Journal of Anthropological Archaeology 36 (2014) 211–227

Contents lists available at ScienceDirect

Journal of Anthropological Archaeology

journal homepage: www.elsevier.com/locate/jaa

A redefinition of waste: Deconstructing shell and fish mound formation among coastal groups of southern Brazil

Ximena S. Villagran

Institute for Archaeological Sciences, Universität Tübingen, Rümelinstrasse 23, 72070 Tübingen, Germany

ARTICLE INFO

Article history:
Received 31 July 2014
Revision received 13 October 2014

Keywords:
Geoarchaeology
Micromorphology
Stable isotope analysis
Archaeofacies analysis
Microfacies
Experimental archaeology
Shell middens
Sambaquis

ABSTRACT

The prehistory of the southern coast of Brazil (Santa Catarina state) is materialized in the present landscape by numerous large-scale shellmounds, shellmounds with a sandy core, and fishmounds. A geoarchaeological approach was applied to understand the sequence and diversity of human actions involved in the settlement of the area as expressed in the multiple mounded structures, dated from the early Holocene to shortly before the arrival of the first colonizers. A detailed account of the composition and history of four stratified shellmounds, two shellmounds with a sandy core, and two fishmounds is given using a standard method for intra and inter site comparisons. The method combines the macroscopic evaluation of the profiles with off-site sampling, provenance of the organic matter in the sediments, and micro-scale identification of components, their alteration, and arrangement. Substantial implications result from this analysis related to the identification of recurrent behaviors in shellmound formation and growth, prehistoric alteration and destruction of habitation sites, development of a built environment, and continuity in mound building as an expression of group identity. Shellmounds and fishmounds show a complex pre-depositional history that denies the traditional view of them as secondary deposits of food remains.

1. Introduction

The southern coast of Brazil was occupied since the beginning of the Holocene (ca. 9000 years ago) (Calippo, 2004; Giannini et al., 2010; Lima et al., 2002) by hunter–gatherer–fisher groups that left the most extraordinary landmark of Brazilian prehistory: the shellmounds or *sambaquis* as they are locally known. These archaeological sites are frequently stratified deposits made of shell valves, fish bone fragments, charcoal, and artifacts (lithic, on bone and on shell), among other components. Some shellmounds contain habitation structures and human burials, which led to their interpretation as multi-functional spaces (Barbosa, 2007, 2001; Gaspar, 1991); while others contain numerous human burials, no clear evidence of domestic areas and are thus interpreted solely as funerary structures (DeBlasis et al., 1998; Fish et al., 2000; Gaspar et al., 2011, 2008; Klokler, 2008; Mendonça de Souza et al., 2012).

Despite the long tradition of shellmound studies dating back to the end of the 19th century and the numerous work done in the last twenty years (Boyadjian and Eggers, 2014; Castilho, 2008; De Masi, 2001; DeBlasis et al., 2007; Eggers et al., 2008; Figuti, 1992; Gaspar, 1998; Hubbe et al., 2009; Klokler, 2008; Okumura, 2007, 2014; Rodrigues-Carvalho et al., 2009; Scheel-Ybert, 2014; Scheel-Ybert et al., 2003; Wesolowski et al., 2007), there is still sparse information on how the shellmounds were formed (i.e. the sequence and diversity of human actions involved in the process). A step forward was taken when researchers began to consider the sites as artifacts, suggested the use of shell valves as construction material, and highlighted the key role of human interments in the formation process (Afonso and DeBlasis, 1994; Figuti and Klokler, 1996; Gaspar, 2004, 1991; Klokler, 2014, 2008). In this perspective, shellmounds are not just accumulations of food debris, but meaningful structures or landmarks that were continuously used for hundreds of years. These structures provide evidence for the socio-political complexity of coastal groups, which are no longer seen as bands of nomadic shellfish gatherers, but rather as demographically dense communities with semi-sedentary or sedentary settlement patterns (DeBlasis et al., 2007, 1998; Fish et al., 2000; Gaspar et al., 2014, 2008).

The conspicuous shellmounds are not the only remnants of coastal communities. Other contemporary archaeological sites exist but have received less attention, with few exceptions (Prous, 1992; Schmitz, 1999, 1996). Such is the case of the comparably smaller shellmounds with a sandy core, which can be as old as the shellmounds and frequently appear as satellite structures (Assunçao, 2010; Peixoto, 2008) and the so-called fishmounds that

E-mail address: ximena.villagran@uni-tuebingen.de

http://dx.doi.org/10.1016/j.jaa.2014.10.002
0278-4165/

appear on the southern coast after the disappearance of shellmounds ca. 2000–1000 yrs. BP (Giannini et al., 2010; Klokler et al., 2011; Villagran et al., 2010). If we consider the diverse mounded structures as artifacts continuously produced by a social action that was widespread in the southern Brazilian coastline, understanding their formation can provide insights into the social, political, and economic organization of these societies. For this, studies must incorporate a uniform approach to reveal the similarities and differences in the prehistoric coastal settlements.

Attempts have been made to develop standard sampling methods for zooarchaeological and botanical analysis (Klokler, 2013; Scheel-Ybert, 2013; Scheel-Ybert et al., 2005; Wesolowski, 2013), for the excavation of human burials (Mendonça de Souza et al., 2013), and the description of profiles (Gaspar et al., 2013; Ramos et al., 2013). However, the use of a geoarchaeological approach that incorporates standardized soil/sediment descriptions and sampling is also necessary. Despite the great potential of a geoarchaeological perspective for stratigraphic analysis to understand mound construction (Sherwood and Kidder, 2011), the use of geoarchaeology to study shellmound formation processes has been less common. Nonetheless, sediments retain valuable information on the multiple steps of shell/fishmound formation, the activities behind this and the alteration processes during and after site abandonment.

In this paper, the focus is on a group of shellmounds and fishmounds of the southern coast of Santa Catarina state whose chronology spans from ca. 7400 yrs. BP to 700 yrs. BP. In this area, shellmounds are rich in human interments and reach monumental sizes, with hundreds of meters long and tens of meters wide, though their current size may be underestimated due to extensive mining for lime production done through the first half of the 20th century. Shellmounds with a sandy core appear as both isolated units or as accompaniments to larger shellmounds. Fishmounds are a late phenomenon frequently containing human burials and pottery sherds associated with inland groups. The sites are representative of prehistoric coastal settlements not only in Santa Catarina state, but also in other coastal areas of Brazil.

In this paper, the formation of the sites is discussed with emphasis on the history of the sediments, the selection, transport and alteration of the anthropogenic and natural particles used for mound building through hundreds and, in some cases, thousands of years. Analyses will provide a substrate for discussing daily activities, resource management, funerary events, contact with other groups, and the social significance of the mounds.

2. Shellmound formation

The traditional models proposed to explain the formation of Brazilian shellmounds were based on the center vs. periphery dichotomy. The models describe a central area of daily occupation, with huts and hearths, surrounded by a periphery where discarded food items and other debris were successively accumulated (Barbosa, 1999; Gaspar and DeBlasis, 1992; Gaspar et al., 1994; Guidon, 1964; Laming-Emperaire, 1975; Orssich, 1977; Tiburtius, 1966). The same domestic shell-ring model has been described in other shell middens of South America (Tierra del Fuego) (Orquera and Piana, 2000; Orquera, 1996; Vila et al., 2011; Villagran et al., 2011) where the sites are less than one tenth the size of many Brazilian shellmounds. Studies have shown the domestic nature of the small-scale shell middens containing actual evidence of domestic huts inside, which opposes the multi-functional or funerary use proposed for most of the large-scale Brazilian shellmounds. This attests to the conceptual constrains of the normative view (sensu Claassen, 1991) that shellmounds or middens are always secondary deposits for the accumulation of domestic food debris.

The models that emphasize the mechanical action of shellmound growth have substantial consequences for the way we conceive the formation of the sites. By considering the shellmounds as by-products of food discard, the nature of their sedimentary components (e.g. faunal remains) and their cultural significance can be overlooked. Shellmounds are an integral part of the society and artifacts of long-term production. In this sense, the formation of the shellmounds must be understood not only as resulting from discard of subsistence elements, but as a historically meaningful action with inextricable social and political significance. The vision of shellmounds as artifacts adds much to this line of thought.

Recent studies have shown that some shellmounds, especially those with a high concentration of human burials, grew from the sequential and concomitant deposition of funerary mounds following feasting activities (DeBlasis et al., 1998; Fish et al., 2000; Gaspar et al., 2013, 2011; Karl, 2000; Klokler, 2014, 2008). Similar interpretations are given for shell middens in other parts of the world, like on the coast of California and the Southeast coast of the United States (Luby and Gruber, 1999; Luby et al., 2006; Russo, 2014, 2004; Sassaman, 2008; Saunders and Russo, 2011; Saunders, 2014). Thus, shellmound interpretation has pivoted from the daily discard of food items to symbolic funerary ritual: from a secular view within prehistoric organization of space, to meaningful structures that were built to communicate a message through generations. This signals the multiplicity of perspectives required in shellmound archaeology and the complexity of their study.

By treating the sediments and the sites as artifacts, with a life history of their own, we can abstract ourselves from conceiving faunal remains exclusively as residues from everyday life (and death). This perspective incorporates in the analysis the whole diversity of sedimentary components contained in the sites, from the macro to the microscopic scale, as well as the diversity of depositional behaviors acting in the incremental events (sensu DeBlasis et al., 1998; Fish et al., 2000) responsible for mound formation and growth. In this sense, a geoarchaeological approach can provide the necessary theoretical, methodological, and technical framework for standardized stratigraphic and sediment analysis in an overall regional context. This will allow an integration of the analyses regarding the diversity of coastal sites (shellmounds, fishmounds and shellmounds with a sandy core) that synchronically and diachronically characterized the prehistoric landscape of the southern Brazilian coast.

3. Study area

The southern coast of Santa Catarina state (Fig. 1) consists of Holocene coastal lagoons that developed from a larger bay-lagoon system. The bay-lagoon existed before the maximum Holocene sea-level rise (Giannini, 1993; Giannini et al., 2007) reached the area between 5700 and 5100 years BP, or even before (according to Angulo et al. (2006, 1999)). The lagoons were the epicenter of shellmound settlement and acted as central loci for coastal communities (DeBlasis et al., 2007). In addition to being situated on the lagoon margins, shell and fishmounds are also found on rocky points, aeolian dunes and paleo-tombolos (Giannini et al., 2010). The robust chronology available for the area-thanks to the "Sambaquis and Landscape" research project, which dated more than sixty sites and produced more than one hundred radiocarbon ages-shows a continuous occupation starting from ca. 7400 BP and lasting for almost 6000 years (DeBlasis et al., 2007; Giannini et al., 2010).

Three types of sites were identified in the area: stratified shellmounds ($n = 35$); shellmounds with a sandy core ($n = 22$); and fishmounds ($n = 4$). The oldest sites are stratified shellmounds located far from the present-day coastline. Shellmounds with a sandy core and fishmounds only appear near the seacoast, and only the first

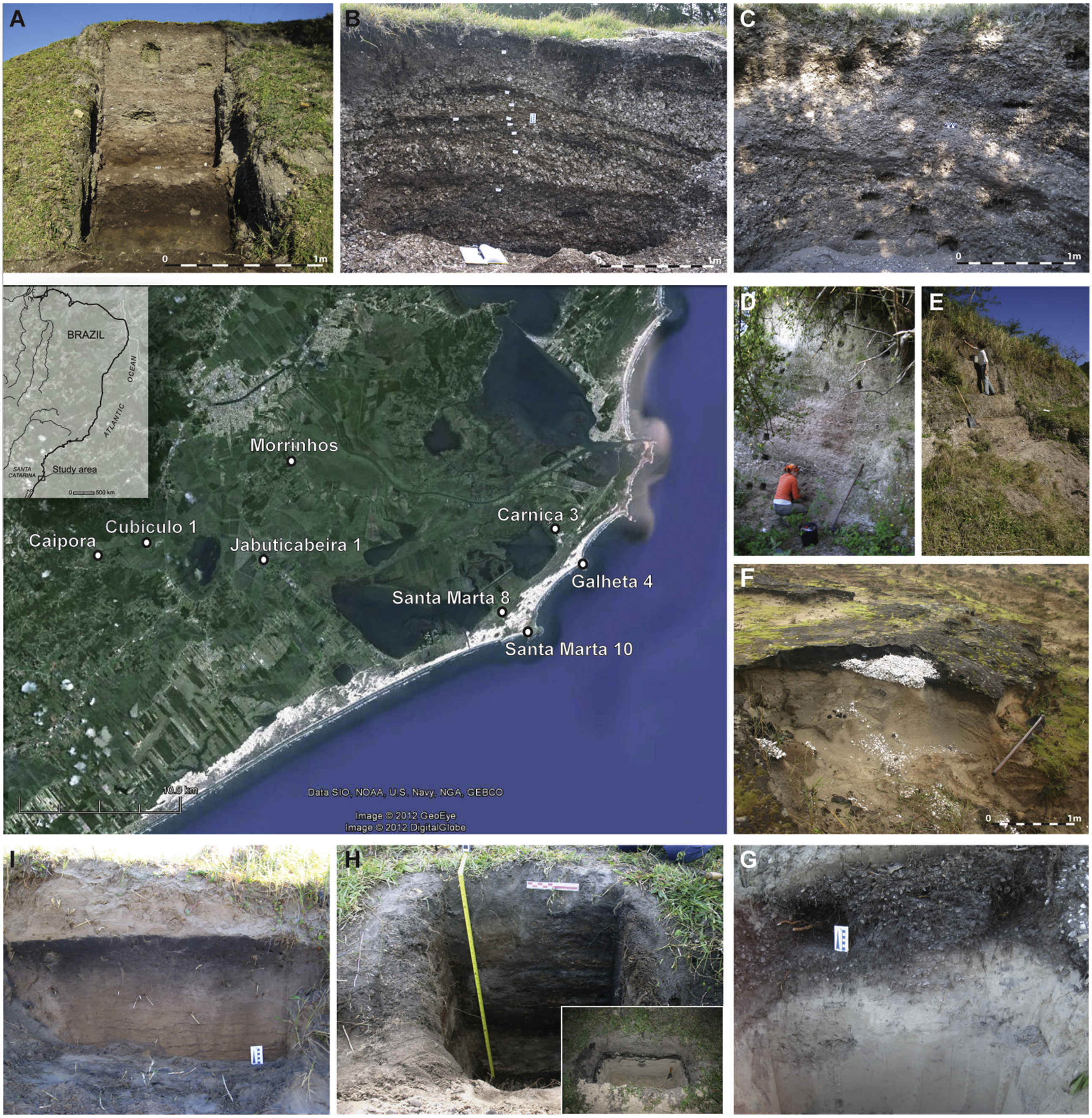


Fig. 1. Map with location of the study area and the eight sites analyzed in this work: (A) Caipora; (B) Cubículo-1; (C) Jabuticabeira-1, lower profile; (D) Jabuticabeira-1, upper profile; (E) Morrinhos; (F) Santa Marta-10; (G) Carniça-3; (H) Santa Marta-8 with detail of the off-site sample location showing loamy black layer beneath sandy sediments; (I) Galheta-4.

are contemporaneous with the stratified shellmounds. Eight sites were selected for this study (Fig. 1). Table 1 summarizes the information on site chronology, location and size. Caipora is the oldest site in the region, probably built prior to the maximum Holocene transgression on the shores of the large bay-lagoon (Fig. 1A). Cubículo-1 (Fig. 1B), Morrinhos (Fig. 1C) and Jabuticabeira-1 (Fig. 1D and E) were built already in the regression phase. Santa Marta-10 (Fig. 1F) is the oldest shellmound with a sandy core. It is made of a shell ring deposited over a dune and covered by loamy sand sediments. The sandy core at Carniça-3 (Fig. 1G) is an anthropogenic dune, as supported by sedimentological analysis (Tanaka et al., 2009), having been built with sediments taken from the beach ridges and/or eaolian deposits nearby. Santa Marta-8 (Fig. 1H) is a typical mounded and stratified deposit, while Galheta-4 (Fig. 1I) consists of a layer of sand, fish bones, and organic matter over aeolian dunes located a few meters from an area of human interments (DeBlasis and Farias, 2007).

4. Methods

The eight sites were analyzed following the method of archaeofacies analysis developed at the interface between archaeology and geosciences (following Anderton, 1985; Courty, 2001; Orquera and Piana, 1992; Stein, 1992; Walker, 1983). The method points at interpretation of the activity, or sequence of activities, associated with site formation from analysis of the stratigraphic profiles. The three main steps of archaeofacies (AF) analysis are: (1) identification of

Table 1
Information on chronology, natural substrate of site location and size of the eight sites studied. Calibration made at 2 sigma with CALIB 6.0 (Stuiver and Reimer, 1993) and SHCal04 protocol (McCormac et al., 2004). Dates taken from Giannini et al. (2010).

Site	Chronology		Substrate	Size (m)
	^{14}C age	Cal. yrs BP		
Shell mound				
Caipora	6590 ± 60	7570–7320	Pre-Cenozoic granite hill on colluvial slope	25 × 20 × 3
	5410 ± 60	6280–5950		
Morrinhos	4480 ± 60	5290–4860	Pre-Cenozoic granite hill on colluvial slope	130 × 100 × 10
	3230 ± 70	3570–3220		
Jabuticabeira-1	4185 ± 90	4859–4430	Pre-Cenozoic granite hill and Holocene paleodunes	400 × 150 × 7
	2430 ± 125	2750–2130		
Cubículo-1	3640 ± 50	4078–3716	Pre-Cenozoic granite hill on colluvial slope	550 × 150 × 8
	3500 ± 50	3845–3568		
Sandy core				
Santa Marta-10	5240 ± 70	6180–5750	Aeolian sand dunes on rocky point	10 × 10 × 0.2
Carniça-3	3360 ± 50	3810–3360	Sandspit	40 × 30 × 5
Fish mound				
Santa Marta-8	1710 ± 40	1691–1416	Paleotombolo	75 × 50 × 3
Galheta-4	980 ± 40	927–763	Aeolian sand dunes on rocky point	30 × 30 × 10

AF in the profiles following a list of depositional attributes; (2) laboratory characterization of each AF; and (3) interpretation of the properties, spatial arrangement, and relations between AF (Villagran et al., 2009). For interpretation of the results, off-site sediment samples and experimental tests are useful sources of comparative information. In essence, AF with similar characteristic (defined after field observations and laboratory analysis) can be interpreted as resulting from analogous processes. The intra and inter-site variation of AF within a site or a region demonstrates the different depositional behaviors involved in the settlement.

Bulk and undisturbed sediment samples for micromorphological and stable isotope analysis, respectively, were collected from most of the AF identified in the profiles. Off-site sediment samples were also collected from test-pits in the proximities of Caipora, Cubículo-1, Santa Marta-10, Santa Marta-8 and Galheta-4. An experimental hearth was lit over shellmound deposits to serve as reference for the macroscopic and micromorphological identification of combustion features. The hearth was lit using local wood species and grasses and constantly fed with shells of *Anomalocardia brasiliana* and fish remains (bones and flesh) from a local fish processing plant. The description of the experiment is provided in the supplementary material.

The characterization of AF is conducive to micromorphological analyses because the depositional and post-depositional history of the sediments are perceptible via this method. Thin sections of 30 μm were made from impregnated blocks and viewed at magnifications ranging from 10× to 50× using Olympus BX51 and Zeiss Axioplan 2 microscopes. Descriptions followed the guidelines of Stoops (2003). The micromorphological analysis was done by identification of microfacies (mF) in the thin sections according to depositional attributes such as: coarse fraction (diversity, frequency, fragmentation, orientation and distribution); micromass; microstructure, porosity; and c/f ratio (percentage of the volume occupied by the coarse material and the fine material). This approach derives from the use of mF from the sedimentological perspective of Flugel (2004), as proposed by Goldberg et al. (2009), and has been previously used in shell middens from Tierra del Fuego (Villagran et al., 2011). The relation between AF and mF is bilateral but not directional, since a single AF can be composed by one or multiple mF. As in the case of AF, mF with similar characteristics indicate similar origins and/or analogous formation processes.

For the stratified shellmounds where a higher number of mF was identified, principal component analysis was applied using the results of the micromorphological description as variables. This procedure allows a higher level of certainty to be reached in the identification of recurrent mF. The frequencies of coarse fraction components (shells, bones and mineral grains), porosity, and fine fraction were chosen as variables because of their relation to the parameters used for mF identification (e.g. the percentage of porosity relates to the type of micromass, the frequency of shells relates to the c/f ratio, etc.). Variables were normalized to a total value of 100 to bring them all into proportion with one another. Analysis was done using Minitab 10 statistical software.

Bulk samples were used for determination of total organic carbon (TOC), total nitrogen (TN) and stable isotopes of carbon (δ^{13}C) and nitrogen (δ^{15}N) in the organic matter. The ratio of TOC and TN (C/N ratio) indicates the origin of the organic material, whether aquatic/marine (algae and phytoplankton) or terrestrial (C_3, C_4 or CAM plants). The δ^{13}C values are useful to differentiate between plants with C_3 or C_4 photosynthetic pathway (i.e. forest/shrubs vs. most of tropical Poaceae). The δ^{15}N allows for the identification of the source of nitrates in the sediments, which can derive from vegetal or animal tissue decay (Kendall, 1998; Meyers, 1997; Sifeddine et al., 2004; White, 2001). Carbonates were removed from the samples with HCl (30%) for determination of TOC. Elemental and stable isotope analyses were done with an ANCA SL 2020 mass spectrometer (Europa Scientific) using tungsten capsules containing between 5 and 30 g of sediment according to organic matter content. Results of TOC and TN are expressed in percentages, while isotope ratios are given with a precision of ±0.2‰ and determined according to the VPDB standard for δ^{13}C and atmospheric δ^{15}N.

5. Stratified shellmounds (ca. 7400–2400 BP)

The tens of layers that make up the four studied profiles could be grouped into one main AF, consisting of decametric layers with predominance of shells and bones, with some variations in the dominant mollusk species and the fragmentation of remains (AF3 and 4 in Caipora, AF9 in Cubículo-1, AF3 and 4 in Morrinhos and AF5, 6, 8 and 9 in Jabuticabeira-1, see Figs. 2–4). A secondary AF is always intercalated with the first type and consists of black, centimetric layers with charcoal and burned bone fragments (AF2 in Caipora, AF5 in Cubículo-1, AF5 in Morrinhos and AF4 in Jabuticabeira-1, see Figs. 2–4); and a third AF composed of terrigenous sediments and shells was only described at Caipora and Jabuticabeira-1 over the underlying natural substrate (AF1 in Caipora and AF1 in Jabuticabeira-1, see Figs. 2 and 4).

This means that by focusing exclusively on the depositional attributes of the multiple layers that make up the large-scale shellmounds, the thick and apparently complex stratigraphy seems to be in fact made after the recurrent deposition of similar contents.

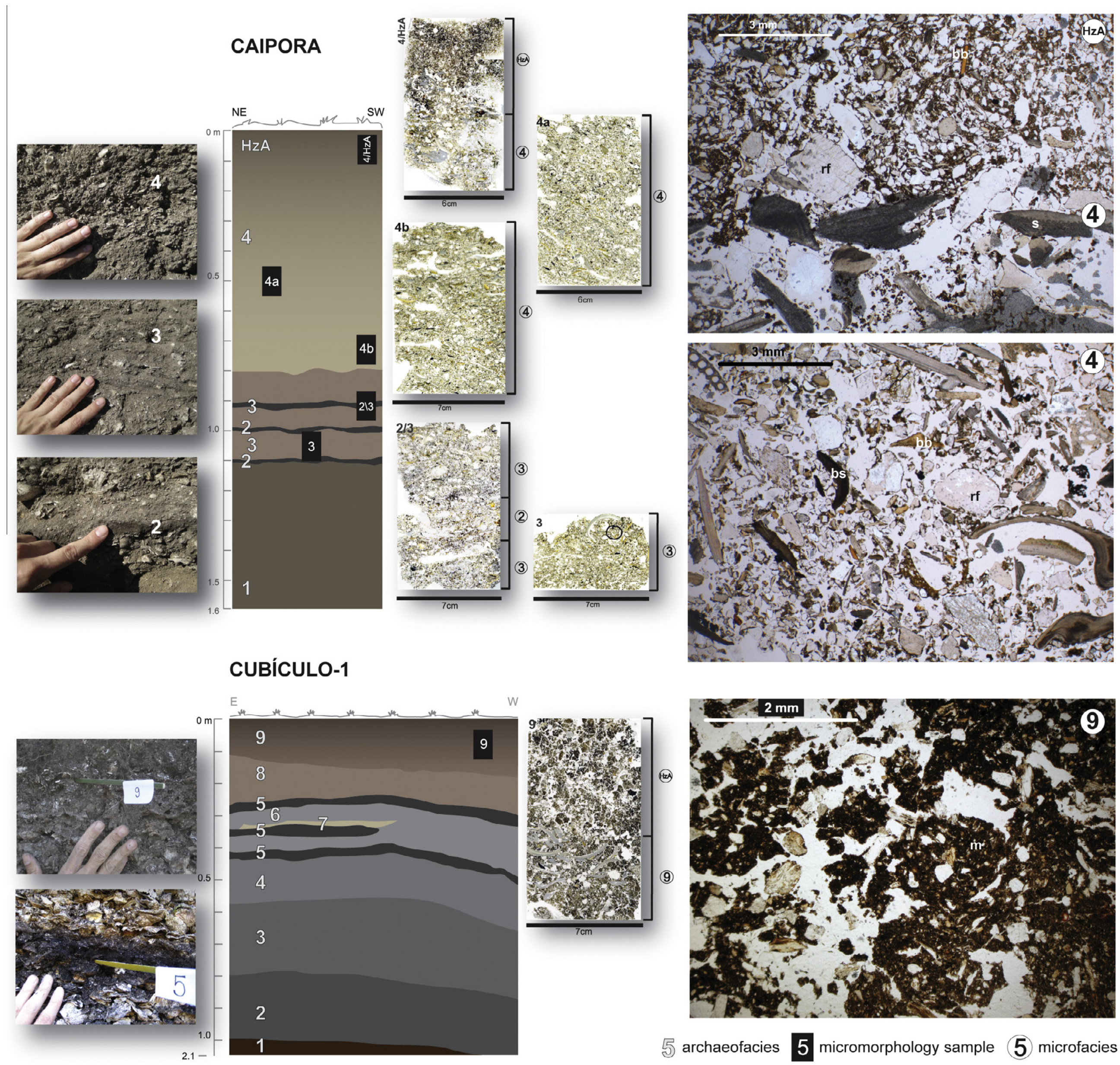


Fig. 2. Caipora and Cubículo-1 sites. Caipora, from left to right: close-up of 3 of the 4 archaofacies (AF) identified in the field, including the decametric AF rich in shell (AF3 and 4) and the thin, black layers rich in charcoal and burned bone (AF2); schematic profile with location of micromorphology samples; scanned thin sections with microfacies (mF) identification; photomicrographs (PPL) of mF4 showing shell fragments (s), burned shell (bs), burned bone (bb) and rock fragments (rf), and of the incipient soil developed on the surface of the mound (mFHzA), poor in shell content. Cubículo-1, from left to right: close-up of 2 of the 9 AF identified in the field, including top decametric AF rich in shell and of the thin, black layers (AF5); schematic profile with location of micromorphology sample, note that only one block could be taken due to the high friability of the sediments; scanned thin section with mF identification; photomicrograph (PPL) of the incipient soil horizon developing on the mound (mF9) with organic micromass (m).

Three main depositional behaviors were identified, one representing the foundations of the sites, and two complementary ones that characterize the whole history of the deposits (shell layers vs. black layers). The similarity in content and mode of deposition gives a hint at the activities that lie behind the stratigraphic profiles.

5.1. The foundations

Due to the large size of the stratified shellmounds, excavations that reach the base of the mounds and contact the natural substrate are not always possible. The profiles only showed contact with the underlying granite hill for Caipora and Jabuticabeira-1. In both cases, the basal layer shows similar attributes: terrigenous sediments with randomly distributed shells and, at least in Caipora, one human burial. This AF may not have been found at Cubículo-1 or Morrinhos because the base of the sites was never reached for study. However, similar AF was described at the base of other shellmounds from the region (Jabuticabeira-2 site) and even in shellmounds from other states (e.g. Amourins site in Rio de Janeiro). Thus, the deposition of a thick layer of sand with shells, possibly associated with an interment may be the inaugural event in shellmound formation. However, more evidence is needed in order to consider this as real pattern.

5.2. The composition

All of the stratified shellmounds are almost entirely made of shells (whole and fragmented), fish bones, charcoal and terrigenous

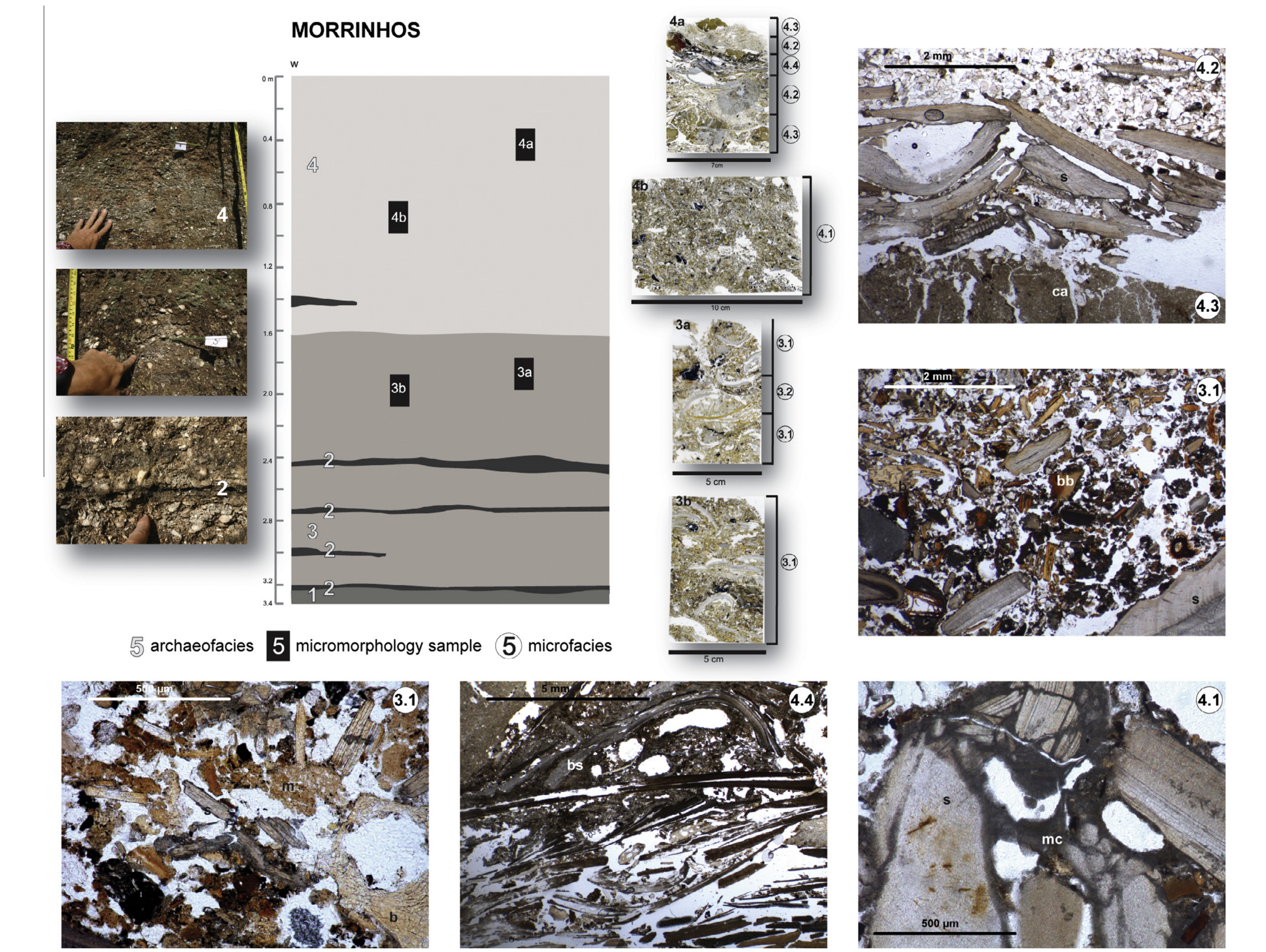


Fig. 3. Morrinhos, from left to right: close up of 3 of the 4 AF identified in the field, including the decametric archaeofacies (AF) rich in shell (AF3 and 4) and the thin, black AF (AF2); schematic profile with location of micromorphology samples; scanned thin sections with microfacies (mF) identification, note the microstratification in sample 4a, including a mF of burned material (mF4.4). Photomicrographs (PPL) of: mF4.2 and 4.3 representing natural sediments from the lagoons, with closed packed shells (s) and clay aggregates (ca); mF3.1 showing a mixture of burned bone fragments (bb) with non-burned bone (b) and shell within organic black micromass and orange phosphatic micromass (m); and mF4.1 with detail of micrite coatings produced after shell dissolution.

sediments. The micromorphological study disclosed key features in the components that are fundamental for interpreting the history of the sediments. Micromorphology also revealed unique evidence to yield an understanding of the dynamics of site formation. For the complete micromorphological description see Tables A–C in supplementary material.

Shell valves and fragments appear in different sizes and states of preservation. Between 5% and 30% show signs of burning at temperatures above 600 °C (Figs. 3 and 4), based on experimental reference material (Villagran, 2014). Shell orientation ranges from random to horizontal (Figs. 2–4). Horizontal distributions can be associated with the way shells fall on the ground during deposition. Another possibility would be trampling on the mounds; however, additional evidence of trampling, such as continuity of in situ broken fragments, linear distribution of the remaining coarse fraction, or laminar/massive microstructures (Balbo et al., 2010; Goldberg et al., 2009; Miller et al., 2010; Schiegl et al., 2003) were not observed. Bone fragments show diverse degrees of fragmentation with clear predominance of fine fragments down to silt size (Figs. 2–4). There are notable differences in terms of color (PPL), birefringence (XPL) and fluorescence (UVL) in adjacent fragments that indicate a mix of fresh bones with bones burned at different temperatures (Miller et al., 2010; Schiegl et al., 2003; Steiner et al., 1995). The micromass contains variable proportions of organomineral clay, micrite, and secondary phosphates. Phosphates may derive from tissue decay rather than bone weathering, since the alkalinity of the deposit would prevent bones from dissolving (Gordon and Buikstra, 1981; Nielsen-Marsh et al., 2007).

The isotopic analysis showed the presence of forest species and shrubs in the organic matter. The $\delta^{13}C$ values and the C/N ratio place the samples into the range of C_3 terrestrial plants (see Table 2 and Fig. 5) (Boutton, 1996; De Niro and Epstein, 1978; De Niro and Hastrof, 1985; Lamb et al., 2006; Meyers, 1997; Sifeddine et al., 2004), which include forest, shrub species, and some Poaceae (Cabido et al., 1997; Collatz et al., 1998; Ehleringer et al., 1997; Rundel, 1980; White, 2001). Plants of C_3 pathway in the shellmounds are consistent with the high frequency of charcoal seen in the profiles and thin sections. Wood may have been collected from the lowland forest nearby (*restinga*) or from the Atlantic rainforest, as shown by anthracological analysis done in other shellmounds of the region (Bianchini, 2008; Scheel-Ybert, 2014, 2001, 2000).

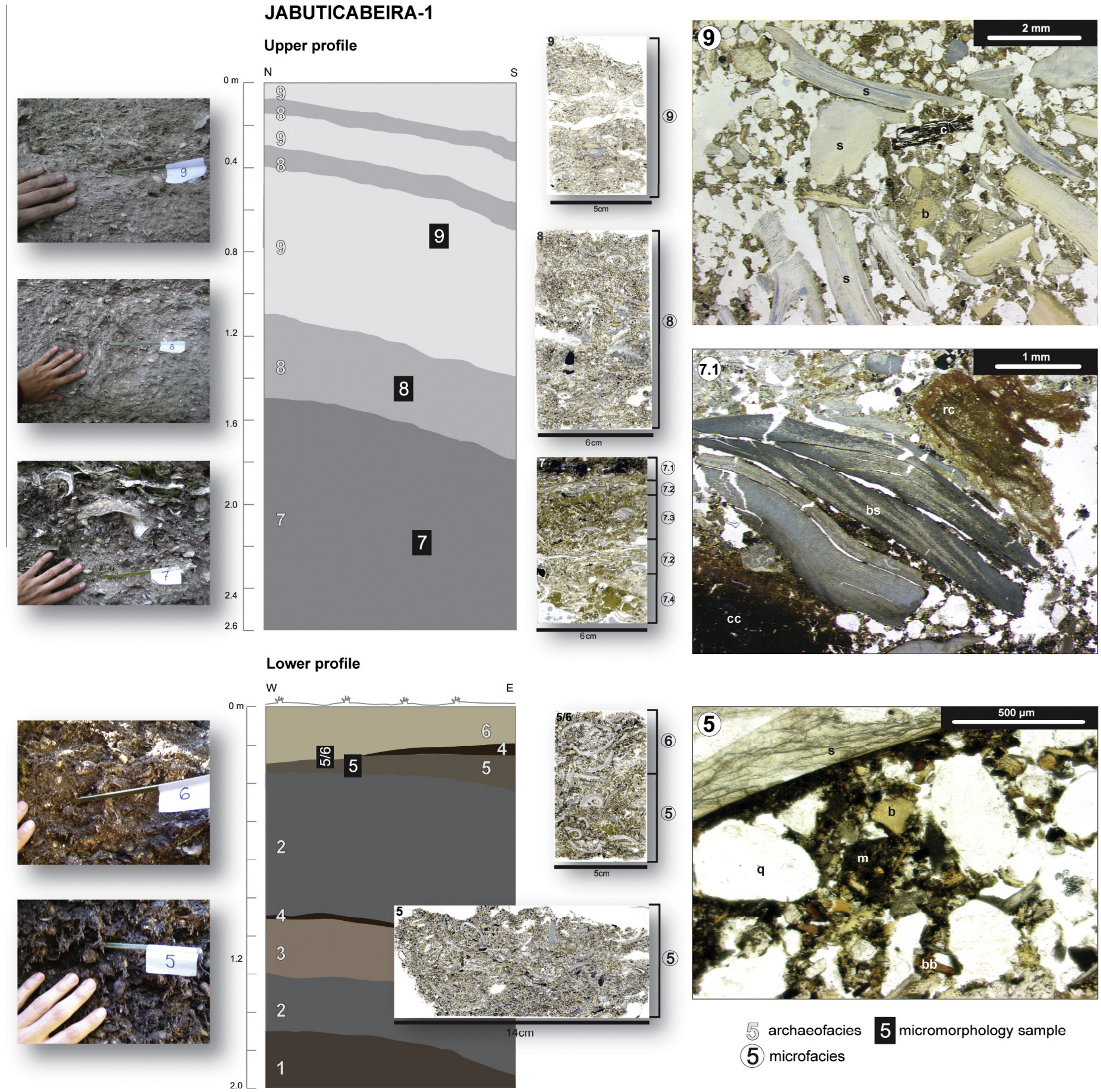


Fig. 4. Jabuticabeira-1 site. Upper profile, from left to right: close-up of the 3 archaeofacies (AF) identified in the field (AF7, 8 and 9), note darker color and presence of large shells in AF7; schematic profile with location of micromorphology samples; scanned thin sections with microfacies (mF) identification; photomicrographs (PPL) of mF9 with random mix of shell fragments (s) and bone (b), and of mF7.1 with burned shell (bs), rubified clay (rc) and carbonized clay aggregates (cc). Lower profile, from left to right: close-up of 2 of the 6 AF identified in the field (AF5 and 6); schematic profile with location of micromorphology samples; scanned thin sections with mF identification; photomicrographs (PPL) of mF5 showing mixture of non-burned (b) and burned bone (bb) down to silt sized fragments, with quartz grains (q) within heterogeneous micromass (m) made of clay, organic matter and phosphates. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

The δ^{15}N values were even more diagnostic to understand site content. Analyses indicate the presence of residues of animal origin in the organic matter (Fogg et al., 1998; Kendall, 1998; Schoeller, 1999; Schoeninger and De Niro, 1984; White, 2001), specifically of marine animals (Commisso and Nelson, 2006; Schoeninger and De Niro, 1984) (see Table 2 and Fig. 5). This is consistent with the animal remains in the shellmounds dominated by mollusks and fishes. In fact, the values fit both with mollusks and the interface between freshwater and marine fishes, corresponding to estuarine or lagoon species (see Schoeninger and De Niro, 1984). This agrees with zooarchaeological analysis indicating that fish species in the shellmounds are the same that currently live in the coastal lagoons (Klokler, 2008; Nishida, 2007). As expected, off-site samples contain no animal nitrates and are exclusively composed of C_3 plants.

High δ^{15}N values can also be related with excrement from omnivores in the sediments, including humans. Omnivore excrement shows high δ^{15}N values (between +10‰ and +22‰) (Choi et al., 2002; Heaton, 1986), but other analyses would be needed to determine their species origin (see for example Birk et al., 2011; Shillito et al., 2011).

Differences in isotopic profiles were reported in the organic matter of the main two AF described for the sites (e.g. shell layers

Table 2
Total organic carbon (TOC), $\delta^{13}C$ (‰), total nitrogen (TC) and $\delta^{15}N$ (‰) in the AF sampled in Caipora (CA), Cubículo-1 (CB1), Morrinhos (MO), Jabuticabeira-1 (JB1), Carniça-3 (CR3), Santa Marta-8 (SM8) and Galheta-4 (GA4), plus data from off-site sampling trenches near CA, CB1, SM10, SM8 and GA4. Numbers at the left of the site abbreviation correspond to the sampled archaofacies. AF in bold correspond to the thin, black layers rich in charcoal and burned bones.

	TOC (%)	^{13}C (δPDB)	TN (%)	^{15}N (δar)	C/N ratio
Site					
CA-4	0.54	−24.47	0.04	12.31	13.50
CA-5	0.84	−23.40	0.07	11.36	12.00
CB1-5	**9.94**	**−26.93**	**0.29**	**10.82**	**34.28**
MO-2	**3.41**	**−23.91**	**0.17**	**10.05**	**20.06**
MO-4	1.76	−24.35	0.11	13.32	16.00
JB1-1	0.42	−23.53	0.04	14.03	10.50
JB1-2	2.43	−24.76	0.15	13.97	16.20
JB1-3	2.90	−22.74	0.18	15.23	16.11
JB1-4	3.37	−25.48	0.11	12.10	30.64
JB1-5	2.26	−24.65	0.14	11.70	16.14
JB1-6	3.00	−23.72	0.18	11.59	16.67
JB1-7	2.11	−23.14	0.13	14.99	16.23
CR3-1	4.08	−28.17	0.24	8.50	17.00
SM8-2	0.76	−23.65	0.06	15.34	12.67
SM8-3	1.22	−24.73	0.10	13.52	12.20
SM10-B	1.72	−24.19	0.09	7.39	19.11
GA4-1	1.57	−23.28	0.11	15.94	14.27
Off-site					
CA-A	1.23	−22.36	0.12	9.78	10.25
CB1-A	1.22	−24.55	0.10	8.40	12.20
CB1-B	3.40	−24.44	0.29	8.75	11.72
SM10-B2	0.20	−24.97	0.02	7.82	10.00
SM8-B	1.17	−20.89	0.09	13.54	13.00
GA4-B	0.36	−21.50	0.02	8.91	18.00

and black layers). The shell layers show higher concentration of animal residues, while the intercalating black layers have mostly plant remains (see Table 2 and Fig. 5). This means that the sites include fresh animal residues deposited together with the shells that were intermittently covered with layers containing mostly burned plant remains and burned bones, on which no flesh remained.

5.3. Weathering and soil formation

The climatic conditions of the study area (sub-tropical humid) are favorable for intense dissolution of the shell carbonate. This process is seen as micrite and micro-sparite coatings around shells and micrite infillings releasing from the fragments (see Fig. 3). Soil development affects the surface layers of the shellmounds. The incipient soil is seen in the field as ~20 cm deep horizons with granular structure and less shell and bone content than the underlying sediments. In thin section, this soil shows a crumb to spongy and/or bridged grain microstructure, as opposed to the intergrain microaggregate microstructure that characterizes the rest of the stratigraphic sequences (see Fig. 2).

The biological alteration of the sediments is mostly seen in the surface layers but also down the profile as faunal excrement, chamber/channel voids, and mammilated aggregates. Besides this, the good preservation of mF relations means that physical disturbances were not intense enough to completely obliterate the record, and that the mixture of materials that characterizes the sediments is in fact a depositional attribute.

5.4. The history

By combining the diverse information on site stratigraphy and composition we can build a better picture of the history of the sediments, the selection of materials, transport, deposition, and transformations through time. The evaluation of the profiles showed the existence of two main depositional behaviors raising the structures: thick (decametric) shell layers made of mollusks, fish, and plant residues (decayed and burned); and thin (centimetric) black layers with burned bones and burned plant remains. A similar intercalation was described at the cemetery site Jabuticabeira-2, the most studied shellmound in the region (Bianchini, 2008; Klokler, 2008, 2014; Klokler et al., 2011; Nishida, 2007; Scheel-Ybert, 2014; Villagran et al., 2011).

Although the shell layers can reach tens of centimeters in thickness, the micromorphological descriptions suggested a certain

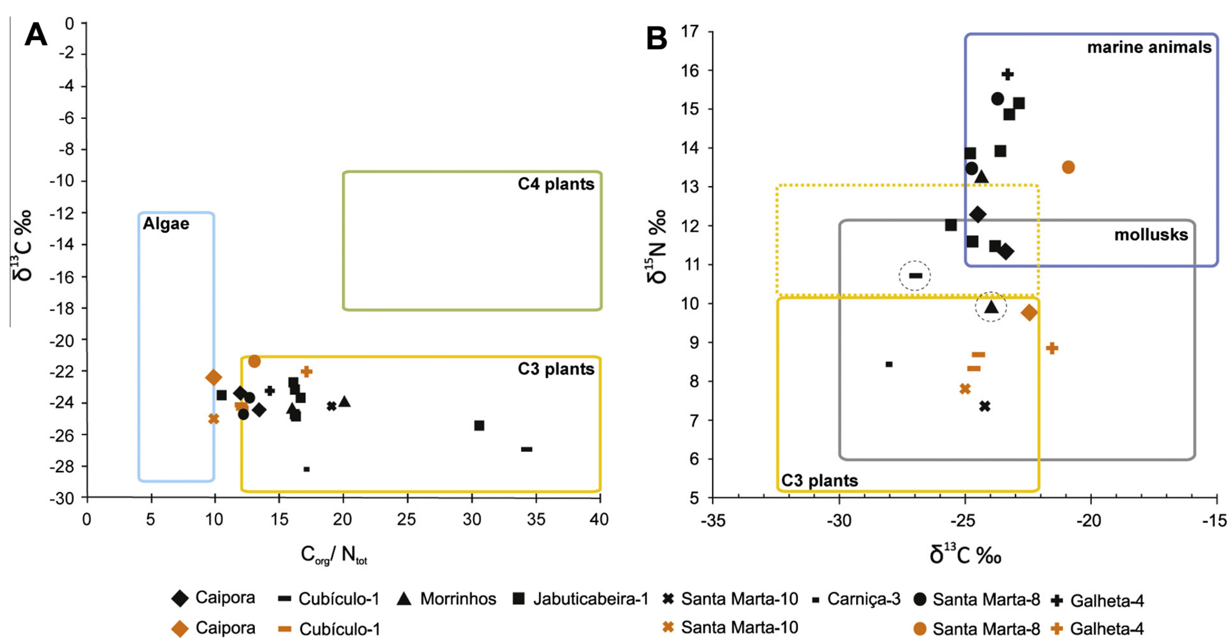


Fig. 5. Scatter plots of isotopic analysis: (A) $\delta^{13}C$ and organic C (C_{org}) vs. total N (N_{tot}); (B) $\delta^{15}N$ vs. $\delta^{13}C$ with fields corresponding to Algae, C4 plants, C3 plants, mollusks and marine animals (reference fields taken from Ben-David et al. (1998), Boutton (1996), Commisso and Nelson (2006), Schoeninger and De Niro (1984), De Niro and Hastrof (1985), Fogg et al. (1998), Lamb et al. (2006), Meyers (1997), and Sifeddine et al. (2004)). Samples surrounded with dashed circle in B were collected from the thin, black layers rich in charcoal and burned bone. Symbols in orange correspond to off-site samples. (For interpretation of the references to colours in this figure legend, the reader is referred to the web version of this paper.)

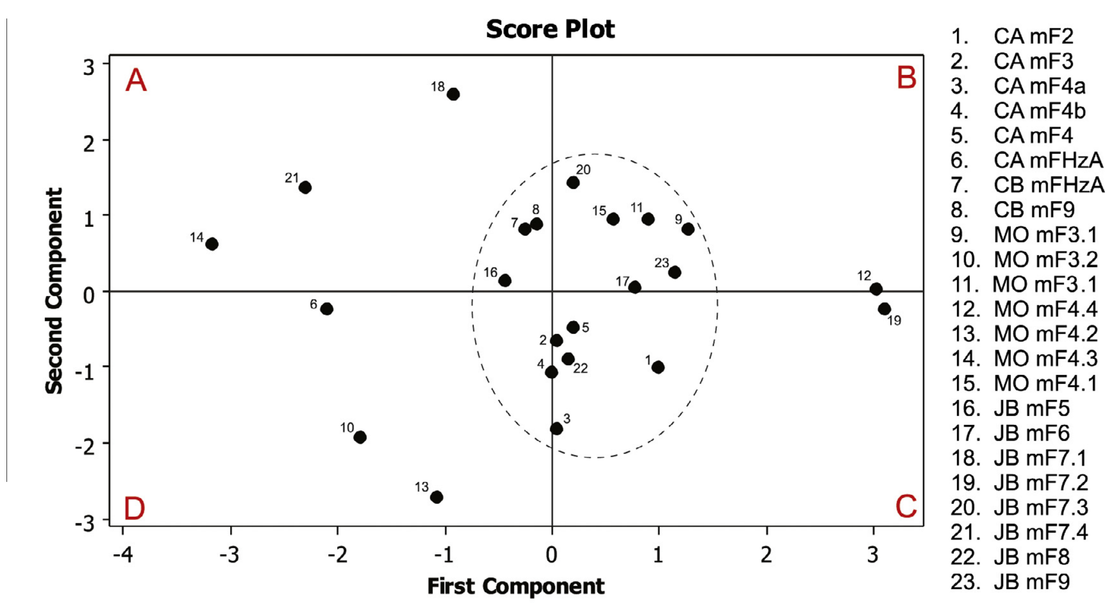
recurrence in their composition. The recurrence is clearly seen in the scatter plot for principal component analysis done for the 23 mF identified in the four stratified shellmounds. The scatter plot shows one main cluster in the center (Fig. 6) that gathers most of the mF (15 mF) identified in more than half the thin sections analyzed per site. A secondary cluster contains 2 mF of close packing shells (mF4.4 in Morrinhos and mF7.2 in Jabuticabeira-1, the first being burned shells). The remaining 6 outliers group mF of natural sediments: lagoonal sand (mF3.2 and 4.2 in Morrinhos); and lagoon clay aggregates (mF4.3 in Morrinhos and mF7.1 and 7.4 in Jabuticabeira-1, the last being burned clay) (Fig. 6).

And what does this recurrence in composition and deposition mean when discussing the formation process of the sites? In this sense, micromorphology descriptions offer key evidence for understanding the history of the sediments. Most sediments in the shellmounds contain a mixture of shells and bones burned at different temperatures (from 200 up to 800 °C). Fish bone fragments show an especially higher incidence of fragmentation and diverse colors from burning, while shells are mostly non-burned. Though the high fragmentation in bone suggests heating, the difference in color, birefringence, and fluorescence of adjacent bones in the sediments would not match with an intact combustion feature. The dissimilarity between the archaeological sediments and a single combustion feature is shown by the experimental hearth, which served as a reference for the macroscopic and microscopic identification of intact combustion features on shellmound deposits (see Figs. 7 and 8) (a full description of the experiment is given in the supplementary material).

The mixture of burned and unburned material with random distribution, high porosity, intergrain microaggregate microstructure and enaulic c/f related distribution points to a mix of components typical of midden deposits (Courty et al., 1989; Matthews et al., 1997). Even the mixed composition seen in the organic matter, with correspondence between high $\delta^{15}N$ and low $\delta^{13}C$ values (mix of C_3 plants and marine animals) has already been described for trash pits and middens (Shahack-Gross et al., 2008). However, the fact that bones show various degrees of burning while shell valves were less affected by heating indicates a more complex pre-depositional history. The mix of burned material with decayed organic tissue from animals and plants suggest transport and redeposition from a midden deposit, where daily refuse and hearths were disposed of.

This action is also supported by sedimentological analysis of the terrigenous sediments in the shellmounds (mineral sand-size grains), which indicate the human transport of natural sediments from the surroundings to the shellmounds. The transport would have been an unintentional consequence of the basket-load action of collecting midden material accumulated over the natural substrate outside the mounds. In other cases, sediments from the mollusk beds were accidentally transported to the mounds together with the inter-tidal resources (Villagran and Giannini, 2014).

The recurrence of depositional behaviors is thus explained by the action of making a shellmound with midden deposits, as shown by micromorphological, isotope, and sedimentological analyses. Despite the fact that most of the shellmound matrix is made of reworked midden deposits and hearth remains, few cases of




```
Eigenanalysis of the Correlation Matrix

Eigenvalue   2,2601  1,5049  0,9376  0,2974  -0,0000
Proportion    0,452   0,301   0,188   0,059   -0,000
Cumulative    0,452   0,753   0,941   1,000    1,000

Variable         PC1     PC2     PC3     PC4     PC5
Shells         0,540   0,230   0,474  -0,418  -0,507
Bones          0,247   0,326  -0,860  -0,170  -0,254
Min.grains    -0,437  -0,593  -0,116  -0,300  -0,595
Porosity       0,508  -0,425  -0,067   0,690  -0,284
Fine fraction-0,446    0,556   0,133   0,480  -0,494
```

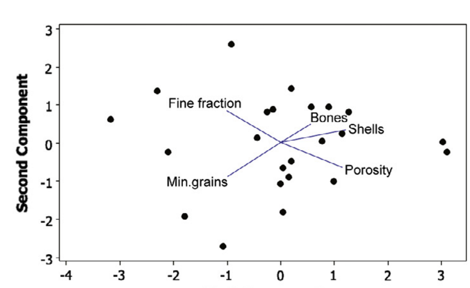


Fig. 6. Score plot for principal components analysis applied using the results of the micromorphological quantification of shells, bones, mineral grains, fine fraction and porosity. Note cluster of points in the center of the graph and outliers between quadrants B and C, and along the left side of the main cluster (quadrants A and D). The main cluster corresponds to the microfacies interpreted as reworking of midden deposits.

Fig. 7. Experimental hearth lit on reworked shellmound deposit: (A) graph of temperature values taken from the flames and the substrate (0–5 cm deep) within 45 min; (B) hearth with maximum temperature reached; (C) view of the hearth 12 h after the fire was out, with temperatures recorded in the substrate down to 15 cm deep.

seemingly intact combustion features were observed in the thin sections and no clear combustion features were seen in the profiles. Only in Morrinhos and Jabuticabeira-1 were milimetric layers of ash, silicified tissue, glassy slag, and burned clay observed associated with shell fragments that were burned at high temperatures (above 600 °C) (mF4.4 in Morrinhos and mF7.1 in Jabuticabeira-1, see Figs. 3 and 4, respectively). However, the contact with the underlying sediment is sharp and there is a stratigraphic inversion in the burned clay aggregates, with rubified clay over carbonized clay (see mF3.1 in Fig. 4). The arrangement of burned components suggests deposition of products from a hearth lit nearby over the shellmound (see Miller et al., 2010). Therefore, besides the main process of midden re-deposition, hearths may also have been lit over the mounds and later swept or cleaned away and covered by new mounding episodes.

6. Shellmounds with a sandy core (ca. 5900–3600 BP)

These shellmounds show a much more simple stratigraphy if compared with the large-scale stratified shellmounds. As their name implies, they are formed by a sandy core of quartzose sand covered by a decametric black layer of loamy sand with organic matter and shells, predominantly of the species *Anomalocardia brasiliana* (Figs. 1F and G and 9). Sedimentological analysis conducted by Tanaka et al. (2009) showed that the sandy core at Carniça-3 is an anthropogenic structure. In Santa Marta-10, field and micromorphological observations showed that the sandy core corresponds to aeolian dunes dated from before the Holocene maximum-transgression (Giannini et al., 2007; Martinho and Giannini, 2001; Sawakuchi et al., 2009). Aside from their compositional simplicity, the effort involved in the formation of these sites is no less noteworthy.

6.1. The composition

Stable isotope analysis indicates the exclusive presence of C_3 plants in the upper black AF that covers the sites, with no evidence of animal tissue (lowest $\delta^{15}N$ of all sites), thus defining an essential compositional difference with the stratified shellmounds (see Table 2 and Fig. 5). It is necessary to clarify that the organic matter does not derive from natural soil formation on sandy substrates, since neither the thickness nor the color of the archeological layers match the natural soil (decametric black layers vs. centimetric brown horizons). In Santa Marta-10, where a sample from the off-site soil horizon was analyzed for its isotopic signature, there is a difference between the C/N ratios of archaeological and natural samples that is worth discussing (19.11 vs. 10.00, respectively, see Table 2). Despite their similar $\delta^{13}C$ and $\delta^{15}N$ values indicating C_3 plants, the divergent C/N ratios are related with a source of organic carbon in the archaeological layers that is not present in the natural soil and that represents an increase of almost 100% TOC content. This source could be microcharcoal derived from fires lit on or near the site, whose remnants have easily disappeared due to the high erosion rates in an aeolian dune context.

6.2. The history

The micromorphological description of Carniça-3 sediments showed that shells make up 50% of the coarse fraction, while burned bone fragments comprise only 3% and charcoal less than 1% (see Table D in supplementary material). In Santa Marta-10 there are no shells outside of the shell ring and no bone fragments or charcoal, but isotope studies showed the presence of fine combustion residues (e.g. microcharcoal). This difference suggests two formation processes for each site, despite their visual similarities, and even questions the reliability of grouping them into one single site category (shellmounds with a sandy core).

A clue on the nature of the difference is given by the way the organic matter is distributed in the sediments. In Santa Marta-10 there are fine coatings of monomorphic organic matter, while in Carniça-3 the organic matter is polymorphic, aggregated as pellets, and has also formed pseudo-coatings (see Fig. 9). These attributes have been associated with podzolic horizons, but their formation follows different paths. The coatings of monomorphic organic matter are formed by dissolved organic carbon produced on the surface, transported down the profile and precipitated (in the spodic B horizon) around mineral grains when conditions are favorable. The pellets of monomorphic organic matter are produced in situ by microbial decay of plant remains, without solubilization or transport in the liquid phase (Buurman and Jongmans, 2005; De Connick, 1980; Phillips and Fitzpatrick, 2008; Van Breemen and Buurman, 2003; Wilson and Righi, 2010). Both processes can explain the formation of spodic horizons in well-drained sandy soils such as the shellmounds with a sandy core. However, the distribution of the organic matter suggests that in Santa Marta-10 the organic material (plants and their combustion residues) accumulated on top of the deposit and was left to decay, resulting in a thick black layer.I In Carniça-3, however, the plant material was already incorporated into the sand with shells and transformed in situ by the soil fauna. This means that, despite their current visual similarity, the way the sites looked was quite different in the past. Santa Marta-10 would have been a dune covered by a mat of fresh and/or burned plants deposited over a ring of closely packed shells transported from the lagoons up to 25 m.a.s.l. By contrast, Carniça-3 was likely a planned project that involved collection and transport of large amounts of sand from the environs to build a 5 m sand mound, sealed by deposition of shells and, again, combustion residues.

7. Fishmounds (ca. 1500–700 BP)

Both of the fishmounds studied can be defined as "mixed" sites. They contain elements associated with the traditional coastal

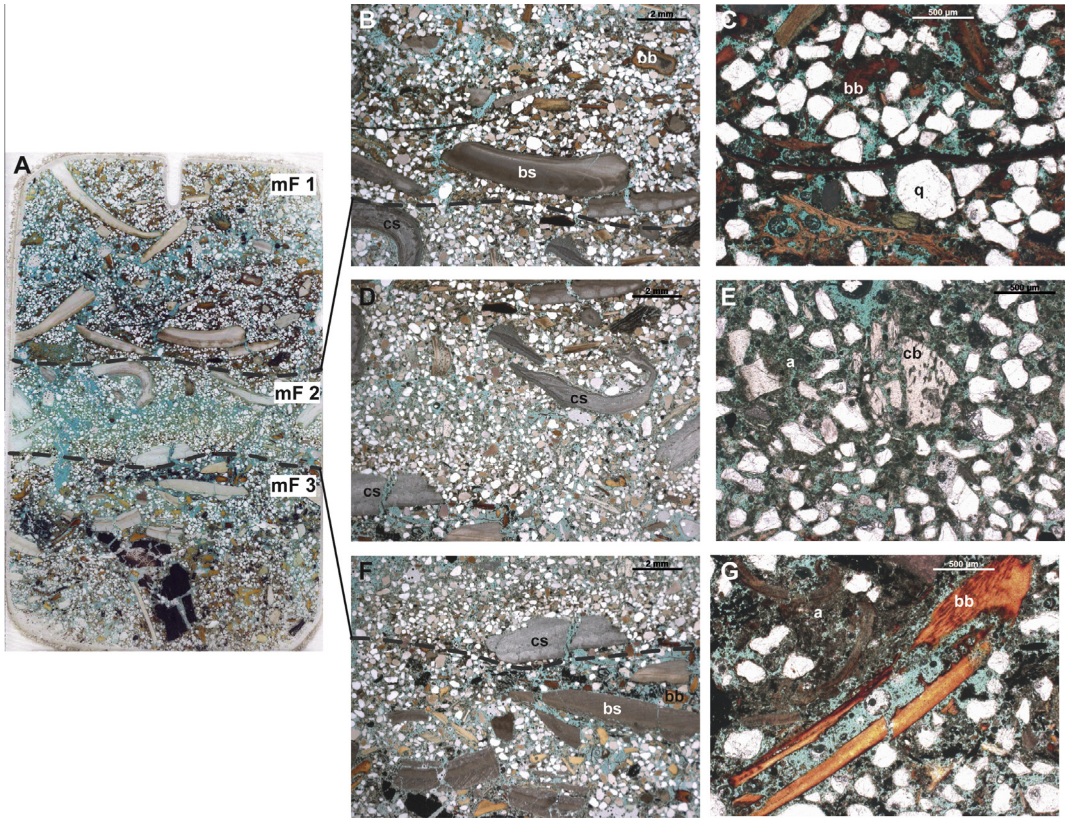


Fig. 8. Micromorphology of the experimental hearth lit on a shellmound deposit: (A) scanned thin section with identification of the 3 typical microfacies (mF) of combustion features in shell deposits: upper burned layer (mF1), calcined layer (mF2), and burned substrate (mF3); (B) contact between mF1 and 2 with burned shells (bs) and burned bones (bb) above mF2 with calcined shells (cs) (PPL); (C) detail of burned bones with dark red color and quartz grains (q) in mF1 (PPL), note the high fragmentation of bones and similar color in contiguous fragments; (D) central layer (mF2) made of calcined shells, calcined bones and ashes (PPL); (E) calcined bones (cb) in ashy micromass (a) in mF2 (PPL), note that all bones in this mF are equally calcined; (F) contact between mF2, containing calcined shell and the underlying mF3 with shells and bones burned at lower temperatures (PPL); (G) groundmass of mF3 with ashes (a) and large burned bone fragment. Samples were impregnated with a blue dyed resin to visualize the porosity. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

cultures, such as maritime economies (fishing, mollusk gathering), human interments inside the mounds (as in the stratified shellmounds), and also pottery sherds associated with ceramist groups from the southern highlands. These attributes, plus the recent chronology (between ca. 1500 and 700 yrs. BP) and the complete absence of shells with predominance of fish remains in the sites, prompted scholars to group them into the same category. However, their stratigraphic profiles contain substantial differences. Although both sites were settled over natural aeolian deposits, Santa Marta-8 is a 2 m-high mound made of closely packed fish bones, while Galheta-4 comprises a black layer with some burned bones and plant remains (Figs. 1H and I, 10).

7.1. The composition

Macroscopic evaluation of the profile in Santa Marta-8 revealed thick layers of fish bones, with some charcoal and lots of sand that make up the site. As for the stratified shellmounds, observation of the sediments under the microscope revealed crucial attributes in the fish bones for interpreting site formation. The isotopic studies of the off-site test-pit (Fig. 1H) verified the existence of settlements outside the mound, expanding our spatial understanding of the archaeological sites.

In the micromorphological description, fish bones, both fragmented and whole, represent almost 70% of the coarse fraction at Santa Marta-8 (see Table E in supplementary material). They are horizontally oriented and show evidence of biochemical weathering and burning. The alteration of bones in Santa Marta-8 is similar to what was described in the stratified shellmounds. Adjacent bones show different colors (PPL), birefringence (XPL) and fluorescence (UVL), indicating mixing of bones heated at different temperatures with non-burned and mostly biochemical weathered bones, without evidence of intact combustion features (Fig. 10).

Another similarity with the stratified shellmounds is the lack of clear evidence of trampling, plus the general horizontal distribution of bone fragments, as is also observed for the shells in the stratified shellmounds. However, in the bottom layer over the sandy substrate, the close packing of the coarse fraction, low porosity and presence of impure, micro-laminated coatings suggests human trampling (Fig. 10). Impure coatings can be formed by exclusively natural or natural-anthropogenic factors and among the latter there is trampling on unvegetated soil (Beckman and Smith, 1974; Courty et al., 1989; Davidson and Carter, 1998; Gebhardt and Langohr, 1999).

The fine fraction in Santa Marta-8 is essentially phosphatic, deriving from bone dissolution and decay of tissue residues, as indicated by isotope studies (Figs. 5 and 10). Besides the remains of C_3 plants in the organic matter, isotopic analysis also proved a high incidence of nitrates of animal origin in the sediments of both fishmounds (highest $\delta^{15}N$ values of all analyzed sites). This is also consistent with the faunal composition of the sites. Apart from secondary phosphates, the fine fraction in Santa Mata-8 contains amorphous siliceous materials, like glassy slag and other byproducts of plant combustion.

Fish bone fragments and charcoal are also predominant in Galheta-4 (~50%) (see Table E in supplementary material). The organic

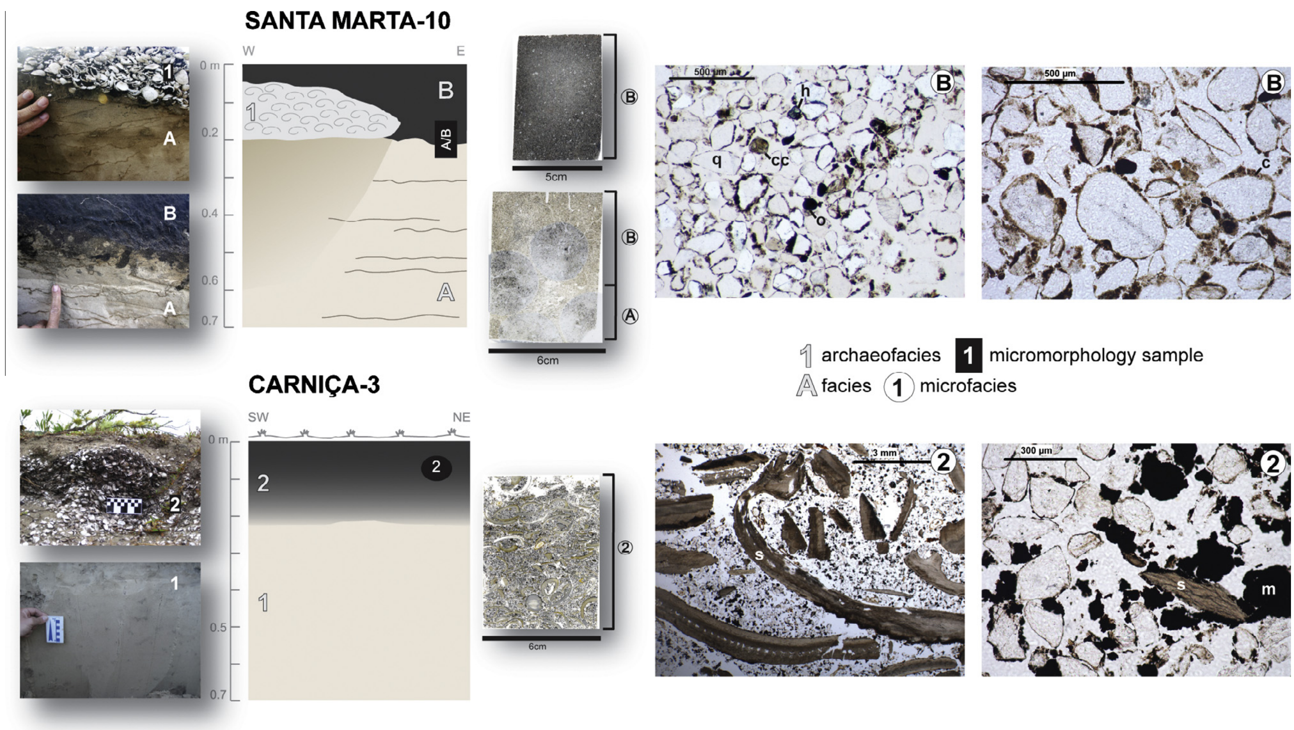


Fig. 9. Santa Marta-10 and Carniça-3 sites. Santa Marta-10, from left to right: close-up of the two facies identified in the field (A and B); schematic profile with location of micromorphology samples; scanned thin sections with microfacies (mF) identification; photomicrographs (PPL) of mFB with quartz grains (q), opaque minerals (o), heavy minerals (h) and clay clasts (cc) coated with minomorphic organic matter. Carniça-3, from left to right: close-up of the two identified archaeofacies (AF1 and 2); schematic profile with location of micromorphology sample; scanned thin section with mF identification; photomicrographs (PPL) of mF2 with shells (s) and quartz grains in micromass made of microaggregates of organic matter (m) and pseudo-coatings.

matter in the sampled profile is rich in animal residues, while in the off-site sample there is no animal input, as expected for natural sediments (Fig. 5). Bone fragments show random distribution, moderate selection (mostly fine or very fine sand sized) and are always burned (Fig. 10). The size and distribution of most bones and charcoal fragments point to the action of a natural agent in the formation of the site (e.g. aeolian). This means that the sampled profile was a peripheral area of the core of the settlement, where human burials covered by fish remains were found.

7.2. The history

In general terms, the stratigraphy and micromorphology of Santa Marta-8 is similar to the stratified shellmounds, pointing at analogous formation processes, while Galheta-4 has a greater similarity to the shellmounds with a sandy core. The sediments in Santa Marta-8 show similarities with the most recurrent AF and mF in the stratified shellmounds. Bones burned at different temperatures appear adjacent and mixed with unheated, decayed bones, charcoal, glassy slag from plant combustion, diatoms and sand. As in the stratified shell mounds, this mixture of discarded and burned materials can be related to reworked midden deposits and dumped hearths. The main difference with the stratified shellmounds refers to the absence of shells in the fishmounds, indicating a significant switch in the building material seemingly associated with an intensified contact with the inland ceramists, as evidenced by the pottery sherds recovered from the site.

Galheta-4 contains the wind-blown remains of combustion structures, including silt-sized bone and charcoal fragments. However, the high concentration of animal nitrates in the sediments and the distribution of the fine organic matter suggest a mixed anthropogenic-natural formation for the site. As described for the shellmounds with a sandy core, Galheta-4 contains coated grains of monomorphic organic matter and pellets of polymorphic organic matter. This indicates both illuviation of organic acids from the surface and in situ decomposition of residues by soil fauna, representing the mix of wind-blown organic particles and the decay of organic material deposited on the surface.

7.3. A place beyond the mounds

An off-site test-pit was opened at about 50 m northeast of Santa Marta-8 and revealed an interesting stratigraphy. Beneath a layer of 30 cm of brownish fine sand there was a centimetric black layer of muddy sand with bone fragments (Fig. 1H). Stable isotope analysis of this layer indicates a prevalent composition of decayed animal residues, with high $\delta^{15}N$ value similar to the archaeological samples (see Table 2 and Fig. 5). This implies the existence of settlements outside the mounded structures, at distances of at least 50 m or perhaps even more. Geophysical surveys conducted by Rodrigues (2009) had detected sub-surface anomalies in the GPR profiles in the paleotombolo where the site is located, but without further interpretations of their nature.

This represents a key finding to visualize the extent of fishmound or shellmound settlements and leads one to consider the reasons why domestic areas are not found on the sites, or seem to be associated with them in any way. The thin layer is currently buried below modern sediments, meaning that other non-visible occupation surfaces may be in fact currently underground, which is the case for most coastal areas in Brazil (see Brochier, 2009) and other parts of the world. If we consider the human action of transporting domestic middens to build the mounds, the sedimentary traces of an ancient midden or domestic space may well be thin layers enriched in organic components and other residues,

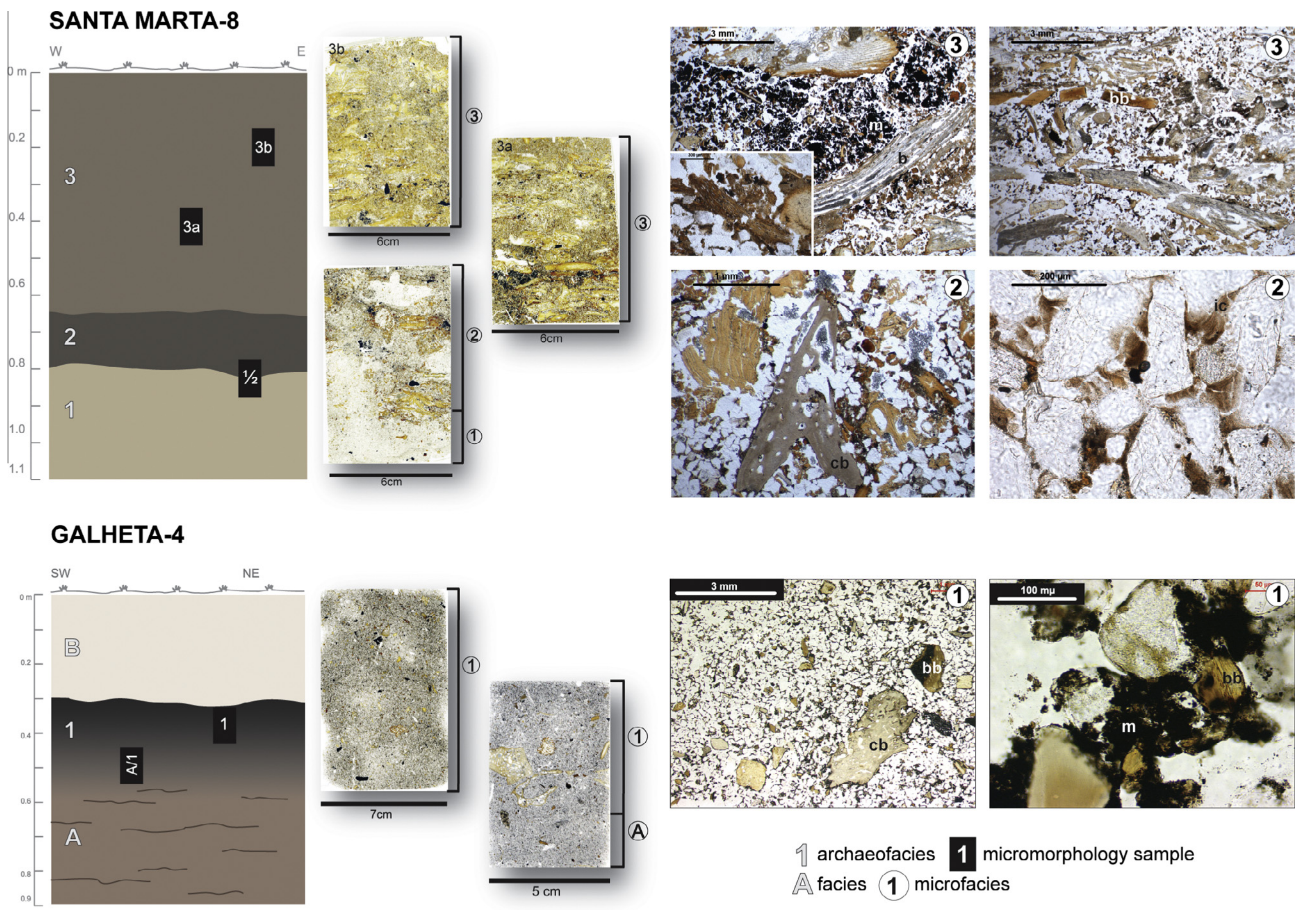


Fig. 10. Santa Marta-8 and Galheta-4 sites. Santa Marta-8, from left to right: schematic profile with location of micromorphology samples; scanned thin sections with microfacies (mF) identification; photomicrographs (PPL) of mF3 with fish bones (b), burned bones (bb) and black micromass (m) made of microcharcoal, with detail of micromass made of phosphates and clay, and of mF2 showing mixture of calcined bones (cb) with burned bones and the impure coatings (ic) indicative of trampling. Galheta-4, from left to right: schematic profile with location of micromorphology samples; scanned thin sections with mF identification; photomicrographs (PPL) of mF1 with calcined bone (cb), burned bone (bb) and black micromass (m).

buried by modern sediments. Thus, to completely understand the extent of prehistoric settlement in the area, traditional excavation an/or survey methods need to incorporate new techniques (see examples of GPR surveys in Thompson and Pluckhahn (2012) and Thompson et al. (2010)).

The findings at Galheta-4 also point at this direction, since the studied profile proved to be an occupation surface peripheral to the location selected for human burials, but not a mounded structure nor the core of the settlement.

8. A redefinition of waste

The stratigraphic, isotopic and micromorphological analysis of large-scale stratified shellmounds showed that their complex and intricate stratigraphy is reduced to at least one main human action: the recurrent re-deposition of midden material possibly carried from domestic spaces. Though the "midden" is a broad concept in archaeology, it commonly refers to formalized areas for the sequential disposal of residues (Needham and Spence, 1997; Wilson, 1994). Middens fall into the category of secondary deposits, sensu Schiffer (1987), showing high concentrations of material and low intensity of trampling. The most frequent and abundant constituent of middens is waste from daily activities (e.g. food preparation and consumption remains, hearths, etc.), although other specialized activities (e.g. feasting, tool manufacture) also contribute but to a lesser extent. Despite the palimpsest nature of midden deposits, they contain key information to understand essential topics of social organization, such as daily practices and resource management. In the case of the large-scale shellmounds, the human labor involved in the relocation of middens provides an insight into the organization of coastal groups, while the potential for a redefined significance of the debris as a motivation for this action gives an insight into their ideological realm.

The analysis done by Klokler (2008, 2014) at the Jabuticabeira-2 shellmound suggests at least two social actions that could account for the complex history of sediments in the stratified shellmounds, and for the continuous growth of the structures. We can either picture a macro-process involving a large, communal midden massively transported to the large-scale shellmounds, whether on a daily basis or in exceptional events to cover the interments; or we can envison a micro-process of relatives, or "affinity groups" (a term coined by M. Gaspar to refer to the social units associated to clusters of burials in a shellmound), who use their own midden while caring for those of their ancestors. In this case, discrete households with a midden of their own would be in charge of transporting materials to the shellmounds to cover the dead, gradually raising the structure.

The dual process of midden destruction/relocation and the phenomenon of "mound raising" can be interpreted as a unique strategy for establishing memories and connecting with past communities (see McAnany and Hodder, 2009). The strategy is based on the termination and/or destruction of a space (the domestic midden) to raise a new structure and give continuity to the material display of a social realm. This process spanned thousands of years, prompting an interpretation of changes in meaning and intention over time. However, the presence of a human burial at the base of the oldest site in the region (Caipora site) suggests that burial practices were probably responsible for mound raising since the early beginnings. However, the social memory manifested in the built environment may not be at the origins of this tradition, since monumental sizes were only reached after hundreds or perhaps thousands of years of repetitive midden relocation and mound revisiting. This may be the first recognizable shift in intent behind mound formation. The second recognizable shift is seen in recent times when fish bones replaced shells as prime material for mound raising, as will be discussed later. The history of the sites may have gone from simple funerary grounds to large, complex structures with hundreds of interments, settling as omnipresent social symbols. At some point between these ends, the structures and the memory contained in them, as large volumes of daily and ritual residues and human interments, gained a life of their own.

Although the high concentration of human remains is a central factor to understand mound formation (see Gaspar et al., 2014), it should not be seen as the sole purpose of it. The complexity of the shellmounds is not only given by their size and the presence of human remains, but also by the intricacy of their formation process. Following Sherwood and Kidder (2011), considering the shellmounds as only recipients for the dead blinds us from seeing them as monumental structures of their own. As already discussed for the Jabuticabeira-2 site (DeBlasis et al., 1998; Fish et al., 2000; Villagran et al., 2010), its long-term conspicuity and social role cannot be exclusively associated to the funerary activities behind its construction. The social impact of the large-scale shellmounds resulted from and was constantly imposed to the daily lives of coastal communities.

Shellmounds with a sandy core are contemporary with the stratified shellmounds; however, their formation process is simpler but not less informative on the organization of coastal groups. In the case of Santa Marta-10, a ring of shells was deliberately built after transporting mollusks more than 25 m.a.s.l. This territorial marker could have been naturally covered by aeolian sands and later protected by placing fresh and burned plant remains on top, capping the structure. In Carniça-3, massive quantities of sand were piled up to build an anthropogenic mound of almost 5 m high, subsequently sealed with shells and combustion residues. Similar sand-mounds without shells, have been described in North America and interpreted as ritual facilities (Sherwood et al., 2013). Both in Santa Marta-10 and Carniça-3, the pace of formation seems to have been fast, although more radiocarbon dates are needed to confirm it.

The fishmounds show clear similarities in terms of formation processes with the stratified shellmounds, despite the presence of pottery sherds associated with inland groups. The re-deposition of midden material is a constant activity in both types of sites, with the difference that shells characterize the first and fish bones the second.

Around 2000–1500 years BP, when inland groups supposedly arrived at the coast, shells lost their significance (see Gaspar et al., 2007) while similar settlement strategies were kept and a new technology of pottery manufacture was adopted. However, the archaeological record does not support a recent settlement of inlanders on the coast. The presence of pottery in the coastal sites is not sufficient to demonstrate this, and other evidence suggests a continuity in the subsistence practice and biological affinity of coastal communities before and after the abandonment of shells as construction material and the adoption of pottery manufacture (Bastos, 2009; Colonese et al., 2014; Neves, 1988; Okumura, 2014, 2007; Prous, 1992; Scherer et al., 2006; Wesolowski, 2000). Similarity in formation processes indicates both continuity and change, most likely triggered by pressures derived from intensification in contact with the inland ceramists. This intensification is also supported by an increase in violence on the coast (see Lessa and Scherer, 2008; Lessa, 2005), changes in the post-martial residence practice (Hubbe et al., 2009) and by the maintenance of identity landmark features, in addition to the abandonment of the traditional symbol of coastal groups, the shells.

9. Conclusion

Geoarchaeological analysis showed an intricate history for the sediments in the four studied shellmounds that goes beyond the immediate, secondary deposition of food remains. This means that traditional models used to explain shellmound formation, such as shell rings or heaps accumulated next to a living space, cannot be supported here. Shellmound growth involved short-scale, but continuous and recurrent actions of collection and transport of midden material. The daily discard of refuse was transformed into a cyclical practice of reusing and redefining the vital ingredients in the group's life: mollusks, fish, and plants. Most importantly, the disarticulation of middens may explain the absence of domestic areas in or associated with the large-scale shellmounds. It is likely that domestic occupations existed outside the mounds, as demonstrated by off-site sediments, but these thin layers are currently buried beneath Holocene sediments, thus challenging traditional expectations of where and how domestic areas should be.

With time, sites seem to have acquired an identity of their own associated with, and very likely driven by, funerary ritual. Given their ubiquity and size it seems impossible to overlook the impact they had among the daily lives of coastal communities or external visitors; the same way their legacy mesmerizes our perception of the present landscape.

The built environment included the large-scale shellmounds, and several sand mounds capped with plant material and, in the final stages, fishmounds. Despite the social changes induced by intensification of contact with inland groups, which included the complete abandonment of shells and the incorporation of pottery, there is continuity in the activities related with mound building, interpreted as a silent resistance against a new order. In this sense, the identity of coastal groups is not given by the use of shells per se, but by the vital process of mound building and the redefinition of waste.

Acknowledgments

I would like to thank the financial support of the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP, proc. 08/51264-0) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq, proc. 142532/2008-8). Special thanks to professors Paulo C.F. Giannini (USP) and Jordi Estevez Escalera (UAB), Paulo DeBlasis (USP), Maria Dulce Gaspar (UFRJ), Marco Madella (IMF/CSIC) and Rosa M. Poch (UdL). Thanks to Kiristen Bright and Danilo Assunção for their assistance in the fieldwork. Thanks to Dr. Kirsten Bos and professor Christopher Miller for their helpful comments on an earlier version of the manuscript. Thanks to two anonymous reviewers for their positive suggestions. Thin sections were made at Earthslides (Cambridge) and micromorphological analyses were made at the Laboratory of Archaeology (IMF/CSIC) and Laboratory of Sedimentary Petrography (IGc/USP). Stable isotope analyses were made at the Laboratory of Stable Isotopes (CENA/USP) under supervision of professor Luiz C.R. Pessenda.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jaa.2014.10.002.

References

Afonso, M.C., DeBlasis, P., 1994. Aspectos da formação de um grande sambaqui: alguns indicadores em Espinheiros II, Joinville. Rev. Mus. Arqueol. Etnol. 4, 21–30.

Anderton, R., 1985. Clastic facies models and facies analysis. In: Sedimnetology: Recent Developments and Applied Aspects. Blackwell Scientific Publications, Oxford, pp. 31–47.

Angulo, R., Giannini, P.C.F., Suguio, K., Pessenda, L.C.R., 1999. Relative sea-level change during the last 5500 years in the Laguna-Imbituba region (Santa Catarina, Brazil), based on vermetid radiocarbon ages. Mar. Geol. 159, 323–339.

Angulo, R., Lessa, G., Souza, M., 2006. A critical review of mid- to late-Holocene sea-level fluctuations on the eastern Brazilian coastline. Quat. Sci. Rev. 25, 486–506.

Assunçao, D., 2010. Sambaquis da paleolaguna de Santa Marta: em busca do contexto regional no litoral sul de Santa Catarina. Universidade de São Paulo.

Balbo, A.L., Madella, M., Vila, A., Estévez, J., 2010. Micromorphological perspectives on the stratigraphical excavation of shell middens: a first approximation from the ethnohistorical site Tunel VII, Tierra del Fuego (Argentina). J. Archaeol. Sci. 37, 1252–1259.

Barbosa, M., 1999. Reconstrução espacial de um assentamento de pescadores-coletores- caçadores pré-históricos no Rio de Janeiro. In: Tenório, M.C. (Ed.), Pré-História Da Terra Brasilis. Universidade Federal do Rio de Janeiro, Rio de Janeiro, pp. 376–380.

Barbosa, M., 2001. Espaço e organizaçao social entre o grupo social do sambaqui IBV4. Universidade Federal do Rio de Janeiro, Cabo Frio RJ.

Barbosa, M., 2007. A ocupação pré-colonial da região dos lagos, RJ: sistema de assentamento e relações intersocietais entre grupos sambaquianos e grupos ceramistas tupinambá da tradiçao Una. Universidade de São Paulo.

Bastos, M., 2009. Mobilidade humana na pré-história do litoral brasileiro: Análise de isótopos instáveis de estrôncio no sambaqui do Forte Marechal Luz. Fundaçao Oswaldo Cruz.

Beckman, G.G., Smith, K.J., 1974. Micromorphological changes in surface soils following wetting, drying and trampling. In: Rutherford, G.K. (Ed.), Soil Microscopy. The Limestone Press, Ontario, pp. 832–845.

Ben-David, M., Bowyer, R.T.T., Duffy, L.K.K., Roby, D.D.D., Schell, M., Schell, D.M., 1998. Social behavior and ecosystem processes: river otter latrines and nutrient dynamics of terrestrial vegetation. Ecology 79 (7), 2567–2571.

Bianchini, G.F., 2008. Fogo e paisagem: evidências de práticas rituais e construção do ambiente a partir da análise antracológica de um sambaqui no litorral sul de Santa Catarina. Universidade Federal do Rio de Janeiro.

Birk, J.J., Teixeira, W.G., Neves, E.G., Glaser, B., 2011. Faeces deposition on Amazonian Anthrosols as assessed from 5β-stanols. J. Archaeol. Sci. 38, 1209–1220.

Boutton, T.W., 1996. Stable carbon isotope ratios of soil organic matter and their use as indicators of vegetation and climate change. In: Boutton, T.W., Yamasaki, S.I. (Eds.), Mass Spectrometry of Soils. Marcel Dekker, New York, pp. 47–82.

Boyadjian, C.H., Eggers, S., 2014. Micro-remains trapped in dental calculus reveal plants consumed by Brazilian shell-mound builders. In: Roksandic, M., Mendonça de Souza, S., Eggers, S., Buschnell, M., Klokler, D. (Eds.), The Cultural Dynamics of Shell-Matrix Sites. University of New Mexico Press, Albuquerque, pp. 279–288.

Brochier, L.L., 2009. Controles geoarqueológicos e modelos morfoestratigráficos: implicaçoes para o estudo das ocupações pré-históricas na costa sul-sudeste do Brasil. Universidade de São Paulo.

Buurman, P., Jongmans, a.G., 2005. Podzolisation and soil organic matter dynamics. Geoderma 125, 71–83.

Cabido, M., Ateca, N., Astegiano, M.E., Anton, A.M., 1997. Distribution of C3 and C4 grasses along an altitudinal distribution gradient in Central Argentina. J. Biogeogr. 24, 197–204.

Calippo, F.R., 2004. Os sambaquis submersos de cananéia: um estudo de caso de arqueologia subaquática. Universidade de São Paulo.

Castilho, P.V., 2008. Utilization of cetaceans in shell mounds from the southern coast of Brazil. Quat. Int. 180, 107–114.

Choi, W., Lee, S., Ro, H., Kim, K., Yoo, S., 2002. Natural 15 N abundances of maize and soil amended with urea and composted pig manure. Plant Soil 245, 223–232.

Claassen, C., 1991. Normative thinking in shell-bearing sites. Archaeol. Method Theor. 3, 249–298.

Collatz, G.J., Berry, J.A., Clark, J.S., 1998. Effects of climate and atmospheric CO_2 partial pressure on the global distribution of C4 grasses: present, past, and future. Oecologia 114, 441–454.

Colonese, A.C., Collins, M., Lucquin, A., Eustace, M., Hancock, Y., de Almeida Rocha Ponzoni, R., Mora, A., Smith, C., Deblasis, P., Figuti, L., Wesolowski, V., Plens, C.R., Eggers, S., de Farias, D.S.E., Gledhill, A., Craig, O.E., 2014. Long-term resilience of late holocene coastal subsistence system in Southeastern South America. PLoS One 9, e93854.

Commisso, R., Nelson, D., 2006. Modern plant $\delta^{15}N$ values reflect ancient human activity. J. Archaeol. Sci. 33, 1167–1176.

Courty, M.A., 2001. Microfacies analysis assisting archaeological stratigraphy. In: Goldberg, P., Holliday, V.T., Reid Ferring, C. (Eds.), Earth Sciences and Archaeology. Kluwer, New York, pp. 205–239.

Courty, M.A., Goldberg, P., Macphail, R.I., 1989. Soils and Micromorphology in Archaeology. Cambridge University Press, Cambridge.

Davidson, D.a., Carter, S.P., 1998. Micromorphological evidence of past agricultural practices in cultivated soils: the impact of a traditional agricultural system on soils in Papa Stour, Shetland. J. Archaeol. Sci. 25, 827–838.

De Connick, F., 1980. Major mechanisms in formation of spodic horizons. Geoderma 24, 101–128.

De Masi, M.A., 2001. Pescadores coletores da costa sul do Brasil. Pesquisas 57.

De Niro, M., Epstein, S., 1978. Influence of diet on the distribution of carbon isotopes in animals. Geochim. Cosmochim. Acta 42, 495–506.

De Niro, M.J., Hastrof, C.A., 1985. Alteration of 15N/14N and 13C/12C ratios of plant matter during the initial stages of diagenesis: studies utilizing archaeological specimens from Peru. Geochim. Cosmochim. Acta 49, 97–115.

DeBlasis, P., Farias, D., 2007. Proejto arqueológico Sambquis e Paisagem: Pesquisas no sítio Galheta IV, Campanha 2007.

DeBlasis, P., Fish, S.K., Gaspar, M.D., Fish, P.R., 1998. Some references for the discussion of complexity among the sambaqui moundbuilders from the southern shores of Brazil. Rev. Arqueol. Am. 15, 75–105.

DeBlasis, P., Kneip, A., Scheel-Ybert, R., Giannini, P.C.F., Gaspar, M.D., 2007. Sambaquis e paisagem: dinâmica natural e arqueologia regional no litoral sul do Brasil. Rev. Arqueol. Sudam. 3, 29–61.

Eggers, S., Petronilho, C.C., Brandt, K., Jericó-Daminello, C., Filippini, J., Reinhard, K.J., 2008. How does a riverine setting affect the lifestyle of shellmound builders in Brazil? Homo 59, 405–427.

Ehleringer, J.R., Cerling, T.E., Helliker, B.R., 1997. C4 photosynthesis, atmospheric CO_2, and climate. Oecologia 112, 285–299.

Figuti, L., 1992. Les sambaquis COSIPA (4200 à 1200 ans BP): étude de la subsistance chez les peuples préhistoriques de pêcheurs-ramasseurs de bivalves de la côte centrale de l'état de São Paulo. Museum National d'Histoire Naturelle, Brésil.

Figuti, L., Klokler, D., 1996. Resultados preliminares dos vestígios zooarqueológicos do sambaqui Espinheiros II (Joinville, SC). Rev. Mus. Arqueol. Etnol. 6, 169–188.

Fish, S.K., De Blasis, P., Gaspar, M.D., Fish, P.R., 2000. Eventos incrementais na construçao de sambaquis, litoral sul do estado de Santa Catarina. Rev. Mus. Arqueol. Etnol. 10, 69–87.

Flugel, E., 2004. Microfacies of Carbonate Rocks: Analysis, Interpretation and Application. Springer, Berlin.

Fogg, G., Rolston, D.E., Decker, D.L., Louie, D.T., Grismer, M.E., 1998. Spatial variation in N isotope values beneath nitrate contamination sources. Ground Water 36, 418–426.

Gaspar, M.D., 1991. Aspectos da organizaçao social de pescadores-coletores: região compreendida entre a Ilha Grande e o delta do Paraiba do Sul. Universidade de São Paulo, Rio de Janeiro.

Gaspar, M.D., 1998. Considerations of the sambaquis of the Brazilian coast. Antiquity 72, 592–615.

Gaspar, M.D., 2004. Cultura: comunicaçao, arte, oralidade na pré-história do Brasil. Rev. Mus. Arqueol. Etnol. 14, 153–168.

Gaspar, M.D., DeBlasis, P., 1992. Construção de sambaquis: síntese das discussões do grupo de trabalho e colocaçao da proposta original. In: Anais Da VI Reunião Científica Da Sociedade de Arqueologia Brasileira. Rio de Janeiro, pp. 811–820.

Gaspar, M.D., Barbosa, D., Barbosa, M., 1994. Análise do processo cognitivo de construção do Sambaqui Ilha da Boa Vista (RJ). Clio 1, 110–124.

Gaspar, M.D., Buarque, A., Cordeiro, J., Escórcio, E., 2007. Tratamento dos Mortos entre os Sambaquieiros, Tupinambá e Goitacá que ocuparam a Região dos Lagos, Estado do Rio de Janeiro. Rev. Mus. Arqueol. Etnol. 17, 169–189.

Gaspar, M.D., DeBlasis, P., Fish, S.K., Fish, P.R., 2008. Sambaqui (shell mound) societies of coastal Brazil. In: Silverman, H., Isbell, W.H. (Eds.), Handbook of South American Archaeology. Springer, New York, pp. 319–337.

Gaspar, M.D., Klokler, D.M., DeBlasis, P., 2011. Traditional fishing, mollusk gathering, and the shell mound builders of Santa Catarina, Brazil. J. Ethnobiol. 31, 188–212.

Gaspar, M.D., Klokler, D., Bianchini, G.F., 2013. Arqueologia estratégica: abordagens para o estudo da totalidade e construção de sítios monticulares. Bol. Mus. Para. Emílio Goeldi 8, 517–533.

Gaspar, M.D., Klokler, D., DeBlasis, P., 2014. Were sambaqui people buried in the trash? In: Roksandic, M., Mendonça de Souza, S., Eggers, S., Buschnell, M., Klokler, D. (Eds.), The Cultural Dynamics of Shell-Matrix Sites. University of New Mexico Press, Albuquerque, pp. 91–100.

Gebhardt, A., Langohr, R., 1999. Micromorphological study of construction materials and living floors in the medieval motte of Werken (West Flanders, Belgium). Geoarchaeology 14, 595–620.

Giannini, P.C.F., 1993. Sistemas Deposicionais no Quaternário Costeiro entre Jaguaruna e Imbituba. Universidade de São Paulo, SC.

Giannini, P.C.F., Sawakuchi, a.O., Martinho, C.T., Tatumi, S.H., 2007. Eolian depositional episodes controlled by Late Quaternary relative sea level changes on the Imbituba–Laguna coast (southern Brazil). Mar. Geol. 237, 143–168.

Giannini, P.C.F., Villagran, X.S., Fornari, M., Rodrigues, D., Menezes, P., Tanaka, A.P., Assunçao, D., De Blasis, P., Amaral, P., 2010. Interações entre evolução sedimentar e ocupação humana pré-histórica na costa centro-sul de Santa Catarina, Brasil. Bol. Mus. Para. Emílio Goeldi. Série Ciências Humanas 5, 105–128.

Goldberg, P., Miller, C.E., Schiegl, S., Ligouis, B., Berna, F., Conard, N.J., Wadley, L., 2009. Bedding, hearths, and site maintenance in the Middle Stone Age of Sibudu Cave, KwaZulu-Natal, South Africa. Archaeol. Anthropol. Sci. 1, 95–122.

Gordon, C., Buikstra, J.E., 1981. Soil pH, bone preservation and sampling bias at mortuary sites. Am. Antiq. 46, 566–571.

Guidon, N., 1964. Nota prévia sobre o sambaqui Mar Casado. In: Homenaje a Fernando Marquez-Miranda. Universidad Complutense de Madrid, Madrid, pp. 176–204.
Heaton, T.H.E., 1986. Isotopic studies of nitrogen pollution in the hydrosphere and atmosphere: a review. Chem. Geol. 59, 87–102.
Hubbe, M., Neves, W.A., Castro de Oliveira, E., Strauss, A., 2009. Postmarital residence practice in southern Brazilian coastal groups: continuity and change. Lat. Am. Antiq. 20, 267–278.
Karl, R., 2000. The Relative Chronology of Cultural Episodes at the Coastal Sambaqui, Jabuticabeira II, in Santa Catarina. University of Arizona, Brazil.
Kendall, C., 1998. Tracing nitrogen sources and cycling in catchments. In: Kendall, C., McDonell, J.J. (Eds.), Isotope Tracers in Catchment Hydrology. Elsevier B.V, Amsterdam, pp. 519–576.
Klokler, D.M., 2008. Food for Body and Soul: Mortuary Ritual in Shell Mounds (Laguna – Brazil). University of Arizona.
Klokler, D., 2013. Em um mar de conchas, por onde começar? In: Gaspar, M.D., Mendonça de Souza, S. (Eds.), Abordagens Estratégicas Em Sambaquis. Habilis, Erechim, pp. 177–192.
Klokler, D., 2014. A ritually constructed shell mound. In: Roksandic, M., Mendonça de Souza, S., Eggers, S., Buschnell, M., Klokler, D. (Eds.), The Cultural Dynamics of Shell-Matrix Sites. University of New Mexico Press, Albuquerque, pp. 151–162.
Klokler, D., Villagran, X.S.S., Giannini, P.C.F.C.F., Peixoto, S., Deblasis, P., 2011. Juntos na costa: zooarqueologia e geoarqueologia de sambaquis do litoral sul catarinense. Rev. Mus. Arqueol. Etnol. 20, 53–75.
Lamb, A., Wilson, G., Leng, M., 2006. A review of coastal palaeoclimate and relative sea-level reconstructions using $\delta^{13}C$ and C/N ratios in organic material. Earth-Sci. Rev. 75, 29–57.
Laming-Emperaire, A., 1975. Problemes de prehistoire brasilienne. Ann. Écon. Soc. Civil. 5, 1229–1260.
Lessa, A., 2005. Reflexões preliminares sobre paleoepidemiologia da violência em grupos ceramistas litorâneos: I) sítio Praia da Tapera – SC. Rev. Mus. Arqueol. Etnol. 15, 199–207.
Lessa, A., Scherer, L.Z., 2008. O outro lado do paraíso: novos dados e reflexões sobre violência entre pescadores-coletores pré-coloniais. Rev. Mus. Arqueol. Etnol. 18, 89–100.
Lima, T.A., Macario, K.D., Anjos, R.M., Gomes, P.R.S., Coimbra, M.M., Elmore, D., 2002. The antiquity of the prehistoric settlement of the central-south Brazilian coast. Radiocarbon 44, 733–738.
Luby, E.M., Gruber, M.F., 1999. The dead must be fed: symbolic meanings of the shellmounds of the San Francisco Bay Area. Cambridge Archaeol. J. 9, 95–108.
Luby, E.M., Drescher, C.D., Lightfoot, K.G., 2006. Shell mounds and mounded landscapes in the San Francisco Bay area: an integrated approach. J. Isl. Coast. Archaeol. 1, 191–214.
Martinho, C.T., Giannini, P.C.F., 2001. Petrografia e microscopia eletrônica de varredura de diferentes geraçoes de pelaodunas eólicas quaternárias do Morro de Santa Marta, Município de Laguna, SC. Pesqui. Geoci. 28, 53–66.
Matthews, W., French, C.A., Lawrence, T., Cutler, D.F., Jones, M.K., 1997. Microstratigraphic traces of site formation processes and human activities. World Archaeol. 29, 281–308.
McAnany, P.a., Hodder, I., 2009. Thinking about stratigraphic sequence in social terms. Archaeol. Dialog. 16, 1.
Mendonça de Souza, S., Liryo, A., Bianchini, G.F., Gaspar, M.D., 2012. Sambaqui do Amourins: mortos para mounds? Rvi. Arqueol. 25, 84–103.
Mendonça de Souza, S., Wesolowski, V., Lessa, A., Rodrigues-Carvalho, C., 2013. Habilis, Erechim, pp. 127–154.
Meyers, P., 1997. Organic geochemical proxies of paleoceanographic, paleolimnologic, and paleoclimatic processes. Org. Geochem. 27, 213–250.
Miller, C.E., Conard, N.J., Goldberg, P., Berna, F., 2010. Dumping, sweeping and trampling: experimental micromorphological analysis of anthropogenically modified combustion features. Paleo@nthropologie, 25–37.
Needham, S., Spence, T., 1997. Refuse and the formation of middens. Antiquity 71, 77–90.
Neves, W.A., 1988. Paleogenética dos grupos pré-históricos do litoral sul do Brasil (Paraná e Santa Catarina). Pesquisas 43.
Nielsen-Marsh, C., Smith, C., Jans, M., Nord, A., Kars, H., Collins, M., 2007. Bone diagenesis in the European Holocene II: taphonomic and environmental considerations. J. Archaeol. Sci. 34, 1523–1531.
Nishida, P., 2007. A coisa ficou preta: estudo do processo de formaçao da terra preta do sítio arqueológico Jabuticabeira II. Universidade de São Paulo.
Okumura, M., 2007. Diversidade morfológica craniana, micro-evolução e ocupação pré-histórica da costa brasileira. Universidade de São Paulo.
Okumura, M., 2014. Do cultural markers reflect biological affinities? In: Roksandinc, M., Mendonça de Souza, S., Eggers, S., Buschnell, M., Klokler, D. (Eds.), The Cultural Dynamics of Shell-Matrix Sites. University of New Mexico Press, Albuquerque, pp. 173–187.
Orquera, L.A., 1996. Tunel VII: La estratigrafía. Treballs d́Etnoarqueologia Encuentro en los Conchales Fueguinos 3, 83–103.
Orquera, L.A., Piana, E.L., 1992. Un paso hacia la resolucion del palimpsesto. In: Borrero, L.A., Lanata, J.L. (Eds.), Análisis Espacial En La Arqueología Patagónica. Búsqueda de Ayllu SRL, Buenos Aires, pp. 21–52.
Orquera, L.A., Piana, E.L., 2000. Composicion de conchales de la costa del canal beagle – Primera parte. Relac. Soc. Argentina Antropol. 25, 249–274.
Orssich, A.S., 1977. O sambaqui do Araujo I, nota previa. Cad. Arqueol. 2, 1–60.
Peixoto, S., 2008. Pequenos aos montes: uma análise dos processos de formação dos sambaquis de pequeno porte do litoral sul de Santa Catarina. Universidade Federal do Rio de Janeiro.
Phillips, D.H., Fitzpatrick, E.A., 2008. Biological influences on the morphology and micromorphology of selected Podzols (Spodosols) and Cambisols (Inceptisols) from the eastern United States and north-east Scotland. Geoderma 90, 327–364.
Prous, A., 1992. Arqueologia Brasileira. Universidade de Brasilia, Brasilia.
Ramos, R.R.C., Garcindo, L.B., Bianchini, G.F., 2013. Sambaquis: análise e registro estratigráfico através do uso de fotomosaicos. In: Gaspar, M.D., Mendonça de Souza, S. (Eds.), Abordagens Estratégicas Em Sambaquis. Habilis, Erechim, pp. 75–88.
Rodrigues, S.I., 2009. Contribuições dos métodos GPR e Eletromagnético Indutivo em estudos de sítios arqueológicos de sambaquis costeiros no Estado de Santa Catarina. Universidade de São Paulo.
Rodrigues-Carvalho, C., Lessa, A., Mendonça de Souza, S., 2009. Bioarchaeology of the sambaqui groups: skeletal morphology, physical stress and Trauma. In: Humans: Evolution and Environment. BAR International Series 2026, Oxford, pp. 15–20.
Rundel, P.W., 1980. The ecological distribution of C4 and C3 grasses in the Hawaiian Islands. Oecologia 45, 354–359.
Russo, M., 2004. Measuring shell rings for social inequality. In: Gibson, J.L., Carr, P.J. (Eds.), Signs of Power: The Rise of Cultural Complexity in the Southeast. University of Alabama Press, Tuscaloosa, pp. 26–70.
Russo, M., 2014. Ringed shell features of the southeast United States: architecture and midden. In: Roksanndik, M., Mendonça de Souza, S., Eggers, S., Burchell, M., Klokler, D. (Eds.), The Cultural Dynamics of Shell-Matrix Sites. Albuquerque, pp. 21–39.
Sassaman, K., 2008. The new archaic: it ain't what it used to be. SAA Archaeol. Rec. 8, 6–8.
Saunders, R., 2014. Shell rings of the lower Atlantic coast of the United States: defining function by contrasting details, with reference to Ecuador, Colombia and Japan. In: Rocksandinc, M., Mendonça de Souza, S., Eggers, S., Burchell, M., Klokler, D. (Eds.), The Cultural Dynamics of Shell-Matrix Sites. University of New Mexico Press, Albuquerque, pp. 41–55.
Saunders, R., Russo, M., 2011. Coastal shell middens in Florida: a view from the Archaic period. Quat. Int. 239, 38–50.
Sawakuchi, A.O., Giannini, P.C.F., Martinho, C.T., Tanaka, a.P.B., 2009. Grain size and heavy minerals of the Late Quaternary eolian sediments from the Imbituba–Jaguaruna coast, Southern Brazil: depositional controls linked to relative sea-level changes. Sediment. Geol. 222, 226–240.
Scheel-Ybert, R., 2000. Vegetation stability in the Southeastern Brazilian coastal area from 5500 to 1400 14C yr BP deduced from charcoal analysis. Rev. Palaeobot. Palynol. 110, 111–138.
Scheel-Ybert, R., 2001. Man and vegetation in Southeastern Brazil during the Late Holocene. J. Archaeol. Sci. 28, 471–480.
Scheel-Ybert, R., 2013. Antracologia: preservados pelo fogo. In: Gaspar, M.D., Mendonça de Souza, S. (Eds.), Abordagens Estratégicas Em Sambaquis. Habilis, Erechim, pp. 193–218.
Scheel-Ybert, R., 2014. Landscape and use of plants by southern and southeastern Brazilian shell-mound builders. In: Roksandic, M., Mendonça de Souza, S., Eggers, S., Burchell, M., Klokler, D. (Eds.), The Cultural Dynamics of Shell-Matrix Sites. University of New Mexico Press, Albuquerque, pp. 289–300.
Scheel-Ybert, R., Eggers, S., Wesolowski, V., Petronilho, C.C., Boyadjian, C.H., Deblasis, P., Barbosa, M., Gaspar, M.D., 2003. Novas perspectivas na reconstituição do modo de vida dos sambaquieiros: uma abordagem multidisciplinar. Rev. Arqueol. SAB 16, 109–137.
Scheel-Ybert, R., Klökler, D., Gaspar, M.D., Figuti, L., 2005. Proposta de amostragem padronizada para macro-vestígios bioarqueológicos: antracologia, arqueobotânica, zooarqueologia. Rev. Mus. Arqueol. Etnol. 15–16, 139–163.
Scherer, L.Z., Rodrigues-Carvalho, C., Schmitz, P.I., 2006. Marcadores de estresse musculo-esquelético em populaces pescadoras, caçadoras e coletaroas do litoral central de Santa Catarina. Pesquisas 63, 55–80.
Schiegl, S., Goldberg, P., Pfretzschner, H.-U., Conard, N.J., 2003. Paleolithic burnt bone horizons from the Swabian Jura: distinguishing between in situ fireplaces and dumping areas. Geoarchaeology 18, 541–565.
Schiffer, M., 1987. Formation process of the archaeological record. University of New Mexico, Albuquerque.
Schmitz, P.I., 1996. Visão de conjunto dos sítios da Tapera, Armação do Sul, Laranjeiras I e II, Pântano do Sul e Cabeçudas. Pesquisas 53, 183–190.
Schmitz, P.I., 1999. Cerâmica Taquara e Itararé em concheiros. Rev. CEPA 23, 177–179.
Schoeller, D.A., 1999. Isotope fractionation: why aren't we what we eat? J. Archaeol. Sci. 26, 667–673.
Schoeninger, M.J., De Niro, M., 1984. Nitrogen and carbon isotopic composition of bone collagen from marine and terrestrial animals. Geochim. Cosmochim. Acta 48, 625–639.
Shahack-Gross, R., Simons, A., Ambrose, S.H., 2008. Identification of pastoral sites using stable nitrogen and carbon isotopes from bulk sediment samples: a case study in modern and archaeological pastoral settlements in Kenya. J. Archaeol. Sci. 35, 983–990.
Sherwood, S.C., Kidder, T.R., 2011. The DaVincis of dirt: geoarchaeological perspectives on Native American mound building in the Mississippi River basin. J. Anthropol. Archaeol. 30, 69–87.
Sherwood, S.C., Blitz, J.H., Downs, L.E., 2013. An integrated geoarchaeology of a late woodland sand mound. Am. Antiq. 78, 344–358.

Shillito, L.-M., Bull, I.D., Matthews, W., Almond, M.J., Williams, J.M., Evershed, R.P., 2011. Biomolecular and micromorphological analysis of suspected faecal deposits at Neolithic Çatalhöyük, Turkey. J. Archaeol. Sci. 38, 1869–1877.
Sifeddine, A., Wirrmann, D., Albuquerque, A., Turcq, B., Cordeiro, R., Gurgel, M., Abrao, J., 2004. Bulk composition of sedimentary organic matter used in palaeoenvironmental reconstructions: examples from the tropical belt of South America and Africa. Palaeogeogr. Palaeoclimatol. Palaeoecol. 214, 41–53.
Stein, J.K., 1992. Interpreting stratification of a shell midden. In: Stein, J.K. (Ed.), Deciphering a Shell Midden. Academic Press, San Diego, pp. 71–93.
Steiner, M.C., Weiner, S., Bar-Yosef, O., 1995. Differential burning and fragmentation of archaeological bone. J. Archaeol. Sci. 22, 223–237.
Stoops, G., 2003. Guidelines for Analysis and Description of Soil and Regolith Thin Sections. Soil Science Society of America, Madison.
Stuiver, M., Reimer, P., 1993. Extended 14C database and revised CALIB radiocarbon calibration program. Radiocarbon 35 (1), 215–230.
Tanaka, A.P.B., Giannini, P.C.F., Fornari, M., 2009. A planície costeira holocênica de Campos Verdes (Laguna, SC): evolução sedimentar inferida a partir de georradar (GPR), granulometria e minerais pesados. Rev. Bras. Geoci. 39, 750–766.
Thompson, V.D., Pluckhahn, T.J., 2012. Monumentalization and ritual landscapes at Fort Center in the Lake Okeechobee basin of South Florida. J. Anthropol. Archaeol. 31, 49–65.
Thompson, V.D., Pluckhahn, T.J., Thmpson, V.D., Pluckkahn, T.J., 2010. History, complex hunter–gatherers, and the mounds and monuments of crystal river, Florida, USA: a geophysical perspective. J. Isl. Coast. Archaeol. 5, 33–51.
Tiburtius, G., 1966. O sambaqui da Conquista (NR-9). Bolteim Parana. Geogr. 18 (19), 71–126.
Van Breemen, N., Buurman, P., 2003. Soil Formation. Kluwer Academic Publishers, New York.
Vila, A., Estevez, J., Piana, E., Madella, M., Barceló, J.A., Zurro, D., Clemente, I., Terradas, X., Verdún, E., Piqué, R., Mameli, L., Briz, I., 2011. Microstratigraphy of shell middens of Tierra del Fuego. In: Oostereberg, L. (Ed.), Evolutions and Environment. Proceedings of the XV World Archaeological Congress (Lisbon, 4–9 September 2006). British Archaeological Reports, Oxford, pp. 109–119.
Villagran, X.S., 2014. Experimental micromorphology on burnt shells of Anomalocardia brasiliana (Gmelin 1791) (Bivalvia, Veneridae) and its potential for identification of combustion features on shell-matrix sites. Geoarchaeology 29, 389–396.
Villagran, X.S., Giannini, P.C., 2014. Shell mounds as environmental proxies on the southern coast of Brazil. The Holocene 24, 1009–1016.
Villagran, X.S., Giannini, P.C.F., DeBlasis, P., 2009. Archaeofacies analysis: using depositional attributes to identify anthropic processes of deposition in a monumental shell mound of Santa Catarina State, southern Brazil. Geoarchaeology 24, 311–335.
Villagran, X.S., Klokler, D., Nishida, P., Gaspar, M.D., De Blasis, P., 2010. Lecturas estratigraficas: arquitetura funeraria y depositación de residuos en el sambaquí Jabuticabeira II. Lat. Am. Antiq. 21, 195–216.
Villagran, X.S., Balbo, A.L., Madella, M., Vila, A., Estevez, J., 2011. Stratigraphic and spatial variability in shell middens: microfacies identification at the ethnohistoric site Tunel VII (Tierra del Fuego, Argentina). Archaeol. Anthropol. Sci. 3, 357–378.
Walker, R.G., 1983. Facies Models. Geological Association of Canada, Toronto.
Wesolowski, V., 2000. A prática da horticultura entre os construtores de sambaquis e acampamentos litorâneos da região da Baía de São Francisco, Santa Catarina: uma abordagem bio-antropológica. Universidade de São Paulo.
Wesolowski, V., 2013. Micro-vestígios vegetais: o que os olhos nao vêem. In: Gaspar, M.D., Mendonça de Souza, S. (Eds.), Abordagens Estratégicas Em Sambaquis. Habilis, Erechim, pp. 219–238.
Wesolowski, V., Mendonça de Souza, S., Reinhard, K., Ceccantini, G., 2007. Grânulos de amido e fitólitos em cálculos dentários humanos: contribuição ao estudo do modo de vida e subsistência de grupos sambaquianos do litoral sul do Brasil. Rev. Mus. Arqueol. Etnol. 17, 191–210.
White, W.M., 2001. Stable isotope geochemistry. In: Geochemistry, pp. 370–420.
Wilson, D., 1994. Identification and assessment of secondary refuse aggregates. J. Archaeol. Sci. 1, 41–68.
Wilson, M.A., Righi, D., 2010. Spodic materials. In: Stoops, G., Marcelino, V., Mees, F. (Eds.), Interpretation of Micromorphological Features of Soils and Regoliths. Elsevier, Amsterdam, pp. 251–273.