

Paleoshorelines and the Sambaquis of Brazil

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INTRODUCTION

The paleoshorelines of the past 7000 years have been systematically studied since 1974 by scientists from the University of São Paulo, the Federal University of Bahia, and the National Observatory (CNPq) in association with the Institute of Scientific Research for Development in Cooperation (ORSTOM), in France. Studies have been completed on the Quaternary coastal formations of the States of São Paulo, Rio de Janeiro, Bahia, Sergipe, Alagoas, northern Espírito Santo, Paraná, and Santa Catarina (Figure 1). Systematic surveys of sedimentary deposits at the mouths of the Paraíba do Sul, Doce, Jequitinhonha, and São Francisco Rivers have also been undertaken in order to determine the role played by sea level variations and by littoral drift in the construction of these coastal plains (Figure 1). The Quaternary coastal marine deposits of Rio Grande do Sul have been investigated by a team from the federal university of that state (Villwock et al., 1986). The most important conclusions from these studies have been reviewed in Suguio et al. (1985) and Martin et al. (1987).

To reconstruct a paleoshoreline, it is necessary to define a marker for it in time and space. The latter can be established by determining its present position with respect to the shoreline at the time of its formation. The age of formation or deposition of the marker must also be determined. A marker thus defined gives the position of an ancient shoreline at a certain time in the past relative to the present shoreline.

Evidence for Quaternary paleoshorelines comes from several sources. Sandy littoral

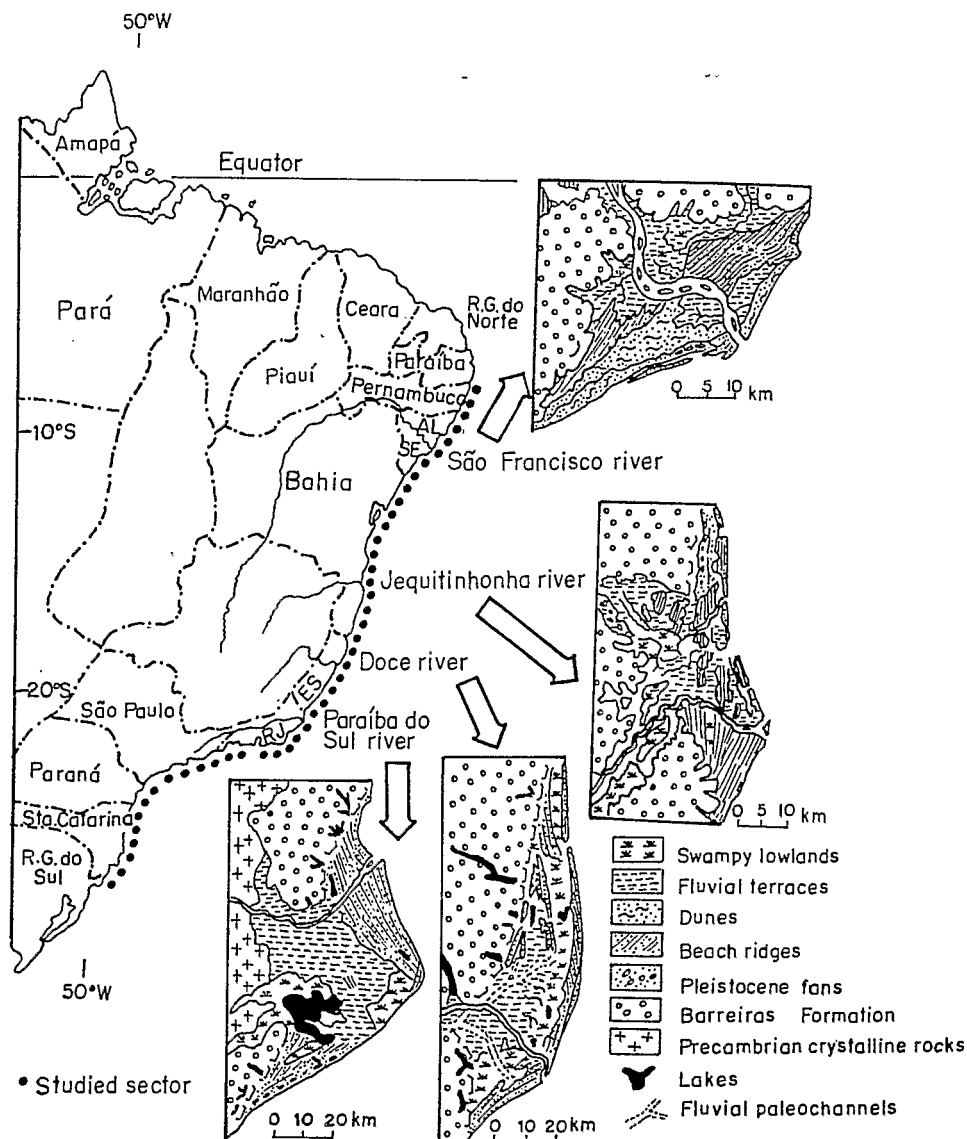


Figure 1. Coastal zones of Brazil with indication of the studied areas, including the most important Quaternary deltaic features.

deposits elevated high above present, equivalent deposition zones provide indisputable evidence for former raised sea levels. Detailed mapping together with about 800 absolute age determinations has led to the recognition of two principal generations of sandy terraces, recording two periods of high Quaternary marine stands.

Along most of the rocky portion of the Brazilian coast, there is biological evidence for marine levels higher than at present. This generally consists of oyster and limpet (gastropod) deposits and sea urchin holes situated above the present living zone of these organisms. In sandy terraces, one can also find fossilized burrows of *Callichirus major*, a marine arthropod, above their present living zone (Suguio and Martin, 1976a).

In coastal areas of Brazil, particularly between the States of Espírito Santo and Santa Catarina, several hundred giant sambaquis (shell middens) have been built-up from the food remains of ancient human inhabitants (Figure 2) (Löfgren, 1893; Bigarella, 1951a, 1951b; Empéaire and Laming, 1956; Hurt, 1974; Martin and Suguio, 1976b; Martin et al., 1981/1982). The location and species content of these sambaquis can also provide evidence of past shorelines.

PALEOSHORELINES AND RELATIVE SEA LEVEL CHANGES DURING THE LAST 7000 YEARS ALONG THE BRAZILIAN COAST

Papers by Martin and Suguio (1975, 1978), Martin et al. (1979a,b, 1980), Suguio and Martin (1976b, 1978), Suguio et al. (1980), and Bittencourt et al. (1979) and others, recently reviewed by Suguio et al. (1985) and Martin et al. (1987), provide valuable information about paleoshorelines and relative sea level changes along the Brazilian coast.

An evolutionary history of these regions during the Quaternary has been reconstructed from this information. About 123,000 years ago, the relative sea level stood about 8 ± 2 m above the present level. Between the end of this transgression (Cananéia transgression) and the beginning of the following regression, a first generation of sandy beach ridges was deposited. During the last glacial when the sea level was low, these deposits were carved by rivers, and a system of valleys, some very large and deep, developed. The original wave-built terrace surfaces, frequently marked by beach-ridge alignments, have been preserved only in interfluvial zones. When, during the Holocene, the sea level reached its



Figure 2. Partial view of a huge sambaqui, located beside a sand dune, near the present strandline. It is composed almost exclusively of *Anomalocardia brasiliana* shells (Jaguaruna, State of Santa Catarina). For scale, compare with the vehicle used during the field surveys.

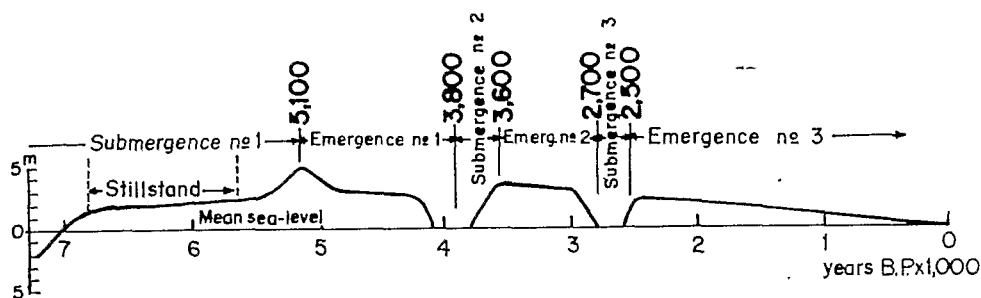


Figure 3. Schematic relative sea level fluctuation curve during the last 7000 years for the northern area of Salvador (State of Bahia). From Martin, L., Flexor, J.-M., Vilas-Boas, G.S., Bittencourt, A.C.S.P., and Guimarães, M.M.M. (1979a). In: *Proc. 1978 Int. Symp. Coastal Evolution in the Quaternary*, pp. 264–274. Suguio, K., Fairchild, T.R., Martin, L., and Flexor, J.-M., Eds., São Paulo. Used by permission.

present position (about 7000 to 6500 C-14 years ago; Santos transgression), the low-lying parts of the ancient terraces were invaded by the sea, forming extensive lagoonal systems.

Relative sea level fluctuation curves for the last 7000 years have been constructed for several sectors of the Brazilian coast, which indicate that:

- The present-day mean sea level was surpassed for the first time about 6500 to 7000 B.P.
- By about 5100 B.P., the sea level had risen to about 4 to 5 m above today's mean sea level.
- At about 3800 B.P., the sea level experienced a low stand and was positioned slightly below today's mean sea level.
- At 3600 B.P., the sea level rose to 2.5 to 3.5 m above today's level.
- At 2700 B.P., the sea level again experienced a low stand, dropping slightly below the present-day mean sea level.
- By about 2500 B.P., a third high stand was reached. At this time, the sea level rose 2 to 2.5 m above today's mean sea level, and since then it has been gradually dropping.

In summary (Figure 3), three main phases of submergence (7000 to 5100 B.P., 3800 to 3600 B.P., and 2700 to 2500 B.P.) and three main phases of emergence (5100 to 3800 B.P., 3600 to 2700 B.P., and 2500 B.P. to the present) can be recognized along the central Brazilian coast during the Holocene.

INFORMATION ABOUT PALEOSHORELINES TO BE DERIVED FROM THE SAMBAQUIS

Geographic Position

In coastal areas subjected to an emergence period following a submergence phase, such as the central coast of Brazil, prehistoric settlement sites located further inland were probably associated with a period of maximum lagoonal extent during a period of maximum sea level. Some central coast sambaquis occur as far as 30 to 35 km inland from the present shoreline.

It may be assumed that the location of settlements is decided primarily by proximity

to shellfish beds of sufficient richness to provide nourishment over a long period of time (Fairbridge, 1976). Obviously, shallow and quiet water bays, lagoons, and estuarine zones, with muddy surfaces exposed during low tides, would be more favorable locations than sandy areas at the open-ocean margin. In the former case, biological productivity is much higher. It is probable that the prehistoric occupants chose campsites above high-tide level, immediately adjacent to favorable collecting grounds where conditions of comfort and safety were available. If this is true, one may assume a close relationship between the positions of the sambaquis and the paleoshorelines, and the position of some sambaquis well inland can be explained only by a lagoon extension significantly greater, and hence a sea level higher, than at present.

While it is relatively easy to establish the geographic relationship between the position of a sambaqui and a nearby ancient lagoon, estuary, or bay, it is much more difficult to establish the vertical relationship between the altitude of the sambaqui's substrate and the position of the sea level during its construction. We can only assume that initially it was above the local high-water spring tide (HWST) level, a very important assumption for interpreting sambaquis whose substrates are now located beneath the present HWST. It is possible that some of the latter sambaquis originated as wastedumps below houses which were built on poles standing in shallow water during high tides. This possibility can be eliminated by a detailed investigation of the sambaqui's substrate and composition. The assumption that sambaquis were built-up close to mollusk-collecting areas allows the nearest paleoshoreline to the site to be cited as the location of shellfishing areas at the time of the site's occupation.

Size of the Sambaquis

The sambaquis exhibit a variety of shapes and sizes, ranging from huge, elongated ($300 \times 60 \times 60$ m) or ellipsoidal ($86 \times 40 \times 25$ m) mounds to small, circular (10×1 to 1.5 m) accumulations. One sambaqui examined by Fairbridge (1976) in the State of Santa Catarina was approximately 20 m high and 100 m in diameter, representing about 2.5 billion shellfish, that is, 100 shellfish per day for a group of 100 people for 500 years.

In general, the more inland sambaquis are smaller than those situated near the present strandline. This is to be expected as maximum lagoon extent periods were very short. Thus, only in the outer lagoon zones was there sufficient time for the buildup of huge sambaquis.

Faunal Composition

About 50 different species of mollusks have been identified within the sambaquis of the Brazilian coast (Bigarella, 1949), but there are only five dominant species:

- *Anomalocardia brasiliiana* Gmelin
- *Ostrea brasiliiana* sp.
- *Ostrea arborea* Chemnitz
- *Lucina jamaicensis* Chemnitz
- *Modiolus brasiliensis* Chemnitz

Except for *O. arborea*, which lives fixed on aerial roots of mangrove trees, these bivalves live within sandy or clayey-sandy sediments deposited in shallow-water lagoons and bays. Shell remains of other organisms are generally very scarce.

TABLE I. Variation of $\delta^{13}\text{C}_{\text{PDB}}$ as a Function of Position of the Samples Within a Paleolagoon, Coastal Plain of the State of São Paulo --

Sample	Radiocarbon Age (B.P.)	$\delta^{13}\text{C}_{\text{PDB}}$ (o/oo)	Distance from Open Sea (km)
Itapoã III	5245 \pm 125	-0.63	5
Jataituba	5235 \pm 150	-3.26	20
Vapumaúva II	5080 \pm 60	-0.06	1
Pariquêra-Açu	5035 \pm 140	-3.66	24
Vapumaúva I	4680 \pm 115	-0.12	2
A196	4636 \pm 100	-6.17	18
Ubatuba	3870 \pm 100	-0.02	?
A132	3775 \pm 130	-5.69	33

From Flexor, J.-M., Martin, L., and Suguio, K. (1979). In: Proc. 1978 Int. Symp. Coastal Evolution in the Quaternary, pp. 356-375. Suguio, K., Fairchild, T.R., Martin, L., and Flexor, J.-M. Eds. São Paulo. Used by permission.

C-13/C-12 Ratios of the Carbonate Shells

$\delta^{13}\text{C}_{\text{PDB}}$ measurements of the carbonate shells show a spectrum of values changing as a function of the influence of continental environmental conditions during the carbonate formation. Shells from lagoonal organisms show $\delta^{13}\text{C}_{\text{PDB}}$ values between those for fresh-water (about 13 o/oo) and those for marine organisms (about 0 o/oo), varying as a function of their geographic position within the lagoon (Flexor et al., 1979). Shells from outer zones (nearer the open-sea edge of a lagoon) show only slightly negative $\delta^{13}\text{C}_{\text{PDB}}$ values, while those from inner zones are clearly characterized by more negative values (Table I). In the latter cases, carbon derived from the decomposition of land plants has been incorporated by the mollusks within their carbonate shells. Deeper and inner portions of the lagoons are characterized by poor water circulation, promoting the accumulation of large quantities of plant-derived organic material. This is independent of water salinity and explains why the carbonate shells of inner lagoon organisms exhibit $\delta^{13}\text{C}_{\text{PDB}}$ values characterized by a strong land influence. Conversely, according to the increase or decrease of the lagoonal area, shells from the same locality will have distinct $\delta^{13}\text{C}_{\text{PDB}}$ values. If such shells are found in stratified sambaquis, their $\delta^{13}\text{C}_{\text{PDB}}$ values will be good indicators of lagoon oscillations and thus indirectly of sea level fluctuations (Martin et al., 1985).

For example, looking at Figure 4, if the sambaquis located at A, B, and C are of a similar age, they will be expected to show quite different $\delta^{13}\text{C}_{\text{PDB}}$ values for their carbonate shells, with A being quite negative and C close to zero. On the other hand, if B and C show several periods of occupation, the least-negative $\delta^{13}\text{C}_{\text{PDB}}$ values will correspond to periods of greatest lagoonal extent and the most negative to periods of lagoon contraction. These data cannot provide information on paleosea-level position with respect to the present level. However, they can indicate falling and rising lagoon levels and the approximate time of maximum and minimum still stands.

Dating of the Sambaqui

The usefulness of dates from sambaquis depends on the position of the dated sample within the mound. If a sample from the basal portion has been dated, it should correspond to the beginning of the site's occupation and thus provide a minimum date for the establishment of the neighboring shoreline. On the other hand, if the sample comes from the

surface of the sambaqui and thus dates the end of occupation, it should indicate the approximate date at which shellfish were no longer available in the vicinity.

If central portions of inland sambaquis are dated, particularly periods of desertion and reoccupation, the departures may be tied to periods of lagoonal desiccation, or low-sea-level periods, and the reoccupations to periods of resurgent high sea level.

Types of Substrates

Sambaquis are located on four distinctive types of substrates (Figure 5).

Type I: Pleistocene marine terraces. These terraces are found inland from the maximum extent of Holocene lagoons. Therefore, the sambaquis found on them should have been built during periods of highest Holocene sea level.

Type II: Holocene marine terraces. These terraces were deposited as beach ridges during the regressive phases that followed the sea level maxima, particularly the 5100-B.P. Santos transgression. Sambaquis on these terraces have necessarily been constructed after high Holocene-sea-level stands, and in some cases their positions on the terraces can provide additional data on sea levels.

Type III: Ancient lagoonal deposits. These lagoon deposits are located in front of sandy marine terraces. Hence, the sambaquis found on them must have been constructed after a period of high sea level, probably during the ensuing lowering of the sea level. One

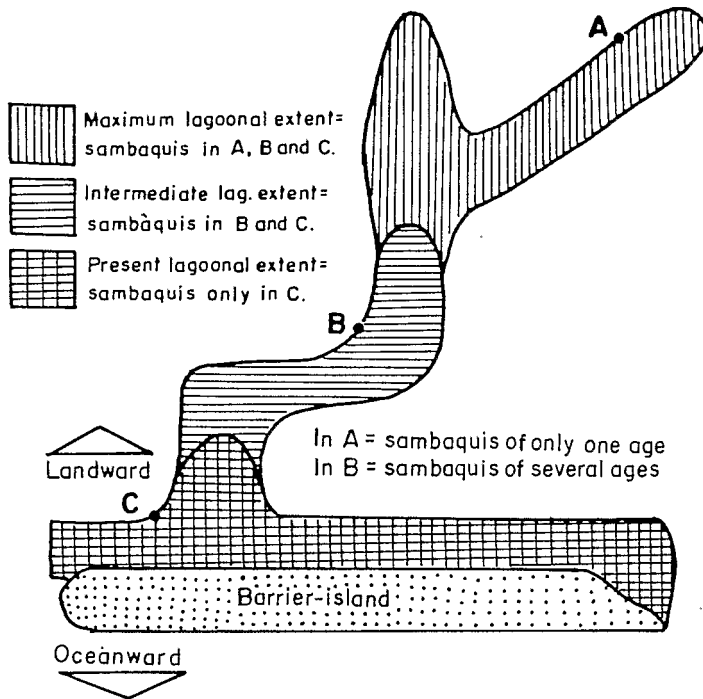


Figure 4. Age variations of the sambaquis as a function of changes in lagoonal extension along the Brazilian coast during the Holocene.

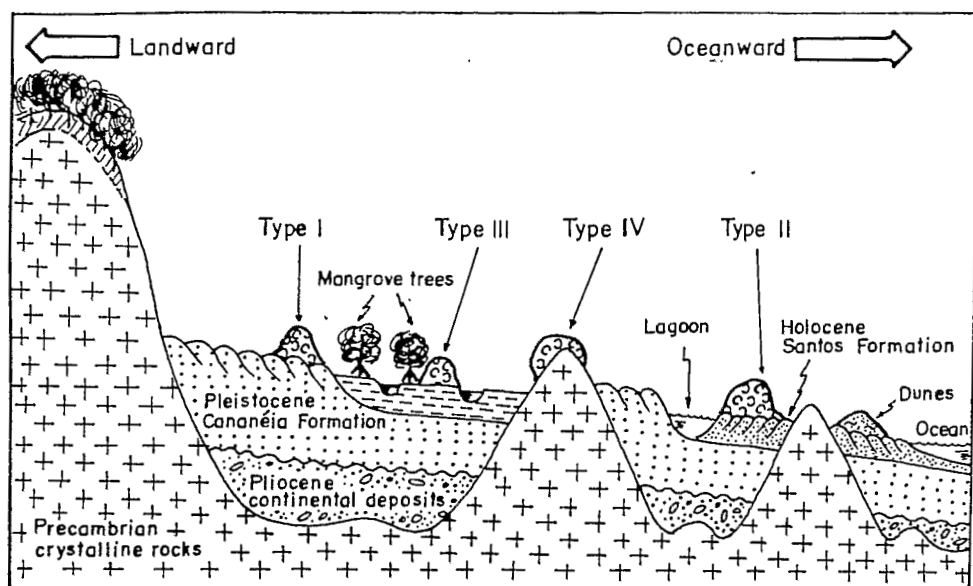


Figure 5. Distinctive types of substrates of the sambaquis along the Brazilian coast. (Modified from Fairbridge, R.W. (1976) *Science*. 191: 353–359.)

must be cautious in interpreting their elevation because the lagoonal organic clay is subject to compaction under the weight of the shell midden, thus diminishing the height of the substrate.

Type IV: Crystalline rocky hills. These hills are located at the margins or centers of ancient lagoons or bays. As they are never covered by high sea stands, they may have been occupied at any time and are thus not sensitive time markers. However, those situated more inland may have been settled when the lagoon reached its greatest extent.

COMPARISON OF GEOLOGICAL AND ARCHAEOLOGICAL DATA ON SEA LEVEL

Cananéia-Iguape Region (State of São Paulo)

The Cananéia-Iguape sedimentary plain has the shape of a large crescent and covers an area of about 2500 km². Its outer portion is presently drained by a lagoonal system and tidal estuaries (Figure 6). A large part of the plain is occupied by remnants of more or less dissected Pleistocene terraces and by dried-out ancient lagoons, at the far inland margins of which several sambaquis have been found.

Shell debris and wood fragments from littoral marine or lagoonal deposits have been dated, and this information, when associated with the nature of the sediments, indicates that (Figure 7A):

- About 6600 to 6500 B.P., the relative sea level reached approximately its present level and was rising.

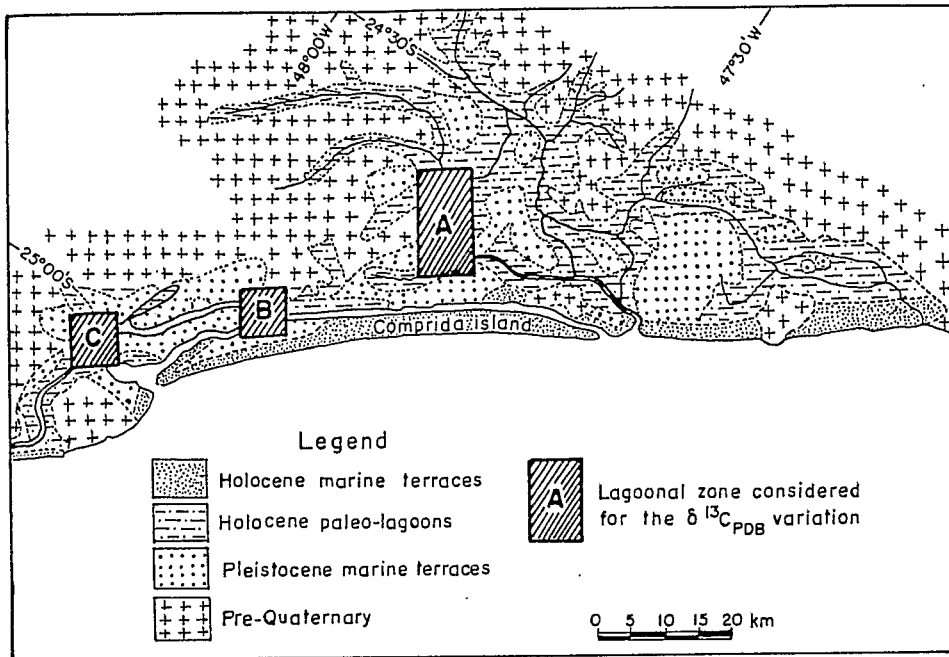


Figure 6. Schematic geologic map of the Cananéia-Iguape coastal plain (State of São Paulo).

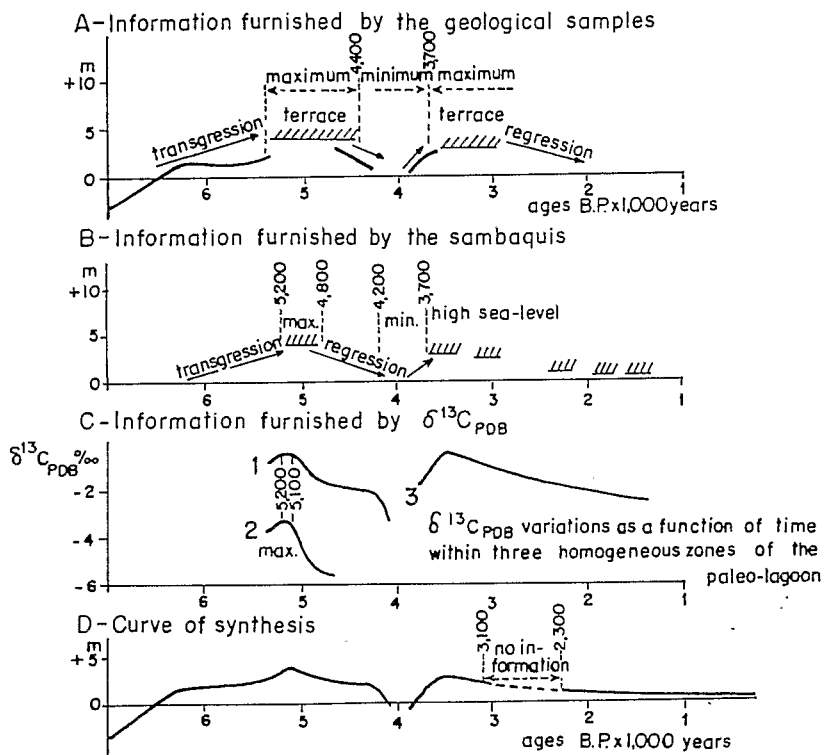


Figure 7. Reconstruction of relative sea level fluctuation curve for the past 7000 years in the Cananéia-Iguape region (State of São Paulo).

- About 5400 B.P., the relative sea level was about 1.5 m above its present level.
- About 4400 B.P., the relative sea level was about 2 m higher than its present level, but was falling. Hence, between 5400 and 4400 B.P., the relative sea level passed through a maximum height which, according to morphological data, must have been 3.5 to 4 m above the present one.
- Between 4400 and 3700 B.P., the relative sea level passed through a minimum.
- Between 3800 and 3700 B.P., the relative sea level rose very rapidly, reaching a second maximum of about 3 m above its present level.
- After the second maximum, the relative sea level returned more or less steadily to its present level. Unfortunately, we have insufficient data for detailing this return.

Dating of sambaquis in this area confirms the conclusions on relative sea level reached on the basis of geological evidence. As indicated above, between 5400 and 4400 B.P., the relative sea level was higher than at present, attaining a maximum of 3.5 to 4 m above its current level. The maximum lagoonal extent which would accompany this high stand should result in the establishment of inland sambaquis (Tables II and III). The location of these sambaquis only makes sense if the sea level is higher than at present (Figure 7B) and the ages of these shell middens lie between 5200 and 4800 B.P. These dates narrow the estimate of the time for maximum lagoonal extent, which we now estimate at about 5100 B.P. Moreover, the location of later sites suggests that by 4100 B.P., the sea level was no more than 0.5 m above the present level. This confirms the conclusion reached on the basis of geological evidence that the sea level reached a minimum between 4100 and 3800 B.P.

Table IV shows that the oldest of the late-Holocene sambaquis (Estaleiro, 3690 \pm 80 B.P.) is situated on a Pleistocene terrace, which should indicate a high lagoon level. This hypothesis seems to be confirmed by the $\delta^{13}\text{C}_{\text{PDB}}$ value of its shell carbonate. This value is much less negative than is that of the shells of Sambaquinho, which was built in the same area when the sea level could have been 0.5 m above sea level at the most. This

TABLE II. General Characteristics of the Sambaquis Constructed Between 5400 and 4400 Years B.P.

Sambaqui	Radiocarbon Age (B.P.)	Laboratory Number	Nature of Substrate	Position in the Paleolagoon	$\delta^{13}\text{C}_{\text{PDB}}$ (o/oo)
Itapoã III	5245 \pm 125	Bah 365	P.T.	Outer	-0.63
Jataituba	5240 \pm 150	Bah 346	P.T.	Inner	-3.26
Guaxixi	5110 \pm 100	Bah 370	P.T.	Outer	-0.48
Vapumaúva	5080 \pm 60	Bah 365	P.T.	Outer	-0.06
Pariqüera-Açu	5035 \pm 140	Bah 295	P.T.	Inner	-3.88
Juruvaúva I	5010 \pm 115	Bah 359	P.T.	Outer	-0.76
Juruvaúva	4970 \pm 110	Bah 361	P.T.	Outer	-1.34
Batatal	4920 \pm 100	I 9186	P.T.	Outer	—
R. das Pedras I	4860 \pm 100	Bah 343	C.B.	Inner	-3.17
Momuna	4790 \pm 100	Bah 308	P.T.	Inner	-5.39
R. das Pedras III	4750 \pm 110	Gif 3641	P.T.	Inner	-4.67
	4710 \pm 145	Bah 300			
Rio Comprido	4560 \pm 110	Gif 3646	C.B.	Outer	—
Cananéia	4340 \pm 110	Gif 3435	P.T.	Outer	-1.28
	4300 \pm 140	Bah 302			

Note: P.T. = Pleistocene Terrace; C.B. = Crystalline Basement; Bah = Laboratório de Física Nuclear Aplicada, Universidade Federal da Bahia, Brazil; Gif = Laboratoire de Faibles Radioactivités, Gif-Sur-Yvette, France; I = Isotopes, U.S.A.

TABLE III. Sambaquis Constructed Between 5000 and 3700 Years B.P. on Holocene Terraces and Paleolagoonal Deposits

Sambaqui	Radiocarbon Age (B.P.)	Laboratory Number	Position of Sea Level	$\delta^{13}\text{C}_{\text{PDB}}$ (o/oo)
Vapumaúva II	4680 \pm 110	Bah 362	< +3.5 m	-0.72
Nóbrega	4380 \pm 160	SPC 21	< +3.5 m	—
Boguaçu II	4160 \pm 100	Bah 303	< +1.5 m	-1.39
	4120 \pm 100	Gif 3436		
Ararapira II	4175 \pm 100	Bah 290	< +0.5 m	-1.67
Ubatuba	3870 \pm 100	Bah 294	< +2.0 m	-0.02
Ararapira I	3790 \pm 110	Gif 3437	<0 m	—

Note: Bah = Laboratório de Física Nuclear Aplicada, Universidade Federal da Bahia, Brazil; SPC = Centro de Pesquisas Geocronológicas, Instituto de Geociências, USP, Brazil; Gif = Laboratoire de Faibles Radioactivités, Gif-Sur-Yvette, France.

TABLE IV. Sambaquis Constructed Since 3700 Years B.P.

Sambaqui	Radiocarbon Age (B.P.)	Laboratory Number	Nature of Substrate	Position of Sea Level	$\delta^{13}\text{C}_{\text{PDB}}$ (o/oo)
Estaleiro	3690 \pm 80	Bah 367	P.T.	>0 m	-0.65
Fosfasa I	3350 \pm 135	Bah 340	P.T.	>0 m	-1.80
Pereirinha	3330 \pm 125	Bah 286	H.T.	>0 m	-0.09
Boguaçu III	3220 \pm 90	Bah 307	H.T.	< +3 m	-3.25
	3090 \pm 110	Gif 3645			
Pindu	3090 \pm 120	Bah 348	C.B.	>0 m	-4.31
Guarapari	2285 \pm 45	Bah 368	L	< +1 m	-2.24
R. das Minas	1850 \pm 100	Gif 3643	H.T.	< +0.5 m	—
Sambaquinho	1500 \pm 120	Bah 292	L	< +0.5 m	-2.61
Itapitangui	1490 \pm 120	Bah 293	H.T.	< +1.5 m	-4.45
Vamiranga	1015 \pm 70	Bah 369	P.T.	Indefinite	-3.81

Note: H.T. = Holocene Terrace and L = lagoonal.

confirms the geological conclusion that between 3800 and 3700 B.P., the relative sea level reached +3 m maximum. The sambaqui Boguacu I (3080 \pm 55 B.P.) was constructed when the sea level could not have been more than 2.5 m above the present level, indicating that by 3100 B.P. the maximum of 3 m was passed. Finally, the information from the sambaquis Guarapari and Sambaquinho indicates that the relative sea level at about 2300 and 1500 B.P. was no more than 1 and 0.5 m above present level respectively. This provides data on the rate of sea level fall in the latest period not available from geological data.

As discussed above, $\delta^{13}\text{C}_{\text{PDB}}$ values can be used as an index to marine vs. continental influences and as indirect evidence of relative sea level change (Figure 7C). Three groups of sambaquis in the Cananéia-Iguape coastal plain can be used to assess the value of $\delta^{13}\text{C}_{\text{PDB}}$ values in estimating sea level change (Figure 4: A, B, and C). The sambaquis in Group A were inhabited between 5200 and 4800 B.P., those in Group B between 5200 and 4800 B.P., and those in Group C between 3800 and 1500 B.P.

Group A consists of seven sambaquis on the Cananeia coastal plain (Figure 4). The first six have ages ranging from 5200 to 4200 B.P. during the first Holocene transgression (Table V). It would be valuable to have information on a sambaqui constructed about 4100 B.P., when the sea level could not have been higher than 0.5 m above its present level. We could then compare the $\delta^{13}\text{C}_{\text{PDB}}$ values of carbonate shells formed in the same geo-

graphic position between 5200 and 4100 B.P., encompassing the first Holocene regressive phase. Lacking this, we have considered a sambaqui dated to about 1000 B.P., when the sea level was quite similar to that at 4100 B.P., assuming that the $\delta^{13}\text{C}_{\text{PDB}}$ values will also be comparable.

When plotted as a function of time (curve 1 in Figure 7C), the $\delta^{13}\text{C}_{\text{PDB}}$ values show a maximum between 5200 and 5100 B.P., decrease rapidly until about 4800 B.P., and then decrease slowly until 4200 B.P. Thereafter, the interpolated data suggest another rapid decrease to 4100 B.P. These $\delta^{13}\text{C}_{\text{PDB}}$ differences can be interpreted both in terms of changing lagoonal extent and, assuming constant local tide range, in terms of changing relative sea level as follows:

- Maximum lagoonal extent, and sea level maximum, occurred between 5200 and 5100 B.P.
- The maximum was followed by a rapid decrease in lagoonal extent, indicating a quick sea level lowering between 5100 and 4800 B.P.
- Lagoonal extent and, hence, relative sea level were stationary between 4800 and 4200 B.P.
- Lagoonal extent reduced rapidly after 4200 B.P., suggesting an equally rapid sea level lowering.

Group B consists of three sambaquis from an area of the inland portion of the Iguape coastal plain (Figure 4, area B). The data derived from these sambaquis (Table VI) allows

TABLE V. Variation of $\delta^{13}\text{C}_{\text{PDB}}$ as a Function of Age Within the Same Portion of a Paleolagoon, Coastal Plain of the State of São Paulo, Brazil

Sample	Radiocarbon Age (B.P.)	$\delta^{13}\text{C}_{\text{PDB}}$ (o/oo)
Itapoã III	5245 \pm 125	-0.63
Guaxixi	5110 \pm 70	-0.48
Juruvaúva I	5010 \pm 115	-0.78
Juruvaúva III	4970 \pm 150	-1.34
Juruvaúva II	4305 \pm 140	-2.07
Itapoã II	4215 \pm 140	-2.27
Vamiranga	1015 \pm 70	-3.81

From Flexor, J.-M., Martin, L., and Suguio, K. (1979). In: Proc. 1978 Int. Symp. Coastal Evolution in the Quaternary, pp. 365-375. Suguio, K., Fairchild, T.R., Martin, L., and Flexor, J.-M., Eds. São Paulo. Used by permission.

TABLE VI. $\delta^{13}\text{C}_{\text{PDB}}$ Values of Carbonate Shells from Three Sambaquis Constructed in the Same Inner Zone of the Iguape Coastal Plain

Sambaqui	Radiocarbon Age (B.P.)	$\delta^{13}\text{C}_{\text{PDB}}$ (o/oo)
Jatituba	5250 \pm 150	-3.26
Pariquera-Açu	5040 \pm 140	-3.88
Momuna	4790 \pm 115	-5.81

TABLE VII. $\delta^{13}\text{C}_{\text{PDB}}$ Values of Carbonate Shells from Four Sambaquis of the Cananéia Coastal Plain

Sambaqui	Radiocarbon Age (B.P.)	$\delta^{13}\text{C}_{\text{PDB}}$ (o/oo)
Fosfasa II	3790 ± 110	-2.63
Estaleiro	3490 ± 60	-0.67
Guarapari	2285 ± 45	-2.24
Sambaquinho	1500 ± 120	-2.61

the creation of a curve of variation of $\delta^{13}\text{C}_{\text{PDB}}$ which shows that the maximum was well established between 5200 and 5100 B.P. and that the fluctuation was very rapid between 5100 and 4800 B.P. (curve 2 in Figure 7C).

Group C consists of four sambaquis located on the Cananéia coastal plain (Figure 4, area C) which date from 3800 to 1500 B.P. (Table VII). The $\delta^{13}\text{C}_{\text{PDB}}$ variation curve for area C is given in Figure 7C (curve 3). Between 3800 and 3500 B.P., values increase very rapidly and then decrease. Put in terms of relative sea level, it appears that there was a rapid rise between 3800 and 3500 B.P., followed by a drop.

The results of $\delta^{13}\text{C}_{\text{PDB}}$ analyses provide additional confirmation of both the geological and archaeological conclusions adumbrate above. Thus, radiocarbon dating of shell debris and fossil wood fragments from both sedimentary deposits and sambaquis, as well as information on the $\delta^{13}\text{C}_{\text{PDB}}$ of carbonate shells from sambaquis, have allowed us to establish a fluctuating relative sea level curve for the Cananéia-Iguape region (Figure 7D). The accuracy of this curve is supported by the agreement between the three independent lines of information used to create it.

Santos-Itanhaém region (State of São Paulo)

The Santos-Itanhaém coastal plain has the same characteristics as the Cananéia-Iguape area. A lagoonal system originated during each high-sea-level period and sambaquis, some of which have been dated, were established at the margins of paleolagoons. The data from this area will be summarized rapidly as it confirms the results from the Cananéia-Iguape area.

A large number of radiocarbon dates of shell debris and fossil wood fragments contained in lagoonal and shallow-marine deposits, as well as of vermetid incrustations, have allowed us to delineate a rather detailed curve of relative sea level fluctuations for this region (Figure 8A). This curve is quite similar to that for Cananéia-Iguape, although some differences in amplitude are apparent.

Dated sambaquis are much less numerous here than in the Cananéia-Iguape area, but they are important for corroborating the information from dated geological samples (Figure 8B; Table VIII).

The sambaquis Rio Preto, Araraú, and Mundo Novo are situated in an inner portion of the Itanhaém paleolagoon. Hence, they should have been inhabited during maximum lagoonal extent. However, if this hypothesis is correct, the conditions during maximum lagoonal extent were different in Itanhaém than in the Cananéia-Iguape region. The $\delta^{13}\text{C}_{\text{PDB}}$ values of the shells from these sambaquis are much more negative than those of the samples dating the high-sea-level period of Cananéia-Iguape. The $\delta^{13}\text{C}_{\text{PDB}}$ values of the sambaquis from Itanhaém are greater than that of the sambaqui Momuna (Table II), which is the

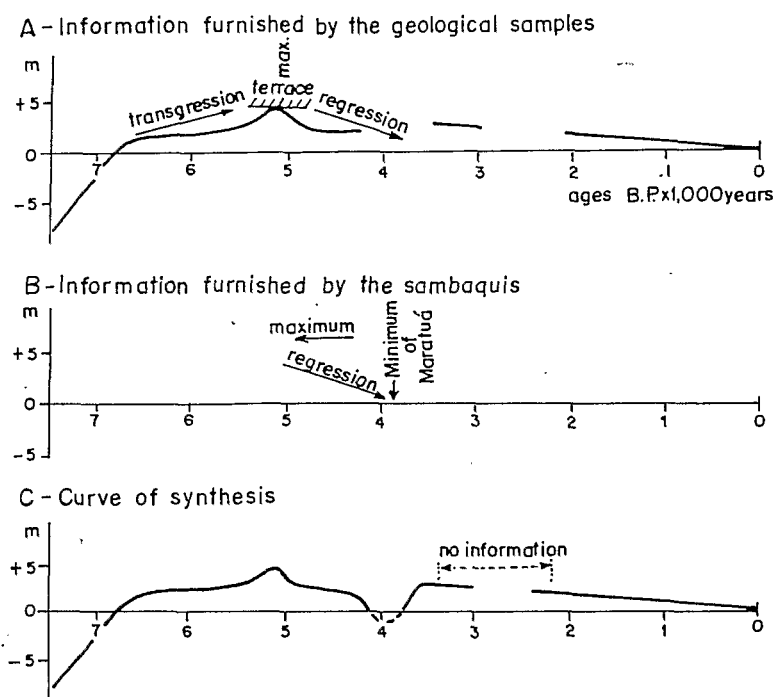


Figure 8. Reconstruction of relative sea level fluctuation curve for the past 7000 years in the Santos-Itanhaém region (State of São Paulo).

TABLE VIII. General Characteristics of the Dated Sambaquis of the Santos-Itanhaém Coastal Plain

Sambaqui	Radiocarbon Age (B.P.)	Laboratory Number	Nature of Substrate	Position of Sea Level	$\delta^{13}\text{C}_{\text{PDB}}$ (o/oo)
Piaçaguera	4930 \pm 100	I 4491	C.B.	>0 m	—
Rio Preto	4635 \pm 100	Bah 331	P.T.	>0 m	-6.07
Araraú	4630 \pm	Bah 296	C.B.	>0 m	-5.29
Mundo Novo	4575 \pm 110	Bah 446	C.B.	>0 m	-8.91
A229	4520 \pm 130	Bah 328	P.T.	< +3.5 m	-2.98
Mar Casado	4400 \pm 130	Gif 1194	H.T.	< +3.5 m	—
Maratúá	3925 \pm 145	Bah 382	L	<0 m	—
	3865 \pm 95	Gif 9185			

Note: I = Isotopes, U.S.; Bah = Laboratório de Física Nuclear Aplicada, Universidade Federal da Bahia, Brazil; Gif = Laboratoire de Faibles Radioactivités, Gif-Sur-Yvette, France.

most negative of the Cananéia-Iguape sambaquis from this 4600-B.P. period. This suggests that the continental influence in the inner portion of the Itanhaém paleolagoon was very strong, perhaps because the maximum had passed and the paleolagoon was beginning to dry out.

The sambaquis A229 and Mar Casado (Table VIII), located on a Holocene terrace, obviously were constructed after the transgression maximum, when the sea level was probably less than their 3.5 and 3-m elevations above the present level. This is supported by the moderate $\delta^{13}\text{C}_{\text{PDB}}$ value of sambaqui A229.

The sambaqui Maratuá, which has, unfortunately, been completely destroyed, has furnished the most interesting information (Figure 8B). The base of this sambaqui was located below the present sea level. This fact cannot be attributed to substrate subsidence due to the sambaqui's weight because the sambaqui's layers were not deformed in any way. If the sambaqui had sunk under its own weight, the center would be expected to have lowered farther than the margins and the layers would be deformed. Laming-Emperaire (1968) submitted two samples from this sambaqui to be dated at the beginning of radiocarbon investigations. The results, 7330 ± 1300 B.P. (Gif-15) and 7800 ± 1300 B.P. (Gif-16), were initially accepted because the dates did coincide with a period when relative sea level was definitely lower than today. However, archaeological remains within the sambaqui of Maratuá suggested much later dates. Redating of Laming-Emperaire's samples produced ages of 3925 ± 145 B.P. (Bah-382) and 3865 ± 95 B.P. (Gif-9185), which are more in keeping with the artifactual evidence. They also confirm the hypothesis adduced from the Cananéia-Iguape region that relative sea level about 3800 B.P. was lower than today.

FINAL CONSIDERATIONS

Sambaquis cannot be used directly to reconstruct, in space and time, the positions of former sea levels as it is not possible to directly establish a vertical relationship between the base of a sambaqui and the sea level. The only thing of which we are more or less certain is that the base of the sambaqui was above the local HWST level at the beginning of its occupation. If we postulate that the paleoinhabitants established their campsites near the mollusk-harvesting place, it is easy to establish the geographical relationship between a sambaqui and an ancient lagoonal, estuarine, or shallow-marine zone. Sambaquis located further inland were probably associated with a period of maximum lagoonal extent, correlated with a sea level maximum. However, it is necessary to ascertain that coastal progradation was unrelated to intense continental sedimentation, but, rather, to a relative sea level change. If one has a series of dates from a number of sambaquis, they can be used to confirm or adjust the dates derived from geological materials. Thus, for example, sambaquis whose substrates are located beneath the present high-tide level suggest a period of lower sea level. Values of $\delta^{13}\text{C}_{\text{PDB}}$ for carbonate shells from dated sambaquis give us additional information about the high- or low-sea-level positions, as well as about the trend of sea level change.

Archaeologically, we have confirmed the close association of sambaquis with past shorelines. This supports our hypothesis that the ancient inhabitants did not carry their shellfish dinners long distances, but, rather, established their settlements in close proximity to their molluscan resources. In studies of sambaquis in other zones, it will be possible not only to reconstruct the paleoenvironment of the site from its location relative to features of the paleoshoreline, but also to hypothesize a range of possible dates from a sambaqui located in its situation based on our sea level-fluctuation curves. Excavation and dating of the sambaqui will further test and refine the curves, so that the two areas of research continue to support and amplify one another.

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