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Earthen mound formation in the Uruguayan lowlands (South America): micromorphological analyses of the Pago Lindo archaeological complex

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A B S T R A C T

The stratigraphic excavation of the Pago Lindo archaeological complex, in central-eastern Uruguay (La Plata basin), helped to propose an alternative model for mound formation that expresses the intrinsic complexity of prehistoric earthen architecture. This model, known as the spatial–temporal discontinuous model, sees mound complexes as multi-functional areas, with diverse earth works occupied and abandoned intermittently. Since earthen mound sediments are homogeneous, resemble natural soils and show evidences of intense bioturbation, soil micromorphology was used to confirm, refute and further investigate issues raised during field work, related with the prime material used for mound construction, detection of major episodes of mound building, identification of activity areas and taphonomic processes. In this paper, we present the results of the micromorphological analyses of two different earth works from the Pago Lindo archaeological complex (a mound and a micro-relief). Analyses proved the recurrent use of surface horizons for mound and micro-relief building throughout the entire period of site occupation. It also demonstrated the difficulty in identifying discrete depositional episodes and occupation surfaces, because of the intense bioturbation. Two activity areas where recognized: a domestic hut built over a platform, ca. 1600 yrs. BP; and an area of plant residue accumulation over a platform, raised almost 800 hundred year after the domestic hut. The practice of cleaning the occupation surfaces was interpreted from the complete absence of bioarchaeological remains (bones and micro-charcoal). The use of micromorphology as a complementary tool in the stratigraphic excavation of Pago Lindo unraveled evidences that corroborate a newly proposed model for mound growth.

1. Introduction

The South American lowlands comprise a broad region of the continent whose pre-Columbian populations have traditionally been viewed as mobile groups of hunter–gatherers (Steward, 1944). In some specific areas of the lowlands, such as the Amazon basin, llanos de Moxos, Pantanal and Paraná delta, recent archaeological research has proved that intense social changes took place at around 1000 AD which include: rising of complex societies; growth of densely populated villages; technological specialization; earthen architecture; slash and burn agriculture; and plant management (Balée and Erickson, 2006; Barreto, 2006; Bonomo et al., 2011; Erickson, 2008; Heckenberger et al., 2003; Neves and Petersen, 2006; Roosevelt, 1999; Schaan, 2008; Wüst and Barreto, 1999). In this paper, we will focus on the Uruguayan lowlands, located in the south-east of the continent. The region has the earliest evidences of cultivars and village systems of South America, which date back to the mid-Holocene (around 4000 yrs. BP) (Iriarte et al., 2004). These innovations developed independently from the Amazonian cultural complexes and belong to the earthen mound culture of the La Plata basin, which appears from 5000 BP, in the east of Uruguay and south of Brazil, associated to permanent and semi-permanent wetlands, prairies with palm trees and lagoons.

The first earthen mounds in Uruguay, locally known as *cerritos*, appear around ca. 5000–4800 years BP in the south eastern wetlands (Bracco, 2006; Bracco et al., 2000a; Lopez Mazz, 2001). These are artificial mounds of 20–40 m in diameter and 0,5–7 m high, of diverse shape and function whose construction may have taken hundreds to thousands of years (Lopez Mazz, 2001). Mound complexes are formed by circular, elliptical and horse-shoe arrangements of earthen structures, frequently with a central

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plaza. The high density of mounds, the contemporaneous growth of many of them and the regularities detected in their spatial arrangement lead to the interpretation of an architectural planning for the development of mound complexes (Gianotti, 2005; Iriarte et al., 2004; Iriarte, 2006; Lopez Mazz, 2001). Earthen mounds are only one of many earth works that exist in the Uruguayan lowlands, which include micro-reliefs (mounds of less than 1 m high), platforms, elongated rises, borrow pits (Bracco et al., 2000a; Femenías et al., 1990; Lopez Mazz and Gianotti, 1998; Iriarte, 2006; Lopez Mazz, 2001), anthropic lagoons and channels (Gianotti et al., 2009).

In the 1990s researchers proposed that mounds were built by complex hunter–gatherers (Lopez Mazz, 2001; Lopez Mazz and Bracco, 1994). Later research identified village systems with horticulture (Iriarte et al., 2004; Iriarte, 2006), ceremonial platforms (Bracco et al., 2000a; Gianotti, 2005; Lopez Mazz, 2001; Lopez Mazz and Gianotti, 1998) and burial mounds with evidences of different mortuary practices, such as single craniums and bodies with violence marks (Gianotti and Lopez Mazz, 2009; Pintos and Bracco, 1999). These evidences lead researchers to propose that mound builders point to an incipient Formative period in the region (Iriarte et al., 2004; Lopez Mazz, 2001). Some researchers also proposed a local periodization for mound construction that includes two basic stages: the preceramic mound period (ca. 4500–3000 BP), characterized by mixed economies (Iriarte, 2006), with high residence mobility, bifacial lithic technology (Lopez Mazz, 2001) and domestic earthen mounds (Gianotti, 2005); and the ceramic mound period (ca. 3000- until contact with Spanish colonizers), characterized by increased sedentism, demographic growth, ceramic technology (Lopez Mazz, 2001) and burial mounds (Lopez Mazz and Gianotti, 1998; Gianotti and Lopez Mazz, 2009).

1.1. Traditional models for mound growth

Two models have been proposed for mound growth, which result in substantial interpretations on the cultural dynamics of the populations responsible for the formation of earthen mound complexes: 1) the “layer-by-layer growth model” (LBL) refers to the intentional digging of soil as prime material for construction of domestic, ceremonial and funerary platforms through organized labor, within a frame of emerging complexity among hunter–gatherers, seen as social systems with and incipient hierarchy and semi-sedentary settlement patterns (Cabrera, 2000; Gianotti, 2005; Iriarte et al., 2004; Lopez Mazz, 2000, 2001; Pintos, 1999); 2) the “continuous growth model” (CG), which states that living in the same place caused the accumulation of sediments in a mound-shaped structure, thus questioning the intentionality behind mound formation, refusing the deliberate construction of platforms and denying the social complexity associated with the supposedly earthen architecture (Bracco, 2006; Bracco and Ures, 1999).

New strategies for the excavation and analyses of earthen mounds, proposed by Gianotti et al. (2009), are being used to test the two models and unravel the architecture and social dynamics involved in mound formation. This novel approach involved the meticulous excavation of earthen mounds form the Pago Lindo archaeological complex, in north eastern Uruguay, where occupation spans from 3000 to 700 yrs. BP. The archaeological complex is formed by tens of mounds of different shapes and sizes, some of them reaching 300 m long and 30 m wide, with almost 4 m high. The whole complex has a semi-circular arrangement that follows a meander from an affluent stream of the Caraguatá River (Fig. 1A). Most structures are placed over the bar deposit. Two possibly anthropic lagoons were identified in the site, one that is currently active and located in the center of a group of mounds, and a second silted lagoon located to the south east of the mound complex (Fig. 1B).

The excavation of Pago Lindo is based on the hypothesis that earthen mounds grew from overlapping domestic occupations of seasonal and/or semi-permanent settlements, as has been proposed for other regions of the country (see Iriarte, 2006). To test this hypothesis, wide areas of the site have been studied following the method of stratigraphic excavation proposed by Carandini (1997) and Harris (1991). This lead to the proposal of a third model for mound formation, named by Gianotti et al. (2009) as the “spatial–temporal discontinuous model” (STD).

The model states that earthen mound formation does not follow a unidirectional sequence of accumulating sediments in the same place, whether intentionally or not. Since mounds are located within archaeological complexes formed by a diversity of earth works, mound building would be a compound process that involves the domestic occupation of one area with simultaneous platform building in another, relocation of habitation areas through time within the same space and seasonal abandonment of the site with re-occupation and shifts in site function. The stratigraphic excavation of Pago Lindo revealed the spatial complexity in mound formation that contradicts the first-sight simple stratigraphy of Uruguayan earthen mounds. It unveiled evidences that confirm the STD model, such as: borrow pits within the mound complex; clear construction events that increase mound height; platforms and foundation layers for domestic occupation; occupation floors circumscribed by post molds; and differential concentration of stone and ceramic artifacts in specific areas of the mound complex.

To confirm or refute field observations made during the stratigraphic excavation of the site, such as identification of discrete episodes of mound construction, activity areas, occupation floors and post-depositional processes affecting the integrity of the archaeological record, micromorphological analyses were done for the first time in Uruguayan archaeology. Soil micromorphology is the microscopic study of undisturbed soil and sediment samples to interpret the depositional and post-depositional processes involved in their genesis. In archaeology, it is widely used for site formation studies and identification of activity areas (Courty et al., 1989; Courty, 2001).

Micromorphological studies on earthen mounds have been made in urban tells (Ge et al., 1993; Matthews, 2010; Matthews et al., 1997; Milek, 2012), medieval artificial hills (Gebhardt and Langohr, 1999) and monumental structures from the North American Late Archaic and Formative periods (Sherwood and Kidder, 2011). In these sites, complex stratigraphies are already visible at the macroscopic scale and micromorphology is used to refine field observations on living floors, trampling, spatial distribution of activity areas, site function (ritual and domestic spaces), cultivation practices, cattle enclosures etc. Few micromorphological studies have been made in earthen mounds made of homogeneous deposits that resemble natural soils (see Arroyo-Kalin, 2008; Cremeens, 2005), such as the Uruguayan earthen mounds, where the macroscopic indicators of stages in mound formation (e.g. sharp boundaries between layers) and activity areas (e.g. trampled surfaces) are less evident. In these contexts, the microscopic differences and particularities of stratigraphic units, mostly erased by pedogenic processes, must be searched in subtle changes in texture, microstructure, c:f ratio, composition of the micromass and pedofeatures.

In this paper, we will focus on the micromorphological analyses of one earthen mound and a micro-relief in the Pago Lindo archaeological complex. The aims of this work can be summarized as: 1) investigate the sources of the sedimentary material used for mound building; 2) define the similarities and differences between stratigraphic units from diverse features within the archaeological

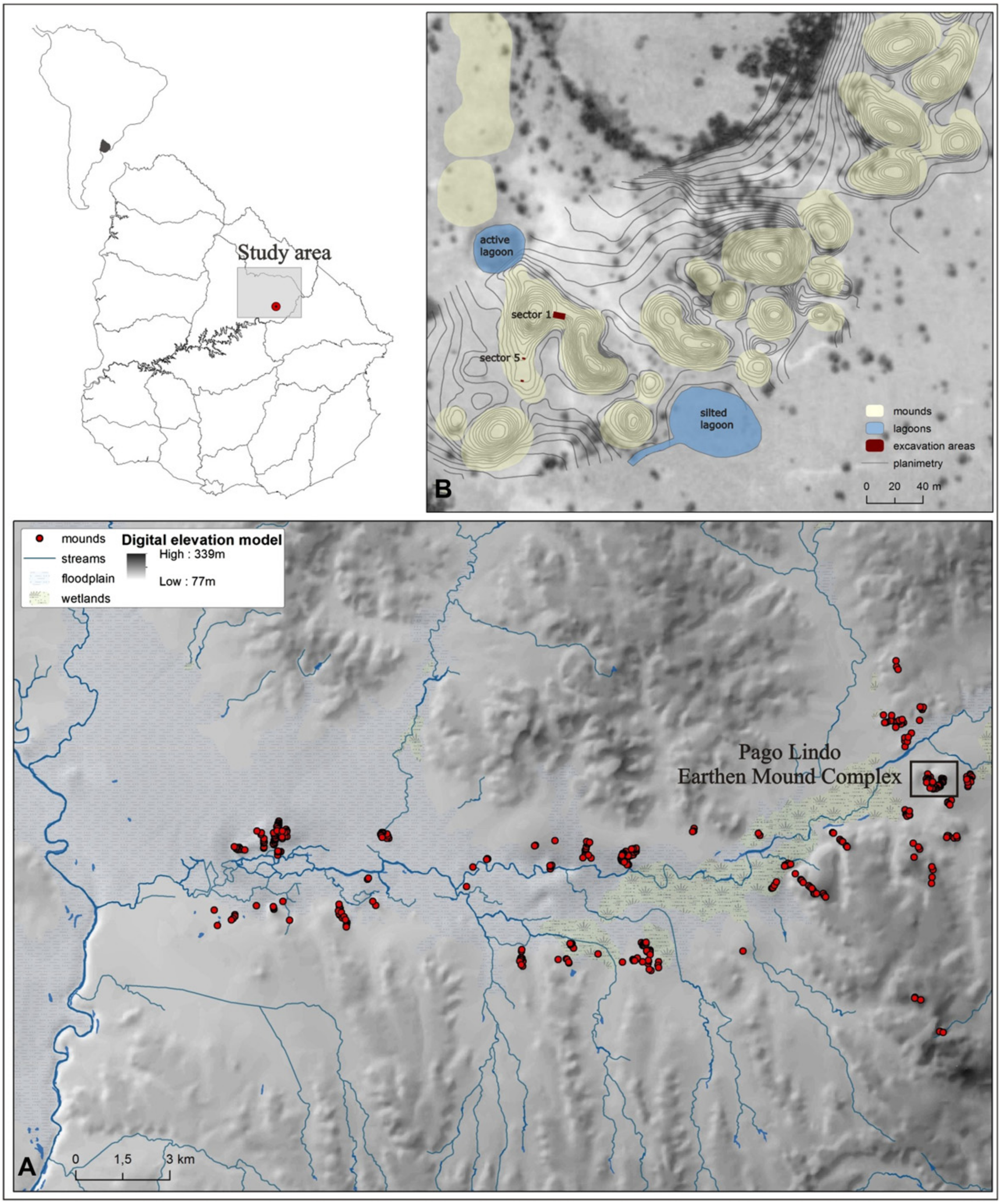

Fig. 1. Earthen mounds from the lowlands of central Uruguay in the margins of the Caraguatá River (A). The Pago Lindo earthen mound complex with location of mounds, active lagoons, silted lagoons, and the two excavation areas discussed in this study (sectors 1 and 5) (B).

complex (mounds and micro-reliefs); 3) search for microscopic indicators of trampling, activity areas and abandonment episodes; 4) explore the taphonomic processes that can be causing the potential loss of bioarchaeological components (such as bones, charcoal and plant remains).

2. Materials and methods

A set of nine undisturbed samples was collected for micromorphological analyses from two sectors in the Pago Lindo archaeological complex: sector 1 (16 × 4 m), located between two major mounds; and sector 5 (2 × 1 m), a micro-relief to the southwest of sector 1 (Fig. 1B). Sample locations aimed at investigating the stratigraphic units (SU) at higher resolution that can be seen in the field (Fig. 2). See Table 1 for further description of SU and sampling objectives.

Undisturbed blocks for micromorphological analyses were oven-dried and impregnated at the Soil Micromorphology Laboratory of the Escola Superior de Agronomia “Luiz de Queiroz” (ESALQ/USP) with a mixture of polyester resin, catalyst and diluent. Thin sections of 7.5 cm × 4.5 cm × 30 μm were prepared at Earthslides Laboratory in Cambridge (England). Analyses were

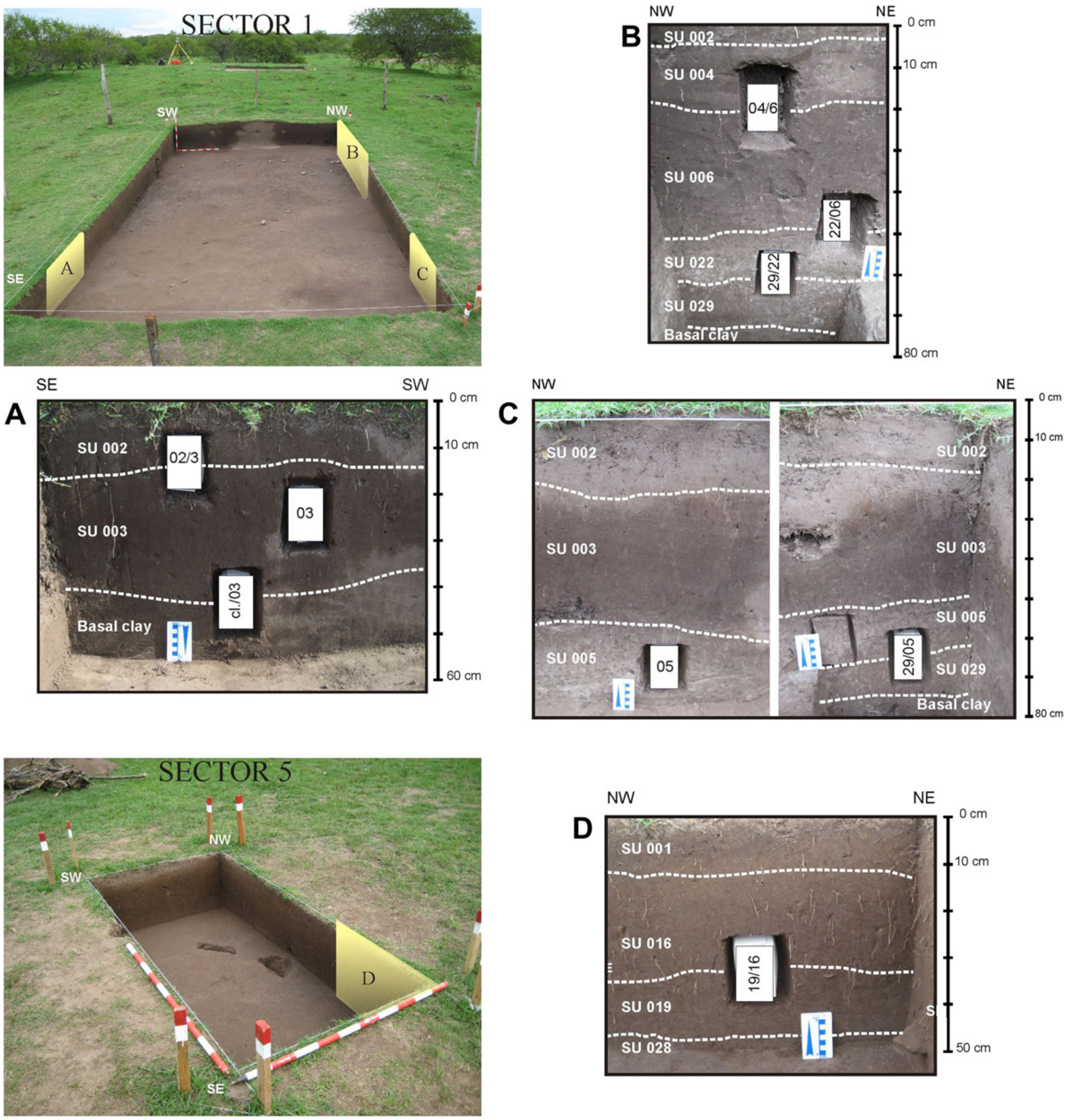

Fig. 2. Excavation areas in sector 1 and 5 with location of sampled profiles (yellow boxes). Profiles sampled for micromorphology in corner A of sector 1 (A), corner B of sector 1 (B), corner C of sector 1 (C), and sector 5 (D) with identification of stratigraphic units and undisturbed samples. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

done in the Laboratory of Sedimentary Petrography of the Instituto de Geociências (IGc/USP) under plane polarized light (PPL) and cross polarized light (XPL), with a Zeiss Axioplan 2 optical microscope at magnifications ranging from 25× to 400×. Description followed the guidelines of Bullock et al. (1985), Courty et al. (1989) and Stoops (2003).

3. Results

The micromorphological analysis of Pago Lindo evidences the intense bioturbation of sediments, seen as recurrent passage features, excrements and mammilated crumbs. These attributes point at the definition of the whole mounded area as a reworked surface A horizon. It also showed a striking similarity between most of the stratigraphic units studied in sectors 1 and 5, indicating that discrete stratigraphic units, as well as mounds and micro-reliefs, are micromorphologically indistinguishable. The similarity refers to porosity, microstructure, mineral coarse fraction components and the complete absence of micro-bioarchaeological remains. The main difference between some stratigraphic units refers to pedofeatures and c:f ratio that are indicative of spodic horizons and clay illuviation. No evidences of micro-stratiphication, sharp boundaries and surface crusts were identified.

Sector 1: In corner A, both SU 02 and 03 show the same micromorphological characteristics, with high frequency of excrements (mitods, mammilated, bacilo-cylinder). The basal clay deposit, sterile in archaeological remains, shows a speckled micromass of cross-striated clay with about 5% of orthic iron oxide nodules (Fig. 4 B–C; Table 2).

In corner B the micromass is composed of monomorphic and polymorphic organic matter. The upper units SU 04 and 06 show similar micromorphological characteristics, with pellicular grain microstructure and increased organic matter content in SU 06 (Fig. 5A; Table 3). The major contrast refers to the high concentration

Table 1
Samples for micromorphological analyses collected from sector 1 and 5 of the Pago Lindo archaeological complex, with description of the stratigraphic units (SU), sampling objectives and figure reference.

Sector	Samples	SU description	Objectives	Figure reference
1/A	02/03 03 cl./03	**SU 02**: Construction episode. Very dark brown sandy loam with archaeological material (stone, ceramic, red ochre and charcoal). Dated 690 ± 35 yrs BP. **SU 03**: Construction episode. Greyish brown sandy loam with archaeological material (stone tools, pottery, red ochre and charcoal). Dated 990 ± 35 yrs BP. **cl.**: Clay deposit underneath the mound, sterile in archaeological material.	Characterization and contact between SU 02 and 03, and SU 03 and the sterile clay deposit underneath the mounded area.	Fig. 2A
1/B	04/06 22/06 29/22	**SU 04**: Construction episode. Very dark brown sandy loam with archaeological material (stone tools, pottery, red ochre and charcoal). Dated 800 ± 35 yrs BP. **SU 06**: Construction episode. Very dark brown sandy loam with archaeological material (stone tools, pottery, red ochre and charcoal). **SU 22**: Possible habitation platform. Brown sandy loam with archaeological material (stone tools, red ochre and charcoal). **SU 29**: Natural soil beneath the habitation platform at SU 22. Very dark gray sandy clay loam with few stone artifacts, interpreted as the possible first human settlement in the area.	Characterization and contact between SU 04 and 06, 22 and 06 and 29 and 22.	Fig. 2B
1/C	05 29/05	**SU 05**: Possible habitation platform. Grayish brown sandy loam with archaeological material (stone tools, red ochre and charcoal) and postholes. Dated 1633 ± 33 yrs BP.	Characterization of SU 05 and the contact between SU 05 and 29.	Fig. 2C
5	19/16	**SU 16**: Eroded sediments from the mounds at sector 1. Dark brown sandy loam with many archaeological materials (stone tools, pottery, red ochre and charcoal). **SU 19**: Construction episode. Dark brown sandy loam with stone artifacts. Dated 1213 ± 34 yrs BP.	Characterization and contact between SU 19 and 16 were two large stone artifacts were recovered during excavation.	Fig. 2D

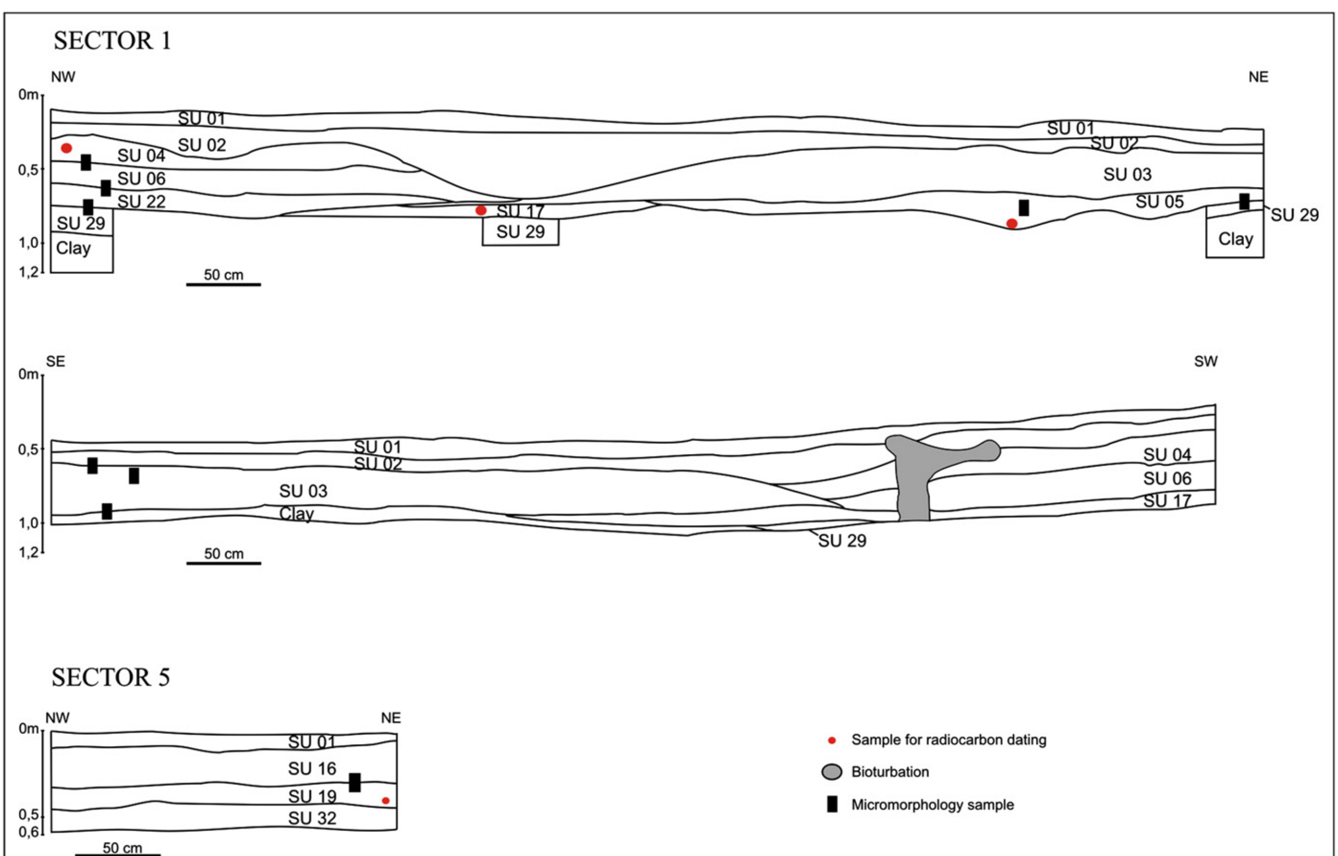

Fig. 3. Stratigraphic profiles of sector 1 and 5, with location of micromorphology samples and samples for radiocarbon dating.

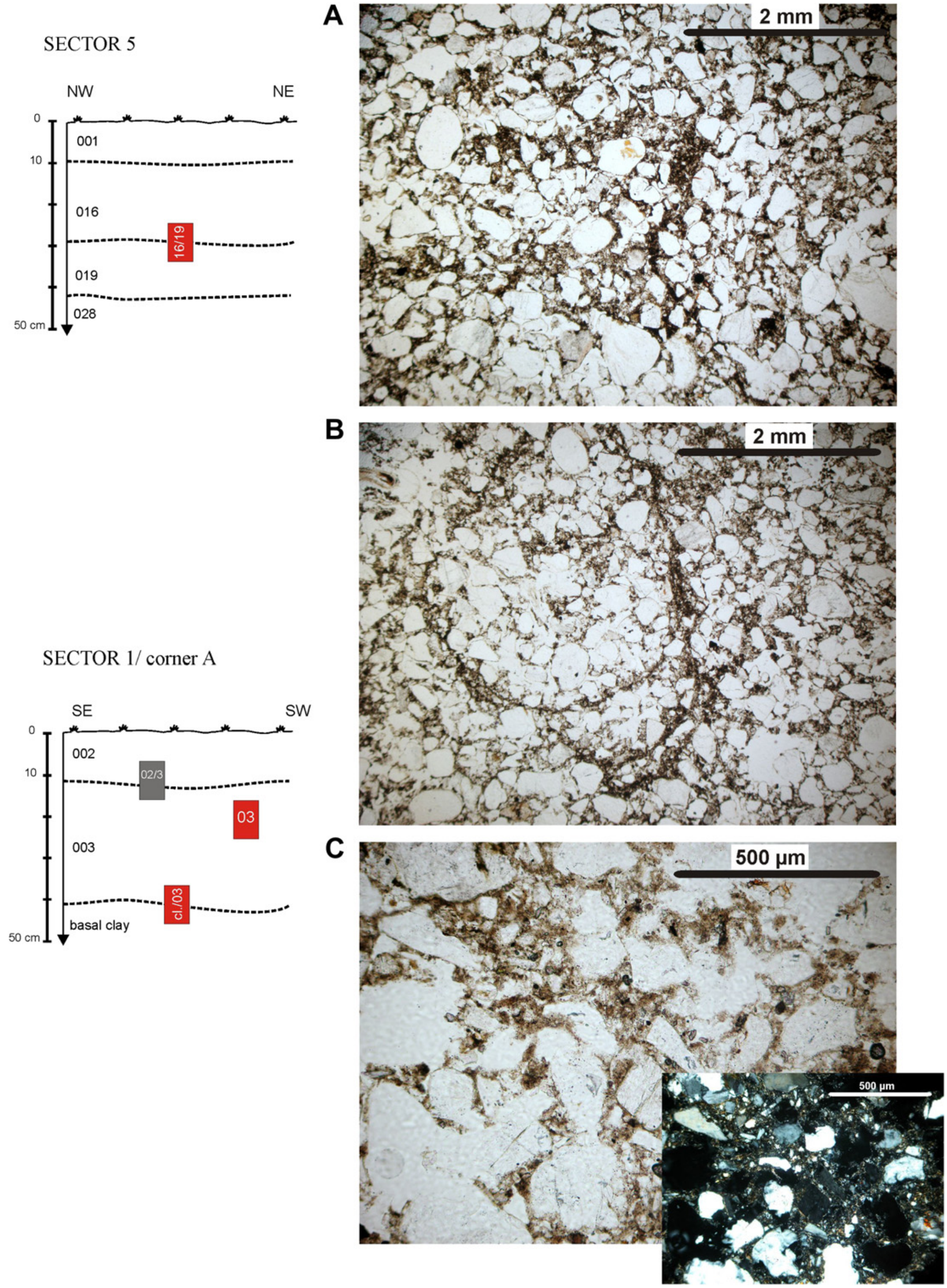

Fig. 4. Sampled profiles in sector 5 and corner A of sector 1. Photomicrograph (PPL) of the transition between SU 16 and 19 in sector 5, showing a reddish-brown organomineral micromass and spongy and intergrain microaggregate microstructure (A). SU 03 in corner A from sector 1 with passage features (B). The basal clay deposit of the mound complex, with detail in XPL showing cross-striated clay composition (C). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

(around 20%) of dusty clay coatings exclusively in the transition between SU 22 and 29 (Fig. 5B). The frequency of orthic iron oxide nodules is similar to corner A.

Sample 05/29, from corner C (Table 4), showed the same attributes as samples 22/29, in corner B. SU 05 is characterized by an organic micromass formed by very fine organic granules and about 5% dusty clay coatings (Fig. 5C). SU 29 is characterized by the mixture of a black organic micromass and cross-striated clay, with about 10% of dusty and limpid clay coatings (Fig. 5D).

Sector 5: This sector of the mound shows more micromorphological similarities with corner A of sector 1 (Fig. 4A), with a reddish-brown organomineral micromass and spongy and

Table 2
Microstratigraphic description of undisturbed samples collected from corner A of sector 1.

Sp.	mF	Porosity	%	Aggregates	Size	Microstructure	c/f ratio	c/f rel. distr.	Quartz	Feldspars	Heavy min.	Opaque min.	Rock frag.	Burnt clay	Charcoal	Tissue	Roots	Color	Limpidity	b-fabric	Composition	PF
02/3		cx-p	10	gr	50 µm	Spongy – intergrain microaggregate	80/20	en.	••••••	••	•	•	•	•			•	■	lp	und	Organomineral	co Fe-nod exc
03		cx-p	10	gr	50 µm	Spongy – intergrain microaggregate	80/20	en	••••••	••	•	•	•				•	■	lp	und	Organomineral	co exc
03/cl.	3	cx-p	10	gr	50 µm	Spongy	80/20	en	••••••	••	•	•	•				•	■	lp	und	Organomineral	Fe-nod
	cl.	cx-p	10	gr	30 µm	Spongy	75/25	en	••••••	••	•	•	•				•	■	sp	cry	Cross-striated clay	co Fe-nod

Class frequencies after Bullock et al. (1985): • very few (<5%); •• few (5–15%); ••• common (15–30%); •••• frequent (30–50%); ••••• dominant (50–70%); •••••• very dominant (>70%). Sp = sample; mF = microfacies; PF = pedofeatures; cx-p = complex packing; gr = granules; en = enaulic; lp = limpid; sp = speckled; und = undifferentiated; co = coatings; Fe-nod = iron oxi(hydroxi) nodules; exc = excrements.

intergrain microaggregate microstructure. No micro-bioarchaeological remains were found or traces of differential pedogenesis.

4. Discussion

4.1. Prime material and mound construction

Most stratigraphic units from sector 1 (SU 02, 03, 04, 06, 05, 22) and sector 5 (SU 16 and 19) show evidence of being made of reworked surface horizons of sandy loam texture, such as: intergrain microaggregate microstructure, enaulic c:f related distribution, organic micromass made of mammilated crumbs, with many biopores and excrements. This shows that major mounds and micro-reliefs are composed of the same sedimentary material, digged from surface horizons and redeposited as either small-scale or large scale construction episodes. Soil material used for mound construction would have been collected from the proximities of the structures, always within the mound complex, as indicated by the shallow borrow pits at Pago Lindo.

The ten stratigraphic units identified during field work and analyzed here show remarkable micromorphological similarities. Some of the attributes that were used to distinguish between stratigraphic units in the field, such as compaction, porosity and color, are actually related with pedogenesis and not to depositional differences. In sector 1, SU 02 and 03 (corner A) could be grouped into one single stratigraphic unit. The same was observed for SU 04 and 06 (corner B), SU 05 and 22 (corners B and C, respectively), and SU 16 and 19, from sector 5. No evidences of long term abandonment and depositional hiatuses were found in the contact between these units, such as differential pedogenesis or soil crust formation.

This means that SU 02 and 03 would represent a single depositional episode, of about 50 cm high, and not two discrete mound building moments. However, radiocarbon dating of charcoal pieces found in SU 02 and 03 showed a 300 year difference between them. This can be explained by two possibilities: that SU 02 and 03 are actually discrete episodes of mound formation whose limits were erased by biological activity, since both are formed by burrowing surface horizons from the proximities; or that charcoal pieces moved downwards through the soil by bioturbation, with older charcoal moving further down the profile than recently deposited charcoal. In this respect, the evaluation of stratigraphic profiles and radiocarbon dating shows that SU 03 is differently shaped than SU 02, and that SU 04 and 06 are intermediate depositional episodes between them (almost 200 years after SU 03 and 100 years before SU 02) which would reinforce the first hypothesis (see Fig. 3). SU 02 extends through all of sector 1, covering SU 03, 04 and 06, while SU 03 shows a concave geometry that lies beneath SU 04 and 06, and is only visible in the southwest and northeast corners of sector 1.

The same ambiguous situation is observed for SU 16 and 19 in sector 5. The presence of two large polished stone artifacts in the contact between the stratigrapic units indicates that, besides their textural and micromorphological affinity, they represent two discrete episodes of mound formation whose sedimentary boundaries were erased by bioturbation. Moreover, the affinity of SU 16 from the micro-relief with SU 02 and 03 from the mounded area, suggests that SU 16 could have been formed by eroded mound sediments, as interpreted from field observations.

In the case of SU 04 and 06 there are no stratigraphic nor micromorphological evidences of them being distinct units, which means that they can be grouped into one single depositional episode (now SU 04/06). The same can be said for SU 22 and 05 (now SU 05/22). Although they were identified as discrete units, because of the lack of horizontal continuity in the excavation profiles (see Fig. 3) they are macroscopically and micromorphologically the

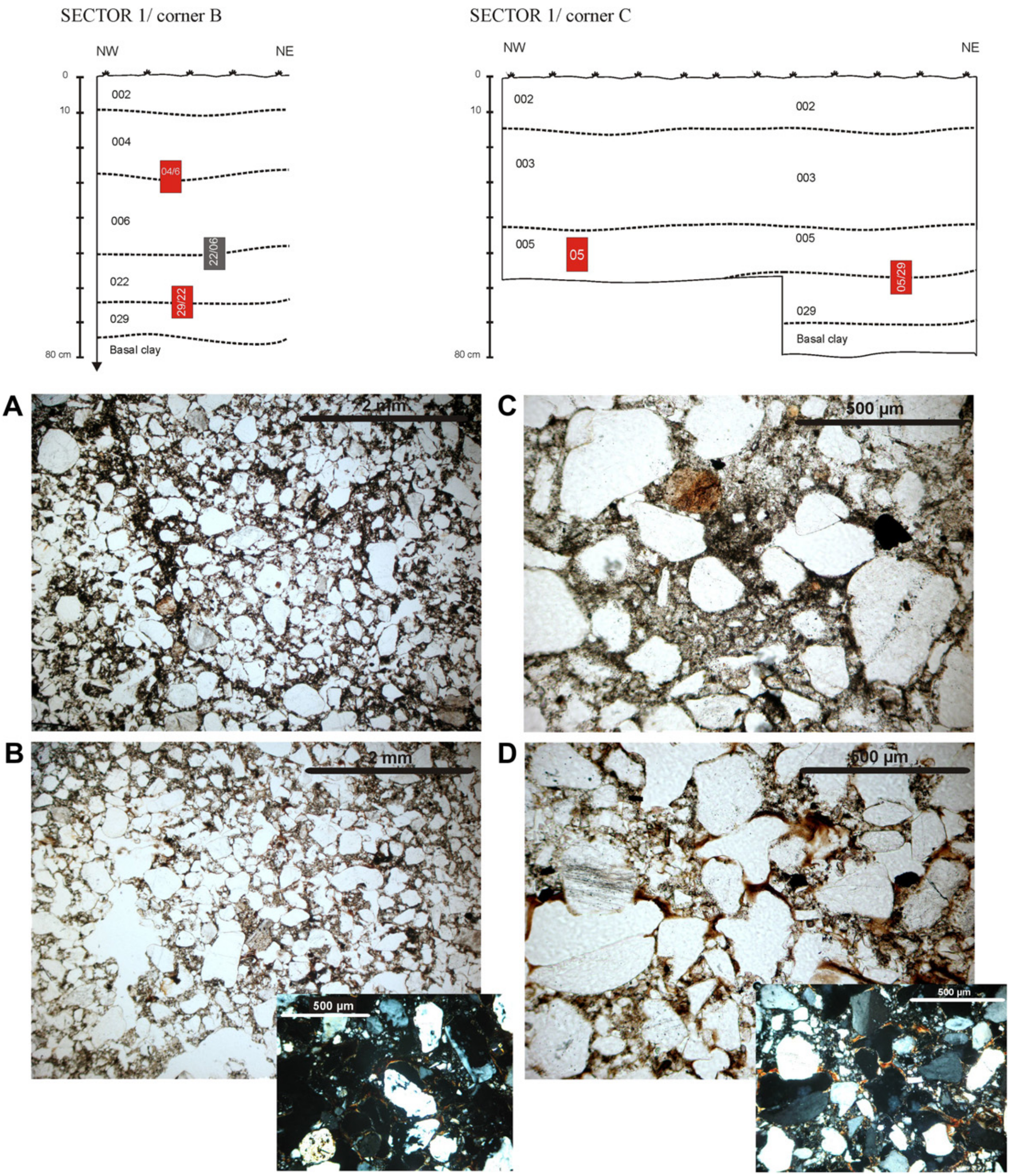

Fig. 5. Sampled profiles in corner B and C of sector 1. Photomicrograph (PPL) of the transition between SU 04 and 06 from corner B of sector 1 showing monomorphic and polymorphic organic matter (A). Transition between SU 22 and 29 with dusty clay coatings (B). SU 05 from corner C of sector 1 with organic micromass formed by very fine granules (C). SU 29 with dusty and limpid clay coatings (D).

same and are a single deposit underneath SU 04/06, in corner B, and SU 03, in corner C.

The macroscopic and micromorphological similarities between SU 02 and 03 from the mounded area, and SU 16 and 19 from the micro-relief, do not necessarily imply a chronological affinity between them. Radiocarbon dates have shown a time gap of around 200 years between occupation of the micro-relief (SU 19) and the mound building episode identified as SU 03 (Table 1). Their similarity and chronological continuity can be interpreted as a recurrence in the building practices and mound architecture through time and space. During the whole occupation of the Pago Lindo archaeological complex, that lasted more than 2300 years, surface horizons were repeatedly digged for mound building and site maintenance in different locations and following diverse purposes. The choice for surface horizons as the only prime material for mound building is probably related with the technology available for such architectural endeavors, which would consist mainly on baskets and small containers made of perishable material.

Interesting to note is that the homogeneity in the sedimentary record of most part of the major mounds and the micro-relief does not correlate with the frequency distribution of the artifactual record. As seen in Table 5, stratigraphic units show clear differences in the concentration of stone tools and pottery sherds. The highest concentration of artifacts appears in SU 03 and 02, followed by SU

Table 3
Microstratigraphic description of undisturbed samples collected from corner B of sector 1.

Sp.	mF	Porosity	%	Aggregates	Size	Microstructure	c/f ratio	c/f rel. distr.	Quartz	Feldspars	Heavy min.	Opaque min.	Rock frag.	Burnt clay	Charcoal	Tissue	Roots	Color	Limpidity	b-fabric	Composition	PF
04/06		cx-p cn	15	gr	30 μm	Spongy – pellicular grain	70/30	en chit	••••••	•	•	•	•				•	■	lp	und	Organic matter	co
06/22		cx-p cm	10	gr	30 μm	Spongy	90/10	en	••••••	•	•	•	•				•	■	lp	und	Organic matter	Fe-nod
22/29		cx-p cm	10	gr	30 μm	Spongy	90/10	en	••••••	•	•	•	•				•	■	lp	und	Organic matter	co Fe-nod

Class frequencies after Bullock et al. (1985): • very few (<5%); •• few (5–15%); ••• common (15–30%); •••• frequent (30–50%); ••••• dominant (50–70%); •••••• very dominant (>70%). Sp = sample; mF = microfacies; PF = pedofeatures; cx-p = complex packing; cn = channel; cm: chamber; gr = granules; en = enaulic; chit = chitonic; lp = limpid; und = undifferentiated; co = coatings; Fe-nod = iron oxi(hydroxi) nodules.

Table 4
Microstratigraphic description of undisturbed samples collected from corner C of sector 1.

Sp.	mF	Porosity	%	Aggregates	Size	Microstructure	c/f ratio	c/f rel. distr.	Quartz	Feldspars	Heavy min.	Opaque min.	Rock frag.	Burnt clay	Charcoal	Tissue	Roots	Color	Limpidity	b-fabric	Composition	PF
05		cx-p pl cn	15	gr	30 μm	Spongy	90/10	en.	••••••	••	•	•	•					■	lp	und	Organic matter	co
05/29	5	cx-p cn	15	gr	30 μm	Spongy	90/10	en	••••••	•	•	•	•				•	■	lp	und	Organic matter	Fe-nod
	29	cx-p	10	gr	30 μm	Spongy	90/10	en chit gef	••••••	•	•	•	•					■	lp	und	Organic matter	co
																		■	sp	cry	Cross-striated clay	co inf

Class frequencies after Bullock et al. (1985): • very few (<5%); •• few (5–15%); ••• common (15–30%); •••• frequent (30–50%); ••••• dominant (50–70%); •••••• very dominant (>70%). Sp = sample; mF = microfacies; PF = pedofeatures; cx-p = complex packing; cn = channel; gr = granules; en = enaulic; lp = limpid; sp = speckled; und = undifferentiated; cry = crystallitic; co = coatings; Fe-nod = iron oxi(hydroxi) nodules; inf = infillings.

Table 5
Frequency of archaeological material found in each stratigraphic unit (SU) from sectors 1 and 5 of the Pago Lindo archaeological complex.

Sector	SU	Pottery	Stone	Total
1	02	64	1346	1410
1	03	27	2326	2353
1	04/06	5	327	332
1	05/22	10	1336	1346
1	29	–	168	168
5	16	5	146	151
5	17	–	191	191

05/22, 04/06 and 29. This means that, besides the apparent simple stratigraphy of earthen mounds, associated with the physical–chemical and biological properties of the prime material used for construction in more than 2300 years, differences in the use of space through time can still be traced by combining macro and microstratigraphic analyses with artifact frequency distribution. This proves that multiple lines of evidence must be put together in order to observe and understand the real complexity behind earth mound architecture in space and time (see Sherwood and Kidder, 2011).

4.2. Trampling and activity areas within the mound complex

Both in corners B and C from sector 1, SU 29 shows a great concentration of dusty clay coatings with diffuse extinction line. Dusty clay coatings are considered evidence of unprotected soil surface slacking by rain splash impact, and subsequent clay illuviation with finely dispersed organic matter (Jongerius, 1983). The presence of dusty clay coatings at about 60 cm deep indicates that SU 29 is a buried horizon, of about 3000 years BP, that was covered by a major mound construction episode, represented by SU 05/22, interpreted as a habitation platform built ca. 1600 years ago (Table 1).

Dusty clay coatings have been interpreted as evidences of past agriculture when located under the A_p horizon (or ploughed zone) (Macphail et al., 1990, 1987; Thompson et al., 1990), a vision questioned by other authors (Carter and Davidson, 1998; Usai, 2001), but also of trampling, mainly by livestock, over exposed or unvegetated soils surface (Beckman and Smith, 1974; Carter and Davidson, 1998; Courty et al., 1989; Gebhardt and Langohr, 1999). Micromorphological evidences of livestock enclosures would include dung spherulites (Brochier, 1992; Canti, 1998; Shahack-Gross, 2003, 2011) and high concentrations of grass phytoliths with microlaminated structure (Albert et al., 2008; Shahack-Gross, 2003, 2011). None of these evidences were seen at the Pago Lindo archaeological complex, and there are not evidences of animal domestication in the prehistory of the Uruguayan lowlands. Therefore, human and not animal trampling on unvegetated ground would have caused the dislocation of fine material through the soil profile, seen as dusty clay coatings.

The transition from SU 29 to SU 05/22 is gradual and some dusty clay coatings are present. Thus, trampling must have occurred over SU 05/22, the earthen platform that buried SU 29. The presence of postholes and small ditches displayed in a circular manner in the lower limit of SU 05/22 indicates the existence of a covering structure over the earthen platform. This correlates with the increased concentration of large stone artifacts in this unit, as seen in Table 5. The artifactual content of SU 05/22 indicates that the covering structure was probably used for habitation (Blasco et al., 2011). Evidences of prepared floors were not identified in SU 05/22, proving that occupation may have taken place over the clean soil surface.

The similarity between SU 05 and 22, and their horizontal discontinuity, suggests two possibilities for the location of the domestic hut: there could have been two separate huts, one in corner B and other in corner C; or there could have been a large u-shaped hut whose continuity remained outside the excavation area (Fig. 6A–B).

In corner B from sector 1, SU 04/06 are differentiated from other stratigraphic units for the high concentration of polymorphic and monomorphic organic matter. In these units the micromass is mostly distributed as organic coatings that indicates podsolization process in this part of the mound (Van Breemen and Buurman, 2003; Buurman and Jongmans, 2005; Lundström et al., 2000). The incipient formation of a spodic horizon exclusively in corner B was possibly triggered by an increased concentration of organic litter over SU 04/06, deposited 800 years ago. The evidences if podsolization can be used as an indirect sign of past activity area in corner B, the only part of the mound complex where this process was observed.

In Fig. 1B it can be seen that sector 1 is located between two major mounds. The mound construction episode represented by SU 04/06 in corner B is interpreted to be the outer limit of the western mound, which is the tallest mound in the archaeological complex. Since excavation only covered the inter-mound area and not the center of the mound, where activities were more intense, it is difficult to confidently interpret the function of the western mound. SU 04/06 evidence the remodeling and volume enlargement, 800 years after, of a previous mound, identified as SU 05/22. Similar situations have been reported in other mound complexes of the region, such as: Los Ajos site, where several pre-existent mounds were reworked to build platforms during the ceramic mound period (Iriarte, 2006); Paso Barrancas, where burnt ant hills were used for construction and consolidation of earthen structures (Bracco et al., 2000b); and Los Indios, where a land bridge was built to connect two major mounds and create a central plaza, while sediment was added to the pre-existent earthen structures (Lopez Mazz, 2001; Lopez Mazz and Gianotti, 1998). The differential composition of the western mound sediments, seen in thin section as high amounts of decayed organic matter, can be explained as related with the construction and remodeling activities there performed, which included increasing the mound volume and the possible preparation of special surfaces, with leaf or grass mats over the earthen structure.

This opposes the domestic occupation episode of SU 05/22, around 1600 years BP, with the construction and maintenance activities in the platform of corner B (SU 04/06), built 800 years after, with evidences of a possible prepared surface made of perishable plant material.

4.3. Site taphonomy

The microscopic analyses of thin sections from Pago Lindo shows strong evidences of bioturbation, such as channels produced by soil fauna, voids related with root action and ellipsoidal excrements of various sizes. These observations were apparent during field work, when many faunal channels and roots were seen, mixing the sediments from different stratigraphic units and altering their integrity. This means that reworking and displacement of macro and micro artifacts within the mound sedimentary matrix could have been rather intense. It also means that, as stated in the first topic, boundaries between stratigraphic units that can indicate discrete episodes of mound construction are likely to be disturbed by bioturbation.

The absence of bone micro-fragments in the site could be explained by the low pH values of these sediments (between 5 and 6), since bone can be completely dissolved in acid environments

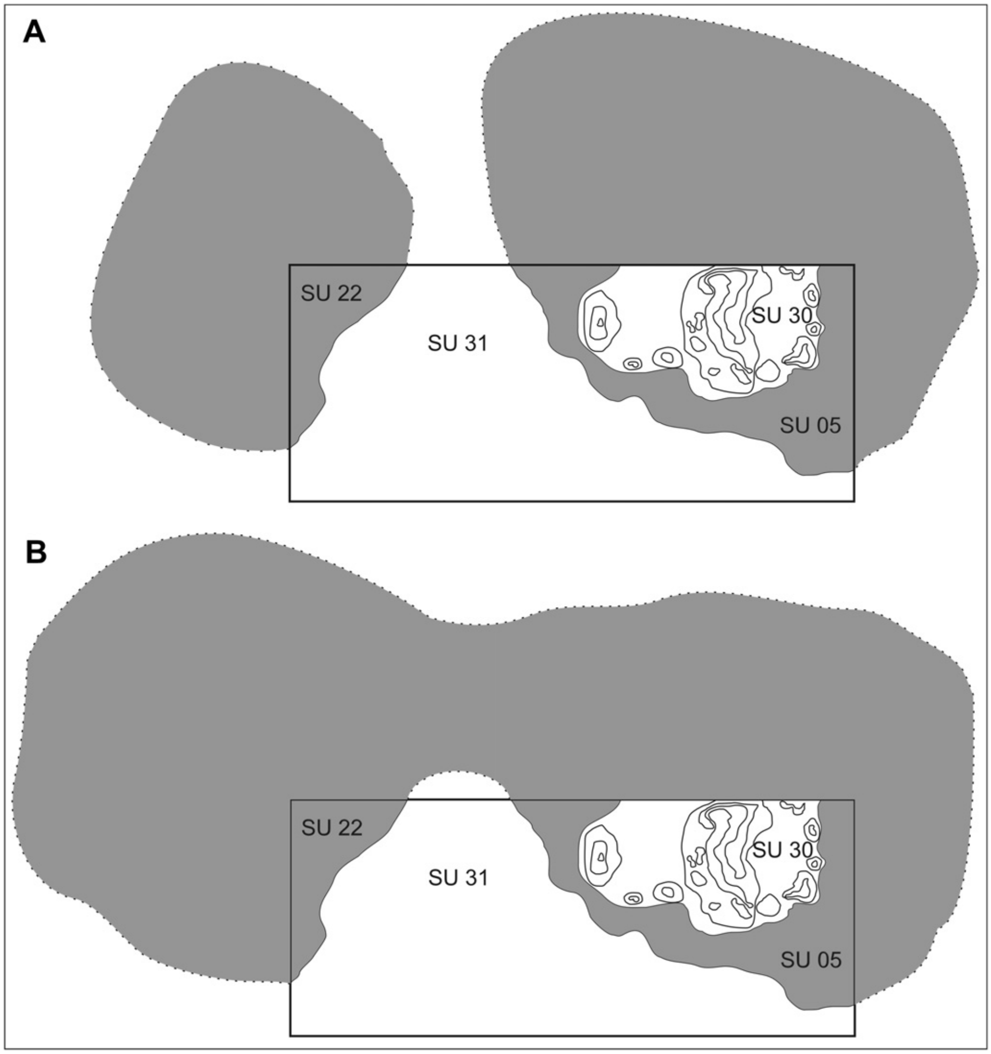

Fig. 6. The two possible alternatives for configuration of SU 22 and 05 in sector 1: there would have been two covering structures in this area of the site (A), or a single structure whose continuity remained outside the excavated area (B).

(Berna, 2004; Lucas and Prévôt, 1991; White and Hannus, 1983). However, if bone deposition was considerable, as expected in domestic areas, some evidence must have remained, even in the microscopic level and in corrosive soil environments like this one, favorable for phosphate dissolution (see Nielsen-Marsh et al., 2007). In fact, anthropogenic dark earths from Amazonia, with high percolation rates and acid pH, do include bone fragments of different sizes, showing that bones can be preserved when deposition rates are high (Arroyo-Kalin, 2008; Lima, 2002; Schaefer et al., 2004).

If dissolution removed bones from the soil, corrosive environments can explain the lack of bone but not of charcoal, since charcoal does not dissolve in acid environments (Schmidt and Noack, 2000; De Souza Falcão et al., 2003). We interpret that the absence of micro-bioarchaeological materials at Pago Lindo, such as bone and charcoal, suggests that these materials were never deposited, or that the occupation surface was regularly cleaned by its inhabitants. Frequent cleaning of an occupation surface may result in the complete removal of components (Milek, 2012). In fact, a low frequency of macroscopic charcoal, carbonized seeds and bone fragments (especially otter teeth) have been found during excavation, which can be used as evidence for validating the cleaning hypotheses.

5. Conclusions

The stratigraphic excavation of Pago Lindo, as opposed to excavation following artificial levels, unraveled the complexity behind earthen mound architecture in the central-eastern Uruguayan lowlands. As part of this novel approach for the excavation and analyses of earthen mounds, soil micromorphology was integrated as a complementary tool to solve field questions on the nature of the prime material used for mound construction, detection of major episodes of mound building, identification of activity areas and taphonomic processes.

The diversity of earth works that characterizes the central and south-eastern lowlands of the country are composed of homogeneous sediments with unclear and complex stratiphications and many bioturbations. As demonstrated in this work, in the Pago Lindo archaeological complex at least two different types of earth works show the same sedimentary composition: mounds and micro-relief, made by the recurrent use of surface horizons as prime material for mound building. Soil material was possibly collected from the proximities of the occupation area as indicated by the shallow borrow pits within the mound complex. This corroborates previous hypotheses based on grain size analyses from other earthen mounds in the lowlands of Uruguay, which also

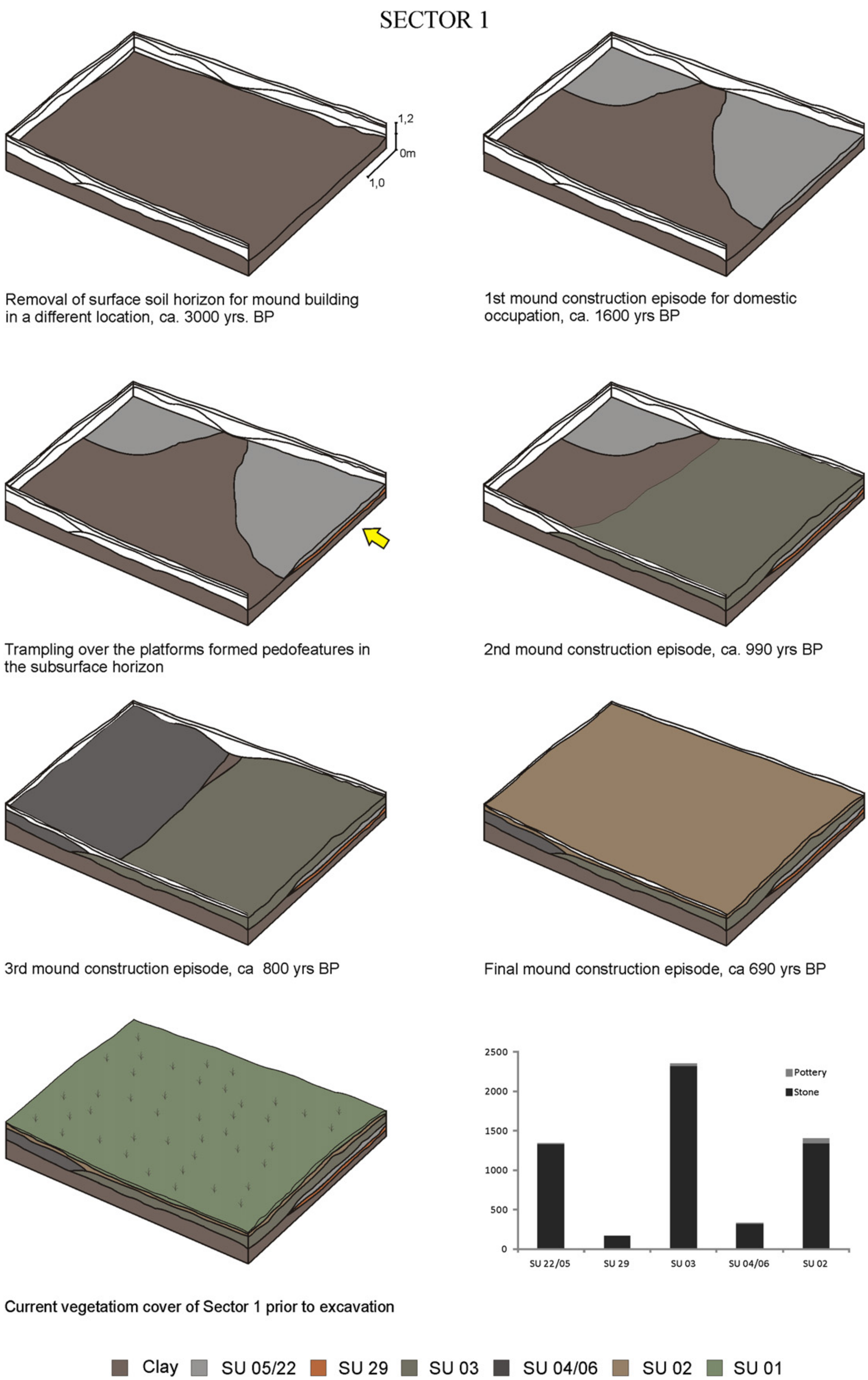

Fig. 7. Schematic model for mound growth, built after the stratigraphic and micromorphological analysis of sector 1, with diagram of artifact frequency per SU (lithic and ceramic).

proved the use of surface horizons in earthen mound construction (Bracco et al., 2000a, 2000b; Gianotti et al., in press). The physical-chemical and biological characteristics of soil material obscure the preservation of clear boundaries between layers that would be interpreted as major depositional episodes. It also enhances taphonomic processes related with bioturbation, which may be causing the displacement of artifacts in the deposit.

Besides being a major taphonomic agent, bioturbation did not completely erase the history of human occupation at Pago Lindo. Evidences of podsolization processes observed exclusively in one corner of the excavation area show that plant litter was accumulated over a mounded structure in this portion of the site, 800 years ago. Such accumulation may be related with mound remodeling for volume enlargement and surface preparation over the tallest structure within the mound complex. Similar processes have been observed in other mound complexes of the region, with evidences of maintenance, remodeling and reuse of pre-existent mounds (Iriarte, 2006; Lopez Mazz, 2001; Lopez Mazz and Gianotti, 1998).

Likewise, dusty clay coatings in a specific portion of the sterile substrate and in the construction episode that buried it, serve as evidence of intense human trampling under a covering structure, interpreted as a domestic occupation by the artifactual assemblage. The small quantity of macroscopic bone and charcoal fragments in the site and the complete absence of micro-bioarchaeological remains can be used as evidence of the regular practice of cleaning the occupation surfaces.

The micromorphological analyses of the Pago Lindo archaeological complex proved that mound formation followed discrete depositional episodes of reworked soil material, as proposed by the LBL growth model. These platforms were built in different moments of the site's history and distinct activities and structures were made over them, such as domestic huts, where residues were constantly cleaned, or areas for the accumulation of organic debris. In this respect, micromorphological findings also fit the new model for mound growth proposed by Gianotti et al. (2009). The continuous occupation of the domestic hut caused the translocation of clay through the profile observed as clay coatings in SU 29. Episodes of mound construction explain the presence of mound shaped stratigraphic units made of reworked surface horizons, like SU 22/05, SU 03 and SU 04/06. Changes in the uses of space through time are seen in corner B and C, where a platform with plant debris accumulation (SU 04/06) and domestic huts (SU 05/22 and 03), respectively, were abandoned and covered by a major mound building episode (SU 02).

Fig. 7 shows a schematic model for the evolution of sector 1 that involved four major episodes of spatially contiguous mound construction, with domestic occupation and platform building. The STD model states that mound complexes are formed as a result of the discontinuous and recurrent process of occupation of the same space. Although it incorporates and unites proposals from the LBL and CG models, the STD model does not see mound building and site occupation as the result of the vertical growth of discrete locations, whether episodic or constant, but as a spatial–temporal discontinuous process. In Fig. 8 the three models for mound growth are schematized using Harris matrices. The diagrams illustrate the conceptual differences between the three models. The simplicity of the LBL and CG models is opposed to the complexity that is intrinsic to long-term earthen mound architecture, seen in the STD model as a wide-scale space construction project and not as a single-mound rising endeavor.

The implications of the STD model are important for discussing how settlement patterns have changed through time and how that reflects the social organization of prehistoric populations and their strategies for territory building. In a regional scale, the formation of mound complexes in the Uruguayan lowlands can be understood with the same logic proposed for the STD model: not as a lineal or evolutionary sequence, but as a processes marked by the recurrent and spatial discontinuous occupation of the same settlements, with different rhythms and intensities that generated the variability of earthen mound architecture. The first mounds are associated to small domestic units, made by groups that subsisted on a mixed economy based on hunting, fishing and gathering. These initial stages, where no clear building activity was identified, lead some authors to identify these as ambiguous monuments (Gianotti, 2005; Villagran, 2006).

From 3000 BP there is an intensification of domestic activities, with longer occupation of the sites and increased mound building with platforms, micro-reliefs, borrow pits and central plazas

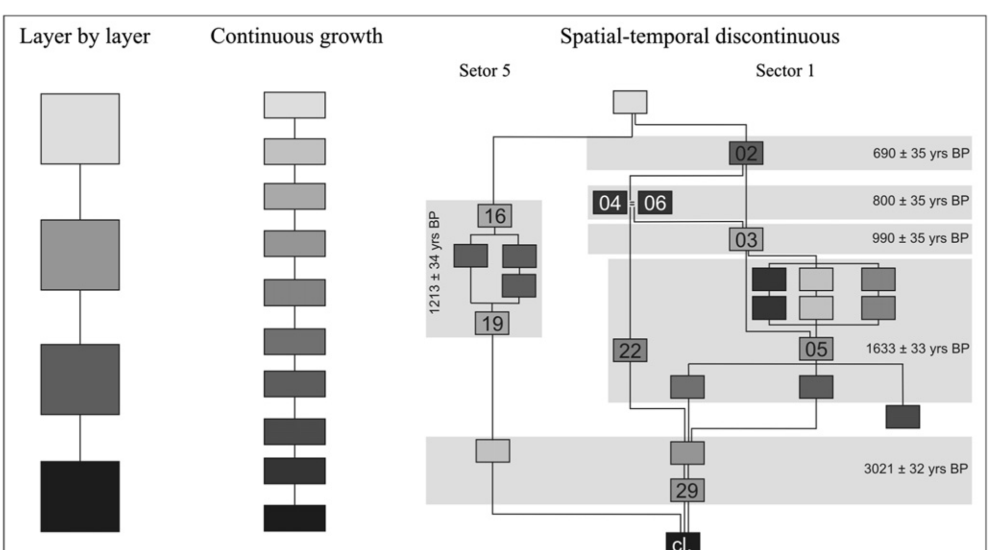

Fig. 8. Harris matrices showing the three models proposed for mound formation: layer by layer (LBL), continuous growth (CG) and spatial–temporal discontinuous model (STD). The spatial–temporal discontinuous model includes the stratigraphic relations of the ten SU studied in sectors 1 and 5 of the Pago Lindo archaeological complex with the radiocarbon datings associated with each of them. The schematic comparison between the three models evidences the conceptual differences that arise from conceiving mound formation as a unidirectional processes (LBL and CG models) and the actual complexity that is reveled from the stratigraphic excavation of earthen mounds (STD model).

(Iriarte, 2006; Lopez Mazz, 2001; Lopez Mazz and Gianotti, 1998). These structures, identified in Pago Lindo and in other multi-component sites of the region, respond to well planned villages (Dillehay, 1995; Iriarte, 2006). This moment also sees earthen architecture as funerary monuments (sensu Criado-Boado, 1989; Criado-Boado et al., 2006), which represent firs order elements for the social construction of the landscape. In this sense, mound complexes are seen as the territorial expression of a communitarian organization. In recent times, after 1000 BP, there is a decrease in building activities and a returned emphasis on domestic structures.

Further stratigraphic excavations and micromorphological work must be done in the Pago Lindo archaeological complex and other earthen mound sites from the region to refine the STD growth model and advance in the use of soil micromorphology in the analyses of earthen mound complexes.

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