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Miscanti-1: Human occupation during the arid Mid-Holocene event in the high-altitude lakes of the Atacama Desert, South America

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ABSTRACT

This paper presents an interdisciplinary study of the Miscanti-1 archaeological site, located in the Holocene terrace deposits accumulated on the eastern margin of Miscanti Lake (4120 m.a.s.l.), northern Chile (23.7° S, 67.7° W). The human response to environmental and climatic variability in the Mid-Holocene (9500-4500 cal yr BP) is discussed through the zooarchaeological, lithic and paleoenvironmental records. We propose that, due to the increased aridity of the period, Miscanti Lake became a brackish paleowetland that attracted discrete groups of hunter-gatherers from lower elevation Andean areas. In contrast with the high frequency of human occupations known for the humid Late Pleistocene and Early Holocene (12600-9500 yr cal BP), the Miscanti-1 site is one of the few occupations recorded in the Atacama Highlands during the Mid-Holocene period. Data analysis suggests logistic and short-term campsite use for hunting the wild camelids that were attracted by the wetlands and fresh water (8100–8300 yr cal BP). In contrast to previous proposals for this period, we propose that access to high altitude environments did not cease, but was made possible by a shift to highly scheduled mobility and a specialized bifacial technology. Finally, the temporal and spatial links of Miscanti-1 are discussed in a regional context.

1. Introduction

Consensus currently exists that during the Late Pleistocene and Early Holocene (16000-9700 yr cal BP), climatic conditions in the Atacama Desert (18–25°S) on the western slope of the Andes (>2000 m.a.s.l.) were more humid than today (Betancourt et al., 2000; Grosjean et al., 1997; Latorre et al., 2006, 2002; Moreno et al., 2007; Nester et al., 2007; Núñez et al., 2005; Placzek et al., 2009; Quade et al., 2008; Rech et al., 2002; Sáez et al., 2016). The last glacial wet event corresponds to the widespread pluvial stages resulting from the expansion of the tropical circulation belt to 24–25°S (Kessler, 1991; Markgraf, 1989). Also called the "Central Atacama Pluvial Event" (CAPE), has been split into two phases: CAPE I (17500-14200 yr cal BP) and CAPE II (13800-9700 yr cal BP) (Gayó et al., 2012; Latorre et al., 2006; Placzek et al., 2009; Quade et al., 2008). In the Central Andes, two major lake expansion pulses have been registered, linked to the regional CAPE event: the Tauca phase (18000-14000 yr cal BP) and the Coipasa phase (13000-10000 yr cal BP) (Placzek et al., 2006; Sylvestre et al., 1999). However, the timing of the Tauca wet phase proposed for the large Central Andean lakes is different from that for lakes in the southern Atacama (25°S), particularly CAPE I dated around 14,500 yr cal BP (Sáez et al., 2016).

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The Mean Annual Precipitation (MAP) in the southern Atacama Desert exceeded 400–500 mm on the western slope of the Andes, compared to 200 mm currently (Grosjean, 1994; Kull and Grosjean, 1998). As result, large paleolakes formed in the basins located in the "high *puna*" (above 3800 m.a.s.l.), covering areas six times larger than today (Grosjean et al., 2001, 1997). Two peaks are recorded for elevated lacustrine levels of high altitude lakes in the *altiplano*: one around 12800 yr cal BP and another before 10200 yr cal BP (Geyh et al., 1999; Grosjean et al., 2001; Valero-Garcés et al., 1999, 1996).

The greater infiltration of groundwater increased phreatic levels in the pre-Andean floor (3000–3800 m.a.s.l.) and the foothills (2000 m.a.s.l.) (Betancourt et al., 2000; Grosjean et al., 1997; Latorre et al., 2002; Quade et al., 2008; Sáez et al., 2016). Wetter conditions even reached the intermediate depression or *pampa* (1000 m.a.s.l.) where extremely arid conditions prevail, as has been observed in the central Atacama (Gayó et al., 2012, 2010; Latorre et al., 2013; Nester et al., 2007).

Under these more favourable conditions, groups of hunter-gatherers that populated the highlands of the Atacama Desert (Fig. 1A) during the Late Pleistocene-Early Holocene transition had access to most of the environmental scenarios available. An important set of settlements distributed on the western slope of the Andes shows circuits of seasonal mobility between the high puna (>3800 m.a.s.l.), the basins and ravines of the pre-Andean floor (3000–3800 m.a.s.l.) and the oases of the foothills (2000 m.a.s.l.) (Fig. 1B) (Bao et al., 2015; Cartajena et al., 2014; De Souza, 2004; Grosjean and Núñez, 1994; Loyola et al., 2017a,b; Núñez et al., 2002).

During the Mid-Holocene (9500-4500 yr cal BP), the water levels of high puna lakes dropped dramatically as a result of lower rainfall and a sustained increase in temperatures (Bao et al., 2015; Geyh et al., 1999; Grosjean and Núñez, 1994; Grosjean et al., 2003, 2001, 1997, 1995; Valero-Garcés et al., 1996; Wirrmann and Oliveira Almeida, 1987). Several studies agree that these arid conditions were a widespread event in the central and south-central Andes (Placzek et al., 2009; Sifeddine et al., 1998; Sylvestre et al., 1999; Wirmann and Mourguiart, 1995). In the southern Atacama, this dry period has been identified between 9500 and 4000 yr cal BP through the study of lacustrine sediments in the Miscanti Lake (4200 m.a.s.l.) and groundwater discharge deposits in Sierra Varas (3446 m.a.s.l.) (Grosjean et al., 2003, 2001; Sáez et al., 2016).

After the decrease in lacustrine levels and the contraction of Miscanti Lake (Fig. 1), hypersaline conditions prevailed and in some sectors the previously deposited sediments were exposed to the atmosphere (Valero-Garcés et al., 1996). However, around 6000 to 5500 yr cal BP, several humid events occurred (Grosjean et al., 2003). Similar phenomena have been found in the short humid pulses recorded near the Salar de Atacama, Salar de Uyuni and Potosi (Abbott et al., 2003; Baker et al., 2001; Bobst et al., 2001). Moreover, the same pattern of events has been registered in distant

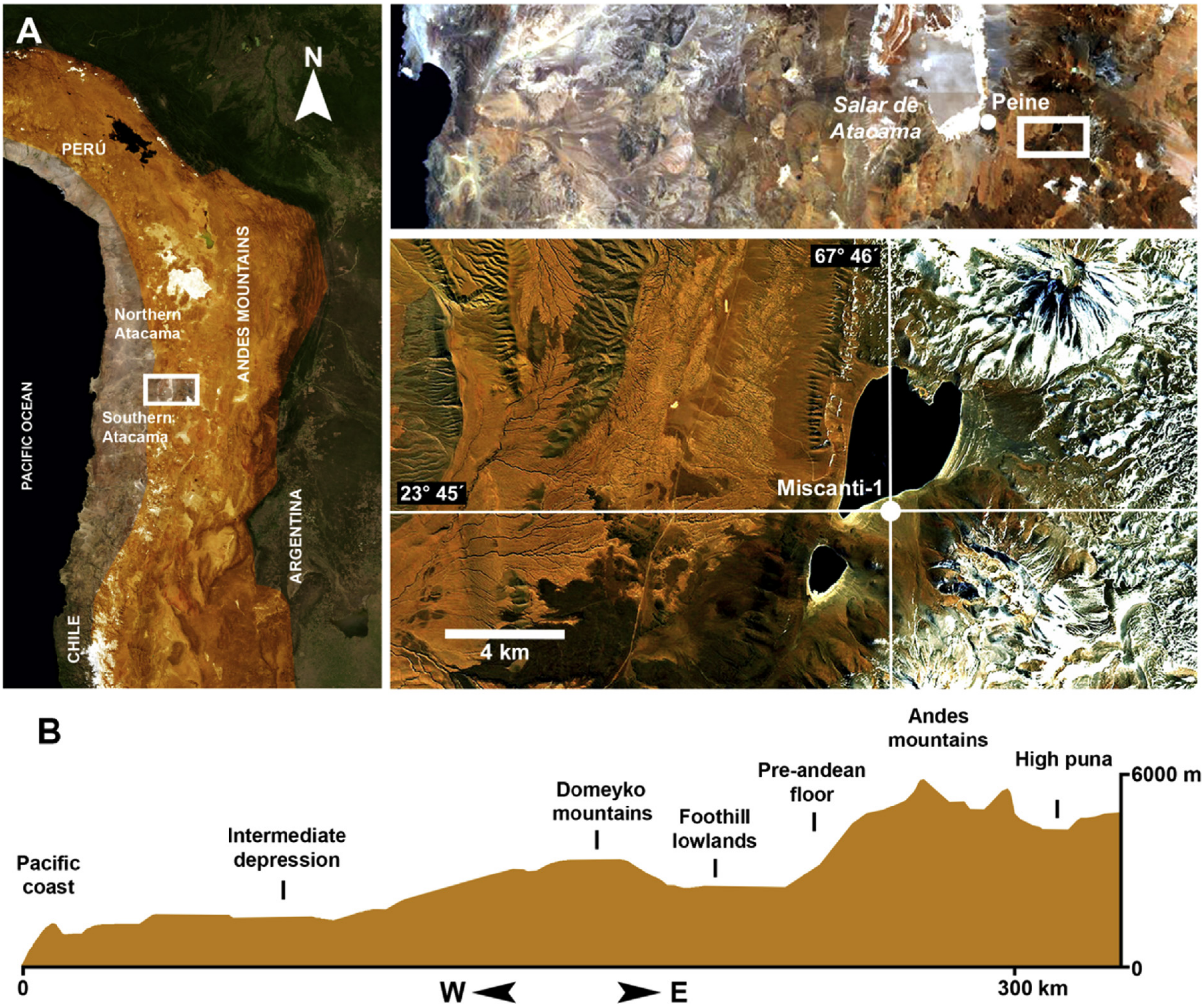

Fig. 1. Study Area: (A) Location of Miscanti-1 site, (B) Geomorphologic profile of Central Atacama Desert.

regions of the Andean cordillera, such as central Patagonia (Ariztegui et al., 2010).

On the eastern slope of the Andes (north-western Argentina), the Mid-Holocene would have also been an extremely arid period, with more intense effects in the eastern sector (Tchilinguirian and Morales, 2013; Yacobaccio and Morales, 2005). Two pulses of higher humidity than today are observed in this period: the first occurred at the beginning of the Mid-Holocene, between 8200 and 7600 BP (9100–8300 yr cal BP). The second was from 6300 to 6100 BP (7200–7050 yr cal BP) (Yacobaccio and Morales, 2005). In north-eastern Argentina arid conditions consolidated much later, from 8500 to 9000 yr cal BP, and became more accentuated only around 6800 yr cal BP (Olivera et al., 2004).

The climatic and environmental conditions of the Mid-Holocene were heterogeneous and variable, with a differential impact in both spatial and temporal terms. The archaeological record is consistent in this regard. Under the adverse conditions of the Mid-Holocene, most human occupations on the western slope of the Andes in the southern Atacama Desert (22–25.5°S) were abandoned. The marked discontinuity in human occupation in the archaeological record led to this process being described as an “archaeological silence” (Núñez et al., 2005). It is now accepted that human groups relocated to alternative spaces called ecological refuges or “ecoshelters” (Núñez et al., 2013, 1999), where there was a stable and highly diverse concentration of plant, water and faunal resources (Grosjean et al., 2007; Núñez et al., 1999). This new scenario allowed greater control of access to resources and gradual territorial circumscription (Núñez et al., 1999).

The spatial reorganization of human groups around more productive zones or micro-habitats seems to have been a region-wide process, and explains why the frequency of dated sites is much lower than in earlier periods (Grosjean et al., 2005, 1997; Núñez et al., 2005, 1999). In fact, a macro-regional demographic bottleneck during the Mid-Holocene has been hypothesized (Barberena et al., 2017).

In the southern Atacama during this arid period, groups of inland hunter-gatherers inhabited the *quebradas* (ravines) of the pre-cordillera, where resources were concentrated on the floors of valleys such as Puripica and Tulán (Núñez et al., 2013). Isolated concentrations of flora and fauna, especially around year-round springs and meadows, permitted the establishment of archaic settlements in the pre-Andean sectors of the Atacama basin, including the adjacent high puna. All sites of sporadic occupation are located in valleys, near wetlands associated with large springs where subsistence resources were locally still available despite a generally arid climate (Betancourt et al., 2000; Grosjean et al., 2001, 1997).

Only one small Mid-Holocene human occupation has been recorded in Quebrada Tulán (SE of the Atacama basin); it is found in the stratigraphic profile of Tulán-67, a small rock-shelter located on the southern side of the ravine at 2669 m.a.s.l. Occupations dated 5320 ± 90 BP (6281-5769 yr cal BP) (Hedges et al., 1989 in Dransart, 1991:296) and 5940 ± 50 BP (6855-6552 yr cal BP) (Núñez et al., 2005) suggest recurrent low intensity occupations (Núñez et al., 2013).

In Quebrada Puripica in the SE Atacama (22°48′S, 68°04′W; 3250 m.a.s.l.), an ecological refuge gradually developed in the confluence area of the Puripica stream and Quebrada Seca, where a shallow lake and wetland environment formed in the backwaters of the emerging alluvial cone. Sterile fluvial sands have preserved the oldest small fireplace P-39/40 (7409-6569 yr cal BP) corresponding to a short term, single occupation by a small, highly mobile group. A second campsite (7167-6737 yr cal BP) contains a few bone artefacts and a large number of lithic artefacts and bone remains (*L. guanicoe*), showing production of lanceolate artefacts. Around 6886-6406 yr cal BP, a more diversified technology and occupation pattern is found characterized by denser campsites, where high mobility and the use of exotic materials continued to be important (Núñez et al., 2013.)

On a wider scale, it is remarkable that all the sites dating from the Mid-Holocene period in the central and southern Atacama are found exclusively on the pre-Andean floor (3000–3800 m.a.s.l.). In contrast, the situation on the eastern slope of the Andes (north-western Argentina) is quite different: firstly, in some areas the archaeological records do not show any occupational discontinuity; and secondly, a more recurrent occupation of high elevation sites is observed. An important number of archaeological sites in north-western Argentina suggest a change in mobility strategies and technology during the Mid-Holocene, for example Hornillos-2 (4020 m.a.s.l.) (Yacobaccio and Morales, 2005), Quebrada Seca-3 (4100 m.a.s.l.) (Aschero et al., 1993–94; Pintar, 2009), Cueva Salamanca-1 (3667 m.a.s.l.) (Pintar, 2014, 2009), Peña de la Cruz-1 (3665 m.a.s.l.) (Martínez, 2003), Alero Cuevas (4400 m.a.s.l.) and Abrigo Pozo Cavado (3700 m.a.s.l.) (López, 2013).

These regional differences have led to a suggestion that environmental conditions were especially arid in the southern Atacama during the Mid-Holocene. In this scenario, human groups limited their access to the high puna and developed greater territorial circumscription on the pre-Andean floor (Núñez et al., 2005).

Certainly the evidence of Quebrada Puripica and Tulán, have enabled understanding of the cultural process and adaptative strategies during the prolonged Mid-Holocene drought between 9000 and 4200 yr cal BP Núñez et al. (2013, 2002) People did not completely abandon this area, but moved to alternative, newly-created habitats in wetlands in steep valleys, or where large springs or regional river systems and newly-formed wetlands in the flat bottoms of former paleolakes ensured that resources remained stable.

Núñez et al. (2002) gave a general overview of pre-Andean ecoshelters; meanwhile a detailed review of high-altitude sites is required to understand the role of these occupations in the general context. Miscanti-1 is one of the few settlements found so far in the high puna on the western slope of the Andes, which was occupied during the arid Mid-Holocene. During this arid period, the paleolake was replaced by wetlands and grazing areas in the flat bottom of the former lake, and thus more favourable habitats were created in a drier climate (Grosjean et al., 2001). A similar scenario has been suggested for other regions as Lago Cardiel (Central Patagonia) where low lake levels coincided with increasing human occupation, suggesting that the basin was used during intervals with lower effective moisture. The drying of the lake may have attracted both fauna and groups of hunter-gatherers, since water resources at the time were quite scarce (Ariztegui et al., 2010).

The main object of our work is to contribute to the identification of the characteristics and dynamics of human occupations at high-altitude lakes in the puna during an arid period of the Mid-Holocene, and specifically to understand which technological and mobility strategies ensured the continuity of resource exploitation in high altitude environments under more restrictive conditions. Our main approach is to cross environmental proxies with archaeological data from lithic and zooarchaeological evidence.

2. Miscanti lake setting

2.1. Current morphology, hydrology and vegetation of the lake

Miscanti Lake (23°44′S, 67°47′W) is a relatively small (13.5 km^2), shallow (10 m maximum depth), brackish endorheic lake, located 1.5 km from Lake Meniques. The hydrographic basin in which both lakes are situated lies on a major fault between the Domeyko pre-cordillera (3500 m.a.s.l.) to the west and the Andes Mountains to the east (6800 m.a.s.l.). The lake is currently surrounded by discrete forage vegetation that contrasts with the arid landscape. Plants like *Festuca* sp., *Fabiana* sp. and *Stipa chrysophylla* form caespitose gramineous meadows on the beaches and alluvial cones that descend into the basin. These plants attract groups of vicuña (*Vicugna vicugna*) which also feed on the adjacent *tolar* – sparse upland vegetation with predominantly low, woody-shrubby vegetation and grasses. Avian species include communities of flamingos (*Phoenicopterus chilensis*), horned coot (*Fulica cornuta*), speckled teal (*Anas flavirostris*) and puna rhea (*Pterocnemia pennata*).

Four main lacustrine environments can be distinguished (Valero-Garcés et al., 1999, 1996): (1) lake shorelines, where there is high erosion and low deposition; (2) freshwater springs located in the north of the area; (3) littoral margins, dominated by steep slopes to the west and a gentle dip to the east and south which is easily flooded; and (4) the lake area characterized by clear water and the absence of surface flows, allowing macrophytes to colonize the lake bottom (Valero-Garcés et al., 1999) (Fig. 1A). The eastern margin, where the old beach terraces containing the Miscanti-1 archaeological deposits studied here are located, is covered by old lacustrine deposits composed of pyroclast-rich gravel and sands, diatomites, calcarenites and stromatolites.

Miscanti Lake is mainly fed by groundwater inflow. There is also a wet season with significant precipitation (annual average 200–250 mm), concentrated in the summer (December to February) due to the influence of the so-called Altiplano Winter. However, the potential evaporation (c. 2000 mm year^{-1}) far exceeds precipitation rates (Grosjean et al., 2001), leading to the formation of a saline lake environment (Valero-Garcés et al., 1996). In the upper part of the basin, however, there is a spring of fresh water of excellent quality that does not exceed 217 g/l TDS (Total Dissolved Salts), fed by groundwater discharge (Risacher et al., 1998).

2.2. *Hydro-geomorphological and environmental evolution of Miscanti Lake during the Plio-Holocene*

Limnological, tectonic, sedimentological, mineralogical, volcanic, geochemical and biological studies and other paleoclimatic proxies were performed in Miscanti Lake, providing a better understanding of its paleoenvironmental evolution (Grosjean et al., 2001; Valero-Garcés et al., 1999, 1996). The absence of depositional interruptions and sedimentary gaps allowed the application of core-drilling and high-resolution seismic techniques to a depth of 25 m. Three major seismic units were identified: (1) Late Glacial - Early Holocene pelagic sediments derived from a much more extensive lake more than 20 m deep (Valero-Garcés et al., 1999) (Fig. 2A and B); (2) Mid-Holocene, represented by coastal deposition round a shallow lake; and (3) Late Holocene, composed of pelagic sediments on an eroded surface (Grosjean et al., 2001; Valero-Garcés et al., 1996).

Around 22000 yr cal BP, during the Glacial period, local tectonic and volcanic activity produced water entrapment resulting in a large, shallow fresh-water lake (38.2 km^2) which reached its highest water level 29 m above the present lake (4179 m.a.s.l.) (Fig. 2C). This was followed by an arid event during the Last Glacial Maximum (18000 BP) which caused the lake to dry out (Grosjean et al., 2001). The Late Glacial lake started to re-form around 14000 yr cal BP, related to the more humid conditions of the second phase of the CAPE event. Two peaks of elevated lacustrine levels have been proposed: the first occurring around 12800 yr cal BP and the second before 10200 yr cal BP (Geyh et al., 1999; Grosjean et al., 2001) when the terrestrial vegetation was established (Grosjean et al., 2001). In hydrological terms, the basin was transformed from a landscape shaped by exorheic processes to one of endoreic alluvial fans (Grosjean et al., 2001; Valero-Garcés et al., 1996).

In the warmer, wetter conditions of the Pleistocene-Holocene transition, Miscanti Lake reached its highest water level 29 m above the present lake level at 4179 m.a.s.l. On the gentle lake margins between these two levels, extensive zones can be recognized with preserved beach ridges generated during retraction pulses of the Early Holocene lake (Geyh et al., 1999; Grosjean et al., 2001; Valero-Garcés et al., 1996).

At the beginning of the Mid-Holocene (9500 yr cal BP), an arid environment developed. While there were slight fluctuations in cycles lasting between decades and several centuries, with evidence of isolated strong storms, the drying process turned Miscanti Lake into a brackish pool or even a bog (Grosjean et al., 2001; Valero-Garcés et al., 1996). The pollen analysis carried out by Grosjean et al. (2001) reveals an absence of freshwater plants at the beginning of the Mid-Holocene, whereas brackish plants (*Ruppia* sp.) are widely represented. Between 9000 and < 6000 yr cal BP, brackish aquatic species disappear, suggesting that the lake was extremely shallow and ephemeral, perhaps drying out periodically in some areas. In fact, aquatic plants were replaced by wetland species (i.e. *Cyperaceae*), indicating that lake drying during the driest period resulted in wetlands and mudflats/mires at the bottom of the lake basin (Grosjean et al., 2001).

On the other hand, the record of the largest group of terrestrial plants (*Gramineae*) does not present major differences between the Early Holocene and Late Holocene; however, we find a decrease in species such as *Chenopodiaceae* typical of lower elevations (below 3500 m.a.s.l.), consistent with the decline in lake levels and the formation of beaches. The pollen concentrations of smaller groups such as the genus *Adesmia* and the Verbenaceae family are significantly reduced or disappear during the Mid-Holocene (Grosjean et al., 2003); instead we find spores of coprophilous fungi (genus *Cercophora*) and a concentration of herbivores (camelids) attracted by the wetlands (Grosjean et al., 2001).

The perennial condition of the lake was reactivated only after the current average precipitation of 150–200 mm a year was reached, around 3600 yr cal BP (Grosjean et al., 2001; Valero-Garcés et al., 1996).

2.3. *The archaeological site*

On the eastern margin of the lake, areas with preserved beach ridges extend as far as 942 m from the present shoreline. The Miscanti-1 site (4172 m.a.s.l.) is located on these beach terraces 10 m above the present shoreline (Fig. 2A). On the surface, heavily eroded faunal remains, hearth residues and lithic artefacts were recorded in an area of 80 m^2 (Fig. 3). A stratigraphic test was performed (60 × 20 cm) and a quantitative block of 20 cm^2 was excavated for a sediment and pollen analysis, taken in 5 cm levels.

3. Results

3.1. *Stratigraphy and chronology*

The archaeological deposit reached a depth of 20 cm (levels 1 to 4) where the sterile base was found (without cultural material). The sedimentary matrix corresponds mostly to volcanic ash (<0.2 mm) with abundant clasts (0.4–1 mm) representing about 30% of the sample. The clasts are mainly angular or rounded fragments of pumice stone. In addition, brown silica fragments, white rounded silica (vuggy silica), angular and sub-angular fragments of plagioclase, iron oxides and roots were observed. The organic matter at the surface would be related to plant colonization of lake shorelines, and a small proportion of sand would come from a pyroclastic deposit of andesitic composition or dacitic ash.

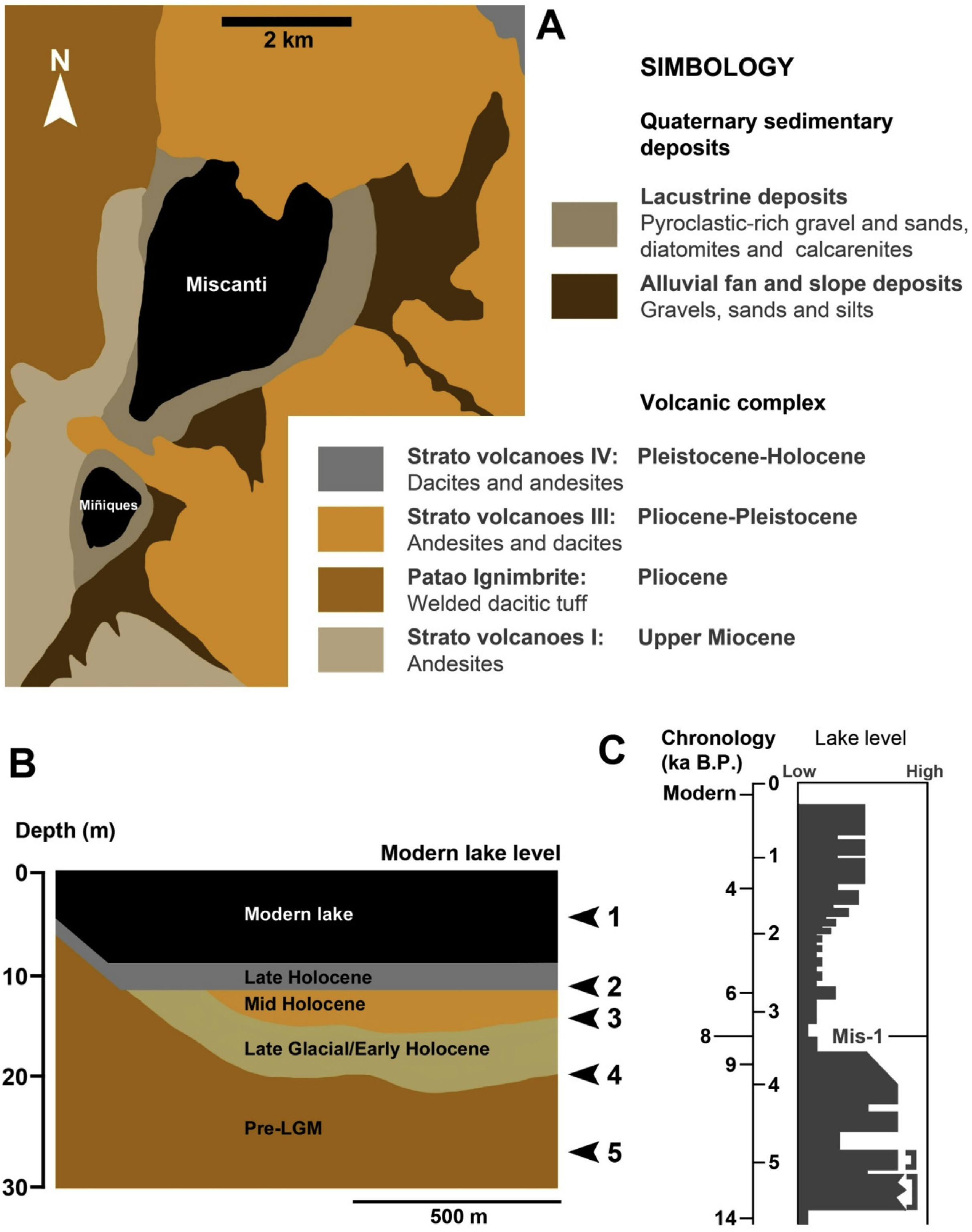

Fig. 2. Geomorphology of Miscanti Lake: (A) Geological formations (B) Estimated lacustrine levels (C) Lake level chronology (modified from Grosjean et al., 2001).

Layer I, comprising the uppermost 5 cm, is characterized by a light-coloured sediment without cultural material. Layer II is a dark ash deposit down to a depth of 20 cm; charcoal associated with lithic artefacts, lithic debris and skeletal remains were recovered from this layer. A first date of 7300 ± 40 BP (8172-7983 yr cal BP) was obtained from charcoal samples recovered in the test pit (10–15 cm deep). A second charcoal dating recovered in the 2 mm grid provided an age of 7430 ± 30 BP (8335-8055 yr cal BP). All dates were calibrated by OxCal v 4.3.2 (Bronk Ramsey, 2017) using the ShCal13 curve (Hogg et al., 2013).

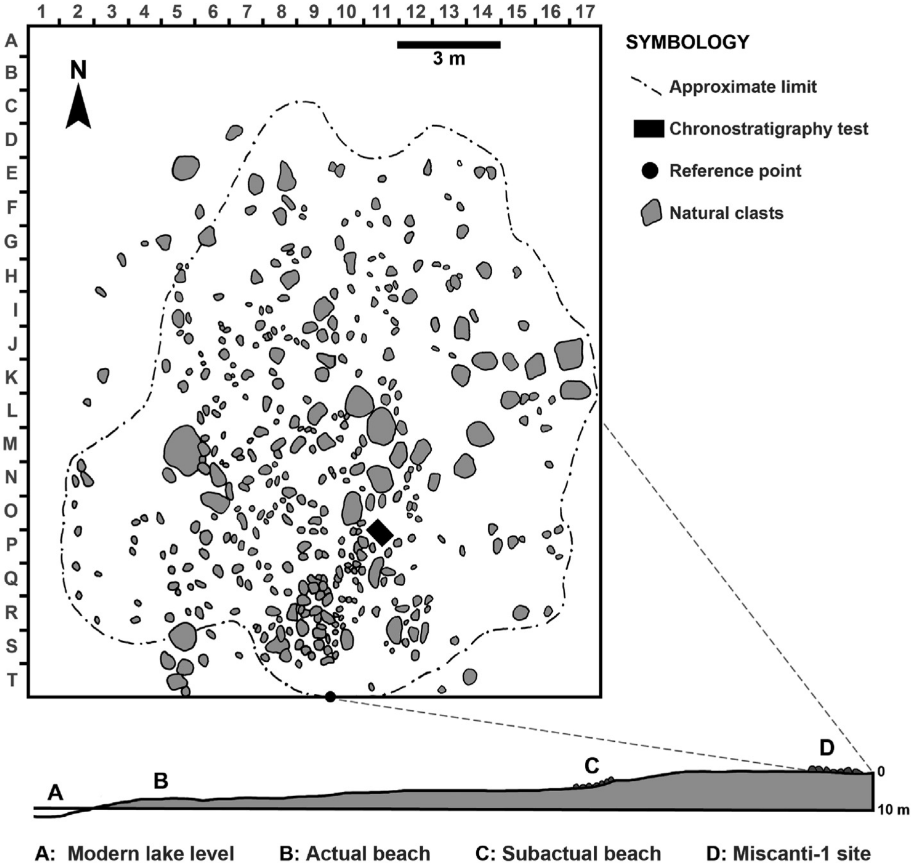

Fig. 3. Location of Miscanti-1 and geomorphology of the site.

3.2. *Lithic assemblage*

The lithic assemblage (n = 304) includes 56 bifacial tools, three unifacial tools on flake and 245 flakes and debris fragments; fragmentation exceeds 50% in all categories (Table 1). No signals of trampling or other potential post-deposit fracturing processes were observed, suggesting that the fragmentation occurred in contexts of use or manufacture.

By classifying artefact particles in size ranges every 5 mm, a differential distribution is obtained along the vertical axis (Fig. 4). It is likely that smaller artefacts were included by burial at lower levels, while larger items were exposed or near the surface. This phenomenon is common in aeolic-lacustrine depositional environments, where humidity also encourages the adherence of smaller artefacts to sedimentary substrate (Borrazzo, 2011; Loyola et al., 2017a and b).

Table 1
Fragmentation by class of artefact.

Anatomic Section	Bifacial tool		Debris		Unifacial Tool		Total	
Complete	27	48,2%	88	35,9%	1	33,3%	116	38,2%
Proximal	10	17,9%	25	10,2%	–	0,0%	35	11,5%
Mesial	2	3,6%	30	12,2%	–	0,0%	32	10,5%
Distal	6	10,7%	60	24,5%	1	33,3%	67	22%
Longitudinal	–	0,0%	10	4,1%	–	0,0%	10	3,3%
Edge Fragment	2	3,6%	29	11,8%	1	33,3%	32	10,5%
Fragmented Stem	1	1,8%	–	0,0%	–	0,0%	1	0,3%
Fragmented tip	8	14,3%	–	0,0%	–	0,0%	8	2,6%
Thermal shock fragment	–	0,0%	1	0,4%	–	0,0%	1	0,3%
Indeterminable	–	0,0%	2	0,8%	–	0,0%	2	0,7%
Total	**56**	**100%**	**245**	**100%**	**3**	**100%**	**304**	**100%**

Another important factor in this process is the shape of the artefacts (Bertrán et al., 2012). Flat trend artefacts are less susceptible to burial, while isotropic particles are rapidly included in the stratigraphy. Horizontal migration transport seems to have been less scarce: aeolic abrasion (partial or total) is mainly found on only one side of the artefacts, indicative of relative stability (Borrazzo, 2004). This means that the artefacts were exposed to subaerial conditions in the same position for most of their taphonomic history (Table 2).

The predominant raw materials in the assemblage are coarse-grained rocks, mainly basalts (68.8%) and tuffs (20.4%). Acid raw materials, such as vitrified rhyodacites, silex, felsites and obsidian, form a minority (Fig. 5). However, differential management of raw materials is not observed. The cortex is absent in practically all raw materials.

When technological categories are compared (Fig. 6), we note the absence of lithic cores (the central mass of rock from which flakes are detached by percussion) (A1). The same is true of flakes related with the production and maintenance of cores, and those used as unifacial tool blanks (A2). Certainly, cores were not transported to or reduced at the site. While unifacial tools (C1) are scarce (n = 3), the number of unifacial tool flakes (C2 and C3) is slightly higher. Probably a few finished unifacial tools were brought in, where they were retouched and used, to be transported out of the settlement at a later date.

The case of bifacial tools is totally opposite. Excluding the indeterminate debris, bifacial tools (B1) are the predominant technological category (n = 54) (Fig. 6), with a total volume of 572,609.484 mm^3. However, bifacial reduction (B2) and thinning (B3) flakes are scarce in the assemblage and most of them were discarded without reaching the end of their useful life. This being

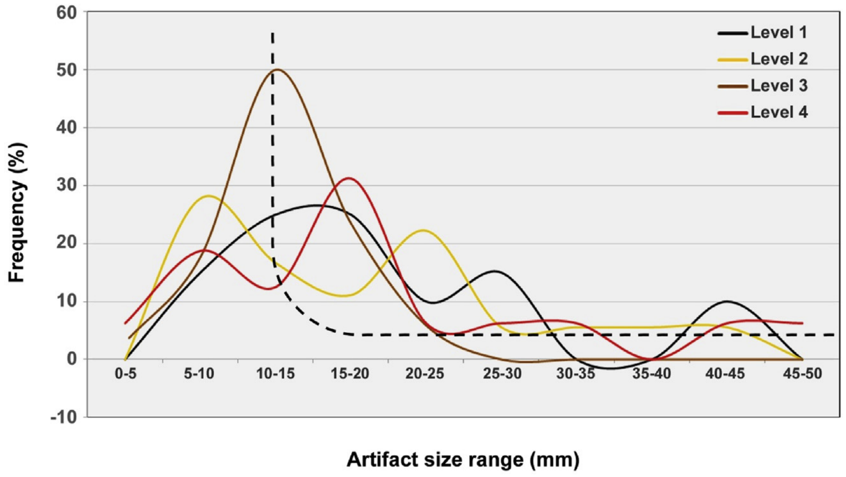

Fig. 4. Frequency (vertical axis) of size ranges (mm) (horizontal axis) by stratigraphic level.

Table 2
Differential extent of aeolic abrasion.

Corrosion Extend	Surface		Level 1		Level 2		Level 3		Level 4	
Absent	0	0%	2	10,0%	1	5,56%	1	2,9%	3	18,8%
Partial on one side	0	0%	1	5,0%	0	0%	1	2,9%	1	6,3%
Total on one side	2	4,3%	13	65,0%	10	55,6%	21	61,8%	7	43,8%
Partial on both sides	0	0%	0	0%	0	0%	0	0%	0	0%
Total on one side and partial on the other	10	21,3%	0	0%	1	5,6%	1	2,9%	1	6,3%
Total on both sides	35	74,5%	3	15,0%	2	11,1%	5	14,7%	2	12,5%
Indeterminate	0	0%	1	5,0%	4	22,2%	5	14,7%	2	12,5%
Total	**47**	**100%**	**20**	**100%**	**18**	**100%**	**34**	**100%**	**16**	**100%**

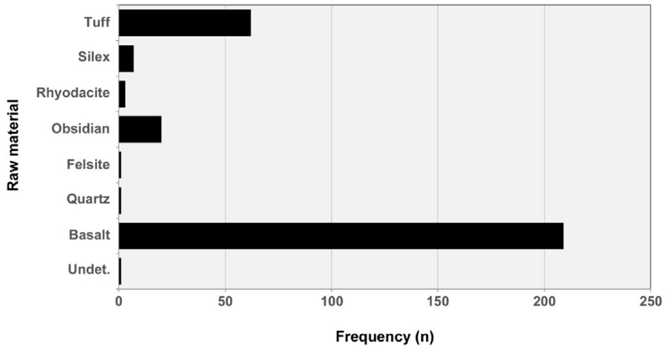

Fig. 5. Artefact distribution and frequency of raw materials.

the case, it is possible to argue that the bifacial tools entered the site already finished, and only final stages of reduction and edge reactivation (D1) were performed at Miscanti-1.

Moreover, some indicators in the debris flakes point to a greater importance of bifacial knapping, rather than core reduction or unifacial retouching. In the first place, we note the presence of facetted (n = 8/7.1%) and pseudo-facetted (n = 10/8.9%) butts, which are directly related to final bifacial shaping in this case. While it is true that plane (n = 33/29.4%), filiform (n = 30/26.7%) and punctiform (n = 17/15.18%) butts predominate, butt angles are always less than 67° (Table 3), indicating bifacial retouching and edge re-sharpening.

Typologically, all the bifacial tools fall into the category of projectile points, where lanceolate (Fig. 7 A, D and F) and pentagonal

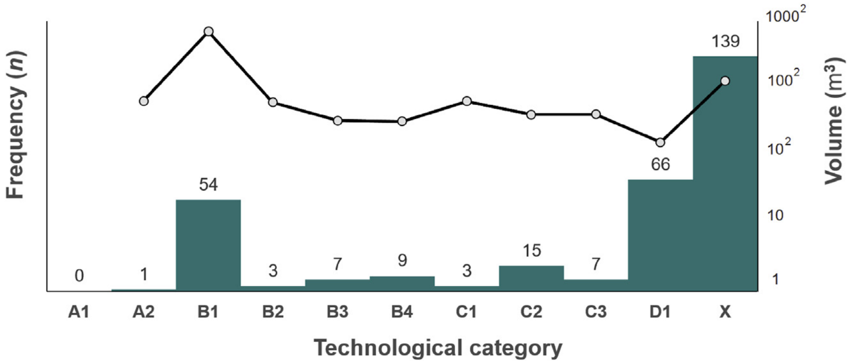

Fig. 6. Frequency (bars) and volume (lines) by technological category. A1: Cores, A2: Core reduction flakes, B1: Bifacial tools, B2: Bifacial tool fragments, B3: Bifacial reduction flakes, B4: Bifacial thinning flakes, C1: Unifacial tools, C2: Unifacial reduction flakes, C3: Unifacial retouch flakes, D1: Edge reactivation flakes, X: Indeterminate debris.

Table 3
Type butt frequency and angle.

Butt type	Frequency (*n*)	Frequency (%)	Mean of butt angle (°)	Standard deviation
Cortical	1	0,89%	–	–
Plain	33	29,46%	66,97	8,26
Facetted	8	7,14%	64,38	7,25
Pseudo-Facetted	10	8,93%	57,20	6,83
Filiform	30	26,79%	66,38	7,59
Punctiform	17	15,18%	67,36	8,61
Broken	13	11,61%	–	–
Total	**112**	**100%**	**65,52**	**8,27**

(Fig. 7B and C) shapes predominate. Two cases come from stratigraphy and the rest were recovered from the surface. Considering the vertical selection processes and the taphonomy of the site, it is possible to argue that most of the knapping activities conducted at the site were related to the finishing of tools of this kind. There is a remarkable presence of perverse fractures (Table 4, Fig. 7D and E) which commonly occur during the thinning of bifacial tool sections (Weitzel, 2012).

Longitudinal impact fractures, which normally occur in the context of use, were observed in some projectile points (Fig. 7F). At assemblage level, transverse, rectangular and oblique fractures predominate; these can occur both in the context of production and – in the case of tools – in use. Intentional fractures (radial, complete cone and snap) are rare. The same is true of fractures associated with trampling or post-deposition factors, allowing us to discard the incidence of external factors.

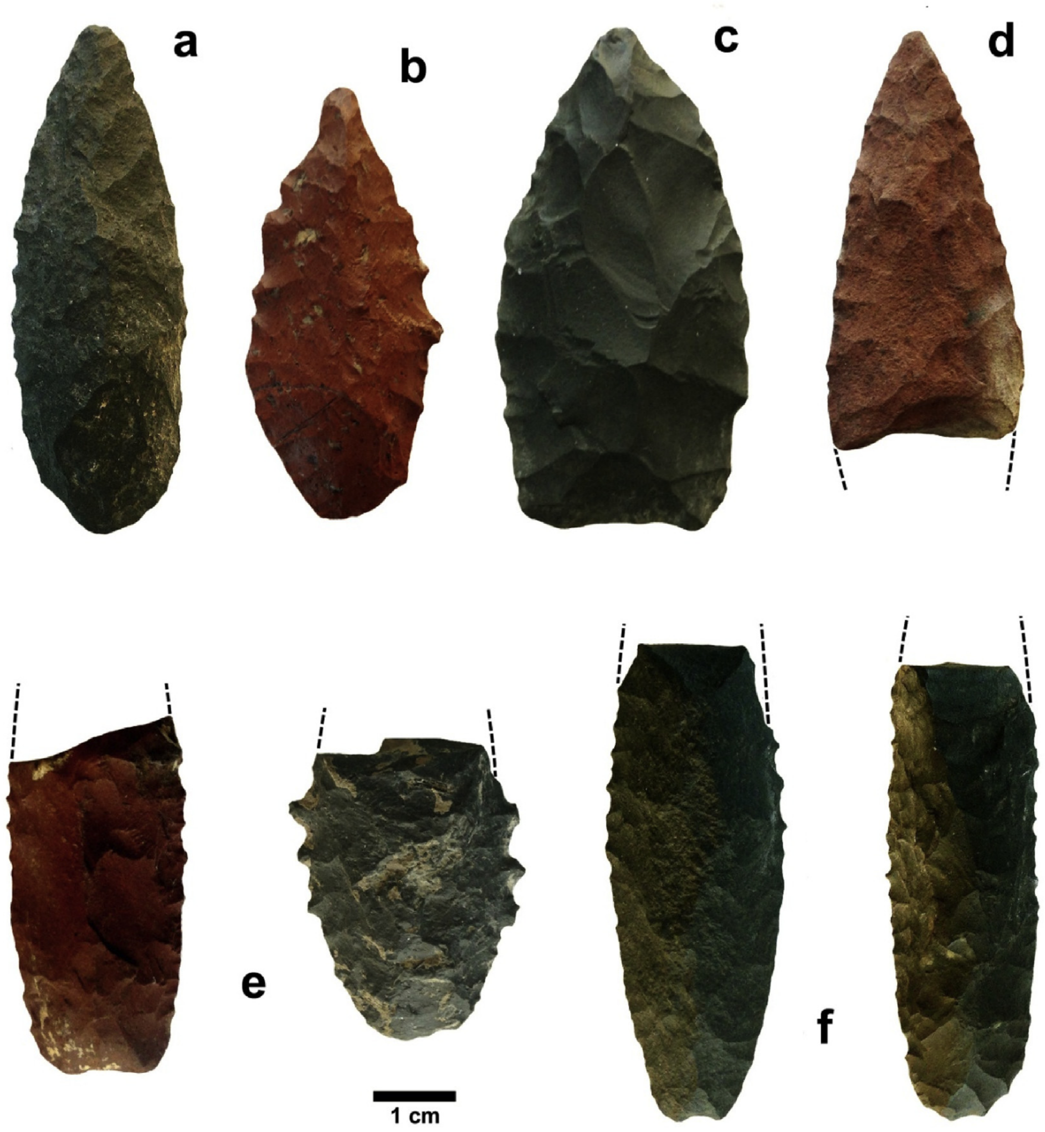

Fig. 7. Projectile points: (a) lanceolate (b) denticulated (c) pentagonal (d) and (e) perverse fractures, (f) lanceolate with longitudinal fracture (impact).

Table 4
Types of fracture according to artefact class.

Fracture Type	Bifacial tool		Flake		Unifacial tool		Total	
Longitudinal impact	2	5,9%	1	0,6%		0,0%	3	1,6%
Undetermined edge fragment		0,0%	2	1,3%		0,0%	2	1,0%
Bending		0,0%	5	3,2%		0,0%	5	2,6%
Lateral snap		0,0%	9	5,7%		0,0%	9	4,7%
Oblique	5	14,7%	3	1,9%		0,0%	8	4,2%
Perverse	8	23,5%		0,0%		0,0%	8	4,2%
Rectangular		0,0%	32	20,4%	1	50,0%	33	17,1%
Snap	1	2,9%		0,0%		0,0%	1	0,5%
Thermal shock		0,0%	1	0,6%		0,0%	1	0,5%
Transverse	16	47,1%	104	66,2%	1	50,0%	121	62,7%
Undetermined	2	5,9%		0,0%		0,0%	2	1,0%
Total	**34**	**100%**	**157**	**100%**	**2**	**100%**	**193**	**100%**

The projectile points assemblage consists mostly of lanceolate designs (n = 43/86%) and, to a lesser extent, pentagonal forms (n = 6/12%). Only one triangular point (n = 1/2%) was recorded. Metric analysis of certain variables from the perspective of functional design (De Souza, 2006; Hughes, 1998; Ratto, 2003) casts some significant trends by comparing the two dominant designs (Table 5). Pentagonal points show cross-sections (width/thickness) with higher values (MW U = 14, p = 0.004, DF = 1) and greater mass (MW U = 129, p = 0.01, DF = 1); these two trends are commonly related with increased shaft weight and thickness (Hughes, 1998). It has been suggested that projectiles with a higher total shaft length would have greater resistance to high kinetic energy and oblique angle of impact (Ratto, 2003).

However, the strength qualities of the projectiles are also related to other factors. The preferential use of coarse-grained basic rocks (tuffs, basalts and andesites) is significant, since they present greater tenacity and mechanical resistance than acid rocks (felsite, silex, rhyodacyte, obsidian, quartz and felsite); these properties are enhanced by the use of thick cross-sections (Fig. 8). It must also be remembered that the functional design of the projectiles is directly influenced by the hunting tactics used (Aschero and Martínez, 2001). In the case of non-throwing hand spears, even though the points are usually large and heavy, resistance becomes irrelevant because the angle of incidence on the prey is controlled directly by the hunter (Ratto, 2003). This fact might sustain the argument that the pentagonal points were used in hand spears.

Lanceolate points would be components of smaller projectile systems, for which resistance was more important than other qualities. This is consistent with the fact that coarse-grained raw materials also form the majority in this group. In combination with thicker cross-sections, lanceolate points offer a greater impact resistance. Moreover, lanceolate designs reduce the risk of fracture by avoiding exposed areas (stem, wings and sharp tips, for example). Jointly, these attributes prolong the useful life of hunting tools and delay the need for replacement in a context of greater “temporal stress” (Torrence, 1983). Thus we may argue that lanceolate points, in contrast to pentagonal, were used in throwing darts propelled with spear-throwers.

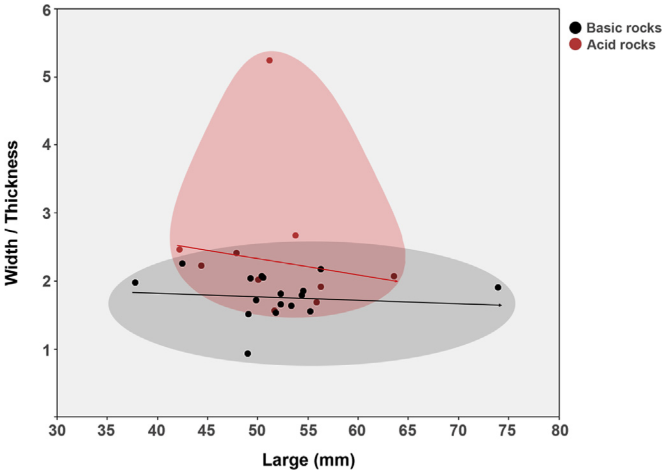

Fig. 8. Cross-section (mm) of projectile points by raw material (acid/basic).

Nevertheless, it must also be considered that reworking (Hocsman, 2009a, 2009b; 2007) is observed in some tools. This refers specifically to repairs of impact fractures at the tip that involve significant changes in the original design. For this reason, the possibility cannot be discarded that part of the morphological variability of the projectiles is due to reworking, although these cases represent quite a low proportion. Only in one case was recycling of a longitudinally fractured lanceolate projectile point identified; in that piece, the surface exposed after the fracture was used as a burin. The low proportion of such cases may also be diagnostic of a technological assemblage which was highly specialized for hunting, while other activities were not contemplated.

3.3. *Archaeofaunal assemblage*

A total of 1189 skeletal remains was recovered. The clear majority (85.4%) corresponds to fragments of long bones, bone

Table 5
Variable values of functional design in projectile points.

Variable	Morphological Type	Minimum	Maximum	Median	Medium	S.D. Standard Deviation
Mass	Lanceolate	5,7	13,9	9,6	9,7	2,1
	Pentagonal	9,9	16,2	12,8	13,1	2,4
A Secc	Lanceolate	0,77	1,44	1,05	1,05	0,19
	Pentagonal	1,08	1,65	1,60	1,43	0,23
E/A	Lanceolate	0,36	1,44	0,53	0,57	0,09
	Pentagonal	0,30	1,65	0,38	0,40	0,12

splinters, flat bones and small fragments from camelids. Only 174 (14.6%) could be identified; although the remains of birds and rodents were recorded, most of the remains correspond to camelids (Table 6).

The assemblage is highly fragmented; most bone splinters and fragments of cortical tissue (74.8%) are smaller than 2 cm. There are no significant traces of weathering and only 6 fragments appear whitened, which is consistent with their location at surface level (0–5 cm). Remains of radicles are also observed in 26 cases, revealing quick deposition and subsequent growth of plant cover. Only one piece of evidence showed signs of abrasion, while 14 pieces have manganese spots, suggesting very humid conditions. The density would not have an impact on the differential conservation of the set because the result of the correlation between the % MAU and the density values (Stahl, 1999) is negative and not significant ($rs = -0.371\ p > 0.143$). The large number of individuals recovered, despite the small volume of the excavation, is striking (Table 7).

In the case of camelids, it was possible to determine a MNI of 4 individuals based on the size of the specimens. Two correspond to camelids from the large group (*Lama guanicoe*) and two to the small (*Vicugna vicugna*), one of which is a juvenile vicuña (under 24 months). In addition, remains of a juvenile individual (fragments of skull, cervical vertebra, radius and ulna) were recovered; however, it could not be assigned to either of the size groups. The remains could belong either to one of the juvenile vicuñas or to a fifth young individual (less than 9 months), or even a neonate from the large size group (Table 8).

In both size groups, both the axial skeleton (teeth, cervical vertebrae and pelvis) and the appendicular portions (femur, tibia, metapodial and short bones) are represented. In the representation of the anatomical units of camelids as a whole, no significant correlation is observed between % MAU and the economic utility values (Borrero, 1990) ($rs = 0.230\ p > 0.359$), representing both the discarding of remains from processing, and consumption as such (Table 9).

Also of interest is the presence of three fragments of vicuña metapodium diaphysis which present one or more traces of impact on the dorsal side associated with bone fracture. This suggests intentional fracture of the bone to obtain marrow or for making artefacts.

The zooarchaeological assemblage further includes two bone artefacts with rounded ends and U-shaped sections. Both present active ends of similar dimensions (5–6 mm wide), with traces of chipping and deep, steep ridges. These traces are consistent with those described from experimental activities of retouching by pressure on lithic material (Patou-Mathis, 2002; Santander and López, 2012). Development of such artefacts requires a very low investment in work, meaning that they could be created rapidly. They were probably made in the context of carcass processing activities together with the retouching or final shaping of lithic artefacts, according to the evidence at the site.

The composition of the faunal assemblage suggests the capture and processing of different taxa for dietary purposes. A limited number of the remains ($n = 24$) showed evidence of exposure to thermal action (most of them minimal fragments); for this reason the bone assemblage is thought to be associated with a processing and discard area. Even though the remains were discarded in open spaces, high fragmentation is not related with exposure to subaerial conditions. On the contrary, the remains were covered rapidly, denoting a stable sediment deposition environment at the lake margin. The diversity of taxa points out to subsistence heavily based on the consumption of camelids, both vicuñas and guanacos, but complemented with birds and rodents, which is usual for archaeological sites in the region (Cartajena, 2003; Cartajena et al., 2005; Núñez et al., 2005).

Table 7
Taxonomic composition of faunal assemblage.

Taxa	NISP	MNI
Vicugna vicugna	22	2
Lama guanicoe	9	2
Camelidae indet.	116	–
Lagidium viscacia	7	2
Chinchillidae	5	–
Ctenomys sp.	1	1
Rodentia indet.	10	–
Metriopelia sp.	3	3
Aves indet.	1	–
Total	**174**	**10**

Table 8
Unfused skeletal remains of camelids (ranges taken from Kaufmann, 2009).

Anatomical Unit	NISP	Age Range
Unfused Radio and ulna shaft	2	Under 9 months
Unfused Metapodium	2	Under 24 months
Unfused II Phalanx px	1	Under 20 months

Rodents are represented mainly by Chinchillidae: a MNI of two vizcachas (southern vizcacha) and one chululo (*Ctenomys* sp.) could be identified. In the case of birds, the identified remains belong to *Metriopelia* sp. ($n = 3$), represented by the sternum. The presence of these birds is consistent with their distribution in the puna associated with sandy steppes, lake beaches, rocky terrains, grasslands and forests of *Polylepis* sp. (Fjeldså, 1993). The latter genus is represented in the pollen column from Miscanti Lake (Grosjean et al., 2001), being more abundant during the early Holocene. During the Middle Holocene the presence of *Polylepis* decreased markedly, with forage plants (grasses and sedges) the dominant vegetation.

In the arid conditions of the Mid-Holocene, Miscanti Lake would have been one of the few places in the high puna where resources were available (Grosjean et al., 2001), and the fauna remains recovered are consistent with this situation. The results suggest the presence of guanacos and vicuñas together. Water bodies offered fresh water while the moisture-saturated soils of the lacustrine beaches resulted in suitable meadows and bogs for vicuñas to feed. The two species generally occupy different habitats, often adjacent and differentiated only by elevation (Lucherini, 1996; Lucherini et al., 2000). This situation is observable in other high Andean lakes from the Early Holocene (Cartajena et al., 2005).

Both the faunal composition and the high number of individuals recovered in Miscanti-1 suggest similar conditions to those observed in high Andean salt flats such as Salar de Huasco

Table 6
Faunal remains recovered.

Number of Identified Specimens				General Categories				
Camelids	Rodents	Birds	Total	Long Bones	Bone Splinters	Flat Bones	Minimal Fragments	Total
147	23	4	174	90	353	263	301	1015
84,5%	13,2%	2,3%	100%	8,9	34,8	25,9	29,7	100%

Table 9
Frequency of anatomical units quantified in terms of NISP., MNE, MAU, % MAU (Mengoni Goñalons, 1999) for adults (A) and juvenile (J).

Anatomical Unit	NISP A	MNE A	MAU A	%MAU A	NISP J	MNE J	MAU J	%MAU J
Cranium	16	1	1,0	100,0	12	1	1,0	100,0
Upper M2-1	1	1	–		–	–	–	–
P4	1	1	–		–	–	–	–
Molar/Premolar	32		–		1	–	–	–
Hyoid	1	1	0,5	50,0	–	–	–	–
Atlas	–	–	–	–	1	1	1,0	100,0
Axis	1	1	1,0	100,0	–	–		–
Cervical	8	2	0,4	40,0	2	1	0,2	20,0
Thoracic	1	1	0,1	8,3	–	–	–	–
Lumbar	7	3	0,4	42,9	–	–	–	–
Pelvis	4	2	1,0	100,0	–	–	–	–
Medial Rib	3	2	0,1	8,3	1	1	0,0	4,2
Scapula	5	1	0,5	50,0	2	1	0,5	50,0
Radius shaft	–	–	–	–	2	1	0,5	50,0
Ulna shaft	–	–	–	–	1	1	0,5	50,0
Forth Carpal	3	3	0,2	21,4	–	–	–	–
Femur shaft	1	1	0,5	50,0	–	–	–	–
Ds Tibia	2	1	0,5	50,0	–	–	–	–
Calcaneus	2	1	0,5	50,0	–	–	–	–
Px Metatarsal	1	1	0,5	50,0	–	–	–	–
Px Metapodium	–	–	–	–	1	1	0,3	25,0
Shaft Metapodium	6	1	0,3	25,0	–	–	–	–
Ds Metapodium	2	2	0,3	25,0	2	2	0,3	25,0
Sesamoid	2	2	0,1	12,5	–	–	–	–
I phalanx px	7	3	0,4	37,5	–	–	–	–
I phalanx ds	3	2	0,3	25,0	–	–	–	–
III phalanx	1	1	0,1	12,5	–	–	–	–

(6320 + 50 BP; 3830 m.a.s.l.), another Pleistocene paleolake located further north that was strongly affected by the arid conditions during the Mid-Holocene (Núñez et al., 2005). The faunal assemblage recovered at the Huasco-2 site consists mainly of vicuñas and guanacos but also of abundant rodents (southern vizcacha and *Ctenomys* sp.), as well as birds (*Metriopela* sp., *Fulica* sp. and Ardeidae).

3.4. Pollen assemblage

Miscanti Lake is located in the High-Andean steppe, a characteristic environment above 4000 m.a.s.l. in which plant communities are normally dominated by the Poaceae family (Latorre et al., 2002). The Miscanti pollen assemblage has a “high tolar” spectrum, most common in mid-range altitudes between 3100 and 3800 m.a.s.l. in the south-central Andes. This is sustained by the predominance of the Asteraceae family, genera *Baccharis* and *Senecio*, rather than Poaceae (Fig. 9). However, the proportion of species of the Chenopodiaceae is maintained, perhaps associated with incursions of plants from lower elevations into high Andean environments, as well as with azonal vegetation on the edges of brackish marshland. In any case, these results suggest a drier, warmer climate during the Middle Holocene than exists today.

There is a relatively small presence of Cyperaceae and other taxa characteristic of swamp environments, while abundant oxidised (charred) organic matter is observed. The absence of freshwater plants such as *Myriophyllum* sp. is remarkable, with halophyte species such as *Ruppia* sp. predominating. These data suggest drying of these lacustrine environments during the Mid-Holocene; Miscanti Lake would have been saline and ephemeral, with brackish wetlands around its margins where a wide biotic diversity would have concentrated.

4. Discussion

4.1. A specialized campsite for hunting

It is now accepted that the available forage spaces in the Atacama Desert were reduced during the Mid-Holocene. Human groups concentrated in “ecoshelters” on the pre-Andean floor (3000–3800 m.a.s.l.), resulting in greater territorial circumscription (Núñez et al., 2005). Despite the long-term aridity, wetlands – like Miscanti Lake – formed in some parts of the highlands, with high availability of water and biotic resources. These isolated environments were attractive for mobile groups of hunter-gatherers, who continued to visit them on a seasonal basis. In this context, the

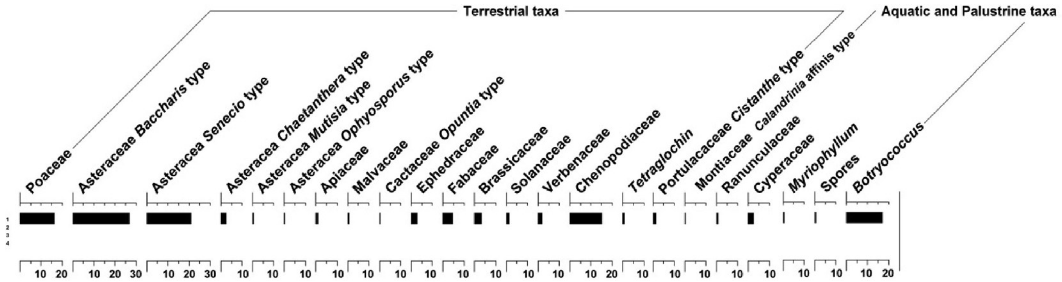

Fig. 9. Pollen profile of Miscanti Lake.

Miscanti-1 functioned as a specialized hunting camp occupied during brief periods.

According to the taxonomic variability observed in the zooarchaeological record, the central resource was wild camelids. These species, which generally occupy different ecological floors, were attracted by the wetlands which formed when Miscanti Lake contracted due to the low rainfall. This reaffirms the importance of these environments in terms of available resources during the Mid-Holocene.

4.2. *An effective strategy for high altitude and arid conditions?*

The large temporal stress (Torrence, 1989, 1983) resulting from limited access to high altitude environments required a shift in mobility patterns and the use of a specialized bifacial technology, with tools produced in advance and transported for the final reduction stages. Knapping activities focused almost exclusively on consumption and discard of bifacial tools, with a low rate of maintenance and recycling. However, it should also be considered that the reduction of available environments during the Mid-Holocene could result in the spatial dissociation of resources. So far, locally available sources of lithic raw material have not been recorded, so limitations in lithic procurement must have been a key factor.

Bifacial projectile points are the most numerous tool category found. This trend denotes the functional nature of the campsite, specializing almost exclusively in hunting activities, although the effects of differential transport patterns on the variability of the assemblage must not be ignored. The zooarchaeological analysis is categorical in pointing to discrete but consistent processing activities and consumption of faunal resources on the site. Unifacial tools on flake linked to carcass processing were probably transported by the hunters group on leaving the camp as part of an "individual" procurement strategy (Kuhn, 1995). Projectile points on the other hand were discarded intentionally in place, although their useful life was far from concluded. Tool maintenance was not contemplated due to temporal stress and the specialized function of the site. It is also possible that projectile points were discarded temporarily, constituting raw material reserves for future incursions.

4.3. *Lanceolate technologies and the regional links of Miscanti-1*

Lanceolate projectile points have a wide spatial and temporal variability and they can never be conceived as a chrono-cultural marker. Although at first associated with the Ayampitín tradition, lanceolate points have been recorded in different archaeological contexts in South America (Bryan, 1978; Dillehay, 1997). It is assumed that they entered from North America in the late Pleistocene and spread to the Andes region (Salcedo, 2014), where they are common in different cultural periods in the central and south-central Andes (Aldenderfer, 1999, 1998; Cardich, 1964, 1958; Dauelsberg, 1983; Lynch and Stevenson, 1992; MacNeish et al., 1980; Muñoz and Chacama, 1993; Núñez and Moragas, 1978; Ravines, 1965; Rick and Moore, 1999; Santoro and Chacama, 1982; Santoro and Núñez, 1987).

Not only are lanceolate projectile points frequent in several Mid-Holocene assemblages in Argentina (Aschero and Martínez, 2001; Martínez, 2003; Pintar, 2014), Bolivia (Capriles et al., 2016; Schobinger, 1988) and Chile (De Souza, 2014; Núñez et al., 2005; Santoro, 1989; Santoro et al., 2016), but this trend continued and even increased in later periods (Hoguin, 2013; Núñez et al., 2005).

On the other hand, important technical and morphological variability exists in lanceolate technologies during the Mid-Holocene. The different types include elongated lanceolate (Aschero and Martínez, 2001; Martínez, 2003), bifacial lanceolate (Hoguin, 2013, 2016), small lanceolate (Aschero et al., 2011), lanceolate on blade (Fernández, 1983; Hoguin, 2013; López, 2008), stemmed lanceolate (Núñez et al., 2005), lanceolate with wings (Osorio et al., 2011; Santoro, 1989; Santoro et al., 2016), etc. Their design cannot therefore be considered either standardized or uniform.

It should also be considered that lanceolate point projectiles (in a broad sense) usually coexist with a wide diversity of other designs. In fact, one of the main characteristics of the Mid-Holocene in the Atacama puna is the diversification of hunting strategies, directly reflected in an increase in the variability of projectile points (Aschero and Martínez, 2001). In Puripica-3 there are small lanceolate projectile points, but there is also an important frequency of stemmed, rhomboidal and pentagonal points (Núñez et al., 2005). Similar trends have been reported in Mid-Holocene contexts in the Alto Loa basin, for example at Corte de La Damiana (3100 m.a.s.l.), Alero Huiculunche (3000 m.a.s.l.) (De Souza, 2004, 2014), Confluencia-2 (2500 m.a.s.l.) (Jackson and Benavente, 1994; Núñez, 1983) and Huasco-2 (3830 m.a.s.l.) (Núñez et al., 2005), etc.

5. Conclusions

During the arid period of the Mid-Holocene, human groups were concentrated in pre-Andean ecoshelters while they continued to access the Andes Highlands, maintaining a mobility pattern that was of key importance during the early Holocene. However, with the arid environmental conditions, a shift from residential to logistic mobility was required.

This change also involved the development of a highly specialized bifacial technology. Apart from typological links, certain technological, petrological and functional variables allow us to consider lanceolate projectile points as a "flexible" design, part of a technological strategy in response to a specific context. They were used in projectiles thrown with spear-throwers, in which resistance was more important than penetration. This is expressed in the use of coarse-grained raw materials, thick cross-sections and a design that avoid planes of weakness. The greater temporal stress in the occupation of the highlands probably encouraged the use of projectile points which reduced the risk of damage during hunting, mainly in consideration of the difficulties of replacing them and technical investment in their maintenance.

Pentagonal points on the other hand are related to larger projectiles that would have formed part of hand-held systems. These larger heads are made with very thin sections for better penetration. In these cases, resistance was not a major factor. The coexistence of these two systems could also reflect the use of multiple hunting tactics. The diversification of technological strategies was probably a key aspect for coping with the unpredictability of the environment and reducing risk (Aschero and Martínez, 2001).

Thus, human groups continued to hunt wild camelids, as in the early Holocene, but in wetlands which formed round the margins of shallow lakes. Paradoxically, the Mid-Holocene arid conditions generated new habitats in the highlands where biotic resources concentrated during moments of dramatic climatic change. Certainly not all high level lakes responded in the same way. So far, Miscanti Lake is in the only area that developed these particular conditions, suggesting that it provided a high-altitude ecoshelter for human populations. Although this phenomenon may seem isolated in our area of study, it draws attention to the need to evaluate its links with other neighbouring and distant areas of the Atacama, not only in the paleoenvironmental context, but also in terms of technology, mobility, subsistence and functional relations with other synchronic occupations.

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