Radiocarbon, Vol 56, Nr 2, 2014, p 489–499 DOI: 10.2458/56.16954

CHRONOLOGICAL MODEL OF A BRAZILIAN HOLOCENE SHELLMOUND (SAMBAQUI DA TARIOBA, RIO DE JANEIRO, BRAZIL)

K D Macario[1,7] • R C C L Souza[2] • D C Trindade[3] • J Decco[3] • T A Lima[4] • O A Aguilera[5] • A N Marques[5] • E Q Alves[1] • F M Oliveira[1] • I S Chanca[1] • C Carvalho[6] • R M Anjos[1] • F C Pamplona[5] • E P Silva[2]

ABSTRACT. Since the beginning of the Holocene, hunter-gatherers have occupied the central-south Brazilian coast, as it was a very productive estuarine environment. Living as fishers and mollusk gatherers, they built prehistoric shellmounds, known as *sambaqui*, up to 30 m high, which can still be found today from the Espírito Santo (21°S) to Rio Grande do Sul (32°S) states, constituting an important testimony of paleodiversity and Brazilian prehistory. The chronology of the Sambaqui da Tarioba, situated in Rio das Ostras, Rio de Janeiro, is discussed herein. Selected well-preserved shells of *Iphigenia brasiliana* and charcoal from fireplaces in sequential layers were used for radiocarbon dating analysis. Based on a statistical model developed using OxCal software, the results indicate that the settlement occupation begun most probably around 3800 cal BP and lasted for up to 5 centuries.

INTRODUCTION

In the central-south Brazilian coast, the Holocene faunal assemblage, sea-level changes (Suguio et al. 1985, 1991; Angulo and Lessa 1997; Angulo et al. 1999, 2006, 2007; Dias 2009; Dias et al. 2009), and long-term oscillation of coastal upwelling intensity (Carbonel 1998; Castelao and Barth 2006; Mahiques et al. 2010) are closely related to the human occupation. Therefore, archaeological information provides an alternative data set that allows to better understand the past, building a baseline for time-depth climatic and environmental interpretation, and shedding light on the impact of modern civilization on the environment (Lotze et al. 2006). Therefore, this study on the early human settlement, the pristine environment, and the biodiversity patterns for a given locality in the Brazilian coast will be informed by a radiocarbon data set for evaluating the time-depth occupation and environmental changes in the Holocene.

The best *in situ* testimonies for prehistoric chronology research in the Brazilian coast are the archaeological sites known as shellmounds (*sambaquis*). They are prehistoric mounds of discarded edible mollusks. It is now well established that the Sambaquis are not only archaeological funerary places but also habitation settlements, with evidence of diverse activities (food processing, artifacts manufacturing, habitation structures). Most Brazilian shellmounds date from 6000 to 2000 cal BP (Prous 1992; Gaspar 1996; Lima 1999/2000; Wagner et al. 2011), with a few dates up to 9000 cal BP (Lima et al. 2002). These shellmounds were mainly studied under the scope of archaeological research (e.g. Von Ihering 1903; Gliesch 1930; Fróes de Abreu 1932; Leonardos 1938). The early

1. Instituto de Física, Universidade Federal Fluminense, Av. Gal. Milton Tavares de Souza, s/n, Niterói, 24210-346 RJ, Brazil.
2. Laboratório de Genética Marinha e Evolução, Instituto de Biologia, Depto. de Biologia Marinha, Universidade Federal Fluminense, Outeiro São João Batista, s/n, Niterói, 24001-970 RJ, Brazil.
3. Instituto Brasileiro de Pesquisas Arqueológicas, Rua Marques de Leão, 53 Engenho Novo, 20780-140, Rio de Janeiro, 20785-060 RJ, Brazil.
4. Departamento de Antropologia, Museu Nacional Universidade Federal do Rio de Janeiro, Quinta da Boa Vista s/n, São Cristóvão, Rio de Janeiro, 20940-40 RJ, Brazil.
5. Departamento de Biologia Marinha, Instituto de Biologia, Outeiro São João Batista, s/n, Universidade Federal Fluminense, Niterói, 24001-970 RJ, Brazil.
6. Departamento de Geoquímica, Instituto de Química, Outeiro São João Batista, s/n, Universidade Federal Fluminense, Niterói, 24001-970 RJ, Brazil
7. Corresponding author. Email: kitamacario@gmail.com.

Proceedings of the Radiocarbon and Archaeology 7th International Symposium
Ghent, Belgium, April 2013 | Edited by Mark Van Strydonck, Philippe Crombé, and Guy De Mulder

occupation of the coast is probably related to the environmental conditions and high productivity of the coastal ecosystem. The extinction of shellmound builders is associated with the arrival of inland populations with an agriculture-based culture and warrior characteristics (Macario et al. 2009).

Shellmounds are characterized as artificial accumulations of seafood remains, mostly comprising seashell, blue crabs, croakers, sharks, and rays (Mello and Coelho 1989; Heredia et al. 1989; Lima 1991; Figuti 1993; Figuti and Klökler 1996; De Masi 2001; Souza et al. 2003, 2010a; Santos and D'Incao 2004; Scheel-Ybert et al. 2009; Hilbert and Lucena 2010; Klokler et al. 2010; Gernet and Birckolz 2011).

Mollusk fauna in shellmounds are abundant and diverse, comprising 124 taxa in Rio de Janeiro (Souza et al. 2010b), 77 in Santa Catarina (Klokler et al. 2010; Souza et al. 2011), 87 in São Paulo (Souza et al. 2011), 59 in Paraná (Gernet and Birckolz 2011; Souza et al. 2011), and 30 in Rio Grande do Sul (Souza et al. 2011). *Anomalocardia brasiliana* (Gmélin, 1791) is the most frequent and abundant species (Souza et al. 2010a,b, 2011, 2012). In addition to mollusks, the *sambaquis* have great quantities of fish bones and, eventually, otoliths placed along well-defined archaeostratigraphic sections during prehistoric occupation. Therefore, these shellmounds have a great potential for ^{14}C dating studies, and are a source to better understand not only human occupation but environmental changes in the Brazilian coast during the Holocene.

Brazilian shellmounds are located in diverse places along more than 2000 km within the central-south coast (Figure 1), numbering hundreds in the states of Rio de Janeiro (RJ), São Paulo (SP), Paraná (PR), Santa Catarina (SC), and Rio Grande do Sul (RS) (Wagner et al. 2011). In Santa Catarina, some shellmounds reach monumental size, representing landscape constructions along the coast and reflecting cultural building processes (DeBlasis et al. 2007; Villagran et al. 2011). Less documented shellmounds are reported from Pará (PA) in northern Brazil (Silveira and Schaan 2005).

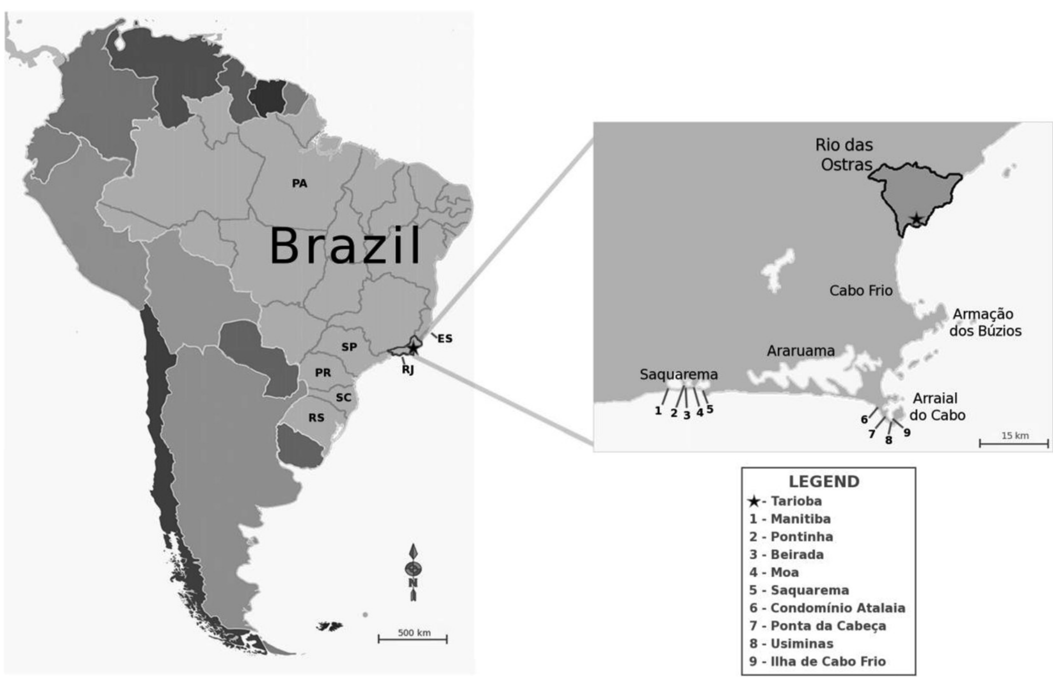

Figure 1 Map showing the studied region in the southeastern Brazilian coast and some shellmound localities including Sambaqui da Tarioba (denoted with a star symbol).

The object of this research, Sambaqui da Tarioba, was previously studied by Dias (2001) within the framework of an archaeological project in Rio das Ostras, and based on the hypothesis of a long-term occupation ranging from 4000 to 2000 BP. Currently, the original context is destroyed and the adjacent landscape modified. Many shellmounds have been dated, based on various sample materials (charcoal, shell, or bone), under the scope of different research groups and supported by independent laboratories and technical analysis.

The history of ^{14}C analysis of Brazilian shellmounds is a consequence of the available tools for chronological support in the archaeological research, most of them based on foreign analytical services. Absolute ages, without statistical models or result calibrations, have been generally published in inaccessible papers and/or used in unpublished dissertations. In such contributions, critical reviews of these chronologies were minimized and the real context (such as sample number, type of specimens, and the analytical method) was poorly tested, lacking rigorous control.

The ^{14}C chronology has recently been summarized by Guimarães (2007) for the *sambaquis* of the Saquarema lagoon complex, and from the Arraial do Cabo region by Tenorio et al. (2010), both in the Rio de Janeiro State. These data were arranged in a schematic diagram, enabling observation and comparison of the supposed occupational periods, dating for the upper and lower archaeofacies, and exceptional sequence layers used for chronology (Figure 2).

The goal of this contribution is to use the Sambaqui da Tarioba as a model for ^{14}C dating analysis, in order to integrate the comprehensive data set and build a chronological panorama of early prehistoric occupation during the Holocene, as well as interpret them in a perspective of the climatic changes undergone in the southeastern Brazilian coast area. We thus discuss the chronology of the Sambaqui da Tarioba based on a statistical model developed with the OxCal software (Bronk Ramsey 2009).

MATERIALS AND METHODS

Geological and Oceanographic Setting

The extensive Brazilian sandy coast is characterized by large Holocene sediment deposits, which originated from reworked siliciclastic materials (Mahiques et al. 2010). ^{14}C analyses from Holocene deposits, generally based on faunal samples from natural sandy beaches, are limited due to the reworking conditions and the absence of a well-defined stratigraphy, resulting in uncertain long-term chronological information for paleoclimatological research. Over the years, riverine flows have exported these deposits. The action of littoral current and eolic energy has transported these sediments, forming sandy beaches, estuarine areas, deltas contours, tidal platforms, and marginal lagoons. Shellmound deposits, on the other hand, present alternative sources for environmental data, since faunal material including mollusk shell and fish otoliths (carbonate) is contextualized and appropriate for ^{14}C dating along a well-defined archaeostratigraphic section during prehistoric occupation.

Sambaquis can be found on the Quaternary coastal plain in the municipality of Cabo Frio, Rio de Janeiro State, Brazil. Inner and outer lagoons systems were isolated from the Atlantic Ocean by a sandy bar formed during Quaternary sea-level fluctuations. According to Martin et al. (1997), the geological evolution of this coastal plain occurred between 7000 and 5100 cal BP. Quaternary deposits in Cabo Frio overlap the Pliocene/Pleistocene post-Barreira Formation, characterized by varied clays and conglomerates sandy lenses (Martin et al. 1997; Fonseca 1998).

The Brazilian southeastern continental shelf was occupied by the South Atlantic Central Water transported by the Brazilian Current Waters (Memery et al. 2000), characterized by high temperatures ranging from 22° to 27°C and salinity of 36.5 to 37.0, respectively. The coastal region in south

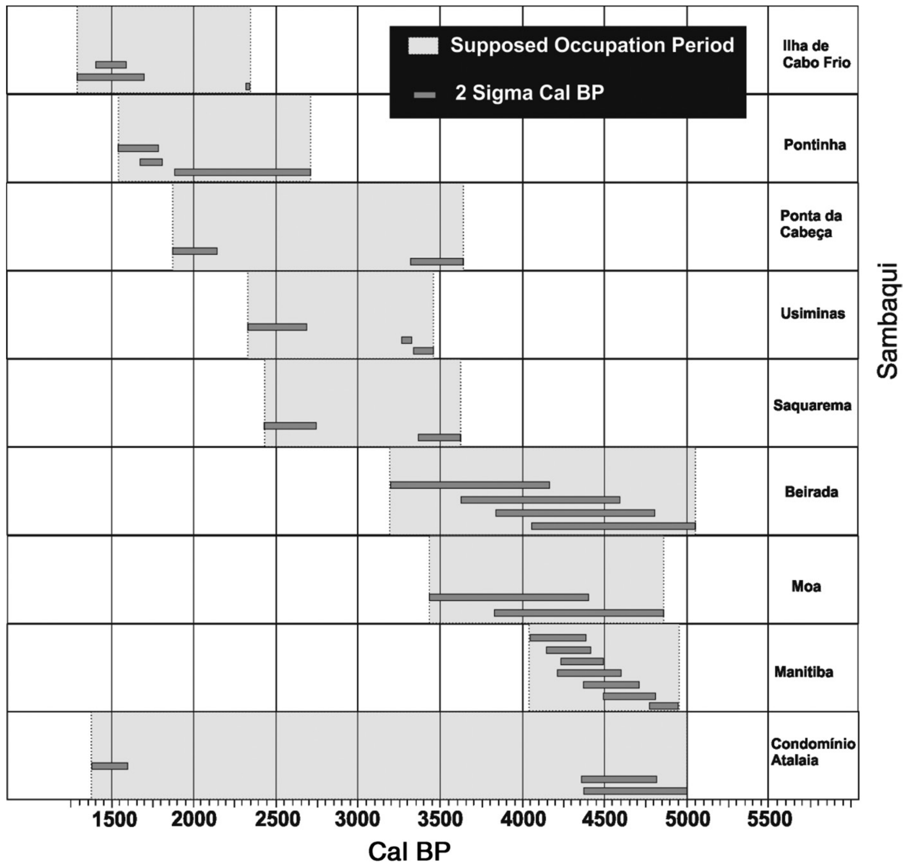

Figure 2 Schematic diagram showing *sambaqui* chronological data from the Saquarema lagoon complex and Arraial do Cabo region (based on Guimarães 2007; Tenorio et al. 2010).

Cabo Frio exhibits a strong cross-shelf sea surface temperature gradient, reflecting the influence of persistent coastal upwelling of relatively cold waters (18° to 16°C). This phenomenon occurs especially during the austral spring and summer, when the strength of the northeast winds is more intense (Castro and Miranda 1998; Castelao and Barth 2006; Carrière et al. 2009). The upwelling intensity is highest around the Cabo Frio region extending 150–400 km from Arraial do Cabo (Coelho-Souza et al. 2012).

2.2. Sampling

The Sambaqui da Tarioba is located in Rio das Ostras (22°31′40″S, 41°56′22″W), Rio de Janeiro state, Brazil (Figure 1). All necessary permissions have been obtained from the Instituto do Patrimônio Histórico e Artístico Nacional (IPHAN) for this study, which complied with all relevant regulations. The excavation method has followed the formal archaeological field protocol of Scheel-Ybert (2005–2006). It consisted of two section holes with 1 m^2 (UFF-T0-1 and UFF-T0-2), reaching the natural strata at 110 and 120 cm deep, respectively. Bulk samples were collected each 10 cm, and almost two tons of sediment were recovered from the two main sections and examined. Each bulk sample was sieved with 4-mm mesh, and the mollusk shells, crustacean decapod dactyls, fish bones and otoliths, shark and ray teeth, and human and animal bones picked from the samples and washed with current water. Selected well-preserved shells of *Iphigenia brasiliana* (Lamarck, 1818) in sequential layers were used for ^{14}C dating analysis. The sandy matrix surrounding the specimens was removed and cleaned with fine-tipped dental tools and a brush. Specimen numbers are provided below, with complete repository information including collection name and geographic location.

Archaeofacies Sections

Archaeofacies from the sectors T-01 and T-02 were characterized by the presence of fine- to medium-grained sand interbedded with shell valves, bone remains, wood fragments, and charcoal. The context is a massive shell valve accumulation on dark sandy matrix, rich in organic detritus, without a natural stratification. Five artificial successive layers were established in the excavation of sector T-01: S1: poorly friable sediment, with black soil, many fragmented shells, and concretions of hearth remains; S2: friable sediment, with black soil, many fragmented shells, and concretions of hearth remains; S3: many shells, animal and human bones, otoliths, shell artifacts, and pigments; S4: many shells, animal and human bones, otoliths, shell and bone artifacts, and various pigments; S5: the amount of shells increased significantly in the first 5 cm, where sediment was black soil. The Tarioba sector T-02 has three artificial layers: S1: poorly friable sediment, with black soil, shells, fish bones and otoliths, animal bones, and many present-day materials (such as nails, glass, and bricks); S2: many shells, both whole and ground, friable fine sediment, animal and human bones, shell artifacts, quartz river stone (used as beaters), and otoliths. This layer has an intrusion (S3) that can be observed in Figure 4. It is important to note that from the homogeneity of this layer it is possible to conclude that it belongs to a single depositional event, and not from a long-term (over centuries) slow deposition; S4: sediment from hearth with charcoal and sparse concretions within the whole level following archaeological layer arrangement, which is settled over a basal yellow sand (Figures 3 and 4). The artificial occupational layers are randomly deposited; therefore, it is possible that these strata could be reworked over time as a result of rebuilding of the shellmound, ceremonial burial activity, erosion, and sandy dune deposition. In this sense, the layers are not strictly horizontal and sequential. This conclusion is based on field observations and the fact that the two sectors that are spatially very close display slight differences in the layer arrangement.

Experimental Procedure

Sets of three individual shell samples were measured from each sampling spot. Two groups of 11 specimen samples were prepared and analyzed at the Physics Institute of the Universidade Federal Fluminense, while the third group was sent to Beta Analytic (Miami, USA) for comparison. Additionally, four charcoal samples were measured. At the Radiocarbon Laboratory (LAC-UFF), the shell samples were chemically treated with 0.5M HCl to remove the outer layer, which could be contaminated. For each set of samples, calcite blanks and IAEA C2 carbonate were prepared as control samples. Phosphoric acid was injected with a syringe into evacuated vials to obtain CO_2. For charcoal samples, acid-base-acid (ABA) treatment was used with 1M hydrochloric acid and 1M sodium hydroxide. Pretreated organic samples were combusted in prebaked quartz tubes containing silver powder and cupric oxide at 900°C for 3 hr in a muffle oven. The reference materials used were IAEA C5 wood and C6 sucrose and reactor graphite was used as the chemistry and combustion blanks. The gas was purified by means of dry-ice/ethanol traps in the graphitization line (Macario et al. 2013). Graphitization was performed using the zinc/titanium hydrate method with iron catalyst (Xu et al. 2007). Individual torch-sealed tubes were heated at 520°C for 7 hr in a muffle oven. Graphitized samples were pressed in each of the 40-cathode wheels of the SNICS ion source and measured in a 250kV single stage accelerator system (SSAMS). The isotopic fractionation was corrected by measuring the $\delta^{13}C$ on-line in the accelerator. Background was measured using processed calcite blanks for carbonate samples and processed graphite for organic samples. Graphite and calcite processed blanks yielded average $^{14}C/^{13}C$ ratios of 6×10^{-13} and 7×10^{-13}, respectively.

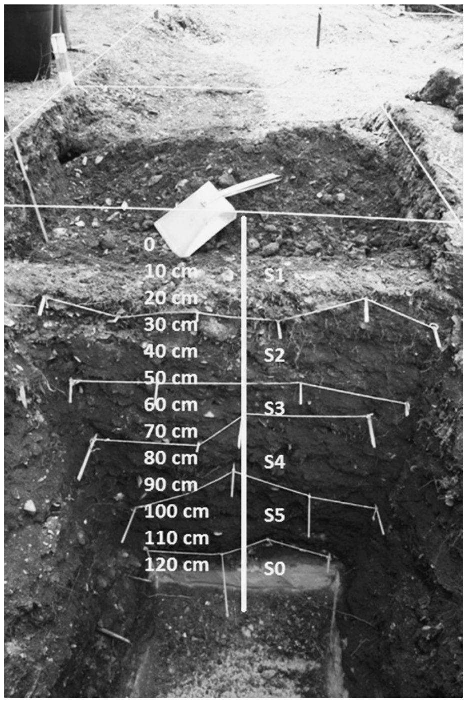

Figure 3 Stratigraphic layers at sector T-01 of Sambaqui da Tarioba with identified depths.

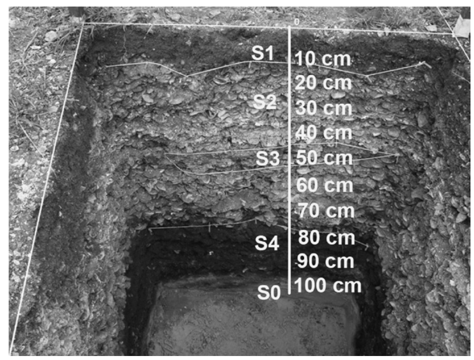

Figure 4 Stratigraphic layers at sector T-02 of Sambaqui da Tarioba with identified depths.

Average machine background was 10^{-13} for unprocessed graphite. Accuracy was checked by measuring reference materials within the 2σ range of consensus values. Calibration was performed with OxCal software (Bronk Ramsey 2009) using the Marine13 calibration curve (Reimer et al. 2013) with an offset of 8 ± 17 yr (Angulo et al. 2005) to account for local corrections for shell samples and the Southern Hemisphere atmospheric curve SH13 (Hogg et al. 2013) for charcoal samples.

RESULTS AND DISCUSSION

Sets of three individual shells specimens from 11 spots among the two studied sectors were measured, one at Beta Analytic (sample set a) and two at the LAC-UFF (sample sets b and c). Four charcoal samples were measured. The ^{14}C dates obtained are presented in Table 1 along with laboratory codes.

The ^{14}C dates from the Tarioba sector T-01 show that archaeofacies were not deposited in a regular depth sequence, once older layers are found mixed in younger strata. In the same way, shells from the same depths showed a spread in dates. These results can be interpreted as a reworking of the material that was accumulated during settlement or burial activities. The dates from the Tarioba sector T-02 show a more uniform archaeostratigraphic layering without evidence of aberrant disturbed sediment.

Terrestrial samples results are in good agreement with shell samples results provided that calibration was performed with the SH13 atmospheric curve and Marine13 marine curve, respectively. In order to obtain probability distributions for the beginning and end of the occupation, a sequential model was used considering two assumptions. First, the sand layer was considered as the natural pre-occupational phase register, which limits the occupational period. Therefore, the model takes into account that shells from the base layer (S0) show a complete absence of cultural activity, which de-

Table 1 Radiocarbon dates and sample spot locations. ID starting with a letter c denotes charcoal samples. All other samples are from individual shells.

Laboratory code	^{14}C age (BP)	Sample ID (sector/layer/group)	Depth (cm)
BETA-335464	3720 ± 30	T1S0A	
LACUFF-13033	3743 ± 26	T1S0B	110–120
LACUFF-13044	4127 ± 24	T1S0C	
BETA-335465	3860 ± 40	T1S1A	
LACUFF-13028	3391 ± 26	T1S1B	0–10
LACUFF-13039	3800 ± 49	T1S1C	
BETA-335466	3670 ± 30	T1S2A	
LACUFF-13029	3747 ± 62	T1S2B	30–40
LACUFF-13040	3533 ± 29	T1S2C	
LACUFF-13045	3172 ± 33	CT1S2	40
BETA-335467	3660 ± 30	T1S3A	
LACUFF-13030	3567 ± 50	T1S3B	50–60
LACUFF-13041	3654 ± 32	T1S3C	
BETA-335468	3810 ± 30	T1S4A	
LACUFF-13031	3567 ± 27	T1S4B	80–90
LACUFF-13042	3968 ± 31	T1S4C	
BETA-335469	3780 ± 40	T1S5A	
LACUFF-13032	3507 ± 22	T1S5B	100–110
LACUFF-13043	3979 ± 35	T1S5C	
BETA-335470	3910 ± 30	T2S0A	
LACUFF-12046	3710 ± 68	T2S0B	120–130
LACUFF-13038	3729 ± 35	T2S0C	
BETA-335471	3740 ± 30	T2S1A	
LACUFF-12047	3588 ± 65	T2S1B	10–20
LACUFF-13034	4043 ± 26	T2S1C	
LACUFF-13047	3479 ± 38	CT2S2	35
BETA-335472	3620 ± 30	T2S2A	
LACUFF-12045	3692 ± 68	T2S2B	40–50
LACUFF-13035	3852 ± 31	T2S2C	
LACUFF-13048	3561 ± 53	CT2S3A	60
BETA-335473	3810 ± 40	T2S3A	
LACUFF-12043	3662 ± 64	T2S3B	60–70
LACUFF-13036	3510 ± 36	T2S3C	
LACUFF-13046	3420 ± 61	CTS3B	75
BETA-335474	3820 ± 40	T2S4A	
LACUFF-12048	3662 ± 66	T2S4B	80–90
LACUFF-13037	3473 ± 25	T2S4C	

fines dating obtained from there as the beginning of pre-occupational times (Figures 3 and 4). Secondly, the top layer was disregarded due to the fact that some of the dates obtained therein probably originated from recent human activities in the area, including mixing with the disposal material from the first excavation done in the site. Therefore, the statistical model can give a calibrated chronological sequence that predicts pristine condition (base), prehistoric occupational time and shellmound construction phase, and final phase marked by ending of activities and abandonment of the site.

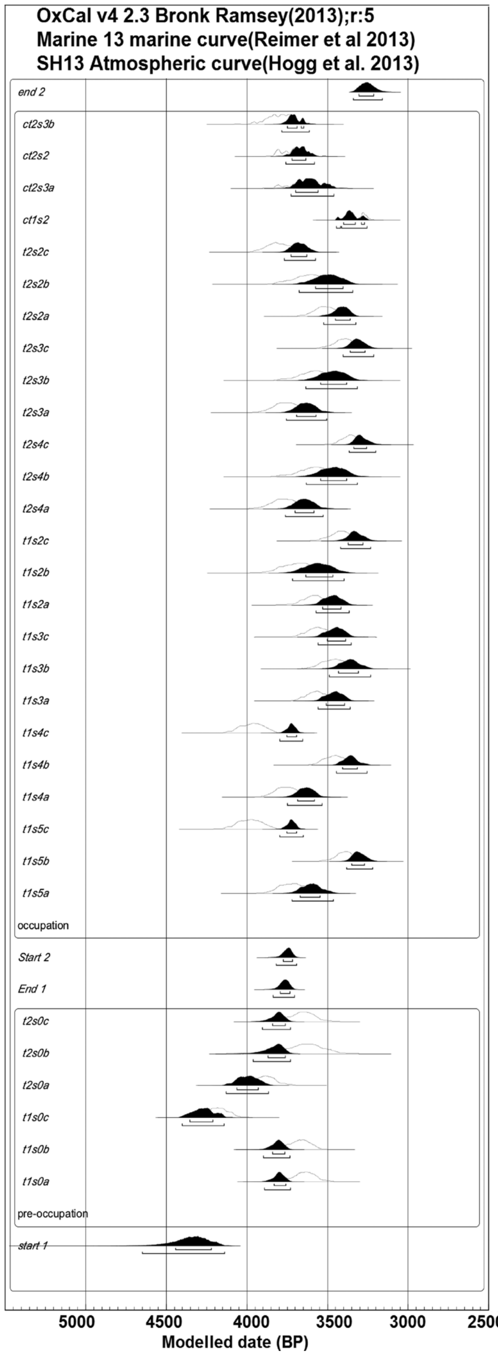

Figure 5 Calibration model using OxCal v 4.2.3 Bronk Ramsey (2009); marine data from Reimer et al. (2013) and Southern Hemisphere atmospheric data from Hogg et al. (2013).

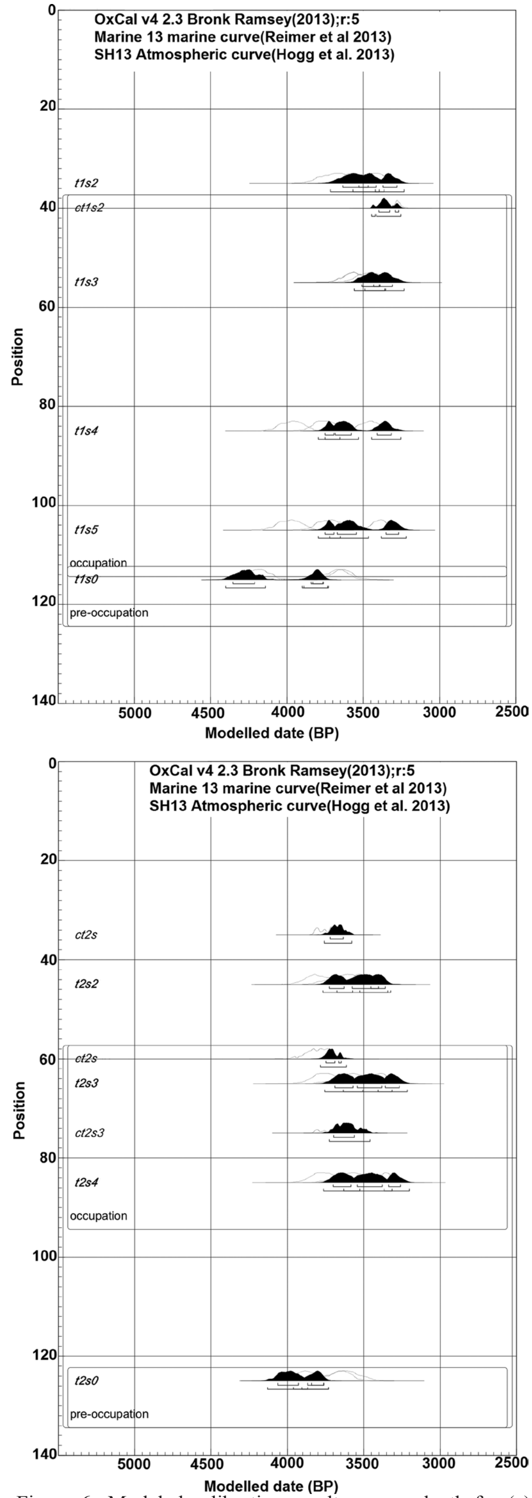

Figure 6 Modeled calibration results versus depth for (a) sector T-01(top) and (b) sector T-02 (bottom).

Results from the obtained probability distributions indicate, within a 2σ range, dates for the beginning and end of occupation of the site between 3818–3691 and 3339–3160 cal BP, respectively (Figure 5). Therefore, the occupation probably lasted for up to 5 centuries and was contemporaneous with other shellmounds in the region. Figure 6 shows both of the studied sectors, with depth and sampling spots indicated.

Analysis of the malacological remains from the excavations carried out at the Tarioba shellmound led to the identification of 47 taxa. Based on Rios (1994), the representativeness of mollusk diversity found at Tarioba was analyzed using the percentage of bivalve and gastropod species in relation to the total number of species recorded for Brazil (6.76%) and for the state of Rio de Janeiro (10.2%). The data obtained from Tarioba indicate little or no evolution of the patterns of composition, richness and distribution of molluskan biodiversity in the Rio das Ostras region (Souza et al. 2010).

Concerning the absolute chronology, it is important to note that shell samples can always be affected by reservoir effects, especially in upwelling regions, where different waters masses meet. Despite the fact that the analysis done here used a marine curve to calibrate the results, and even though a supposed offset of 8 ± 17 yr was taken into account for local corrections, it is still desirable to have comparisons with terrestrial samples. Therefore, the results of charcoal samples are important in order to establish a more accurate chronology. The observed results for charcoal samples are in good agreement with the shell sample results, indicating no major divergence between terrestrial and marine calibrated results or among individual shells from the same archaeofacies within the studied period. On the other hand, a more detailed study of paired samples from each layer of other shellmounds with longer occupational periods could identify and clarify possible variations through time.

CONCLUSIONS

A chronology of the Sambaqui da Tarioba was established based on the study of shells from the mollusk *Iphigenia brasiliana* as well as from charcoal samples obtained at different layers from two excavated sectors in this shellmound. ^{14}C AMS analyses were used in a sequential chronology model developed with OxCal. Results from the obtained probability distribution allowed predicting an occupation time not exceeding 500 yr for this site, with dates ranging between 3818–3691 cal BP (beginning of occupation) and 3339–3160 cal BP (occupation ending). Molluskan biodiversity results have shown no significant differences from the present pattern. Shells from the mollusk *Iphigenia brasiliana* demonstrated good results, and to be a good candidate for reservoir effect comparisons in the studied region.

ACKNOWLEDGMENTS

The authors would like to thank CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico,) CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior), FAPERJ (Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro), and PRONEX (Programa de Apoio a Núcleos de Excelência) for financial support.

REFERENCES

Angulo RJ, Lessa GC. 1997. The Brazilian sea-level curves: a critical review with emphasis on the curves from the Paranagua and Cananeia regions. *Marine Geology* 140(1–2):141–66.

Angulo RJ, Giannini PCF, Suguio K, Pessenda LCR. 1999. Relative sea-level changes in the last 5500 years in southern Brazil (Laguna-Imbituba region, Santa Catarina State) based on vermetid ^{14}C ages. *Marine Geology* 159(1–4):323–39.

Angulo RJ, Souza MC, Reimer PJ, Sasaoka SK. 2005. Reservoir effect of the southern and southeastern Brazilian coast. *Radiocarbon* 47(1):67–73.

Angulo RJ, Lessa GC, de Souza MC. 2006. A critical review of mid- to late-Holocene sea-level fluctuations on the eastern Brazilian coastline. *Quaternary Science Reviews* 25(5–6):486–506.

Angulo RJ, Reimer PJ, de Souza MC, Scheel-Ybert R, Tenorio MC, Disaro ST, Gaspar MD. 2007. A tentative determination of upwelling influence on the paleosurficial marine water reservoir effect in southeastern Brazil. *Radiocarbon* 49(3):1255–9.

Bronk Ramsey C. 2009. Bayesian analysis of radiocarbon dates. *Radiocarbon* 51(1):337–60.

Carbonel C. 1998. Modelling of upwelling in the coastal area of Cabo Frio (Rio de Janeiro - Brazil). *Revista Brasileira de Oceanografia* 46:1–17.

Carrière O, Hermand JP, Calado L, de Paula AC, Silveira ICA. 2009. Feature-oriented acoustic tomography: upwelling at Cabo Frio (Brazil). *Proceedings of OCEANS '09 MTS/IEEE Biloxi Conference - Marine Technology for Our Future*: Global and Local Challenges: Marine Technology Society, IEEE. p 1–8.

Castelao RM, Barth JA. 2006. Upwelling around Cabo Frio, Brazil: the importance of wind stress curl. *Geophysical Research Letters* 33(3): L03602.

Castro BM, Miranda LB. 1998. Physical oceanography of the western Atlantic continental shelf located between 4°N and 34°S - coastal segment 4. In: Robinson AR, Brink KH, editors. *The Sea*. New York: John Wiley & Sons. p 209–51.

Coelho-Souza SA, López MS, Guimaraes JRD, Coutinho R, Candella RN. 2012. Biophysical interactions in the Cabo Frio upwelling system, Southeastern Brazil. *Brazilian Journal of Oceanography* 60(3):353–65.

DeBlasis P, Kneip A, Scheel-Ybert R, Giannini PCF, Gaspar MD. 2007. Sambaquis e paisagem: dinâmica natural e arqueologia regional no litoral do sul do Brasil. *Arqueologia Sul-Americana* 3(1):29–61.

De Masi MAN. 2001. Pescadores coletores da costa sul do Brasil. *Pesquisas* (sér. Antropologia) 57:1–136.

Dias O. 2001. O Sambaqui da Tarioba. In: Dias O, Decco J, Fróes MM, editors. *Pré-história de Rio das Ostras: sítio arqueológico Sambaqui da Tarioba*. Rio das Ostras: Fundacao Rio das Ostras de Cultura. p 110.

Dias FF, Seoane JC, Castro JW. 2009. Evolução da linha de praia do Peró, Cabo Frio, RJ nos últimos 7.000 anos. *Anuário do Instituto de Geociências*, *UFRJ* 32(1):9–20.

Dias FF. 2009. Variações o nível relativo do mar na planície costeira de Cabo Frio e Armação dos Búzios, RJ: Reconstrução paleoambiental holocênica e cenários futuros [PhD thesis]. Niterói: Universidade Federal Fluminense. 147 p.

Figuti L. 1993. O homem pré-histórico, o molusco e os sambaquis: considerações sobre a subsistência dos povos sambaquieiros. *Revista do Museu de Arqueologia e Etnologia de São Paulo* 3:67–80.

Figuti L, Klökler D. 1996. Resultados preliminares dos vestígios zooarqueológicos do sambaqui Espinheiros II (Joinville, SC). *Revista do Museu de Arqueologia e Etnologia de São Paulo* 6:169–87.

Fonseca MJG. 1998. *Mapa geológico do estado do Rio de Janeiro*. Rio de Janeiro: DNPM. 141 p.

Fróes de Abreu S. 1932. A importância dos sambaquis no estudo da prehistória do Brasil. *Revista da Sociedade de Geografia* 35:3–15.

Gaspar MD. 1996. Análise das datações radiocarbônicas dos sítios de pescadores, coletores e caçadores. *Boletim do Museu Paranaense Emílio Goeldi* 8:81–91.

Gernet M, Birckolz CJ. 2011. Fauna malacológica em dois sambaquis do litoral do Estado do Paraná, Brasil. *Biotemas* 24(3):39–49.

Gliesch R. 1930. Sobre a origem dos sambaquis. *Egatea* 17(3):199–208.

Guimarães MB. 2007. A ocupação pré-colonial da região dos Lagos, RJ: sistema de assentamento e relações intersocietais entre grupos sambaquianos e grupos ceramistas Tupinambá e de tradição Una [PhD thesis]. São Paulo: Universidade de São Paulo. 382 p.

Heredia OR, Tenório MC, Gaspar MD, Buarque A. 1989. Environment exploitation by prehistorical population of Rio de Janeiro. In: Neves C, editor. *Coastlines of Brazil*. New York: American Society of Civil Engineers. p 230–39.

Hilbert LM, Lucena CA. 2010. Análise ictioarqueológica dos sítios: Sambaqui do Recreio, Itapeva e Dorva, Municípios de Torres e Três Cachoeiras, Rio Grande do Sul, Brasil. *V Mostra de Pesquisa da Pós-Graduação – PUCRS*. Programa de Pós-Graduação em Zoologia, Faculdade de Biociências, PUCRS.

Hogg AG, Hua Q, Blackwell PG, Niu M, Buck CE, Guilderson TP, Heaton TJ, Palmer JG, Reimer PJ, Reimer RW, Turney CSM, Zimmerman SRH. 2013. SHCal13 Southern Hemisphere calibration, 0–50,000 years cal BP. *Radiocarbon* 55(4):1889–903.

Klokler D, Villagrán XS, Giannini PCF, Peixoto S, Deblasis P. 2010. Juntos na costa: zooarqueologia e geoarqueologia de sambaquis do litoral sul Catarinense. *Revista do Museu de Arqueologia e Etnologia de São Paulo* 20:53–75.

Leonardos OH. 1938. *Concheiros naturais e sambaquis*. Papéis Avulsos, Departamento Nacional da Produção Mineral, Serviço de Fomento da Produção Mineral. p 1–109.

Lima TA. 1991. Dos mariscos aos peixes: um estudo zooarqueológico de mudança de subsistência na pré-história do Rio de Janeiro [PhD thesis]. São Paulo: Universidade de São Paulo.

Lima TA. 1999/2000. Em busca dos frutos do mar: os pescadores- coletores do litoral centro-sul do Brasil. *Revista da USP* 44:270–327.

Lima TA, Macario KD, Anjos RM, Gomes PS, Coimbra MM, Elmore D. 2002. The antiquity of the prehistoric settlement of the central-south Brazilian coast. *Radiocarbon* 44(3):733–8.

Lotze HK, Lenihan HS, Bourque BJ, Bradbury RH, Cooke RG, Kay MC, Kidwell SM, Kirby MX, Peterson CH, Jackson JBC. 2006. Depletion, degradation, and recovery potential of estuaries and coastal seas. *Science* 312(5781):1806–9.

Macario KD, Buarque A, Scheel-Ybert R, Anjos RM, Gomes PRS, Beauclair M, Hatté C. 2009. The long-term Tupiguarani occupation in southeastern Brazil. *Radiocarbon* 51(3):937–46.

Macario KD, Gomes PRS, Anjos RM, Carvalho C, Linares R, Alves EQ, Oliveira FM, Castro MD, Chanca IS, Silveira MFM, Pessenda LCR, Moraes LMB, Campos TB, Cherkinsky A. 2013. The Brazilian AMS Radiocarbon Laboratory (LAC-UFF) and the intercomparison of results with CENA and UGAMS. *Radiocarbon* 55(2):325–30.

Mahiques MM, Sousa SIHDM, Furtado VV, Tessler MG, Toledo FAD, Burone L, Figueira RCL, Klein DA, Martins CC, Alves DP. 2010. The southern Brazilian shelf: general characteristics, Quaternary evolution and sediment distribution. *Brazilian Journal of Oceanography* 58:25–34.

Martin L, Suguio K, Domingues JML, Flexor JM. 1997. *Geologia do Quaternário costeiro do litoral norte do Rio de Janeiro e Espírito Santo*. Belo Horizonte: CPRM. 112 p.

Mello EMB, Coelho AS. 1989. Moluscos encontrados no sambaqui de Camboinhas, Itaipu, Niterói, estado do Rio de Janeiro, Brasil. *Memórias do Instituto Oswaldo Cruz* 84(4):377–80.

Memery L, Arhan M, Alvarez-Salgado XA, Messias MJ, Mercier H, Castro CG, Rios AF. 2000. The water masses along the western boundary of the south and equatorial Atlantic. *Progress in Oceanography* 47(1):69–98.

Prous A. 1992. *Arqueologia Brasileira*. Brasília: Editora Universidade de Brasília.

Reimer PJ, Bard E, Bayliss A, Beck JW, Blackwell PG, Bronk Ramsey C, Grootes PM, Guilderson TP, Haflidason H, Hajdas I, Hatté C, Heaton TJ, Hoffmann DL, Hogg AG, Hughen KA, Kaiser KF, Kromer B, Manning SW, Niu M, Reimer RW, Richards DA, Scott EM, Southon JR, Staff RA, Turney CSM, van der Plicht J. 2013. IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP. *Radiocarbon* 55(4):1869–87.

Rios EC. 1994. *Seashells of Brazil*. Rio Grande: Museu Oceanográfico Prof. E.C. Rios da Fundação Universidade de Rio Grande.

Santos CRMD, D'Incao F. 2004. Crustáceos no cerrito Ariano Souza, Rio Grande, Rio Grande do Sul e distribuição de Callinectes sapidus (Brachyura, Portunidae). *Iheringia*. *Série Zoologia* 94:73–6.

Scheel-Ybert R, Klokler D, Gaspar MD, Figuti L. 2005–2006. Proposta de amostragem padronixada para macrovestigios bioaqueológicos: antracologia, arqueobotanica, zooarqueologia. *Revista do Museu de Arqueología e Etnologia de São Paulo* 15–16:139–63.

Scheel-Ybert R, Afonso MC, Barbosa-Guimaraes M, Gaspar MD, Ybert JP. 2009. Considerações sobre o papel dos sambaquis como indicadores do nível do mar. *Quaternary and Environmental Geosciences* 1(1):3–9.

Silveira MI, Schaan DP. 2005. Onde a Amazônia encontra o mar: estudando os sambaquis do Pará. *Revista de Arqueologia* 18:67–79.

Souza RCCL, Fernandes FC, Silva EP. 2003. A study on the occurrence of the brown mussel *Perna perna* on the sambaquis of the Brazilian coast. *Revista do Museu de Arqueologia e Etnologia de São Paulo* 13:3–24.

Souza RCCL, Trindade DC, Decco JD, Lima TA, Silva EP. 2010a. Archaeozoology of marine mollusks from Sambaqui da Tarioba, Rio das Ostras, Rio de Janeiro, Brazil. *Zoologia* (Curitiba) 27:363–71.

Souza RCCL, Lima TA, Silva EP. 2010b. Holocene molluscs from Rio de Janeiro state coast, Brazil. *Check List* 6(2):301–8.

Souza RCCL, Lima TA, Silva EP. 2011. *Conchas Marinhas de Sambaquis do Brasil*. Rio de Janeiro: Technical Books.

Souza RCCL, Lima TA, Silva EP. 2012. Remarks on the biodiversity of marine molluscs from Late Holocene Brazilian shell mounds. In: Christine L, editor. *Proceedings of the General Session of the 11th International Council for Archaeozoology Conference*. Oxford: Archaeopress. p 245–56.

Suguio K, Martin L, Bittencourt ACSP, Dominguez JML, Flexor JM, Azevedo AEG. 1985. Flutuações do nível relativo do mar durante o Quaternário superior no litoral brasileiro e suas implicações na sedimentação costeira. *Revista Brasileira de Geociências* 15:273–86.

Suguio K, Martin LM, Flexor JM. 1991. Paleoshorelines and the sambaquis of Brazil. In: Johnson LL, Stright M, editors. *Paleoshorelines and Prehistory: An Investigation of Method*. Boca Raton: CRC Press. p 83–99.

Tenorio MC, Afonso MC, Pinto D. 2010. Arqueología do Arraial do Cabo com foco nos sítios da Ilha do Cabo Frio. *Revista do Museu de Arqueologia e Etnología, São Paulo* 20:127–45.

Villagran XS, Klokler D, Peixoto S, DeBlasis P, Giannini PCF. 2011. Building coastal landscapes: zooarchaeology and geoarchaeology of Brazilian shell mounds. *Journal of Island & Coastal Archaeology* 6(2):211–34.

Von Ihering H. 1903. A origem dos sambaquis. *Revista do Instituto Histórico e Geográfico de São Paulo* 8:446–57.

Wagner G, Hilbert K, Bandeira D, Tenorio MC, Okumura MM. 2011. Sambaquis (shell mounds) of the Brazilian coast. *Quaternary International* 239:51–60.

Xu X, Trumbore SE, Zheng S, Southon JR, McDuffee KE, Luttgen M, Liu JC. 2007. Modifying a sealed tube zinc reduction method for preparation of AMS graphite targets: reducing background and attaining high precision. *Nuclear Instruments and Methods in Physics Research B* 259(1):320–9.