Archaeofacies Analysis: Using Depositional Attributes to Identify Anthropic Processes of Deposition in a Monumental Shell Mound of Santa Catarina State, Southern Brazil

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In the coast of Santa Catarina State (southern Brazil), a large population of monumental shell mounds characterizes a highly dynamic coastal setting. In this paper, sedimentary facies analysis was adapted for description, sampling, and interpretation of shell mound complex and repetitive archaeostratigraphic successions. Archaeofacies identification in the field, according to depositional attributes, is tested by contrasting field description with multi-element chemical analyses, total carbon and nitrogen determinations, and micromorphological descriptions. Two vertical sequences at the black deposit of Jabuticabeira II shell mound were studied and preliminary results showed that: (1) depositional attributes are a reliable base for archaeofacies identification in the field, (2) the formation process of this site involved a sequence of anthropic depositional processes, where burned refuse was redeposited over the shell mound following a ritual construction pattern, and (3) the black deposit includes a double palimpsest that refers to provenance and meaning of mound construction material. © 2009 Wiley Periodicals, Inc.

INTRODUCTION

Along the southern coast of Santa Catarina State, southern Brazil, monumental shell mounds characterize an anthropic landscape built within a highly dynamic coastal lagoonal setting. These shell mounds, known for their great conspicuousness, are composed of *Anomalocardia brasiliana*, though other mollusks and gastropods (*Ostrea* sp., *Mytillus* sp., *Donax* sp., *Thais* sp.) can also be found as main components, either mixed within the matrix or as discrete layers in the archaeosedimentary successions. None of the monumental shell mounds have shown unquestionable evidence of having served as residential settlements, which leads to their categorization as funerary structures (Fish et al., 2000; Gaspar, 1998; DeBlasis et al., 2004).

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Geoarchaeology: An International Journal, Vol. 24, No. 3, 311–335 (2009)

Published online in Wiley Interscience (www.interscience.wiley.com). DOI:10.1002/gea.20269

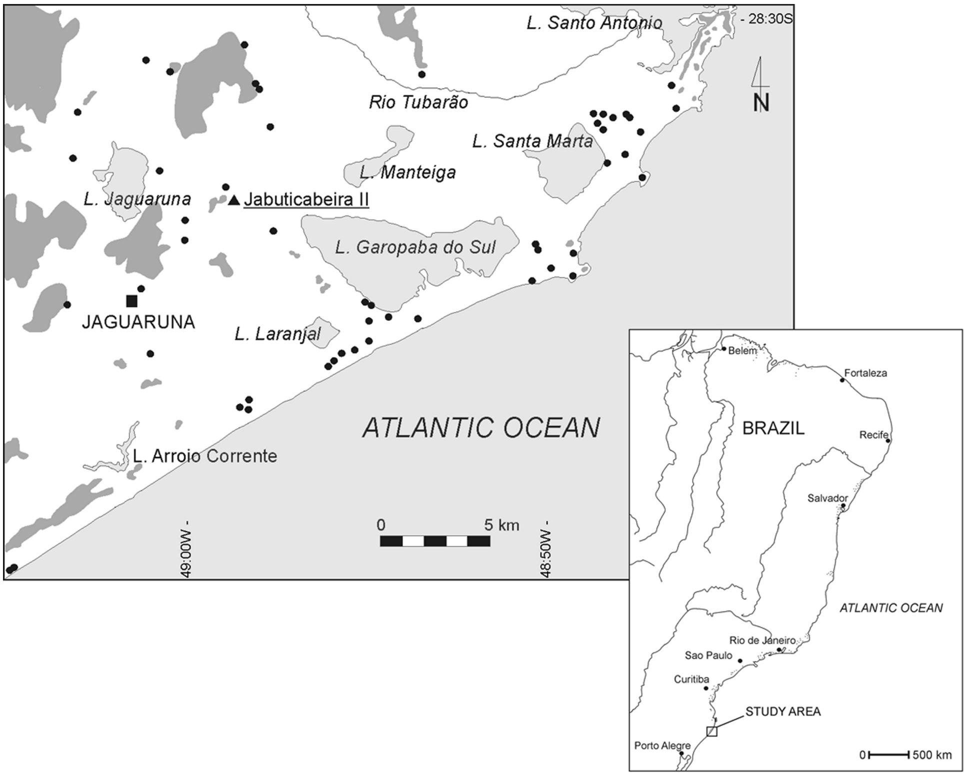

Figure 1. Southern coast of Santa Catarina State (Brazil), showing shell mound sites as circles and location of Jabuticabeira II site as a triangle.

Occupation of this territory by shell mound builders began ca. 6000 B.P., intensified between ca. 4200–2000 cal. yr B.P., and lasted until ca. 1500–1000 B.P. (De Blasis et al., 2007). During these thousands of years, numerous sites were constructed, reaching up to a total of 86 sites counted so far in the study area of approximately 700 square kilometers (691.87 km^2) (Figure 1). Mound-building accompanied the closing up of a great paleobay (Giannini, 1993, 2002; Giannini et al., 2007) that existed in the area during the transgressive flooding, prior to Holocene maximum relative sea-level rise (2.1 ± 0.5 m in 5916–5587 cal. yr B.P., according to Angulo et al., 1999; Angulo, Lessa, & Souza, 2006). This paleobay evolved to the lagoonal system that currently characterizes the area through two different but simultaneous processes: The first corresponds to the partial isolation of a body of water by the growth of a transgressive barrier closing the bay; and the second to the drowning of dissected SW–NW valleys in preexistent regressive marine terraces of Pleistocene age (Giannini, 1993, 2002). The partial sedimentary filling of the lagoon was favored by a subsequent smooth oscillating decrease in sea level. Eolian deposits are widespread over the lagoonal, barrier, and strandplain systems and have evolved as independent depositional systems from the Pleistocene to the Holocene (Giannini, 1993, 2002; Giannini et al., 2007).

Human settlement in this portion of the Brazilian coast depended on the natural shaping of the landscape, but also participated and influenced its final outlook. Before ca. 4000 B.P., when relative sea level was approximately 2 m higher than at present, at least 14 shell mounds had already been built on dry land. By the time relative sea level diminished to 1 m higher than the present level, between ca. 4000 and 2000 years B.P., most shell mounds were clearly following a settlement pattern that involved the raising of small structures around large monumental sites defining clusters, with the closing lagoons as epicenters (Figure 1). Shell mound construction and occupation of the area lasted until ca. 1500–1000 B.P., when these groups suddenly disappeared; many of their sites were later occupied by inland Jé and Guarani ceramists that later controlled the region (Kneip, 2004; DeBlasis et al., 2007; Gaspar et al., 2007).

Despite the progressive reduction of the bodies of water, utilization of this area by shell mound builders remained stable, as main food resources were not affected by this process (DeBlasis et al., 2007). Desalinization may have accompanied the progressive reduction of paleolagoons (Amaral et al., 2008; Fornari et al., 2008), which could explain the disappearance of mangrove in the region and the decline in the abundance of some mollusks, especially oysters and *Anomalocardia brasiliana*. This process would have been accentuated ca. 2000 years ago and may be related to the appearance of the black topmost deposits observed in some shell mounds of the region (DeBlasis et al., 2007). Black deposits represent the complete abandonment of shell as main construction materials and its substitution by fish bones, charcoal, and ashes, turning the top portion of shell mounds into fish mounds. However, the nature of this depositional change is still under study, and preliminary evidence suggests a combination of natural and cultural factors as responsible for the appearance of these archaeological sediments.

In terms of distribution, chronology, scale, and raw materials, shell mound construction can be considered as another depositional process among the many involved in the configuration of this particular scenery. These anthropic sedimentary bodies integrate natural particles into the building process, with shells of diverse species of mollusks and sand grains that equally appear as terrigenous particles in natural deposits. The complex archaeostratigraphy of shell mounds is formed by a combination of mainly anthropic but also natural formation and transformation processes, closely related to environmental conditions and landscape dynamics. Anthropic-built successions depend on the presence and dislocation of natural deposits that influence the nature of raw materials and their provenance, and its outcome is constrained by natural weathering processes that alter sedimentary remains.

In highly dynamic contexts, such as marine and coastal settings, geologists rely on the concept of sedimentary facies to study the chronology, evolution, and configuration of depositional systems. In sedimentology, a facies is a sedimentary unit characterized by a group of diagnostic depositional attributes identified in the field that are used, together with laboratory characterization, to infer the process responsible for facies deposition (Walker, 1979; Anderton, 1985; Miall, 1990). The process-response facies concept emerge with pioneer work on depositional systems (Fisher & McGowen, 1967) and reached its greater diffusion with the publication of Walker's Facies Models in 1979, though the term dates back to the 19th century in geology. In archaeology, the use of facies analysis is progressively becoming more common, as can be seen in Stein (1987, 1992, 2001), Brochier (1990, 2002), Brochier et al. (1992), Barham (1995), Gilbertson (1995), Courty (2001), and Courty and Fedoroff (2002), among others.

In coastal lagoonal settings where anthropic depositional processes act as geomorphic agents, we propose the inclusion of their products, defined elsewhere as archaeological facies (Brochier, 1990, 2002; Stein, 1992) or as archaeofacies by the authors, for evaluation of landscape evolution and archaeological site formation. Including humans as sedimentary agents, responsible for building massive anthropic deposits such as large-scale shell mounds, allows constructing complete scenarios of landscape development by integrating natural and anthropic geomorphic processes.

By visual appreciation of archaeosedimentary sections in monumental shell mounds of southern Brazil, which at first glance appear to be highly complex stratigraphies, a pattern of recurrent depositional events could be identified that mainly involve the anthropic remobilization and deposition of natural and artifactual particles. These processes repeat themselves in time and space, within a site (archaeofacies that appear repeatedly in a vertical section) and between different sites (same archaeofacies identified in different shell mounds). Identification of these processes, as well as study of their compositional attributes and the patterns they define, represents a fundamental step toward recognition of cultural formation processes.

Though the concept of sedimentary facies is wide enough to embrace any type of sediment, even archaeological ones, which may obviate the need for creation of a new terminology (archaeological facies or archaeofacies), we consider this semantic distinction important as a way of emphasizing the methodological and conceptual adaptations that are required when using a term originally developed for large-scale natural sedimentary processes in smaller-scale anthropic depositional ones. For example, to avoid interference of post-depositional alterations that modify sedimentary products, and thus lead to erroneous stratigraphic evaluations, a set of depositional attributes is used in sedimentology to describe vertical sections for facies identification. Clearly, the same criteria used in sedimentary successions cannot be applied in archaeological contexts. Therefore, in this paper we define a set of specific depositional attributes that must be used in the field when describing archaeosedimentary sections for identification of archaeological facies.

Extensive description and sampling were performed on two complex stratigraphies in one of the most impressive shell mounds in the region to test whether such depositional attributes represent a confident base for archaeofacies identification in the field (Figures 3, 4, 5; Tables I, II). This integrated and systematic approach allowed independent examination of depositional and post-depositional processes in the formation of archaeostratigraphic successions and the natural/cultural agents therein involved.

METHODS

The Study Area

This research has concentrated on the most excavated shell mound of the area: the Jabuticabeira II site (Figures 1, 2). This monumental shell mound (6 m high,

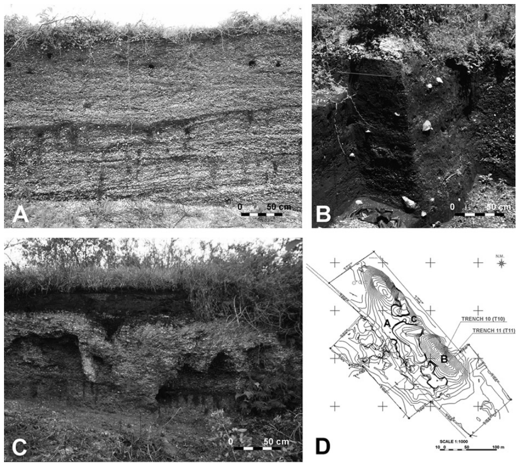

Figure 2. The three main stratified deposits [shell (A), black (B), and concreted deposit (C)] that compose the Jabuticabeira II shell mound, and their location (D).

400 m long, and 250 m wide) is considered a communal cemetery, not only for the great number of human burials it contains (a total estimated at 43,000), but also due to the characteristics of the stratigraphic successions, mostly interpreted as intentional mound building related to funerary ritual (DeBlasis et al., 1998; Fish et al., 2000; Gaspar, 2000; Karl, 2000), an interpretation strongly reinforced by archaeofaunistic spatial structuring analysis (Klokler, 2001, 2008; Nishida, 2007).

Archaeostratigraphic sections of Jabuticabeira II show three main stratified deposits (Figure 2): a shell deposit in the base (up to 3.5 m thick), in which a series of black millimetric layers occur (where most human burials rest); a diagenetically concreted shell deposit (up to 1 m thick); and, covering the first two, a black clayey sand deposit of decimetric to metric thickness (0.5–2.5 m thick) including enormous amounts of fish bone fragments and charcoal, where burials are numerous and artifacts, especially fire-cracked rock, are very common. Mound formation began around 3000 B.P., while deposition of the black deposit started ca. 2000 years ago and lasted until ca. 1000 B.P.

Shell mining activities in Jabuticabeira II (and many other sites) during the 1960s and '70s left behind long walls transecting the mound that turned out to be useful in structural archaeostratigraphic studies, allowing for macroscopic analysis of the site's depositional successions. The mounding-up process followed a construction pattern that involved the raising of synchronic and diachronic smaller mounds associated with discrete funerary areas; the recurrence and overlapping of such structures created an overall incremental pattern that, in due time, acquired monumental dimensions (Klokler, 2001, 2008).

The presence of the shell deposit is the diagnostic attribute of all Brazilian shell mounds, but the black deposit that covers Jabuticabeira II can only be seen in a limited number of them after 2000 B.P. (Morrote, Mato Alto II, Encantada II, Enseada I,

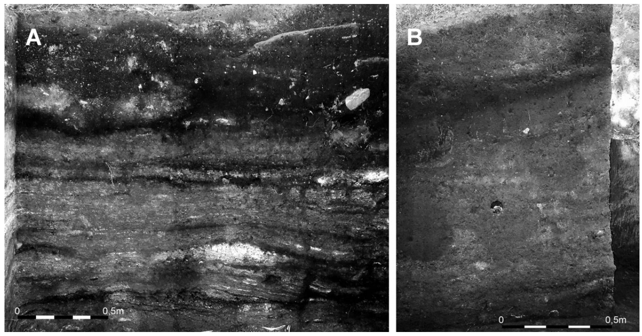

Figure 3. Black deposit of Jabuticabeira II at T11 (A) and T10 (B).

Carniça II). Black deposits could have been a standard attribute in shell mounds, although they greatly suffered the effects of recent anthropic interventions such as mining activities that, for the purpose of shell extraction, have widely devastated these fish mounds in order to reach shell concentrations of economic significance.

For the study of the upper black deposit of Jabuticabeira II, two trenches were specifically opened in 1999 into its thicker portion at the top of the mound [trench 10 (T10) and trench 11 (T11)], and studied since then (Figure 3). In both trenches the stratigraphic succession showed a great variety of archaeological lenses and features, including post holes, combustion structures, human burials, sand and ash lenses, etc., in an archaeosedimentary matrix of mostly archaeofaunistic composition.

Description and Sampling of Archaeological Facies

In archaeology, as in sedimentology, attributes used to describe and define archaeological facies are exclusively depositional, related to the original configuration of an archaeological layer. Shifts in anthropic depositional processes can be recognized in the field by changes in texture, composition, and shape of the archaeological layers, among other aspects. Attributes defined for identification of archaeological facies in the field, though similar to the ones used in sedimentology, are meant to characterize anthropic processes of deposition and include diagnostic cultural indicators that are not found in natural systems. Description and definition of archaeological facies in the field were made according to the following criteria:

1. Composition of the matrix (including texture, color, and mineralogy).
2. Macroscopic components (sand grains, shell, fish bones, charcoal, artifacts, human burials, etc.).
3. Shape of facies (nature of boundaries, whether sharp, gradual, diffuse, etc.) and thickness.
4. Structures (combustion structures, burial pits, post holes, sand, ash or charcoal lenses, etc.).
5. Orientation (fabric) of macroscopic components in the matrix.

Variation in any of these attributes is a sufficient requisite to distinguish a number of archaeofacies in a vertical succession. Although the list of descriptive criteria is not a new one for field archaeologists, and though it may seem quite short and succinct, this list comprises depositional attributes alone and is designed to work as a checklist in the field only for description of archaeological successions. All other properties that researchers may feel are missing from this list are probably post-depositional ones (produced by weathering and/or diagenetic agents), and therefore are not included in archaeofacies description. Such post-depositional attributes may include consistency, pedological structure, root presence, cementation, packing, and fragmentation, among other properties that must also be recorded, though only laboratory analyses will further explain their significance. Color of sediments is included in archaeofacies description as it is closely related to the nature of macroscopic components; however, this attribute can be post-depositional as well, and its origin (whether depositional or post-depositional) should be carefully evaluated in the field by contrasting it with other attributes, in order to avoid erroneous identification of archaeological facies. Likewise, gradual or diffuse boundaries are generally produced by post-depositional agents, so they should be recorded only if other depositional attributes indicate a discrete archaeofacies.

Description of the south wall of T11 (Figure 4) and the west and north walls of T10 (Figure 5) in the black deposit of Jabuticabeira II was made following the list of depositional attributes proposed in this paper (composition of the matrix, macroscopic components, shape and thickness of facies, structures and orientation of macroscopic components). Post-depositional properties, such as color, root presence, and porosity were registered as additional observations. To test the efficiency of the method for identification of recurrent depositional patterns in archaeological sites, all the archaeosedimentary layers observed in the vertical sections were described and registered in addition to the similarities they presented. This procedure was performed as an evaluation test to see if the proposed attributes do synthesize and simplify description of extensive successions, so archaeological facies were identified in the field, and later in the laboratory, after contrasting field description with chemical characterization and micromorphology.

Bulk samples were collected in T11 (Figure 5) to perform the following studies: multi-element (major, minor, and trace) chemical analyses by X-ray fluorescence spectometry (using a Phillips PW24010 instrument); and total carbon and nitrogen, using an LECO analyzer CHN-1000. All samples were prepared and analyzed at the University of São Paulo's Laboratory of Chemistry and ICP-OES/MS and Laboratory of X-Ray Fluorescence, by a method proposed by Mori et al. (1999). Multi-element chemical composition (including major, minor, and trace elements such as Si, Al, Mn, Mg, Ca, Na, K, Ti, P, Fe, C, Cu, Rb, S, Sr, and Zn) plus total carbon and nitrogen determinations (Table IV) were used as variables in hierarchical cluster analysis made using Minitab statistical software (version 15).

Undisturbed sediments samples were also collected from T11 and T10 (Figures 4, 5) and impregnated with epoxy resin under vacuum from which 7.0×4.5 cm thin sections (30 μm) were made at the Laboratory of Micromorphology of the College of Agronomy, University of São Paulo (ESALQ/USP). Observations were performed with

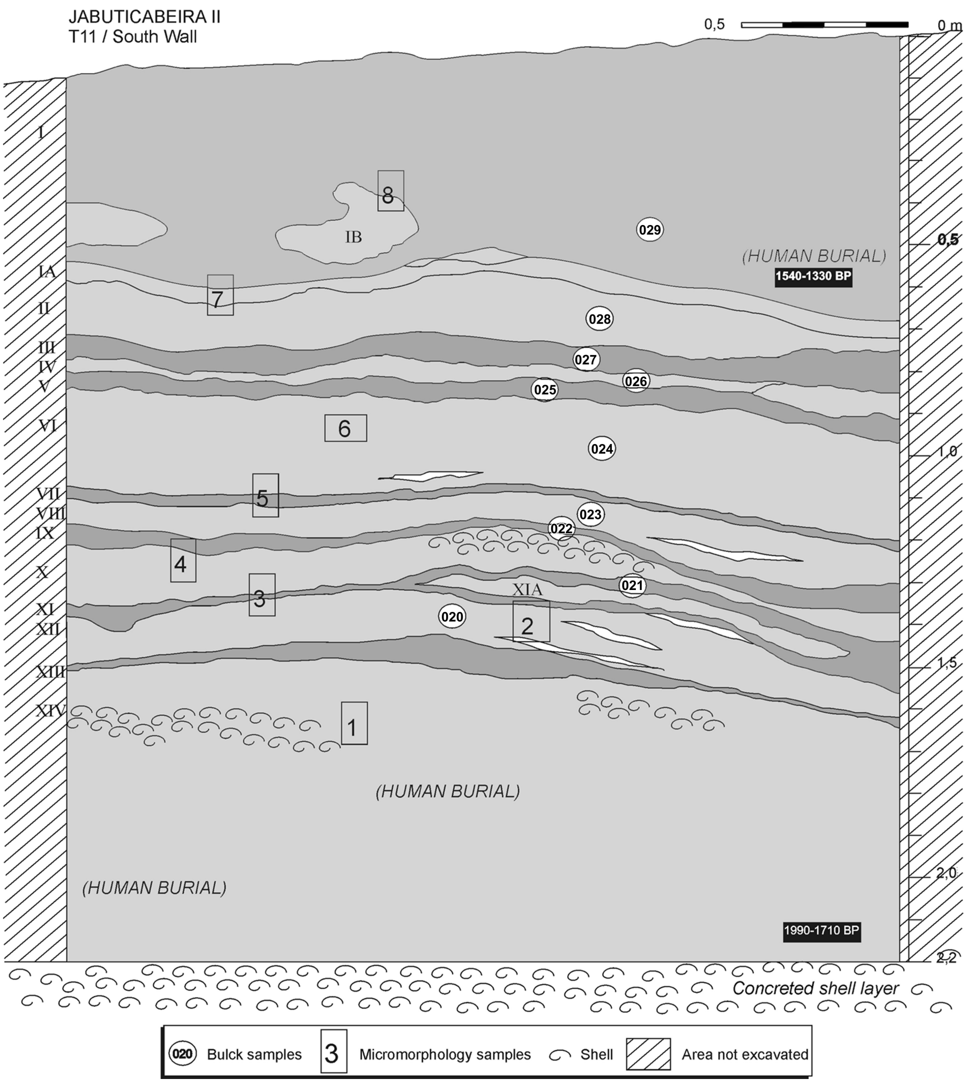

Figure 4. T11 stratigraphy and sample locations.

a petrographic microscope (Zeiss Axioplan 2) in plane-polarized (PPL) and cross-polarized light (XPL), at magnifications ranging from 25× to 400×, and description was made following the international system for soil thin-section description (Bullock et al., 1985; Stoops, 2003). Scanning electron microscopy (SEM), using a Leo 440i electron microscope, was conducted on the blocks prepared for thin-section analysis. Samples were coated with carbon or gold, according to micromass composition, and images were taken with a Kontron 300 and analyzed for elemental composition using an EDS Oxford attachment. Both microscopic studies were performed at the

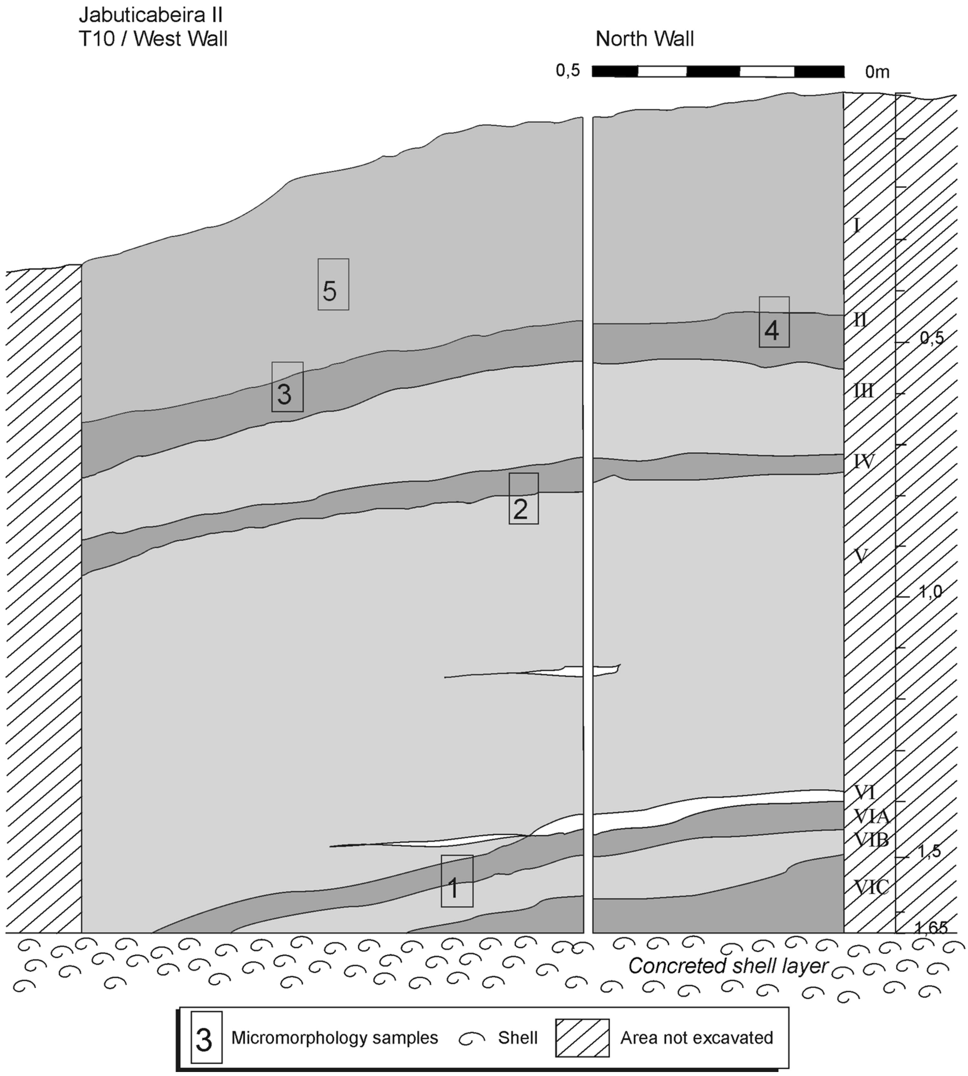

Figure 5. T10 stratigraphy and sample locations.

Laboratory of Petrography and the Laboratory of Scanning Electron Microscopy of the Institute of Geosciences at the University of São Paulo (IGc/USP).

Part of these laboratory analyses were used as a numerical basis to statistically compare and contrast field classification of archaeofacies with laboratory classification. But, most important, they offered substantial information that helped to refine our knowledge concerning composition of these archaeological sediments and the processes involved in their configuration, which provided the basis for site formation interpretations.

RESULTS

Field description

Field description of vertical successions in the black topmost deposit of Jabuticabeira II, according to depositional attributes, identified fourteen layers in T11 (Table I) and nine layers in T10 (Table II). From the total of 23 layers described, seven archaeological facies could be identified (see Figure 6 and Table III) based on bone fragment concentration, differential presence of particular components (lithic artifacts, charcoal, burnt bone, ashes), and shape and thickness of layers. Archaeofacies 1 (Table I: T11 I; Table II: T10 I), the most superficial and thick of all archaeological facies identified, is not found elsewhere in the succession because it presents the lower frequency of bone fragments in the coarse fraction, together with shell concretions and lithic artifacts. Archaeofacies 2 (Table I: T11 III, V; Table II: T10 II, IV, VIA, VIC) is up to 5 cm thick and rich in charcoal and burnt bone fragments, while archaeofacies 4 (Table I: T11 VII, IX, XI), though equally rich in burnt bone fragments, presents a considerable amount of ash in its composition. A similar situation occurs with archaeofacies 3 (Table I: T11 II, IV; Table II, T10 III) and 5 (Table I: T11 VI, VIII, X, XII, XIV; Table II: T10 V, VIB), both up to 5 cm thick and rich in weathered bone fragments, though archaeofacies 5 also includes ash in its composition and sand lenses in its internal structure, and has a higher frequency of bone fragments. Archaeofacies 6 (Table I: T11 XIII) clearly differs from other facies as it represents a bonfire that could also be appreciated in the horizontal section during excavation of T11. Finally, archaeofacies 7 (Table II; T10 VI) is a sand layer composed of quartzose sand grains and some, probably intrusive, bone fragments.

Layer XIV represents a combination of burnt, carbonized, and calcined bones, concreted shell, and huge amounts of ashes and charcoal. It was grouped into archaeofacies 5 because the actual condition of its components (burned and concreted) is probably a post-depositional attribute related to the presence of a bonfire (archaeofacies 6) immediately on top of it, as well as the vertical movement and washing of fine material through the profile.

Multi-Element Chemical Characterization

Identification of seven archaeofacies from field description of T11 and T10 vertical successions (Figure 6) was contrasted with quantitative results obtained from multi-element chemical analyses performed on nine samples from T11. X-ray fluorescence has the advantage of including the solid fraction into chemical measurements, so composition of the solid and solute fractions are both computed in the results. This diminishes the influence of post-depositional processes that are an important agent for compositional alterations of the ionic and colloidal fractions and makes chemistry an additional indicator of depositional archaeofacies.

In the black layer, chemical data can be related to composition of the matrix and the nature of macroscopic components, both depositional attributes that helped to differentiate between archaeofacies. For example, all archaeofacies present high concentrations of silica, ranging from 50% to 80% (see Table IV); this is probably related

Table I. Description of archaeological layers of T11 according to depositional attributes.

Layers	Composition of the Matrix	Macroscopic Components	Shape of Facies	Internal Structures	Orientation of Macroscopic Components	Observations
I 0–48 cm	Silty clay loam	Bone fragments (10%); shell; lithic artifacts; 1 human burial	Abrupt		Non-oriented	10YR 3/2 very dark grayish brown. Firm
II 48–61cm	Clay loam	Bone fragments (15%); shell; Stone flakes	Abrupt/undulated		Non-oriented	5YR 3/2 dark reddish brown. Very friable
III 61–67 cm	Clay loam	Bone fragments (5%); charcoal	Abrupt/undulated		Non-oriented	10YR 2/1 black. Friable
IV 67–70	Clay loam	Bone fragments (30%); shell	Abrupt/plane		Preferential horizontality	10YR 4/2 dark grayish brown. Very friable
V 70–74 cm	Clay loam	Bone fragments (10%); charcoal	Abrupt/plane		Non-oriented	10YR 2/1 black. Friable
VI 74–98 cm	Clay loam	Bone fragments (40%); ashes	Abrupt/plane	Sand lenses; ash lenses	Preferential horizontality	10YR 4/2 dark grayish brown. Very friable
VII 98–100 cm	Clay loam	Bone fragments (<5%); ashes; charcoal	Abrupt/plane		Non-oriented	7.5YR 3/1 very dark gray. Friable
VIII 100–106 cm	Clay loam	Bone fragments (50%); ashes; charcoal; stone flakes	Abrupt/plane	Sand lenses; ash lenses	Preferential horizontality	10YR 3/2 very dark grayish brown. Very friable
IX 106–111 cm	Clay loam	Bone fragments (5%); ashes; charcoal	Abrupt/plane		Non-oriented	10YR 3/1 very dark gray. Friable
X 111–125 cm	Sandy clay	Bone fragments (50%); concreted shell; ashes; stone flakes	Abrupt/plane		Preferential horizontality	10YR 4/2 dark grayish brown. Very friable
XI 125–128 cm	Sandy clay	Bone fragments (7%); ashes; charcoal	Abrupt/plane		Non-oriented	7.5YR 3/1 very dark gray. Friable
XII 128–139 cm	Sandy clay	Bone fragments (30%); ashes	Abrupt/plane	Sand lenses; ash lenses	Preferential horizontality	10YR 4/3 brown. Very friable
XIII 139–141 cm	Silty	Burnt bone fragments (50%); charcoal; ashes	Lenticular Abrupt/undulated		Non-oriented	10YR 4/2 dark grayish brown. Hard
XIV 141–178 cm	Silty	Burnt bone fragments (50%); ashes; concreted shell; 2 human burials	Base, abrupt contact with concretionated shell layer		Non-oriented	10YR 4/2 dark grayish brown. Firm

Table II. Description of archaeological layers of T10 according to depositional attributes.

Layers	Composition of the Matrix	Macroscopic Components	Shape of Facies	Internal Structures	Orientation of Macroscopic Components	Observations
I 0–42 cm	Silty clay loam	Bone fragments (7%); shell; lithic artifacts	Abrupt/plane		Non-oriented	7.5YR 3/1 very dark gray. Firm
II 42–52 cm	Silty loam	Bone fragments (<5%); charcoal	Abrupt/plane		Non-oriented	7.5YR 2.5/1 black. Friable
III 52–72 cm	Silty loam	Bone fragments (5%); shell; stone flakes	Abrupt/plane		Preferential horizontality	10YR 3/1 very dark gray. Very friable
IV 72–78 cm	Clay loam	Bone fragments (5%); charcoal	Clear/plane		Non-oriented	10YR 2/1 black. Friable
V 78–140 cm	Sandy clay	Bone fragments (30%); ashes	Abrupt/undulating	Sand lenses; ash lenses; black organic lenses (10YR 2/1 black)	Preferential horizontality	10YR 2/2 dark brown. Friable
VI 140–145 cm	Loose sand	Bone fragments (<5%)	Abrupt/plane		—	10YR 6/2 light brownish gray. Loose
VIA 145–150 cm	Clay loam	Bone fragments (<5%); charcoal	Abrupt/plane		Non-oriented	7.5YR 2.5/1 black. Friable
VIB 150–157 cm	Sandy clay	Bone fragments (25%)	Abrupt/plane		Preferential horizontality	7.5YR 3/3 dark brown. Very friable
VIC 157–165	Clay loam	Bone fragments (<5%); charcoal	Base, abrupt contact with concreted shell layer		Non-oriented	7.5YR 2.5/1 black. Friable

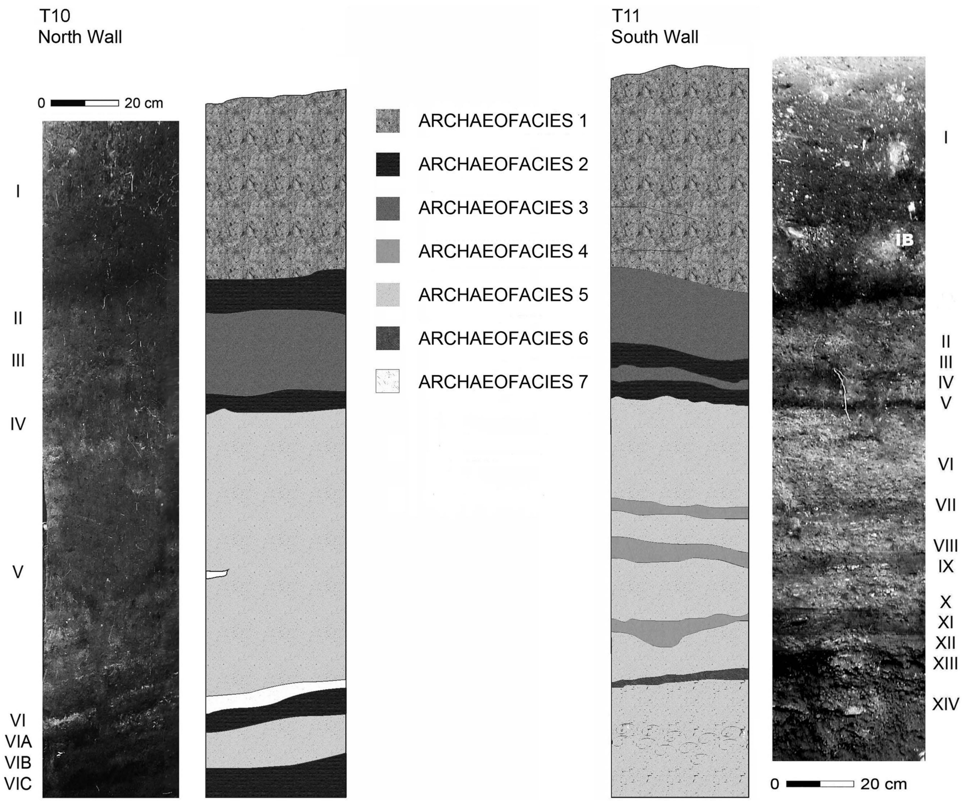

Figure 6. Schematic vertical section of T10 and T11 with archaeofacies localization.

to the large amounts of quartzose sand that compose these sediments. Likewise, the difference in composition between facies 2 and 4, mainly composed of burnt bone fragments, and facies 3 and 5, where bones are considerably more abundant, as well as more altered and less burnt (see Table III), was also reflected in chemical indicators. Total phosphate and calcium concentration were higher in archaeofacies 3 and 5, where bone fragments are more abundant, and total carbon percentages were dominant in archaeofacies 2 and 4, where bones are mainly burnt and micromass appears to be composed of micro-charcoal aggregates (see Figure 8; Tables IV, V, VI).

However, we must not discard the influence that post-depositional processes also have on the solid fraction. For example, semi-quantitative microprobe analyses (MEV-EDS) made on fresh bone fragments from the black layer showed that these particles are mainly composed of calcium, carbon, and phosphorus, with trace amounts of sodium, magnesium, and iron. This shows that many normal components of bone tissue, such as potassium, manganese, and strontium, are no longer part of their current composition, probably due to post-depositional processes of chemical washing and leaching.

Table III. Archaeofacies identified from T11 and T10 vertical successions.

Archaeofacies	Descriptive Attributes	Archaeological Layers
1	Bone fragments (<10%), shell and lithic material. Dark brown	T11 I T10 I
2	Charcoal and burnt bone fragments (10–15%). Black	T11 III, V T10 II, IV, VIA, VIC
3	Bones (10–30%), very fragmented and weathered, shell (sometimes concreted). Brown	T11 II, IV T10 III
4	Charcoal, burnt bones (10–15%) and ashes. Gray	T11 VII, IX, XI
5	Bones (30–50%), very fragmented and burnt; charcoal, ashes, and sand lenses. Occasional concreted shell Light grayish brown	T11 VI, VIII, X, XII; XIV T10 V, VIB.
6	Charcoal, calcined and carbonized bones. Lenticular. Black	T11 XIII
7	Loose sand. Yellow	T10 VI

Table IV. Multi-element chemical composition (in percentages) of nine archaeological layers sampled in T11.

(%)	I	II	IV	V	VI	VIII	IX	XI	XII
Si	52.11	46.51	41.23	76.83	49.97	57.84	73.50	79.73	64.57
Al	1.68	1.01	1.14	2.01	0.71	0.83	1.22	1.14	0.90
Mn	0.157	0.335	0.188	0.060	0.097	0.093	0.064	0.067	0.149
Mg	0.29	0.18	0.20	0.15	0.20	0.19	0.14	0.12	0.15
Ca	19.33	24.30	26.65	6.81	22.86	18.71	9.37	6.75	15.93
Na	0.44	0.33	0.34	0.23	0.32	0.29	0.22	0.16	0.27
K	0.24	0.14	0.16	0.31	0.10	0.12	0.20	0.16	0.16
Ti	0.168	0.099	0.096	0.187	0.081	0.118	0.183	0.197	0.115
P	13.87	18.22	20.43	4.67	17.00	14.11	6.32	4.61	12.09
Fe	1.00	0.05	0.57	1.07	0.38	0.43	0.63	0.59	0.40
Co	0.0026	0.0029	0.0022	0.0070	0.0026	0.0030	0.0065	0.0078	0.0029
Cu	0.0071	0.0046	0.0036	0.0064	0.0037	0.0029	0.0038	0.0041	0.0022
Rb	0.0008	0.0006	0.0006	0.0013	0.0004	0.0004	0.0008	0.0008	0.0005
S	0.0736	0.0712	0.0692	0.0330	0.0794	0.0893	0.0617	0.0349	0.0539
Sr	0.0723	0.0867	0.1020	0.0428	0.0809	0.0700	0.0456	0.0353	0.0583
Zn	0.0457	0.0590	0.0519	0.0233	0.0329	0.0366	0.0304	0.0401	0.0348
C	4.73	2.67	2.75	2.65	2.78	2.65	2.77	2.38	1.37
N	0.3894	0.1763	0.2868	0.1689	0.2497	0.1828	0.1938	0.1580	0.0561

In any case, multielement chemical characterization by X-ray fluorescence was used as a source for more detailed information on archaeofacies composition, despite the influence that post-depositional processes may have on the solid and ionic fractions. Therefore, hierarchical cluster analyses were made to see whether or not archaeofacies classification made following the list of descriptive depositional attributes also corresponds with those based on properties determined by laboratory characterization.

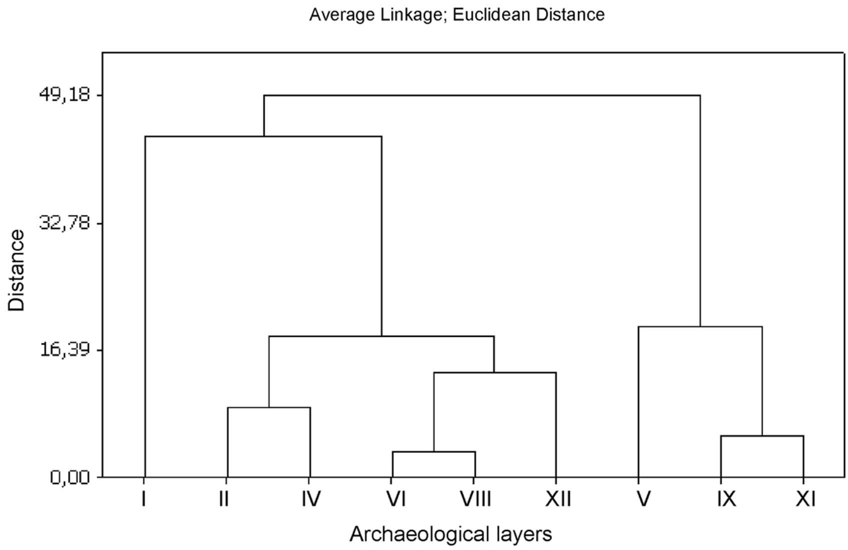

Figure 7. Dendrogram for multielement chemical composition of T11.

Figure 7 shows the dendrogram built for multielement chemical composition of nine archaeological layers from T11; it can be clearly seen how three main clusters were obtained. The first cluster includes layer I, which corresponds to the topmost layer of T11, which is clearly different from subjacent layers in shape, thickness, and composition and was therefore defined as archaeofacies 1. The second main cluster groups all layers with altered bone fragments as main components and is subdivided into two subclasses: one that includes layers II and IV, identified by depositional descriptive criteria as archaeofacies 3; and another that includes layers VI, VIII, and XII, all included into archaeofacies 4, which is similar to archaeofacies 3 but contains ash in its composition and sand lenses in its structure. The last class includes layers up to 5 cm in thickness, with charcoal and burnt bones as principal components. It is also subdivided into layer V, which represents archaeofacies 2, and layers IX and XI, which together represent archaeofacies 5, which also have the particularity of including considerable amounts of ash in their composition.

Thus, multielement characterization of archaeofacies that compose the black deposit can be related to the depositional attributes that helped to define them in the field, such as composition of the matrix and macroscopic components. This analysis is also an important source of information for refining our knowledge on archaeofacies composition that is not observable in the field.

Micromorphology Description

Micromorphological analyses of the black deposit were performed to broaden our knowledge of archaeofacies composition, to know the hierarchies and relations between components, and to identify the influence of post-depositional processes.

Description of thin sections from T10 and T11 (Tables V and VI) showed a series of properties that are common to all archaeological facies identified, including: intergrain microaggregate microstructure; complex packing voids with random distribution; enaulic c/f–related distributions; coarse fraction consisting of quartz grains, bone, and charcoal fragments with varying proportions of siliceous aggregates; and pedogenic features that include mamilated excrements, pendent and capping cryptocrystalline coatings (of mainly phosphate composition), and organic nodules of anortic and disortic type.

The coarse fraction is dominated by quartz grains with random distribution, good selection, and high sphericity and rounding (Figure 8), which coincides with grain-size evidence of its paleolagoonal origin (Villagran, 2008). The second and third most important constituents are bones and charcoal, both poorly selected, angular, rough, and randomly distributed. High fragmentation observed in bones (Figure 8) can be the result of intense weathering, but the considerable amount of burnt bones observed also suggests that fragmentation can as well be the result of bone weakening after heating and burning. When heated, bones became more fragile to any external pressure exerted (Steiner, Weiner, & Bar-Yosef, 1995), such as trampling, a probable cause in a site that remained active for more than 2000 years, or transport and remobilization of materials during the mound building process.

Inorganic particles of biological origin, like phytoliths and diatoms, were also found in considerable amounts in the black layer (Figure 9), especially grass phytoliths and diatoms typical of estuarine environments (Amaral, pers. comm.). But the most curious and equally abundant component of the coarse fraction are the so-called “siliceous aggregates” (Schiegl et al., 1994), which display the optical behavior of amorphous silica (Figure 9). Their morphology does not relate them with microfossils or any known element, and their mineralogical constitution and general appearance leads to the interpretation that they can be either the product of melted quartz grains, phytoliths, or diatoms. These siliceous particles have high fusion points, but when coexisting with alkaline materials in a deposit (such as bones), such thresholds can lower until temperatures easily attained in anthropic fires (800–1000°C) (Courty, Goldberg, & Macphail, 1989; Berna, Matthews, & Weiner, 2004).

The main micromorphological differences among archaeofacies are related to composition of the micromass and frequency of bone and charcoal fragments in the coarse fraction. Two different micromasses compose the black deposit of Jabuticabeira II: a yellowish-brown, low-birefringence, undifferentiated (cryptocrystalline) b-fabric micromass; and a black, organic, amorphous micromass. These two fine materials generally appear mixed in all archaeological facies into an organo-mineral micromass, varying only in their relative proportions. In archaeological facies rich in burnt bone and charcoal fragments, such as archaeofacies 2 and 4, the black organic micromass is predominant and almost exclusive, while in archaeofacies 1, 3, and 5, rich in altered bone fragments, the yellowish-brown micromass is predominant and appears in some areas mixed with organic fine material and phytoliths (Figure 8).

Microprobe analyses were performed in thin sections from archaeofacies 2 and 3 to determine the composition of their respective micromasses. The black organic micromass that characterizes archaeofacies 2 and 4 is mainly composed of carbon

Table V. Summary thin-section micromorphology descriptions, Jabuticabeira II: T10.

							Coarse Mineral Material				Coarse Organic Material				Pedogenic Features		
Section	Microstructure	Porosity	(%) Pores	Distribution	c/f Ratio	Related Distribution	Quartz	Fish Bones	Phytoliths	Diatoms	Siliceous Aggregates	Charcoal	Tissue Residues	Micromass	Anortic Nodules	Excrements	Coatings
T10/5 Layer I	Intergrain microaggregate	Complex packing voids	•••	Random	60:40	Enaulic	•••	••				•	•	Organo-mineral Dark brown	•		•
T10/4																	
Upper Layer I	Intergrain microaggregate	Complex packing voids	•••	Random	60:40	Enaulic	•••	•••				•	••	Organo-mineral Dark brown		•	•
Lower Layer II	Intergrain microaggregate	Complex packing voids	••	Random	50:50	Enaulic	•••	•••			•	••		Organic Black		•	•
T10/3																	
Upper Layer I	Intergrain microaggregate	Complex packing voids	•••	Random	30:70	Enaulic	•••	•••				•••		Organo-mineral Dark brown		•	•
Lower Layer II	Intergrain microaggregate	Complex packing voids	••••	Random	50:50	Enaulic	••	•••		•	•	••	•	Organic Black		•	•
T10/ 2																	
Upper Layer IV	Intergrain microaggregate	Complex packing voids	•••	Random	50:50	Enaulic	•••	•••				••		Organic Black			•
Lower Layer V	Intergrain microaggregate	Complex packing voids	•••	Random	60:40	Enaulic	•••	•••	••	••	•	•	•	Organo-mineral Yellowish-brown		•	•
T10/ 1																	
Upper Layer VIA	Intergrain microaggregate	Complex packing voids	•••	Random	50:50	Enaulic	•••	•••				•••		Organic Black			•
Lower Layer VIB	Intergrain microaggregate	Complex packing voids	••••	Random	40:60	Enaulic	•••	•••	••	••		•	•	Organo-mineral Yellowish-brown		•	•

Frequency class refers to the appropriate area of section (Bullock et al., 1985): • Very few; •• Few; ••• Frequent/Common; •••• Dominant/Very dominant.

Table VI. Summary thin-section descriptions, Jabuticabeira II: T11.

Section	Microstructure	Porosity	(%) Pores	Distribution	c/f Ratio	Related Distribution	Coarse Mineral Material: Quartz	Coarse Mineral Material: Fish Bones	Coarse Mineral Material: Phytoliths	Coarse Mineral Material: Diatoms	Coarse Organic Material: Siliceous Aggregates	Coarse Organic Material: Charcoal	Coarse Organic Material: Tissue Residues	Micromass	Pedogenic Features: Anortic Nodules	Pedogenic Features: Excrements	Pedogenic Features: Coatings
T11/8 Layer I	Intergrain microaggregate	Complex packing voids	•••	Random	30:70	Enaulic	•••	•••				•••		Organo-mineral Dark brown			
T11/7 Layer II	Intergrain microaggregate	Complex packing voids	••••	Random	70:30	Enaulic	•••	•••		•	•		•	Organo-mineral Yellowish brown		•	•
T11/6 Layer VI	Intergrain microaggregate	Complex packing voids	••••	Random	80:20	Enaulic	•••	•••	••	•	•	•	•	Organo-mineral Yellowish-brown	•		•
T11/ 5																	
Upper Layer VI	Intergrain microaggregate	Complex packing voids	•••	Random	70:30	Enaulic	•••	••••	•	•		•	•	Organo-mineral Yellowish brown		•	•
Lower Layer VII	Intergrain microaggregate	Complex packing voids	•••	Random	50:50	Enaulic	•••	•••			•	••		Organic Black			•
T11/ 4																	
Upper Layer IX	Intergrain microaggregate	Complex packing voids	••••	Random	60:40	Enaulic	•••	•••	•			••		Organic Black			•
Lower Layer X	Intergrain microaggregate	Complex packing voids	••••	Random	70:30	Enaulic	•••	•••	•			•	•	Organo-mineral Yellowish brown		•	•
T11/ 3 Layer XI	Intergrain microaggregate	Complex packing voids	•••	Random	60:40	Enaulic	•••	•••			••	•		Organo-mineral Dark brown		•	•
T11/ 2 Layer XII	Intergrain microaggregate	Complex packing voids	••••	Random	70:30	Enaulic	•••	•••	•		•	•	•	Organo-mineral Yellowish brown			•
T11/ 1 Layer XIV	Intergrain microaggregate	Complex packing voids	••••	Random	60:40	Enaulic	•••	•••		•	•	•		Organo-mineral Yellowish brown			•

Frequency class refers to the appropriate area of section (Bullock et al., 1985): • Very few; •• Few; ••• Frequent/Common; •••• Dominant/Very dominant.

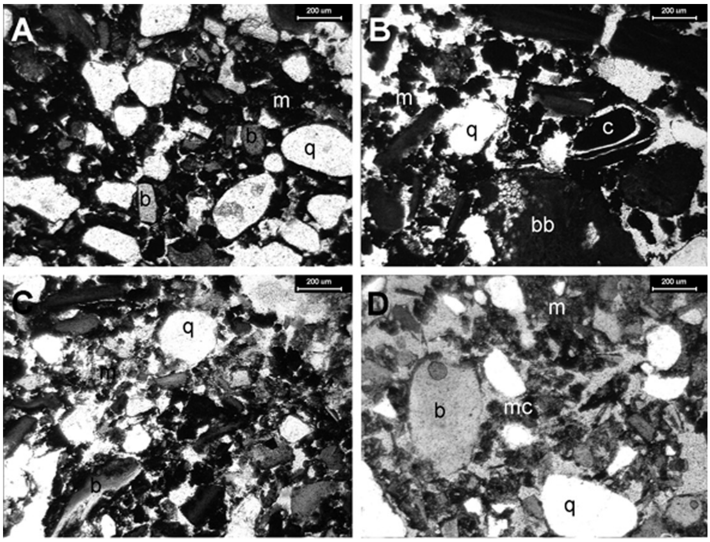

Figure 8. Photomicrographs in plane-polarized light (PPL) of archaeological microfacies at Jabuticabeira II: (A) archaeofacies 1, organo-mineral micromass (m), coarse fraction composed of quartz grains (q) and very fragmented bone (b); (B) archaeofacies 2, black organic micromass (m), quartz grains (q), burnt bone fragments (bb) and charcoal fragments (c); (C) archaeofacies 3, organo-mineral micromass of mainly phosphatic composition (m), coarse fraction composed of altered bone fragments (b) and quartz grains (q); (D) archaeofacies 5, phosphatic micromass (m) with microcharcoal (mc), quartz grains (q), and bone fragments (b).

and oxygen, with minor concentrations of silica and calcium, which confirms its charcoal composition. The organo-mineral, yellowish-brown, undifferentiated micromass that characterizes archaeofacies 1, 3, and 5 proved to be a mixture of calcium-phosphate with an organic material, and is mainly composed of carbon and phosphorus, calcium, and minor amounts of manganese, magnesium, silica, sodium, iron, chlorine, and aluminum.

In general terms, an intercalation between the phosphatic cryptocrystalline micromass and the black carbonaceous micromass can be observed in successive archaeofacies through the section. Such differences in micromass composition, which is coincident with the composition of the coarse fraction (altered bones vs. burnt bones), would not be related to post-depositional processes, but to the different anthropic processes of deposition that configured the black deposit.

DISCUSSION

For the black deposit of Jabuticabeira II, archaeofacies analysis showed that the complexity of this archaeostratigraphic body can be simplified into seven different types of depositional products (Figure 6) associated with different anthropic processes of deposition that are recurrent in time, as they appear several times in the same succession, and in space, as observed in both trenches opened for study. Cluster analysis from multielement chemical composition corroborated field description as a confident

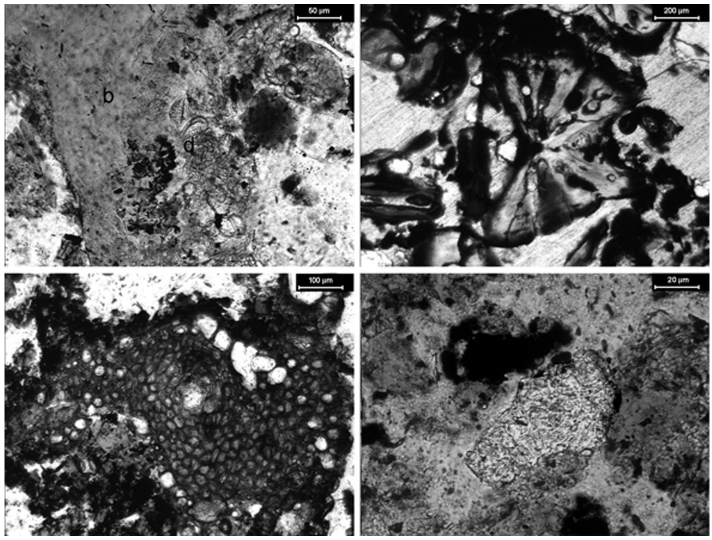

Figure 9. Photomicrographs in plane-polarized light (PPL) of some of the microscopic components of the black deposit: (A) dissolved bone fragment (b) with diatom inclusions (*Rhopalodia gibberula*) (d) from archaeofacies 3 (T10); (B) burnt fish bone from archaeofacies 6 (T11); (C) tissue residue from archaeofacies 2 (T10); (D) siliceous aggregate from archaeofacies 3 (T10).

basis for archaeofacies identification, as classification built according to depositional attributes was later confirmed by multivariate statistical analysis of chemical properties determined in the laboratory. Micromorphological information showed that, besides the apparent complexity of archaeostratigraphic profiles at Jabuticabeira II, the archaeological layers that compose the black deposit share a series of common structural attributes, with variations related to the frequency of coarse fraction components and composition of the micromass.

Macroscopic and microscopic attributes of all archaeofacies identified indicate an affinity with secondary refuse deposits. As opposed to heavily used areas, secondary deposits show high concentrations of material with low intensity of trampling (Schiffer, 1987:126), which show up micromophologically as intergrain microaggregate microstructures, complex packing voids, and randomly distributed components, probably as a result of mixing of coarse and fine particles through collection, deposition, and mixing as material falls onto the ground (Matthews et al., 1997:289). The kind of secondary deposit identified in the literature that best approximates what is observed at Jabuticabeira II are middens (Courty, Goldberg, & Macphail, 1989; Goldberg & Whitbread, 1993; Wilson, 1994; Matthews et al., 1997; Needham & Spence, 1997; Beck & Hill, 2004). These are formalized refuse areas that take the form of a mound or a thick layer rich in organic and inedible food debris. Macroscopically, middens present a large amount of bones, shell, and charcoal fragments, all randomly distributed (Goldberg & Whitbread, 1993). In thin section, middens show angular shell and bone fragments, open packing, high porosity, and aggregates that mix mineral and organic material (mainly phosphates and decomposed organic matter, respectively) (Courty, Goldberg, & Macphail, 1989).

However, the use of the term midden raises some controversies when applied to Brazilian shell mounds, as it relates to sites with subsistence activities, hiding the symbolic meaning of shell mound construction related to funerary rituals. In Jabuticabeira II, the problem with the term midden is also related to the high concentration of human burials it contains and the construction pattern interpreted from vertical section evaluation, and archaeofaunistic analyses of synchronic and diachronic funerary mounds (Klokler, 2001, 2008; Nishida, 2007). At the same time, some pre-depositional attributes, such as the high mixture of material with different degrees of burning, suggest an even more complex formation process for this deposit.

The black deposit is mainly composed of burnt material, whether fish bones, charcoal, quartz grains, siliceous aggregates, phytoliths, etc., mixed in a matrix that comprises carbonaceous and phosphatic micromasses. Though it presents evidence of *in situ* burning (a hearth identified both in horizontal and vertical sections in T11 that corresponds to archaeofacies 6), the diverse degrees of thermal alteration (from slightly burnt to carbonized and calcined bones, siliceous aggregates, and charcoal) and the random distribution of highly mixed burnt particles suggests a process of remobilization of components from ancient hearths.

Therefore, construction of the black deposit may have involved discrete episodes of deposition of thermally altered material, whose burning was performed in a different location from that of final deposition and discovery. Our preliminary hypothesis is that materials were originally accumulated around bonfires or in a secondary midden-like deposit where they suffered the effects of burning at high temperatures. Subsequently, those materials were transported to the shell mound, already with traces of alteration, where they were redeposited into a highly mixed archaeosedimentary matrix covering human burials. Thus, archaeological facies would represent distinct moments of remobilization of thermally altered material from its original location in a midden or around bonfires, to final deposition in the black deposit.

We suppose that archaeofacies contain the residues of daily subsistence, because of the high concentration of inedible food debris, such as fish bones and charcoal, that characterizes the black layer as a whole. However, it is probable that part of the components of the black layer that are not related to mound building and are directly associated with interments may actually be the residues of feasting and ritual banquets, as demonstrated by Klokler (2008) for the funerary layers inside the shell deposit.

Therefore, this upper portion of Jabuticabeira II shell mound could actually be a tertiary deposit (*sensu* Schiffer, 1987) built from re-working of discarded food items (of daily or feasting activities) in a ritual construction pattern. However, we prefer not to call the deposit tertiary, but the archaeofacies that it is composed of, as the black deposit also includes primary deposits such as human burials, combustion structures, and post holes. Thus, two kinds of palimpsest are included in this deposit: cumulative and of meaning, as defined by Bailey (2007). The thousands of fish bones, charcoal, and other components that form this great archaeosedimentary body represent a multiplicity of episodes of consumption, burning, and deposition. This intense mixing resulted from the activity of remobilization of materials from one deposit to another, with the consequent transmutation of their symbolic meaning.

The intercalation between archaeofacies with altered bone and phosphatic micromass (3 and 5) and archaeofacies with burnt bone and carbonaceous micromass (2 and 4) clearly indicates a constructive intentionality that is probably associated with different provenances and even meanings for each group of sedimentary material. This archaeofacies association involves various anthropic processes of deposition (at least seven) that are related to ritual activities of funerary mound construction over the shell deposit.

The sequence of events represented by archaeofacies association still needs more study and refinement; at present, we can only be sure that much of the complex archaeostratigraphy that characterizes Jabuticabeira II is indeed related to anthropic depositional processes and not caused by post-depositional alterations. However, the relationship between pre- and post-depositional processes of either anthropic or natural character is still being studied and will surely offer some more interesting clues to the formation processes of this monumental shell mound. Other laboratory procedures must complement these results to provide a solid base for interpretation of the sequence of events reflected in the sections and the formation processes of the site as a whole. Especially for post-depositional processes and natural formation processes, more detailed analyses are still needed in order to confirm or refute our preliminary hypothesis.

CONCLUSIONS

Facies analysis, as defined in modern sedimentology, was adapted to study archaeostratigraphic sequences in coastal lagoonal settings for identification of recurrent anthropic processes of deposition in monumental shell mounds. As depositional phenomena, the stratigraphy of archaeological sediments in monumental shell mounds can be treated in terms of archaeological facies, or archaeofacies, which refers to descriptive units that represent the materialization of an anthropic depositional process recurrent in time and space. In mound building, where anthropic processes of deposition create a completely new archaeosedimentary body by massive transport and deposition of clastic, bioclastic, and artifactual material, application of archaeofacies analysis involves four main steps:

1. Detailed description in the field of the archaeostratigraphic record according to depositional attributes (composition of the matrix, macroscopic components, shape and thickness of facies, structures, and orientation of macroscopic components).
2. Characterization of archaeofacies through laboratory analysis of their properties (chemical, mineralogical, micromorphological, etc.).
3. Search for archaeofacies models in the geoarchaeological literature (archaeofacies similar to those identified at the site) or experimental archaeology.
4. Interpretation and deduction of the anthropic processes of deposition and natural post-depositional dynamics that configured the vertical succession.

For the black deposit at Jabuticabeira II, field description and laboratory characterization, by multielement chemical analyses and micromorphology, showed the existence of a constant pattern in mound building that involves the sequential deposition of highly fragmented and altered food debris (bones, phytoliths) and burnt material (charcoal, ashes, siliceous aggregates, carbonized and calcined bones) into a series of anthropic depositional process associated with construction of funerary mounds. The search for archaeofacies models in the literature suggested that the black deposit could actually be a midden, though the large number of human burials it contains actually indicates that material from a midden or deposited around bonfires may have served as raw material for mound construction. Formation of this upper portion of Jabuticabeira II may have involved the accumulation of food items around bonfires or in a secondary midden-like deposit where burning took place, after which they were transported to the shell mound in a ritual construction pattern. This suggests that archaeological facies that compose this deposit may be tertiary facies produced after subsequent episodes of anthropic transport and deposition.

The authors would like to thank the financial support of Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP process 04/11038-0 and 05/57321-7) in the interdisciplinary research project that studies human occupation in the southern coast of Santa Catarina State ("Sambaquis and Landscape: Modelling the Inter-Relationship Between Cultural and Natural Formation Processes in the Southern Coast of Santa Catarina"), coordinated by Paulo DeBlasis (MAE/USP), Maria Dulce Gaspar (MN/UFRJ), and Paulo C.F. Giannini (IGc/USP). We also want to thank Fundación Carolina and acknowledge the help and collaboration of Marco Madella and the Laboratory of Archaeology (IMF/CSIC, Barcelona), as well as Isaac J. Sayeg and staff of the Laboratories of Petrography and Scanning Electron Microscopy of the University of São Paulo. Special thanks to two of our anonymous reviewers for their helpful and supportive comments, which greatly improved the final version of this paper, and Daniela Klokler and David Mehalic for their cooperation in the English revision.

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Received 22 August 2008
Accepted for publication 13 January 2009
Scientific editing by Richard Macphail