Geoarchaeological and Paleoenvironmental context of the human settlement in the Eastern Tandilia Range, Argentina

Gustavo A. Martínez, Diana L. Mazzanti, Carlos Quintana, Alejandro F. Zucol, María de los Milagros Colobig, Gabriela S. Hassan, Mariana Brea, Esteban Passeggi

PII: S1040-6182(12)03399-X
DOI: 10.1016/j.quaint.2012.12.032
Reference: JQI 3604

To appear in: *Quaternary International*

Please cite this article as: Martínez, G.A., Mazzanti, D.L., Quintana, C., Zucol, A.F., Colobig ¸, M.d.l.M., Hassan, G.S., Brea, M., Passeggi, E., Geoarchaeological and Paleoenvironmental context of the human settlement in the Eastern Tandilia Range, Argentina, *Quaternary International* (2013), doi: 10.1016/j.quaint.2012.12.032.

Geoarchaeological and Paleoenvironmental context of the human settlement in the Eastern Tandilia Range, Argentina

Gustavo A. Martínez [a,b]*, Diana L. Mazzanti*[b]*; Carlos Quintana*[b]*, Alejandro F. Zucol*[c]*,*
María de los Milagros Colobig[c]*,, Gabriela S. Hassan*[d]*, Mariana Brea*[c]*, Esteban Passeggi*[c]

[a] Instituto de Geología de Costas y del Cuaternario, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata, Funes 3350, 7600 Mar del Plata, Argentina. gamarti2003@yahoo.com.ar

[b] Laboratorio de Arqueología Regional Bonaerense, Universidad Nacional de Mar del Plata, Argentina

[c] Laboratorio de Paleobotánica, CICYTTP-Diamante CONICET, Materi y España s/n, Diamante, 3105, Entre Ríos, Argentina.

[d] Instituto de Investigaciones Marinas y Costeras (IIMyC), FCEyN, CONICET-Universidad Nacional de Mar del Plata.

Abstract

The Tandilia range is a discontinuous series of hills and valleys located at the central area of the Pampean region (Argentina). The process of human settlement reached in this zone the highest population densities and reoccupation levels of Southern South America, developing under the strongly changing climatic conditions that characterized the Pleistocene-Holocene transition. This paper analyzes the geoarcheological and paleoenvironmental record of the Pleistocene-Holocene transition (c. 9400-10,500 ^{14}C BP) recovered from cave and rockshelter sedimentary successions of the Tandilia range. The analysis of several lines of evidence (stratigraphic, geoarchaeological, archaeological, zooarchaeological, and paleobotanical), suggests that a cold arid to semi-arid climate characterized the late Pleistocene (c. 10,500 BP), and changed abruptly to warmer conditions towards the beginning of the Post-Glacial Period. As a consequence of this climatic amelioration, the populations inhabiting the Tandilia range would have been benefited by a higher availability of resources, which could explain the higher levels of site density and reoccupation found in the area during this period.

Keywords*: early human settlement, pampean region, Argentina, paleoindian, Pleistocene/Holocene*

1. Introduction

Although the process of human occupation of the Pampean region began c. 12,100 ^{14}C BP (Politis, et al., 2004; Steele and Politis, 2009; Prates, et al., 2011), most archaeological evidence is found between c. 11,000 and 9600 ^{14}C BP. During this period, a wide variety of pampean sub-environments became fully occupied. The highest human population densities were registered in the eastern Tandilia range (Mazzanti, 2003; Flegenheimer, et al., 2006; Mazzanti, et al., in press) and, in a lesser extent, in the contiguous Interserrana Plain (Martínez, 1999; Politis, et al., 2004) (Figure 1).

The region studied in this paper comprises the eastern Tandilia range (Figures 1 and 2), an area characterized by hills, isolated rocky outcrops, and extensive table-form massifs with interior valleys. Given their geomorphological characteristics, these hills would have constituted a very suitable environment for human settlement, particularly during the periods of cold and dry climate that characterized the Pleistocene-Holocene transition. The most important benefits offered would have consisted in a wide visual domain over the surrounding landscapes, the presence of abundant freshwater sources, and the proximity to the Atlantic Ocean, with the consequent increased biodiversity, which included flora and fauna both of continental and coastal origin. In this context, the hydrological catchments would have acted as a nucleus for attracting human groups, as it occurred in the most important river of the region, the Quequén Grande river (Martínez, 1999; Gutierrez and Martínez, 2008; Martínez *et al.*, this volume). Palynological evidence also suggested that these micro-environmental conditions would have favoured the development of extensive grasslands (Prieto, 1996; Quatrocchio et al., 2008) inhabited by herbivorous animals, that eventually became important for hunting and settlement for specialized or domestic tasks.

The earliest occupation levels registered in the caves and rockshelters, dated between c. 10,500 and 9600 ^{14}C BP, were recurrently found over a notable stratigraphic discordance that indicates a change in depositional and post-depositional processes (Martínez, 2007). The end of the Pleistocene was also characterized by a continental-scale massive extinction of megamammals (Martin, 1984; Politis, et al., 1995; Haynes, 2006). In the Tandilia range and surrounding areas, this extinction occurred at the end of the Pleistocene and affected most of the big herbivorous species utilized by humans, leading to a decrease in the diversity of potential preys, as is reflected in the archaeological records at Cueva Tixi and Cueva El Abra. However, human subsistence was not severely affected, since populations maintained a generalist pattern that prevailed throughout the early Holocene (Quintana, 2001).

The high concentration of archeological sites observed in the Tandilia microregion enhances the importance of this area for the study of the processes of early settlement in the

Pampean region. Besides the nine sites presented in this work (Figure 2), a total of eight rockshelter and open-air sites have been already studied in the adjacent central-eastern sector of the Tandilia range (Flegenheimer et al., 2006; Prates et al., 2011). As a whole, this diversity of sites demonstrates the functional variability and the types of settlements that characterized early human populations in this region. These earliest settlements would have developed under fluctuating paleoclimatic conditions (Politis et al., 2004; Martínez, 2006; Grill et al., 2007) similar to those described for southern Patagonia between 12,000 and 11,000 ^{14}C BP (Miotti and Salemme, 1999, 2003; Borrero, 2003).

In this paper, the stratigraphic and paleoenvironmental context of nine sites attributable to the initial human population of the eastern Tandilia range are discussed. The archaeological sites studied include Cueva Tixi, Abrigo Los Pinos, Cueva El Abra, Cueva La Brava, Cueva Burucuyá, Lobería I Sitio 1, and Amalia Sitio 2, as well as two small rockshelters, El Mirador and Abrigo La Grieta, where excavations have been recently initiated (Figure 2). The main objective is to analyze the paleoenvironmental conditions prevailing in the region during the settlement process, through the analysis of several types of proxy records, which include geoarchaeological, zooarchaeological, archaeological, paleobotanical (charcoals), and microfossil (diatom and phytolith) data. The studied records have been recovered from stratified sediments located at the base of the sequences of caves and rockshelters. These circumstances optimized the discovery of cultural contexts with good integrity and favoured the use of several proxy data.

Although research is still in progress, the information provided in the present contribution becomes of great value in order to address questions of local and regional interest regarding the dynamics of human population in the Pampean region: What was the geographical significance of the Tandilia range in the process of human settlement? Why did human occupation develop so intensively after c. 10,500 ^{14}C BP? Moreover, this contextual framework of the social dynamics of the area poses more general questions related to the initial population of Southern South America, particularly the Atlantic region, which lead to the question: How where the prevailing paleoenvironmental conditions and landscape during the earliest human occupation of the eastern Tandilia range?

2. Material and Methods

Allostratigraphic units of caves and rockshelters were defined based on their sedimentary characteristics (texture, color, types of limits and structures) and pedogenetic features. Particle size analysis was performed by sieving and pipetting. Organic carbon content was determined by the Walkley and Black method (Walkley and Black, 1934), and pH was measured with a pH-meter in a suspension with a soil/water ratio of 1:2.5. Radiocarbonic dates were performed both through the ^{14}C conventional and Accelerated Mass Spectrometer (AMS) methods (Table 2).

Diatom analyses were conducted on the Loberia I, Cueva Tixi and Cueva El Abra sequences. In each site, sediment samples were collected following the defined allostratigraphic units. Samples were processed through standard methodologies (see Hassan et al., 2009) and permanent drop slides were made with Naphrax®. On each slide at least 300 diatom valves were counted in random transects using a magnification of 1000X. The species were characterized according to their ecological requirements, and particularly moisture preferences, following McMillan and Rushforth (1985); Van Dam et al. (1994); Johansen (1999); Lowe et al. (2006) and Poulíčková y Hašler (2007). Constrained incremental sum of squares cluster analysis (single linkage, Euclidian distance) was performed on diatom percentages to define diatom zones in the fossil sequences using the computer program TILIA CONISS (Grimm, 2004).

Detailed phytolith analysis were conducted in a representative profile of Loberia 1 site 1, and then compared with selected samples from the lower section of Cueva Tixi archaeological site, in a chronological lapse between 10.375 $^{\pm}$ 90 and 7.700 yr B.P. The samples were processed using standard wet oxidation and heavy flotation techniques (with sodium polytungstate solution, specific gravity 2,345) following Zucol, et al. (2010a and b); while morphotype assignation and counting were made according to the descriptive scheme of Zucol et al. (2010c). The phytolith diagram was performed using POLPAL, Numerical Analysis programs (Walanus and Nalepka, 2002), and comparative cluster analysis were conducted using PAST (Paleontological statistics software, Hammer, et al., 2001).

The archaeological charcoals were identified by examining freshly fractured surfaces (cross, radial and tangential sections) using reflected light. They were identified using standard wood key, wood atlases and descriptions by Metcalfe and Chalk (1950), Tortorrelli (1956), Tuset (1963) and InsideWood database (2004-onwards). The terminology for the wood features follows the IAWA Lists of Features Suitable for Harwood Identification (IAWA Committee, 1989). Charcoal remains were compared to extant species, particularly present-day taxa from the Eastern edge of the Tandilia Range (Buenos Aires, Argentina). The collected remains were deposited in the Colección Científica del Laboratorio de Arqueología de la Facultad de Humanidades, Universidad Nacional de Mar del Plata.

3. Study Area and Stratigraphic Context

The climate is humid-temperate with a mean annual precipitation of 979 mm (for the last 20 years) and mean temperatures of 20°C in January and 7°C in July (Romanelli et al., in press). The potential evapotranspiration values estimated for the same period by the Thornthwaite method, ranged from 696 to 766 mm/year, with an average of 740 mm/year (Kruse et al., 1997).

Two mountain ranges are present in the southern Pampean region: Ventania in the southwest (maximum height: 1,243 masl), and Tandilia in the northeast (525 masl; Figure 1). The two ranges are separated by the Interserrana Plain, an extensive plain filled by continental Cenozoic deposits, with a maximum altitude of 200 masl (Figure 1). The eastern Tandilia range constitutes a group of table-like hills of flat summit, composed of lower-Paleozoic sub-horizontal quartzite strata (Balcarce Formation, Dalla Salda and Iñiguez, 1979). The hills that form this portion of the range present maximum elevations of c. 300 masl, they are elongated in an east-west direction, and end in the Atlantic Ocean. They are separated by wide valleys and undulated plains (Figures 1 and 2). The late Pleistocene-Holocene sediments that cover the intermountain and plain areas are sometimes present in the horizontal summits of the main ranges. These deposits are composed of loess or reworked silt of aeolian and volcaniclastic origin (Teruggi, 1957; Tricart, 1973).

Most of the analyzed archaeological sites of eastern Tandilia are located in caves and rockshelters developed on quartzite cliffs near to the ranges summits. In some cases, however, these are located in low quartzite rocks outcropping in the Interserrana Plain (Figure 2). The origin of these cavities has been attributed to dissolution processes of the siliceous cement on quartzites, occurred during wet periods during the Cenozoic (see Martínez, 2007, and references therein). Although caves and rockshelters are known as highly efficient sediment traps (Colcutt, 1979), in Tandilia only a few of them present sedimentary matrices. The infilling material can be both endogenous, derived from ceiling and wall by dissolution, physical weathering and collapse; or exogenous sediments, mainly composed by primary or reworked loess blown in by the wind or carried by running water (Table 1). Dissolution of quartzite can be very important in the endogenous processes since quartz sandy sediments constitute a significant percentage of the stratigraphic sequences of some caves (i.e.; up to 90% in Los Pinos and Cueva Tixi; Martínez et al., 1999).

The development of the late Pleistocene-Holocene sedimentary matrices of the caves and rockshelters is very variable, ranging from 0.40 to 2 m (Figure 3). These deposits are usually graded beds, indicating a decrease in energy from the late Pleistocene to the late Holocene.

Early human occupations in eastern Tandilia sites are dated between 9570 and 10,672 ^{14}C BP (see Table 2). These archaeological levels are located immediately above erosional or depositional stratigraphic unconformities (Figures 3 and 4). These discordances separate the coarser and stone-rich Pleistocene sediments from the sandy-clayed Holocene silts (Figure 3). The presence of these coarse angular rock fragments has been related to mechanical weathering processes linked to the cold and arid climatic conditions (e.g. Tonni and Fidalgo, 1978; Prado et al., 1987; Alberdi et al., 1989; Bonadonna et al., 1999; Martínez, 2001) that characterized the Last Glacial Maximum (IOS 2; Martínez, 2007). There are also distinct colour changes between sediments located above (brown-gray, 10 YR 5 / 2) and below the unconformities (very pale brown, 10 YR 7 / 4) (Martínez et al., 1999; Martínez and Osterrieth, 2003).

Holocene sediments show typical signs of humid conditions, like pedogenetical modifications (i.e. Los Pinos and Cueva Burucuyá) and diatomaceous levels (i.e. Cueva Tixi, Cueva La Brava, Cueva Burucuyá). Moreover, in most of the profiles the organic matter content was higher in Holocene than in late Pleistocene sediments (Table 1). pH varied between 3 and 5 (the only exception was Cueva Tixi, where it ranged between 7 and 8; Martínez et al., 1999; Martínez, and Osterrieth, 2001), which may explain the low preservation of bones in these sites.

4. Archaeological Context

This section summarizes the results of the archaeological studies performed on the nine sites mentioned above, which are representative of the functional variability of the local system and provides information about the early settlement of hunter-gatherer groups in the Tandilia range valleys. Three of the analyzed sites showed evidence of residential occupation (Cueva Tixi, Cueva El Abra, and Abrigo Los Pinos), particularly through a repeated use of their interior chambers for a variety of activities related to residential settlement. The archaeological records from the other four sites (Cueva La Brava, Cueva Burucuyá, Amalia Sitio 2, and Lobería I Sitio 1) indicated only occasional utilization, and presented lower amounts of archaeological materials (Mazzanti, 2003; Mazzanti et al., 2010). The two most recently excavated sites (Cueva El Mirador and Abrigo La Grieta), preliminarily assigned to the Pleistocene-Holocene transition because of their stratigraphic characteristics and the nature of the archaeological materials assemblages, evidenced a more specific set of activities that were complementary to the functions of the surrounding sites.

Six sites were situated on the same hill, with five of these located in the valley of Arroyo La Vigilancia, at a very short distance from each other (Figure 2). This proximity has allowed addressing the mobility patterns of domestic groups, in terms of the repeated use of these strategic local sites on the landscape. The archaeological evidence analyzed includes lithic artefacts and mineral pigments collected in all sites, materials from bowl-shaped combustion structure found in three sites (Cueva La Brava, Cueva Burucuyá, and Abrigo Los Pinos), and an abundant and diverse assemblage of well preserved faunal remains found in Cueva Tixi (Mazzanti, 1997, 1999, 2003; Quintana, 2001).

Studies of lithic technology integrated information about the diversity of transported stones used in various stages of artefacts production (Valverde, 2002, 2003, 2004). Some patterns for the procurement of raw material and the mobility strategies, that characterized the social circuits of interactions among these ancient populations, can now be proposed (Mazzanti, 2003). The results are in general agreement with the modalities of stone material procurement proposed by Bayón and Flegenheimer (2004) for the Pampean region, which involve carrying and possible visits to procurement source areas (Tandilia, Ventania, and the Atlantic coast) by highly mobile groups. Some of the artefacts found in the Tandilia sites were made with a red silicified limestone, a material that could have originated in Uruguay (Flegenheimer et al., 2003, Bonomo and Blasi, 2010). The presence of artefacts made from this type of stone could reflect the extensive social interaction space within which these initial human settlement groups developed.

Artefacts recovered at sites with evidence of residential activities indicated a strong tendency toward the exploitation of local stones (medium- and coarse-grained orthoquartzites from the Balcarce Formation. The only exception was Cueva Tixi, where allocthonous stones predominated (fine-grained orthoquartzites from the Sierras Bayas Group). These patterns reflect important aspects of the technological decisions made by these early groups and provide evidence about their mobility patterns within the mountain range system. Rocks from Barker (Sierras Bayas Group) (Figure 1) were exploited to obtain fine orthoquartzites and mineral pigments (Porto López and Mazzanti, 2010). These raw materials were transported in a variety of forms (nodules, cores, flakes, tools) to sites located more than 70 km away. Movements to the Atlantic coast were also inferred around 11,000 ^{14}C BP, based on the presence of basalt cobbles and silica stones collected from beaches about 60 km away. To the west, outcrops of andesites, silicas, ftanites, silicified dolomite stone, and other types of rocks are found. Towards the south, in the Ventania mountain range, sources of rhyolites and meta-quartzites are found (Bayón et al., 1999). All these stone types were identified in very low proportions in assemblages from the nine sites, mainly in waste flake deposits. Their presence indicates a profound level of knowledge on stone sources, both within and beyond the Tandilia range system. More ephemeral or re-occupied sites also indicate that small, very mobile groups developed multiple, diverse settlements with high levels of functional variability and predominant use of local resources.

5. Faunal Remains

The zooarchaeological record from eastern Tandilia comprises materials from the Cueva El Abra and Cueva Tixi sites, although only the later contains abundant and well-preserved remains (Quintana, 2004; Quintana et al., 2003). The Cueva Tixi record consists of 4,149 bone specimens identified to various taxonomic levels, including 33 species-level assignments (this number is approximate since the small bird remains were not identified) (Table 3). Nine of these species showed evidence of human activity, such as fractures, cut marks, or manufacturing of bone artefacts. Most of the species not utilized by humans were transported to the cave by birds during periods without human occupation. These birds created a deposit of pellets, from which 2,423 microvertebrate bones were recovered (caviomorph and cricetid rodents, marsupials, and birds). These bones showed a good preservation, with moderate fragmentation and little evidence of alteration by digestion.

The sample from Cueva El Abra is poor and only consumption of the deer *Ozotoceros bezoarticus* could be identified. Indeterminated fragments of ungulate bones were also present, indicating an intense alteration of the skeleton. The occupants of Cueva Tixi developed a generalized subsistence strategy (Quintana and Mazzanti, 2001). Resources exploited included high-rank taxa such as guanaco (*Lama guanicoe*) and deer (*Ozotoceros bezoarticus*); low-rank taxa such as vizcachas (*Lagostomus maximus*), coypos (*Myocastor coypus*), ñandú (*Rhea* sp.) eggs, and three species of armadillos (*Chaetophractus villosus*, *Dasypus hibrydus*, and *Zaedyus pichyi*); and intermediate-rank taxa such as the ñandú and a giant extinct armadillo (*Eutatus seguini*) (Table 3) (Quintana and Mazzanti, 2001).

Caviidae rodents, lizards, and medium-sized birds were available in the landscape during the late Pleistocene (and were recovered from Paleoindian levels), but were only incorporated into the subsistence system during the Late Holocene. In contrast with sites on the Interserrana Plain, in these mountainous sites megamammals were not recorded, although their presence in natural Late-Pleistocene strata confirms their presence in the area. Three species recorded for this period, *Eutatus seguini*, *Dusicyon avus* (a large fox), and *Galea tixiensis* (a wild cavy) became extinct during the late Pleistocene, the Middle Holocene, and the Late Holocene, respectively. A fourth species, *Monodelphys* sp., possibly became extinct during the Late Holocene (Goin, 2001). The faunal assemblages from these late Pleistocene levels contained some species considered to have value as climate indicators. However, there are also non-analogous associations present that demonstrate the co-existence of species from arid environments (*Lestodelphys halli*, *Zaedyus pichiy*, and *Dolichotis patagona*) and sub-tropical environments (*Cavia aperea*, *Monodelphys* sp., *Dasypus hybridus,* and *Oxymycterus* sp.) (Quintana, 2001; Goin, 2001).

A third Paleoindian site, Cueva Burucuyá, lacked faunal remains associated with the early human occupation. Underlying the archaeological level, dated between to 10,000 – 10,672 BP, a lower stratum presented a markedly uneven upper surface that contains deep ichnites from megamammals, which cover the entire excavated area (Quintana et al., 2001) (Figure 4). This assemblage of footprints forms the base of the stratum in which the archaeological materials were found.

6. Palaeobotanical Record

This section presents an overview of the results of the palaeobotanical studies carried out in the studied sites. As these studies are currently in progress, analysis will focus only on the sequences were the Pleistocene-Holocene transition has been analyzed in detail. Stratigraphic diagrams showing the distribution of the paleobotanical indicators along the complete sequences are presented, in order to provide an historical framework for the discussion of the changes inferred for the Pleistocene-Holocene transition.

6.1. Diatoms

Diatom communities respond quickly to environmental changes and are composed of a large number of species with different tolerances to physical and chemical variables. Consequently, they are well-established indicators for both monitoring present changes in water condition, and tracking past environmental changes through the analysis of the assemblages preserved in sediments (see Smol and Stoermer, 2010). In Argentina, continental diatoms have been used to infer paleoenvironments in southern (Zárate et al., 2000; Hassan et al., 2004), and western Pampas (González and Maidana, 1998), and Patagonia (Markgraf et al., 2003; Mayr et al., 2005).

Diatom studies were carried out in three of the sites studied in the present contribution: Lobería I, Cueva Tixi and Cueva El Abra. The Lobería I sequence was dated between c. 9800 to 160 ^{14}C BP. A total of 35 diatom species were identified, from which only 13 reached relative abundances >2% in at least one sample and were plotted (Figure 5). Cluster analysis allowed dividing the sequence into two three diatom zones (Figure 5), from which the first one (Zone I, units 7 to 5E) comprised the Pleistocene-Holocene transition. The four samples grouped into this zone were dominated by different diatom assemblages, which could be indicating fluctuating environmental conditions for this moment. Unit 7 was dominated by *Diadesmis gallica,* accompanied by *Nitzschia hantzschiana*. *D. gallica* is frequently confined to the surface of caves, mosses, and neutral to slightly alkaline soils, being able to grow under low light intensity (Johansen, 1999). Unit 6B was dominated by *Melosira* sp., together with *Diadesmis contenta* and *N. hantzschiana*. Unit 6 A was characterized by a high abundance of *N. hantzschiana*. Unit 5E was dominated by *Pinnularia borealis* and *P. subcapitata*. Those taxa inhabit environments with higher water content, in some cases attached to moss surfaces, and are absent in strictly aerial substrates.

Eight samples, corresponding to levels B to F, were studied in Cueva Tixi. These levels were dated to between c. 10000 and 700 ^{14}C BP (Martínez, 2007). A total of 35 diatom taxa were identified, from which only 13 reached frequencies ≥ 2% in at least one sample (Figure 6A). Three diatom zones were defined according to cluster analysis. Zone I, located at the base of the sequence, comprised the Pleistocene-Holocene transition. This sample was dominated by *Denticula elegans* and *Nitzschia hantzschiana*, and indicates low water availability in the environment, as is dominated by taxa highly tolerant to dissecation.

Five sediment samples were studied in Cueva El Abra, corresponding to units 4 to 1, ranging from c. 9800 to 960 ^{14}C BP (Martínez, 2007). Twenty four diatom taxa were identified in the remaining sedimentary units, from which only 11 reached frequencies ≥ 2% in at least one level and were plotted (Figure 6B). Sedimentary levels from the Pleistocene-Holocene transition (unit 4) did not contain diatom frustules, possibly indicating a lack of water availability into the cave.

Overall, diatom assemblages were dominated mainly by aerophilic diatoms (Figure 7). These taxa are present in a variety of sub-aerial environments, such as mosses, wood, wet rocks, as well as lichen phycobionts. Their development is mainly limited by their ability to survive to dry moments of different longitude and periodicity (Johansen, 1999). Their dominance in the studied caves indicates that although they have been wet during the Holocene, the moisture was mostly restricted to cave walls and other wet substrates. Many of the identified taxa, such as *Diadesmis gallica*, *D. contenta*, *Frankophila similioides*, *Nitzschia amphibia* and *Pinnularia subcapitata*, have been registered alive in modern environments of the Tandilia range. They inhabit caves with high moisture levels, where water infiltrates through the walls allowing the development of mosses (Hassan, unpublished data). This modern information is, however, scarce and further study on the distributional patterns of the modern diatom flora inhabiting these caves is needed in order to adjust the paleoenvironmental inferences, particularly in relation to moisture reconstructions.

6.2. Phytoliths

Phytolith studies are important archaeobotanical resources, especially in early archaeological records, where it is difficult to find well preserved botanical macroremains. Recent phytolith studies carried out in the Pampean region allowed advancing both in paleoenvironmental and human plant management knowledge (Osterrieth, et al., 2000; Zucol, et al., 2002; Zucol, et al., 2007, Zucol, et al., 2008; Colobig and Zucol, 2008; Zucol, et al., 2010c, Mazzanti, et al., 2010; Colobig, 2011). These siliceous microremains are very resistant to destruction and representative of local processes, constituting excellent proxies for analyzing the discrepancies between the archaeological settlements and the surrounding areas from a paleoecological perspective.

The Lobería I profile showed a very complete phytolith record, which allowed dividing the sequence into five phytolith zones (Figure 8). The Pleistocene-Holocene transition (samples 6B and 7) was included in zone I, and characterized by the presence of elongated elements with smooth (Figure 9.10), wavy (Figure 9. 11) or serrate (Figure 9.18) contour associated with short (Fig. 9.16) and elongated truncated cones (Figure 9. 17); point-shaped phytoliths were more abundant in sample 7. These dominant elements were accompanied by low abundances of bilobate (Figure 9.14, 15) and polylobate phytoliths, other truncated cones types, saddle, globular and festucoid boat-shaped elements. Abundant articulated epidermal phytoliths were observed (Figure 9. 12), more of them with dicot affinities (Figures 9.9). Sponje spicules and chrysophycean stomatocysts were scarce.

In Cueva Tixi, the phytolith assemblage of the basal section (unit F), corresponding to the Pleistocene-Holocene transition, was characterized by the dominance of elongated phytoliths of smooth and wavy contour (Figures 9.3), together with short prismatic, truncated cones (Figures 9.6 and 9.7) and bilobate elements. Elongated phytoliths with serrate and denticulate contour, with concave or straight ends, point shaped, polyhedral bulliforms, fan-shaped, rondel, globular (Figure 9. 13) and bilobate (Figure 9.5) were also present, although in lower abundances. Articulated phytoliths with different epidermal trichome elements were also abundant, while sponje spicules and stomatocysts were scarce. The comparative phytolith assemblage's analysis from lower sections of the studied sites (Figure 10) can establish that the sample E1 of Cueva Tixi show similarities with the sample 7 from Lobería I sequence, chronologically located in different times.

6.3. Charcoal

Archaeological sites of the Eastern Tandilia Range have scarce and very fragmentary anthracological records. However, these materials appear as small twigs and sprigs without the diagnostic features that allow a good systematic identification, are suitable for radiocarbon dating.

Archaeological charcoal can be employed to identify trees, shrubs and herbs in the area around human settlements (Bonomo et al., 2011 and references therein). Also, concentrated charcoal is usually a sign of human selection and used of forest resources (Figueiral, 2005). The archaeological charcoal used as paleoenvironmental indicator has been discussed for varied authors (see Marconetto, 2010) because the charcoals are the result of selective practices performed by humans rather that a faithful representation of environment (Piqué i Huerta, 1999; Marconetto 2005, 2010). However, is possible generate palaeoecological and palaeoenvironmental data on the basis of anatomical features of the archaeological charcoal instead of focusing on the floristic associations of the remains (Marconetto, 2010).

Of all the anthracological material recovered, samples from Cueva El Abra were the only that allowed a systematic determination. These pieces were assigned to *Salix* sp. (Salicaceae), recognized by semi-ring porous to diffuse porous, predominantly solitary vessels and rarely in radial multiples. The vessels are hexagonal in outline. Apotracheal axial parenchyma is scarce. Rays are very narrow and short, uniseriate and biseriate and 7–27 cells high. Rays are homogeneous composed of upright or square cells. *Salix* sp. was used as fuel because these charcoals were found concentrated and might indicate selection of resources by hunter-gatherer groups. This combustion structure has been dated by ^{14}C (AMS) to 9834 $^{\pm}$ 65 B.P.

7. Discussion

The sedimentary sequences analyzed in this paper show a record of early occupations that cover a span of c. 1000 y (9600-10,500 ^{14}C BP). Various lines of evidence (stratigraphic, sedimentological, geoarchaeological, diatoms, phytoliths, wood charcoal, faunal, and archaeological) indicate that the post-glacial climatic amelioration took place very quickly around 10,500 BP. The late Pleistocene-Holocene transition represented one of the most distinctive and recurrent sedimentary records found in the caves and rockshelters of the eastern Tandilia range. This transition is stratigraphically represented by an erosional unconformity, which is marked by a change in grain size, colour, and compaction in relation to the overlying and underlying sediments. This unconformity corresponds to a change in the sedimentary dynamics, and is located immediately below the first early occupation layers (c. 9600-10,500 AP). The underlying late Pleistocene sediments reflect colder and drier paleoclimatic conditions, while the overlying deposits correspond to the post-glacial climatic amelioration. Specifically, the Holocene deposits have smaller grain sizes, show pedogenetic modifications, and have higher amounts of organic matter. The identification of this boundary could represent a useful criterion for locating new sites, since it separates the archaeologically sterile deposits from the deposits reflecting human occupation. Zárate (1997) identified this boundary at Cerro El Sombrero (in the central-east Tandilia range); although in this case the underlying deposits consisted of a truncated paleosol that, according to the author, would have developed prior to the Late Glacial Maximum. Similar deposits were also identified by Martínez et al. (1997) at the site of Abrigo Los Pinos, beneath the deposit underlying the occupation layer (U4) (Figure 3). These were assigned tentatively to the last interglacial (OIS 5e, c. 120 ky BP).

Paleoclimatic information regarding the Pleistocene-Holocene transition in the Pampean region is abundant and is derived from a wide range of proxy evidence. Based upon information from sites located in the adjacent Interserrana Plain, Politis, et al. (2004), Martínez (2001), and Grill et al. (2007) postulated that initial population took place under arid to semi-arid climatic conditions. The human populations that would have lived in this area c. 11,000-10,000 BP would therefore done so under colder, dry sub-humid conditions (Quattrocchio et al., 2008; Tonni and Cione, 1994; Prieto, 1996; Tonni et al., 1999, 2003). Between c. 10,500 and 9000 BP a change in these dry conditions towards higher rainfall levels and temperatures has been indicated by numerous proxy records from the Pampas region (Tonni and Fidalgo, 1978; Prado et al., 1987; Alberdi et al., 1989; Tonni y Cione, 1994; Prieto, 1996; Zárate et al., 1995, 2000; Zarate, 1997; Borrero et al., 1998; Bonadonna et al., 1999; Tonni et al., 1999; Martinez, 1999, 2001, 2007; Prieto et al., 2004; Grill et al., 2007; Gutierrez y Martínez, 2008; Gutierrez et al., 2010).

Phytoliths and diatoms were the most abundant botanical remains recovered from the studied profiles. The analysis of phytoliths contributed to the knowledge of the paleoclimatic conditions prevailing in the Pleistocene-Holocene transition, as well as to the discussion of some aspects of plant management in these early times where other botanical records are scarce. The sensibility of phytoliths to microenvironmental changes may explain not only the variations of elements produced by local and current vegetation inside the caves, but also those produced by anthropic remains. In the Loberia I site 1, the presence of pooid and danthonioid elements in the basal and middle zones (I and II) associated with the alternation of panicoid/chloridoid of the zone I suggest that climatic conditions were dry and temperate during the Pleistocene-Holocene transition. On the other hand, the Cueva Tixi sequence shows an increase of pooid (including festucoid) and chloridoid phytoliths in the basal sample (F). Cueva Tixi profile indicates colder conditions to the early Holocene (zone III) than Loberia I site 1. The presence of cold weather and dry conditions has also been reported for the early Holocene-Pleistocene by regional studies of other proxies (Prado, et al., 1987; Bonadonna, et al., 1995; Tonni, et al., 1999).

Variations in the phytolith analysis among the two sites can be attributed to the position of each cave in the landscape and its differential human use. For instance, one question that needs further discussion is whether phytoliths observed in Loberia I site 1 were the result of anthropic management or a consequence of the microclimate of the site and its altitudinal context. In this sense, an important variable to consider is the position in the landscape of each of the caves: while Lobería is located in low landscapes (98 m in height), Cueva Tixi is situated in a higher and more exposed (176 masl). Hence, these differences in altitude and exposition may be influencing the variability of the botanical microremains inside the sites. The presence of globular elements in early times may indicate human activity, but must be considered that are also present in the soil parent material. Recent evidence shows that globular elements are present along the complete sequences inside the sites, and they are not coincident with megathermic elements, suggesting a possible introduction by human groups (Colobig, 2011).

Diatom assemblages were present in Lobería I and Cueva Tixi successions since late Pleistocene (before c. 10,000 ^{14}C BP), while in Cueva El Abra sediments younger than *c*. 2900 ^{14}C BP did not contain diatom valves. In the Loberia I sequence, dominant diatoms from unit 7 (late Pleistocene) indicated the lowest moisture availability conditions from all the sequence, as signaled by the aerial diatom *Diadesmis gallica*. Overall, the conditions in this cave were drier during the late Pleistocene and were followed by a climatic amelioration since the Pleistocene Holocene transition. The dominance of *Denticula elegans* and *Nitzschia hantzschiana* at the basal levels (Unit F, figure 4) of Cueva Tixi (before c. 10,000 ^{14}C BP) also indicates low moisture environmental conditions for the Pleistocene-Holocene transition, as these are very tolerant to long dry periods. The absence of diatoms at the basal levels of Cueva el Abra (late Pleistocene to mid Holocene) and their appearance through the late Holocene, are suggesting that this site also evolved from dry conditions during the Pleistocene-Holocene transition to wetter conditions through late Holocene. Hence, although local constraints cannot be discarded, the coincidence in the inferences made from these three sites could be signaling dry conditions for the late Pleistocene in this region. The possible climatic amelioration occurred during the Holocene is also supported by Cueva tixi record, where an increase in diatom assemblages indicating wetter conditions was recorded through middle Holocene (Unit C).

Hearts are a common feature in early setlements of most of the sites. Charcoal fragments recorded in Cueva El Abra, dated 9800 BP were identified as *Salix* sp. This taxon was part of a riparian landscape with gallery forests and is characteristic of the few forest communities that occur in the area. *Salix* sp. is very common across rivers and streams and the flood pulse is a key-factor in the establishment of the *Salix* forests (Liotta, 2001). This species lives in subhumid and semiarid regions under a temperate to warm-temperate climate. Furthermore, the soil should be moist, sandy, and with good drainage. The Cueva El Abra site is located at the foot of the Arroyo La Vigilancia valley, which contains a small river course that lacks flow during the dry seasons. This river reflects the basic drainage characteristics of the eastern Tandilia range, where no larger, permanent rivers exist. The gallery forests that characterize the vegetation in these valleys would have required a precipitation regimen sufficient to maintain permanent river flow, an unlikely scenario given the drier climatic conditions at the end of the Pleistocene. However, the presence of *Salix* charcoal supports the idea of a wetter rainfall regimen, which would have been established around 10,000 BP in these mountains. This is in agreement with the recording of new mammalian taxa that make up non-analog associations. The presence of species characteristic of subtropical environments, such as

Cavia aperea, *Monodelphys* sp., *Dasypus hybridus*, and *Oxymycterus* sp., could be considered as components of an emerging, expanded biological richness that developed with the arrival of new environmental conditions, which may have characterized a large ecotonal area.

The archaeological sites discussed here comprised part of the same mobility system, and also reflect social processes of territorial consolidation that involved other sites of similar ages in the adjacent regions of the Tandilia range and the Interserrana Plain. A strong relationship with the Paso Otero 5 site was especially noticed, as a consequence of the types of stone utilized (orthoquartzites from the Sierras Bayas Group, basalts from the Atlantic coast, and silicified limestones from southern Uruguay and/or the Pampas). The Paso Otero 5 site also shows signs of reutilization by very mobile groups during the period 10,440- 9400 BP, and is considered as a locus of specialized hunting and/or scavenging activities related to megamammals (Martínez and Gutiérrez, 2011).

The archaeological evidence found in the studied sites indicates that the early population of the area occurred at the end of the Pleistocene, in coincidence with the period of major climatic and environmental changes, such as the process of deglaciation that originated the extinction of part of the fauna. Hunter-gatherer societies were repeatedly present in the eastern mountainous environment, but as part of much broader mobility ranges that included the adjacent Interserrana Plain and the Atlantic Ocean coast. The search for resources, especially stone for production of tools, involved an area of social interaction that included territories as far away as the Río de la Plata river basin in present-day Uruguay (Flegenheimer et al., 2003)

Although records of occupations earlier than those discussed here do exist, both on the Interserrana Plain (Arroyo Seco, Site 2) and in the Tandilia range (Cerro La China sites 1 and 2 and Cerro El Sombrero) (Flegenheimer, 1987; Zárate and Flegenheimer, 1991) (Figure 1), they come from different stratigraphic contexts and not all are specifically from cave sites. The particular stratigraphic situation found in all nine of the sites discussed in this work, located in the same micro-region, reflect the magnitude of post-glacial climate change. This is represented by the stratigraphic unconformity and the development of new conditions in terms of sedimentary dynamics around 10,500 BP. The change to wetter conditions would also have generated a very advantageous pattern of resource availability in the mountainous landscapes (water, vegetation, and fauna), thereby attracting human occupation. This is manifested by the high density of sites represented in the same valley, and in the recording of recurrent episodes of use of certain strategic temporary sites.

8. Conclusion

The late Pleistocene-Holocene boundary is represented in the stratigraphical sequences of caves and rockshelters from eastern Tandilia range by a clear discordance. It is dated between 10,500 and 9600 BP, in coincidence with the initial human settlement. The identification of this unconformity could serve as a useful criterion for locating new occupations, since it separates the archaeologically sterile deposits from those that contain human occupations. Despite the local micro-environmental conditions recorded in caves and rockshelters, a regional generalized trend was inferred from the different evidence analyzed. In this sense, new paleobotanical records also indicate an abrupt climatic change from more arid late Pleistocene conditions to post-glacial climatic amelioration occurred towards c. 10,500 BP.

The Tandilia mountain range represented an optimal environment that favoured early population of the Pampas region. For the micro-region of the eastern Tandilia range, human groups were interesed in occupying particular mountainous loci during the process of territorial consolidation of the Pampas. The environmental change towards warmer and wetter climatic conditions led to a wider range of natural resources, which included a concentrated degree of biodiversity in flora and fauna from both continental and coastal zones, as well as the abundance of fresh water. This in turn appears to have led to both higher density and greater intensity of human occupation in the eastern Tandilia range.

Acknowledgements

This investigation was financed by ANPCyT (PICT 08, Nº1390) and UNMdP. The authors wish to thank to Gustavo Martínez (UNICEN) and the anonymous reviewers for their valued and constructive comments. We are grateful to M.V. Bernasconi and. M. Farenga for drawing the diagrams and figures and Pablo Guerstein for comments.

References

Alberdi, T.A., Menegaz, J.L., Prado, J.L., Tonni, E.P., 1989. La fauna local Quequén Salado - Indio Rico (Pleistoceno tardío) de la Provincia de Buenos Aires, Argentina. Aspectos paleoambientales y bioestratigráficos. Ameghiniana 25 (3), 225-236.

Bayón, C., Flegenheimer, N., 2004. Cambios de planes a través del tiempo para el traslado de roca en la pampa bonaerense. Estudios Atacameños 28, 59-70.

Bayón, C, Flegenheimer, N., Valente, M., Pupio, A., 1999. Dime cómo eres y te diré de donde vienes?: la procedencia de rocas cuarcíticas en la Región Pampeana. Relaciones de la Sociedad Argentina de Antropología XXIV, 187-235.

Bonadonna, F.P., Leone, G., Zanchetta, G., 1999. Stable isotope analyses on the last 30 ka molluscan fauna from Pampa grasland, Bonaerense region, Argentina. Palaeogeography, Palaeoclimatology, Palaeoecology 153, 289-308.

Bonomo, M., Blasi, A., 2010. Base regional de recursos líticos del delta del Paraná. Estudio petrográfico de artefactos y afloramientos en el sur de Entre Ríos. Cazadores-recolectores del Cono Sur. Revista de Arqueología 4, 17-41.

Bonomo, M., Colobig, M.M., Passeggi, E., Zucol, A.F, Brea, M., 2011. Multidisciplinary studies at Cerro Tapera Vázquez Site (Pre-Delta National Park; Argentina): Archaeological, sedimentological and paleobotanical evidence. Quaternary International 245, 48-61.

Borrero, L.A., 2003. Taphonomy of the Tres Arroyos 1 Rockshelter, Tierra del Fuego, Chile. In: Miotti and Salemme (Eds.), South America: Long and Winding Roads for the First Americans at the Pleistocene/Holocene Transition. Special Vol. of Quaternary International 109-110, 87-94.

Borrero, L.A., Zárate, M., Miotti, L., Massone, M., 1998. The Pleistocene-Holocene transition and human occupations in the southern cone of South America. Quaternary International 49/50, 191-199.

Colcutt, S., 1979. The Analysis of Quaternary Cave Sediments. World Archaeology 10, 290-301.

Colobig, M.M., 2011. Estudios paleoetnobotánicos en sitios del borde oriental de Tandilia (Provincia de Buenos Aires). Pautas de aprovechamiento y uso de recursos vegetales en las sociedades de cazadores- recolectores. Unpublished Ph.D. Thesis, Universidad Nacional de Rosario.

Colobig, M.M., Zucol, A.F., 2008. Estudios de microrrestos silíceos de la secuencia sedimentaria del sitio 1 de la Localidad arqueológica Lobería I (Buenos Aires, Argentina) Análisis preliminar.

Actas del V Congreso de Arqueología de la Región Pampeana Argentina. Santa Rosa, La Pampa, pp. 91-92.

Dalla Salda, L., Iñiguez, M., 1979. La Tinta, Precámbrico y Paleozoico de Buenos Aires. VII Congreso Geológico Argentino, Buenos Aires, Argentina, pp. 539–550.

Figueiral, I., 2005. Quantification in charcoal analysis? Yes, but not always. Example from problematic Portuguese sites. In: Molera, J., Farjas, J., Roura, P., Pradell, T. (Eds.), VI Congreso Ibérico de Arqueometría. Universidad de Girona, Girona, España, pp. 223-228.

Flegenheimer, N., 1987. Recent research at localities Cerro La China and Cerro El Sombrero, Argentina. Current Research in the Pleistocene 4, 148-149.

Flegenheimer, N., Bayón, C., Valente, M., Baeza, J., Femenías, J., 2003. Long distance tool stone transport in the Argentine Pampas. Quaternary International, 109-110, 49-64.

Flegenheimer, N., Bayón, C., Puppio, A., 2006. Llegar a un nuevo mundo. La arqueología de los primeros pobladores del actual territorio argentino. Museo y Archivo Histórico Municipal, Área de Arqueología y Antropología, Dirección de Cultura y Educación, Municipalidad de Necochea, Bahía Blanca.

Goin F., 2001. Marsupiales (Didelphidae: Marmosinae y Didelphinae). In: Cueva Tixi: Mazzanti D., Quintana C., (Eds.), Cazadores y Recolectores de las Sierras de Tandilia. I. Geología, Paleontología y Zooarqueología, Publicación Especial 1. LARBO-UNMDP, pp. 75-114.

González, M.A., Maidana, N.I., 1998. Post-Wisconsinian paleoenvironments at Salinas del Bebedero basin, San Luis, Argentina. Journal of Paleolimnology 20, 353–368.

Grill, S., Borromei, A., Martínez, G., Gutierrez, M., Cornou, M.E., Olivera, D., 2007. Palynofacial analysis in alkaline soils and paleoenvironmental implications: The Paso Otero 5 archaeological site (Necochea district, Buenos Aires province, Argentina). Journal of South American Earth Sciences 24, 34-47.

Grimm, E.C., 2004. TILIA Software, Illinois State Museum, Research and Collection Center, Springfield, IL, USA.

Guilderson, T.P., Burkle, L., Hemming, S., Peltier, W.R., 2000. Late Pleistocene sea level variations derived from the Argentine Shelf. Geochemistry, Geophysics, Geosystems, Vol. 1, Paper number 2000GC000098. Published December 15, 2000.

Gutiérrez, M.A., Martínez, G., 2008. Trends in the faunal human exploitation during the late Pleistocene and early Holocene in the Pampean region (Argentina). Quaternary International 191, 53-68.

Gutiérrez, M.A., Martínez, G., Luchsinger, L, Grill, S, Zucol, A.F., Hassan, G.S., Barros, M.P., Kaufmann, C.A, Álvarez M.C., 2010. Paleoenvironments in the Paso Otero locality during late Pleistocene-Holocene (Pampean region, Argentina): An interdisciplinary approach. Quaternary International, in press.

Hammer, Ø, Harper, D.A.T., Ryan, P.D., 2001. Past: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica, vol. 4, issue 1, art. 4: 9 pp., 178 kb. http://palaeoelectronica.org/2001_1/past/issue1_01.htm

Hassan, G.S., Espinosa, M.A., Isla, F.I., 2004. Análisis paleoambiental de una secuencia del Holoceno Tardío del Arroyo Claromecó (provincia de Buenos Aires, Argentina) basado en diatomeas. Ameghiniana 41(2), 161-170.

Hassan, G.S., Tietze, E., De Francesco, C.G., 2009. Modern diatom assemblages in surface sediments from shallow lakes and streams in southern Pampas (Argentina): palaeoenvironmental implications. Aquatic Sciences 71, 1015-1621.

Haynes, G., 2006. A review of some attacks on the overkill hipótesis, with special attention to misrepresentations and doubletalk, Quaternary Internacional 169-170, 84-94.

IAWA Committee, 1989. IAWA list of microscopic feature for hardwood identification. International Association of Wood Anatomists. Bulletin 10, 219–332.

InsideWood, 2004-onwards. Published on the Internet. http://www.insidewood.lib. ncsu.edu/search [april 2011].

Johansen, J.R., 1999. Diatoms of aerial habitats. In: Stoermer, E.F. y Smol, J.P. (Eds.), The diatoms: Applications for the environmental and Earth Sciences, Cambridge University Press, London, pp. 264-273.

Kruse, E., Laurencena P., Deluchi, M., Varela, L., 1997. Caracterización de la Red de drenaje para la evacuación hidrológica en la Región Interserrana (Provincia de Buenos Aires). Actas del I Congreso Nacional de Hidrogeología y II Seminario Hispano–Argentino sobre Temas Actuales de Hidrología Subterránea, Bahía Blanca, pp. 133–145.

Liotta, J., 2001. Rasgos biológicos de *Salix humboltiana* Wild. y régimen de pulsos de inundación. Interciencia 26, 397-403.

Lowe, R.L., Morales, E., Kilroy, C., 2006. Frankophila biggsii (Bacillariophyceae), a new diatom species from New Zealand, New Zealand. Journal of Botany 44, 41-46.

Marconetto, M.B., 2005. Recursos Forestales. Oferta y Disponibilidad en contextos Aguada. In: La Cultura de la Aguada y sus Expresiones Regionales. EUDELAR – Universidad Nacional de La Rioja, pp. 183-198.

Marconetto, M.B., 2010. Paleoenvironment and anthracology: determination of variations in humidity based on anatomical characters in archealogical plant charcoal (Ambato Valley, Catamarca, Argentina). Journal of Archaeological Science 37, 1186-1191.

Markgraf, V., Bradbury, J.P., Schwalb, A., Burns, S.J., Stern, C., Ariztegui, D, Gilli, A, Anselmetti, F.S., Stine, S., Maidana, N.I., 2003. Holocene paleoclimates of southern Patagonia: limnological and environmental history of Lago Cardiel, Argentina. Holocene 13, 581–891.

Martin, P., 1984. Prehistoric overkill: the global model. In: Martin P., Klein, R (Eds.), Quaternary Extintions. A Prehistoric Revolution. University of Arizona Press, Tucson, pp. 354-403.

Martínez, G., 1999. Tecnología, subsistencia y asentamiento en el curso medio del Río Quequén Grande: Un enfoque arqueológico. Unpublished Ph.D. Thesis, La Plata.

Martínez G., 2001. Archaelogical research in Paso Otero 5 site. “Fish-tail” projectile points and megamammals in the Pampean region of Argentina. Antiquity 75 (289), 523-528.

Martínez, G., 2006. Arqueología del curso medio del río Quequén Grande: estado actual y aportes a la arqueología de la región pampeana. Relaciones de la Sociedad Argentina de Antropología XXXI, 249-275.

Martínez, G., Gutiérrez, M., 2011. Paso Otero 5: a summary of the interdisciplinary lines of evidence for reconstructing early human occupation and paleoenvironment in the Pampean region, Argentina. In: D. Vialou (Ed.), Peuplements et Préhistoire de l’Amérique, Muséum National d’Histoire Naturelle, Département de Préhistoire, Paris, Francia, pp. 271-286.

Martínez, G., Gutiérrez, M., Tonni, E., (this volume). Paleoenvironments and faunal assemblages at the Paso Otero locality (Argentina) during the late Pleistocene-early Holocene. Quaternary International.

Martínez, G.A., 2007. Procesos de formación de sitios en reparos rocosos de Tandilia. Cazadores - Recolectores del Cono Sur. Revista de Arqueología 3, 105-127.

Martínez, G.A., Osterrieth, M., 2001. Estratigrafía, Procesos formadores y Paleoambientes. In: D. Mazzanti y C. Quintana (Eds.), Cueva Tixi: Cazadores y Recolectores de las Sierras de Tandilia Oriental. 1 Geología, Paleontología y Zooarqueología, Laboratorio de Arqueología, Facultad de Humanidades, Universidad Nacional de Mar del Plata, pp. 19-34.

Martínez, G.A., Osterrieth M., 2003. The Pleistocene-Holocene stratigraphic record from early archaeological sites in caves and rockshelters of Eastern Tandilia, Pampean Region, Argentina. In: Miotti L., Salemme M., Flegenheimer N. (Eds.), Where the south winds blow. Ancient evidence of Paleo South Americans, College Station, Center for the Studies of the First Americans (CSFA) and Texas A&M University Press, pp. 63-68.

Martínez, G.A., Osterrieth, M., Mazzanti, D.L., 1999. Estratigrafía de sitios arqueológicos en reparos rocosos en las sierras de La Vigilancia y Valdés, sistema de Tandilia, provincia de Buenos Aires. XII Congreso Nacional Arqueología Argentina, La Plata, Actas III, pp. 139-144.

Mayr, C., Fey, M., Haberzettl, T., Janssen, S., Lücke, A., Maidana, N.I., Ohlendorf, C., Schäbitz, F., Schleser, G.H., Struck, U., Wille, M., Zolitschka, B., 2005. Palaeoenvironmental changes in southern Patagonia during the last millennium recorded in lake sediments from Laguna Azul (Argentina). Palaeogeography, Palaeoclimatolology and Palaeoecology 228, 203–227.

Mazzanti, D.L., 1997. Excavaciones arqueológicas en el sitio Cueva Tixi, Buenos Aires, Argentina. Latin American Antiquity, 8 (1), 55-62.

Mazzanti, D.L., 1999. Ocupaciones humanas tempranas en Tandilia oriental (Provincia de Buenos Aires). XII Congreso Nacional de Arqueología Argentina, Actas III, 149-155.

Mazzanti, D.L., 2003. Human Settlements in Caves and Rockshelters during the Pleistocene-Holocene Transition in the Eastern Tandilia Range, Pampean Region, Argentina. In: Miotti L., Salemme M., Flegenheimer N. (Eds.), Where the south winds blow. Ancient evidence of Paleo South Americans, College Station, Center for the Studies of the First Americans (CSFA) and Texas A & M University Press, pp. 57-61.

Mazzanti, D.L., Martínez, G.A., Quintana, C.A., Asentamientos tempranos en Tandilia oriental, Provincia de Buenos Aires. Contextos arqueológicos y procesos de formación de sitios. Proceedings of V Simposio Internacional "El Hombre Temprano en América", La Plata, in press.

Mazzanti, D.L., Colobig, M.M., Zucol, A.F., Martínez, G.A., Porto López, J., Brea, M., Passeggi, E., Soria J.L., Quintana, C.A., Puente, V., 2010. Investigaciones arqueológicas en el Sitio 1 de la Localidad Lobería I. In: Berón, M., Luna, L., Bonomo, M., Montalvo, C., Aranda, C., Carrera Aizpitarte, M. (Eds.), Mamül Mapu: pasado y presente desde la arqueología pampeana, Editorial Libros del Espinillo, Ayacucho, pp. 99-114.

McMillan, M., Rushforth, S.R., 1985. The diatom flora of a steam vent of Kilauea Crater, island of Hawaii, Pacific Science 39, 294-301.

Metcalfe, C., Chalk, L. 1957. Anatomy of the Dicotyledons, I. Clarendon, Oxford, 724 pp.

Miotti, L., Salemme, M.C., 1999. Biodiversity, taxonomic richness and specialists–generalist during late Pleistocene/Early Holocene times in Pampa and Patagonia (Argentina, Southern South America). Quaternary International 53–54, 53–68.

Miotti, L., Salemme, M.C., 2003. When Patagonia was colonized: people mobility at high latitudes during Pleistocene/Holocene transition. Quaternary International 109–110, 95–111.

Osterrieth, M., Zurro, D., Mazzanti, D.L., Zucol, A.F., 2000. The first study of silica phytoliths in an archaeological cave of the Pampean plains of Argentina. “La Amalia site”: a case study. Actas 3rd I.M.P.R Man and the (palaeo) environment. The phytolith evidence I. Tervuren, Bélgica, pp. 44-46.

Piqué i Huerta, R., 1999. Producción y uso del combustible vegetal: una evaluación arqueológica. Treballs d`Etnoarqueologia, 3. Universidad Autónoma de Barcelona, Consejo Superior de Investigaciones Científicas, Madrid.

Politis, G, Messineo, P. y Kauffman, C., 2004. El poblamiento temprano de las llanuras pampeanas de Argentina y Uruguay. Complutum 15, 207-224.

Politis, G., Prado, J.L., Beukens, R., 1995. The human impact in Pleistocene-Holocene extinctions in South America: the Pampean case. In: Johnson, E. (Ed.), Ancient People and Landscape Museum of Texas Tech University, Lubbock, TX, pp. 187-205.

Porto López, J.M., Mazzanti, D.L., 2010. Análisis arqueométrico de sustancias colorantes provenientes de contextos tempranos de las sierras de Tandilia oriental. In: Bertolino S., Cattáneo, R., Izeta, A. (Eds.), La Arqueometría en Argentina y Latinoamérica, Facultad de Filosofía y Humanidades, Universidad Nacional de Córdoba, pp. 339-343.

Poulíčková, A., Hašler, P., 2007. Aerophytic diatoms from caves in central Moravia (Czech Republic), Preslia 79, 185-204.

Prado, J.L., Menegaz, A., Tonni, E.P., Saleme, M., 1987. Los mamíferos de la fauna local Paso Otero (Pleistoceno tardío), provincia de Buenos Aires. Aspectos paleoambientales y bioestratigráficos. Ameghiniana 24, 217-233.

Prates, L., Politis, G., Steele, J., 2011. Radiocarbon chronology of the early human occupation of Argentina. Proceedings of SAA, 76th Annual Meeting, California, USA.

Prieto, A., 1996. Late quaternary vegetational and climatic changes in the pampa grassland of Argentina. Quaternary Research 45, 73-88.

Prieto, A.R., Blasi, A.M., De Francesco, C.G., Fernández, C., 2004. Environmental history since 11,000 ^{14}C yr BP of the northeastern Pampas, Argentina, from alluvial sequences of the Luján River. Quaternary Research 62, 146–161.

Quattrocchio, M.E., Borromei, A.M., Deschamps, C.M., Grill, S., Zabala, C., 2008. Landscape evolution and climate changes in the late Pleistocene-Holocene southern Pampa (Argentina): evidence from palynology, mammals and sedimentology. Quaternary International 181, 123-138.

Quintana, C.A., 2001. Composición y cambios en la secuencia faunística. In: Cueva Tixi: Mazzanti, D., Quintana C., (Eds.), Cazadores y Recolectores de las Sierras de Tandilia. I. Geología, Paleontología y Zooarqueología, Publicación Especial 1. ARBO-UNMDP, pp. 37-64.

Quintana, C.A., 2004. Zooarchaeological record in early sediments of caves from Tandilia range, Argentina. Current Research in the Pleistocene 21, 19-20.

Quintana, C.A., Mazzanti, D.L., 2001. Selección y aprovechamiento de recursos faunísticos. In: Cueva Tixi: Mazzanti, D.L., Quintana, C.A. (Eds.), Cazadores y Recolectores de las Sierras de Tandilia. I. Geología, Paleontología y Zooarqueología, Publicación Especial 1. LARBO-UNMDP, pp. 181–209.

Quintana, C.A., Valverde, F., Albino, A., 2003. Registro de fauna del sitio Cueva El Abra, Tandilia oriental, Provincia de Buenos Aires. XIII Congreso Nacional de Arqueología Argentina, Actas 3, 317-324.

Quintana, C.A., Martinez, G.A., Osterrieth, M., Mazzanti, D., 2001. Footprints of mammals in a cave of eastern edge of Tandilia range, late Pleistocene of Buenos Aires Province, Argentina. Current Research in the Pleistocene, 18, 110-111.

Romanelli A., Massone, H., Quiroz Londoño, O., Integrated hydrogeological study of surface water and groundwater resources in the Southeastern of Buenos Aires Province, Argentina. International Journal of Environmental Research, 5 (4), in press.

Smol, J.P. and Stoermer, E.F. [Editors]., 2010. The Diatoms: Applications for the Environmental and Earth Sciences, Second Edition. Cambridge University Press. Cambridge, 667 pp.

Steele J., Politis G., 2009. AMS ^{14}C dating of early human occupation of the southern South America. Journal of Archaeological Science 36, 419-429.

Teruggi, M.E., 1957. The nature and origin of the Argentine loess. Journal of Sedimentary Petrology 27, 322– 332.

Tonni, E.P., Cione, A.L., 1994. Los mamíferos y el clima en el Pleistoceno y Holoceno de la provincia de Buenos Aires. Jornadas Arqueológicas Interdisciplinarias, Programa de estudios Prehistóricos, 127-142.

Tonni, E.P., Fidalgo, F., 1978. Consideraciones sobre cambios climáticos durante el Pleistoceno tardío-Reciente en la provincia de Buenos Aires. Aspectos ecológicos y zoogeográficos relacionados. Ameghiniana 15 (1-2), 235-253.

Tonni, E.P., Cione, A., Figini, A., 1999. Predominante of arid climates indicated by mammals in the pampas of Argentina during the late Pleistocene and Holocene. Palaeogegraphy, Palaeoclimatology, Palaeocology 147, 247-281.

Tonni, E.P., Huarte, R.A., Carbonari, J.E., Figini, A.J., 2003. New radiocarbon chronology for the Guerrero Member of the Luján Formation (Buenos Aires, Argentina): paleoclimatic significance. Quaternary International 109-110, 45-48.

Tortorelli, L., 1956. Maderas y Bosques argentinos. Acme Editorial, Buenos Aires, 910 pp.

Tricart, J.L., 1973. Geomorfología de la Pampa Deprimida. Base para los estudios edafológicos y agronómicos, INTA, Vol. XII Colección Científica, 202 pp.

Tuset, R., 1963. Descripción y clave macroscópica de maderas indígenas del Uruguay. Maldonado, Uruguay. Silvicultura 19, 5-57.

Valverde, F., 2002. Variabilidad de recursos líticos en dos sitios paleoindios de las sierras de Tandilia oriental, Provincia de Buenos Aires. In: Mazzanti, D., Berón, M., Oliva, F. (Eds.), Del Mar a los Salitrales. Diez mil años de Historia Pampeana en el Umbral del Tercer Milenio, LARBO/SAA, Mar del Plata, pp. 281-288.

Valverde, F., 2003. Análisis de los desechos líticos de la ocupación inicial del sitio Cueva Tixi (provincia de Buenos Aires): cadena operativa de producción y técnicas de talla tempranas. Relaciones de la SAA, Tomo XXVIII, 185-202.

Valverde, F., 2004. Análisis comparativo de las secuencias de producción lítica en dos sitios correspondientes a la transición Pleistoceno-Holoceno, Tandilia oriental. In: Martínez, G., Gutiérrez, M., Curtoni, R., Berón, M., Madrid P. (Eds.), Aproximaciones Contemporáneas a la Arqueología Pampeana. Perspectivas teóricas, metodológicas, analíticas y casos de estudio. Facultad de Ciencias Sociales, Universidad Nacional del Centro de la Provincia de Buenos Aires, Olavarría, pp. 403-418.

Van Dam, H., Mertens, A., Sinkeldam, J., 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands, Netherlands Journal of Aquatic Ecology 28, 117-133.

Walanus, A., Nalepka, D., 2002. POLPAL. Counting pollen, tables storage and diagrams plotting. System manual. W. Szafer Institute of Botany. Polish Academy of Sciences, Poland, pp. 25.

Walkley, A., Black, A., 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science 37, 29-38.

Zárate, M., 1997. Late Pleistocene geoarchaeology of the southern pampas, Buenos Aires, Argentina. Anthropologie XXXV, 197-205.

Zárate, M., Flegenheimer, N., 1991. Geoarchaeology of the Cerro La China Locality (Buenos Aires, Argentina): Site 2 y Site 3. Geoarchaeology: An International Journal 6 (3), 273-294.

Zarate, M., Espinoza, M., Ferrero, L., 1995. La Horqueta II, río Quequén Grande: ambientes sedimentarios de la transición Pleistoceno-Holoceno. IV Jornadas Geológicas y Geofísicas Bonaerenses, Actas 1, Junín, pp. 195-204.

Zarate, M., Kemp, R., Espinosa, M., Ferrero, L., 2000. Pedosedimentary and palaeoenvironmental significance of a Holocene alluvial sequence in the Southern Pampas, Argentina.The Holocene 10 (4), 481–488.

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

Zucol, A.F., Brea, M., Mazzanti, D.L., 2008 Análisis de restos orgánicos presentes en cerámicas arqueológicas de las Sierras de Tandilia (Provincia de Buenos Aires, Argentina). In: Korstanje M.A., Babot, M.P. (Eds.), Matices Interdisciplinarios en Estudios Fitolíticos y de Otros Microfósiles, editado por BAR International Series S1870, pp. 201- 208.

Zucol, A.F., Brea, M., Osterrieth, M., Martínez, G., 2002. Análisis fitolítico de un horizonte sedimentario del Sitio 2 de la Localidad Arqueológica Amalia (Holoceno temprano). In: Mazzanti, D.L., Berón, M.A., Oliva, F. W. (Eds.), Del Mar a los Salitrales. Diez mil años de Historia Pampeana en el Umbral del Tercer Milenio. LARBO-SAA, Mar del Plata., pp. 355-363.

Zucol, A.F., Passeggi, E., Brea, M., Patterer, N.I., Fernández Pepi, M.G., Colobig, M. M., 2010a. Phytolith analysis for the Potrok Aike Lake Drilling Project: Sample treatment protocols for the PASADO Microfossil Manual In: Corbella, H. & Maidana, N. I. (Eds.). 1ª Reunión Internodos del Proyecto Interdisciplinario Patagonia Austral y 1er Workshop Argentino del Proyecto Potrok Aike Maar Lake Sediment Archive Drilling Project. Proyecto Editorial PIPA, Buenos Aires, pp 81-84.

Zucol, A.F., Colobig, M.M., Patterer, N.I., Fernández Pepi, M.G., Passeggi, E., Brea, M., 2010b. Phytolith analysis for the Potrok Aike Lake Drilling Project: general methodologies for analysis. In: Corbella, H. & Maidana, N. I. (Eds.). 1ª Reunión Internodos del Proyecto Interdisciplinario Patagonia Austral y 1er Workshop Argentino del Proyecto Potrok Aike Maar Lake Sediment Archive Drilling Project. Proyecto Editorial PIPA, Buenos Aires, pp 85- 88.

Zucol A.F., Colobig, M.M., Passeggi, E., 2010c. Estudio de microrrestos silíceos del sitio Lobería I (Sitio 1), como una aproximación al conocimiento del uso de los recursos vegetales en el holoceno tardío en reparos rocosos de las sierras de Tandilia (Buenos Aires, Argentina). In: Cazadores-recolectores de las Sierras de Tandilia Oriental. El Holoceno tardío. Mazzanti, D.L., (Ed.), Publicación Especial 3, Laboratorio de Arqueología UNMDP, in press.

FIGURE CAPTIONS

Figure 1. Location of the study area in Buenos Aires province. Some archaeological sites used as reference: 1. Cerro La China. 2. Cerro El Sombrero. 3. Arroyo Seco. 4. Paso Otero 5. Infered paleocoast at c. 11,000 BP wich correspond to c. -70 masl (after Guilderson *et al*., 2000) is indicate on atlantic ocean.

Figure 2. Location of sites and archaelogical localities in Eastern Tandilia Range.

Figure 3. Stratigraphical profiles of the sites (modified of Martínez and Osterrieth, 2003 and Mazzanti *et al*., 2010).

Figure 4. Stratigraphic sequence of Burucuyá cave composed of late Pleistocene to Holocene sandy-clayed silts, diatomaceous silts and a diatomite layer. A reamarkable late Pleistocene-Holocene boundary related to footprints of mammals (ichnites) can be observed.

Figure 5. Relative frequency diagram of diatom composition and moisture groups for the sequence from Loberia I site.

Figure 6. Relative frequency diagram of diatom composition and moisture groups from: A) Cueva Tixi, and B) Cueva El Abra sites.

Figure 7. Dominant diatom species: 1) *Achnanthes coarctata*, 2) *Amphora pediculus*; 3) Caloneis *hyalina*; 4) *Cocconeis placentula*; 5) *Denticula elegans*; 6) *Diadesmis contenta*; 7) *D. gallica*; 8) *Eunotia* sp.; 9) *Frankophila similioides*; 10) *Hantzschia amphyoxis*; 11) *Hyalodiscus* sp.; 12) *Luthicola mutica*; 13) *Melosira* sp.; 14) *Melosira dickiei*; 15) *Navicula atomus*; 16) *N. fragilaroides*; 17) *Navicula* cf. *minima*; 18) *Nitzschia hantzschiana*; 19) *N. inconspicua*; 20) *N. terrestris*; 21) *Orthoseira dendroteres*; 22) *O.roeseana*; 23) *Pinnularia borealis*; 24) *P. subcapitata*. Scale: 5 µm.

Figure 8. Phytolith Diagram of Achaeological locality Loberia I, Site 1.

Figure 9. Different non articulated and articulated phytoliths observed in the studied profile samples. 1-2 Saddle. 3, 11 Elongated elements with wavy contour. 4, 6-7, 16-17 Truncated cones. 5, 14-15 Bilobates. 8 Dicot affinity element. 9, 12 Articulated phytoliths. 10 Elongated element with smooth contour. 13 Globular. 18 Elongated element with serrate contour. Scale bar in 11: 20 µm.

Figure 10. Cluster analysis of Achaeological locality Loberia I, Site 1 and Cueva Tixi sites using correlation coeficient (cophenetic correlation coeficient: 0.8424).

Table 1. Field descriptions and laboratory data for Loberia I profile. Notes: AU= Allostratigraphic Unit; SH=Soil Horizon; AC= Archaeological Component; C=Color (dry); OM=Organic Matter; P=Phosphorus. ▲=Archaeological Materials.

Table 2: Radiocarbon dates from the studied sites.

Table 3. Faunal record of paleoindian levels of Cueva Tixi and Cueva El Abra. ✝ Extinct species. (1) A *Monodelphis* species different to *M. dimidiata* (see Goin 2001). (2) A species undetermined of *Canis,* may be *Canis avus* young specimens. (3) A species undetermined of *Canis.* (4) At least 4 species. In parentheses are the numbers of armadillo plates or bird eggshells.

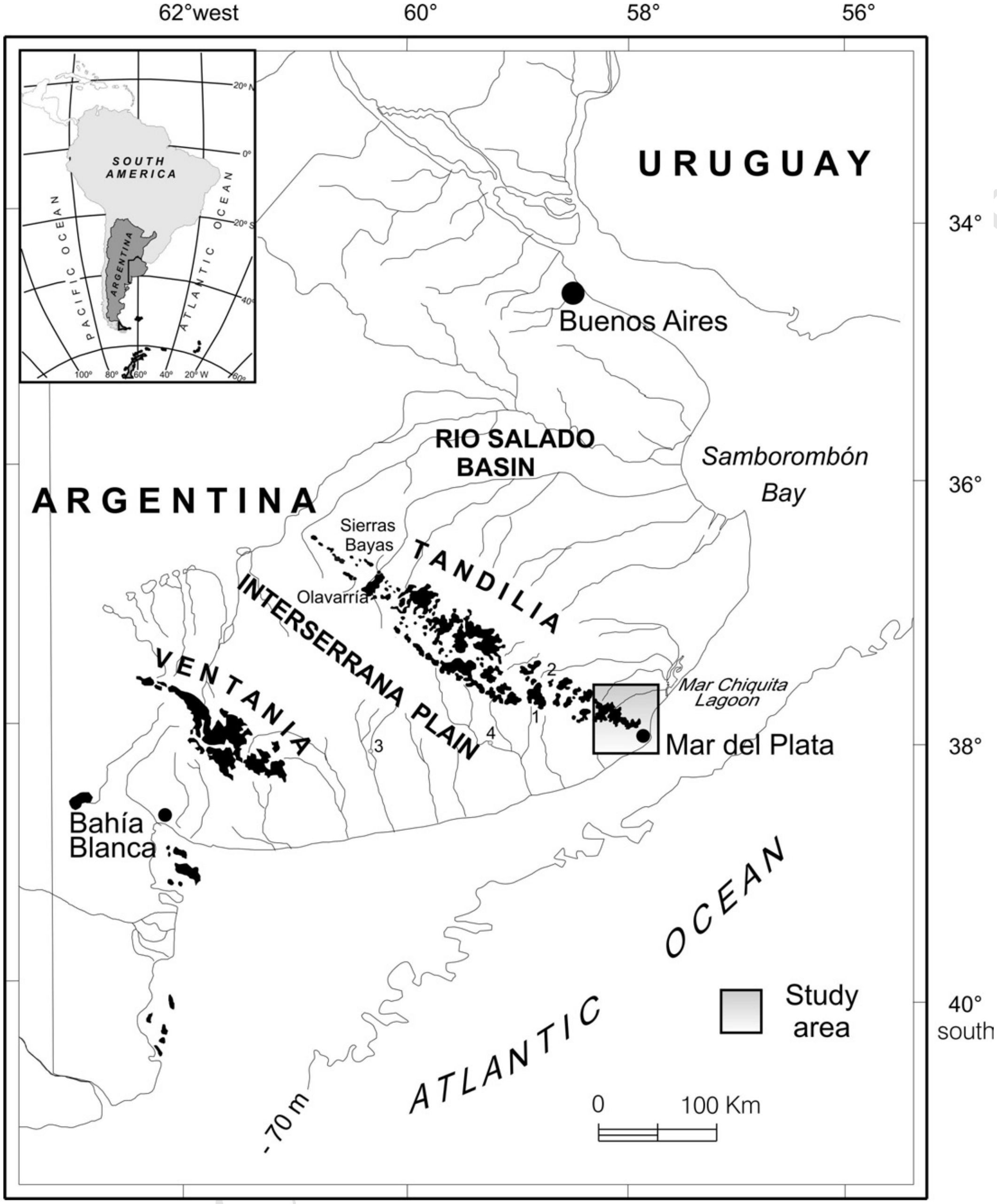
AU		Deph (cm)	SH	AC	Sand %	Silt %	Clay %	C (10YR)	pH	OM	N total (g kg^{-1})	P (ppm)
1		6.5	AC		32	49	19	3/2	3,98	9.96	6,66	1389.6
2		14.5	2AC	▲	32	49	19	3/3	3,93	8.94	4,56	1361.1
3		15	3C	▲	32	43	25	3/1.5	5,39	10.83	6,99	1591.8
4		25	4C	▲	38	40	22	3/3	4,15	6.89	3,78	679.9
5	a	27	5Cb	▲	39	40	21	3.5/3	4,19	5.88	3,64	729.9
	b	34			36	43	21	4/2	4,05	6,53	3,23	553.7
	c	40			37	46	17	4/2.5	4,04	5.86	3,10	394.8
	d	48			37	48	15	4/2	4,08	4.88	3,30	539.2
	e	55			43	43	14	4/2.5	3,88	5.00	2,56	528.5
6	a	94		▲	40	50	10	4/3	3,70	4.74	2,26	967.5
	b	104		▲	45	43	12	4/2	4,04	3.97	2,26	1157.9
7		180			55	38	7	7/3	4,17	6.69	2,28	1208.7

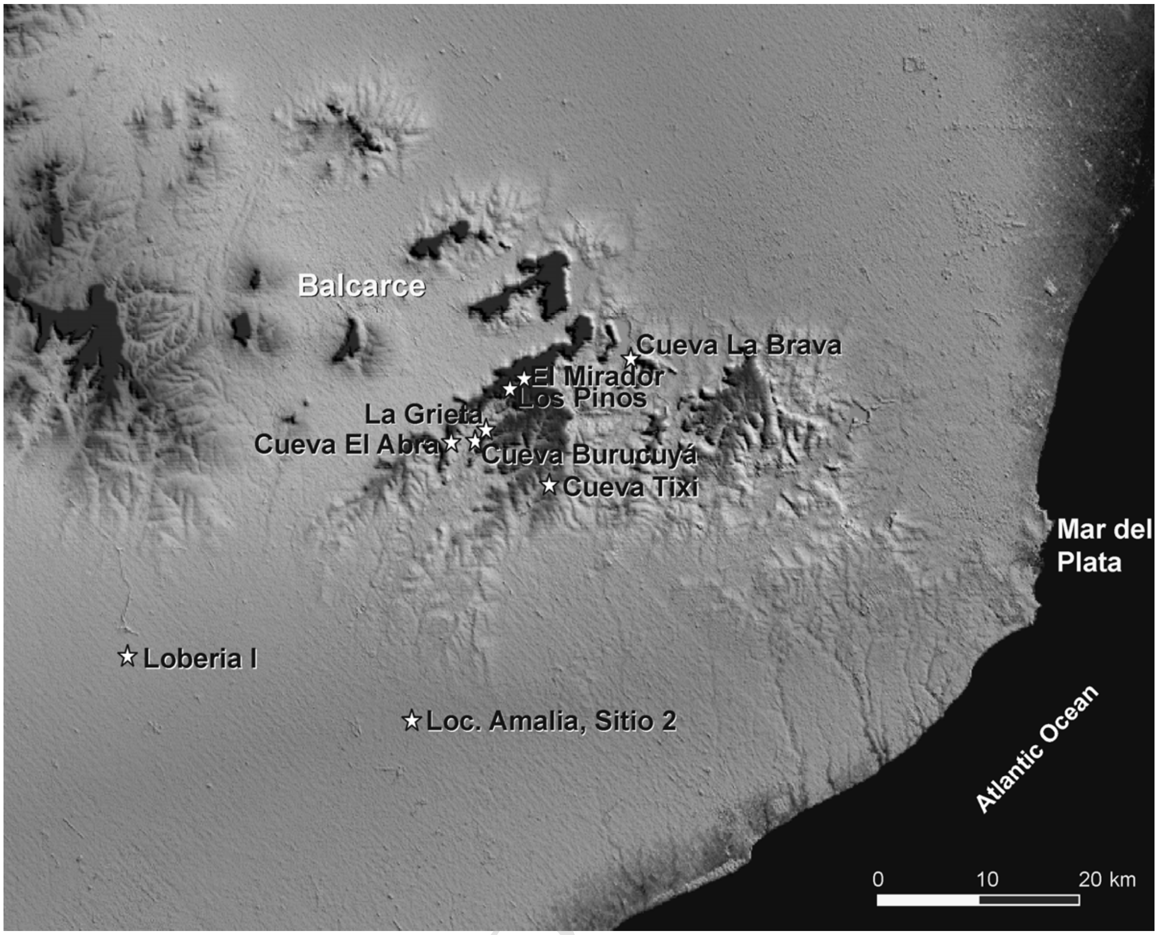
Table 2

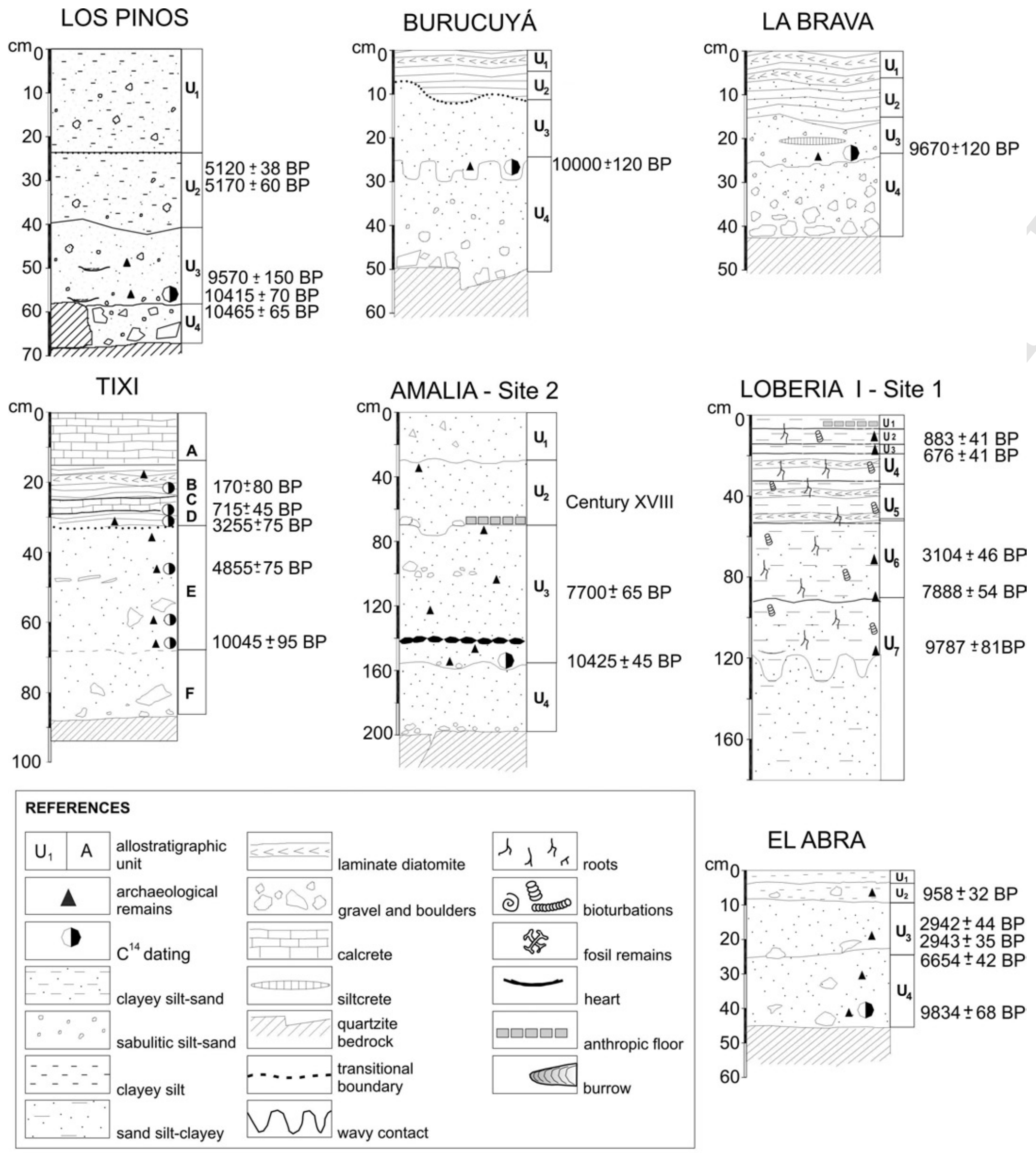
Site	^{14}C Age (yr BP) Charcoal	Lab
Cueva Tixi	10,045 ± 95 (AMS) 10,375 ± 90 (AMS)	AA-12131 AA-12130
Abrigo Los Pinos	9570 ± 150 10,465 ± 65 (AMS) 10,415 ± 70 (AMS)	LP-630 AA-24045 AA-24046
Cueva Burucuyá	10,000 ± 120 10,672 ± 56 (AMS)	LP-863 AA-94640
Cueva El Abra	9834 ± 65 (AMS) 10,270 ± 200 (AMS)	AA-38098 AA-94641
Cueva La Brava	9670 ± 120 10,178 ± 54 (AMS)	LP-550 AA-94639
Amalia Sitio 2	10,425 ± 75 (AMS)	AA-35499
Lobería I Sitio 1	9787 ± 81 (AMS)	AA-81063

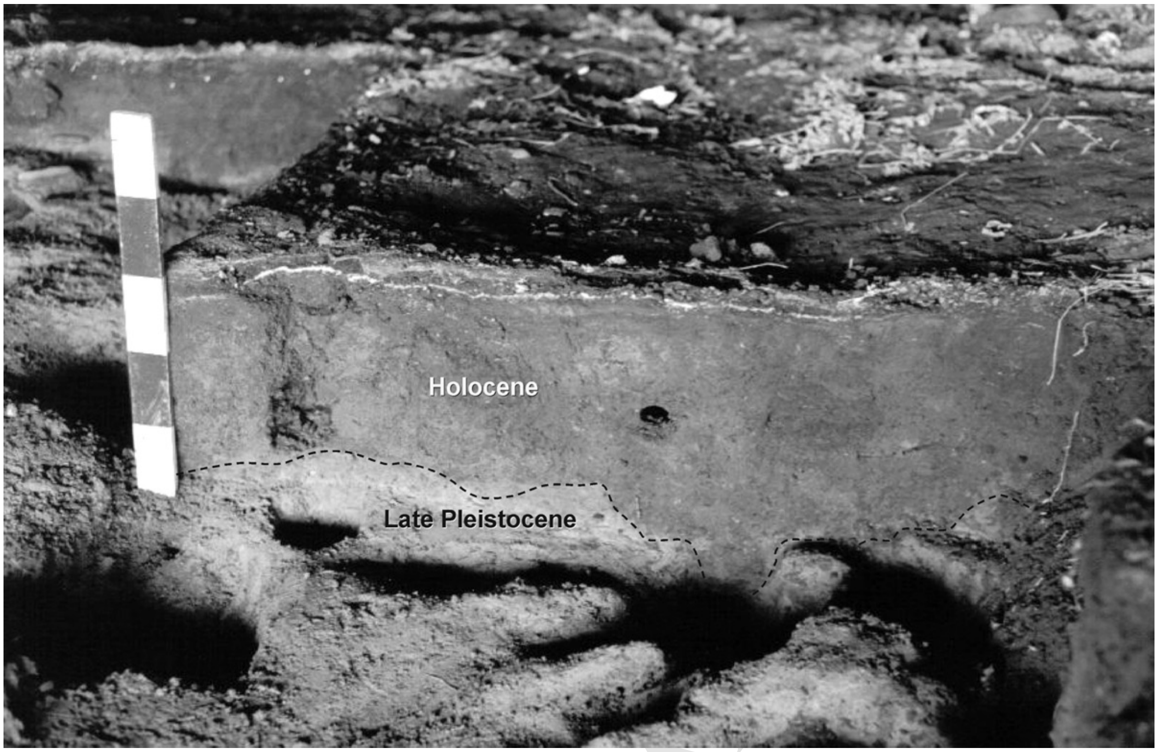
	Cueva Tixi NISP	**Cueva El Abra NISP**
Lestodelphys halli	14	
†(1) *Monodelphis* sp.	5	
Thylamys sp.	6	
Didelphidae indet.	3	
Akodon azarae	41	
Calomys sp.	3	
Holochilus brasiliensis	3	1
Necromys obscurus	27	
Oxymycterus rutilans	9	
Reithrodon auritus	464	
Cavia aperea	17	
Ctenomys talarum	190	8
Dolichotis patagonum	4	3
†*Galea tixiensis*	41	
Lagostomus maximus	31	12
Myocastor coypus	4	
†*Canis avus*	8	
(2) Canis sp. A	1	2
(3) Canis sp. B	19	
Lycalopex gimnocercus	1	
Puma concolor	2	
Chaetophractus villosus	6 (412)	96
Dasypus hybridus	6	
† *Eutatus seguini*	8 (20)	
Zaedyus pichiy	232	13
Lama guanicoe	51	
Ozotoceros bezoarticus	23	1
Tupinambis cf. *merianae*	5	
Bothrops sp.	4	
Colubridae indet.	1	1
Amphibia indet.	1	
Rhea americana	7 (31)	
(4) Aves indet	(24)	1

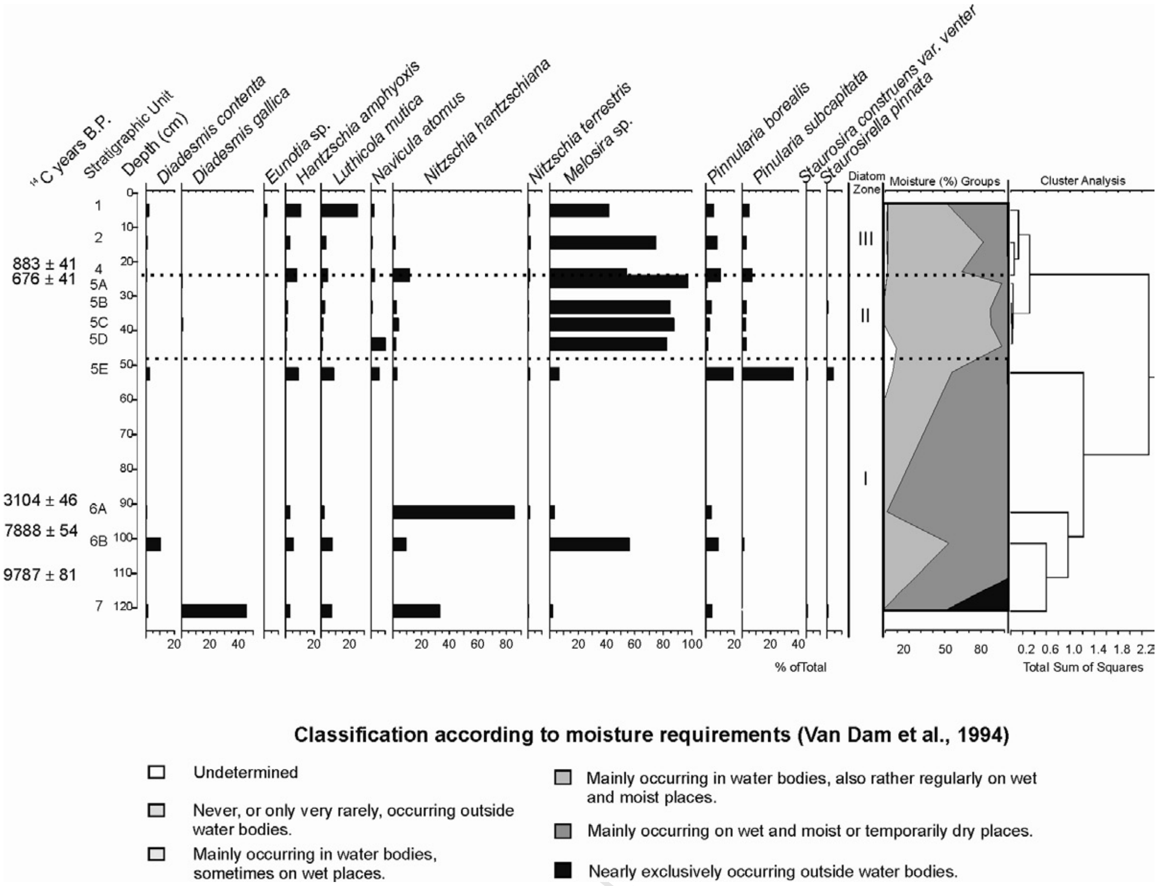
Table 3

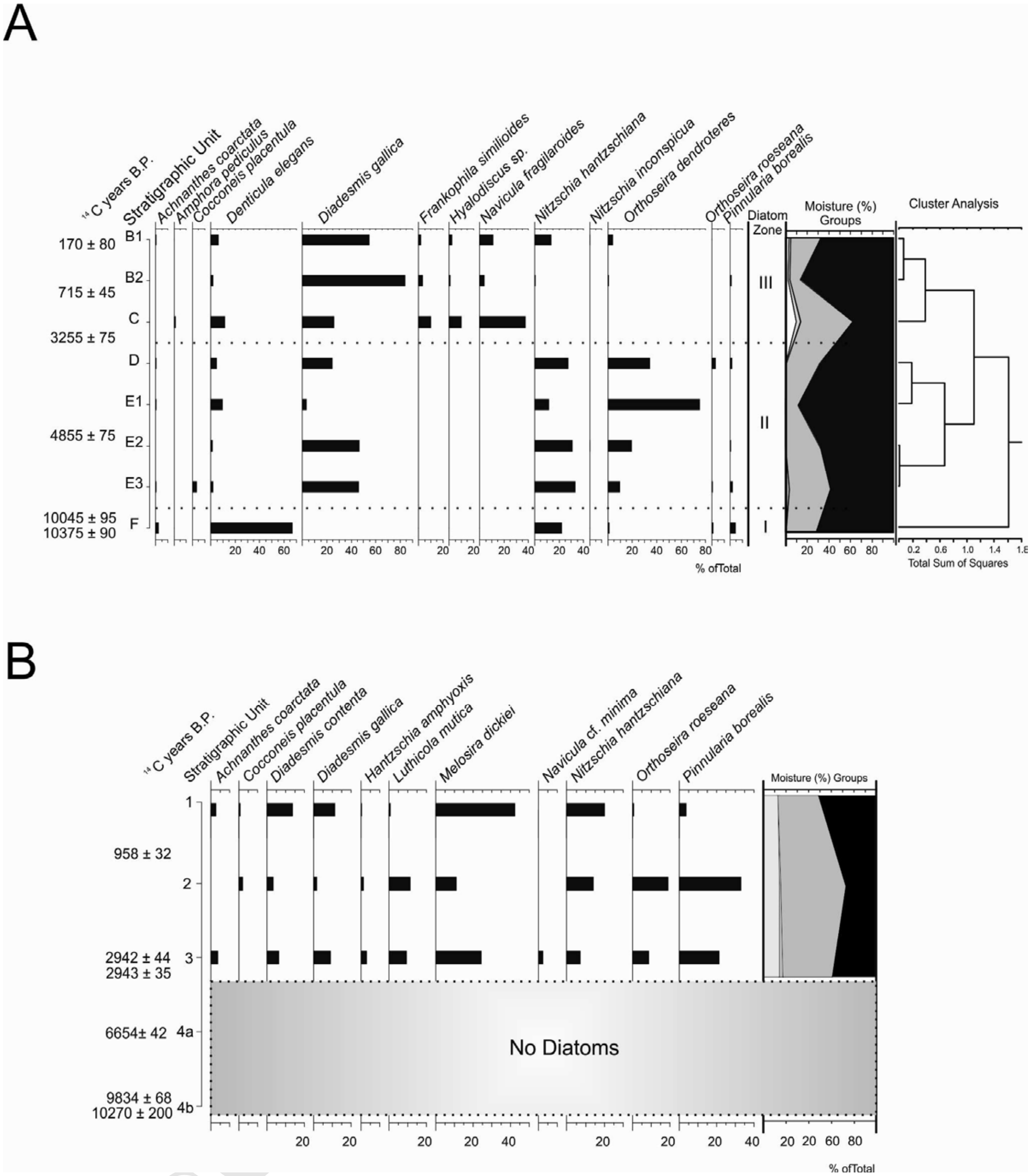

62°west
60°
58°
56°
34°
36°
38°
40°
south
SOUTH AMERICA
ARGENTINA
PACIFIC OCEAN
ATLANTIC OCEAN
20° N
0°
20° S
40°
60°
100°
80°
40°
20° W
URUGUAY
Buenos Aires
RIO SALADO BASIN
Samborombón Bay
ARGENTINA
Sierras Bayas
Olavarría
TANDILIA
INTERSERRANA PLAIN
VENTANIA
1
2
3
4
Mar Chiquita Lagoon
Mar del Plata
Bahía Blanca
ATLANTIC OCEAN
-70 m
Study area
0
100 Km

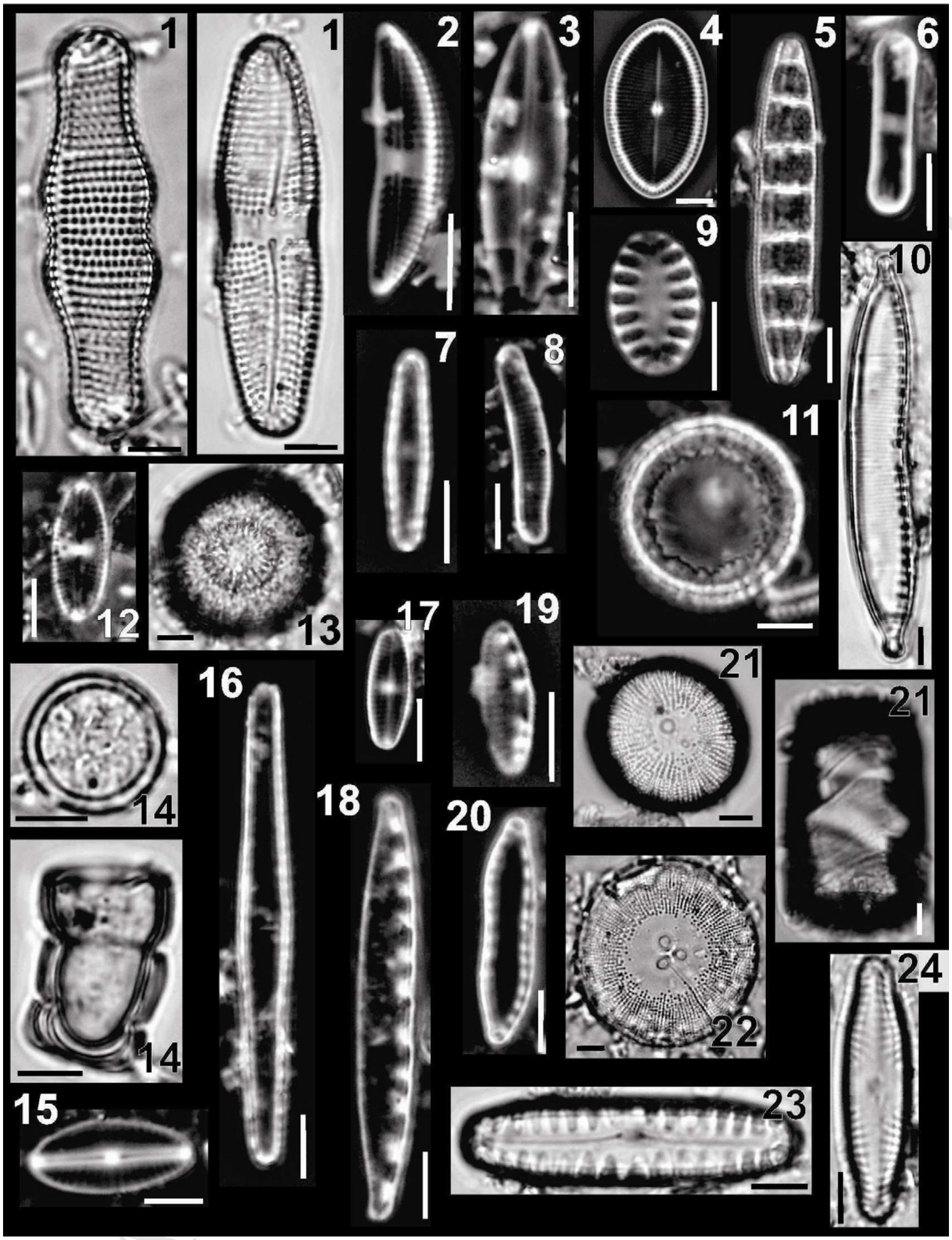

Balcarce
Cueva La Brava
El Mirador
Los Pinos
La Grieta
Cueva El Abra
Cueva Burucuyá
Cueva Tixi
Mar del Plata
Loberia I
Loc. Amalia, Sitio 2
Atlantic Ocean
0
10
20 km

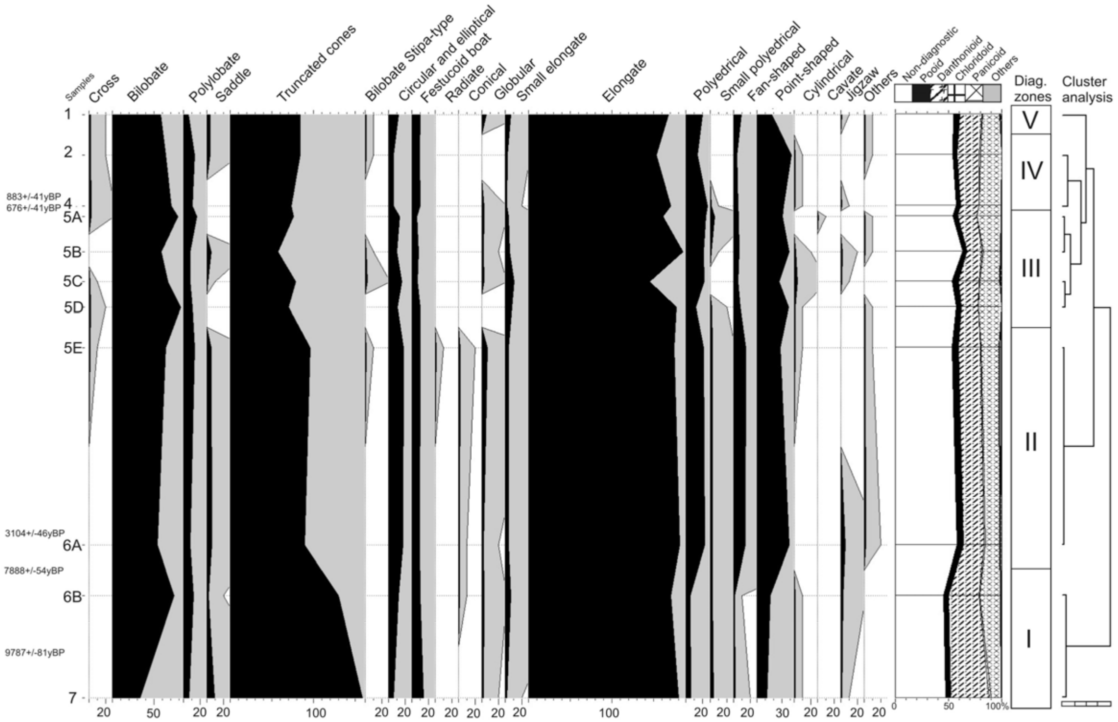

LOS PINOS
cm 0 10 20 30 40 50 60 70
U1
U2
U3
U4
5120 ± 38 BP
5170 ± 60 BP
9570 ± 150 BP
10415 ± 70 BP
10465 ± 65 BP
BURUCUYÁ
cm 0 10 20 30 40 50 60
U1
U2
U3
U4
10000 ± 120 BP
LA BRAVA
cm 0 10 20 30 40 50
U1
U2
U3
U4
9670 ± 120 BP
TIXI
cm 0 20 40 60 80 100
A
B
C
D
E
F
170 ± 80 BP
715 ± 45 BP
3255 ± 75 BP
4855 ± 75 BP
10045 ± 95 BP
AMALIA - Site 2
cm 0 40 80 120 160 200
U1
U2
U3
U4
Century XVIII
7700 ± 65 BP
10425 ± 45 BP
LOBERIA I - Site 1
cm 0 40 80 120 160
U1
U2
U3
U4
U5
U6
U7
883 ± 41 BP
676 ± 41 BP
3104 ± 46 BP
7888 ± 54 BP
9787 ± 81BP
EL ABRA
cm 0 10 20 30 40 50 60
U1
U2
U3
U4
958 ± 32 BP
2942 ± 44 BP
2943 ± 35 BP
6654 ± 42 BP
9834 ± 68 BP
REFERENCES
U1 A allostratigraphic unit
archaeological remains
C14 dating
clayey silt-sand
sabulitic silt-sand
clayey silt
sand silt-clayey
laminate diatomite
gravel and boulders
calcrete
siltcrete
quartzite bedrock
transitional boundary
wavy contact
roots
bioturbations
fosil remains
heart
anthropic floor
burrow

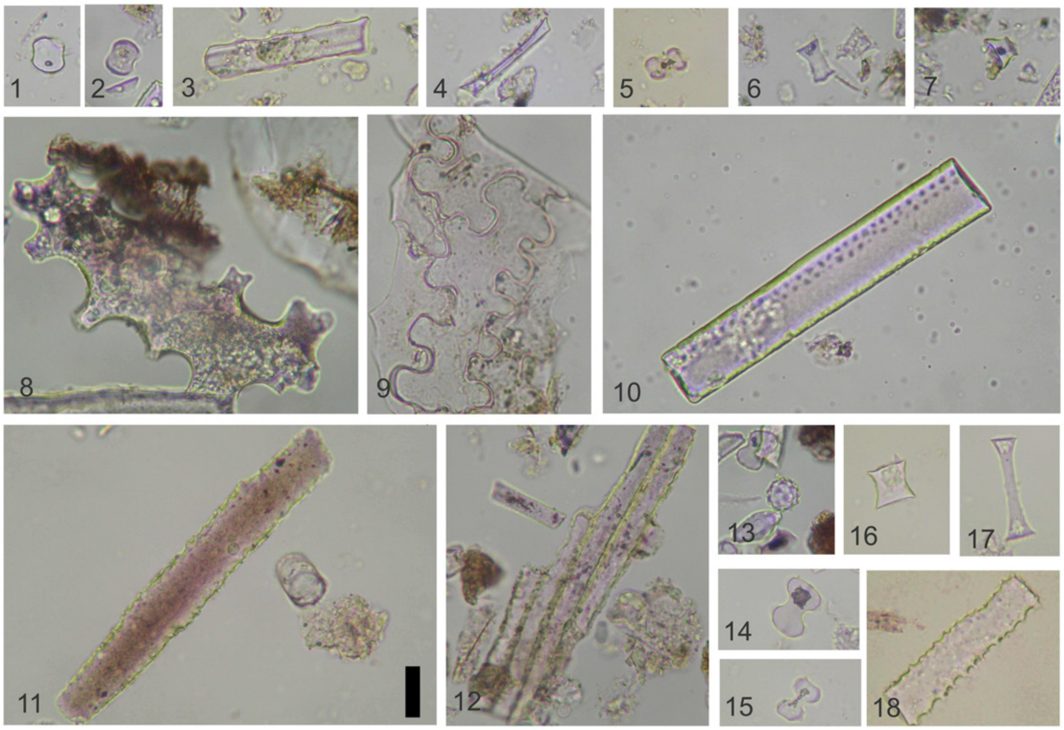

Holocene
Late Pleistocene

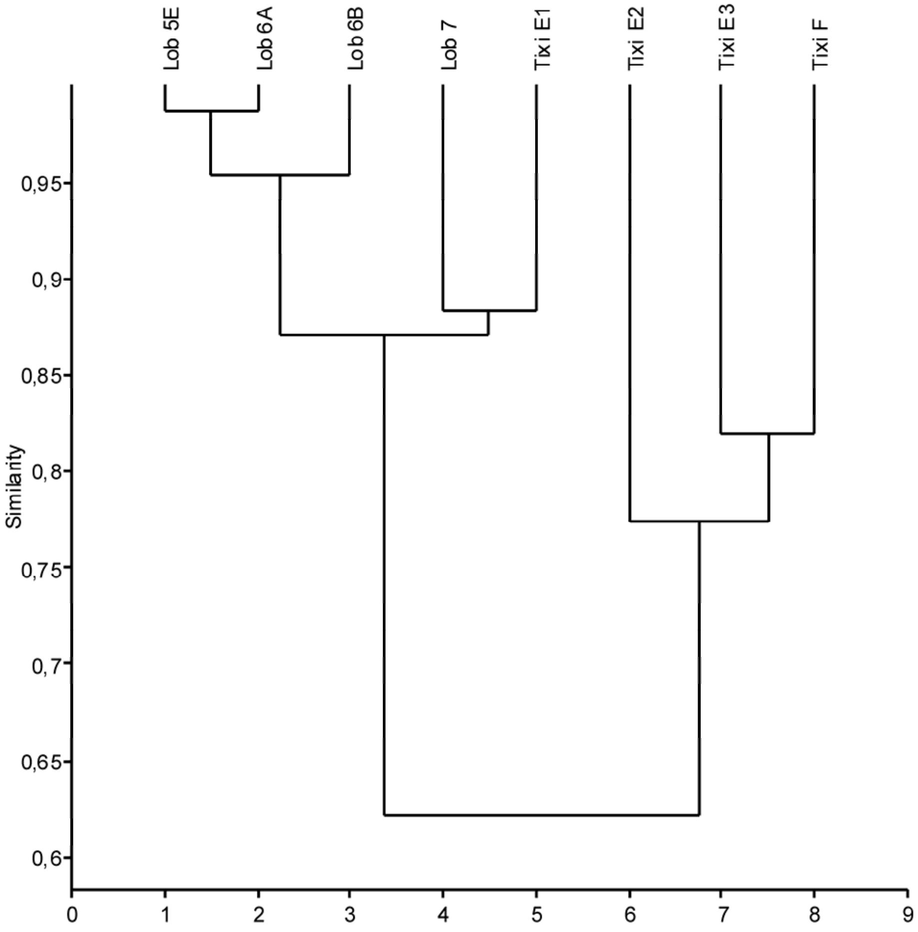

¹⁴C years B.P.
Stratigraphic Unit
Depth (cm)
Diadesmis contenta
Diadesmis gallica
Eunotia sp.
Hantzschia amphyoxis
Luthicola mutica
Navicula atomus
Nitzschia hantzschiana
Nitzschia terrestris
Melosira sp.
Pinnularia borealis
Pinularia subcapitata
Staurosira construens var. venter
Staurosirella pinnata
Diatom Zone
Moisture (%) Groups
Cluster Analysis
883 ± 41
676 ± 41
3104 ± 46
7888 ± 54
9787 ± 81
1
2
4
5A
5B
5C
5D
5E
6A
6B
7
0
10
20
30
40
50
60
70
80
90
100
110
120
III
II
I
% of Total
Total Sum of Squares
0.2 0.6 1.0 1.4 1.8 2.2
Classification according to moisture requirements (Van Dam et al., 1994)
☐ Undetermined
☐ Never, or only very rarely, occurring outside water bodies.
☐ Mainly occurring in water bodies, sometimes on wet places.
☐ Mainly occurring in water bodies, also rather regularly on wet and moist places.
☐ Mainly occurring on wet and moist or temporarily dry places.
■ Nearly exclusively occurring outside water bodies.


A
¹⁴C years B.P.
Stratigraphic Unit
Achnanthes coarctata
Amphora pediculus
Cocconeis placentula
Denticula elegans
Diadesmis gallica
Frankophila similioides
Hyalodiscus sp.
Navicula fragilaroides
Nitzschia hantzschiana
Nitzschia inconspicua
Orthoseira dendroteres
Orthoseira roeseana
Pinnularia borealis
Diatom Zone
Moisture (%) Groups
Cluster Analysis
170 ± 80
715 ± 45
3255 ± 75
4855 ± 75
10045 ± 95
10375 ± 90
B1
B2
C
D
E1
E2
E3
F
III
II
I
% ofTotal
Total Sum of Squares
B
¹⁴C years B.P.
Stratigraphic Unit
Achnanthes coarctata
Cocconeis placentula
Diadesmis contenta
Diadesmis gallica
Hantzschia amphyoxis
Luthicola mutica
Melosira dickiei
Navicula cf. minima
Nitzschia hantzschiana
Orthoseira roeseana
Pinnularia borealis
Moisture (%) Groups
958 ± 32
2942 ± 44
2943 ± 35
6654± 42
9834 ± 68
10270 ± 200
1
2
3
4a
4b
No Diatoms
% ofTotal


1
1
2
3
4
5
6
9
10
7
8
11
12
13
17
19
21
21
14
16
18
20
22
24
14
15
23


Samples
Cross
Bilobate
Polylobate
Saddle
Truncated cones
Bilobate Stipa-type
Circular and elliptical
Festucoid boat
Radiate
Conical
Globular
Small elongate
Elongate
Polyedrical
Small polyedrical
Fan-shaped
Point-shaped
Cylindrical
Cavate
Jigzaw
Others
Non-diagnostic
Pooid
Danthonioid
Chloridoid
Panicoid
Others
Diag. zones
Cluster analysis
1
2
883+/-41yBP
676+/-41yBP
4
5A
5B
5C
5D
5E
3104+/-46yBP
6A
7888+/-54yBP
6B
9787+/-81yBP
7
V
IV
III
II
I
20
50
20
20
100
20
20
20
20
20
20
20
100
20
20
20
30
20
20
20
20
0
50
100%


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18


Lob 5E
Lob 6A
Lob 6B
Lob 7
Tixi E1
Tixi E2
Tixi E3
Tixi F
Similarity
0,95
0,9
0,85
0,8
0,75
0,7
0,65
0,6
0
1
2
3
4
5
6
7
8
9