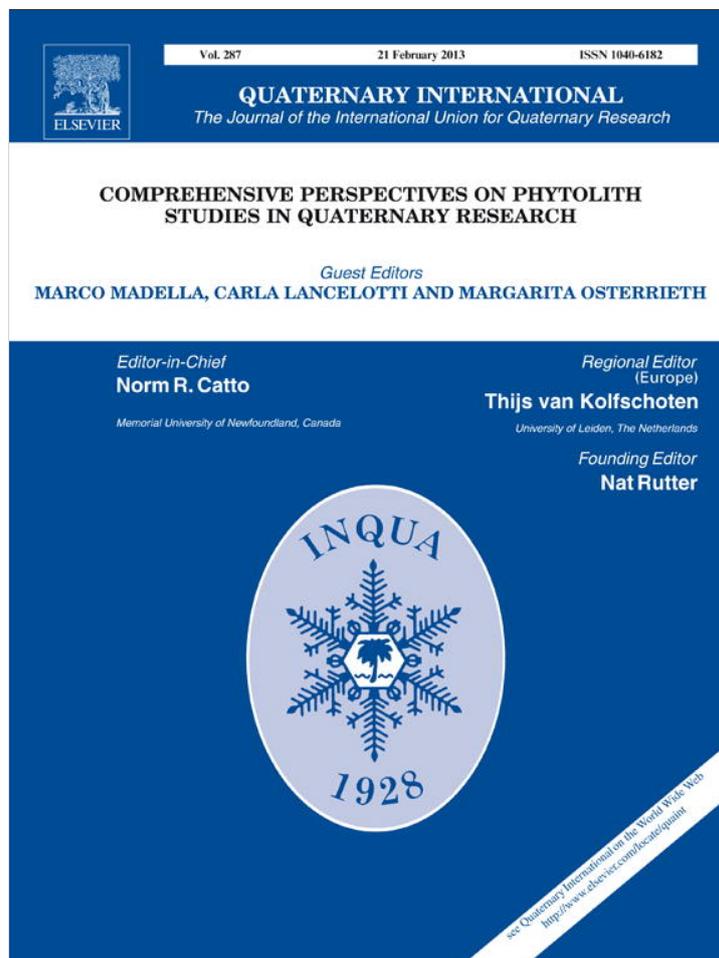


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Paleoenvironmental studies of Alfar archaeological site (mid-Holocene; Southeastern Pampas of Argentina): Silicophytoliths, gastropods and archaeofauna

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ABSTRACT

The firsts results of the silicophytolith research carried out for the sedimentary sequence of Alfar archaeological site are presented. The aims of this study were to identify the vegetation associations and to contribute to the reconstruction of past environments during the hunter-gatherers' occupation of the site in the mid-Holocene. This siliceous microfossil data is also complemented with other proxy evidence derived from the freshwater gastropods recorded throughout the stratigraphic sequence and the zooarchaeological study of the bone remains recovered from the site. The results of this multi-proxy approach show the existence of a permanent cover of gramineous communities on a lagoon margin and a considerable pedogenetic activity during human occupation. The obtained data indicates that the human populations occupied Alfar site under dry conditions, but with the warm climate of the mid-Holocene Hypsithermal.

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1. Introduction

Palaeoclimatic and palaeoenvironmental information indicates that in the mid-Holocene, between 7500 and 5000 BP, there occurred a global temperature increase that, in most cases led to a rise in aridity, and other times in humidity (e.g., Mayewski et al., 2004; Vivo and Carmignotto, 2004; Behling et al., 2005; Ackerley and Renwick, 2010). In the Pampean region, some authors (Prieto, 1996; Mancini et al., 2005) have held that this change to a warmer climate produced an increase in humidity due to more frequent rainfall. Other researchers (Tonni, 1994; Vizcaino et al., 1995; Tonni et al., 1999) have suggested arid regional conditions and limited sectors with humid conditions that would be a result of local situations, or the alternation of humid moments amid lengthy arid periods.

In the littoral sector of the Interserrana area, the temperature increase at the outset of the mid-Holocene generated a rise in sea-

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level, producing Holocene beach ridges with values of up to 2–6 m asl. From the analysis of different regional curves for the variation of sea-level in Buenos Aires province, it was recently suggested that the mid-Holocene marine transgressive maximum took place between 6500 and 6000 BP (Schnack et al., 2005). This rise led to the overflow of river basins, forming freshwater bodies (Stutz, 2000; Espinosa et al., 2003) and estuaries at the mouths of the main watercourses flowing into the sea (Fidalgo and Tonni, 1983; Fasano et al., 1987; Isla et al., 1996; Espinosa et al., 2003; Vilanova et al., 2006). After 6000 BP, the regressive phase began. With the withdrawal of the sea, shallow estuary lagoons were formed with restricted connection to the sea (i.e. marshes) (Osterrieth, 1998; Espinosa et al., 2003; Ferrero et al., 2005; Vilanova et al., 2006).

Coinciding with these mid-Holocene climatic and environmental changes, significant cultural transformations took place in America and round the world, from the migration of entire populations to new regions to changes in patterns of adaptation, the system of settlement, and socio-political organization (Sandweiss et al., 1999; Anderson et al., 2007a; see also papers compiled in Zárate et al., 2005). Several authors (Grosjean et al., 1997; Nuñez et al., 2001; Berón, 2004; Barrientos and Pérez, 2005; Gil and Neme, 2010) observed that during this period of rapid climatic

variations a hiatus in archaeological evidence existed in some regions of South America, sometimes called the “archaic gap” or “archaeological silence”. On this basis, the withdrawal from entire areas by human populations and their migration to other sectors offering more benign conditions was proposed (see discussion in Araujo et al., 2005–06). In the Southeast of the Pampean region, the decrease in the frequency of archaeological sites related to the Hypsithermal (above all between 6000 and 5000 BP) was explained, on the one hand, by a demographical decrease caused by a decline in the main food sources, such as the guanaco (Politis, 1984) or the local emigration or extinction of the Pampean foragers (Barrientos, 1997; Barrientos and Pérez, 2005). On the other, it was identified with a rise in residential mobility that generated less visible occupations owing to the exploitation of specific resources in different environments (Martínez, 1999). It is in the context of these alternative interpretations and supra-regional problems that the palaeoenvironmental information derived from the study of the Alfar archaeological site, occupied by hunter-gatherers during the mid-Holocene, becomes relevant.

The aim of this study is to contribute to the reconstruction of past environments especially during the hunter-gatherer occupation of Alfar archaeological site in the mid-Holocene of the Pampean region. In order to identify changes in plant communities over time, silicophytolith research was carried out in the sedimentary sequence of Alfar. This amorphous silica data is complemented with other proxies that also offer palaeoclimatic and palaeoecological information: freshwater gastropods recorded throughout the sequence and the faunal remains associated with the archaeological occupation.

The process of biomineralization is a widespread phenomenon in nature. Biomineralizations are mineral or amorphous structures of biogenic nature generated by the metabolic activity of different organisms (Jahren, 1996). Amorphous silica biomineralizations are generated by different organisms such as diatoms, chrysophytes, sponges and plants. Silicophytoliths (hydrated amorphous silica) are biomineralizations of vegetal origin and, due to their intrinsic characteristics (e.g., production related to physiological and environmental conditions, resistance to decay, ubiquity), can be good indicators of former vegetation cover, environmental conditions and pedogenesis (Osterrieth, 2000, 2008a, 2008c; Blinnikov et al., 2002; Strömberg, 2004; Iriarte, 2006), as well as of diagenetic and taphonomical processes (Osterrieth et al., 2009). From the phytogeographical point of view, the Southeastern Pampean region belongs to the Pampean Province within the Chaco Domain in the Neotropical Region, where the prevailing vegetation is a grass steppe (Cabrera, 1976). In the Pampas, the pristine vegetation throughout the late Quaternary was composed of Poaceae (Cabrera, 1976), one of the most productive of silicophytoliths among plant families (Piperno, 1988; Epstein, 1994).

Silicophytoliths were observed in the Pampean loess (Frenguelli, 1930; Teruggi, 1957; Osterrieth, 2008c). In Argentina, particularly in the province of Buenos Aires, numerous silicophytolith studies of Quaternary pedosedimentary sequences, especially in coastal areas have been completed (Osterrieth, 1998, 2008a, 2008b; Osterrieth et al., 1998, 2008). In pedoarchaeological sequences the silicophytolith studies were carried out only on some archaeological sites of the Southeastern Pampean region (Osterrieth et al., 2002, 2008; Zucol et al., 2002; Bonomo et al., 2009; Mazzanti et al., 2010; Gutiérrez et al., 2011). They have contributed to a complete paleoenvironmental interpretation, in some cases associated with the Hypsithermal. During this climatic event, in several pedoarchaeological levels of this sector, high silicophytolith content was observed and, at the ancient levels, there was observed a high content of C4 grasses silicophytoliths, indicating warmer and drier conditions (Osterrieth et al., 2002).

2. Alfar archaeological site

Alfar (38° 5' 48.9"S, 57° 33' 20.7"W) is located in Mar del Plata City, Department of General Pueyrredón, Buenos Aires province (Fig. 1). It is located on the right margin of the Corrientes stream, 0.65 km north-west of the modern littoral (Argentine Sea, South-western Atlantic Ocean). In 2006 a total surface of 17 m² were excavated, where 6275 lithic artifacts and 8945 faunal remains were recovered. The archaeological remains were deposited on fluvial and aeolian sediments more than 3.5 m underground.

The Alfar sedimentary sequence is 450 cm thick with ten stratigraphic units (Fig. 2), of which the first four (units I–IV) are natural deposits. From the bottom up, these units, the focus of study, are: unit I, compact sandy silty; unit II, silty sand sediments; unit III, sandy silt; and unit IV, lenticular bedding. The other six units (V–X) are a product of the combination of modern anthropic intervention (dredging of the watercourse) and geological processes, with a succession of silt with soils at the top (V, VII), silt with shells (IX), discordances and aeolian sands with shells (VI, VIII, X).

Four sedimentary samples were previously analyzed (Bonomo and Leon, 2010). The objective was to establish the physico-chemical characteristics of the matrix containing the archaeological remains (unit II and base of unit III) and the sediments lying immediately below (unit I) and above (top of unit III). As shown in Table 1, sediments from units I, II, and III are sandy to silty. The scanty presence of organic matter in units I and II indicate an oxygenated environment that becomes a reducing medium in unit III. However, the increase in the carbonate content of the latter unit points to saturation conditions (a reducing medium) or a greater drying out of previously damp sediments.

The archaeological materials were recovered from between 445 and 385 cm depth (Fig. 2) in sandy sediments turning into silty. According to previous research (Bonomo and Leon, 2010), the archaeological remains were deposited on the edge of a paleolagoon located on the dune line. The disappearance of archaeological materials coincides with a rise in the water level, with the sediments overlying human occupation (385–330 cm) corresponding to the lagoon bed.

The main resources exploited in Alfar were coastal cobbles reduced by the bipolar technique and marine otariids (Otaridae). Other marine taxa (*Amiantis purpurata*, *Mesoderma mactroides*, *Spheniscus* sp., Cetacea) and continental taxa (*Lama guanicoe*, *Ozotoceros bezoarticus*, *Chaetophractus villosus*, *Ctenomys* sp., *Conepatus* sp., *Dusicyon* sp., *Lagostomus* sp., *Theristicus* sp., Rheidae, among others) were recorded (Table 2). A radiocarbon age of 5700 ± 64 ¹⁴C BP (AA82081) was obtained from an Otariidae tooth (N°G1.C2.N11). This date corresponds to 6392–6492 cal BP (Calib 6.0.1 Program, using 1 sigma and SHCal04) and places the human occupation within the range of the Hypsithermal (=Climatic Optimum) warm event.

3. Materials and methods

3.1. Analysis of silicophytoliths and other amorphous silica biomineralizations

For the analysis of amorphous silica biomineralizations (Osterrieth, 2004), P3 profile of grid 7 (Fig. 2) was selected to be the most extensive and found closest to the sampling area in which there was a previous exploratory study of silicophytoliths (Bonomo et al., 2008) and the physico-chemical analysis of sediments mentioned above. In the P3 profile, 21 samples were taken every 10 cm from levels located at 450 and 240 cm depth. To increase sampling resolution, two of the 21 samples (S1 and S7) were divided in half (M1bottom, M1top, M7bottom, M7top), because they were located at the beginning and the end of the human occupation. The P3

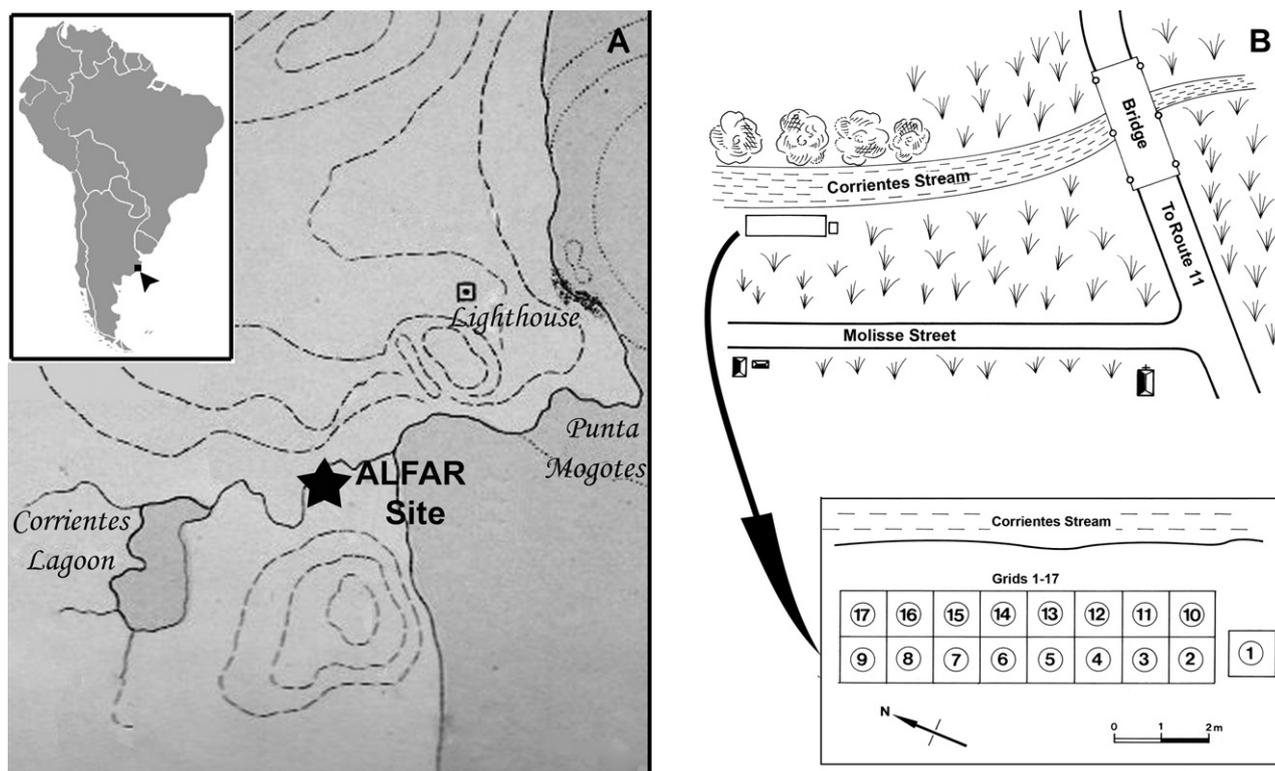


Fig. 1. Geographical location of Alfar archaeological site (A) and excavation area, with a detail of the excavated grid-squares (B).

samplings cover from I to VIII stratigraphic units, although the focus was on units I to V (from 450 to 310 cm). At this stage the total sample was analyzed, which determined the percentage of amorphous silica biomineralizations (silicophytoliths, diatoms, spicules, chrysophytes) and charcoals with respect to the total mineralogical components in each level. About 5 g soil were taken from each sample (Alvarez et al.,

2008). Organic matter was oxidized with 30% hydrogen peroxide at 70 °C. The clay minerals were extracted by repeated centrifugation at 1000 rpm for 3 min. Once the sample was clean, it was mounted on immersion oil, and 500 grains were counted under optical (OM, Zeiss, 450× magnification) and petrographic microscopes (PM, Olympus BXPol, 600× magnification), to calculate the corresponding percentages. The qualitative analysis of the silicophytolith morphologies was made according to the Madella et al. (2005) and Twiss (1992) specifications. Part of the samples were observed by scanning electron microscope (SEM) (Jeol JSM-6460 LV) and analyzed by energy dispersive X-ray analysis (EDAX) to explore a possible relationship between opal silica composition and silicophytolith deterioration.

3.2. Analysis of gastropods

Simultaneously to silicophytolith sampling, for the malacological analysis P1 and P2 profiles were sampled (Fig. 2). These profiles from I to V stratigraphic units were located in the archaeological excavation sector in grids 3 and 5, to control lateral variations in the mollusc record. Twenty eight samples were collected at 10 cm intervals (fourteen in each profile) from levels located at 450 and 310 cm depth. In the malacological analysis each sample was sieved (0.5 φ), carefully washed and dried. All molluscs recovered were counted under a binocular loupe (Iroscope, 40× magnification) and discriminated at the species level. Relative abundances and densities were calculated. The taphonomical attributes observed in shells were: fragmentation, abrasion, different coloration, and polished surface (shine).

3.3. Analysis of faunal remains

Faunal specimens from 11 grid-squares (NISP = 1608) (grids 2–7 and 11–15) associated with the human occupation of the Alfar

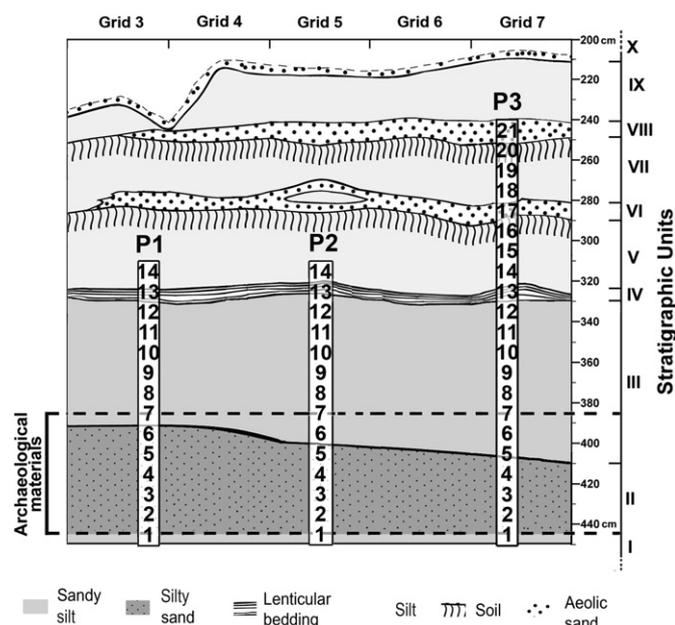


Fig. 2. Stratigraphic sequence of the Alfar archaeological site with the three sample profiles. P1 and P2 = Alfar profiles 1 and 2 (malacological samples), and P3 = Alfar profile 3 (phytolithic samples).

Table 1

Textural analysis, organic matter, carbonates, and pH from four sedimentary samples from grid 7 of Alfar archaeological site. Note: Size analyzed using a Malvern Mastersizer model 2000 LASER particle counter; organic matter determined by the Walkley and Blake (1965) procedure; carbonates determined with a "Netto" digital calcimeter; pH determined from a 1:1 soil:water paste.

Sample	Depth (cm)	Unit	Archaeological remains	Texture (Folk)	Mz (phi)	% Organic matter	% Carbonates	pH
S4	350–345	III	absent	Sandy silt	5.421	0.53	0.40	6.82
S3	395–390	III	present	Sandy silt	5.159	0.60	0.40	7.01
S2	425–420	II	present	Silty sand	3.515	0.43	0.30	6.97
S1	450–445	I	absent	Sandy silt	4.597	0.41	0.20	6.88

site (Fig. 2) were studied with the aim of complementing information derived from the other proxies. To evaluate environmental conditions on a site scale, at the time of the deposition of the archaeological material and after, when they were buried, the following taphonomical variables were taken into consideration: weathering, geological abrasion, root marks, and chemical deposition (Behrensmeier, 1978; Andrews, 1990; Lyman, 1994; Fisher, 1995; Gutiérrez and Kaufmann, 2007). In addition, from the taxa present at the site, animal habitats and local and regional climatic conditions were analyzed (Burgos and Vidal, 1951; Olrog and Lucero, 1981; Williams, 1991; Tonni et al., 1999; Darrieu and Camperi, 2001; Bastida and Rodriguez, 2003; Canevari and Balboa, 2003; Narosky and Yzurieta, 2003; Jaureguizar, 2004; Laita and Aparicio, 2005; Bârquez et al., 2006; Leynaud et al., 2006; Politis et al., 2011). In order to evaluate vertical variations, the taphonomical traces were analyzed in the 5 cm artificial levels used in the archaeological excavation.

Table 2

Taxonomical abundance at the Alfar archaeological site. NISP = number of identified specimens.

Taxa	NISP
MOLLUSCA	30
<i>Amiantis</i> sp.	2
<i>Mesoderma</i> sp.	2
MAMMALIA	310
Didelphidae	2
Dasypodidae	315
<i>Chaetophractus villosus</i>	149
<i>Tolypeutes matacus</i>	19
Carnivora	1
cf. <i>Ducysion</i> sp.	2
<i>Conepatus</i> sp.	3
Otariidae	343
Artiodactyla	4
<i>Lama guanicoe</i>	34
Cervidae	2
<i>Ozotoceros bezoarticus</i>	14
Cetacea	2
<i>Pontoporia blainvillei</i>	5
Rodentia	111
<i>Holochilus brasiliensis</i>	2
<i>Lagostomus</i> sp.	49
cf. <i>Microcavia</i> sp.	1
<i>Ctenomys</i> sp.	74
AVES	25
Rheidae	119
Caradriforme	2
Psittacidae	1
<i>Theristicus</i> sp.	1
<i>Spheniscus</i> sp.	20
TELEOSTOMI	26
<i>Myliobatis</i> sp.	1
AMPHIBIA	3
Subtotal	1674
Indeterminate (≥ 2 cm)	312
Total	1986

4. Results

The silicophytoliths, diatoms, gastropods, and archaeofaunal materials have offered information on the diverse parts of the pedostratigraphic sequence in which the archaeological remains of Alfar site are deposited. Only silicophytoliths are present throughout the whole sampled stratigraphic column.

4.1. Analysis of silicophytoliths and other amorphous silica biomineralizations

Generally, silicophytoliths are an important fraction in all the samples of P3, being about 17–54% of the total mineralogical components of the sediments (Fig. 3A). Most relevant light minerals are potassium and Ca–Na feldspars, fragments of quartz, alterites, volcanic ashes and few muscovites. Heavy minerals are scarce and they are represented by opaque minerals, epidotes, amphiboles and pyroxenes (Fig. 4a). Although their state is variable, they are usually subangular to rounded. The variability in particle size is considerable, some levels being texturally more heterogeneous than others (Fig. 4b), agreeing with the texture defined in Table 1. Particularly in relation to archaeological materials, gypsum crystals were observed in the transition between units II and III (S5: 410–400 cm depth), (Fig. 4c), and the MEB analysis suggests the presence of staurolites in unit II (S3: 430–420 cm) (Fig. 4d). This is a rare iron aluminosilicate of metamorphic origin that could be associated with the rocks of the Tandilia crystalline basement. Their excellent state of preservation is striking, which could be indicating a little transport.

Based on amorphous silica biomineralization (silicophytoliths, chrysophytes, diatoms and spicules) and charcoal contents with respect to the total mineralogy of sediments, the following groups were designated (Fig. 3A):

- Unit I has the lowest silicophytolith content, about 17%. From 445 cm, the silicophytolith content increases from 30% to about 50% at the end of stratigraphic unit II (S5). The charcoals show the same trend, with the maximum of all the sequence from 445 to 430 cm, just at the beginning of the human occupation in unit II. In these samples, chrysophytes were also observed (Fig. 4e).
- At the base of unit III, from 400 to 370 cm depth (S6 to S8), the silicophytolith content decreases to values close to 40%. Within S7, the top level (385–380 cm) increases about 10% of the silicophytolith content with respect the lower one (390–385 cm) related to human occupation. S9 (370–360 cm) presents the highest silicophytolith content (about 60%) and chrysophytes of all the sequence (Fig. 4f,j,k). From 360 cm depth, the silicophytolith content decreases to the top of unit III with values close to 30%. Unit IV has less charcoals and a third of the total mineralogy is silicophytoliths.
- From S14 to the top, the sampled stratigraphic units (V to VIII) that were affected by modern human modifications start. At the base of stratigraphic unit V, in S14 (320–310 cm), diatoms begin to appear, and in S15 (310–300 cm) spicules and scleras

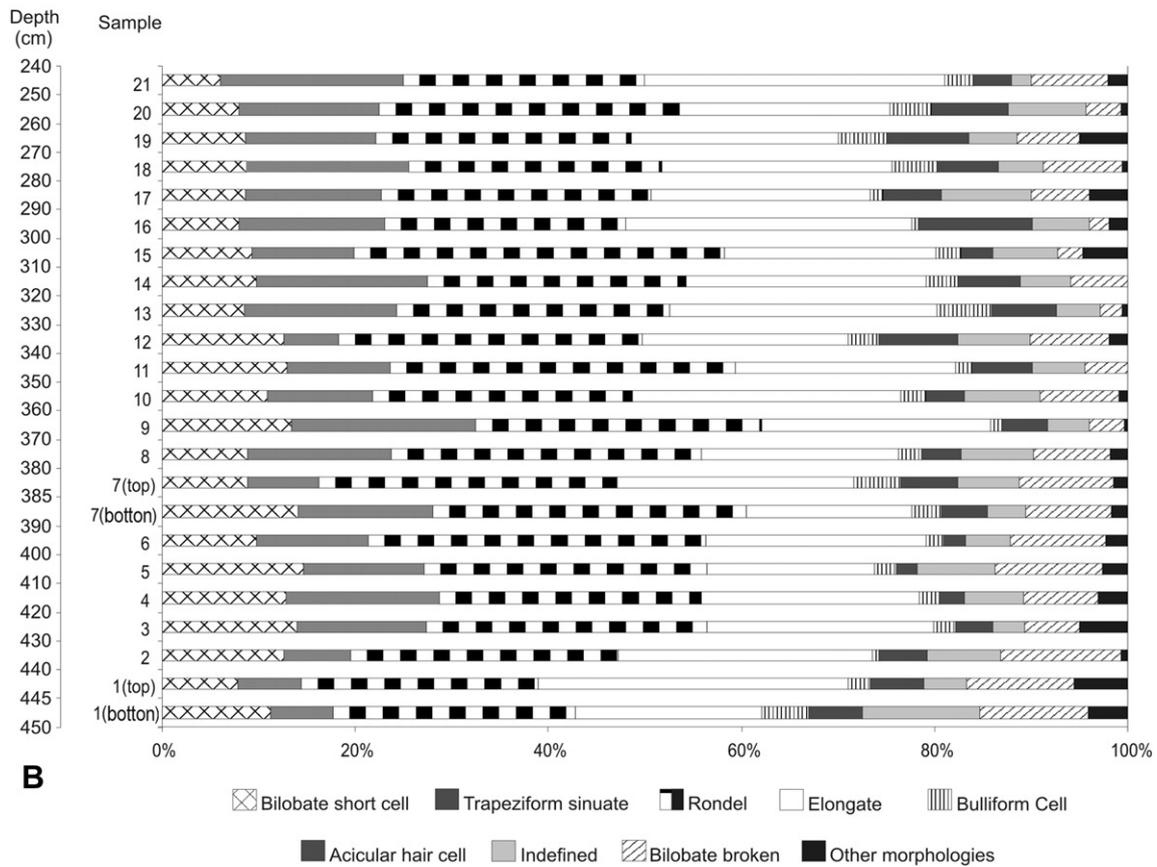
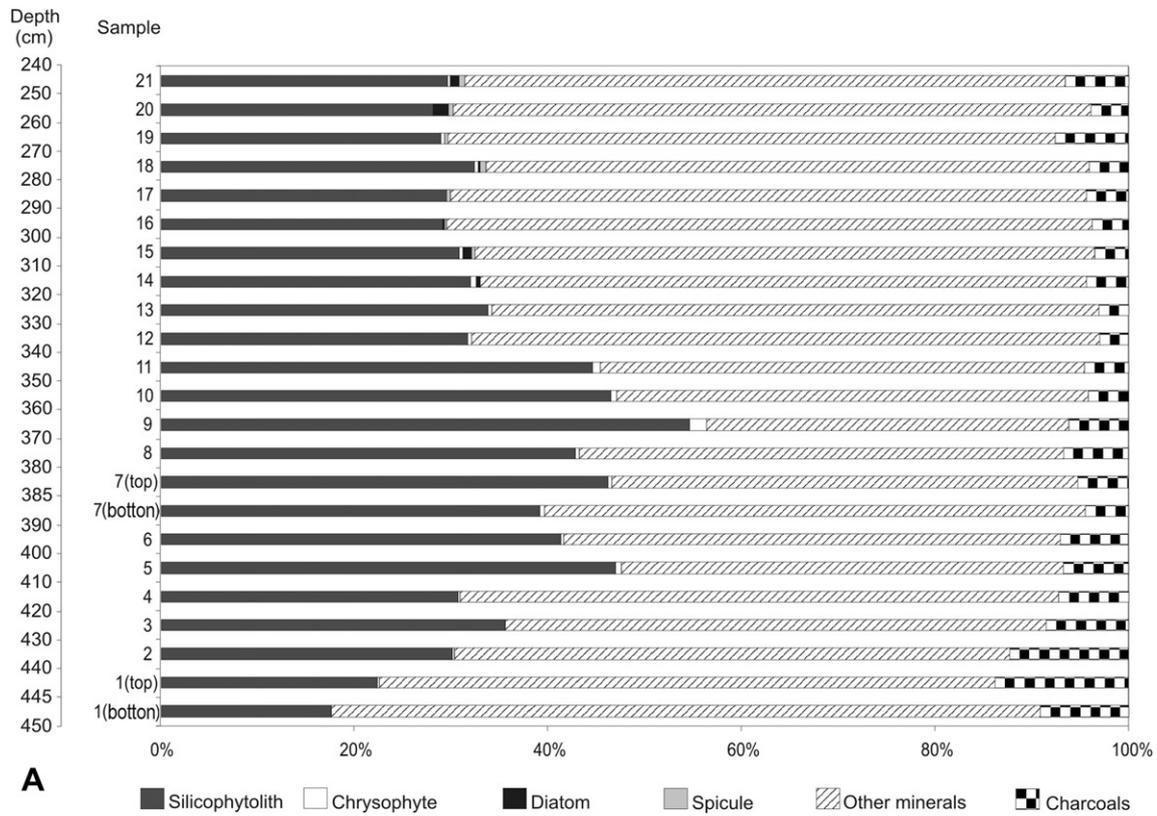


Fig. 3. Analysis of amorphous silica biomineralizations and charcoals. A) Silicophytolith, chrysophyte, diatom, spicule and charcoal content (% of the total mineralogical components of the soil). B) Silicophytolith predominant morphologies (% of silicophytolith fraction).

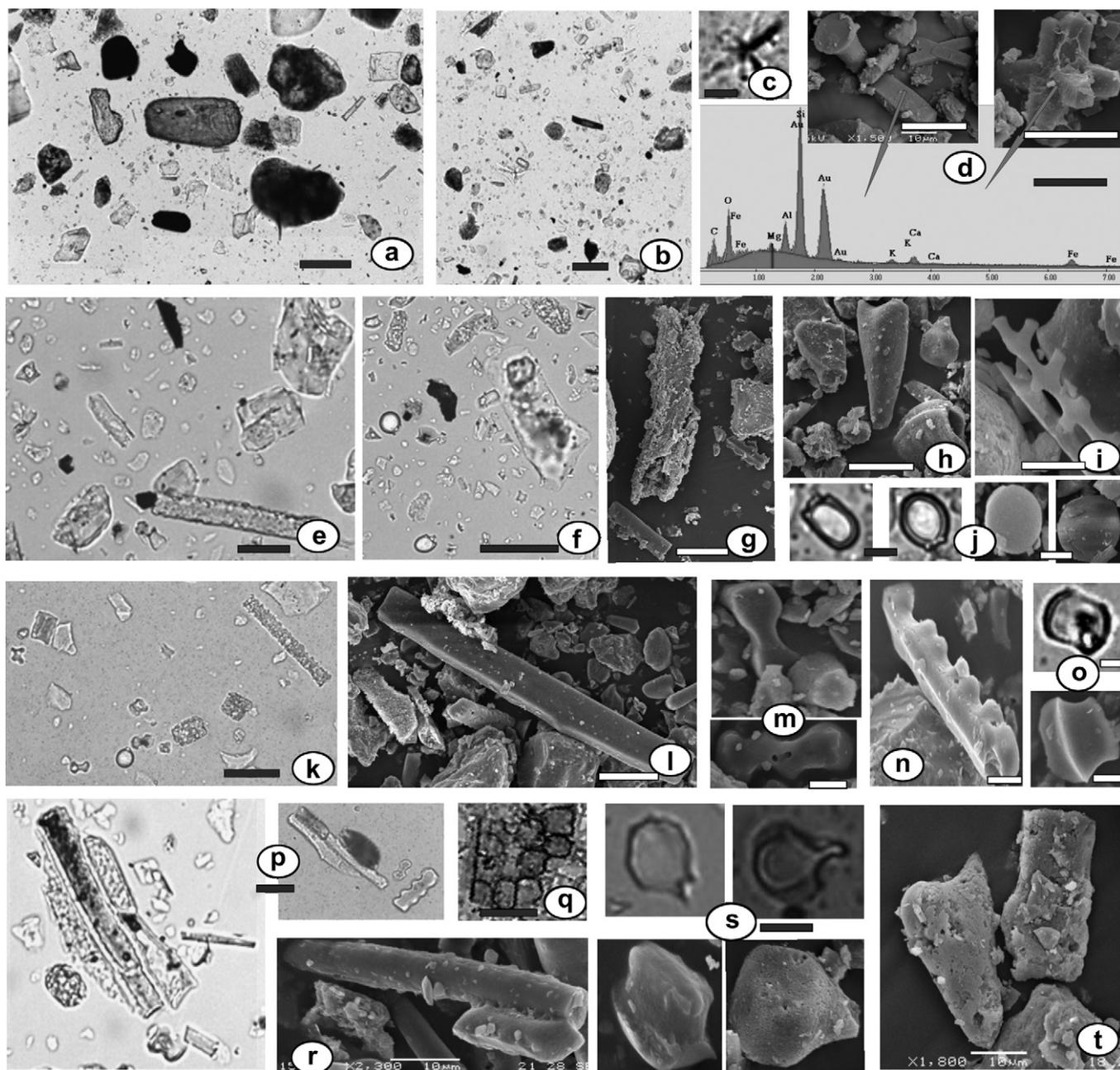


Fig. 4. Amorphous silica biomaterializations and charcoals recorded at Alfar archaeological site. a, b = panoramic view of heavy (a) and light (b) mineralogy, and silicophytoliths of unit I (OM), c = gypsum in the transition between units II and III (OM), d = staurolites in unit II (SEM and EDAX), e = panoramic view of charcoals and silicophytoliths of the boundary between units I and II (OM), f = panoramic view of silicophytoliths and chrysophytes in the unit III (OM), g = charcoals (SEM), h = silicophytoliths and diatoms of the boundary between units IV and V (SEM), i = spicules (SEM), j = detailed view of chrysophytes (OM and SEM), k = predominant silicophytolith morphologies: elongates, bilobates, cross, and chrysophytes (OM), l = elongates (SEM), m = bilobates silicophytolith (SEM), n = trapeziform sinuate silicophytolith (SEM), o = saddles (OM and SEM), p–r = silica skeletons composed of elongates and subepidermal cells (OM and SEM), s = broken bilobates (physical degradation, OM and SEM), t = weathered silicophytoliths and unidentified silicophytoliths (chemical degradation, OM). Bar: a, b = 100 μ m; c, j, m, n, o, s = 2 μ m; d, e, f, g, h, i, k, l, p, q, r, t = 20 μ m.

(Fig. 4h). In S17 (290–280 cm) there are no chrysophytes or diatoms, and only a few spicules (Fig. 4i) were observed. The top samples (S20–S21: 260–240 cm) only differ from the lower ones because of their higher diatom content, although not exceeding 3%.

In summary, the content of other amorphous silica biomaterializations (chrysophytes, diatoms and spicules) is very low in the whole sequence (Figs. 3A and 4). Chrysophytes represent about 0.3–1.7% of the total mineralogy and, although their distribution is

fairly uniform in the P3 profile, they are the only ones present from unit II to IV (from 445 to 320 cm), being more representative in samples 5, 9 and 11. Diatoms and spicules are present in the upper units of the profile (units V to VIII). Diatoms represent about 0.2–1.6% of the mineralogical components and, although S20–S21 (260–240 cm) are the samples with the highest content, they appear from 320 cm (S14) to 290 cm (S16). Spicules represent 0.2–0.6% of the total mineralogy, and appear from 310 cm (S15) to 240 cm (S21). The samples S15, S18 and S21 are the only ones containing, although in low proportion, spicules, diatoms and

chrysophytes in addition to abundant silicophytoliths. Black particles were observed in most of the samples, some of them opaque minerals, and charcoals the others (Fig. 4e,g).

Within the silicophytolith fraction, predominant morphologies are characteristic of the Poaceae family, rondels (23–38%), elongates (17–34%), trapeziform sinuates (1–19%), bilobate short cells (6–15%), acicular hair cells (2–12%) and bulliform cells (0.6–6%) being the most representative (Fig. 3B, 4l–n). Although there is a great homogeneity in the morphotypes throughout the profile, certain changes in the contents of some morphologies corroborate the changes observed from the quantitative analysis of silicophytoliths.

At 450–440 cm (S1), bilobate short cells, trapeziform sinuate and undefined silicophytoliths decrease towards the top level in the base of unit II, whereas elongates increase their content. At 430–420 cm (S3) globular equinates were observed. As in S1, at 390–380 cm (S7) bilobate short cells and trapeziform sinuate decrease to the upper level in unit III. In S9 (370–360 cm), which presents the lowest content of indefinite silicophytoliths and broken bilobate short cells, but silica skeletons are present, a higher environmental stability were also observed. In this sample from unit III there are saddles, a typical morphology of C4 plants (Fig. 4o), that could indicate drought periods of variable extension. This water deficit favours the concentration of alkaline salts that modify the soils, enabling the development of C4 communities. Although with a low representation, this chloridoid morphotype is present throughout the stratigraphic units I–VI. At 320–310 cm (S14) a change evident in the decrease of rondels and bulliform cell increase was observed. From 300 cm (S16) elongates and bulliform cells increases their content and, although some of them are not weathered, most are corroded or broken.

A notable aspect is the presence in unit III (S6, S7top, S9) of silica skeletons with grass affinity mostly composed by elongates and, in lesser proportion by short cells (Fig. 4p–r). In units V and VI (S14 and S17) sulcate tracheids were also observed. Another important aspect is the weathering state of silicophytoliths. In all the samples, the physical weathering was recorded as broken bilobate short cells (2–13%) (Figs. 3B and 4s). The chemical weathering was recorded on indefinite silicophytoliths (2–12%) and in silicophytoliths that, although they were classified, show different degree of weathering (Figs. 3B and 4t).

4.2. Analysis of gastropods

The malacological composition is represented by five species of gastropods (Table 3; Fig. 5): *Heleobia parchappii*, *Biomphalaria*

peregrina, *Zilchogyra costellata*, *Miradiscops brasiliensis* and *Succinea meridionalis*. The recovered shells are 792 and the abundance between both stratigraphic profiles is very similar, 383 in P1 and 407 in P2. In the two sampling profiles the most abundant corresponds to *B. peregrina*, followed by *H. parchappii*, *S. meridionalis*, *M. brasiliensis* and *Z. costellata*. The last one is recorded only in one of the two sampled profiles, in P1.

In relation to the abundance of each gastropod species some differences are observed throughout the stratigraphic sequence. In the first place, unfortunately in the deposits that contain the archaeological remains, at the base of the sequence, the record of gastropods or fragments of them is null. Secondly, the presence of molluscs is recorded at the top of the sequence, specifically in unit III since 370 cm in P1 and since 360 cm in P2. In P1 the higher abundance of molluscs is represented by aquatic species and taxa with a wide range of environmental tolerance, *H. parchappii*. Afterwards, the level with greatest abundance is the sample 12 (340–330 cm) as a consequence of the sudden increase of *B. peregrina*; after that a decrease of this species is observed. However, in the P2 *B. peregrina* is the only species recorded in S10 (360–350 cm) and the most abundance is recorded in S14 (320–310 cm) in the top of the sampling profile as result of an increase of *B. peregrina* and *H. parchappii*. The taphonomical analysis indicates signals of fragmentation in *B. peregrina* (S10) in P2. In units IV and V the remains of marine and freshwater shells show abrasion, high fragmentation and fragments with rounded edges.

4.3. Analysis of the archaeofaunal remains

In a previous paper (Bonomo and Leon, 2010) a brief exposition on surface of the archaeological materials was determined from the stages of weathering (stages 0 and 1 = 82%) of the bone remains. Additionally, 86% of the bones were included in stage 1 of geological abrasion, indicating that they were only affected in situ by water without giving rise to a subrepresentation of the sample. Root marks were observed in low proportions (13.2%), whereas chemical deposition corresponds wholly to specimens stained with manganese oxide (4.7%). In the same way, the scarce collagen content of the bones might be linked to the variations in the phreatic stratum (Bonomo et al., 2008). Therefore, this indicates that the archaeological materials were discarded in a water-containing context, a variable condition after they were buried, and they were subsequently quickly covered by sediments that were pedogenized.

Considering these variables in a vertical sense the following differences are observed (Fig. 6): 1) in unit II there is greater

Table 3
Malacological composition of Alfar Profile 1 (P1) and Profile 2 (P2).

Profile-sample	Depth (cm)	Unit	Species					Total	%
			<i>Heleobia parchappii</i>	<i>Biomphalaria peregrina</i>	<i>Zilchogyra costellata</i>	<i>Miradiscops brasiliensis</i>	<i>Succinea meridionalis</i>		
P1-S14	310–320	V	9	82	0	1	2	94	22.98
P1-S13	320–330	IV	0	84	0	5	0	89	21.76
P1-S12	330–340	III	0	123	0	3	0	126	30.81
P1-S11	340–350	III	0	21	0	0	0	21	5.13
P1-S10	350–360	III	0	4	1	0	0	5	1.22
P1-S9	360–370	III	59	5	0	4	6	74	18.09
Subtotal	–	–	68	319	1	13	8	409	–
P2-S14	310–320	V	61	102	0	0	6	169	44.13
P2-S13	320–330	IV	1	59	0	3	0	63	16.45
P2-S12	330–340	III	0	93	0	1	0	94	24.54
P2-S11	340–350	III	0	54	0	0	0	54	14.10
P2-S10	350–360	III	0	3	0	0	0	3	0.78
Subtotal	–	–	62	311	0	4	6	383	–
% Total of species			16.42	79.55	0.13	2.14	1.76	–	100.00

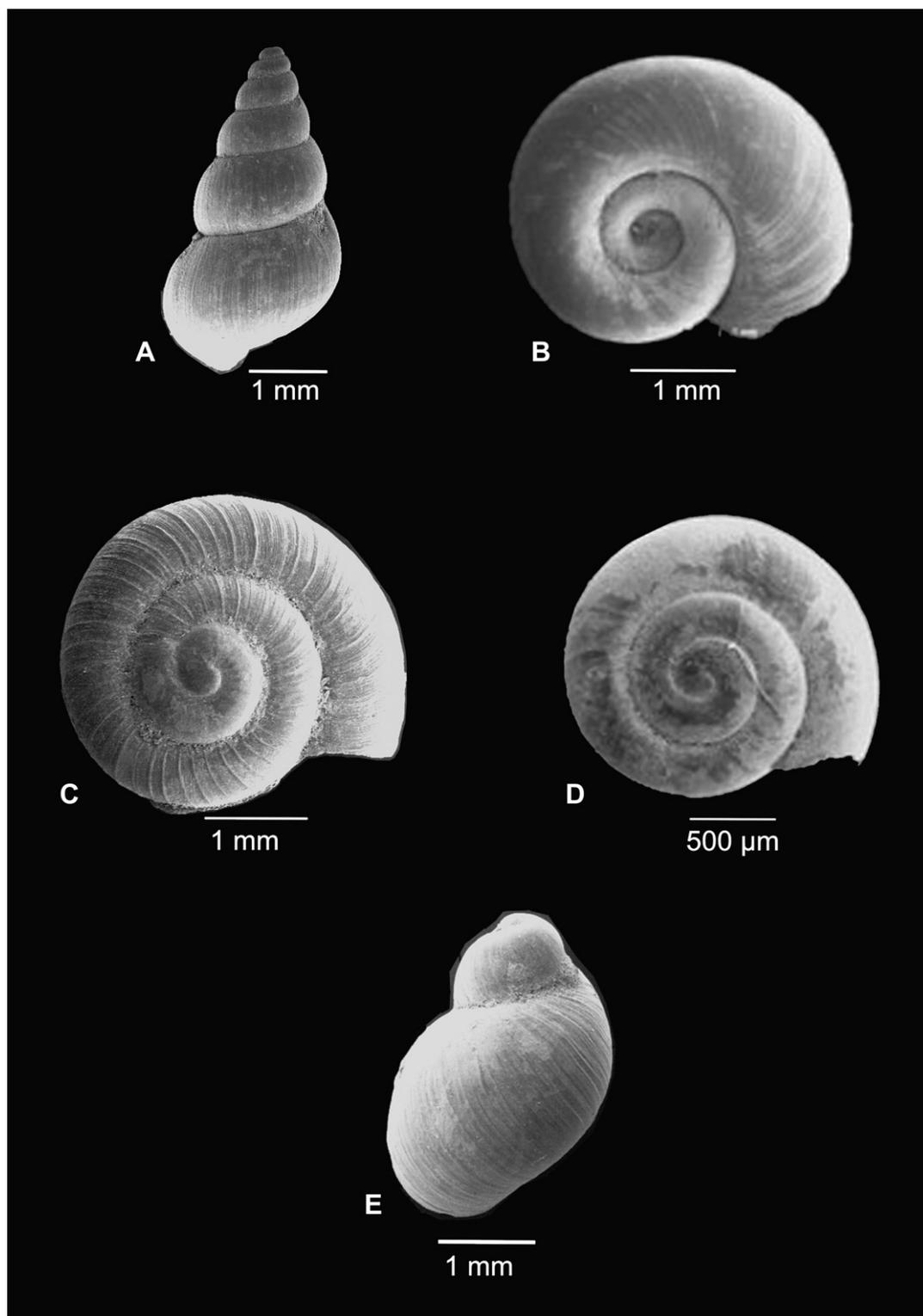


Fig. 5. Continental gastropods identified in Alfar A = *Heleobia parchappii*, B = *Biomphalaria peregrina*, C = *Zylchogira costellata*, D = *Miradiscops brasiliensis* and E = *Succinea meridionalis*.

weathering between 425 and 410 cm depth; 2) although abrasion is less between 445 and 415 cm, it is more intense (stage 1, 2, and 3 sensu *Gutiérrez and Kaufmann, 2007*); 3) the percentage of specimens showing root marks is higher between 440 and 420 cm (unit II), peaking at between 400 and 395 cm depth (base of unit III), 4) stage 1 abrasion is heavier between 415 and 385 cm in the top of II and the

base of unit III, and 5), manganese oxide is more frequent on the upper levels, especially between 420 and 395 cm depth.

Taking into account the taxa of the archaeofaunal record that provide palaeoenvironmental information on a local and regional scale, disparities are observed when bearing in mind their environmental requirements (*Table 4*). For the base of unit II

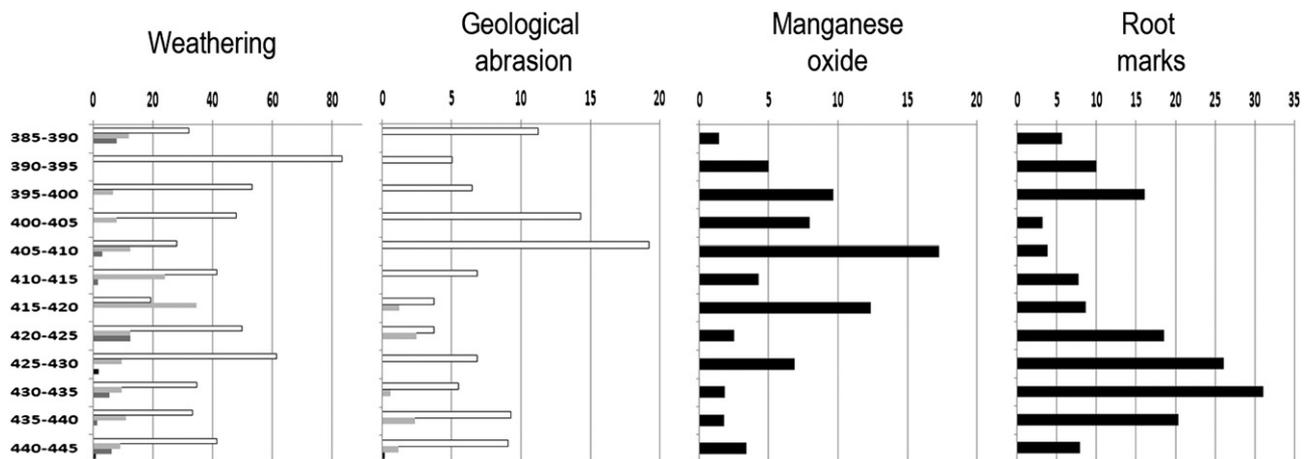


Fig. 6. Vertical distribution of relative frequencies for the four taphonomical variables. Note: Color of the bars, in weathering: white = stage 1, light grey = stage 2; dark grey = stage 3, black = stage 4; in geological abrasion, white = stage 1, light grey = stage 2, black = stage 3; in Manganese oxide and root marks, black indicates the presence of these variables.

(445–425 cm) the predominant species are *Ch. villosus*, *Tolypeutes matacus*, *Lagostomus* sp., *L. guanicoe*, *O. bezoarticus*, *Ctenomys* sp. and *H. brasiliensis*. Their distributions (Olrog and Lucero, 1981; Canevari and Balboa, 2003; Bárquez et al., 2006; Politis et al., 2011) and the environmental variations of their habitats (e.g., the water index, Burgos and Vidal, 1951, and mean annual temperature, Politis et al., 2011), indicate sub-humid dry regional conditions. On a local scale, the presence of the above-mentioned mammals, *Pontoporia blainvillei*, *Theristicus* sp., *Spheniscus* sp., indeterminate fishes, *Myliobatis* sp., and *Amiantis* sp. indicate multiple lateral facies from sea or estuary ones passing alongside the edges of bodies of water to steppes and prairies (Olrog and Lucero, 1981; Bastida and Rodriguez, 2003; Narosky and Yzurieta, 2003; Laita and Aparicio, 2005; Bárquez et al., 2006). The presence of *T. matacus*, *H. brasiliensis* and *P. blainvillei* suggests it will have been hot (Tonni et al., 1999; Jaureguizar, 2004).

For the top of unit II (420–405 cm) mammals once more indicate sub-humid dry conditions on a regional scale (*T. matacus*, *L. guanicoe*, *O. bezoarticus*, *Ctenomys* sp., Table 4), yet the representativity of *Ctenomys* sp. (57.7%), hints at the surrounding landscape having been one of dunes and sandy prairies according to its environmental requirements (Olrog and Lucero, 1981; Bárquez et al., 2006). At the same time the persistence of *T. matacus* might imply that the environmental temperature continued to be hot.

The taxa on the base of unit III (400–385 cm) indicate situations of wide-ranging regional humidity and temperature, though perhaps in sub-humid dry conditions (e.g., *L. guanicoe*). Contrarywise, the presence of Amphibia would be evidence of a local pool facies (Williams, 1991; Leynaud et al., 2006, Table 4). These results point to variations in water level, with drying out and flooding, and changes from marine environments to continental, and edges to beds.

5. Discussion

The integration between archaeological and paleoenvironmental studies of the diverse proxies analyzed in this paper allow the presence of water to be presumed in the whole stratigraphic sequence, though with drying-out/retraction, and flooding events. In general, concentrations and variations of amorphous silica biomineralizations (silicophytoliths, crysophytes, diatoms, and spicules) and malacological record mostly agree with the previously proposed evolution of the stratigraphic sequence (Bonomo and Leon, 2010). The presence of chrysophyte cysts throughout the sequence would indicate recurrent saturation levels, but during

short periods in which diatoms and sponge spicules become associated with these shallow-water bodies. The high content of silicophytoliths throughout the sequence is evidence of a continuous plant covering, predominantly of grasses, that will have supported an also continuous pedological development. The pedogenesis has mostly evolved under hydromorphic conditions, alternating with short periods of dryness. The first of these periods is recorded in the top of unit II, where archaeofauna also indicates sub-humid dry conditions during human occupation.

The content of charcoals is highest at the base of the sequence (top of stratigraphic unit I and base of II), which could be a product of water saturation as well as the combustion activities carried out by the humans who occupied the site in the past. Silicophytolith proportions increase in concordance with the initial settlement of humans and the anthropic introduction of useful plants.

Silica skeletons are easily disarticulated, and the presence of articulated silicophytoliths is a good indicator of environmental stability (Osterrieth et al., 2002, 2009). These articulates, smooth elongates and whole crenates, acicular hair cells with conspicuous points, bilobates, trapeziforms, all of them very well preserved, were found at the following depths: 445–440 cm, 410–400 cm, 385–380 cm, 370–360 cm, 330–320 cm, 300–290 cm, and 260–250 cm, which could identify those levels as surfaces stabilized for considerable intervals of time during the Holocene. Some could correspond to Entisoles and Hapludoles, typical soils on the banks of watercourses or bodies of water. The level with the most conspicuous pedogenesis is the middle sector of stratigraphic level III (370–360 cm). This paleosol has the largest articulated silicophytolith content, and the fewest broken bilobates, both evidence of higher environmental stability when humans abandoned the settlement and consequently stopped anthropic modification of the natural landscape.

In particular, the most representative silicophytolith morphologies correspond to C3 type sub-families. The bilobate short cells are characteristic of the Panicoideae sub-family, rondels of the Pooideae and Stipoideae sub-family, and the trapeziform sinuate to that of the Pooideae. The presence of C4 grass (saddle) silicophytoliths, although scarce, is found in all the units of the lower and middle sector of the profile, units I to IV, including the profile sector that contains the archaeological material. They indicate drought periods when the hydric stress might generate salts that condition the growth of typical C4 plants, related to climatic changes from damp and fresh to warmer and drier, although they could also be associated with local microtopographical modifications linked to the extent and

Table 4
Vertical distribution of the taxa in relative frequencies.

Depth (cm)	<i>Lama guanicoe</i>	<i>Ozotoceros bezaarticus</i> sp.	<i>Spheniscus sp.</i>	<i>Amiantis sp.</i>	<i>Chaetophractus villosus</i>	<i>Chaetophractus villosus</i>	<i>Tolypeutes maticus</i>	<i>Ducysson</i> cf. sp.	<i>Conepatius</i> sp.	<i>Pontoporia blainvilliei</i>	<i>Holochilus brasiliensis</i> sp.	<i>Lagostomus</i> sp.	<i>Ctenomys</i> sp.	<i>Theristicus</i> sp.	TELEOSTOMI	<i>Myliobatis</i> sp.	AMPHIBIA
385–390	6.5	14.28	11	0	1.3	0	0	50	0	0	0	0	4.6	0	3.75	0	33.33
390–395	0	0	0	0	0.7	0	0	0	0	0	0	0	1.6	0	0	0	0
395–400	0	0	0	0	0	100	0	0	0	0	0	0	11	0	0	0	33.33
400–405	3	14.28	11	0	0	0	0	0	0	0	0	2.4	6.3	0	0	0	0
405–410	6.5	0	0	0	1.4	0	0	0	0	0	0	2.4	17	0	0	0	33.33
410–415	16	0	5.6	0	0	10.5	0	50	0	0	0	5	25	0	3.75	0	0
415–420	6.5	14.28	0	0	0	0	0	0	0	0	0	2.4	9.4	0	3.75	0	0
420–425	6.5	14.28	0	0	0	5.3	0	0	0	0	0	0	6.3	0	12	0	0
425–430	3	14.28	11	0	0	10.5	0	0	0	0	0	2.4	11	0	12	100	0
430–435	6.5	14.28	5.6	0	0	31.6	0	0	0	0	0	15	3.1	0	19	0	0
435–440	6.5	14.28	5.6	0	0.7	10.5	0	0	0	0	50	30	1.6	0	3.75	0	0
440–445	39	0	50.2	100	95.9	31.6	0	0	0	100	50	38	3.1	100	42	0	0

morphodynamics of the body of water. These conditions of higher salinity and an increase in the pH at those levels might explain the high degree of corrosion of the silicophytoliths, particularly at the profile base (unit I). The abundance of broken but not corroded bilobate morphotypes is clear evidence of processes connected with the increase in the transport and mobility dynamics of these silicophytoliths as clastic particles in saturated mediums on the edges of lagoons.

The appearance of gastropods in the record is coincident with the boundaries of stratigraphic units III and IV over the archaeological levels (~370–330 cm). This difference between both sampling profiles could be related to slope of the landscape while corresponding to the same unit. In unit III, P1 malacological data at 370–360 cm depth indicate a shallow-water body and latter desiccation or evapotranspiration facies suggested by presence of calcium carbonate and species of *M. brasiliensis* (370–360 cm) and *Z. costellata* (360–350 cm); terrestrial species that live under vegetation cover in decomposition and humus. The highest chrysophytes content in this level corroborate the presence of a water body. The highest silicophytolith content and the more conspicuous presence of the saddle morphotype at this depth could corroborate the event of desiccation or evapotranspiration, allowing the development of C4 plant communities. Taphonomical characteristics and low abundance of gastropods in 360–350 cm depth suggest a level with alteration and allochthonous shells of *B. peregrina* in P2. At 350–340 cm depth there is a slight increase of individual of freshwater species in association with the evidence of high fragmentation of shells and abundant root concretions.

Malacological abundance and taxonomic associations indicate in 340–330 cm depth freshwater characteristics that could be related with shallow environments in both sampling profiles. From 330 to 310 cm, aquatic taxa of gastropods increase more in P2 than in P1 during soil development. This inference takes into account the presence of roots and micro mollusc punctoidea that inhabit soils with high humidity and percentage of plant cover (Miquel et al., 2007; Miranda and Cuezco, 2010). These results complement the inferences from phytoliths that also indicate the presence of a paleosol. However, among the taphonomical signals at the top of sampling sequence are a mixture of autochthonous and allochthonous malacological materials, possibly linked with a stream current and/or sea of higher energy that incorporated indeterminate fragments of marine molluscs.

In unit II and the base of unit III containing the archaeological materials, the gastropod record is nonexistent. Human occupation may have altered the natural conditions of the place and limited the development of microenvironments favorable to mollusc populations. The higher abundance of species and taxonomic diversity of mollusc at both profiles indicate that between units III and IV, different flooded sectors in irregular surface of the landscape are recorded, located on the archaeological deposits.

The taphonomical variables taken from faunal specimens represented in the archaeological occupation indicates that the materials were buried quickly and were subjected in situ to the influence of water. The taphonomical effects observed on bones of different taxa of unit II, and the sedimentary (Table 1) and silicophytolith analyses (Fig. 3) indicate a depositional context at the edge of an interdune lagoon, the water volume of which was subjected to alternate events of retraction and flooding. The abrasion observed on some remains was probably produced by waves in the body of water, on the banks of which vegetation developed leading to pedogenesis.

The recorded fauna is diverse and from different habitats, which reflects past human selection. Estuarine and continental taxa are represented, from dry environments as well as humid and associated with high temperatures. The high frequency of *Ctenomys* sp.

and the record of moderately weathered specimens on the top of unit II would indicate the drying out of the body of water and a decrease in the rate of sediment deposition compared to previous and later levels.

The context of a lagoon edge seems to be modified on the top of unit III. The smaller proportion of specimens with root marks, the greater abundance of remains with abrasion, the decrease in the deposition of manganese oxide (maybe in a saturated medium in water under conditions of anoxia, Dorn and Oberlander, 1981), the higher content of organic matter in muddier sediments (Table 2), and the presence of Amphibia indicate that the presence of water lasted longer compared with unit II. This context coincides with the environment transformation on the bottom of a lagoon, which could be correlated with the lack of later human occupation of Alfar.

6. Conclusions

In summary, the results of the palaeobotanical analyses, complemented with the archaeofaunal and sediments studies, show the existence of a considerable pedogenetic activity and a permanent cover of gramineous communities on a lagoon edge with a certain margin of wave activity. The existing vegetation corresponded mainly to communities of grasses (Poaceae), less so Panicoideae, Stipoideae and limited Chloridoideae. This place with abundant grasses at the water-edge was chosen by the Pampean hunter-gatherers to set up a residential camp around 5700 years ago. **During the human occupation the volume of water appears to diminish, salt-concentration increased, and C4 type grasses are recorded.** After the settlement was abandoned, water covered the occupation surface and, just as before it was occupied, saturated, anaerobic, and reducing conditions occurred.

In general, the obtained data indicates that the human populations occupied Alfar site under dryness conditions, but with warm climate at mid-Holocene. From this time of the Holocene (6000–5000 BP), marked by important climatic changes, there are few archaeological sites in the region. Nevertheless, new Pampean sites dated within this period have been recently detected (Bayón et al., 2010; Gutiérrez et al., 2011; Massigoge, 2011), showing that there is no pronounced gap or hiatus in the archaeological record as in other regions across South America. The differences in the quantity of sites from former and later periods may be due to the location of the hunter-gatherer settlements on specific environments, such as the Atlantic coast where marine resources were available and also related to problems of reduced visibility and low preservation. The evidence from Alfar is connected with the radiocarbon dates recently obtained for other archaeological sites, and human skeletons buried in the coast under study (Bonomo, 2011; Bonomo et al., 2011) that range from 7623 to 430 BP and show a continuity in the use of the Interserrana coast since the Early Holocene until the arrival of Europeans in the Río de la Plata.

Mid-Holocene was a period marked by global, but not uniform, significant changes in precipitation, temperature, sea-level, faunal distribution and/or vegetation cover that affected past human populations in different degrees (see discussion in Anderson et al., 2007a). These climatic changes had different effects on the availability of water, animals and plants utilized by humans around the world. During this period, warmer than the Early Holocene and the Late Holocene, Pampean hunter-gatherers continued the occupation of the region, apparently without drastic cultural changes. However, after the mid-Holocene, a reorientation of the hunter-gatherer subsistence in detriment of marine resources occurred (Bonomo et al., 2011). In contrast to many other coastal areas of the continent (e.g., Moss et al., 2007; Anderson et al., 2007b; Bonomo, 2011), when aquatic ecosystem stabilized after mid-Holocene in the Pampean Atlantic coast there is no evidence of intensive use of

marine fauna (shellfish, fish, and sea mammals). On the contrary, the exploitation of marine resources declined in the Late Holocene, and there is a focus of the diet on continental resources, especially on terrestrial mammals.

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Appendix. Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.quaint.2012.03.039.

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