

Late Holocene palaeoenvironments of the Nutria Mansa 1 archaeological site, Argentina

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Abstract This paper presents results of interdisciplinary palaeoenvironmental research carried out on a sediment sequence from the Nutria Mansa 1 archaeological site. This late Holocene site is located in the Pampean plains, Argentina. Siliceous microfossils were recorded (i.e. phytoliths, diatoms, chrysophytes, sponges) and micro-charcoal was analyzed. In addition, fauna identified at the site were correlated with regional palaeoclimatic evidence. Based on the microfossil associations, we concluded that the human occupations occurred beside a fluvial and brackish-freshwater lacustrine setting. Grass communities were located on its margins that developed under a warm temperate climate with evidence for dryness and marked seasonality in part of the record. Although

some stratigraphic and faunal evidence indicates a possible temperature increase, these fluctuations were not sufficient to extirpate mammals of arid and cold environments.

Keywords Pampean region · Late Holocene · Palaeoenvironmental conditions · Phytoliths · Diatoms · Chrysophytes · Sponges · Faunal remains

Introduction

In South America and elsewhere, grasslands are highly altered terrestrial biomes due to agriculture,

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cattle grazing, and the highest population densities in the world (Soriano 1992). In Argentina, the Pampean plains have a temperate humid climate with precipitation between 1,200 and 600 mm annually. These plains are characterized by gramineous plant communities that form temperate and sub-humid steppes lacking arboreal vegetation. As in other parts of the world, these conditions (i.e. ecological, climatic and edaphic) facilitated different types of farming that have caused a transformation of these grasslands when exotic or cultivated species were introduced (León et al. 1984; Burkart et al. 1990). In some regions, it is difficult to recognize pristine relicts of these original plant communities as a result of the modern anthropic modification of the natural landscape (Cabrera 1976; Ghersa and León 2001). Therefore, an understanding of past vegetation in these regions has extreme importance, not only from the archaeological point of view, but also for its palaeoecological and palaeoenvironmental implications.

The Nutria Mansa 1 archaeological site is an open air site buried within alluvial deposits of the Nutria Mansa stream, which flows through the coastal sector of the Pampean region. In this investigation, the environmental factors that influenced this sedimentary sequence during human occupation of this site are reconstructed using siliceous microremains, which are compared with zooarchaeological remains. Through a multi-proxy approach, this project attempted to reconstruct the environmental conditions around the archaeological site at the time it was occupied by human groups at the beginning of the late Holocene. This also takes the regional palaeoclimatic evidence into account and considers how these conditions changed throughout the stratigraphic sequence.

Palaeobotanical analyses based on the identification of phytolith composition at archaeological sites are becoming abundant in publications from the United States (e.g. Pearsall 1982; Bozarth 1987, 1990; Piperno 1988, 2006). In Argentina, the study of phytoliths in archaeological sedimentary sequences has begun to appear in the Northwest (Wurschmidt and Korstanje 1998–1999) and more recently, in the Pampean region (Osterrieth et al. 2002; Zucol et al. 2002). Therefore, there are few studies of this type at archaeological sites in this region.

Phytoliths are amorphous microscopic particles formed in stems, leaves and inflorescences of some

plants (Pearsall 2000). These siliceous bodies are very resistant and have high degrees of preservation in soils and sediments. They provide fundamental evidence which can be used for evaluating the use of vegetation by humans at archaeological sites and to reconstruct the vegetation of past environments in regions where the preservation of remains is poor (Pearsall 1982). Siliceous frustules of diatoms (Class Bacillariophyceae) in sediments complement other types of palaeoenvironmental information (e.g. analysis of phytoliths and chrysophyte stomatocysts), due to their sensitivity to physical and chemical changes in the ecosystem (Gaiser et al. 2004).

Chrysophycean stomatocysts provide useful proxy evidence for palaeoenvironment changes because they are resistant to dissolution, abundant, diverse and well preserved in a variety of contexts. Their presence is related to seasonality and to physical and chemical variables. Stomatocysts have been studied mainly in freshwater habitats such as lakes and ponds (Duff et al. 1995; Pla 2001), where they often dominate the plankton and periphyton (Wilkinson et al. 2001). Nevertheless recent research has also recorded stomatocysts in brackish and marine settings (Rull and Vegas-Vilarrúbia 2000; Piątek and Piątek 2005). Although they are poorly characterized with regard to their systematics (Zeeb et al. 1996; Rull and Vegas-Vilarrúbia 2000; Wilkinson et al. 2001), there is abundant research that describes them in different types of sediments and geologic ages (Vigna 1995; Coradeghini and Vigna 2001; Wolfe and Perren 2001; Kamenik et al. 2005).

This paper presents the results of microremain analyses completed on a sediment sequence from the Nutria Mansa 1 (NM1) site, located in the Humid Pampas of the Pampean region, Argentina. This analysis is focused on siliceous microremains, which in many cases were widely distributed in the sediment sequence. Principal microremain types included phytoliths, diatoms, chrysophycean stomatocysts and sponge spicules. These results were integrated with zooarchaeological information for the purpose of establishing a palaeoenvironmental framework for this sequence, particularly during the earliest human occupation of the site. Finally, this information is compared with palaeoclimatic evidence obtained for the late Holocene from biological and geologic investigations conducted elsewhere in the Humid Pampas (Iriondo and García 1993;

Vizcaíno et al. 1995; Prieto 1996; Tonni et al. 1999; Goin 2001; Prevosti et al. 2004).

Nutria Mansa 1 archaeological site

The Nutria Mansa 1 archaeological site (38°24'54.2" S, 58°15'50.1" W, Fig. 1) is located near Centinela del Mar village (Gral. Alvarado County, Buenos Aires Province), on the margin of the lower Nutria Mansa stream. Alluvial processes have had a major influence on this sediment sequence. As an openair site, Nutria Mansa 1 has also been influenced by large-scale changes in environmental and climatic conditions.

At present, fauna of this region is characteristic of the Pamasic Domain of the Guyano-Brazilian Sub-region of the Neotropical Region (Ringuelet 1961), with the presence of Chacoan, Central and Patagonic elements, with very few species exclusive to this domain. For example, the rodent *Lagostomus maximus* (*vizcacha*) and *Dusicyon gymnocercus* (Pampean fox) are common. The flora shows affinities with the Austral Pampean District of the Pampean Province (Chacoan Domain of the Neotropical Region *sensu* Cabrera 1976), where it is predominantly *flechillas* steppe including grasses of the genera *Stipa*, *Piptochaetium* and *Poa*.

According to the vertical distribution of archaeological materials, the site occupational sequence has Upper Levels and a Lower Component, which were separated by a sterile unit containing no archaeological evidence. The sediment sequence is composed of four stratigraphic units that correspond to the geomorphologic scheme defined by Fidalgo et al. (1991) for floodplains of the main Pampean fluvial valleys (Favier Dubois and Bonomo, *in press*) (Fig. 1). The Upper Levels are buried within the fluvial sediments of stratigraphic Unit I. Archaeological material was distributed from 25 to 40 cm depth from level 0 of the excavation (located 14 cm over the modern surface in profile 2). This unit contained 11 lithic artifacts, 65 bone fragments of unidentified mammals, and two pieces of modern glass.

The Lower Component was distributed between 75 to 160 cm from level 0. Within this component, 2,292 lithic artifacts and 142,732 bones of different taxa were recovered (Fig. 2). Most of the archaeological materials of this component are located in a paleosoil (Unit III). Minor quantities of archaeological remains have been recorded in the fluvial sediments of the Guerrero Member of the Luján Formation (Unit IV) that is located underneath this paleosoil. Over this stable surface, lacustrine deposits correlated with the Río Salado Member of the Luján Formation (Unit II) are present and contain scarce archaeological

Fig. 1 Location of the archaeological site Nutria Mansa 1 and stratigraphic profile with the studied samples

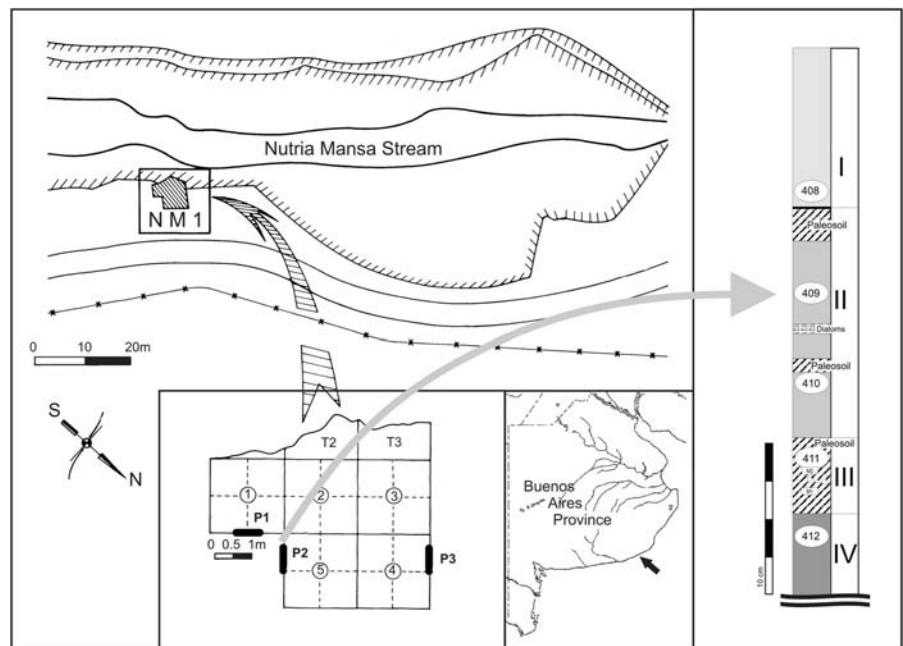
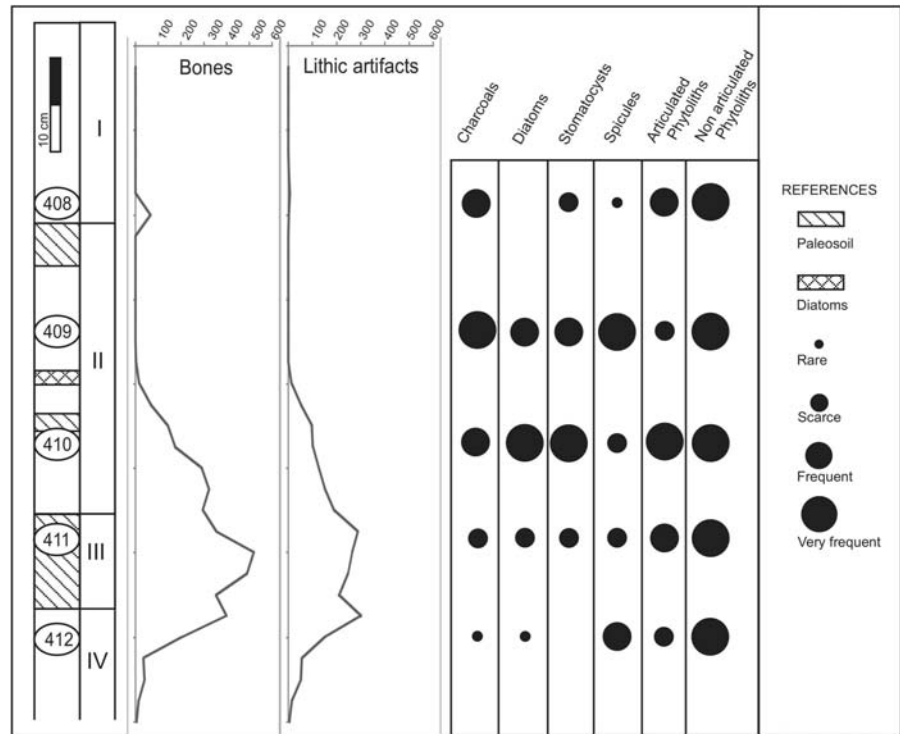


Fig. 2 Presence and abundance of the different type remains in the Nutria Mansa 1 site sediment sequence



materials in the lower portion of this unit. This corresponds to the Lower Component. Three AMS radiocarbon dates obtained on dental material of *Lama guanicoe* (*guanaco* camelid) place the human occupations of this component between 2,700 and 3,100 y BP (Bonomo 2004).

Lithic analysis of the materials from the Lower Component indicates that raw material was procured from a wide variety of sources including the Tandilia Mountain Range (105 km away) and the Atlantic coast (3.5 km away). Nodules and cores were reduced to produce flakes. A variety of flakes were transformed into a diversity of tools that showed evidence of retouch. Faunal analysis indicated a diversity of taxa (Table 1) although *L. guanicoe* generally predominates. Activities related to the processing and consumption of a wide range of *guanaco* skeletal parts were carried out at Nutria Mansa 1. The evidence recorded at Nutria Mansa 1 suggests that multiple activities took place in a base-camp which was occupied during the late Holocene by hunter-gatherers (Bonomo 2005).

Preliminary analysis of the micro-palaeobotanical remains found in the sediment sequence samples (Zucol et al. 2003) showed that between the non-siliceous

Table 1 Taxa represented in Nutria Mansa 1 according to minimum number of elements (MNE)

Taxa	MNE	Taxa	MNE
<i>Carcharodon carcharias</i>	2	<i>Dusicyon</i> sp.	30
Dasipodidae indet.	436	<i>Dusicyon gymnocercus</i>	20
<i>Dasyus hybridus</i>	1	<i>Dusicyon avus</i>	22
<i>Chaetophractus villosus</i>	322	c.f. <i>Dusicyon avus</i>	12
<i>Zaedyx pichiy</i>	109	<i>Chrysocyon brachyurus</i>	1
c.f. <i>Myodon</i> sp. ^a	1	Felidae indet.	2
Sigmodontinae indet.	126	<i>Panthera onca</i>	5
<i>Reithrodon</i> sp.	26	Otaridae indet.	3
<i>Ctenomys</i> sp.	204	Ungulate	197
<i>Lagostomus</i> sp.	113	Artiodactyla	29
<i>Galea musteloides</i>	23	Cervidae indet.	18
<i>Dolichotis patagonum</i>	7	<i>Ozotoceros bezoarticus</i>	15
<i>Myocastor coypus</i>	8	<i>Lama</i> sp.	283
<i>Conepatus</i> sp.	3	<i>Lama guanicoe</i>	1903
Canidae indet.	6	c.f. <i>Scelidotherium</i> sp. ^a	1
Total			3.928

^a Fossil mineralized bones

microfossils, palynomorphs did not appear, while scarce micro-charcoal was confirmed in some samples. The siliceous microfossils (phytoliths, diatoms, sponge spicules and chrysophyte stomatocysts) were abundant.

Materials and methods

Stratigraphy

Four stratigraphic units were defined in the sedimentary profile of Nutria Mansa 1 (Favier Dubois and Bonomo, *in press*) (Fig. 1):

- Unit IV (deepest unit) is composed of sandy loam sediments. Only the upper 22 cm of this unit were exposed.
- Unit III is formed by silty loam sediments and was 20 cm thick. This unit represents a cumulic paleosoil with the development of an A horizon where a majority of the faunal remains and lithic artifacts were recovered.
- Unit II consists of 21 cm of muddy sediments (IIb) and 31 cm of silty loam sediments (IIa), separated by a smooth limit. This unit consists of two weakly developed lacustrine paleosoils which formed in a saturated environment. The lower paleosoil is located 82 cm below the level 0 and is 5 cm thick. The upper paleosoil is located at 42 cm depth and is 9 cm thick. A diatomitic horizon of variable thickness is located between both soils (approximately 73 cm depth).
- Unit I is located at the top of the profile and is separated from Unit II by an erosional contact. It is composed of 42 cm of sandy sediments. The upper portion has undergone a high degree of disturbance and was not considered in these analyses.

Because of alternating erosional events and periods of stability throughout the profile, as well as particular characteristics of certain levels, sediment samples were taken at irregular intervals, based on the sedimentologic characteristics. Sediment samples of profile 2 (P 2; Fig. 1) are archived in the Laboratory of Paleobotany Repository (CICYTTP-Diamante), with the following numbers: 412 corresponds to stratigraphic Unit IV, 411 to Unit III, 410 to the lower section of Unit II (IIb), 409 to the upper section of Unit II (IIa), and 408 to the lower sector of Unit I. These samples permit a first approach to the principal

environmental conditions represented in the stratigraphic sequence.

Sample processing and analysis

Sediment samples were processed following the methods of Zucol and Osterrieth (2002), with the purpose of studying phytoliths and sponge spicules. Samples were washed with soluble salts dissolved in distilled water. Carbonate material was removed with diluted HCl, and organic material was removed by adding H₂O₂ followed by deflocculation of sediment in a Na₄P₂O₇ solution. The silt fraction was extracted by gravity sedimentation methods (<5 µm fraction) and then sieved to separate the >250 µm and 5–250 µm fractions. Heavy-liquid flotation was carried out on the 5–250 µm fractions using a sodium polytungstate heavy-liquid solution at 2.3 g/cm³. The siliceous microfossils were then mounted in Canada Balsam and immersion oil for light microscopy. For the phytolith count, morphotypes were defined using descriptions and classifications proposed by Twiss et al. (1969), Bertoldi de Pomar (1971), Twiss (1992), Kondo et al. (1994), Zucol (1996) and IPCNWG (2005) (Appendix I).

Two main morphotypes of sponge spicules were counted. The first morphotype included smooth spicules (although some had small superficial microspines) of great dimensions and sharpened ends. In general, they had a canal that crosses them longitudinally (i.e. a macrosclere). The second type included spicules with starred ends and a cylindrical body, with a variable number of spines (i.e. a gemosclere).

Chrysophycean stomatocysts were analyzed following Coradeghini and Vigna (2001) and only two categories were enumerated: smooth wall statospores and ornamented wall statospores. Identification of stomatocysts was based on Frenguelli (1935), Duff et al. (1995), and Wilkinson et al. (2001).

Samples of chrysophycean stomatocysts and diatoms were chemically treated following standard techniques, taking into account the studies of Setty (1966) and Battarbee (1986). Organic matter was removed with oxygenated water and carbonates with hydrochloric acid. Both compounds were added to the sediment sample, that was warmed for 15 min and allowed to cool for 24 h. Successive washings with distilled water eliminated the acidity and neutralized the sample. With the purpose of eliminating the great

amount of heavy sediments (sands), simple decantation was done. Distilled water (200 ml) was added to each sample. Then the sample was stirred with a glass bar and allowed to settle for 30 s so that the heavy material was separated from the supernatant. This procedure was repeated four to five times. The supernatant material was put on a cover-glass with an automatic pipette of 0.1 ml, dried on a heating plate at low temperature and mounted on glass slides previously impregnated with a drop of dispersing medium (Cumar, IR: 1.72) dissolved in xilol.

Microscopic observations were made on a Nikon Eclipse E200 with a Nikon Coolpix 990 digital camera of the Paleobotany Laboratory (CICYTTP-Diamante) and a Zeiss Standard 14 with automatic camera of the Phycology Laboratory (FCEN, UBA). Photographs by scanning electronic microscopy (SEM) were made with a Philips microscope Series XL model 30 at the Laboratory of Electronic Microscopy (MACN). In the case of diatoms, an Olympus optical microscope with a 100× oil immersion objective was used for identifying and counting taxa. For the first microscope observation of diatom samples, an Abundance Scale (modified of Ehrlich 1973) was employed. This scale establishes the number of frustules for each 10 observed fields: 0–1 frustules: Rare or Absent; 2–10 frustules: Scarce; 11–50 frustules: Frequent; 51–100 frustules: Abundant; more than 100 frustules: Very Abundant. Then, up to 300 valves were counted along transects.

To establish the abundance of charcoal microremains, an aliquot of each sample was processed without other pre-treatment, after being washed with distilled water. Samples were analyzed for total C (carbon) using the Ball Loss on Ignition procedure (Ball 1964) and for readily oxidizable C using the Walkley-Black wet combustion procedure (Walkley and Black 1934; Walkley 1935). The pH of the sample was also analyzed because it can directly affect the extent of leaching and rate of organic decomposition (Jenny 1941).

Soil texture was determined by dry screening, with the mean texture calculated by the percentage of weight of each fraction according to USDA standard mesh screens sizes. Arbitrary values ranging from 1 (clay) through 7 (very coarse sand) were assigned to each soil fraction and the mean weight was calculated for each sample. Sample pH was determined from a 1:1 soil:water paste.

We attempted to use the Oxidizable Carbon Ratio (OCR) dating procedure, but OCR results were different from AMS ^{14}C dates, and due to the absence of regional calibrations (Frink 1995), OCR dates could not be used (see discussion in Bonomo 2004).

Results

The record of microremains at the Nutria Mansa 1 shows qualitative variability in terms of microremain types and quantitative variability in terms of each type. The presence of micro-charcoal, diatoms, chrysophyte stomatocysts, sponge spicules and phytoliths characterized the sequence jointly with archaeological remains such as bones and lithic artifacts (Fig. 2).

As can be observed in Table 2, the sequence is characterized by fine sediments, although silts are abundant in the upper units (Units I and II). Very fine sands are most abundant in the lower units, particularly in those associated with human occupation (Unit III), which is the unit that possesses the coarsest texture. The pH values increase with depth although there is a decrease in the deepest sample. Compared to the distribution of organic carbon and oxidizable carbon in the sequence, this lower pH value is linked with lower percentages of organic carbon and oxidizable carbon (Table 2).

Micro-charcoal and organic carbon

The major concentrations of micro-charcoal fragments and other organic remains (Fig. 2) were found in the upper part of the sequence (Units I and II) and were scarce in the deepest units (III and IV). In the paleosol of Unit III, there is a scarcity of these organic remains, whereas in Unit IV, they are rare. In Units II and III, the presence of organic and/or carbonaceous remains associated with phytolith material are abundant and in some cases, they made it difficult to see microfossils.

Organic carbon percentages (Fig. 3) were greater in the upper units and decreased in the lower units, while the oxidizable carbon percentages only show a considerable increase in the upper section of Unit II (IIa). The distribution of both carbon percentages resembles the abundance obtained by micro-charcoal fragment counting (Fig. 2).

Table 2 Textural and chemical data for the sediment samples

Unit	Depth (cm)	pH	Organic matter LOI (%)	Oxidizable carbon WB (%)	Silt		Sand				
					Fine (%)	Coarse (%)	Very fine (%)	Fine (%)	Medium (%)	Coarse (%)	Very coarse (%)
I	17	5.9	5.2	2.2	40.4	51.0	7.7	0.1	0.3	0.4	<0.1
IIa	40	7.4	8.5	4.2	80.6	16.4	2.2	0.2	0.3	0.3	0
IIa	60	7.9	5.4	2.2	81.4	17.2	0.3	<0.1	0.8	0.2	0
IIb	88	8.1	6.0	1.5	61.1	33.2	2.6	2.5	0.5	0.2	0
III	124	8	1.3	0.60	12.4	52.4	32.2	1.5	0.7	0.5	0.2
IV	150	7.4	2.2	0.60	33.3	52.8	10.9	1.6	0.6	0.6	0.3

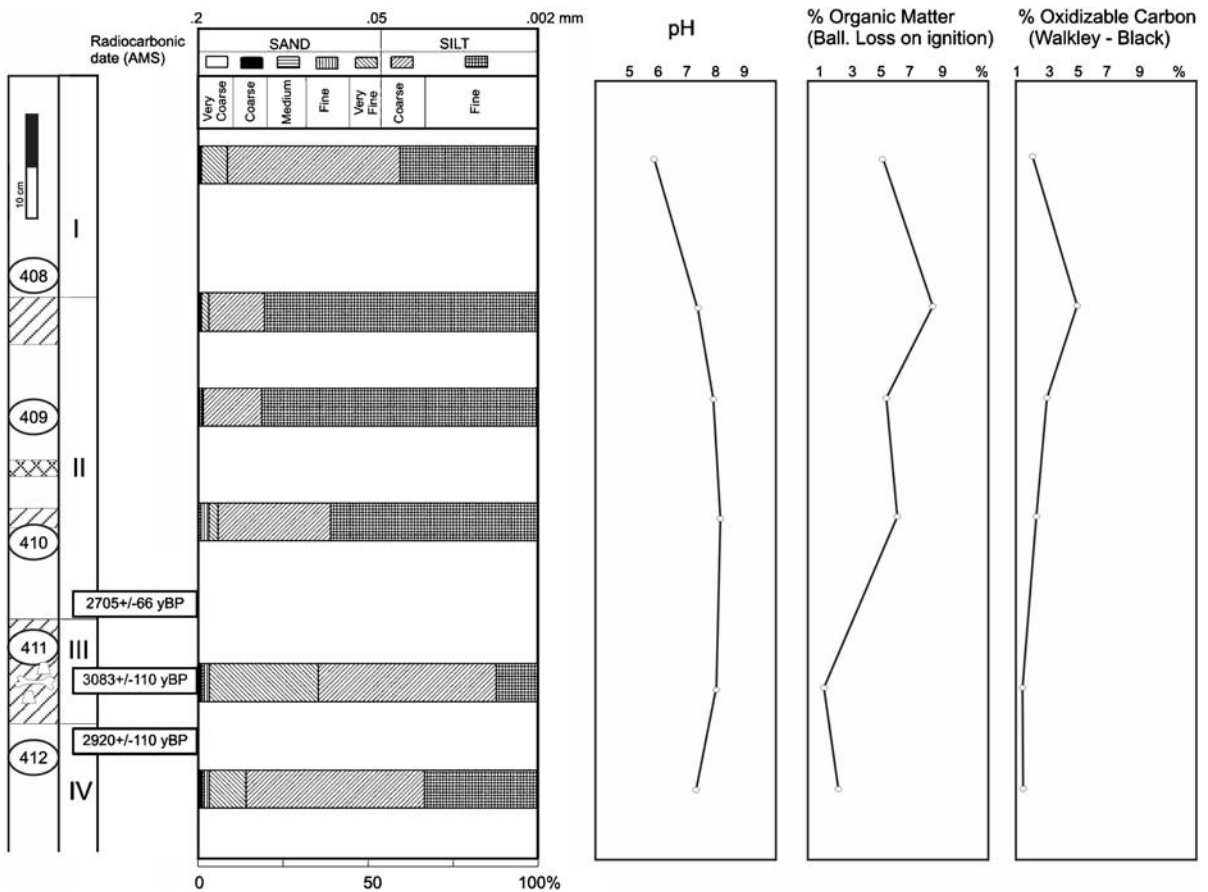


Fig. 3 Textural and principal compositional features of Nutria Mansa 1 site sediment sequence

Chrysophyte stomatocysts

Stomatocysts were observed in all samples, although their presence becomes clearly abundant in Units I to III, particularly in the Unit IIb section (Figs. 2, 4). The majority of the smooth stomatocysts corresponds

to Stomatocyst 10 (*sensu* Coradeghini and Vigna 2001) or *Outesia torquata* (*sensu* Frenguelli 1935; Fig. 5a, b, i, j), Stomatocyst 4 (*sensu* Coradeghini and Vigna 2001) or *Carnegie frenguelli* (*sensu* Frenguelli 1936; Fig. 5c) and Stomatocyst 42 (*sensu* Duff and Smol 1989; Fig. 5e). In addition to these, two

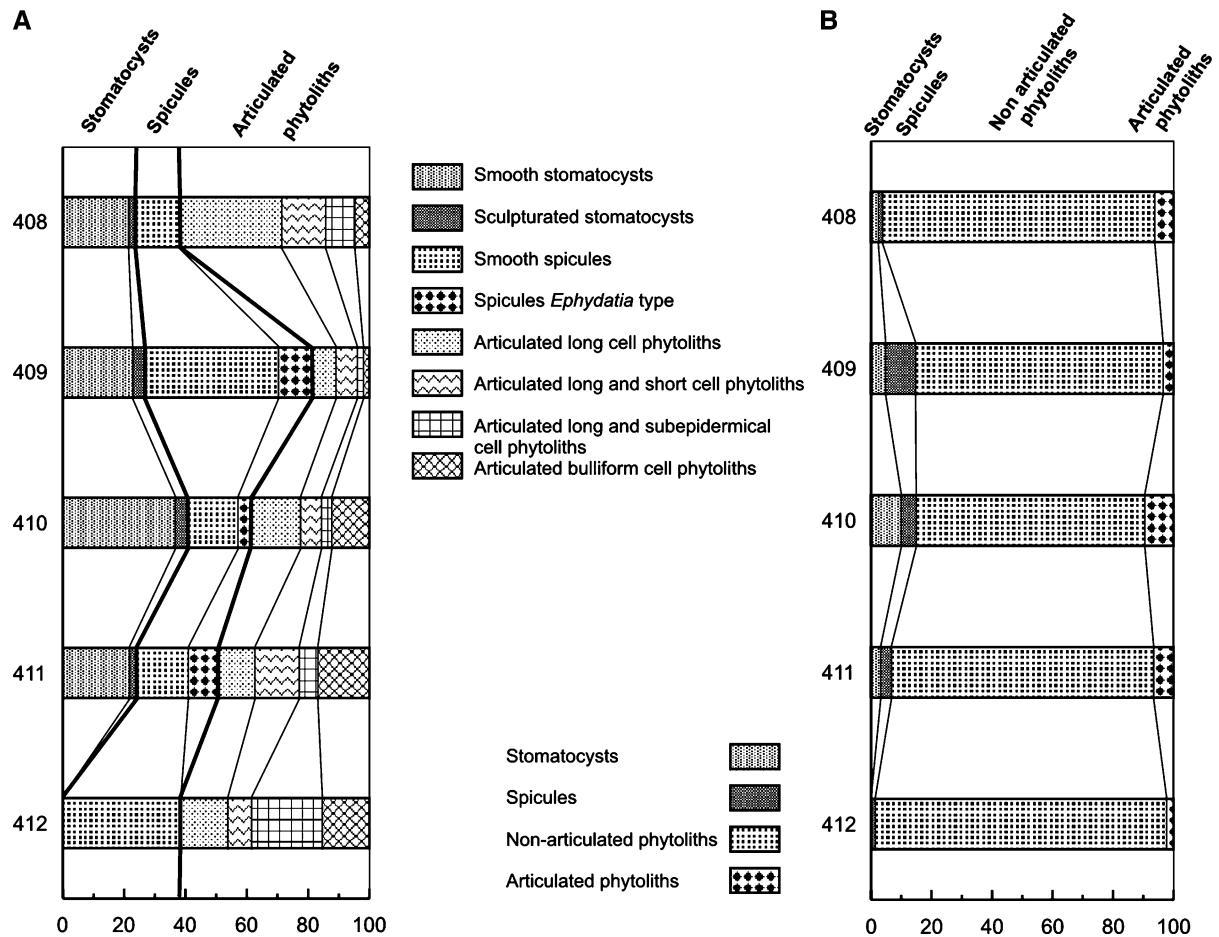


Fig. 4 Abundances of silicified microremains (excepting diatoms). (a) Abundance of the different groups (without the non-articulated phytoliths); (b) Abundance of stomatocysts, spicules and phytoliths (articulated and non-articulated)

other non-identified stomatocysts were observed: one spherical stomatocyst with a thickened wall and a thickened obconical collar with a conical pore (Fig. 5d). The other stomatocyst is oval and the margin collar is thick with a projection that hooks over the pore (Fig. 5h). To confirm the descriptions of the last two morphotypes, additional observations are needed.

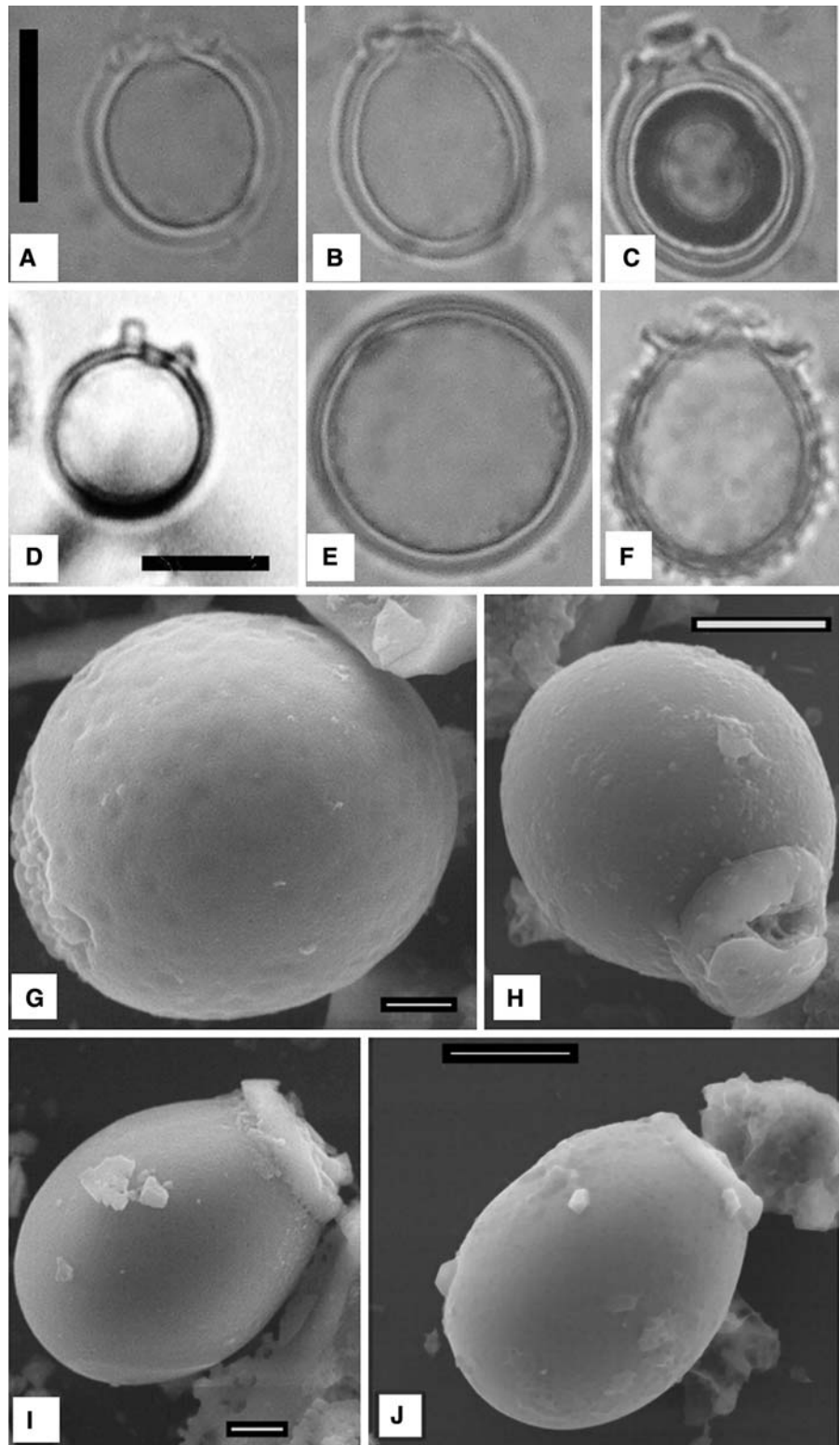
With respect to ornamented wall stomatocysts, the most frequent are Stomatocyst 22 (*sensu* Coradeghini and Vigna 2001; Fig. 5f) and Stomatocyst 281 Form B (Gilbert et al. 1997; Fig. 5g).

Sponge spicules

The different spicule types found along the sediment sequence belong to freshwater sponges. Although in

the profile they appeared continuously, the representation of these aquatic remains was very similar to that of chrysophyte stomatocysts (Fig. 4). Macroscleere spicules (Fig. 6a–c) are most abundant in Unit IV and section IIa of Unit II in complete or fragmentary form, with the most complete ones found in sample 409 (IIa). On the other hand, the gemosclere pertaining to the *Ephydatia* genus (Fig. 6d–j) has greater abundance in IIa and III, although they are also in the Unit IIb section. According to the characteristics of the gemosclere (I. Ezcurra de Drago pers. commun.), it is possible to assign them to *Ephydatia facunda* Welter, 1895 (= *Ephydatia ramsayi*), a species belonging to the Spongillidae family. This cosmopolitan family has a great number of taxa that are primarily periphytic (adhered to diverse types of substrates) and/or pleustonic (Ezcurra de Drago 2004).

Fig. 5 Chrysophycean stomatocysts. (a) Stomatocysts 10 (LM). Scale bar = 20 μm (a, b, c, e, f); (b) Stomatocyst 10 (LM); (c) Stomatocyst 4 (LM); (d) Unidentified Stomatocyst (LM). Scale bar = 5 μm ; (e) Stomatocyst 42 (LM); (f) Stomatocyst 22 (LM); (g) Stomatocyst 281 Form B (SEM). Scale bar = 2 μm ; (h) Unidentified Stomatocyst (SEM). Scale bar = 5 μm ; (i) Stomatocyst 10 (SEM). Scale bar = 2 μm ; (j) Stomatocyst 10 (SEM). Scale bar = 5 μm . White scale bar: scanning electronic microscopy photographs; Black scale bar: optical microscopy photographs



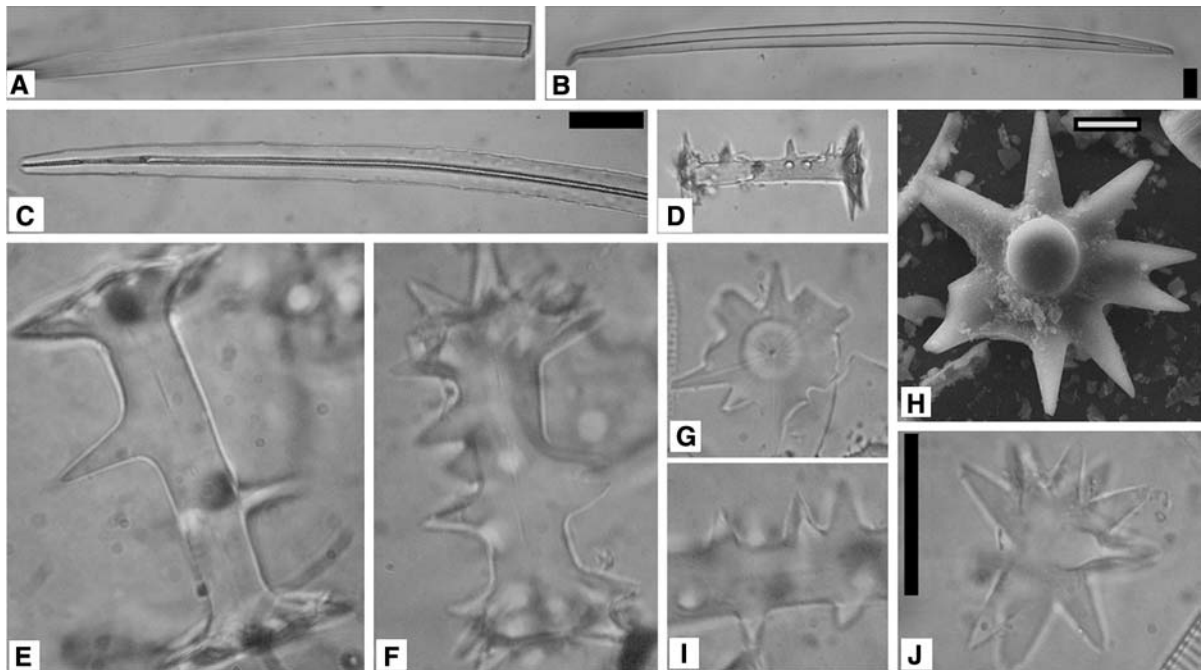


Fig. 6 Sponge spicules. (a–c) Smooth spicules; (d–f) *Ephydatia* sp. type spicules; (g–j) spicule bodies detail. Scale bar = 20 μm ; (in b, in c (a and d) and j (e, f, g and i));

5 μm (in h). White scale bar: scanning electronic microscopy photographs; Black scale bar: optical microscopy photographs

Phytoliths

Considerable numbers of phytoliths were recorded throughout the sediment sequence. The largest absolute amounts appeared in Units I, III and IV. In Unit II (IIa and IIb), a high proportion of spicules and stomatocysts were observed (Fig. 4).

Articulated phytoliths

Articulated phytoliths are significant throughout the profile, although they have larger relative abundance in section IIb. Various forms were observed, including silicified epidermic articulated phytoliths with grass affinity composed of long cells of different contours (Fig. 7g, h, k), long cells associated with intercostal short cells (Fig. 7d, e), hair bases, hooks, prickles, stomatal complex (Fig. 7c) or short cells (Fig. 7i, j). In addition, articulated phytoliths from epidermal cells with cyperoid affinity were also recorded. Other elements of this group are the bulliform cells generally associated with each other or with scarce long cells (Fig. 7a, b). Sub-epidermic cells tied to long cells (Fig. 7f) and fragments made

up of vascular tissue elements were also found in low quantity.

Non-articulated phytoliths

Non-articulated phytoliths were the most abundant siliceous elements found in the different stratigraphic units of Nutria Mansa 1 (Fig. 4b). In this sequence, a great size range was recorded. Among the small morphotypes (Figs. 8, 9), scarce spherical phytoliths (*Globulolita* or globular) were observed. In addition, a greater amount of dumbbell (*Halteriolita* or bilobate), truncated cones (*Estrobilolita* or rondel), saddles (*Doliolita*) and small prismatic phytoliths (*Braquiolita*) were also observed as well as stipoid dumbbells, oblongs of undulated contours and oval to circular sections. The largest phytoliths (Figs. 9, 10) are mainly the prismatic phytoliths (*Prismatolita* or elongate) which are point-shaped and mainly generated from hairs and prickles (*Aculeolita* or unciform) in addition to those polyhedral or fan-shaped phytoliths which originated from bulliform cell silicification (*Flabelolita* and *Securisaxum* or

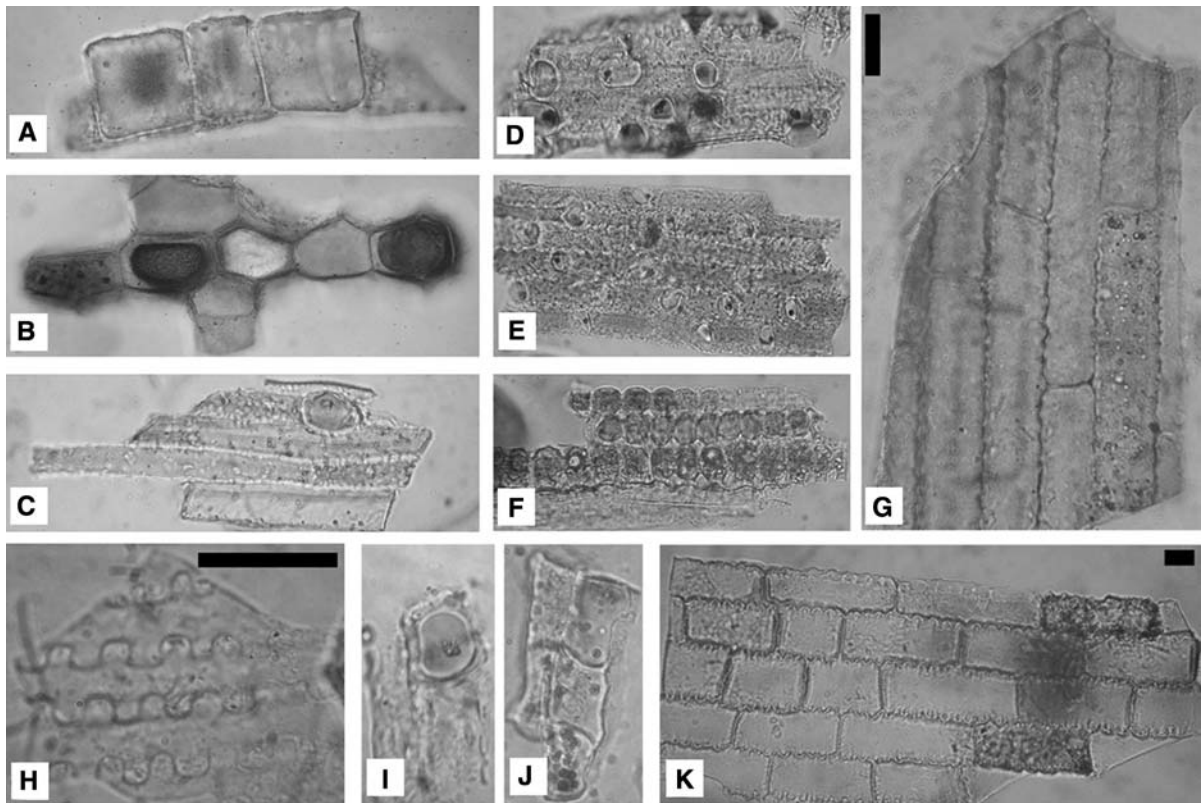


Fig. 7 Articulated phytoliths. (a) Bulliform cells in lateral view; (b) Bulliform cells in surface view; (c) Epidermal articulated phytolith with a stomatal complex; (d–e) Epidermal articulated phytolith with different intercostals short

cells; (f) Sub-epidermal cells; (f–h) Epidermal articulated phytoliths with different types of long cells; (i–j) Epidermal articulated phytoliths with different types of short cells. Scale bar = 20 μm (in g (a–f), in h (i and j) and k)

parallelepipedal). Other morphotypes such as the star-shaped phytoliths (*Asteriolita*) with cyperoid affinity and phytoliths from vascular element silicification, are characteristic in some levels.

In Unit I, an assemblage dominated by rounded and elliptical phytoliths (Fig. 8t–v), truncated cones mainly with long body (Fig. 8r, s), and elongate phytoliths with smooth edges and varied size was observed. The dominant morphotypes are accompanied by dumbbell and point-shaped phytoliths. In this unit, there were morphotypes characteristic of the *Halteriolita vermiculada*, *Nuxolita escrobiculata* and *Prismatolita elongata*.

The Unit II upper section (IIa) contains a phytolith assemblage with a predominance of truncated cone phytoliths, mainly with long bodies (Fig. 8p, q), rounded and elliptical, point-shaped (Fig. 10n), polyhedral (Fig. 10d) and prismatic phytoliths with smooth, undulated or denticulated (Fig. 10a, b, h) edges. In this assemblage, the star-shaped phytoliths

are frequent (Fig. 10e), and dumbbell phytoliths (Fig. 8a, b, f) can be considered as an abundant component in the assemblage, although no individual morphotype was present at high frequency. In this section, *Halteriolita faseolata*, *Braquiolita ondularistata*, *Prismatolita angulata* and *Proteolita cancrinata* morphotypes were characteristic.

The Unit II lower section (IIb) shows a noticeable compositional variation relative to the upper assemblage. A greater abundance of saddle (Fig. 8l, m), truncated cones, polyhedral (Fig. 10d), prismatic (mainly with smooth contour) and fan-shaped form (Fig. 10l, m) phytoliths are abundant. No morphotypes characteristic of the section were observed.

The assemblage of Unit III is characterized by the abundance of phytoliths in truncated cones in its different variants (Fig. 8n, o) and the scarcity of dumbbell phytoliths. Also, a noticeable amount of prismatic phytoliths in the *Prismatolita* and *Securisaxum* variants is recorded (Fig. 10a–c, f–h).

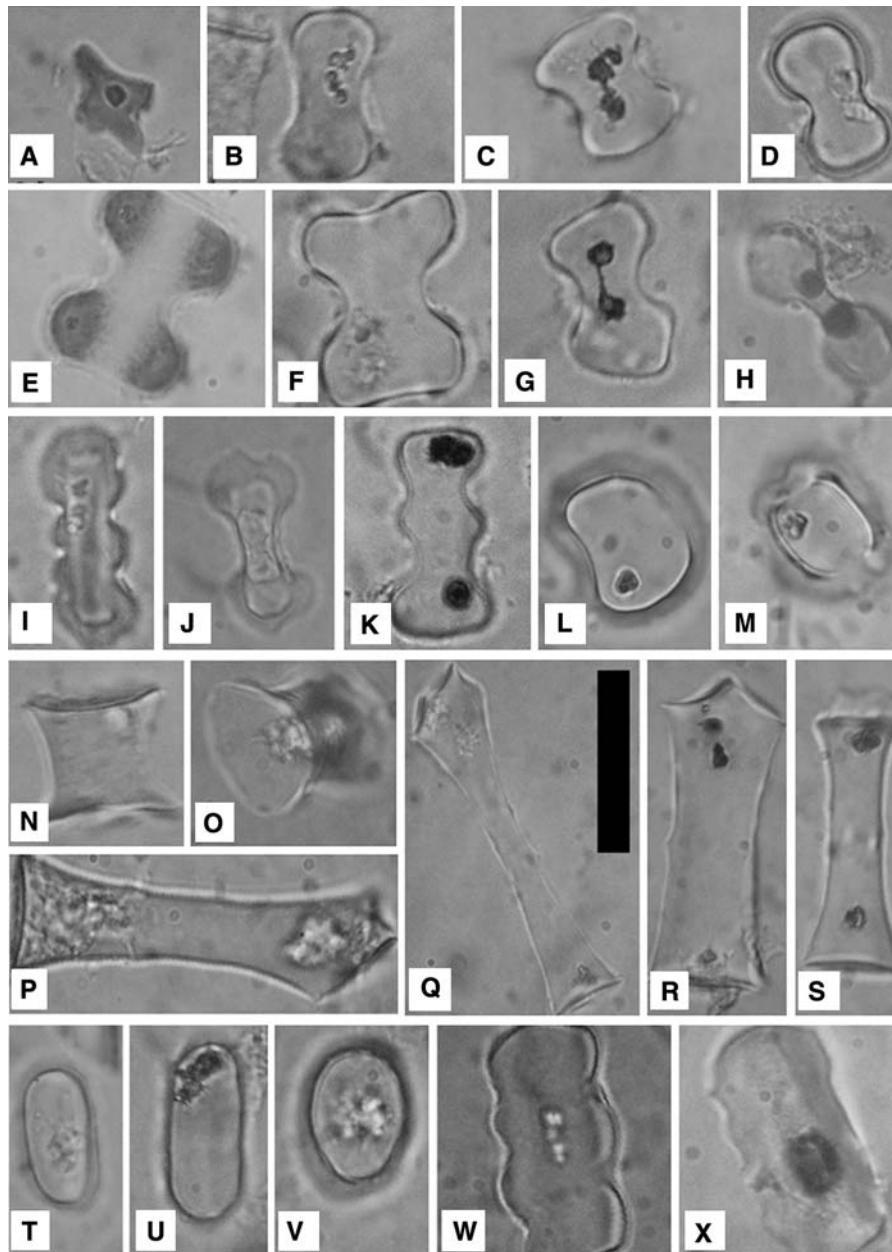


Fig. 8 Non-articulated phytolith. (a) Cross shaped phytolith; (b–k) Different bilobates or dumbbell phytoliths; (l–m) Saddle phytoliths; (n–s) Different rondel phytoliths types; (t–v) Ovate

to orbicular phytoliths; (w–x) Trapeziform polylobate phytoliths. Scale bar = 20 μ m

Unit IV (Fig. 9) presented a phytolith assemblage with smaller relative amounts of phytoliths of a truncated cone shape and a greater abundance of dumbbell phytoliths (Fig. 8c, d, g–k). There was also a significant amount of prismatic and polyhedral phytoliths. No morphotype characteristic of the unit appeared.

Diatoms

In the analyzed samples, there were 22 diatom taxa identified (Figs. 11, 12). In Unit I, the following taxa were recorded although with a very rare frequency: *Hyalodiscus subtilis*, *Surirella striatula*, *Campylodiscus clypeus*, *Nitzschia granulata* and

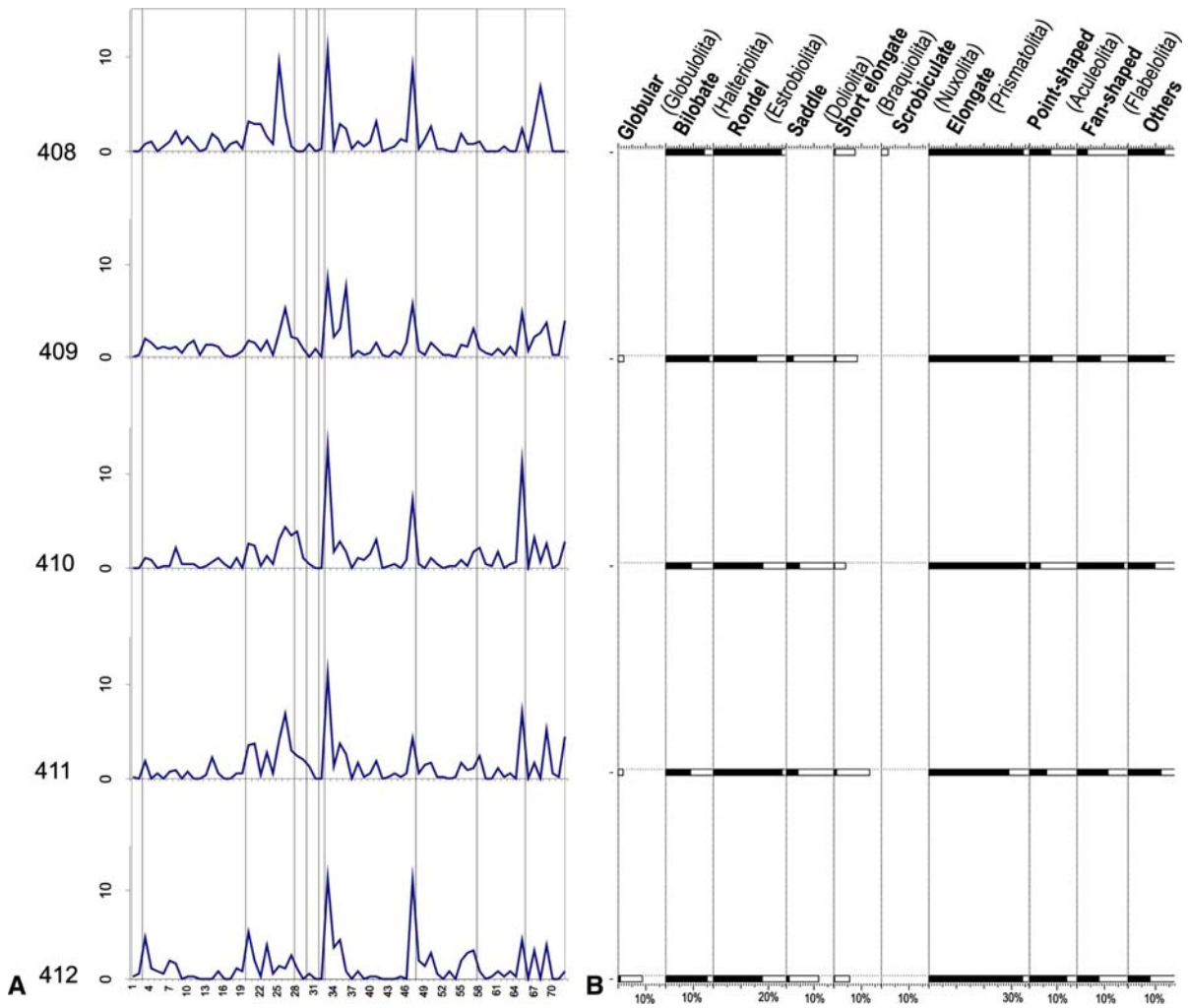


Fig. 9 Non-articulated phytolith diagram, according the codification of the schematic sketch used in quantification (Appendix I). **(a)** Relative abundance of each morphotypes

(b) Relative abundance of morphotypes major groups across the sediment sequence

Navicula spp. The frustules were very rare, with *H. subtilis* the dominant diatom at 26.7% of the total frustules. In section IIa (Figs. 2, 11) the following were observed: *H. subtilis*, *C. clypeus*, *S. striatula*, *N. granulata*, *Anomooneis sphaerophora*, *Synedra ulna*, *Synedra tabulata*, *Cocconeis placentula* and *Navicula* spp. The frustules were frequent and *H. subtilis* dominated with a percentage of 18%. In IIb (Figs. 2, 11) the following were recorded: *H. subtilis*, *Diploneis smithii*, *C. clypeus*, *S. striatula*, *A. sphaerophora*, *N. granulata*, *S. ulna*, *S. tabulata*, *C. placentula*, *Rhopalodia gibberula*, *Denticula elegans*, *Gomphonema olivaceum*, *Cyclotella meneghiniana* and *Navicula* spp. The

frustules are very frequent and the most frequent taxon was *D. smithii* with a relative frequency of 18%. In sediments of Unit III (Figs. 2, 11) the following were recorded: *D. smithii*, *H. subtilis*, *S. striatula*, *S. tabulata*, *R. gibberula*, *C. placentula*, *D. elegans*, *Gomphonema lanceolatum*, *Pinnularia gibba*, *C. clypeus*, *Diatoma* sp. and *Navicula* sp. Frustules are scarce and *H. subtilis* is the predominant species with a relative frequency of 19%. Finally, in Unit IV (Figs. 2, 11) the diatom assemblage is composed by *Achnanthes lanceolata*, *Cymbella cymbiformis*, *Epithemia adnata*, *S. ulna*, *S. tabulata*, *C. placentula*, *D. elegans*, *G. olivaceum*, *Amphora ovalis* and *Nitzschia* sp. The frustules were

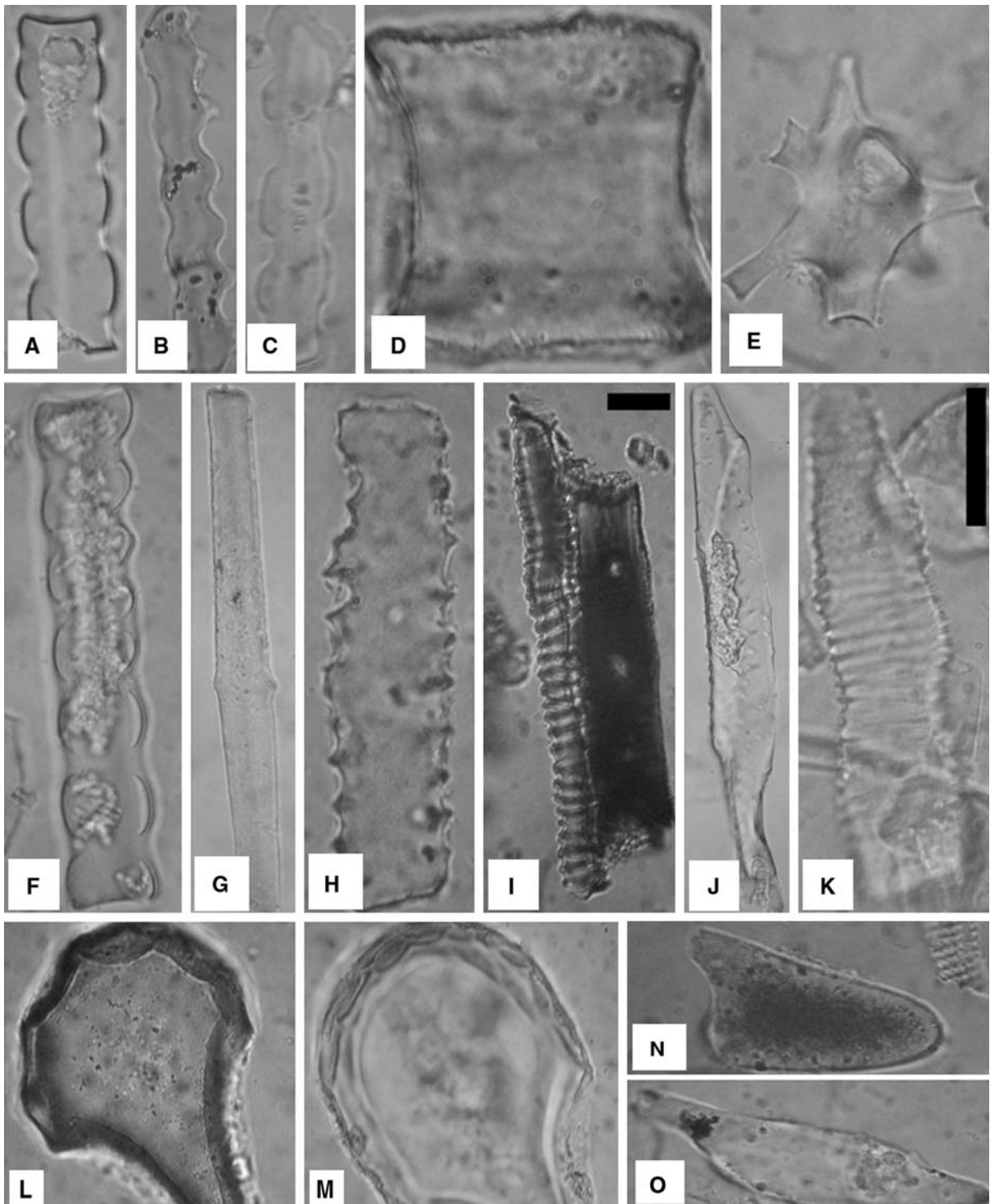


Fig. 10 Non-articulated phytolith. (**a–c**, **f–h**) Different elongated phytoliths; (**d**) Paralleipedal phytolith formed in bulliform cells; (**e**) Radiate phytolith; (**i–k**) Different phytoliths originated in vascular tissue; (**l–m**) Fan-shaped phytolith

formed in bulliform cells; (**n–o**) Unculiforms or point-shaped phytolith. Scale bar = 20 μm (in **i** (**g**, **j**, **l** and **m**) and **k** (**a–f**, **h**, **n** and **o**))

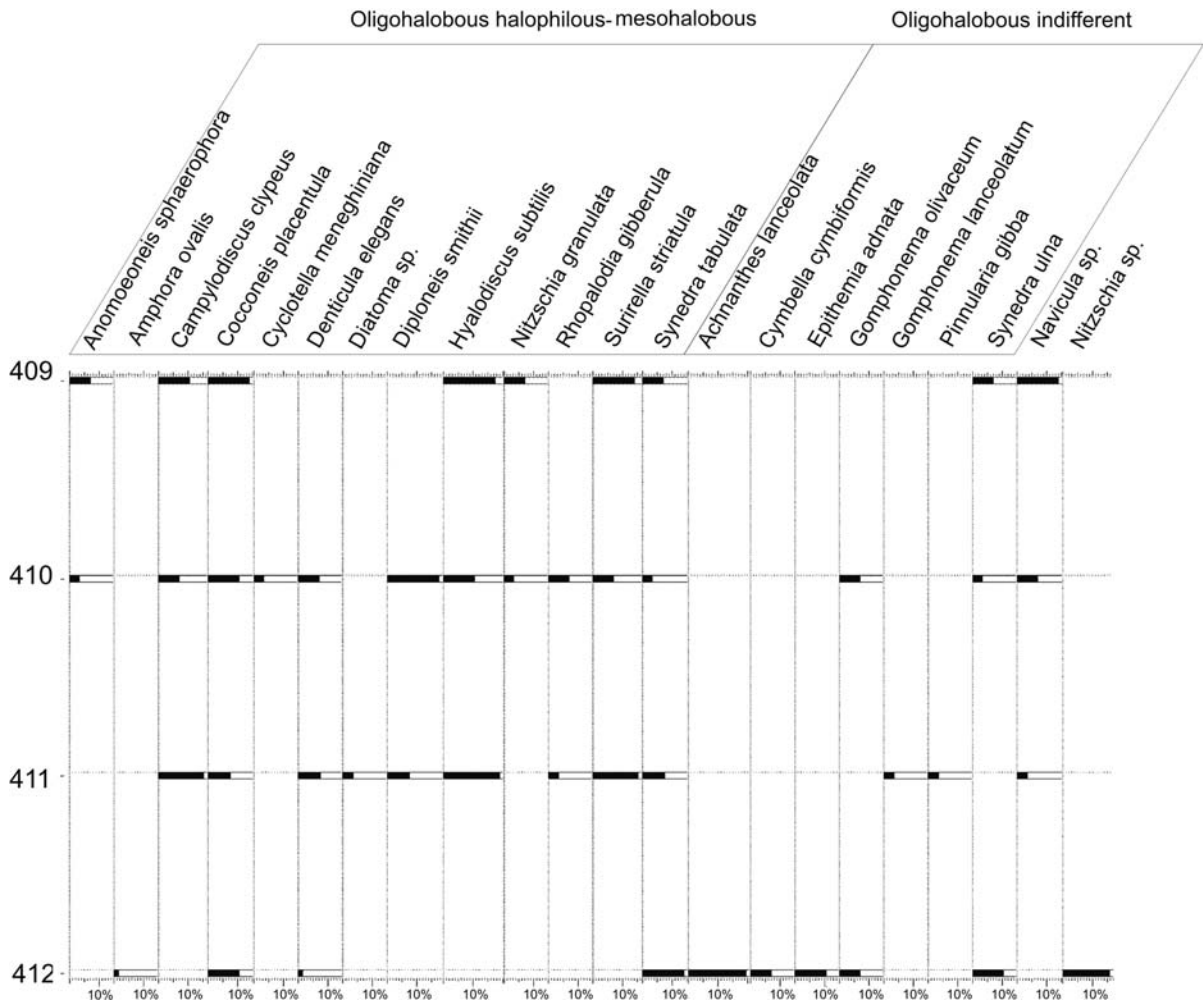


Fig. 11 Diagram showing the diatoms relative frequencies across the sediment sequence, grouping by the oligohalobous, halophilous-mesohalobous, and oligohalobous-indifferent taxa

rare and *A. lanceolata* was the dominant taxon with a percentage of 20%.

Comparative analysis of the sequence

The results show some preliminary tendencies that will be evaluated in each sample. Human influence on the sequence is shown in Unit III (Fig. 2) and decreases in IIb (Lower Component) and in Unit I (Upper Levels). These levels are characterized by a great abundance of phytoliths in their articulated and non-articulated forms in addition to the presence of coarse textural deposits and the lowest percentages of organic carbon. Unit II samples are characterized by their fine texture and high

percentages of organic carbon, jointly with the elevated frequencies of diatoms, sponge spicules, and stomatocysts. The micro-charcoal particle counting showed the major abundance in the upper units, in accordance with the organic carbon and oxidizable carbon percentages.

Unit IV consists predominantly of fine and coarse silts, with low organic and oxidizable carbon percentages, and a small quantity of micro-charcoal. Stomatocysts are not observed although smooth spicules are frequent. Rare diatoms were identified in the assemblage dominated by oligohalobous-indifferent taxa, linked to a freshwater depositional environment. Scarce articulated phytoliths, associated with a very frequent non-articulated phytolith,

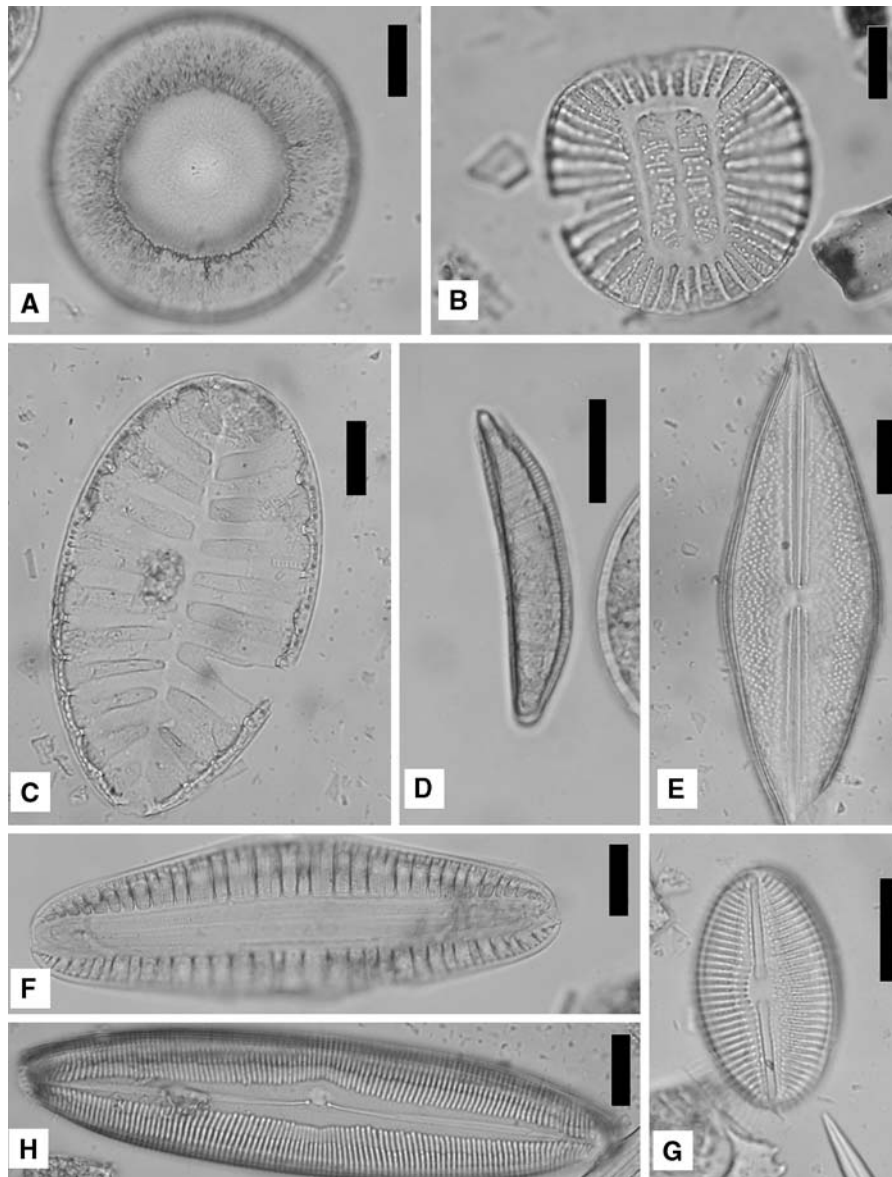


Fig. 12 Diatoms. (a) *Hyalodiscus subtilis* Bailey (LM), Scale bar: 25 μ m; (b) *Campylodiscus clypeus* Ehrenberg (LM), Scale bar: 25 μ m; (c) *Surirella striatula* Turpin (LM), Scale bar: 25 μ m; (d) *Epithemia adnata* (Kützing) Brébisson (LM), Scale bar: 10 μ m; (e) *Anomoeoneis sphaerophora* (Ehrenberg

Pfitzer (LM), Scale bar: 10 μ m; (f) *Rhopalodia gibba* (Ehrenberg) O'Müller (LM), Scale bar: 10 μ m; (g) *Diploneis smithii* (Brébisson) Cleve (LM), Scale bar: 10 μ m; (h) *Caloneis westii* (W. Smith) Hendey (LM), Scale bar: 10 μ m

were observed along with a greater quantity of dumbbell types associated with a truncated cone shape, prismatic, point-shaped and polyhedral phytoliths.

Unit III is a paleosol characterized by coarse silts and very fine sands, low organic and oxidizable carbon percentages, and scarce micro-charcoal. Stomatocysts, spicules, and diatoms are scarce in

contrast to the elevated representation of phytoliths. Diatom taxa show the presence of oligohalobous, halophilous-mesohalobous, and oligohalobous-indifferent types, which might suggest the presence of brackish-water conditions. Based on the scarcity of these remains in the unit (Fig. 2) and the similarity of the taxa composition to that in Unit II assemblages (Fig. 11), it is possible that most of these elements

came from overlying deposits. The phytolith record is one of the principal components of the paleosol assemblage, with abundant articulated phytoliths and the predominance of truncated cone shape phytoliths together with dumbbell, saddles, prismatic and polyhedral phytoliths.

Unit II is the most heterogeneous stratigraphic level, with major fine and coarse sediments, a clear middle diatomitic horizon, and a paleosol towards the top of the section. Micro-charcoal particles, organic and oxidizable carbon percentages increase towards the top of the unit. Although the strong evidence of human activity recorded in Unit III decreased, it is present again in the top unit. Microremain records are heterogeneous too. In the lower section of Unit II (IIb) the elevated abundance of diatoms, stomatocysts and phytoliths and scarce spicules characterize the assemblage. The major abundance of stomatocysts in the sediment sequence is present in this level, with smooth and sculptured types. Diatoms are very frequent; the oligohalobous, halophilous-mesohalobous taxa that predominate in the assemblage (Fig. 11) are related to brackish water body conditions. Articulated phytoliths are very frequent in their different forms, while non-articulated phytoliths are principally represented by truncated cone shape phytoliths associated with scarce proportions of dumbbell and saddle morphotypes. Prismatic and fan-shaped phytoliths, however, are present in considerable abundance.

The upper section (Unit IIa) shows that spicule remains increase, with a high percentage of *Ephydatia* type spicules, while diatoms and stomatocysts are less frequent. A decrease of the oligohalobous-mesohalobous diatom component is evident. These data, along with shifts in spicule abundance led us to conclude that a brackish water body disappeared and was influenced by fluvial processes of the Nutria Mansa stream. The phytolith record shows relatively scarce articulated phytoliths with graminoid and cyperoid affinities, while the non-articulated ones are very frequent truncated cone shapes with dumbbell phytoliths associated with prismatic, point-shaped and fan-shaped phytoliths. It is important to note the record of *Asteriolita* and some prismatic phytoliths with cyperoid features such *Prismatolita angulata*, *P. anisocornisata* and *P. isocornisata*. These

suggested swamp conditions, however, are at odds with the abundance of organic carbon and particularly micro-charcoal abundance in the sediments, that in general originated due to droughts and fire. Lynch et al. (2007) say that “...the interpretation of micro-charcoal is uncertain in swamp and lake as well as marine sediments. Furthermore, the unpredictable temporal and spatial characteristics of fire make it difficult to establish close relationships between fire activity, charcoal production, and deposition (e.g. Clark and Patterson 1997)...” In this particular situation, the abundance of organic carbon and micro-charcoal particles was not probably a consequence of droughts and fire, but a result of anaerobic conditions in the swamp environment, which would have promoted carbonization of the organic matter.

Unit I is the upper sediment deposit and is composed principally of fine and coarse silts, with lower organic and oxidizable carbon percentages and frequent micro-charcoal particles. In this unit, diatoms are very rare, stomatocysts are scarce, and spicules are rare. Both major types of phytoliths are abundant. Articulated phytoliths shaped by long epidermal cells are the most abundant, principally with graminoid affinities. Rondel or truncated cone shaped phytoliths are the morphotypes most abundant among the non articulated phytoliths. In minor proportions, the assemblage has dumbbell, different prismatic types, and point-shaped phytoliths. These results suggest little influence of fluvial activity and more land depositional conditions than in the lower levels.

Discussion and final considerations

The Nutria Mansa 1 site is an open air site. As such, it can be difficult to separate the cultural evidence from the ecological evidence. On the one hand, the site was exposed to fluvial and lacustrine processes that created the sediment deposit. On the other hand, botanical components identified at this site, and their frequencies, could not be, exclusively, the result of natural palaeovegetation. A portion of the botanical remains was surely introduced to the site by human populations who used the plants for food, raw materials for tools, or firewood. It is probable, however, that most of the vegetal remains found in

the site came from the surrounding landscape. This evidence, if interpreted cautiously, allows us to make inferences about the past environment (Pearsall 1982). Nevertheless, humans clearly influenced two units: Unit III (the Lower Component and the most important episode of occupation) and Unit I (the Upper Levels of the sequence, which show more influence of natural agents).

Micro-charcoal frequency, mainly in sample 409 (IIa), is not comparable with the abundance of the other organic microremains. However the presence of micro-charcoal jointly with the organic carbon, oxidizable carbon and textural feature of sedimentary samples showed the subaqueous depositional condition of Unit II. When considered along with the diatoms, spicules and stomatocysts, it is clear that saline conditions existed during deposition of the lower section, and freshwater conditions existed during deposition of the upper section of the unit.

The euryhaline sponge *E. facunda*, found mainly in IIa, is adapted to waters with high calcium and pH, and is one of the scarce genera and species of the Andean Patagonia Subregion and the Araucana Subregion (Ezcurra de Drago 1995). Thus, its presence in these sediments marks a clear predominance of sponges from these temperate subregions over the taxa of the warmer Guayano-Brazilian Subregion.

The chrysophyte stomatocyst distribution shows a larger representation in Units III and II, with a maximum in the lower section of this last unit (IIb). In general, these stomatocysts are indicative of seasonality and their high abundance can indicate change in the water level or change in the salinity of the habitat. In this sequence, chrysophyte stomatocysts were more abundant in the lower section of Unit II, which indicates pronounced stress during this period. They decrease in the top of the section (IIa) and are scarce in Units I and III, and absent in Unit IV.

The number of stomatocysts in relation to the total number of diatom frustules, even in the sections where the stomatocysts were more abundant (IIa and IIb), were very low (4.5% and 5.1%), typical of saline settings (Cumming et al. 1993). This supports the results from other microfossils which suggest the existence of a brackish environment principally in the IIb section.

Articulated phytoliths owe their origin to the gramineous group. They have an affinity with the

arundinoid, stipoid and pooid groups of the Poaceae family. At the present time, the Pampean grasslands of the study area are dominated by these temperate/temperate cold groups. Among the stipoid and pooid, the *flechilla* (*Stipa s.l.*) and different pooid species that form the *flechillar*, are characteristic. The presence of *pajonales* of the *Cortaderia* genera is also recognized among the arundinoid group. This indicates the possible association of elements of *flechillar* with *cortaderales* as happens nowadays in certain zones along Pampean stream margins. In contrast, the representation of panicoid phytoliths of temperate warm/warm characteristics, similar to those which dominate in the prairies, with subtropical species of the genera *Panicum* and *Paspalum* (*pasto miel*, *pasto horqueta*, etc.), is scarce. These data show a predominance of the temperate/temperate cold gramineous groups over the subtropical groups.

Non-articulated phytoliths are primarily associated with grasses and sedges. The ciperoides phytoliths are represented by the radiate morphotype (Asteriolita), several prismatic morphotypes and cones with peripheral spines (Pileolita) that appeared in low abundance. The presence of non-graminoid remains of ciperoid affinity corresponds with the lacustrine origin of some Nutria Mansa 1 sediments and their presence is very important in the Unit IIa section. With regard to the graminoid phytoliths, among those of small size, the truncated cones (Estrobilolita) dominate throughout the profile. In minor frequency, are the bilobate (Halteriolita) and saddle (Doliolita). Their comparative analysis shows a predominance of the arundinoid phytoliths (especially truncated cones) in relation to the panicoid types, particularly in both human occupation sectors (Lower Component and Upper Levels). This relation is also evident in the other group of temperate gramineous types like the pooids.

Among the larger-sized phytoliths, the most conspicuous are elongate (Prismatolita), unciform (Aculeolita), and parallelepipedal and fan-shaped (Securisaxum and Flabelolita, respectively). These morphotypes are not systematically diagnostic, since they are present in the different plant groups, but they do offer some palaeoenvironmental information. For instance, greater representation of grass silicified bulliform cells suggests a response to water stress. Under these circumstances, the plant replaces part of its tissue

with siliceous elements. In this case, silicification of these cells prevents the opening and closing of the foliar blade. Thus, abundance of this type of phytolith in annual plants is connected with variations in climate conditions like pronounced droughts.

The diatom-based palaeoenvironmental inferences considered autoecologic characters like life form, habitat, and salinity preference. Three associations, distinguished by their ecological affinities, were identified; the association of *A. lanceolata*, characteristic of freshwater settings, corresponding to Unit IV; the association of *H. subtilis* of fresh-saline transitional environments, assignable to Units III, IIa and I; the association of *D. smithii* exclusive to brackish waters, in IIb Unit. Unit IV corresponds to a fresh, shallow, and vegetated lagoon, due to the presence of 56.2% freshwater taxa (oligohalobous-indifferent) and 43.8% fresh-saline water taxa (oligohalobous to halophilous), characteristic of benthic and epiphytic habitats. Unit III is associated with a mixed palaeoenvironment, with 87% fresh-saline taxa and 13% freshwater diatom taxa. Section IIb represents a brackish-lacustrine setting, since 90% of the diatoms are mesohalobous, benthic, and epiphytic. Section IIa presents the same characteristics of the previous environment, but with a reduction in species richness. Unit I corresponds to a deposit of scarce, brackish and benthic diatoms.

The different remains analyzed allow us to infer a temperate climate, particularly on the basis of the presence of *E. facunda* sponge in association with a phytolith record dominated by arundinoid and pooid elements. The palaeocomunities described mainly have characteristics related to the dominant fluvial and lacustrine microenvironments of this area, however, we can still infer the general conditions at a regional level. The study at Nutria Mansa 1 shows changes in environmental and climatic conditions throughout the sequence. The associations found in Units IV (Guerrero Member) and III (paleosoil), lead us to infer a temperate/temperate-cold and humid climate. The association of the lower section of Unit II (IIb) shows a change in climatic conditions, with the presence of periodic dryness and climatic seasonality that may have been the cause of zone abandonment by humans. These conditions are inferred from the abundance of articulated phytoliths, and the parallelepipedal and fan-shaped non-articulated phytolith types. The

association of the upper section of Unit II (IIa) demonstrates the return to warm, humid conditions. This is indicated by the diatom taxa and their abundance, the increase of siliceous sponge remains and a notable decline in stomatocysts, articulated and non-articulated phytoliths of the fan-shaped types. This is related to warmer climatic conditions and greater humidity. At a local level, this can also be associated with a floristic replacement of a shallow lagoon community with brackish water conditions, by another one of swamp characteristics, as the ciperoid phytoliths of this level demonstrate. This replacement by a lacustrine or swamp community can be the cause of the appearance of the “carbonized” microremains found in the sediments. This would be a consequence of organic matter deposition under reducing, anaerobic conditions characteristic of a saturated environment. The association of Unit I sediments describes a grassland vegetation of temperate/temperate-warm climate, with arundinoid and pooid phytoliths, and some panicoids. In addition, it shows a decrease in spicule abundance, which may be related to slightly warmer conditions than those in the underlying associations.

The composition of the diatom assemblages indicates that these microalgae vary in response to ecological changes. Considering the temporal deposition of sediments (from base to top), the sequence begins with a shallow freshwater lagoon with abundant vegetation that supported the epiphytic diatoms of the association. In Unit III, a brackish-freshwater association, with scarce diatoms of allochthonous character is recorded. Unit II shows brackish-lacustrine conditions, with the formation of a laminar diatomite of low species richness. In the upper section of Unit (IIa) the diatoms decrease. This may indicate a period of changes in salt content, lagoon reduction, and therefore, increased dryness. Unit I possesses a mixture of brackish diatoms, and has indications of periodic desiccation. Freshwater diatoms of fluvial character were not observed, but the same species found in the lower unit were identified. These microfossil associations of the sequence indicate environmental instability. This can be inferred from shifts in salinity (i.e. changes from oligohalobous-indifferent to mesohalobous diatoms) and fluctuations in the amount of water, as inferred from relative abundances of phytoliths, together with

charcoal microremains, diatoms, stomatocysts and spicules.

Finally, we emphasize that in the Lower Component (fundamentally in Unit III, although to a lesser extent in IIb and IV) species corresponding to different climatic domains are represented (Vizcaíno et al. 1995; Miotti 1998; Tonni et al. 1999; Gómez 2000). Most mammals recorded at the site belong to barren and semi-arid environments of the Central and Patagonic Domain like *Reithrodon* sp. (rabbit mouse), *Zaedyus pichiy* (*piche*), *Dolichotis patagonum* (*mara*) and *Lama guanicoe* (*guanaco*). Remains of *Dusicyon avus*, an extinct canid of cold and barren climates that inhabited the Pampean region until the late Holocene, were also encountered. Furthermore, *Lagostomus* sp., *Chaetophractus villosus* and *Panthera onca* bones were recovered, representing animals of wide climate tolerance. On the other hand, *Dusicyon gymnocercus* (Pampean fox) and *Dasyurus hybridus* (*mulita armadillo*), which inhabit temperate and humid zones, were also identified. This last *armadillo* is of Brazilian origin and would have entered the Pampean region in the late Holocene (Vizcaíno et al. 1995). Other observed subtropical species are *Myocastor coipus* (otter) and *Chrysocyon brachyurus* (*aguará guazú* fox). This canid lives in a wide ecological range, under subtropical to tropical conditions, although it seems to be limited by average temperatures that fall below 19°C (Prevosti et al. 2004). Nevertheless, the association of remains with particular climates is debatable in some cases. For example, only a single metatarsian bone of *C. brachyurus* was recovered at the site, which introduces the possibility that it was transported from a neighboring area.

For the late Holocene in the Humid Pampas, palaeoclimatic data from different lines of evidence are fragmentary and controversial. On the one hand, studies about dominant patterns of atmospheric circulation indicate that during the late Holocene the warm and perhaps more humid climatic characteristics of the middle Holocene were replaced by a semi-arid phase with little precipitation (Iriando and Garcia 1993). The biostratigraphic information of late Holocene terrestrial mammals, with supremacy of Central and Patagonic elements, indicates that semi-arid conditions predominated, with slightly

higher temperatures than today (Tonni et al. 1999). Thus, the dry steppe vegetation, inferred for this period by pollen analyses (Prieto 1996), would have developed as a result of these semi-arid conditions. On the other hand, other lines of evidence indicate that towards the end of the middle Holocene and beginning of the late Holocene, the warm climate persisted, although with less rain than at present. The studies of marsupial remains (Goin 2001) suggest a gradual establishment of the present conditions during the late Holocene, with characteristic fauna of temperate and open environments, defined seasonality, and moderate precipitation. In marine ravines of Centinela del Mar, located near the Nutria Mansa 1 archaeological site, an association of taxa belonging to different zoogeographic domains was recorded (Tonni 1994), which indicates the existence of a mosaic of microenvironmental conditions.





































In conclusion, human occupation, that generated the Lower Component at the Nutria Mansa 1 archaeological site, was associated with a fluvial and brackish-freshwater lacustrine environment with gramineous communities on its margins. A reduction in size of the freshwater body allowed the habitability of the area and the proliferation of grassland communities around 3000 ¹⁴C y BP. These conditions developed in the late Holocene under a temperate climate, with a probable later increase of dryness and seasonality. Zooarchaeological remains are associated as much with barren and cold zones, as with warm and humid settings. Most of the bones come from a paleosol, whose characteristics indicate warm and humid conditions. Although some evidence indicates a possible increase of the temperature with respect to previous periods, these fluctuations did not cause a decline in the fauna of barren and cold environments.

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Appendix I

Phytolith morphotypes schematic drawing used in counting

1 Globulolita esferoquinulata		13 Halteriolita cruciformata		25 Estrobilolita sp 1	
2 Globulolita elipsoequinulata		14 Halteriolita trilobata		26 Estrobilolita sp 2	
3 Halteriolita bitestata		15 Halteriolita inequilobata		27 Estrobilolita sp 3	
4 Halteriolita testilobata		16 Halteriolita catenulata		28 Doliolita equidimensionata	
5 Halteriolita testicotilata		17 Halteriolita vermiculata		29 Doliolita elongata	
6 Halteriolita pandurata		18 Halteriolita stipa type		30 Braquiolita psiloaristata	
7 Halteriolita botulata		19 Halteriolita sp 1		31 Braquiolita ondularistata	
8 Halteriolita testicupulata		20 Estrobilolita equidimensionata		32 Nuxolita escrobiculata	
9 Halteriolita testicaudiculata		21 Estrobilolita elongata		33 Prismatolita psilaristata	
10 Halteriolita testiesferulata		22 Estrobilolita bicuneata		34 Prismatolita serrata	
11 Halteriolita seudocapitata		23 Estrobilolita complanata		35 Prismatolita denticulata	
12 Halteriolita faseolata		24 Estrobilolita cotilata		36 Prismatolita ondulata	
Outline sketches of phytolith morphotypes					

37 Pristmatolita elongata 	49 Aculeolita acuminata 	61 Flabelolita campanulata 
38 Pristmatolita excavata 	50 Aculeolita ancistrata 	62 Flabelolita complanata 
39 Pristmatolita dendriformata 	51 Aculeolita aciculata 	63 Flabelolita hemiflabelata 
40 Pristmatolita isocornisata 	52 Aculeolita acantata 	64 Flabelolita biclinata 
41 Pristmatolita anisocornisata 	53 Aculeolita corniculata 	65 Securisaxum sp 1 
42 Pristmatolita angulata 	54 Aculeolita piliformata 	66 Proteolita cancrinata 
43 Pristmatolita rectata 	55 Aculeolita sp 1 	67 Eliptico sp 1 
44 Pristmatolita sp 1 	56 Aculeolita sp 2 	68 Redondeado sp 1 
45 Pristmatolita sp 2 	57 Aculeolita sp 3 	69 Festucoid boat 
46 Pristmatolita sp 3 	58 Flabelolita euffabelata 	70 Triangular sp 1 
47 Micropristmatolita psilaristatum 	59 Flabelolita elongata 	71 Lobulisaxum sp1 
48 Aculeolita rostrata 	60 Flabelolita excavata 	72 Asterolita sp 1 

Outline sketches of phytolith morphotypes.

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