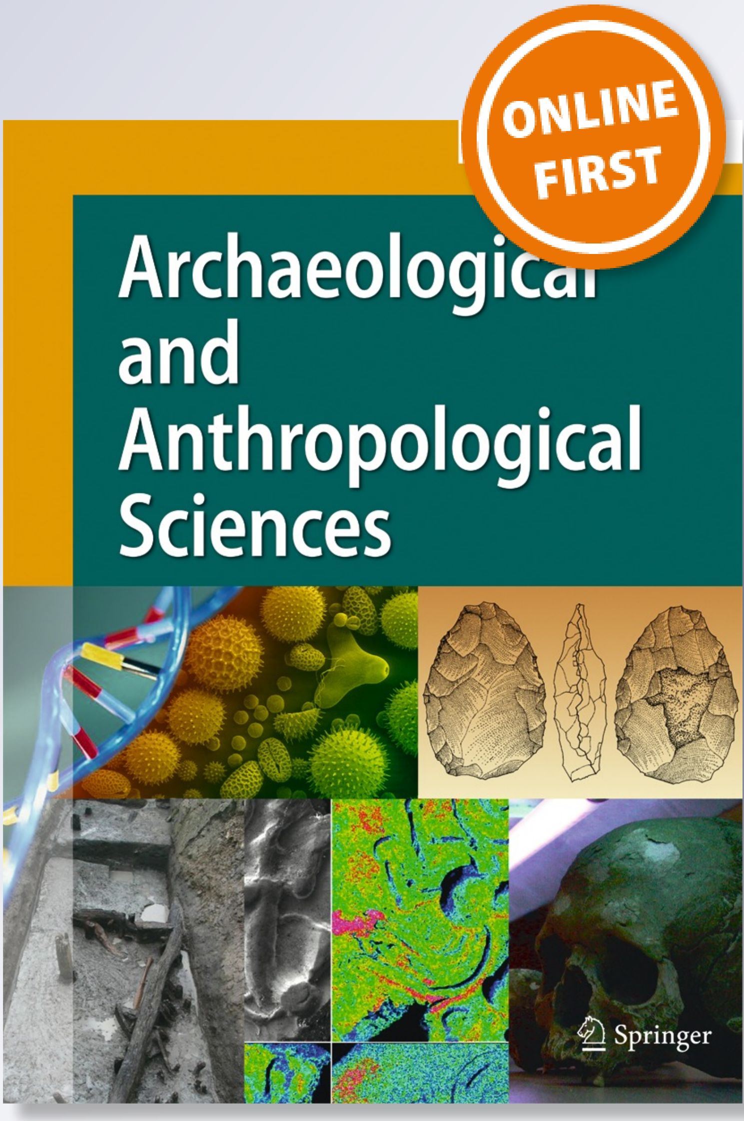
The origin and construction of pre-Hispanic mounds in the Upper Delta of the Paraná River (Argentina)

C. Castiñeira, A. Blasi, G. Politis, M. Bonomo, L. del Puerto, R. Huarte, J. Carbonari, F. Mari & F. García-Rodríguez

Archaeological and Anthropological Sciences

ISSN 1866-9557

Archaeol Anthropol Sci
DOI 10.1007/s12520-012-0107-2



Springer

Archaeol Anthropol Sci
DOI 10.1007/s12520-012-0107-2

ORIGINAL PAPER

The origin and construction of pre-Hispanic mounds in the Upper Delta of the Paraná River (Argentina)

C. Castiñeira · A. Blasi · G. Politis · M. Bonomo · L. del Puerto · R. Huarte · J. Carbonari · F. Mari · F. García-Rodríguez

Received: 13 November 2011 / Accepted: 4 October 2012

Abstract Pre-Hispanic mounds, known as "cerritos," "cerritos de indios," or "aterros" across southeastern South America, are one of the most conspicuous and well-studied cultural manifestations in lowlands archaeology. Nevertheless, in the Upper Delta of the Paraná River, mounds are rarely studied, and even their anthropic origin is under debate. This could be related to the fact that anthropogenic mounds are located on a floodplain where other "mound-like" natural geoforms (generated by fluvial processes) are also present. In addition to this, the natural geoforms also contain evidence of Holocene human occupation (sherds, bones, charcoal, humans burials, etc.), which can lead to interpretive errors of their origin and formation. Thus, this project set out to determine the genesis and evolution of these mounds and also to identify the cultural occupation and transformation of natural landforms found in the area. In this article, natural and anthropogenic systems and processes were identified and characterized through the application of proxy record analysis (i.e., sediment composition, stratigraphy, micromorphology, silica bodies and chronological analysis) at the Los Tres Cerros archaeological locality in the Upper Delta of the Paraná River of Victoria County, Entre Ríos Province, Argentina. This analysis allowed for the recognition of natural anthropogenic interfaces, such as the "pre-mound" occupation as well as evidence of cultural activities such as mound construction, between 1,000 and 500 ^{14}C years BP. These findings were integrated into current research on the variability of mound construction during the Late Holocene in the lowlands of South America.

C. Castiñeira (✉)
CONICET, División Mineralogía y Petrología, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, La Plata, Argentina
e-mail: carolacl2004@yahoo.com

A. Blasi
CIC, División Mineralogía y Petrología, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, La Plata, Argentina

G. Politis
CONICET-INCUAPA, Facultad de Ciencias Sociales de la UNCPBA, Olavarría, Buenos Aires, Argentina

G. Politis
Departamento Científico de Arqueología, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, La Plata, Argentina

M. Bonomo
CONICET, Departamento Científico de Arqueología, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, La Plata, Argentina

L. del Puerto
Ministerio de Educación y Cultura, Centro Universitario Regional Este (CURE), Universidad de la República, Montevideo, Uruguay

R. Huarte · J. Carbonari · F. Mari
Laboratorio de Tritio y Radiocarbono, CIG-LATYR, CONICET, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, La Plata, Argentina

F. García-Rodríguez
Sección Oceanología, Maestría en Ciencias Ambientales, Instituto de Ecología y Ciencias Ambientales, Facultad de Ciencias, Universidad de la República, Montevideo, Uruguay

Published online: 13 November 2012

Keywords Mounds · "Cerritos" · Upper Delta of the Paraná River · Holocene · Depositional systems · Wetlands

Introduction

Mounds are one of the most distinctive archaeological features in the wetland landscapes of southeastern South America (Durán and Bracco 2000; Erickson 2000, 2006; Naue 1973; Schmitz et al. 1991; Torres 1903, 1911). In Argentina, Brazil, Uruguay, and Paraguay, they are known as "cerritos," "túmulos," "aterros," "cerritos de indios," and "tesos" (e.g., Ameghino 1880; Benítez 1942; Ferrés 1927; Figueira 1892; Lista 1878; López and Bracco 1994; Schmitz and Basile 1970; Torres 1903, 1907, 1911; Zeballos 1878; Zeballo and Pico 1878). These terms have been used to refer to earthen mound structures dating ca. 5,500 years ^{14}C BP to ca. 200 years ^{14}C BP (e.g., Bonomo et al. 2010, 2011c; Bracco 1991, 2006; Bracco et al. 2005, 2010a; Iriarte 2006; Iriarte et al. 2004; López 2001; Politis et al. 2011; Schmitz and Basile 1970).

Early interpretations about the role of mounds, among pre-Hispanic populations of Uruguay, northern Argentina, and southern Brazil, were based on their placement on floodplain wetland areas (Ameghino 1880; Arechavaleta 1892; Bauzá 1895; Figueira 1892; Lista 1878; Roth 1888; Torres 1903, 1907, 1911; Zeballos 1878). Debate about the natural or anthropic origin of pre-Hispanic mounds in low gradient plains has been prevalent throughout the history of archaeology in Uruguay, southern Brazil and Northeast of Argentina (e.g., Arechavaleta 1892; Bracco et al. 2000b, 2010b; Figueiras 1892; Frenguelli and de Aparicio 1923; López 2001; Outes 1912; Politis et al. 2011; Serrano 1933; Torres 1903, 1911). This subject has been particularly important and controversial in the Paraná River Delta in Argentina. The presence of ¨cerritos¨ in this area was first reported by the end of the nineteenth century (Ameghino 1880; Lista 1878; Roth 1888; Zeballos 1878). Some authors considered these structures as natural elevations (e.g., overbank ridges, dunes) used by pre-Hispanic peoples for rituals and/or dwelling purposes (Cione et al. 1977; Frenguelli and de Aparicio 1923; Torres 1903). However, other authors interpreted mounds as the result of the anthropogenic accumulation of various sediments and cultural remains, which were generated to preserve human burials deposited there (Ameghino 1880; Lista 1878; Zeballos 1878) or were the location of various cultural activities during floods (Greslebín 1931). Finally, other authors also suggested the coexistence of natural elevations with cultural accretion where many domestic activities took place (Ceruti 2003; Bonomo et al. 2011b; Gaspary 1950; González 1947; Nóbile 2002; Torres 1911).

At this point in the debate, a number of studies have now started to enhance the discussion by contributing valuable data about the genesis, evolution, and purpose of mounds in the Paraná River Delta. Recently, Bonomo et al. (2011a,b,c) reported 65 archaeological sites in the Upper Delta of the Paraná river dated to the Late Holocene (ca. 400–900 ^{14}C years BP). Among these, three mounds were described that characterize the archaeological locality of Los Tres Cerros of Las Moras Island, Victoria County, Entre Ríos Province (Argentina). The genesis of the structures, their chronology, and archeological record were preliminarily described by Politis et al. (2011). In addition, the anthropogenic origin of the various layers that constitute the three mounds were characterized and identified from natural deposits.

In this article, previous studies (Politis et al. 2011) are refined from a geoarcheological point of view. In this sense, the depositional processes are described and identified, the source areas of sediments are identified, and new evidence is presented to support the anthropogenic origin of these mounds. At the same time, various domestic, ritual and burial activities were recognized in one of the mounds during the occupation of the site ca. 1,000 and 500 years ^{14}C BP. This has been achieved by applying techniques such as textural and mineralogical compositional analysis, biosiliceous content analysis, and micromorphological analysis. We add to what is currently known about the regional variability of mound construction and function (e.g., Bonomo et al. 2011c; Bracco and Ures 2001; Bracco et al. 2000a,b; Castiñeira and Piñeiro 2000; Iriarte 2006; Iriarte et al. 2004; Schmitz et al. 1991; Suárez Villagrán 2006).

The study area

The Los Tres Cerros archaeological locality (32°51′17.3″ S and 60° 33′37.6″W, see Fig. 1) consists of three mound structures (LTC1, LTC2, and LTC3) aligned NW–SE 239 m (Fig. 2). This locality is located on the physiographical region usually referred to as the Upper Delta of the Paraná River (e.g., Amatto and Silva 2009; Malvárez 1999). This was also used as a spatial unit of analysis in Argentina archaeology (e.g., Aparicio 1939; Bonomo et al. 2010; Caggiano 1984). However, Cavallotto et al. (2004, 2005) referred to this region as the Coastal Plain of the lower Paraná Basin. For these authors, the Delta area would only comprise of the subaerial part, between the Areco River (34°05′44.91″ S and 59°03′52.48″ W) and the city of Buenos Aires (34°32′02.5″ S and 58°27′33.64″ W) and the underwater delta extending from the city of Buenos Aires to the Samborombón Bay (36°19′38.91″ S and 56°47′53.12″ W).

The coastal plain together with the subaerial platform that constitutes the Paraná Delta *sensu lato*, extends over 320 km of gently sloping terrain genetically linked and related to transgressive–regressive Pleistocene–Holocene events (Cavallotto et al. 2004, 2005; Codignotto 2004; Iriondo et al. 2007; Iriondo and Kröhling 2008). According to paleoenvironmental

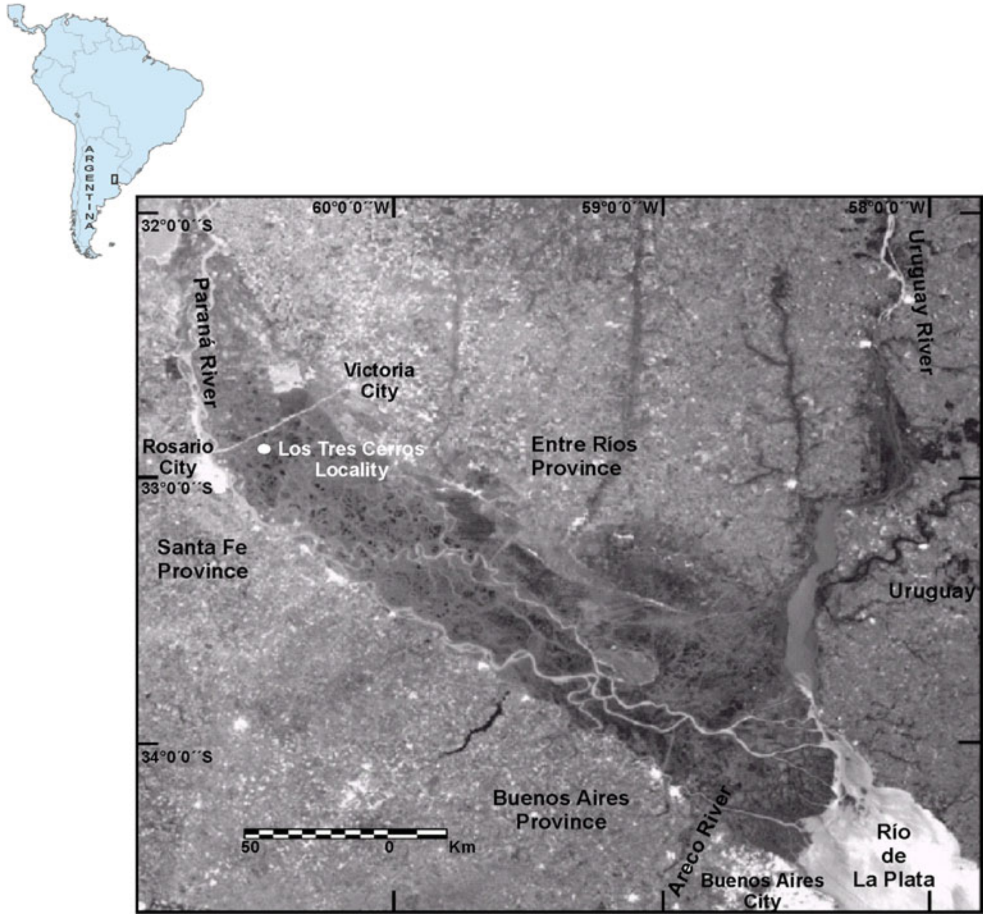


Fig. 1 Study area with the Los Tres Cerros archaeological location (image and references see Cavallotto et al. 2005, p. 356)

reconstructions (Fig. 3), the pre-deltaic tidal plain would have been formed after the end of the transgression that began ca. 18,000 cal. years BP, which reached its highest level close to ca. 6,000 cal. years BP, and later descended at different rates depending on the region (Fig. 4). During this time, in the area of the Los Tres Cerros archaeological locality, an estuary was developing. Clay and silt clay sediments corresponding to the "open estuary facies" (*sensu* Cavallotto et al. 2005) were detected in the area. Later on, during the first regressive stage, the coastal plain began to take shape from the accumulations of different sedimentary facies: deltas, plains with beach ridges, beaches, tidal, and coastal lagoon plains. However, it was during the second stage of the regressive event (after 4,000 cal. years BP) that the coastal plain acquired its present configuration. Therefore, human occupation of the area could have developed on the mud of the pre-deltaic tidal plain or, at a later time, on alluvial clayey mud or mud sediments deposited by floods in the lower Paraná River.

This environmental evolution produced alluvial sediments that characterize the surface and subsurface strata of the area, which contain fine sediments with clay minerals such as illite, smectite, and kaolinite/chlorite (Amato and Silva 2009; Cavallotto 1995). This association of minerals is related to the transportation of suspended solid matter of the Paraná River and that of several tributaries that flow into this sector of the basin (see Bonetto and Orfeo 1984; Depetris and Grifin 1968; Manassero et al. 2008; Mangini et al. 2003, in this connection). Within this alluvium, moderately deep gleyed hydromorphic soils developed (Pereyra et al. 2004).

Physiographically, the study area is characterized by a gently sloping plain frequently flooded by overbank flow from tributaries of the Paraná River. This characteristic has exerted influence on the drainage system and also on the diversity of the vegetation cover (Fig. 3d). This area is made up of two major patterns: In the lower area, there are temporary or permanent "*lagunas*" (shallow lentic environments), which formed and in the higher areas there are scroll bars, a result of continual lateral migration of the fluvial meander loop or single point bars. In the temporarily flooded higher lands, groves of *Salix humboldtiana* (a native willow species) and *Tessaria integrifolia* establish themselves. In areas where flooding is semipermanent, a tall-

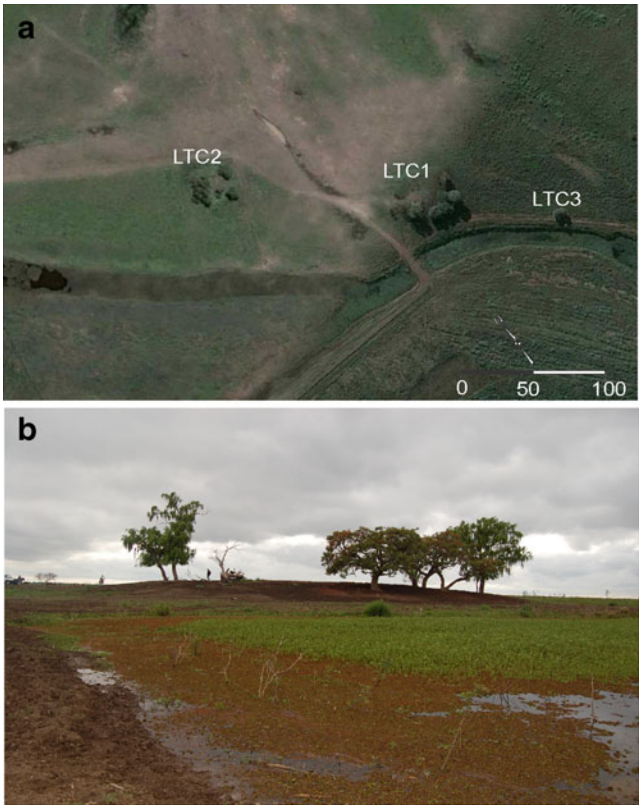


Fig. 2 **a** Satellite image of the Los Tres Cerros locality (Google Earth). **b** Detail of the mound LTC1

grass prairie developed. In most depressions, communities of gramineae grow (Malvárez 1999).

Methodology and technique

Only one of the three mound structures, LTC1 (Fig. 2), has been thoroughly studied. It is the highest of these structures, at 2.10 m above the surrounding surface. It has a maximum diameter of 66.6 m and a minimum of 57.5 m. This mound is located in the center, and it was here where the systematic excavations were undertaken and where the proxy records (sedimentological, microbiological, chronological, and micromorphological) were obtained. In LTC2 and LTC3, one test pit was made at the center of each mound in order to examine their sedimentary and chronological sequence. These preliminary results were published by Politis et al. (2011).

In the LTC1 mound structure, an excavation was carried out using 15 m^2 1×1 m grid squares to a depth of 3 m, allowing a continuous 8 m profile to be exposed (south wall; Fig. 5a). In order to recognize the genesis of mound structures, samples were taken from the excavation exposed profiles in LTC1 and from five auger holes (0.25 m in diameter and collected at depth of 1.0 and 3.0 m) drilled on the plain around the mounds. Analysis of the stratigraphic record in LTC1 focused on the recognition of morphological and compositional attributes of the three layers documented by Politis et al. (2011) and of the lenses of thermoaltered sediments, which contained charcoal and concentrations of organic matter characteristic of layer III. These new results were compared to those published by Politis et al. (2011).

These new sedimentary samples were systematically analyzed for color (Munsell Color Chart), texture, mineralogy, microbiology, micromorphology, and dating. At LTC1, the

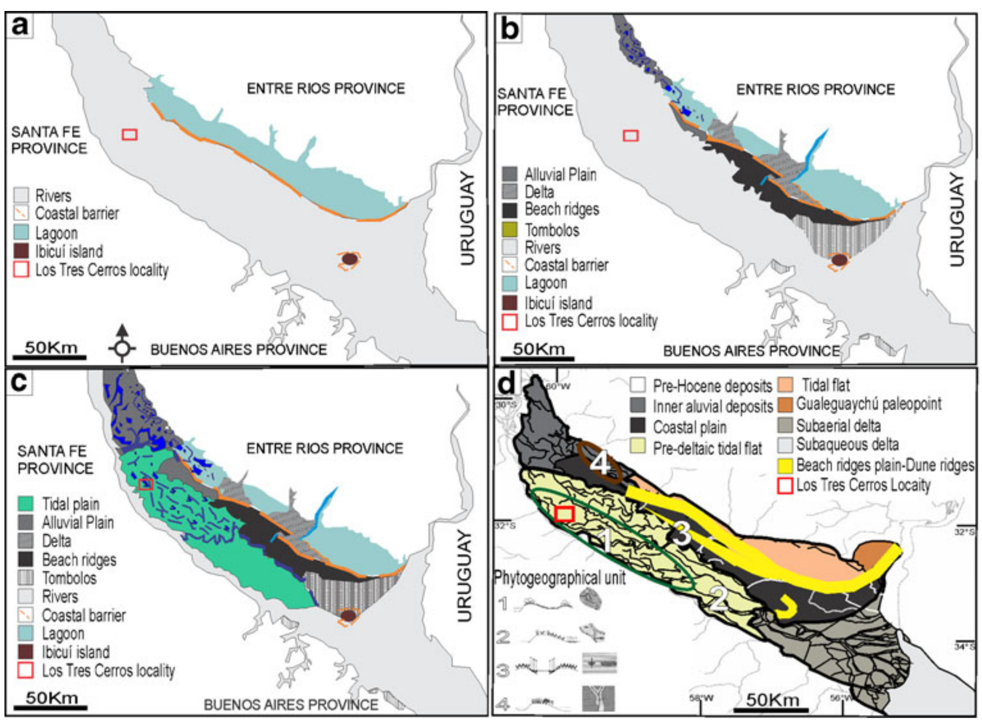


Fig. 3 **a**–**c** Evolution of the deltaic area during the Holocene proposed by Codignotto (2004). **a** 7.5 kacal. years BP; **b** 6 kacal. years BP; **c** 4 kacal. years BP; **d** actual geomorphologic map (*sensu* Cavallotto et al. (2005), with the detail of the phytogeographical units proposed Malvárez (1999:37): (1) forests and prairies associated with Paraná meandering channels and islands; (2) prairies associated with previus tidal plain; (3) prairies associated with ridges and depressions; and (4) patches of prairies associated with low overbank ridges.

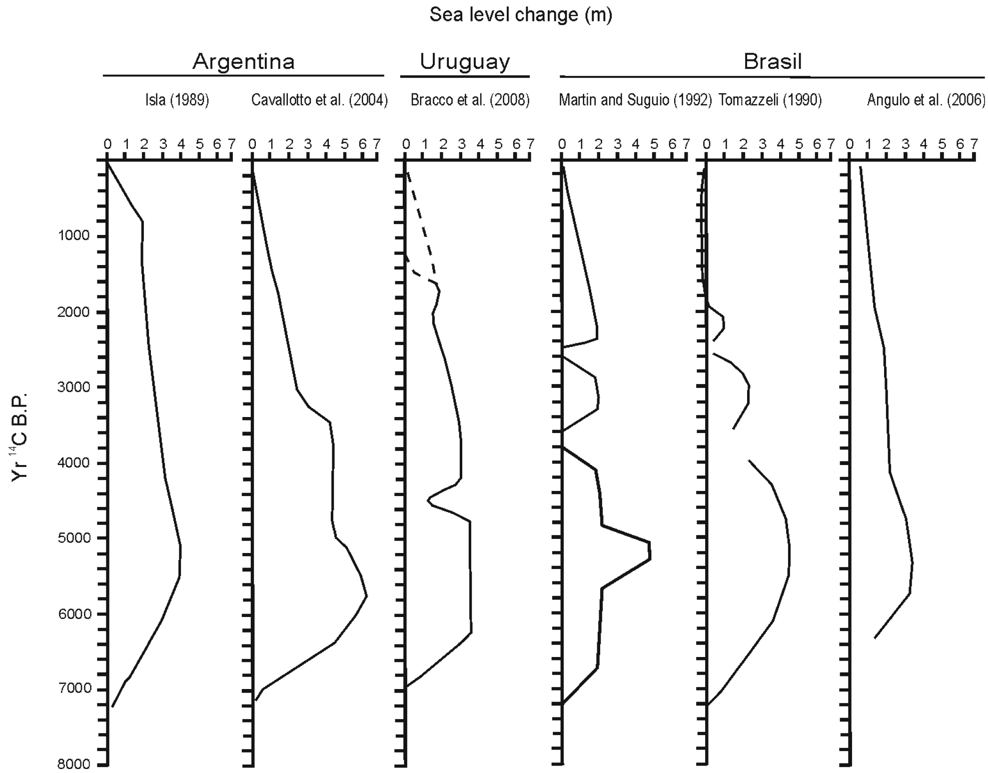


Fig. 4 Holocene sea-level curve evolution for the region (Inda et al. 2011, p. 242)

samples were taken every 5 cm of grid-square 3 of the south wall, and in various previously defined stratigraphic units, from selected sectors of the profiles. From the test pits and auger holes from the alluvial plain at the archaeological locality, the samples of each lithological unit were selected. At the LTC2 and LTC3 mounds, sub-surface samples were taken (down to a depth of 80 cm) to carry out sedimentological and chronological analysis.

Sedimentological analysis

Samples received a preliminary treatment by eliminating organic matter and carbonates with a solution of 30 % H_2O_2 and 35 % HCl. A solution of 2N $Na_4P_2O_7$ and mechanical shaking were used for their dispersion. For the grain size analysis of coarse fractions (gravel and sand), sieving at intervals of half a degree of *phi* was employed, and for the fine ones (silt and clay) the pipette method was used (Carver 1971; Day 1965). The percentages of sand, mud, and clay content were utilized for grain size classification according to Folk (1954). The grains measuring 2–0.062 mm were observed under a binocular microscope, and the percentage of silicoclastic in relation to microarchaeological material (pottery fragments, consolidated lumps of burnt soil, charcoals, bone fragments and *Diplodon* sp. valves) were identified.

The grain mounts of very fine sand fraction (0.125–0.062 mm) was analyzed by using a polarized microscope, while clays were analyzed by RX diffractometry (Phillipps PW3710 Cu tube diffractometer) in natural, glycolated, and calcined oriented preparations. The species of argilominerals were semiquantified according to the method proposed by Pirce and Siegel (1969). A ternary (I-Sm-C/K) diagram was created to represent the DRX results, evaluating the existence of argilomineral association areas (AAA).

Biosiliceous particle analysis

The analysis of biogenic silica content is a common methodology used in archaeological research. This allows for the recognition of anthropogenic signals in the sedimentary record, the understanding of site formation processes, and the reconstruction of climatic and environmental changes, which may have occurred during human occupation (Bracco et al. 2010a; del Puerto et al. 2006; Pearsall 1978, 1982, 2000; Piperno 1988, 2006; Zucol and Bonomo 2008; Zucol et al. 2007). In this investigation, the quali-quantitative study of opal phytoliths, diatoms, chrysophycean cysts, and sponge spicules was aimed at identifying the differences pointed out in Politis et al. (2011) between the anthropogenic deposits of the mound structures and those of the plain on which the Los Tres Cerros mounds are located.

Opal phytoliths are bio-mineral particles that originate from the total or partial silicification of plant cells or intercellular spaces (Mulholland and Rapp 1992). Because they are made of silica, their preservation is possible long after the decay of the parental plant. Thus, the recognition of opal phytoliths will allow for the identification of the management and use of plant species for consumption, and the generation

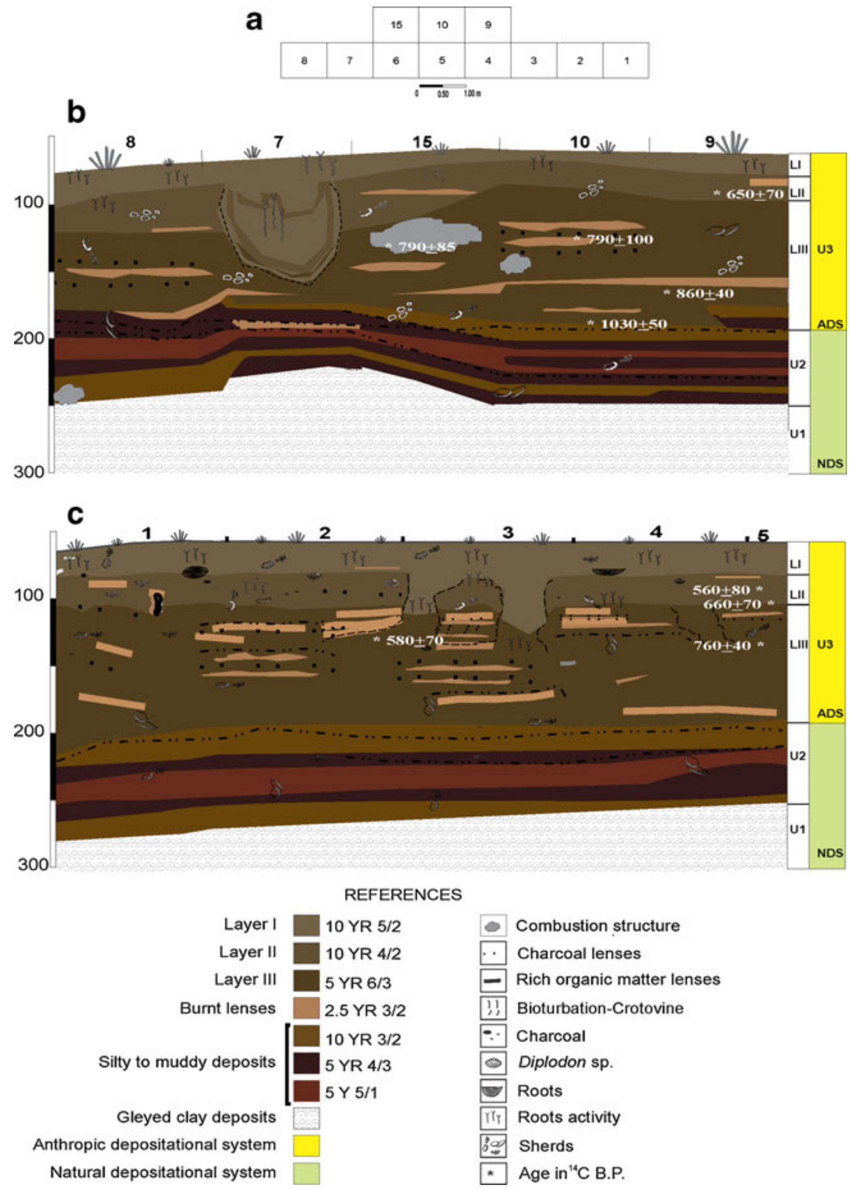


Fig. 5 **a** Scheme of the excavation plane. **b** Diagram of stratigraphic sequences from north wall. **c** Diagram of stratigraphic sequences from south wall

and maintenance of fire places, among other anthropic activities (i.e., shelter construction, soil preparation, etc.), that may have taken place in the interior of structure LTC1. At the same time, the diatom, chrysophycean cyst, and sponge spicule content will allow for the identification of palaeoenvironmental change, differential exposure of the deposits to hydrological dynamics, and the identification of source areas of the sediments used for mound construction.

Diatoms are microscopic unicellular organisms possessing a siliceous skeleton called frustules, which are composed of two semitheques: epitheque and hypotheque. The morphology, structure, ornamentation, among other aspects, allows for taxonomical classification to the species level (Frenguelli 1941, 1945; Jahn et al. 2001; Lange-Bertalot and Simonsen 1978; Metzeltín and García-Rodríguez 2003; Round et al. 1990; Prygiel and Coste 2000). Since they require low intensity light and humidity to develop, it is possible to find them in various environments (e.g. swamps, lakes, soils, and caves). These organisms can be found in the planktonic domain (in the water column) or associated with sediment, rocks, and walls of algae (benthic domain). Diatoms, together with chrysophycean cysts and sponge spicules, are of great palaeoecological importance because they are preserved as fossils, making up referent proxies in the palaeoenvironmental reconstructions (del Puerto et al. 2006; García-Rodríguez 2006; Metzeltín and García-Rodríguez 2003; Metzeltín et al. 2005; Inda et al. 2006).

Chrysophycean algae are a diverse and often abundant group of primarily freshwater phytoplankton, characterized by the endogenous formation of siliceous cysts or stomatocysts (Duff et al. 1995). Chrysophyte taxa are found in many different types of limnological environments, but are often most commonly seen in somewhat acidic or nutrient-poor waters, and are typically less abundant in very alkaline or eutrophic waters (Zeeb and Smol 1993). Sponges are aquatic, sessile, multicellular organisms grouped into a common taxon, termed "phylum Porifera" which comprises most strongly of individualized, radially symmetrical entities. Further studies have divided the phylum Porifera into three classes—Hexactinellida, Demospongiae, and Calcarea. Most Demospongiae and Hexactinellida produce silica-made skeletons consisting of individualized elements (spicules) of lengths ranging from micrometers to centimeters. The spicules of siliceous sponges are composed of amorphous opal ($SiO_2 \cdot nH_2O$). The high diversity of spicule shapes and sizes in both fossil and living sponges has been repeatedly reported (Ezcurra de Drago 1993; Volkmer-Ribeiro 2007).

Samples for biosiliceous particle counting and identification were treated with 2N $Na_4P_2O_7$ for sediment disaggregation and removal of clays. Then, 15 ml of 35 % HCl was added, and the solution was allowed to stand for 24 h to eliminate carbonates. It was rinsed several times with distilled water. Next, 10 ml of 30 % H_2O_2 was added to eliminate organic matter, and then the samples were boiled for 4 h and rinsed five times with distilled water. Permanent slides were mounted in Naphrax for counting and identification. A minimum of 400 biosiliceous particles was counted at ×1,000 magnification in each sample with an Olympus BX 40 microscope. Diatom species were identified and classified according to Frenguelli (1941, 1945), Metzeltín and García-Rodríguez (2003), Metzeltín et al. (2005), and Witkowski et al. (2000). Phytoliths were identified according to Bozarth (1992), del Puerto et al. (2006), del Puerto (2009), Fredlund and Tieszen (1994), Fernández et al. (2006), Gallego and Distel (2004), Twiss (1992), and Zucol (1998, 2000, 2001). Chrysophycean cysts were identified according to Duff et al. (1995), and sponge spicules were recognized according to Ezcurra de Drago (1993).

For the LTC1 sediments, graphs were plotted to depict the relative abundance of phytoliths, diatoms, sponge spicules, and chrysophycean cysts according to their depth. By means of cluster analysis with stratigraphic adjustment (stratigraphically constrained clustering), three biogenic association zones (BAZ) were identified. For this purpose, the Morisita index (Past version Program) was used in order to determine BAZs.

Micromorphological analysis

Micromorphological analyses are especially useful in archaeology to identify sedimentary sequences of activities such as sweeping, incineration, site abandonment, and the detection of postdepositional processes such as erosion, pedogenic, biostratinomic disturbances (e.g., Arroyo-Kalin 2010; Arroyo-Kalin et al. 2008; Berna and Goldberg 2007; Courty 2001; Courty et al. 1989; Goldberg et al. 2009). In our case, the micromorphological studies were implemented to characterize the alternating sequences of thermoaltered sediments, charcoal lenses, and those of organic matter concentration present at structure LTC1. To achieve this, samples were taken from the south wall grid-square 3, in which the limits between lenses showed a clear expression. For the sampling a 4×6×9 cm Kubiena box was used. The preparation of the thin sections followed the directions reported at http://edafologia.ugr.es/micgraf/indexw.htlm. Thin sections were analyzed and described using a Nikon SMZ 745T microscope, Dialux-Pol–Leitz polarized microscope, an Olympus BX40 biological microscope at ×200 and ×400 magnifications, and a Carl Zeiss model Phomi III petrographic microscope. Images were taken using a Sony CCD-IRIS video camera and a Cannon Power Shot A620 photo camera.

The general descriptive criteria were based on the parameters proposed by Bullock et al. (1985) and Stoops (2003). The identification, dispositation, and association of the organic, silicoclastic, and microarchaeological components guided the definition of microfacies in the same sense as given in Goldberg et al. (2009) for the thin sections from Sibudu Cave of KwaZulu-Natal site, South Africa.

Chronology

Eleven radiocarbon dates from the Los Tres Cerros archaeological locality were reported in Politis et al. (2011). In this article, we highlight a new date obtained from the organic content of a sedimentary sample from level 23 (1.8–1.85 m) from the LTC1 site (Table 1). This new date is important because this is the level where the beginning of the anthropogenic elevation is observed. All dates, except one (AA-93218) were processed at the *Laboratorio de Tritio y Radiocarbono*, CIG-LATYR, CONICET-UNLP (Argentina) by means of radiometric methods for conventional count of the radioactive decay. The measurement of ^{14}C activity was performed using liquid scintillation spectometry at an ultra low level, Packard-Tricarb 3170 TR/SL (Huarte and Figini 1988). For calibrating the ^{14}C date obtained the program OxCal. V.4.1.7 was used.

Results

Stratigraphic sequence of mound LTC1

The stratigraphic record of LTC1 has allowed for the identification of two depositional systems (Fig. 5a, b) depending on their depositational agent: a lower, natural one (natural depositional system NDS) and an anthropogenic upper depositional system (ADS). For NSD, two stratigraphic units were identified (U1 and U2). This distinction was based on grain size, sedimentary structures, color, and the presence of aggregates, concretions, and concentration of cultural material, among other features. A unique unit (U3) was identified in ADS, which contained the three layers described in Politis

Table 1 Radiocarbon results for LTC1, LTC2, and LTC3

Site	Level	Depth (cm)	Lab. No.	Material	^{14}C dates (year BP)	Calibrated dates (year AD, 1σ ranges)	Layers
LTC1	5	90–95	LP-2295	Valves	560±80	1,288–1,505	II
	5	90–95	LP-2289	Charcoal	650±70	1,279–1,435	
	7	100–105	LP-2284	Valves	660±70	1,275–1,433	
	9	110–115	LP-2302	Charcoal	790±100	1,130–1,406	III
	10	115–120	AA93218	Bone	775±85	1,217–1,317	
	13	130–135	LP-2281	Charcoal	580±70	1,289–1,464	
	13	130–135	LP-2332	Charcoal	760±70	1,201–1,398	
	16	145–150	LP-2296	Charcoal	860±40	1,158–1,278	
	23	180–185	LP-2572	Charcoal	1,030±50	1,079–1,145	
LTC2		70–75	LP-2303	Organic matter	920±40	1,053–1,216	
LTC3		50–60	LP-2305	Organic matter	600±60	1,320–1,430	

et al. (2011). These layers were basically identified according to the archaeological material concentration and presence of lenses. Lenses are lenticular to tabular layers from 1 to 5 cm thick, which are sometimes placed as laterally continuous lenses or vertically superposed lenses inside each layer.

The stratigraphic sequence exposed at LTC1 and the results of the multiproxy research are described below. The values for the depths of the deposits are expressed in reference to the excavation "0" mark, about 0.8 m above the current surface in the top of the mound. The different excavated levels were numerically designated in ascending order according to the increasing depth. Thus, level 1 belongs to the upper 5 cm, while level 46, refers to the bottom of the excavation

Unit 1 (U1) This unit is a gray (5 Y 5/1), homogeneous, hydromorphic mud deposit, developing from ~2.60 m depth (level 39). It was dug up to 3 m deep being archaeologically sterile at about 2.83 m (level 43). The presence of cultural material began at a depth of ~2.80 m (level 42) and consisted exclusively of a few pottery shreds, (90° angles of inclination) and associated to contraction and expansion crevices. The mineral composition of this unit is mainly quartz, followed by mica, and feldspar. Illite (I) was recognized as the most abundant clay mineral (55–65 %) followed by smectite (Sm, 30–10 %) and chlorite–kaolinite (Ch/K, 23–25 %) (AAA-C, Fig. 6). The biosiliceous content is mainly represented by phytoliths (~60 %), with a dominance of morphotypes attributed to panicoid and orizoid grass, sedges, and reeds. The diatom content varies from 30 % at the deepest levels to 15 % towards the top of the unit, generally appearing as articulated. In the whole U1, benthic diatoms predominate in a 2:1 relationship to planktonic diatoms (Table 2, and Fig. 7), followed by the presence of sponge spicules and a low content of chrysophycean cysts (Fig. 8).

Unit 2 (U2) This unit spans from about 2.60 to 2 m (level 38–level 27). It is a thin (average thickness, 0.10 m) solid, muddy, and muddy–sandy strata of a very dark reddish-brown (10 YR 3/2) to greyish-brown (5 YR 4/3) color, with a high content of organic material (Fig. 5b, c). Throughout the sequence of this unit the archaeological material (pottery, faunal remains, charcoal, etc.) is recovered in primary and secondary positions. At the base, about 2.50–2.55 m deep (level 37), a combustion structure associated with animal bones, and pottery fragments is found. For the mineral composition of U2, quartz and mica predominate. The clay mineral composition (AAA-B, Fig. 6) is different from that of the unit below. The relative abundance of illite increases (I: 60–70 %), smectite decreases (Sm: 10–11 %) and chlorite–kaolinite remains the same (Ch/K, 20–25 %). Phytoliths continue to predominate ~55–50 %, followed by diatoms with a relative abundance of 47–42 % (Figs. 8 and 9). The diatom valves are corroded and broken, with the benthic species again predominate (Table 1 and Fig. 7). Compared to the underlying deposits of U1, a slight

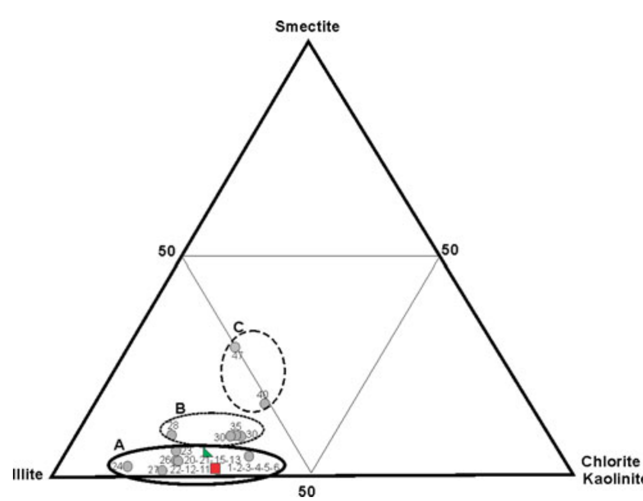


Fig. 6 Ternary diagram for clay minerals association, at LTC1 (gray circle), LTC2 (red square), LTC3 (green triangle), and the different defined areas

Table 2 Identified diatoms

ID Fig. 7	Genus	Domain	Salinity	Presence				
				U1	U2	LIII	LII	LI
a	*Aulacoseira granulata* (Ehrenberg) Simonsen	P	FW	F	F	D	D	D
b	*Aulacoseira itálica* (Ehrenberg) Simonsen	P	FW	F	–	A	A	F
c	*Aulacoseria patagónica* (O. Müller) Simonsen (taken from Frenguelli 1942)	P	FW	R	F	F	F	F
d	*Cyclotella meneghiniana* Kützing	P	FW	F	–	F	F	–
e	*Gomphonema augur* Ehrenberg	B	FW	F	–	–	–	–
f	*Gomphonema anglicum* Ehrenberg	B	FW	–	R	R	R	R
g	*Ephitemia adnanta* Kützing (Brévison)	B	FW/B	F	F	–	–	A
h	*Tabularia tabulata* Agardh	B	B	A	–	–	–	F
i	*Synedra ulna* (Nitzsch) Lange-Bertalot	B	B	D	–	F	R	–
j	*Flagilaria goulardi* (Brévison) Lange-Bertalot	P	B	–	R	R	R	–
k	*Craticula pampeana* Frenguelli	B	FW	–	R	–	–	–
l	*Pinularia latevittata* Cleve	B	FW	–	F	–	–	–
m	*Eunotia monodon*	B	FW	–	–	F	R	–
n	*Eunotia didyma* Grunow	B	FW	R	R	–	–	R

Domain: *P* planktonic, *B* benthic; salinity: *FW* freshwater, *B* brackish, *FW/B* freshwater–brakish; presence: *A* abundant (40–30 %), *D* dominant (50–40 %), *F* frequent (30–10 %), *R* rare (>10 %)

increase was recorded for chrysophycean cysts and a marked fall in spicules (Fig. 8). In the identification of phytoliths, morphotypes of a wild species of cultural interest were recognized. Those that stand out are globular echinate phytoliths produced in palms (*Arecaceae*), short grass cells produced in canes (*Poaceae/Bambusoideae*), tabular papillate phytoliths produced in several sedges (*Cyperaceae*), and a set of less diagnostic forms (jigsaw plates, speralated tracheids, globular smooth, etc.) generated in woody vegetation were identified.

Unit 3 (U3) This unit develops from about 2 m (level 26) to the top of the mound, and it is covered by vegetation. In general, this unit is dark greyish brown (2.5 YR 4/2) with a slightly gravelly sandy mud texture. It has three different layers (LIII, LII, and LI) that have been characterized texturally, mineralogically, and according to the archaeological record reported by Politis et al. (2011, see Table 3).

Layer III (LIII) begins at ~2.00 m achieving a thickness close to 1 m (top of layer III=1.10 m, level 9). The material record is made up of thousands of pottery fragments that include "trimmed" silhouettes and "solid sculpted" appendages. Among the most remarkable finds, there is a whole vessel divided into three hemispherical compartments and three almost complete pieces of the so-called *campanas* (a distinctive pottery artifact with modeled bird heads). Faunal remains indicate the recurrent presence of *Myocastor coypus*, *Hydrochaeris hydrochaeris*, *Lontra longicaudis*, *Canidae*, and micro rodents. Part of this archaeofaunal record shows clear evidence of human processing such as cut marks and burnt surfaces on bones. Valves and fragments of fresh water mollusks (*Diplodon* sp.) and an abundant quantity of whole and fragmented river fish skeletons (*Hoplias malabaricus*, *Leporinus obtusidens*, and *Cichlasoma facetum*) were also recovered. The alternating presence of discontinuous lenses, each of them 1 to about 10 cm thick, of organic matter, charcoal, and burnt sediments has previously been pointed out by Politis et al. (2011) (Fig. 9a) as the most notable characteristic of layer III.

LIII showed notorious compositional differences from U1 and U2. The presence of smectite (Sm, 0–8 %) decreases until it almost disappears and is characterized by AAA-A deposits (Fig. 6). In all layers, phytoliths predominate over diatoms, chrysophycean cysts, and sponge spicules (Fig. 8). In addition to the phytoliths recognized in the previous units is the presence of morphotypes from wild and managed plants. Among managed/cultivated plants, *Cucurbitaceae* and *Cannanaceae* families were identified, as well as morphotypes strongly similar to *Zea mays* (Politis et al. 2011; Sánchez 2011; Sánchez et al. 2011). The statistical analyses enabled the identification of three BAZs. The base of these layers (levels 21–26) presented a lower content of phytoliths in relation to the middle part and a higher presence of planktonic diatoms (Table 2), characterizing BAZ 1 (Fig. 9). In the middle part of these layers (about 1.70–1.40 m, levels 20–14), a maximum peak for the relative abundance of phytoliths was recorded, reaching 80 % of the total silicobiogenics and a marked drop in diatoms, characterizing BAZ 2 (Fig. 9). Towards the top, levels 9–13 (BAZ 3), diatom valves and chrysophycean cysts rise, while phytolith presence decreases (50 %).

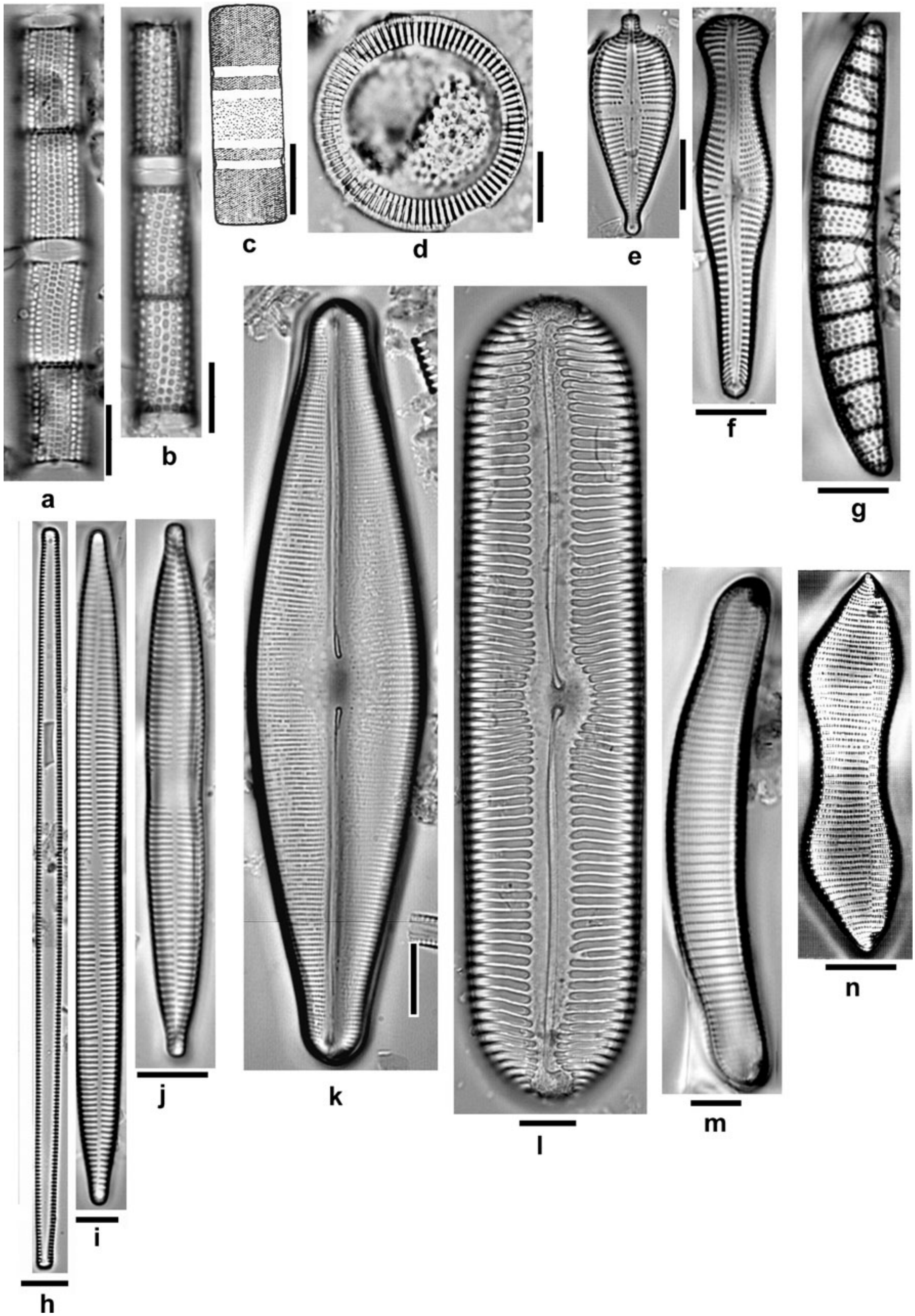


Fig. 7 Identified diatoms. References to the figures in Table 2

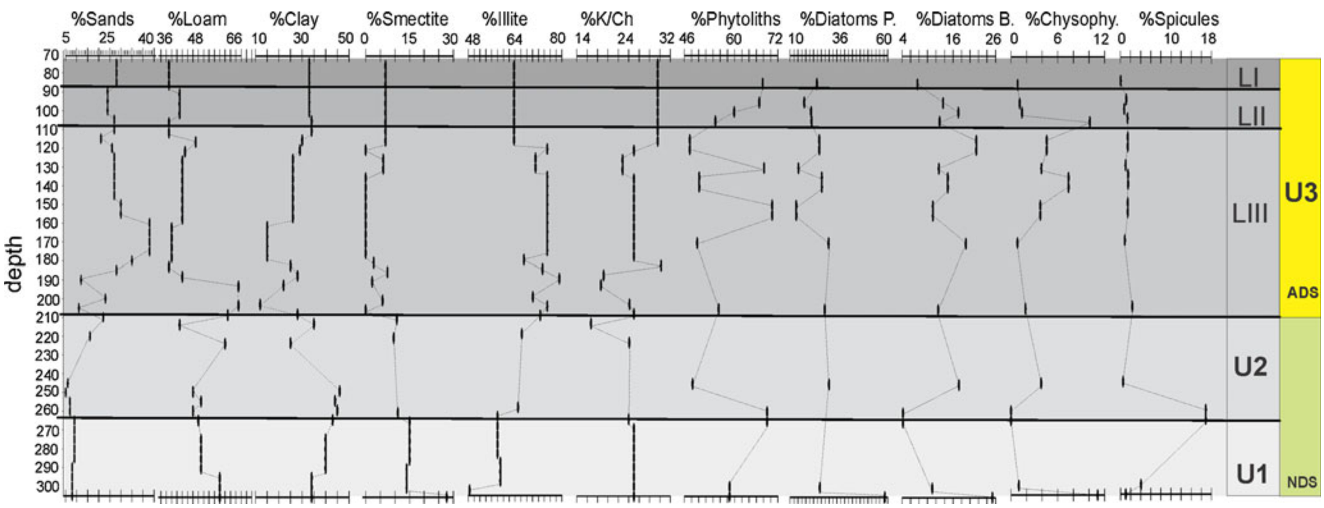


Fig. 8 Results of textural, mineral, and biosiliceous analyses for LTC1. *K/Ch* kaolinite-chlorite; for references for diatoms, see Table 2

Six ^{14}C dates were obtained for LIII (Table 1). One of these, firstly reported here, comes from level 23 and dates the base of this layer at about 1,030±50 ^{14}C years BP. The remaining samples set the chronology of the middle section of the mound between about 860±40 years BP and 660±70 years BP, while sample LP 2281 (580±70 years BP) corresponds to charcoals recovered from the interior of a krotovina (see Fig. 5b) as a result of postdepositational events intervening in the preservation of the record to be shown.

Layers II and I (LII and LI) are located in the middle and upper part of the stratigraphic column of LTC1 (from about 1.09 to 0.80 m, level 8–level 1), and they contain sediments with a high content of organic matter and irregular fragments of burnt soil. Neither layer differs substantially from LIII, as regards color, grain size, and mineralogical composition (Table 3), the deposits corresponding to AAA-A (Fig. 6). Along the profile, root, earthworm, rodent, and other bioturbation features were identified. The cultural material and faunal record is fairly similar to that recovered from layer III, yet the variability of artifacts increases, with lithic artifacts or bone tools, especially projectile points being found (see Politis et al. 2011). In the same way, the presence of whole and fragmented *Diplodon* sp. valves is frequent. According to the biosiliceous association, the bulk of this layer shows affinity with the top of LIII (BAZ 3), with a slight decrease in opal phytoliths content. Diatom valves correspond to the species identified in LIII, with a decrease in benthic and an increase in planktonic species (Table 2 and Fig. 9), often found articulated.

At 15 cm below the present surface on the top section of LII (levels 4 and 5, depth of 85–90), pottery was recovered. It was associated to nodules of unfired clay and with signs of kneading (Politis et al. 2011) and to a combustion structure (grid-square 1, level 6, depth of 95–100). Two ^{14}C dates were obtained for these superficial deposits at LTC1: 560±80 and 650±70 years ^{14}C BP (see Table 1).

Due to its proximity to the present surface, LI shows greater compaction, perturbation, and erosion from the presence of roots, trampling by livestock, and exceptional levels of flooding. As for the content of biosiliceous particles, the phytoliths and chrysophycean increased, with planktonic and benthic diatoms fluctuating in predominance (Fig. 8). This variation can be correlated with its greater exposure to erosion over approximately the last 500 years, according to the chronology obtained for the top section of LII (Table 1).

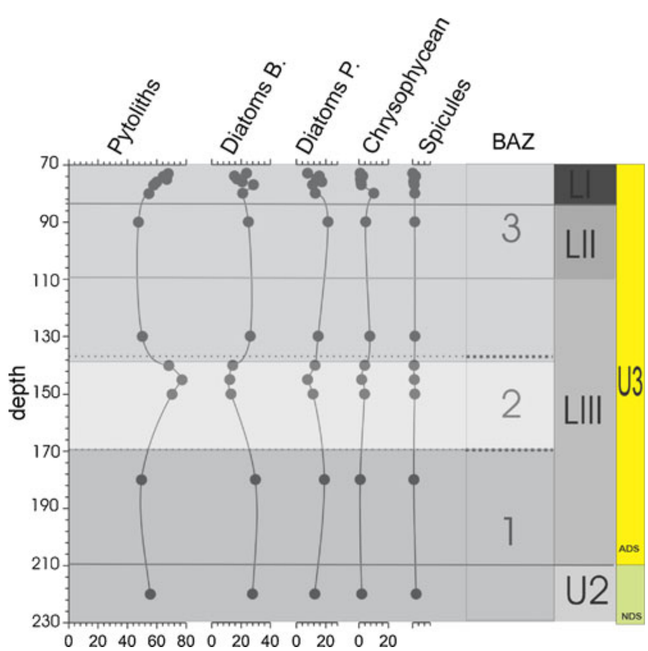


Fig. 9 Areas of biosiliceous association

Table 3 General attributes of LTC1 layers, *sensu* Politis et al. (2011)

Layer	Grain size (Folk´s classification)	Color	Thickness	Observations
I	Slightly gravelly Sandy mud	2,5 YR 3/2 Very dark grayish brown	15 cm	Roots, plants–highly organic matter. Compacted by trampling. Archeological remains
II	Slightly gravelly Sandy mud	2,5 YR 4/2 Dark grayish brown	20–40 cm	Loose. Lenticular burning sediments and crotovines. Bioturbation features. *Diplodón* valves. Abundant archeological remains. Mottled hematite
III	General attributes		1 m	Alternation of high organic, charcoal and burnt sediments in very thin to thin tabular beds 2–10 cm thick each (a–c) and discontinuous. Archeological remains
				Lenticular bed of hematite
	III-a Slightly gravelly Sandy mud	2,5 YR 4/2 Dark grayish brown	Very thin tabular beds	High organic content. Fine charcoal particles
	III-b Slightly gravelly Sandy mud	5 YR 3/4 Dark reddish brown	Very thin tabular beds	Psephitic clasts or fragments of burnt clays and muds, some with valve fragments in their mass. Fe nodules. Charcoal fragments. Fishbone and fish scales. Valves fragments
	Gravelly muddy Sand	5 YR 6/8		Ceramic fragments.
		Yellowish- brown		Sand clast or fragments of burnt clays and muds. Fish scales. Ceramic fragments
	III-c Slightly gravelly Sandy mud	2,5 YR 3/2 Very dark grayish brown	Very thin tabular beds	Carbonate veins. Fine charcoal particles

References: IIIa: beds with high organic content, IIIb- beds of burnt sediments IIIc- beds of burnt sediments with charcoal.

Some preliminary results for LTC2 and LTC3 were also obtained. The texture of samples from both sites was a slightly gravelly, sandy mud with 2.5YR3/2 and 2.5YR4/2 color, just like that of the deposits at LTC1-U3. The type A clay mineral associated is also representative of the sedimentary deposits at structures LTC 2 and LTC 3 (Fig. 6). Radiocarbon chronologies exist for both structures (Table 1), which would primarily indicate that the three sites (LTC1, LTC2, and LTC3) were contemporaneously occupied at some moments during, at least, the four centuries prior to the Spanish arrival.

Microstratigraphy analysis of layer III at LTC1

The alternating presence of discontinuous lenses, organic matter, charcoal, and burnt sediments was clearly recognizable in the middle portion of LIII (1.70–1.40 m, levels 20–14) as well as being sporadically represented in LII (Figs. 5b, c and 10a). The burnt sediment lenses have a thickness of about 4 and 5 cm and are light reddish brown (10YR4/5) in color. Horizontally they are approximately 1.5 m with gradual lateral passages being observed within the sedimentary matrix that characterizes LIII and LII. In some cases, their lateral boundaries are abrupt due to biostratinomic fractures, making it difficult to discern. In general, towards the base and towards the top of these lenses, burnt sediment lenses, concentrations of fine particles of charcoal were identified, which consisted of lenses of less than about 1–2 cm. These smaller lenses are observed within a matrix with a high organic content of a dark brown color (7.5YR4/2). The stratigraphic position and its alternate presence allow us to distinguish the burnt sediment lenses from the morphologically circular combustion structures interpreted as hearths, such as those identified in grid-squares 4, 8, 10, and 15 (see Fig. 5b and c).

In the microstratigraphic analysis of one of these sequences present in grid-square 3 at 1.50 m depth, five microfacies were identified (Fig. 10b):

– Microfacies type 1 (Mt1): massive, made up of phytoliths, diatoms, and few voids. This microfacies is located in the upper portion of thin sections 6–7. It is reddish brown (5YR4/3) and 1.4 cm thick. It shows a compact, subangular microstructure (*sensu* Bullock et al. 1985). Biogenic silica predominate (~60 %) and the articulated phytoliths in epidermic tissues are those with the highest representation which are followed by the presence of articulated diatoms (Fig. 11a–c). Both records show signs of corrosion. It also contains 10 % of carbonaceous material with an average size of 0.086 mm and 5 % of bone fragments

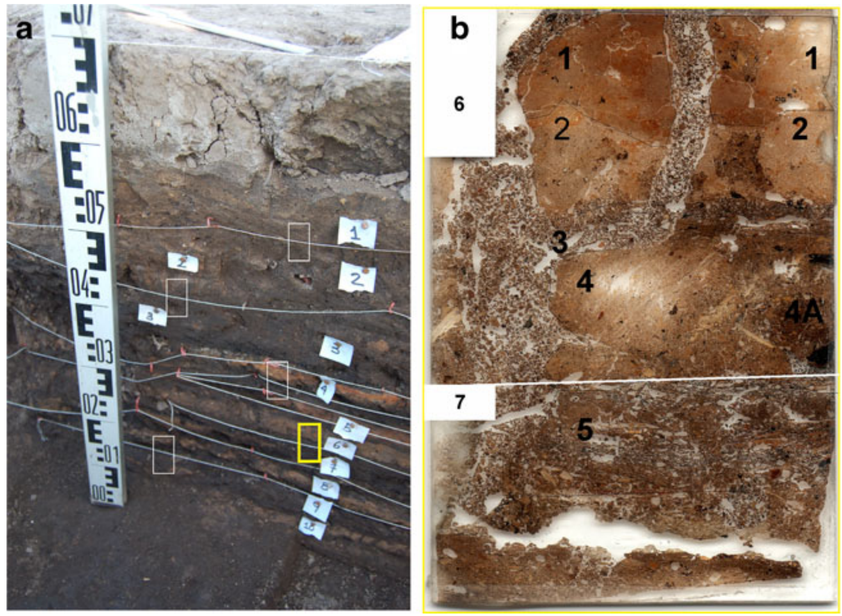


Fig. 10 **a** Micromorphological sampling in south wall of grid square 3. **b** Microfacies identification of thin section (5×7.5 cm)

with an average size of 0.074 mm. Silicoclastic material (10 %) was basically made up of mineral clasts and pellitic lithoclasts, which were coarse to very coarse silt. In Mt1, the presence of ferruginous nodules and clay coating is observed.

– Microfacies type 2 (Mt2): Massive and made up of diatoms. It is below the previous microfacies, reddish (2.5YR5/6), and has a thickness of about 1 cm. Its contact with Mt1 is gradual. The microstructure and biosiliceous content is similar to Mt1 (Fig. 11d–f). However, in this microfacies, diatoms predominate, followed by the presence of phytoliths, and to a lesser extent, sponge spicules. The representation of elongated carbonaceous particles is higher (~15 %) also the void between components and the size of silicoclastic material (0.050 mm). The existence of bone fragments is low (between 1 and 2 %) with an average size of 0.068 mm. Among the microarchaeological components at Mt2, 2–5 mm pottery microfragments were identified.
– Microfacies type 3 (Mt3): microcrotovine. This microfacies stands out from the upper part in thin-section, cutting microfacies Mt1 and Mt2 vertically and horizontally and those that are formed below (see Fig. 10). It is reddish-brown in color (5YR4/4), and corroded diatom valves predominate. The disposition and size of the components show a microstructure of the complex type (*sensu* Bullock et al. 1985), with increasing voids between organic (plant tissue, carbonaceous particles, and bone fragments) and silicoclastic elements (Fig. 11g). Bone fragments in this microfacies reach 20 % with a mean size of 0.090 mm (Fig. 11h). The presence of "ellipsoid" type excrement according to Bullock et al. (1985, p. 134) was also recorded (see Fig. 11i).
– Microfacies type 4 (Mt4): massive, with charcoal particles and prismatic in structure. It is formed below Mt2 in a discordant manner and laterally to Mt3. The sediment that characterizes it is yellowish red (5YR5/6) with an approximate thickness of 1.5–1.8 cm (Fig. 11j). Charcoal particles are abundant (mean size, 0.031 mm; Fig. 11k, l) and are integrated into a matrix where 40 % of the identified material consists of burnt plant tissue with a mean size of 0.150 mm, jigsaw plates (0.050 mm), and 25 % silicoclastic components. The silicobiogenic element is less than in Mt1 and Mt2. Laterally, there is a darker area (7.5YR3/2 brown), with the presence of burnt components (Mt4-A see Fig. 10) that might allow direct exposure to fire. However, in this sector, the presence of organic remains disposed vertically and horizontally, in each case, aligned in parallel (e.g., plant fiber, bone splinters, biogenic carbonate fragments) was also observed (Fig. 11m–o). These organic remains have a mean size of 1 mm and does not show signs of heat-induced alteration or pottery fragments as those of Mt2.
– Microfacies type 5 (Mt5): laminated thermoaltered - charred organic material (Fig. 11p–r). The matrix is a very dark grayish-brown (10YR3/2). It runs below and (in part) above Mt4, making abrupt contact with the latter. It measures some 5 mm in thin section. The microstructure of this facies is of the complex crack-structure type (*sensu* Bullock et al. 1985), an aspect that would allow confirmation of thermoalteration and presumed bioturbation. A parallel grouping of organic components is also found with sizes similar to those of Mt4. Nevertheless, the rise in articulated diatom valves is considerable in a matrix in which silicoclastic

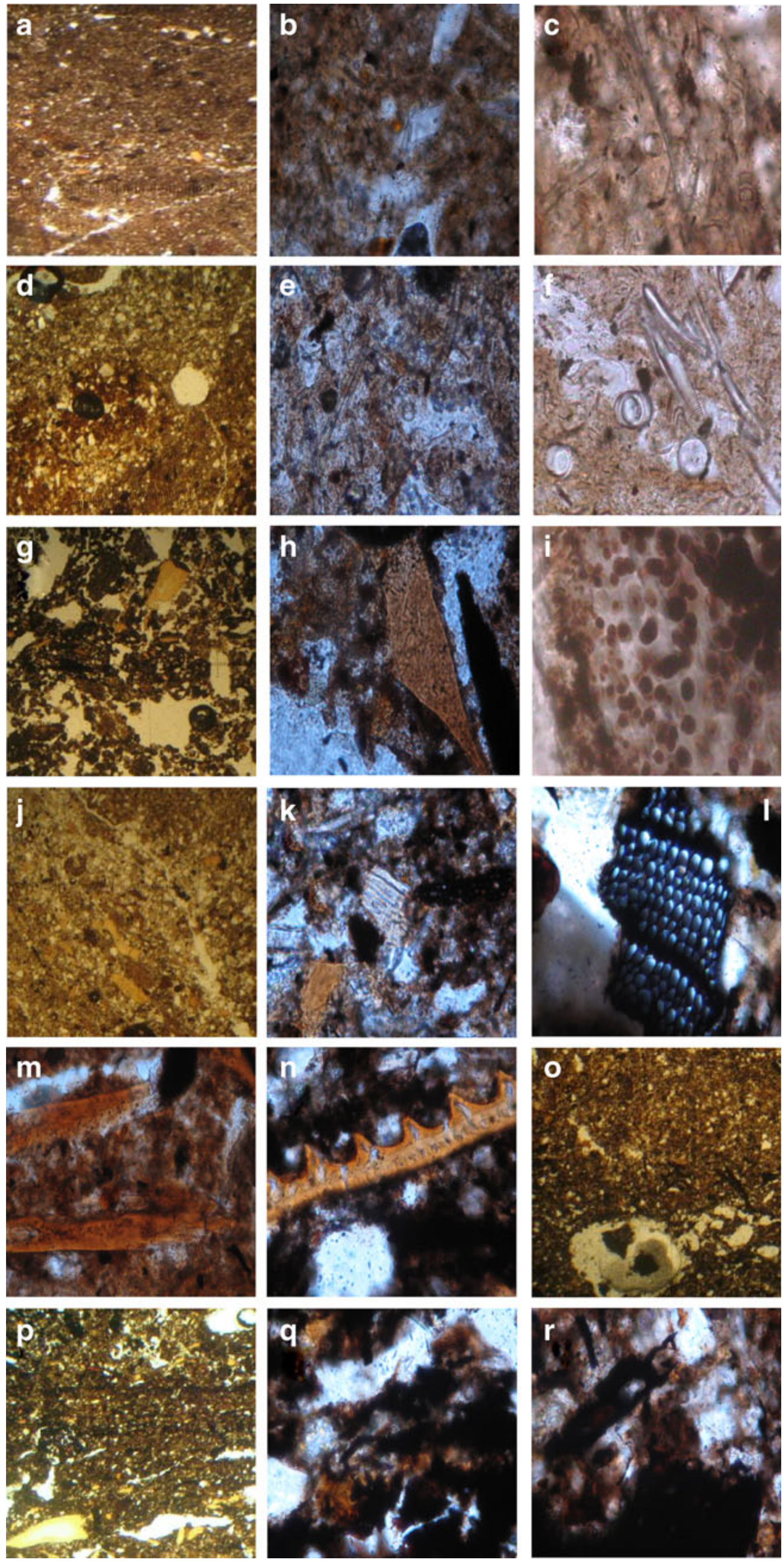


Fig. 11 **a** Compact matrix of Mt1, clastic components average-sized 60 μm. **b**, **c** Massive presence of phytoliths and diatoms (biological microscope ×40). **d** compact matrix of Mt2, clastic components average-sized 50 μm. **e**, **f** Massive presence of diatoms (biological microscope ×40). **g** Weak presence of clastic components (average-sized 50 μm) in Mt3. **h** Bone fragments and carbonaceous particles, average-sized ~109 μm in Mt3. **i** Excrement in Mt3 biological microscope ×40. **j** Mt4 clastic matrix, parallel arrangement of components (average-sized 60 μm). **k** Massive presence of carbonaceous particles (Mt4). **l** Perforated opaque plates in Mt4 (biological microscope ×40). **m**, **n** Fiber plant in Mt4A. **o** Parallel arrangement of carbonaceous particles in Mt4A. **p** parallel lamination charcoal particles in Mt5. **q**, **r** Fiber plant and charcoal particles in Mt5.

material, with average sizes of 0.053 mm, make up only 10 % of the composition.

According to what has been observed, we might propose that microfacies 1–4 characterize the compact, thermoaltered lenses surveyed for layers III and II. Microfacies 5 is characterized by the concentration of carbonaceous material present only in the alternating lenses sequences of layer III. This (Mt5) record is interpreted as evidence of *in situ* incineration of combustible plant material. Likewise, Mt3 is presented as a clear example of postdepositional bioturbation generated by small invertebrates.

Characteristics of deposits in the floodplain at the archaeological locality

Paraná River flooding produces an alluvial accumulation on the surface of the area. According to the test pits dug in the proximal and distal plain surrounding the mound structures (see Politis et al. 2011 Fig. 4, and Table 4 in this paper), these alluvial deposits are of sandy mud, sandy silt, and mud texture, with argilomineral compositions similar to the unit 1 and 2 deposits at site LTC1 (AAA-B and AAA-C).

The textural and mineralogical results from the deposits in the plain reported in Politis et al. (2011) coincide with those obtained in the majority of samples from the more distal and deeper borings carried out at the transects (Table 4, Fig. 12). Still, at auger hole P5 located at 32°51′36.43″–60°31′12.00″ W, 2 km away from the mound structures, a type AAA-A was obtained for surface and subsurface sediments. At present, at this part of the landscape, a shallow-pond laterally linked to the floodplain with the formation of marshes at its edges is observed. In turn, it was possible to record the existence of present-day communities of *Diplodon* sp., a permanent record at the mound structures, and absent from lentic environments associated with these. These results allow us to discuss the possible borrow areas of the sedimentary material used to build the mound structures at the Los Tres Cerros locality.

Discussion

Genesis of mound structures

Regional archaeological literature reports nearby localities—surface and sub-surface sediments—as sources of building material for mounds (e.g., Bracco et al. 2000a,b; Bonomo et al. 2011b; Torres 1911). It is noteworthy that the selection of sediments, gravel, and rocks from relatively distant areas and deriving from specific environments (when local sources are not available) was also reported (e.g., Ameghino 1880; Castiñeira and Piñeiro 2000; Greslebín 1931; López and Castiñeira 2001; Torres 1911; Zeballos 1878; Zeballo and Pico

Table 4 Mineralogical results for the alluvial deposits of the floodplain

ID	Latitude/longitude	Thickness	% Smecite, % illite, % chlorite–kaolinite	AAA	References
Tp4	32°51′16.8″ 60°33′36.2″	0.50 m	16–58–26	B	Politis et al. 2011
		0.75 m	15–60–25	B	
		0.90 m	28–48–24	C	
Tp7	32°51′15.5″ 60°33′33.7″	0.70 m	34–38–28	C	Politis et al. 2011
Tp8	32°51′7.8″	0.20 m	23–43–34	C	Politis et al. 2011
		0.50 m	34–32–34	C	
P1	32°51′15.1″ 60°33′38″	3 m	30–50–20	C	In this paper
P2	32°51′14.6″ 60°33′41.1″	0.85 m	34–40–26	C	In this paper
		2.15 m	17–35–48	B	
		3.05 m	44–42–14	C	
P3	32°50′44″ 60°34′0.2″	2.35 m	33–50–17	C	In this paper
P4	32°54′38.9″ 60°33′57.4″	2.35 m	30–41–29	C	In this paper
P5	32°52′15.5″ 60°33′19.5″	0.85 m	7–71–22	A	In this paper
PD20	32º48′12.48″ 60º29′45.13″	2 - 3 m	25–55–20	C	Amato and Silva 2009

The values obtained for P5 coincide with those of U3- LTC1, and LTC2 and LTC3 deposits

Tp test pits, *P* auger hole, *PD* auger hole by Amato and Silva 2009

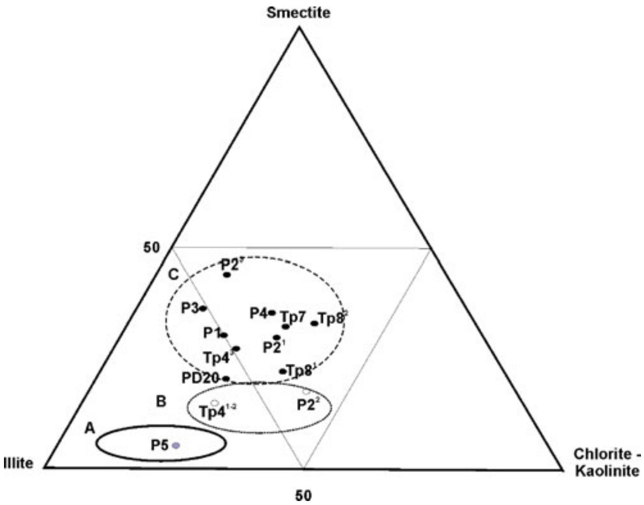


Fig. 12 Ternary diagram with areas of argilomineral association for the alluvial deposits of the floodplain

1878). Both selective behaviors in regional pre-Hispanic construction engineering are mainly linked to the immediate local or regional availability of structuring materials to consolidate, elevate, and preserve mounds. In this sense, it was recently proposed that the argilomineral association (AAA-A) of constitutive layers in the Tres Cerros mound structures, which are clearly different from adjacent deposits in the plain, led to a confirmation of the anthropogenic origin of the mounds (Politis et al. 2011).

For the Los Tres Cerros locality, the alluvial sediments deposited by the Paraná flooding pattern, are texturally characterized as muds with argilomineral associations containing ~40–60 % illite, 10–30 % smecite, and 45–25 % chlorite–kaolinite (e.g., Cavallotto 1995; Depetris and Grifin 1968; Amato and Silva 2009). These values can be correlated with the argilomineral associations found in the basal units 1 and 2 of mound structure LTC1 and also surface and subsurface deposits in the nearby plain. However, they differ from the values recorded for the constituent sediments in LTC1 layers I, II, and III, for the samples obtained from the test pits carried out at structures LTC2 and LTC3, and from the samples taken from bore hole (P5) at the N–S transect.

By obtaining a continuous record for LTC1 for the variations in argilomineral association, we were able to recognize the interface between the underlying natural and anthropogenic deposits that characterize the mound elevation. This interface (in the sense given by López and Gianotti 1997 for Cotinga Mound), is found in the LTC1 stratigraphic sequence at level 27 at 2.05 m depth (Fig. 5b, c), where smectite disappeared (see Fig. 8). At the depth mentioned, there is an abrupt passage from an argilomineral association characteristic of alluvial sediments, to one different from the surface or subsurface deposits in the nearby plain. Thus, from the set of results obtained from the stratigraphic, sedimentological, and biological analyses, we confirm the existence of two depositional systems, according to their origin: a natural depositional system (NDS) and an anthropogenic depositional system (ADS). The NDS is represented by the surface and subsurface deposits of the alluvial plain and by units 1 and 2 excavated at LTC1. ADS is made up of unit 3 (layers III, II, and I) of LTC1 and the upper deposits of LTC2 and LTC3. The significant differences in the constituent ADS deposits compared with the NDS deposits suggest that the sediments characterizing the mounds at the Tres Cerros locality were selected and modified for it construction or anthropic in origin.

According to the results obtained in the argilomineral association of the P5 sediments (E–W transect), one of the possible source areas for mound construction material could be located approximately 2 km east of LTC1. This in turn agrees with the similarities found in the P5 sediment with those of ADS with regards to the diatom content and that attributable to panicoid and oryzoid grass, cyperaceae, and reeds. The state of preservation and association of the biosiliceous content of the LTC1 sedimentary matrix would indicate that the constituent sediments were extracted and transported from lentic environments linked to the development of littoral hydrophilic vegetation. This humid, shallow, and low energy environment would have made the availability and easy extraction of the mud possible. However, it is possible to consider other source areas of mud with or with a low portion of Sm (<10 %), at distances superior to the one recognized in P5. Geological studies of the Pampeano Formation deposits recorded in the Lower Paraná River and affluents, between 10 and 50 km from the archeological locality of Los Tres Cerros, present an argilomineral association similar to that found in P5 and in the mounds (Gonzáles Bonorino 1966; Manassero et al. 2008; Orgeira et al. 2009). The transportation of "pampeano" sediments from the ravines of rivers and streams to build and raise the mounds of the Middle and Lower Paraná was suggested by Ameghino (1880) and by Zeballos (1878). In the locality of Los Tres Cerros, site P5, corresponding to the shortest distance from the location of the source area has little or no presence of Sm. It is possible that the transportation of sediments utilized for the construction of mounds could have been performed with the help of canoes. The use of canoes by aboriginals in the deltaic area of the Paraná is widely recorded (Brunazzo and Rivera 1997; Ceruti and Gonzáles 2007; Greslebin 1931; Lothrop 1932; Márquez Miranda 1932).

With regard to the modification of the constituent sedimentary material from the mounds in question, the textural differences between the ADS and NDS allow the consideration that gravel and sand-sized materials, such as potsherd fragments and lumps of burnt soil, were added to the mud selected for the construction, possibly to compensate for the absence of siliciclastic materials of these sizes in the alluvial landscape of the locality under study. In the case of Los Tres Cerros, the distal supply of building material can, among other factors, be linked to the knowledge of the optimal properties of mud for the making of pottery (choice of AAA-A type mud, with low smectite content). At the same time, the generation and addition of gravel- and sand-sized materials can be framed within the need to favor resistance to erosive factors, an aspect also mentioned in the regional "cerrito" archaeology (e.g., Bracco et al. 2000a,b; Castiñeira and Piñeiro 2000; López and Castiñeira 2001; Salles Machado 2005; Suárez Villagrán 2006)

The evolution of LTC1

The sedimentary and microbiological characteristics (biosiliceous record) allow units 1 and 2 to be assigned to low energy alluvial floodplain deposits. According to geomorphological evolution, these alluvial deposits overly those of the predeltaic tidal flat. Using the evolution of morphological environments proposed by Cavallotto et al. (2005) as a reference, units 1 and 2 would be penecontemporary with the alluvial deposition overlying the fine deposits of the pre-deltaic tidal flat. For these authors, the underlying fine size deposits would be of a minimum age estimated at about 2,550–2,750 ^{14}C years BP according to the chronology obtained by Caggiano (1984). Material associated with a combustion structure at LTC1, in the basal deposits of U2 (at a depth of 2.50 m), would allow us to infer that the earliest record of human occupation of the site could be later than pre-deltaic tidal flat deposits and older than the ^{14}C age obtained for level 23 of around 1,030±50 years BP (see Table 1). In turn, this last date would chronologically mark the beginning of the ADS characterizing mound structure LTC1.

After 560±80 years ^{14}C, BP the accretional anthropogenic process of Los Tres Cerros locality is not present. Perhaps, the erosional processes acting on the surface deposits, erased the anthropic evidence. However, the absence of any unconformity in the top of the sequence dismisses this possibility. On the other hand, the chronological data of the top of the sequence coincide with the aboriginal depopulation of the delta as a consequence of European conquest. The last radiocarbon records for aboriginal occupations in the Upper delta are about 400 years BP (Bonomo et al. 2011c).

The differential trends in biosiliceous content, pottery, and archaeofaunal material, as well as the presence of discontinuous lenses of organic matter, charcoal, and burnt sediments at LTC1, can be correlated with changes in the intensity of occupation at the site, in which multiple activities were carried out. Among these, the microstratigraphic ordering of thin sections 6–7 suggests the development of burning activities, a similar record as that observed by Goldberg et al. (2009) at the Sibudu Cave of KwaZulu-Natal, South Africa.

The association of organic components (e.g., phytoliths, diatoms, plant fibers, carbonaceous particles) identified in microfacies Mt 1, 2, 4, and 5 would point to the supply of plant material collected in sectors of LTC1 and incinerated—in some cases—*in situ*. This combustible material might possibly come from the same places selected for the extraction of the constituent mud of mounds. The microbotanical record and the significant presence of articulated diatoms, as was observed for Mt2, would back up this inference. Instead, the alternating sequences of burned lenses and their correlated record would attesting that after the grass burning development, the accretional events continued, suggesting a slow mound construction rate. The constituent record of Mt1 and the association of different size components in a compact matrix—possibly due to trampling—would make the case for this set of evidences to propose an occupational surface, which also correspond with the presence of hearths, pottery material in a stage of semicompletion (the restricted horizontal dispersion of shreds from a single piece) among other pieces of evidence (in this regard, see Politis et al. 2011).

The remaining microfacial units observed (Mt 2, 4, and 5) would correspond to the *in situ* development of grass and wood burning, but the lateral discontinuity would suggest that the development of these activities took place in restricted and well differentiated spaces. These records also contain carbonaceous particles, bone microfragments and shred microfragments, which may also be due to removal by sweeping, bioturbation and combustion in fire places. As with the studies of Goldberg et al. (2009), there exist significant results for the interpretation of alternating sequences of combustion events, with a continuous lateral development in some sectors. In the aforementioned paper, the authors argued that the stocking up of plant material could be related to the preparation of surfaces that might have been used for different purposes such as sleeping or sitting on, etc., while the incineration of the same would be related to the hygienic maintenance of the camp site. Even though preliminary micromorphological results achieved in this research allow us to correlate the sequence of lenses significantly present in layer III, with the evidence proposed by Goldberg et al. (2009), it is possible to infer the conditioning and maintenance of the living areas. The functional allocation of these events must also consider their correlation with other kinds of activities. For this reason, it is not possible yet to discriminate whether such events of collecting and burning plant material (mostly grasses) respond to matters related to the habitability of the structure and/or to the carrying out of other activities such as burning grass between the series of occupation events which took place, discontinuously for about 500 years.

Conclusion

In Politis et al. (2011), the anthropic character of the genesis and development of the Tres Cerros mound structures was proposed on the basis of textural and mineral compositional differences found with those of the alluvial plain deposits. In this article, we confirm these differences by means of the microfossil record and more detailed micromorphology and sedimentological analyses. By comparing qualitative observation of the biosiliceous content, appreciable differences were found in the phytolithic associations present in samples from the mound structure and those from outer areas. In the samples from outside the structure, a minor variety of morphotypes was observed, with a predominance of those attributable to panicoid and oryzoid grasses, cyperaceae, and reeds; whereas in the LTC1 sediments, the presence of morphotypes that can be assigned to wild and managed/cultivated plants was recorded, which were recognized as valuable resources for the pre-Hispanic populations that inhabited the Paraná Delta (Bonomo et al. 2011a,c; Sanchez et al. 2011). A clear example of wild species use as fuel resources is found in the identified microfacial units.

The integration of sedimentological and microbiological data studied for the whole sedimentary sequence of the structure LTC1 allowed the discrimination between anthropogenic accretional events and pre- and intramound occupational palaeosurfaces. Mound LTC1 stands on alluvial floodplain deposits in a sequence made up of diverse building phases. The different building phases are characterized, on the one hand, by the development of activities possibly related to habitability of the place and, on the other hand, by the deposition of specifically selected and modified mud. This building modality, widely recognized in regional pre-Hispanic archaeology, implies a complex knowledge about the spatiality and quality of available natural sources. The cohesive property of mud is favored by the presence of coarse size particles (burnt lumps and pottery fragments) and organic materials that enhance their resistance. When sediments and/or structuring materials were not immediately available, provision was carried out in proximal or distal areas, and was complemented with the production of elements that lend structural cohesion and solidity (see Bracco et al. 2000a,b; Castiñeira and Piñeiro 2000). In this sense, the labor investment in building engineering is closely related with the solidity and permanence of the structures, underlying the planned character of the "cerritos."

Acknowledgments This is a contribution to the grants, PICT 1203 (Agencia Nacional de Promoción Científica y Tecnológica) to Carola Castiñeira, and PIP-CONICET 1282, ANPCYT 0343, and grant 8149 from the Wenner Gren Foundation for Anthropological Research to Gustavo Politis and Mariano Bonomo. We would like to thank reviewers and Juan Carlos Fernicola, Hugo Inda, and Gustavo Franco for their contributions, comments, and worthy help in paper translation. We also wish to thank Eduardo Apolinaire for his valuable collaboration during field sampling and to Heidi Luchsinger for her help in the English translation.

References

Amato S, Silva A (2009) Estratigrafía cuaternaria del subsuelo de la cuenca inferior del río Paraná. Rev Asoc Geol Argent 64(4):594–602

Ameghino F (1880) La Antigüedad del Hombre en el Plata. Igon hermanos (eds), First Volumen, Buenos Aires

Aparicio F (1939) El Paraná y sus tributarios. In: Levene R (ed) Historia de la Nación Argentina, I. El Ateneo, Buenos Aires, pp 419–442

Arechavaleta J (1892) Viaje a San Luis. In: Figueira JH (ed) El Uruguay en la Exposición Histórica Americana de Madrid. Dornaleche y Reyes, Montevideo, pp 65–91

Arroyo-Kalin M (2010) The amazonian formative: crop domestication and anthropogenic soils. Diversity 2:473–504

Arroyo-Kalin M, Neves G, Woods W (2008) Anthropogenic Dark Earths of the Central Amazon Region: remarks on their evolution and polygenetic composition. In: Woods W, Teixeira W, Lehmann J, Steiner C, Winkler Prins A, Rebellato L (eds) Amazonian Dark Earths: Wim Sombroek's vision. Kluwer, Dordrecht, pp 33–83

Bauza F (1895) Historia de la Dominación española en el Uruguay. Barreiro y Ramos, Montevideo

Benítez L (1942) Supuestos túmulos de YMBYTYMI. Exploración preliminar y primeros resultados. Revista de la Sociedad Científica del Paraguay, V(6):72-89

Berna F, Goldberg P (2007) Assessing Paleolithic pyrotechnology and associated hominin behavior in Israel. Israel J Earth Sci 56:107–121

Bonetto A, Orfeo O (1984) Caracteres sedimentológicos de la carga en suspensión del río Paraná entre Confluencia y Esquina (Prov. de Corrientes). Revista de la Asociación Argentina de Mineralogía. Petrol Sedimentol 15(3–4):51–61

Bonomo M, Aceituno F, Politis G, Pochettino M (2011a) Pre-Hispanic horticulture in the Paraná Delta (Argentina): archaeological and historical evidence. World Archaeol 43(4):557–579

Bonomo M, Ma C, Passeggi E, Zucol A, Brea M (2011b) Multidisciplinary studies at Cerro Tapera Vázquez site, Pre-Delta National Park, Argentina: The archaeological, sedimentological and paleobotanical evidence. Quat Int 245(1):48–61

Bonomo M, Politis G, Castro J (2010) Primeros resultados de las investigaciones arqueológicas en el delta superior del Paraná y su contribución al atlas arqueológico de la provincia de Entre Ríos. Folia Histórica Nordeste 18:33–58

Bonomo M, Politis G, Gianotti C (2011c) Montículos. Jerarquía social y horticultura en las sociedades indígenas del Delta del Río Paraná (Argentina). Lat Am Antiq 22(3):97–333

Bozarth S (1992) Classification of opal phytoliths formed in selected dicotyledons native to the Great Plains. In: Rapp G, Mulholland S (eds) Phytolith Systematics. Plenum, Nueva York, pp 193–214

Bracco R (1991) Dataciones ^{14}C en sitios con elevación. Rev Antropol 1(1):11–17

Bracco R (1994) Cazadores-recolectores de la Cuenca de la Laguna Merín: aproximaciones teóricas y modelos arqueológicos. In: Lanata J, Borrero L (eds) Arqueología de cazadores recolectores. Límites, casos y aperturas. Arqueología Contemporánea 5, Buenos Aires, pp 51–64

Bracco R, Montaña J, Nadal O, Gancio F (2000a) Técnicas de construcción y estructuras monticulares, termiteros y cerritos: de lo analógico a lo estructural. In: Durán A, Bracco R (eds) Arqueología de las Tierras Bajas. Ministerio de Educación y Cultura, Montevideo, pp 285–300

Bracco R (2006) Montículos en la cuenca de la Laguna Merín: tiempo, espacio y sociedad. Lat Am Antiq 17(4):511–540

Bracco R, del Puerto L, Inda H, Castiñeira C (2005) Middle-late Holocene cultural and environmental dynamics in the east of Uruguay. Quat Int 132:37–45

Bracco R, del Puerto L, Inda H, Panario D, Castiñeira C, García-Rodríguez F (2010a) The relationship between emergence of moundbuilders in SE Uruguay and climate change inferred from opal phytolith records. Quat Int 245(1):62–73

Bracco R, Montaña J, Bossi J, Panarello H, Ures C (2000b) Evolución del humedal y ocupaciones humanas en el sector sur de la cuenca de la Laguna Merín. In: Duran A, Bracco R (eds) Arqueología de las Tierras Bajas. Ministerio de Educación y Cultura, Montevideo, pp 99–116

Bracco R, del Puerto L, Castiñeira C, García-Rodríguez F, Panario D, Inda H (2010b) Cambios ambientales y arqueología en el actual territorio del Uruguay. Cazadores Recolectores Cono Sur 3:15–27

Bracco R, Ures C (2001) Ritmo y dinámica constructiva de las estructuras monticulares. Sector Sur de la Cuenca de la Laguna Merín. In: Fundación Fontaina Minelli and Asociación Uruguaya de Arqueología (ed) Arqueología Uruguaya hacia el fin del milenio. Gráficos del Sur, Montevideo, pp 55–68

Brunazzo G, Rivera S (1997) Rescatando Dos Canoas de las Aguas del Olvido. Un Aporte al Conocimiento de Embarcaciones Indígenas Recuperadas en el Partido de Berisso. Rev Museo Plata 2(9):87–91

Bullock P, Fedoroff N, Jongerius A, Stoops G, Tursina T, Babel U (1985) Handbook for soil thin section description. Waine Research Publications, Wolverhampton

Caggiano M (1984) Prehistoria del noreste Argentino, sus vinculaciones con la República Oriental del Uruguay y sur de Brasil. Pesqui Antropol 38:1–109

Carver R (1971) Procedures in sedimentary petrology. Wiley-Interscience, New York

Castiñeira C, Piñeiro G (2000) Análisis estadístico textural para el estudio de las columnas estratigráficas de las excavaciones I y II del Bañado de los Indios. In: Durán A, Bracco R (eds) Arqueología de las tierras bajas. Ministerio de Educación y Cultura, Montevideo, pp 467–478

Cavallotto J (1995) Evolución Geomorfológica de la llanura costera del margen sur del río de la Plata. Dissertation, Universidad Nacional de la Plata

Cavallotto J, Violante R, Colombo F (2005) Evolución y cambios ambientales de la llanura costera de la cabecera del río de la Plata. Rev Asoc Geol Argent 60:353–367

Cavallotto J, Violante R, Parker G (2004) Sea level fluctuation during the last 8600 yrs in the Río de la Plata (Argentina). Quat Int 114 (1):155–165

Ceruti C (2003) Entidades culturales presentes en la cuenca del Paraná Medio (margen entrerriana). Mundo de Antes 3:111–135

Ceruti C, Gonzáles M (2007) Modos de vida vinculados con ambientes acuáticos del Nordeste y Pampa bonaerense de Argentina. Relac Soc Argent Antropol 32:101–140

Cione A, Rizzo A, Tonni E (1977) Relación cultura indígena-medio ambiente en un sitio de Rincón de Landa, Gualeguaychú, Entre Ríos, República Argentina. Nota preliminar. In: Actas del V Encuentro de Arqueología del Litoral, Fray Bentos, pp 121–141

Codignotto J (2004) Delta. Evolución Geológica. Atlas ambiental de Buenos Aires. http://www.atlasdebuenosaires.gov.ar.

Courty M (2001) Microfacies analysis assisting archaeological stratigraphy. In: Goldberg P, Holliday V, Ferring C (eds) Earth sciences and archaeology. Kluwer Academic/Plenum, New York, pp 205–239

Courty M, Goldberg P, Macphail R (1989) Soils and micromorphology in archaeology. Cambridge University Press, Cambridge

Day P (1965) Particle fractionation and particle-size analysis. In: Black C (ed) Methods of soil analysis, Part 1. American Society of Agronomy Inc., Madison, pp 545–567

del Puerto L, García-Rodríguez F, Inda H, Bracco R, Castiñeira C, Adams J (2006) Paleolimnological evidence of Holocene paleoclimatic changes in Lake Blanca, southern Uruguay. J Paleolimnol 36:151–163

del Puerto L (2009) Paleoclima del Pleistoceno tardío y Holoceno del sudeste del Uruguay. Dissertation, Facultad de Ciencias, Universidad de la República Oriental del Uruguay

Depetris P, Griffin J (1968) Suspended load in the Río de La Plata drainage basin. Sedimentology 11(1/2):53–60

Duff K, Zeeb B, Smol J (1995) Atlas of chrysophycean cysts. Developments hydrobiology 99. Kluwer Academic, Dordecht

Durán A, Bracco R (2000). Prólogo. In:Durán A, Bracco R. (eds) Arqueología de las Tierras Bajas, Ministerio de Educación y Cultura, Montevideo, pp 7–8

Erickson C (2000) Lomas de ocupación en los Llanos de Moxos. In: Durán A, Bracco R (eds) Arqueología de las Tierras Bajas. Ministerio de Educación y Cultura, Montevideo, pp 207–226

Erickson C (2006) The domesticated landscapes of the Bolivian Amazon. In: Balée W, Erickson C (eds) Time and Complexity in Historical Ecology: Studies in the Neotropical Lowlands. Columbia University Press, New York, pp 235–278

Ezcurra de Drago I (1993) Distribución geográfica de las esponjas Argentinas (*Porifera: Spongillidae, Potamolepidae y Metaniidae*). In: Boltovskoy L (ed) Relaciones zoogeográficas y vías de poblamiento. Instituto de Limnología "Dr. Raúl A. Ringuelet", La Plata, pp 115–125

Fredlund G, Tieszen L (1994) Modern phytolith assemblages from the North American Great Plains. J Biogeogr 21:321–335

Fernández M, Zucol A, Osterrieth M (2006) Phytolith assemblages and systematic associations in grassland species of the south-Eastern Pampean Plains, Argentina. Ann Bot 98:1155–1165

Ferrés C (1927) Los terremotos de indios. Rev Soc Amigos Arqueol 1:139–151

Folk R (1954) The distinction between grain size and mineral composition in sedimentary rock nomenclature. J Geol 62(4):344–359

Figueira J (1892) Los primitivos habitantes del Uruguay. Uruguay en la Exposición Histórico. Americana de Madrid, Montevideo, pp 161–166

Frenguelli J (1941) Diatomeas del Río de la Plata. Rev Museo Plata 3:213–334

Frenguelli J (1945) Las diatomeas del Platense. Revista del Museo de La Plata, III, pp 77–221

Frenguelli J, de Aparicio F (1923) Los paraderos de la margen derecha del río Malabrigo (Departamento de Reconquista, Prov. de Santa Fe). In: Universidad Nacional del Litoral (ed.), Anales de la Facultad de Ciencias de la Educación, Paraná, pp 7–112

Gallego L, Distel R (2004) Pytolith assemblages in grasses native to central Argentina. Ann Bot 94:1–10

García-Rodríguez F (2006) Inferring paleosalinity changes using the chrysophyte cyst to diatom ratio in coastal shallow temperate/subtropical lagoons influenced by sea level changes. J Paleolimnol 36:165–173

Gaspary F (1950) Investigaciones Arqueológicas y Antropológicas en un Cerrito de la Isla Los Marinos (Pcia. de Entre Ríos). Publicación del Instituto de Arqueología. Lingüística Folk 23:3–66

Greslebín H (1931) Las estructuras de los túmulos indígenas prehispánicos del departamento de Gualeguaychú (Prov. de Entre Ríos), RA. Rev Soc Amigos Arqueol 5:5–51

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

González A (1947). Investigaciones arqueológicas en las nacientes del Paraná Pavón. Publicación del Instituto de Arqueología, Lingüística y Folklore, Vol. XVII, Universidad Nacional de Córdoba, Córdoba

Gonzáles Bonorino F (1966) Soil clay mineralogy of the Pampa plains, Argentina. J Sediment Petrol 36(4):1026–1035

Huarte R, Figini A (1988) La Plata Radiocarbon Laboratory Liquid Scintillation Counting and Interlaboratory Check Samples. Radiocarbon 30(3): 347-350

Inda H, del Puerto L, Bracco R, Castiñeira C, Capdepont I, Gascue A, Baeza J (2011) Relación hombre-ambiente para la costa estuarina y océanica de Uruguay durante el Holoceno. Reflexiones y perspectivas. In: García-Rodríguez F (ed) El Holoceno en la zona costera de Uruguay. UCUR, Montevideo, pp 229–260

Inda H, García-Rodríguez F, del Puerto L, Acevedo V, Metzeltín D, Castiñeira C, Bracco R, Adams J (2006) Relationships between trophic state, paleosalinity and climatic changes during the first Holocene marine transgression in Rocha Lagoon, southern Uruguay. J Paleolimnol 35:699–713

Iriarte J (2006) Landscape transformation, mounded villages, and adopted cultigens: the rise of early Formative communities in south-eastern Uruguay. World Archaeol 38:644–663

Iriarte J, Holst I, Marozzi O, Listopad C, Alonso E, Rinderknecht A, Montaña J (2004) Evidence for cultivar adoption and emerging complexity during the mid-Holocene in the La Plata Basin. Nature 432:561–562

Iriondo M, Kröhling D (2008) In: Universidad Nacional del Litoral (ed) Cambios ambientales en la cuenca del río Uruguay: Desde dos millones de años hasta el presente. Serie Ciencia y Técnica, Santa Fe

Iriondo M, Parma M, Paggi J (2007) The Middle Paraná River: limnology of a subtropical wetland. Springer Verlag, New York

Jahn R, Kociolek J, Witkowski A, Compère P (eds) (2001) Lange-Bertalot-Festschrift: studies on diatoms. A.R.G. Gantnter, Ruggell

Lange-Bertalot H, Simonsen R (1978) A taxonomic revision of the *Nitzschiae lanceolatae* Grunow. 2. European and related extra-European freshwater and brackish water taxa. Bacillaria 1:11–112

Lista R (1878) Les cimetières et paraderos minuanes de la province de Entre-Rios. Revue Anthropol I:365–368

López J (2001) Las estructuras tumulares del litoral Atlántico uruguayo. Lat Am Antiq 3:231–255

López J, Castiñeira C (2001) El sitio arqueológico del Potrerillo de Santa Teresa. Estructura de Sitio y Patrón de Asentamiento en la Laguna Negra. In: Fundación Fontaina Minelli and Asociación Uruguaya de Arqueología (ed) Arqueología Uruguaya hacia el fin del milenio. Gráficos del Sur, Montevideo, pp 147–161

López J, Gianotti C (1997) Construcción de espacios ceremoniales públicos entre los pobladores prehistóricos de las tierras bajas de Uruguay: el estudio de la organización espacial en la localidad arqueológica Rincón de los Indios. Rev Arqueol 11:87–105

Lothrop S (1932) Indians of the Paraná Delta, Argentina. Ann N Y Acad Sci 32:77–232

Malvárez A (1999) El Delta del Río Paraná como mosaico de humedales. In: Malvárez A (ed) Tópicos sobre humedales subtropicales y templados de Sudamérica. Oficina Regional de Ciencia y Tecnología de la UNESCO-ORCYT, Montevideo, pp 35–53

Manassero M, Camillón C, Poiré D, da Silva M, Ronco A (2008) Grain size analysis and clay mineral associations in bottom sediments from Paraná River Basin. Lat Am J Sedimentol Basin Anal 15 (2):125–137

Mangini S, Prendes H, Amsler ML, Huespe J (2003) Importancia de la floculación en la sedimentación de la carga de lavado en ambientes del río Paraná. Rev Ing Hidraulica Mex XVIII:55–69

Márquez Miranda F (1932) La navegación primitiva y las canoas monóxilas. Rev MuseoPlata 9:57–87

Metzeltín D, García-Rodríguez F (2003) Las Diatomeas Uruguayas. DIRAC, Montevideo

Metzeltín D, Lange-Bertalot H, García-Rodríguez F (2005) Diatoms of Uruguay. Iconogr Diatomol 15:1–736

Mulholland S, Rapp G (1992) Phytolith systematics: an introduction. In: Rapp G, Muholland S (eds) Phytolith systematics. Plenum, New York, pp 1–13

Naue G (1973) Dados sobre o estudo dos cerritos na área meridional da Lagoa dos Patos, Rio Grande, R.S. Veritas 71:73

Nóbile J (2002) Asentamiento y Subsistencia en la llanura aluvial del río Paraná (Sector Bajo Paraná): aproximaciones a un modelo regional. In: Cavellini S, Curbelo C, Geymonat J, Pintos S, Marenales M, Moreno M, Rolando G (eds) Arqueología uruguaya hacia el fin del milenio, 1. Gráficos del Sur, Montevideo, pp 187–193

Outes F (1912) Cráneos indígenas del departamento de Gualeguaychú. An Soc Científica Argent 73:5–37

Orgeira M, Vásquez C, Compagnucci R, Raposo I, Pereyra F (2009) Magnetismo de rocas en suelos actuales de la Pampa Ondulada, provincia de Buenos Aires, Argentina. Vinculación del clima con el comportamiento magnético. Rev Mex Cienc Geol 26:65–78

Pearsall D (1978) Phytolith analysis of archaeological soils: evidence for maize cultivation in Formative Ecuador. Science 199 (4325):177–178

Pearsall D (1982) Phytolith analysis: applications of a new paleoethnobotanical technique in archeology. Am Anthropol 84:862–871

Pearsall D (2000) Paleoethnobotany: a handbook of procedures. Academic, San Diego

Pereyra F, Baumann V, Altinieri V, Ferrer J, Tchilinguirian P (2004) Génesis de suelos y evolución del paisaje en el delta del río Paraná. Rev Asoc Geol Argent 59(2):229–242

Pirce J, Siegel F (1969) Quantification in clay mineral studies of sediments and sedimentary rocks. J Sed Petrol 39:187–193

Piperno D (1988) Phytoliths analysis: an archeological and geological perspective. Academic, New York

Piperno D (2006) Phytoliths. A comprehensive guide for archaeologists and paleoegologists. Altamira, Lanham

Politis G, Bonomo M, Castiñeira C, Blasi A (2011) Archaeology of the Upper Delta of the Paraná River (Argentina): mound construction and anthropic landscapes in the Los Tres Cerros locality. Quat Int 245(1):74–88

Prygiel J, Coste M (2000) Guide m´ethodologique pour la mise en oeuvre de l'Indice Biologique Diatom´ees. Agence de l'eau Artois-Picardie, Cemagref Bordeaux, Douai Reguera S (1970) El delta del Paraná. Rev Geog 4(1):97–109

Roth S (1888) Beobachtungen über Entstehung und Alter der Pampasformation in Argentinien. Sonderabdruck aus der Zeitschrift der deutschen geologischen, Gesellschaft, pp 22–23

Round F, Crawford R, Mann D (1990) Diatoms. Cambridge University Press, Cambridge

Salles Machado J (2005) Montículos Artificiais na Amazônia Central: Um estudo de caso do sítio Hatahara. Dissertation, Museu de Arqueologia e Etnologia da Universidade de São Paulo

Sánchez J (2011) Análisis de fitolitos del sitio arqueológico Los Tres Cerros 1 en la isla Las Moras en el Departamento Victoria, Entre Ríos. Graduate dissertation, Facultad de Ciencia y Tecnología, Universidad Autónoma de Entre Ríos, Diamante

Sánchez J, Colobig M, Zucol A (2011) Análisis fitolíticos del sitio Los Tres Cerros 1, Isla las Moras (Victoria, Entre Ríos). Primeros resultados. In: Libro de Resúmenes del VI Congreso de Arqueología de la Región Pampeana, La Plata, p 123

Schmitz P, Basile I (1970) Aterros en areas alagadicas no sudeste do Rio Grande do Sul e Nordeste do Uruguay. An Museo Antropol 3 (3):91–123

Schmitz P, Naue G, Basile-Beker I (1991) Os aterros dos campos do sul: a Tradição Vieira. In: Kern A (ed) Arqueología Prehistórica de Rio Grande do Sul. Mercado Aberto, Porto Alegre, pp 221–250

Serrano A (1933) Las culturas protohistóricas del Este Argentino y Uruguay. In: Memorias del Museo de Paraná. Paraná, Entre Ríos

Stoops G (2003) Guidelines for Analysis and Description of Soil and Regolith Thin Sections. Soil Science Society of America, Madison, WI.

Suárez Villagrán X (2006) Existió la monumentalidad en tierra entre los cazadores-recolectores del Este de Uruguayo? Propuesta Metodológica para el estudio de construcciones Antrópicas en Tierra. Rev Arqueol Sudamericana 2(2):263–290

Torres L (1903) Los cementerios indígenas del sur de Entre Ríos y su relación con los de Uruguay, túmulos de Campana (Buenos Aires) y Santos (Brasil). An Mus Nac 2(s.3a):57–73

Torres L (1907) Arqueología de la cuenca del Río Paraná. Rev Mus Plata XIV:53–122

Torres L (1911) Los Primitivos Habitantes del Delta del Paraná. Biblioteca Centenaria, Universidad Nacional de La Plata, Buenos Aires.

Twiss P (1992) Predited world distribution of C3 and C4 grass phytoliths. In: Rapp G, Mulholland S (eds) Phytolith systematic: emerging issues. Advances in arqueological and museum science, vol1. Plenum Press, New York, pp 113–128

Volkmer-Ribeiro C (2007) South American continental sponges: state of the art of the research. Porifera Research: Biodiversity. Innov Sustain 28:117–121

Witkowski A, Lange-Bertalot H, Metzeltin D (2000) Diatom flora of marine coasts I. In: Lange-Bertalot H (ed) Iconographia diatomologic, vol. 7. Koeltz Scientific, Koenigstein

Zeballos E (1878) Noticie sur un tumulus prehistorique de Buenos Aires. Rev Anthropol I:577–583

Zeballos E, Pico P (1878) Informe sobre el túmulo prehistórico de Campana. An Soc Cient Argent 6:244–260

Zeeb B, Smol J (1993) Chrysophycean stomatocyst flora from Elk Lake, Clearwater County. Minn Can J Bot 71:737–756

Zucol A (1998) Microfitolitos de las Poaceae Argentinas: II. Microfitolitos foliares de algunas especies del género Panicum (Poaceae, Paniceae) de la provincia de Entre Ríos. Darwiniana 36(1–4):29–50

Zucol A (2000) Fitolitos de Poaceae de Argentina.III. Fitolitos foliares de especies del género *Paspalum* (Paniceae) de la Provincia de Entre Ríos. Darwiniana 38(1–2):11–32

Zucol A (2001) Fitolitos. 3. Una nueva metodología descriptiva. Asociaciones fitolíticas de *Piptochaetium montevidense* (Stipeae: Poaceae). Bol Soc Argent Bot 36:69–85

Zucol A, Bonomo M (2008). Estudios arqueobotánicos en el sitio Nutria Mansa 1 (Partido de General Alvarado, Provincia de Buenos Aires): II. Análisis Fitolíticos comparativos de artefactos de molienda. In: Korstanje M, Babot M (eds) Matices Interdisciplinarios en Estudios Fitolíticos y de Otros Microfósiles, BAR International Series S1870, Oxford, pp 173–185

Zucol A, Colobig M, Mazzanti D (2007) Análisis de micro-restos en muestras sedimentarias del sitio 2 de la localidad arqueológica Amalia, provincia de Buenos Aires (Argentina). In: Actas XVI Congreso Nacional de Arqueología Argentina, Jujuy, pp 141-147