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Relative sea-level reconstruction during the last 7,000 years
 along the States of Paraná and Santa Catarina coastal plains:
 Additional information derived from shell-middens

ABSTRACT

Obviously a shell-midden is not the best evidence for ancient sea-level reconstruction in space and time. However, within coastal areas subjected to a submergence followed by an emergence, interesting and even precious information can be supplied by shell-middens when other data are very scarce. Therefore, position and fluctuation trend of the relative sea-levels can be derived from the following information:

- a) geographic situation of the shell-midden in relation to the present sea or lagoonal area, b) nature and age of the substrate on which the shell-midden has been constructed,
- c) altitude of the shell-midden substrate in relation to the present high-tide level, d) times relative to beginning and end of site occupation, as well as, possible moments of abandonment and reoccupation, e) $\delta^{13}\text{C}$ (PDB) values of the carbonate shells, f) dominant species of the mollusc shells, g) size of the shell-midden, etc. Moreover, neither all shell-middens do not derive interesting information and only one dating for each shell-midden will not be commonly enough.

Very numerous shell-middens have been found around the present bays and paleobays of Paranaguá, Guaratuba and São Francisco, as well as in the Santa Catarina island and near the town of Laguna. The information derived from shell-middens, associated with other data, allowed us to establish with good precision the general trends of the relative sea-level changes during the last 7,000 years along the States of Paraná and Santa Catarina coastal plains.

RESUMO

Obviamente um sambaqui não é a melhor evidência para a reconstrução de antigos níveis marinhos no espaço e no tempo. Entretanto, em áreas costeiras submetidas à submersão seguida

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por emersão, informações interessantes e mesmo imprescindíveis podem ser fornecidas pelos sambaquis, quando outros dados são escassos. Portanto, posições e tendências de flutuação dos níveis relativos do mar podem ser obtidas das seguintes informações: a) posição geográfica do sambaqui em relação a mares e lagunas atuais, b) natureza e idade do substrato sobre o qual foi construído o sambaqui, c) altitude do substrato do sambaqui em relação ao atual nível de maré alta, d) momentos de início e término da ocupação do sítio, bem como possíveis momentos de abandono e reocupação, e) valores de $\delta^{13}\text{C}$ (PDB) de conchas carbonáticas, f) espécies dominantes de conchas de moluscos, g) tamanho do sambaqui, etc. Além disso, nem todos os sambaquis fornecem informações interessantes e somente uma datação para cada sambaqui não será suficiente.

Numerosos sambaquis foram encontrados nas margens de baías atuais e paleobaías nas áreas de Paranaguá, Guaratuba e São Francisco, bem como na Ilha de Santa Catarina e próximo a cidade de Laguna. As informações fornecidas pelos sambaquis, juntamente com outros dados, permitiram estabelecer com boa precisão as tendências gerais de variações dos níveis relativos do mar durante os últimos 7.000 anos ao longo das planícies costeiras de Paraná e Santa Catarina.

INTRODUCTION

Artificial accumulations made up of shells of brackish-water and marine organisms are very frequently found in coastal areas around the world.

In coastal areas of Brazil, between the States of Rio de Janeiro and Rio Grande do Sul, several hundreds of giant shell-middens (locally known as sambaquis according to indian terminology) have been built up by ancient inhabitants of these areas whose basic food was shellfish (Martin and Suguio, 1976; Martin et al., 1982).

It may be assumed that site occupation was decided primarily by near occurrence of shellfish in sufficient quantity to provide nourishment over a long period of time. Obviously, shallow and quiet water bay bottoms, lagoonal and estuarine zones, with muddy surface areas exposed during low tides, would have been more favourable than sandy areas at the open ocean margin. In the former case, biological productivity is much higher. It is probable that paleoinhabitants chose campsites above high-tide level, immediately adjacent to favourable collecting grounds, where the best conditions of comfort and safety were found. In this case one may assume an important relationship between the shell-midden's position and the presence of shallow-marine, lagoonal or estuarine zone in the vicinity. Ecological investigation of the dominant mollusc species found in the shell-midden will indicate the paleo-environmental conditions of the surrounding area.

While it is relatively easy to establish the geographic relationship between the shell-midden's position and a nearby ancient lagoon, estuary or bay, it is much more difficult to establish the vertical relationship between the altitude of the base of the shell-midden and the position of sea-level during its construction. We can only assume that initially it was above local High-Water Spring Tide (H.W.S.T) level, a very important assumption for interpreting shell-middens whose substrates are located beneath present H.W.S.T. A detailed investigation of the shell-midden's substrate and composition may provide some criteria to eliminate the possibility of shell-middens having been built up below H.W.S.T. Probably, this is the case with shell-middens originated as wastedumps (mixture of shells and man-made artifacts) below houses which were built on poles standing in shallow-water during high-tides. Furthermore, when the shell-midden is situated near lowland (ancient lagoonal area) we must assume, as a postulate, that its construction occurred near the mollusk collecting area. From these two assumptions, proximity of the collecting zone and construction above local H.W.S.T. level, it is possible to establish a rather close relationship between geographic position of shell-middens and ancient sea-levels.

INFORMATION TO BE DERIVED FROM SHELL-MIDDENS

a) Geographic situation

In coastal areas subjected to a submergence period followed by emergence, like in Brazil, shell-middens located further inland were probably associated with a period of maximum lagoonal extent, obviously when the maximum sea-level occurred.

b) Size

In general, the more inland shell-middens are smaller than those situated near the present strandline. In fact, maximum lagoonal extension periods were very short and only in the external lagoonal zones the time of favourable conditions was sufficiently long to allow the construction of huge shell-middens.

c) Faunal composition

About fifty different species of mollusks have been identified within the shell-middens of the Brazilian coast (Bigarella, 1949 and 1954), but the most dominant species are very few:

Anomalocardia brasiliana sp.
Ostrea brasiliana sp.
Ostrea arborea Chemnitz

Lucina jamaicensis Chemnitz
Modiolus brasiliensis Chemnitz

Except for *Ostrea 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. Some shell-middens are composed practically of one species and others show a mixed composition. *Ostrea* sp. and *Modiolus brasiliensis* are dominant species within more inland shell-middens, and in this case *Anomalocardia brasiliensis* is very scarce or completely absent. On the other hand, shell-middens situated nearer to the open-sea are formed almost entirely of *Anomalocardia*.

d) $^{12}\text{C}/^{13}\text{C}$ ratios of carbonate shells

$\delta^{13}\text{C}$ (PDB) measurements for 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 $\delta^{13}\text{C}$ (PDB) values between those for freshwater ($\approx 13\text{‰}$) and those for marine organisms ($\approx 0\text{‰}$). At the same time, the $\delta^{13}\text{C}$ (PDB) values for carbonate shells from a lagoon change as a function of their geographic situation within the lagoon (Flexor et al., 1979). Shells from outer zones (nearer the open-sea of a lagoon) only show slightly negative $\delta^{13}\text{C}$ (PDB) values, while those from inner zones are clearly characterized by more negative values. In the latter case, carbon derived from decomposition of land plants has been certainly incorporated by the molluscs within their carbonate shells. Deeper and inner portions of the lagoons are characterized by a poor water circulation that propitiates an accumulation of large quantities of plant-derived organic matter. This is independent of water salinity and explains why the carbonate shells of lagoonal organisms exhibit $\delta^{13}\text{C}$ (PDB) values characterized by a strong land influence. Conversely, at the same locality, but at different moments, the $\delta^{13}\text{C}$ (PDB) values change according to the increase or decrease of the lagoonal area. In such case, this parameter will be a good indicator of the lagoonal oscillations and thus indirectly of sea-level fluctuations (Martin et al., 1985).

Taking into consideration the example in Figure 1, it is quite possible to find at "A", "B" and "C" shell-middens of similar age but with quite different $\delta^{13}\text{C}$ (PDB) values for carbonate shells being, for example, very negative in "A" and slightly negative in "C". On the other hand, while in "B" and "C" shell-middens exhibit different ages, the least negative ^{13}C (PDB) values correspond to periods of greatest lagoonal extent and vice-versa.

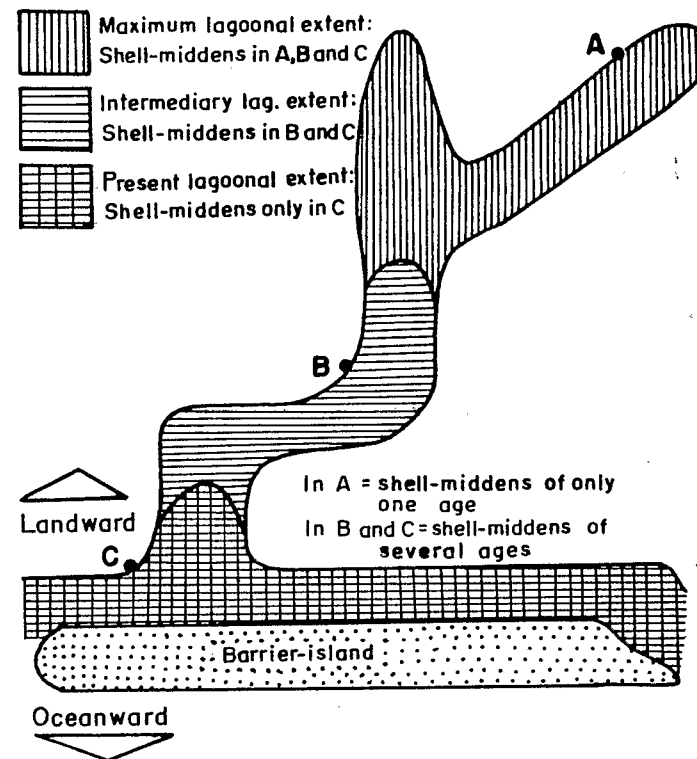


Figure 1. Variations of shell-midden's ages as a function of changes in lagoonal extensions, along the Brazilian coast, during the Holocene.

e) Dated portion of shell-midden

If the basal and central portion has been dated, it is possible that the obtained age corresponds to the beginning of the site occupation. On the other hand, if the dated sample comes from the shell-midden's surface, we can know the end of the site occupation.

In more inland shell-middens the duration of the site occupation could correspond to the maximum lagoonal extent and then to high sea-level period. If we can establish the end of the site occupation, this probably corresponds to the lagoonal desiccation, that is low sea-level period, and the reoccupation could be related to another high sea-level period.

f) Types of substrates

Pleistocene marine terraces - This situation corresponds to shell-middens located on these terraces at the margins of zones

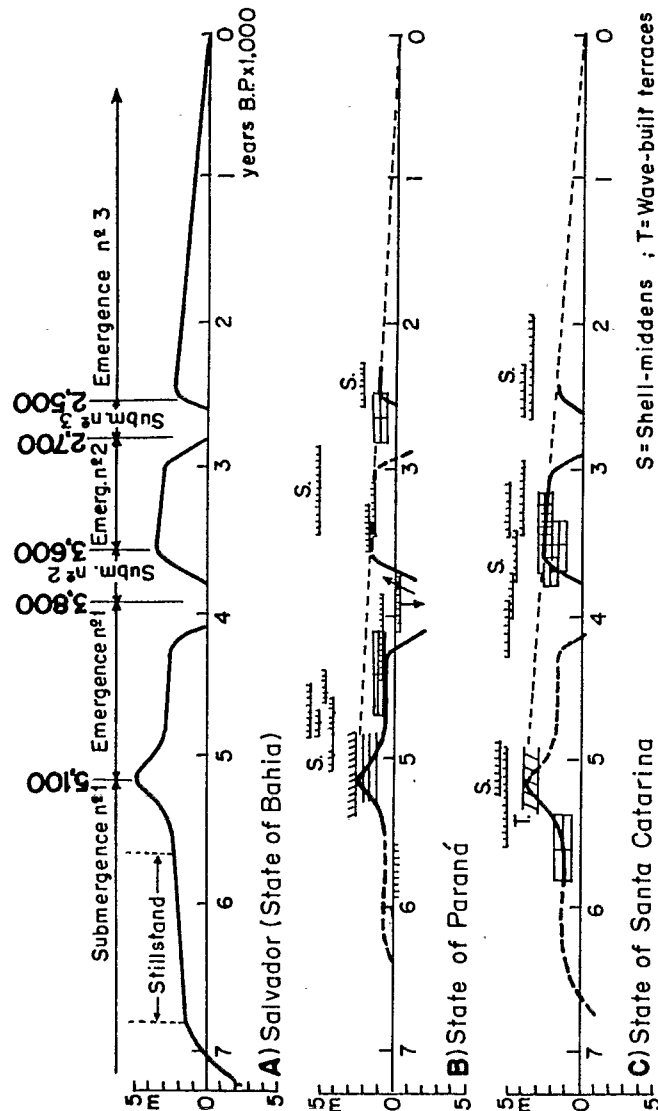


Figure 2. Sea-level fluctuation curves during the last 7,000 years in the Salvador area (State of Bahia), and along the States of Paraná and Santa Catarina.

formerly or presently occupied by lagoons. Among these we must look for the shell-middens constructed during the Holocene maximum lagoonal extent period.

Holocene marine terraces - These shell-middens have necessarily been constructed after the Holocene maximum sea-level stands, and in some cases their positions on the terraces can provide additional data on sea-levels.

Ancient lagoonal deposits - They are located on these deposits in front of sandy marine terraces. Hence, they must have been constructed after a period of high sea-level, probably during the ensuing lowering of sea-level. One must be cautious because the substrate of lagoonal organic clays is liable to have been subjected to compaction, thus diminishing the height of the midden's base.

Crystalline rocky hills - These shell-middens are located at the margins or centers of ancient lagoons or bays, and their ages are very changeable. However, those situated more inland may have been constructed when the lagoon reached its greatest extent.

RELATIVE SEA-LEVEL FLUCTUATIONS DURING THE LAST 7,000 YEARS ALONG THE EASTERN/SOUTHEASTERN BRAZILIAN COAST

Relative sea-level fluctuation curves for the last 7,000 years have been constructed for several sectors of the Brazilian coast (Martin et al., 1979, 1980 and 1983; Suguio et al., 1980). These curves indicate that:

- Present-day mean sea-level was surpassed for the first time about 6,500-7,000 years BP;
- By about 5,100 years BP sea-level had risen to about 4-5 m above the today's mean sea-level;
- At about 3,800 years BP, sea-level experienced a lowstand and was positioned slightly below today's mean sea-level;
- At 3,600 years BP. sea-level rose to 2.5-3.5 m above today's level;
- At 2,700 years BP, sea-level experienced again a lowstand dropping slightly below present-day mean sea-level;
- By about 2,500 years BP, a third highstand was reached. At this time sea-level rose 2-2.5 m above today's mean sea-level, and since then it has been progressively dropping.

In summary, it is possible to recognize along the eastern/southeastern Brazilian coast, during the Holocene, three main phases of submergence (7,000-5,100 years BP; 3,800-3,600 years BP and 2,700-2,500 years BP) separated by three main emergence periods (5,100-3,800 years BP; 3,600-2,700 years BP and 2,500 years BP to the present - Figure 2a).

RECONSTRUCTION OF THE RELATIVE SEA-LEVELS DURING THE LAST 7,000 YEARS ALONG THE STATES OF PARANA AND SANTA CATARINA COASTLINES

1 STATE OF PARANA COASTAL PLAIN

In straight line the State of Paraná coastal plain is less than 100 km long. The reconstruction of ancient sea-levels for the last 7,000 years was insufficient to delineate a fluctuation curve with a great precision. Nevertheless, some information allowed us to establish a suitable average curve.

a) Altitude of maximum Holocene high sea-level

In Paranaguá bay the summit of outer portion of Pleistocene marine terrace (Rio do Maciel, Ilha do Mel, etc) is situated about 2.5 m above the present high-tide level. Alignments of sandy ridges are clearly visible on the surface of these terraces and, then, the maximum Holocene high sea-level has never been higher than 2.5 m above the present level.

b) First episode of high sea-level

In Paranaguá area there are narrow lowlands carved in Pleistocene marine terraces, with the same orientation of ancient sandy ridges, presently drained by tidal channels (Rio Itibere, Rio dos Almeida, Rio Guaraguaçu and Rio do Maciel). In these lowlands, carved in Pleistocene terraces, we find paleolagoonal deposits with mollusc shells recording ancient high sea-levels above the present level. A sample collected at the border of Rio Guaraguaçu indicated an age of $5,400 \pm 230$ years BP (Bah, 1271). The $\delta^{13}\text{C}$ (PDB) value ($+ 0.86\text{‰}$) of this sample suggests a continental influence practically absent, showing that they lived under conditions of high sea-level.

In the Rio Saí Guaçu area, mollusc shells sampled from paleolagoonal deposits were dated as $5,820 \pm 220$ years BP (Bah 1279). Bigarella (1975) also dated mollusc shells from paleolagoonal deposits recording ancient high sea-levels:

- Guaratuba (sample Bi-5)..... $5,770 \pm 150$ y. BP
- Rio Vermelho (Praia do Leste)..... $5,690 \pm 200$ y. BP
- Rio Boguaçu (Guaratuba: Bi-4)..... $4,390 \pm 300$ y. BP

These ages suggest that between 5,800 years BP and 4,400 years BP, approximately, the sea-level was higher than it is today but not having crossed 2.5 m above the present level.

Numerous shell-middens found in this region supply with some interesting additional information. Mollusc shells from the shell-midden of Rio Cacatu (n° 17 of Bigarella, 1950), the innermost of the Paranaguá region, have been dated as $5,050 \pm$

220 years BP (Bah. 1392). The geographic position of this shell-midden indicates that its construction would have been possible only during the maximum lagoonal extent corresponding to the maximum elevation of the sea-level. As the dated shells were collected near the surface of the shell-midden, this age probably indicates the end of site occupation. Several mollusc shells sampled from different levels of the shell-midden of Rio São Joao (n° 11 of Bigarella, 1950), situated at the margin of ancient Baía de Nhundiaquara, indicated the following ages:

Sampling level in relation to shell-midden's surface	Ages (years BP)
125 - 150 cm	$4,960 \pm 110$ (Si. 1022)
150 - 200 cm	$4,810 \pm 100$ (Si. 1023)
175 cm	$4,670 \pm 90$ (Si. 1024)
Base	$4,890 \pm 210$ (Bah. 1393)

Above listed ages suggest that the site occupation began about 5,000 years BP. On the other hand, it appears that this site has been abandoned about 4,700 years BP, when the relative sea-level probably lowered, propitiating the desiccation of the lagoon and provoking the migration of the inhabitants. Shell-middens of Gomes and Saguarema (n° 11 and 10 of Bigarella, 1950) also supplied with very interesting data. They are situated one another at very short distance, but they have been constructed under different conditions. The shell-midden of Gomes is situated on Pleistocene sandy terrace at a border of an ancient lagoonal zone. Probably, at the beginning of installation of the shell-midden the relative sea-level has been above present level and the area in front of it was occupied by a lagoon. Several mollusc shells sampled from different levels have been dated by Rauth (1968), as follow:

Sampling level in relation to shell-midden's surface	Ages (years BP)
25 - 75 cm	$4,490 \pm 140$
100 - 150 cm	$4,490 \pm 80$
250 - 300 cm	$4,860 \pm 70$
Base	$4,890 \pm 70$

These ages suggest that the site occupation began between 5,000 and 4,900 years BP. It has been abandoned about 4,500 years BP as a consequence of relative sea-level drop.

The shell-midden of Saguarema rests on lagoonal deposits situated in front of Pleistocene marine terrace above which the shell-midden of Gomes was constructed. The first idea is that the site of Saguarema has been occupied after that of Gomes. In fact, it is possible that due to sea-level drop the site of Gomes became less interesting and the inhabitants

dislocated to stay nearer to the harvesting place of the molluscs which they used for their nourishment. Several samples collected from different levels have been dated by Rauth (1962) as follow:

Sampling levels in relation to shell-midden's surface	Ages (years BP)
100 - 150 cm	4,060 [±] 70
200 cm	3,900 [±] 70
680 cm	4,310 [±] 70
800 cm	4,070 [±] 70
850 cm	4,370 [±] 70

It seems that the site was occupied between 4,400 years BP (perhaps before this time, because mollusc shells from the basal portion were not dated) and 4,000 years BP. Similarly, it is possible that, as a consequence of relative sea-level drop about 4,000 years BP, this site became less interesting and was abandoned.

c) Indication of relative sea-level change between 4,000 and 3,600 years BP

In Caiobá area, Bigarella (1975) dated mollusc shells sampled from clayey-silty deposits situated below the present sea-level and covered by littoral sands. This sample, contained within a transgressive sequence, was dated as 3,830[±]120 years BP. Then, it is possible to assume that about 3,800 years BP, the relative sea-level was below present sea-level and was rising until reaching the maximum level. Several other radiocarbon ages obtained near this area provided other interesting additional information.

The shell-midden of Joao Godo (n° 29 of Bigarella, 1950) was studied by Rauth (1969) from an archeological viewpoint. It is located in Antonina area and was constructed on crystalline rocks surrounded by emerged lagoonal deposits. Several samples collected from different levels were dated as follow:

Sampling levels in relation to shell-midden's surface	Ages (years BP)
100 - 125 cm	2,980 [±] 130 (Si. 1026)
150 - 200 cm	3,000 [±] 90 (Si. 1027)
225 - 250 cm	3,360 [±] 80 (Si. 1028)
225 - 250 cm	3,300 [±] 90 (Si. 1028A)
Interruption	
250 - 300 cm	4,740 [±] 90 (Si. 1029)

As it is indicated above, the radiocarbon ages suggest that

there was an interruption in the site occupation. In fact, it appears that this site was occupied about 4,800 years BP for the first time and reoccupied between 3,300 and 3,000 years BP. The first abandonment of this site was probably related to sea-level drop, followed by the reoccupation by about 3,300 years BP when the surrounding area was drowned once again, and the second abandonment occurred due to sea-level drop after 3,000 years BP.

The shell-midden of Macedo (n° 52 of Bigarella, 1950) also provided interesting data. This shell-midden was studied by Hurt and Blasi (1960) from an archeological viewpoint. It is located on a sandy terrace whose summit is about 1.6 m above the present high-tide level. This terrace is situated in front of Pleistocene marine terrace. Between the Pleistocene terrace and the shell-midden site there are lagoonal deposits formed when the sea-level was higher than it is today. Probably, the ancient inhabitants harvested their nourishment from this paleolagoon. Then, the sea-level was about 1.6 m above the present sea-level. Several samples collected from different levels indicated the following ages:

Sampling levels in relation to shell-midden's surface	Ages (years BP)
75 - 125 cm	3,310 [±] 60 (P. 482)
125 - 225 cm	3,340 [±] 60 (P. 483)
225 - 275 cm	3,270 [±] 50 (P. 485)
275 - 325 cm	3,370 [±] 60 (P. 486)
325 - 400 cm	3,280 [±] 60 (P. 487)
400 - 475 cm	3,360 [±] 70 (P. 488)
475 - 550 cm	3,420 [±] 60 (P. 489)
550 - 650 cm	3,500 [±] 60 (P. 500)
Near the base	3,670 [±] 180 (Bah. 1265)

These ages suggest that this site was occupied between 3,600 years BP and 3,300 years BP.

Two shell-middens from Rio Boguaçu (Baía de Guaratuba, State of Paraná), corresponding to n° 50 and 51 of Bigarella (1950), supplied with very interesting additional data. The shell-midden n° 51 reposes on an island formed of lagoonal deposits. At the river margin shell-midden has been eroded, showing that in this place its substrate is submerged (below present sea-level). Mollusc shells collected at present sea-level have been dated as 3,920[±]190 years BP (Bah. 1272). The $\delta^{13}\text{C}$ (PDB) value of these shells was -3.56‰. The shell-midden n° 50 is located about 1,200 m from n° 51, and is situated on lagoonal deposits whose summit is about 1.3 m above the present sea-level. Mollusc shells sampled from the lower portion (not on the base) of the shell-midden were dated as 3,290[±]190 years BP (Bah. 1273), and $\delta^{13}\text{C}$ (PDB) value was -0.6‰. This value is clearly less negative than that of n° 51. Flexor et al..

(1979) demonstrated that $\delta^{13}\text{C}$ (PDB) value is a good indicator for lagoonal oscillations; thus, it is possible to conclude that about 3,300 years BP the land influence was much less important than about 3,900 years BP and, consequently, the relative sea-level was higher in the former case than in the latter case. So, a sea-level rise was produced between 3,900 and 3,300 years BP, but this elevation could be higher than 1.3 m above the present level.

Mollusc shells sampled from lagoonal deposits of a paleo-lagoonal area occurring at south of the shell-middens n° 50 and 51 have been dated as $3,160 \pm 170$ years BP (Bah. 1277) and $2,970 \pm 170$ years BP (Bah. 1278). As these shells were practically collected from the surface levels it is possible to conclude that the paleolagoon was desiccated about 3,000 years BP after a relative sea-level drop.

- d) Indication of relative sea-level change between 3,000 and 2,500 years BP

The shell-midden of Ilha das Rosas (Baía de Antonina, State of Paraná) gave some information about this oscillation which has also been evidenced in other sectors of probably below the present level between 3,000 and 2,500 years BP.

- A third high sea-level occurred before 2,500 years BP.

2 STATE OF SANTA CATARINA COASTAL PLAIN

Ancient sea-level reconstructions during the last 7,000 years for the State of Santa Catarina coastal plain were insufficient to delineate a fluctuation curve for several sectors of restricted dimensions. Nevertheless, we obtained a certain pieces of information which allowed us to have a good knowledge of the relative sea-level changes for the last 7,000 years in this sector of the Brazilian coast.

- a) First episode of high sea-level

The downstream portion of the Rio Itajaí-Açu valley is occupied by a sandy marine terrace presenting conspicuous alignments of ancient beach-ridges. Within inner portion of this terrace, at the margin of the river, we studied an outcrop which furnished very important data. At the base of the outcrop there are lagoonal and/or bay bottom clayey deposits. Mollusc shells sampled from these sediments have been dated as $5,580 \pm 240$ years BP (Bah. 1290). These deposits are covered by shallow marine sands. The lower portion of this terrace corresponds to a transgressive phase and the upper part with the sandy ridges to a regressive phase. Between these two phases, the relative sea-level was at a maximum. The lagoonal deposits record an ancient sea-level situated about 1.0 ± 0.5 m above

the present level. After 5,580 years BP the rising sea-level was at a maximum of at least 3.0 m above the present level. This level (+3 m) is indicated by the summit of this outcrop, but during the maximum it is possible that this level was slightly higher because this outcrop is not at the innermost portion of this sandy marine coastal plain.

Two shell-middens presently located about 30 and 22 km from the shoreline, within Rio Itajaí-Açu valley, provided very interesting information about the period of maximum level. In fact, due to their geographical positions, their construction could have been possible only during the maximum lagoonal extent, during the Holocene. At this epoch, the Rio Itajaí-Açu valley was a vast "ria". The shell-midden of Gaspar, situated about 30 km from the present shoreline, was studied by Piazza (1966a) from an archeological viewpoint, obtaining the following ages:

$5,320 \pm 350$ years BP (Si. 362e)

$5,270 \pm 300$ years BP (Si. 362a)

We visited another shell-midden situated about 8 km downstream from Gaspar, at the left margin of the Rio Itajaí-Açu near Ilhota village. This shell-midden is situated on ancient fluvial deposit (Pleistocene ?) at the margin of presently swampy lowland, probably representing an ancient lagoonal zone. Sample SC-16 collected from this shell-midden was dated as $5,340 \pm 210$ years BP (Bah. 1357).

Therefore, it seems logical to think that also in this area the Holocene maximum, as in other sectors of the Brazilian coast, occurred about 5,100 years BP.

- b) Second and third episodes of high sea-levels

Near Barra Velha, at the margin of Rio Itapocu, we found a very interesting outcrop. The lower portion of this outcrop, slightly above the present sea-level, is constituted by clayey deposits, which are covered by shallow marine sands. The lower portion represents a transgressive phase while the upper part corresponds to regressive phase, and the maximum level is situated between them. Wood fragments sampled from the clay have been dated as $3,520 \pm 180$ years BP, when the relative sea-level was about 1.5 ± 0.5 m above the present level. In comparison with other areas, it is possible to think that the maximum was produced about 3,600 years BP.

The shell-midden of Ponta das Almas, situated at the margin of Laguna da Conceicao (Ilha de Santa Catarina), was studied from an archeological viewpoint by both Piazza (1966b) and Hurt (1974). It is constituted by a little shell-midden "B" abutted against the principal shell-midden "A". Several trenches opened during the archeological researches allowed us to obtain a parcial profile of the shell-midden "A" and

complete profiles of the shell-midden "B" and of terrace situated between this shell-midden and the present lagoon. This shell-midden is situated partially on blocks of crystalline rocks and partially on compacted reddish coloured eolian sands. The most ancient age obtained by Piazza is $4,290 \pm 400$ years BP (Si. 222). A trench revealed an occurrence of a notch carved in eolian sands at the southern margin of the shell-midden "A". The summit of this notch is situated about 2.6 m above the present lagoonal high-tide level. Mollusc shells sampled from an ancient beach, in front of the notch, were dated as $3,620 \pm 100$ years BP (I. 2627), according to Hurt (1974). A second dating accomplished by Piazza on shells of the shell-midden "A" indicated an age of $3,690 \pm 100$ years BP (Si. ?). The mollusc shells sampled from the ancient beach could have two origins: a) They could have been reworked from the shell-midden "A" during the high sea-level which carved the notch in the eolian sand. In this case, this high sea-level could not be that of 3,600 years BP but that of 2,500 years BP; b) They could have been originated from the area where the ancient inhabitants harvested their nourishment. This area would have been emerged during low-tides and part of shells would have been transported and deposited on the beaches. This could explain similar ages indicated by the shells of the shell-midden "A" ($3,690 \pm 100$ years BP) and of the ancient beach ($3,620 \pm 100$ years BP). In this case the erosional notch could have been carved in eolian sands during high sea-level of 3,600 years BP. This hypothesis was reinforced by the fact that Hurt evidenced the existence of another high sea-level period after that of notch erosion, when relative sea-level was about 2.0 ± 0.5 m above the present level. This high sea-level occurred before $2,400 \pm 250$ years BP (Si. 111). In fact, this age could correspond to the site reoccupation.

In summary, it is possible that:

- About 4,300 years BP the site was already occupied;
- The lagoonal level (= sea-level) was at a maximum situated 2.6 ± 0.5 m above the present level about 3,600 years BP;
- The shell-midden site was abandoned, for the first time, during a certain unknown epoch, probably due to relative sea-level drop;
- Before $2,400 \pm 250$ years BP, with the site reoccupation, the lagoonal level was once again elevated until a maximum situated 2.0 ± 0.5 m above the present level.

The shell-midden of Carnica, studied from an archeological viewpoint by Hurt (1974), is constituted by two joined shell-middens. The most important was named Carnica "I" and the subsidiary one was designated Carnica "IA". They have been established upon lagoonal deposits partially covered by eolian sands. In areas which are not covered by eolian sands it is possible to see some alignments of sandy ridges on aerial

photos, which probably correspond to ancient lagoonal shore-lines.

The excavations accomplished by Hurt (1974) showed that the lagoonal sediments situated below the shell-midden contain bank of shells, some one in life position (closed valves). Three radiocarbon ages of these shells indicated the following:

$3,300 \pm 150$ years BP (L. 1164B)
 $3,350 \pm 110$ years BP (I. 2620)
 $3,400 \pm 150$ years BP (L. 1164)

Mollusc shells and charcoals sampled from different levels of the same profile gave the following ages:

Height above the shell-midden's base	Ages (years BP)
530 cm	$3,210 \pm 150$ (A. 917) shell
380 cm	$3,370 \pm 150$ (A. 918) charcoal
380 cm	$3,370 \pm 100$ (A. 919) shell
60 cm	$3,310 \pm 150$ (A. 912) shell

Another sample collected 0.5 m below the surface of another profile has been dated as $3,040 \pm 50$ years BP (A. 883/2). It appears that the site began to be occupied about 3,300 years BP; was interrupted about 3,000 years BP probably as a consequence of accentuated sea-level drop. Similarly, it seems that the lagoonal deposits which constitute the shell-midden's substrate, have been eroded during a new period of relative sea-level elevation. The principal shell-midden was partially eroded and the collapsed shells were spread on the beach surface by the waves. During the maximum of high sea-level period, the lagoonal level was situated about 0.5 m below the preceding high-level period. Mollusc shells sampled from a hearth-stone directly upon the lagoonal terrace within the shell-midden "IA" were dated as $2,460 \pm 110$ years BP (A. 959). It seems that this site was reoccupied after this epoch which must correspond approximately to the maximum of the last high sea-level. Another sample collected from near the top of the principal shell-midden indicated an age of $2,250 \pm 100$ years BP (A. 914).

Finally, near this place, there is a lagoonal terrace very rich in mollusc shells whose summit is situated below the terrace upon which the shell-middens were constructed. Sample collected from near the top of this terrace was dated as $2,500 \pm 170$ years BP (Bah. 1380). At this moment the sea-level must have been situated 2.0 ± 0.5 m above the present level.

In summary, it is possible that:

- About $3,400 \pm 150$ years BP the sea-level was dropping and was situated 2.5 ± 0.5 m above the present level;

- The first occupation of the Carnica occurred between 3,300 and 3,000 years BP. It would seem that this site was then abandoned as a consequence of important relative sea-level drop;

- At about 2,500 years BP, the relative sea-level rose once again and at that time it was situated 2.0 ± 0.5 m above the present level, propitiating the site reoccupation:

Based on this information and on that previously obtained from other sectors of the Brazilian coast, it is possible to reconstruct the relative sea-level fluctuations during the Holocene along the State of Santa Catarina coastline as follow (Figure 2c):

- The relative sea-level cut the present level for the first time about 6,500 years BP;

- About 5,100 years BP the relative sea-level was at the first maximum situated about 3.5 m above the present level;

Between 4,100 and 3,800 years BP the sea-level was probably below the present level;

- About 3,600 years BP the relative sea-level was at the second maximum situated about 2.5 ± 0.5 m above the present level;

- Between 2,900 and 2,700 years BP the relative sea-level was probably below the present level;

- About 2,500 years BP, the relative sea-level was probably at the third maximum situated 2.0 ± 0.5 m above the present level.

CONCLUSIONS

In spite of the fact that shell-middens are not the best indicator of ancient relative sea-level positions, they can contribute with interesting additional data in coastal areas subjected to submergence followed by emergence. In general, the accurate position of ancient sea-level at the beginning of shell-midden's construction is unknown but one can deduce whether it was higher or lower than today. Similarly, it is possible to estimate the fluctuation trend through the time.

Therefore, even in the coastal plains of the States of Paraná and Santa Catarina, where only few geological and biological ancient sea-level evidence has been recorded, it was possible to delineate accurate relative sea-level fluctuation curves owing to information derived from shell-middens, very abundant in the area. The curves show close resemblance with those of previously studied sectors of the Brazilian coast, but they are remarkably shifted downward.

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