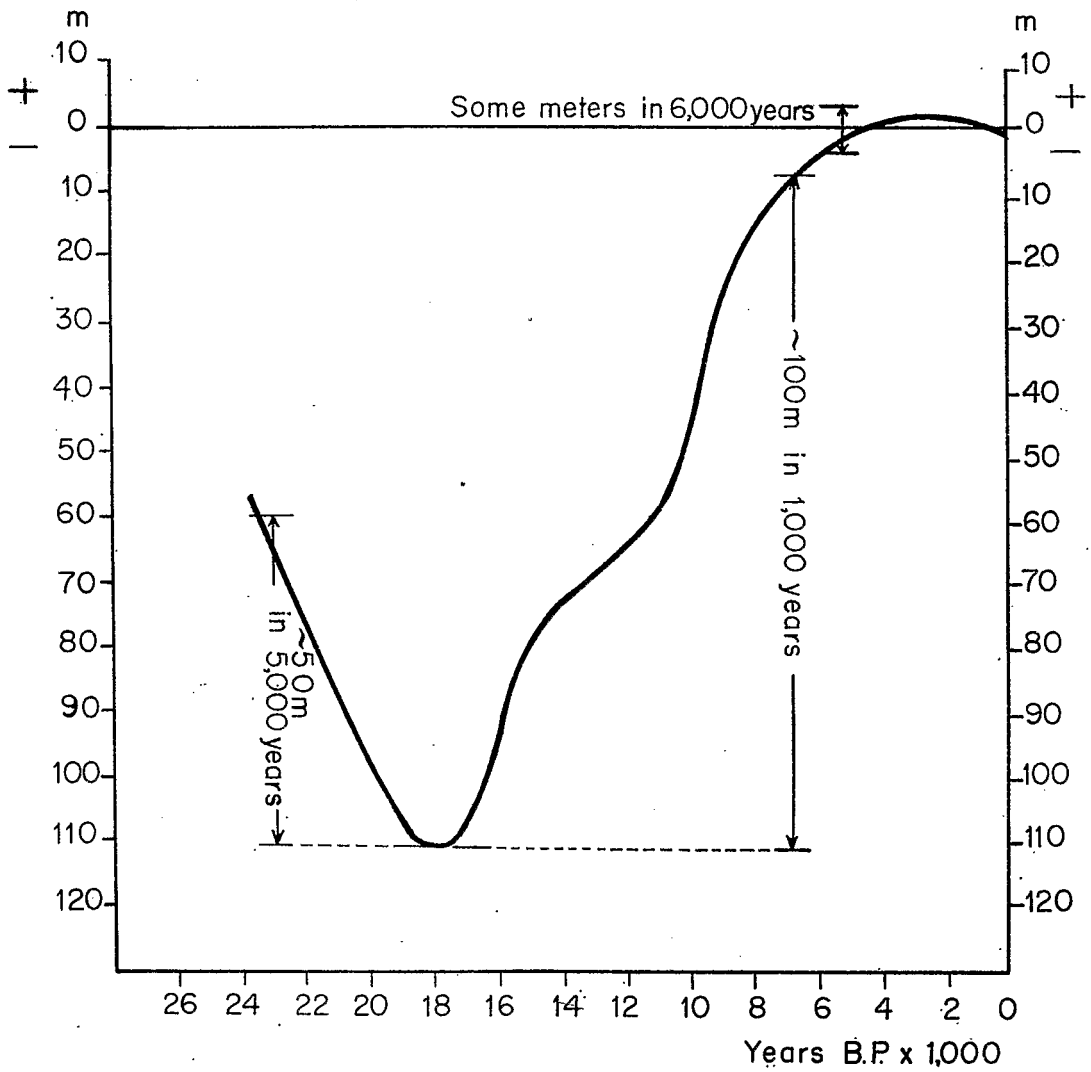
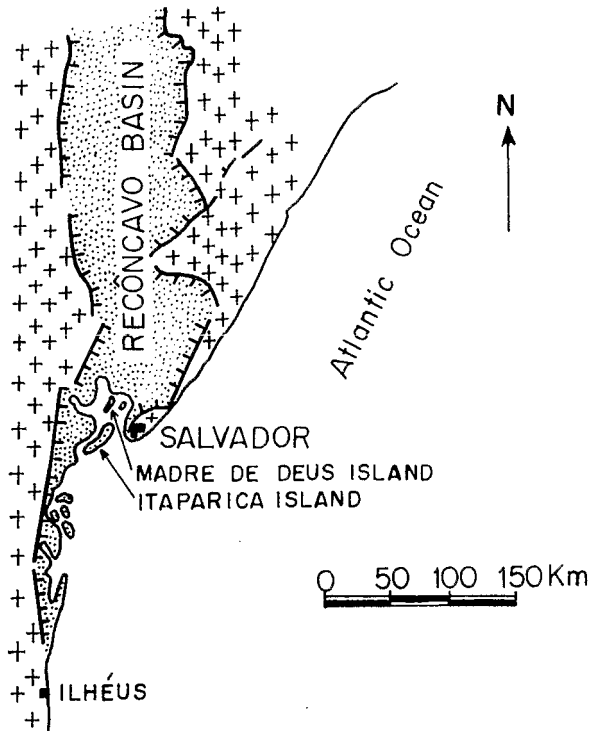
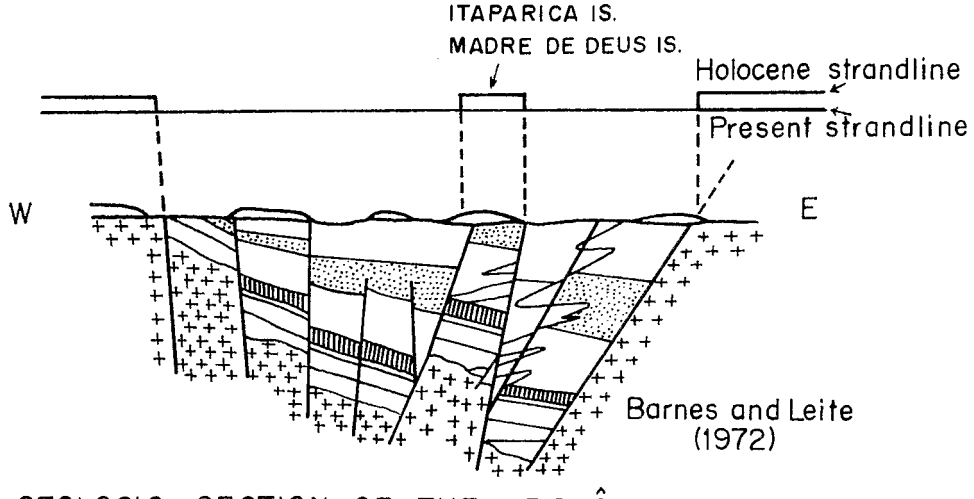


FIGURE 2 - EXAMPLE OF SEA LEVEL CHANGING CURVE VARIATIONS AT IVORY COAST (AFRICA).

AFTER MARTIN (1973)



GEOLOGIC SCHEME OF THE SALVADOR REGION



GEOLOGIC SECTION OF THE RECÔNCAVO BASIN

FIGURE 3 - INFLUENCE OF THE RECÔNCAVO GRABEN ON THE HOLOCENE STRANDLINES.

cavo Basin was still a subsident zone during the Recent Quaternary, with the exception of the zone materialized by the Itaparica and Madre de Deus Islands.

It is interesting to verify that the transition between the different zones is very rapid. There is no gradual transition from an emergence morphological zone to a submergence morphological zone.

THE EVOLUTION OF THE STATE OF SÃO PAULO COASTLINE

The State of São Paulo coastline, with an average NE-SW trend, is limited by 23 and 25° southern latitude and 43 and 45° western longitude (Fig. p).

It shows mixed morphological configurations with emergence characteristics in the southern part and submergence features in the northern part. The São Sebastião region forms approximately the limit between two zones of different behaviour.

The Precambrian basement rocks touch the sea almost everywhere, with the exception of narrow plains mostly constituted by Quaternary marine deposits, such as Ubatuba and Caraguatatuba coastal plains in the north. In the southern part of the São Sebastião Island there are a series of plains essentially formed by Quaternary marine sediments separated by advanced points of crystalline basement that reach the sea. At the present, only the greatest of these plains was studied in detail. That is the Cananéia-Iguape plain situated in the southern State of São Paulo. It is more than 100 km long with a maximum width of 40 km. A detailed mapping and radiocarbon dating permitted to identify a certain number of formations (Martin and Suguio, 1975).

In contact with the precambrian crystalline rocks, there occur rudaceous sediments of a continental formation that can be roughly correlated with the Pariquera-Açu Formation of Bigarella and Mousinho (1965), probably Pliocene in age (Fig. 5).

Above, we find a formation that is argillaceous in its basal part and sandy on the top, called Cananéia Formation (Suguio and Petri, 1973). Its altitudes range from 5 to 6m seaward and 9 to 10 m near the crystalline basement rocks. Studying the microorganisms, Petri and Suguio (1973) showed that the basal argillaceous unit was deposited in a transitional, brackish water environment, changing from a continental to a salt water environment. At the bottom of the sandy unit it is possible to see indications of a transgressive phase, followed by emersion in a regressive phase toward the top (Martin and Suguio, 1975). Many fossil Callianassid burrows that are situated in increasing levels toward the continent indicated that the sea level was rising at that time. The first radiocarbon dating taken from a fossil wood fragment contained in the argillaceous formation gave 28,000 ± 2,000 years B. P. (Sample Ba-227). Since the dating was made under adverse conditions, this sample should be older than the indicated age. Although this dating had not been perfect, it showed that the Cananéia Formation was deposited during the penultimate great transgression.

Situated stratigraphically above the Cananéia Formation but topographically below, the following formations are found:

a) A coastal marine formation essentially constituted by fine to very fine sands, never higher than 3 m —: It is formed by the same sand as the Cananéia Formation, as a result of the reworking of that formation. Radiocarbon dating showed that it was deposited during the last transgressive episode.

b) Mangrove formation that fills up the ancient bays carved in the Cananéia Formation —: Raised mangrove sediments formed

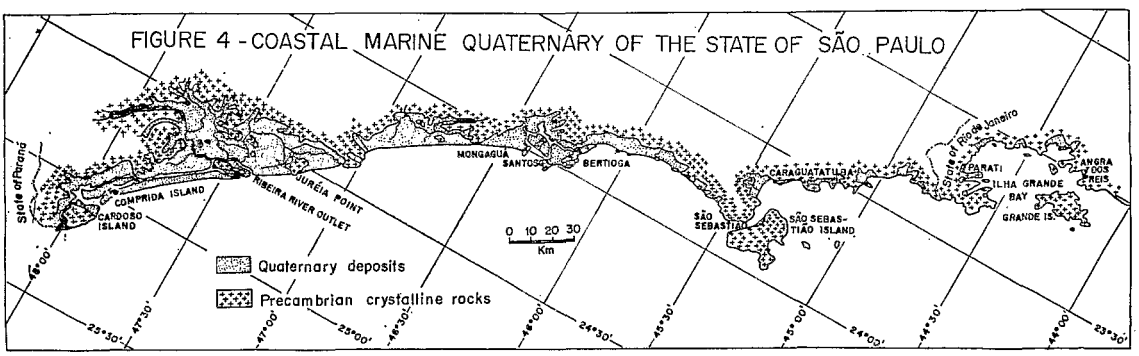


FIGURE 4 - COASTAL MARINE QUATERNARY OF THE STATE OF SÃO PAULO

during a period when the sea level was higher than at present, also occur.

c) Fluviatile-lagoonal formations that are sandy and argillaceous sediments deposited by the Ribeira de Iguape River and its tributaries —: They are found in the eroded zones of the Cananéia Formation that were occupied by a lagoonal system during the periods when the sea levels were higher than at present.

It is interesting to verify the presence of some evidence of a formation more elevated than the Cananéia Formation (15 to 18 m above the average sea level) on the Iguape island, near the Icapara Village. This would be evidence of a transgressive period older than that of the Cananéia Formation.

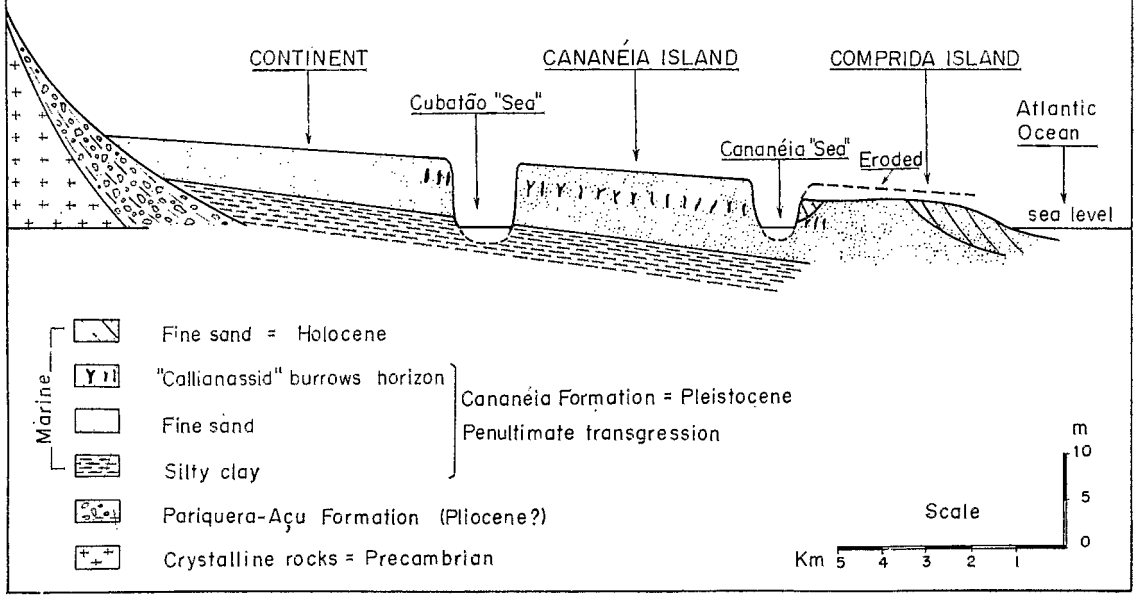
Some sambaquis (Kjökkenmoddings) and fossil plant debris, associated to these morphological periods, permitted the establishment of a sea level changing curve for the Cananéia-Iguape region (Fig. 6).

From these data it was possible to deduce that the sea level was approximately 3 m above the present sea level 5,000 years B. P. This higher sea level was followed by a period when the sea level probably was lower than the present one during 3,900 to 3,400 years B. P. Afterwards, the sea level was again about 3 m higher, relative to the present, near 3,000 and 2,500 years B. P.

Consequently, it was verified that in the southern coastal plain of the State of São Paulo (area with emersion morphology) there were sea levels higher than the present during the Holocene. One of the purposes of this work is to verify that the same levels occur in the northern littoral (area with submergence morphology), especially to see if they have the same altitude, and to check the possible influence of tectonics in the Holocene coastal evolution.

Unfortunately till now we don't have sufficient calculated data to elucidate the question. However, from now on, we can reach some interesting conclusions. From the north to south the areas and the widths of the marine sedimentation Quaternary plains grow regularly (Fig. 4). In the Ilha Grande Bay (State of Rio de Janeiro) the marine Quaternary formations show little development and some genuine «rias» are found in the Parati region. However, it was seen that the marine Quaternary plain of the Cananéia-Iguape region has a considerable surface area (maximum dimensions: 100 × 40 km). The importance of the Pleistocene form-

FIGURE 5 - INTERPRETATIVE PROFILE ACROSS SEVERAL FORMATIONS OF THE CANANÉIA-IGUAPE REGION (S.P.)

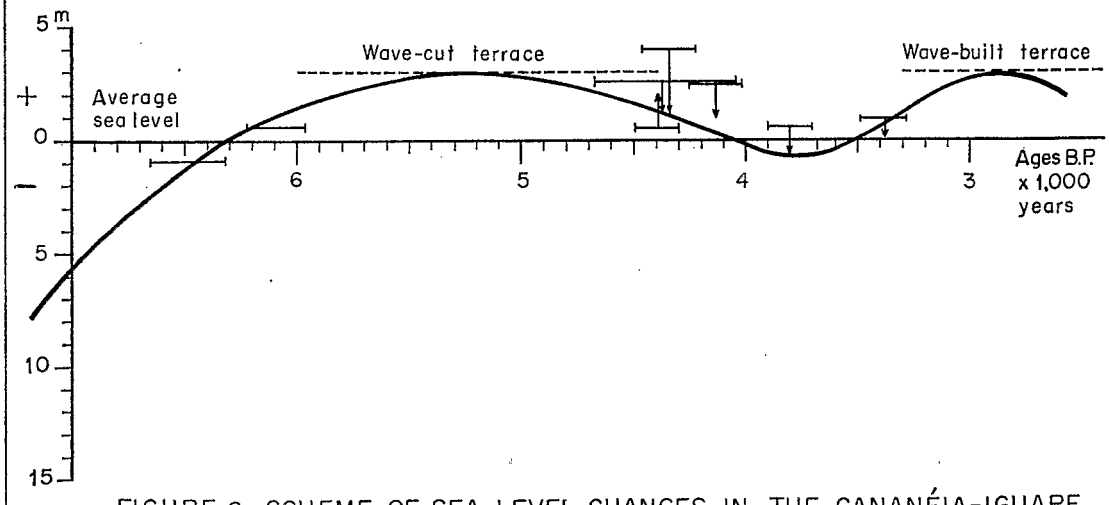


ations also increases regularly from the north to the south. It is necessary to note that the width of the continental shelf is more important in the southern part than in the northern part. In the Parati Mountains region (north) the isobath of 50 m is situated at 8 km from the coastline, in the Santos region, it is located at 50 km, and in the Iguape region (south) it is at 60 km.

Contrary to what occurs in the Salvador region, in the State of Bahia, there is not an abrupt transition from a submersion morphology zone to an emersion characteristic zone. There is a gradual transition appearing very clearly in the regular increase of the sedimentary marine coastal plains surface areas and widths from the north to the south. In this region it seems to be impossible to deduce from the movements of the block systems, isolated by an accident perpendicular to the coastline, dividing the region, to explain the morphological difference existing between the north and the south. On the contrary, it seems necessary to look to a continental inflection system (Bourcart, 1949) for an explanation: the inflection point would be between the raising zone and the submerging zone running along the coastline.

The littoral of the State of São Paulo is situated in the concave portion of the Ponta Grossa tectonic arch that is located in an ancient positive zone. A certain number of evidences shows recent rising in the northern flank of the arch. It is a positive zone in the continent followed by great faults more or less parallel to the coastline. Some of these faults originated the «Serra do Mar» Mountains. Along the offshore area of the State of São Paulo there is a submarine sedimentary basin, called the Santos Basin, that is characterized by a great accident nearly parallel to the coastline . This accident isolated a small, shallow continental basin at the west, called Taubaté Basin («Rift Valley»), from a basin with several thousands of meters of sediments at the east. Consequently there was a negative area in the sea and an inflection point between the rising continental area and the subsiding marine area. According to the position of the inflection point, whether it is on the continent or on the continental shelf, there would be a submersion coast or emersion coast, respectively. The extreme cases of this model are schematically represented in Fig. 7.

With reference to the State of São Paulo coastline the scheme presented in Fig. 8,



FIGUR E 6 - SCHEME OF SEA LEVEL CHANGES IN THE CANANÉIA-IGUAPE REGION (SP) BETWEEN 6,500 AND 2,500 YEARS B.P.

Martin & Suguio (1975).

indicates the inflection point to the north on the continent. It then progresses towards the continental shelf, continually swerving from the coastline. This would explain the coastal plain's regular growth in extent and width.

Obviously this scheme is very simplified. Nevertheless, it is possible to reconstruct the State of São Paulo coastal evolution after Tertiary. Three main evolutive stages are distinguishable: the inflection period, the fracturation period and the renewed inflection period (Fig. 8). It seems that a continental zone uplift and an oceanic zone submergence occurred during the Tertiary, thus generating an inflection line between these two zones. When the tensional strength was great enough, the fractures were produced, originating the «Serra do Mar» on the continent and the Santos fault zone in the ocean. The erosion of the continent occurred in proportion to its uplifting. Simultaneously, the sedimentation occurred in an incipient «graben» in the area, occupied today by the Santos Basin. Probably this fracturation period was not continuous and some periods of interruption propitiated the inflection mechanism's renewal.

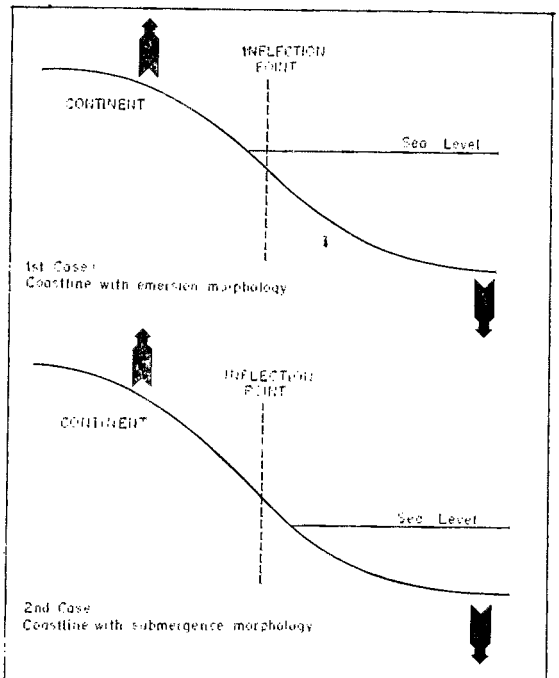


FIGURE 7 - INTERPRETATION OF EMERSION AND SUBMERGENCE MORPHOLOGY COASTLINES BY CONTINENTAL INFLECTION PHENOMENON

If the block systems situated in the left side of the inflection line uplift again, and if the block systems at the right side submerge, a new inflection period would begin and it would fall into the general scheme.

However, this inflection phenomenon is probably not recognizable in the Holocene time scale. Evidently the submerged and emerged coasts differentiation did not occur only during the Holocene. The last transgression was performed on previously existing submersion morphology. Normally, if the inflection mechanism was perceptible during the course of the Holocene, the same age levels slightly elevated in the interior zones than in the exterior zones would be found. Unfortunately this difference of levels together with the normal dipping seaward of the sedimentary layers, would be very difficult to measure.

CONCLUSIONS

Numerous points of the Brazilian coastline show Holocene marine levels indicating higher sea levels than the present's. It would be interesting to verify whether these ancient strandlines were not submitted to deformations in order to estimate the role played by modern tectonism.

In the Salvador region (State of Bahia), the Recôncavo Sedimentary Basin cutting the littoral, probably had a certain activity in the course of the Recent Quaternary. The transition between the areas with an uplifted Holocene coastline and the areas without an uplifted coastline occurs in a very abrupt way.

The State of São Paulo littoral presents a submersion morphology in the north and an emersion morphology in the south. It is necessary to observe that the transition between these zones is very gradual and not abrupt as in the case of the Salvador region. It seems that in this case the explanation of the changin coastline morphology must be looked for in the continental inflection phenomenon.

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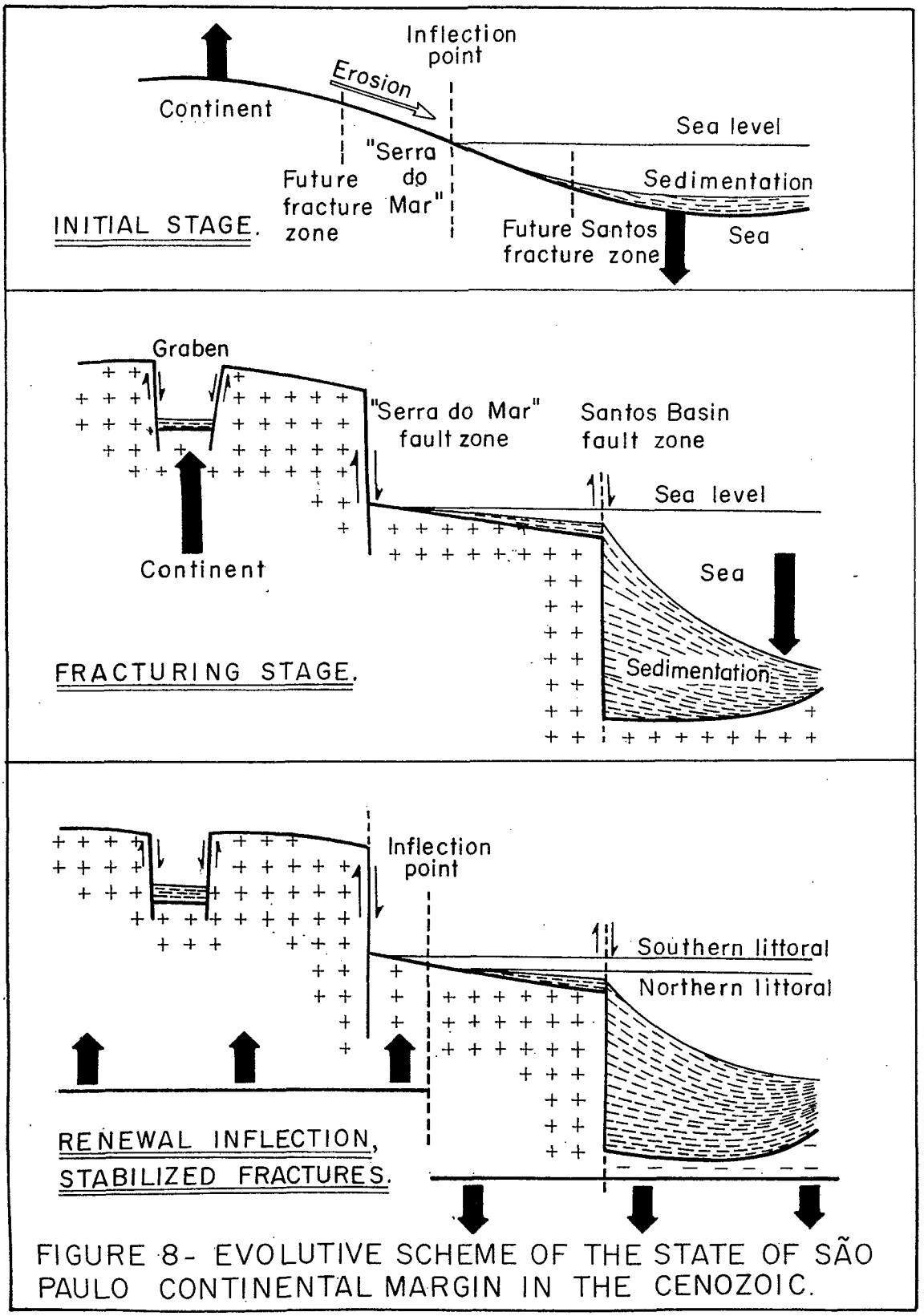

FIGURE 8- EVOLUTIVE SCHEME OF THE STATE OF SÃO PAULO CONTINENTAL MARGIN IN THE CENOZOIC.

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