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Mid-Holocene occupation of the Dry Puna in NW Argentina: Evidence from the Hornillos 2 rockshelter

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ABSTRACT

This paper summarizes the results of the research carried out during a decade at the Hornillos 2 rockshelter, located at 4020 m asl in the Dry Puna of Argentina. The human occupations in this site are bracketed between the Pleistocene–Holocene boundary and the mid-Holocene, challenging the idea of a widespread abandonment of the Andes highlands during mid-Holocene due to extreme arid conditions (*i.e.* the "*silencio arqueológico*" or archaeological silence hypothesis). Nine occupational levels have been recognized in the timed span at the site, the result of hunter–gatherer activities carried out in a highly oscillating and changing environment.

Here we present the mean trends and patterns observed in the full set of lines of inquiry applied in the site: lithic evidence, zooarchaeological analysis, rock art, stratigraphic and spatial analysis, and isotopic data. The outcomes of these studies, together with the site location features, known raw materials sources and regional archaeological evidence, indicate that hunter–gatherer groups reduced their residential mobility, and increased the intensity of their occupations and the rate of technological innovations in the arid and unstable mid-Holocene landscapes.

1. Introduction

The evidence of hunter–gatherer occupations in the Dry Puna of the Argentine Andes is as old as 11,000 BP. In the last three decades, several pieces of evidence of these first Holocene occupations have been recovered, including several stratigraphic occupations in archaeological sites. The majority showed only early Holocene occupations, with vast archaeological evidence including artifacts, ecofacts, and human remains. The patterns emerging from the study of those materials allowed building models related to early peopling of the Dry Puna, which included several organizational domains of hunter–gatherers such as subsistence, mobility, seasonal behaviors, and raw materials sources management.

Mid-Holocene evidence has been much less frequent during the history of archaeological research in the Puna de Atacama. This situation led to some researchers (Núñez and Grosjean, 1994) to suggest the possibility of an abandonment of this region by hunter–gatherers groups due to the hyper-arid conditions suggested by some paleoenvironmental records during this period (*i.e.* the "*silencio arqueológico*" hypothesis). However, recently, some mid-Holocene occupations have been detected in both slopes of the Andean range (Núñez et al., 2005; López, 2008; Pintar, 2009) allowing analysis of some aspects of human organizational patterns during this time-span.

The importance of Hornillos 2 (Figs. 1 and 2) for Andean archaeology is related to the exceptional fact that it has a succession of occupations along the first half of the Holocene, allowing comparison of several early and mid-Holocene components in the same archaeological locality. No other site in the entire Dry Puna permits the analysis and obtaining confident trends for both kinds of occupations. Hence, the goal of this paper is to provide a broad description and analysis of the evidence. This will allow to stablish the changes in the archaeological record during both periods, and the proposal of some hypotheses for explaining the modifications occurred during mid-Holocene in terms of external (*i.e.* climatic changes) or internal (*i.e.* organizational modifications) factors which contributed to diversify the social strategies of hunter–gatherer populations.

2. Current and past environmental settings

The Argentine Puna comprises the arid highlands (between 3000 and 4500 m asl) of the eastern slope of the Andes, between

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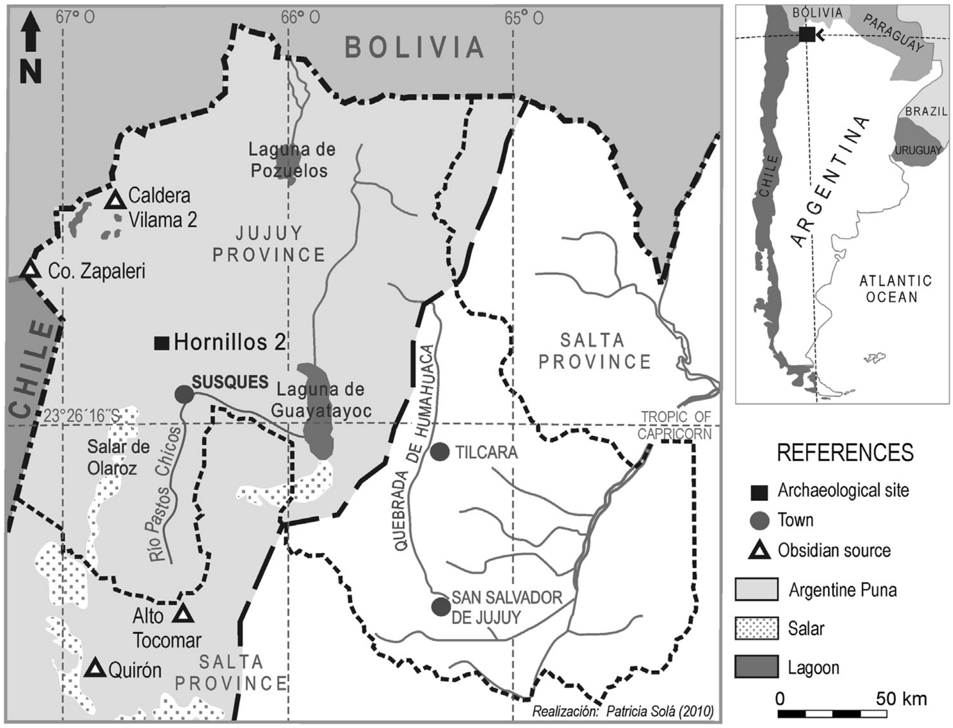

Fig. 1. Hornillos 2 site location and places mentioned in the paper.

22° and 27° S. This area is characterized by high solar radiation due to its high altitude, high daily thermal amplitude, marked seasonality in rainfall, and low atmospheric pressure. The precipitation seasonality is controlled by the South American Monsoon System (Zhou and Lau, 1998; Garreaud et al., 2003). This system produces about 80% of the annual precipitation (*ca.* 200 mm/y) during the austral summer (between December and February) (Bianchi and Yañez, 1992; Vuille and Keimmig, 2004).

This desert biome presents an altitudinal variation in vegetation communities ranging from shrub steppe or “Tolar” located below 4000 m asl to highland grasslands or “Pajonal” situated above 4000 m asl. Between these communities, ~3900–4100 m asl, is a narrow ecotone composed of a mixed steppe. All of the altitudinal vegetation ranges include a particular kind of community with a patched distribution: the “Vegas” (wetlands) (Tchilinguirian, 2009 and Morales, 2011 for a complete review of the environmental setting). This community is dominated in most cases by the Cyperaceae family (Braun Wilke et al., 1999).

Primary productivity is usually concentrated in perennial and stable hydrological systems such as primary basins, high valleys and wetlands (Olivera, 1997). Yacobaccio (1994) defined these patches as ‘nutrient concentration zones’ or NCZ because they contain the majority of the available regional biomass of this desert.

The local fauna of interest as food source for humans includes several mammals as camelids (e.g. the vicuña, *Vicugna vicugna vicugna*, and the guanaco, *Lama guanicoe cacsilensis*), large rodents (*i.e.* viscachas and chinchillas, *Lagidium viscacia* and *Chinchilla laniger*, respectively), and a small cervid (taruca, *Hippocamelus antisensis*).

Past environmental conditions during the Holocene in the South-central Andes have been extensively studied in the past 15

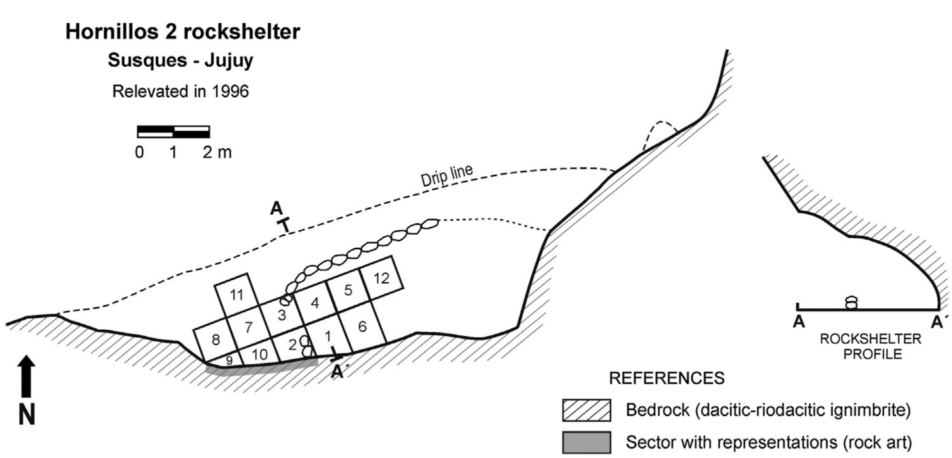

Fig. 2. Hornillos 2 site plan view and excavation grid.

years (see Tchilnguirian and Morales, 2013, for a review of most of the paleoenvironmental archives available related to early and mid-Holocene). Those studies offer a complex picture that have been recently synthesized in broad climatic and environmental tendencies (mostly shared over the whole continent), and particularly and apparently contradictory results in less inclusive spatial scales (see Tchilinguirian, 2009, and Morales, 2011 for complete reviews). Broadly, the environmental conditions in the Andes points towards a moister environment during early Holocene (10–8 ka BP), also showing a weaker seasonality in rainfall and a weak to moderate frequency in short term climatic variability. During mid-Holocene (8–3.5 ka BP) the environments seem to have been warmer and arid with a marked seasonality in rainfall, and a strong and frequent short term climatic variability.

The diversity observed in paleoenvironmental signals of small spatial scale obtained by the research team in the neighboring area of Hornillos 2 is summarized below. This observed diversity has been interpreted as the mere expression of the differential impact of large scale climatic changes in particular environmental settings or hydrological systems (Yacobaccio and Morales, 2005; Morales and Schitteck, 2008; Morales et al., 2008, 2009; Morales, 2011). The multi-proxy paleoenvironmental data have been obtained mostly from several records of three localities: Pastos Chicos (Oxman, 2010; Morales, 2011; Tchilinguirian et al., in press); Lapao (Yacobaccio and Morales, 2005), and Alto Tocomar (Morales and Schitteck, 2008; Morales, 2011).

The Pastos Chicos record (3890 m asl) shows two environmental phases for the 9300–4200 BP time-span that could be interpreted as sub-regional scale information, because this river is a part of one of the larger permanent basins in the area. The first phase points towards a moister and more stable environment for the 9300–7500 BP time-span, and the second to an arid environment between 7500 and 4200 BP, eventually interrupted by moister and intense pulses during the latter part of the period.

The Lapao ravine (3650 m asl), a smaller system, shows compatible conditions with those observed in Pastos Chicos, but more humid pulses have been detected around 8000 BP, implying the presence of a water body in the locality (Oxman, 2010; Morales, 2011). Arid conditions in this locality also established around 7500 BP are reflected in the drought of the wetland, but in this case indicated by a more intense signal than in Pastos Chicos, implying the complete interruption of soil formation in the ravine up to the late Holocene (Oxman, 2010; Morales, 2011; Tchilinguirian et al., in press).

Finally, Alto Tocomar, located along the boundary between Jujuy and Salta provinces at 4300 m asl, shows a very different picture for the mid-Holocene. This record suggests cold and less developed soils during the early Holocene and more humid conditions than expected regionally during the mid-Holocene, indicating the presence of a wetland environment until ~5500 BP. This apparent incompatibility with regional signals has been explained as a result of the nature of soil development above 4000 m asl (Morales, 2011). The evolution of soils at these altitudes involves the cyclical process of freeze–thaw, and melting phases could have been intensified during mid-Holocene due to warmer temperatures. These conditions should have favored the formation of productive wetland environments above 4000 m asl.

3. Stratigraphy and chronology of Hornillos 2

Hornillos 2 is a rockshelter with a small cave (23° 13′ 47″ S, 66° 27′ 22″ W; 4020 m asl) formed in Neogene ignimbritic deposits with a surface of 42 m^2. It is located at 22 km NNW of Susques village (Fig. 1) on the right margin of a small protected valley, Agua Dulce. Currently, 26% of the total surface has been excavated (Fig. 2) revealing ten layers (1, 2, 3, 4, 5, 6, 6a, 6b, 6c and 6d) reaching 118 cm depth in one of the squares. The radiocarbon dates obtained from five layers (Table 1, Fig. 3) resulted in a coherent chronological

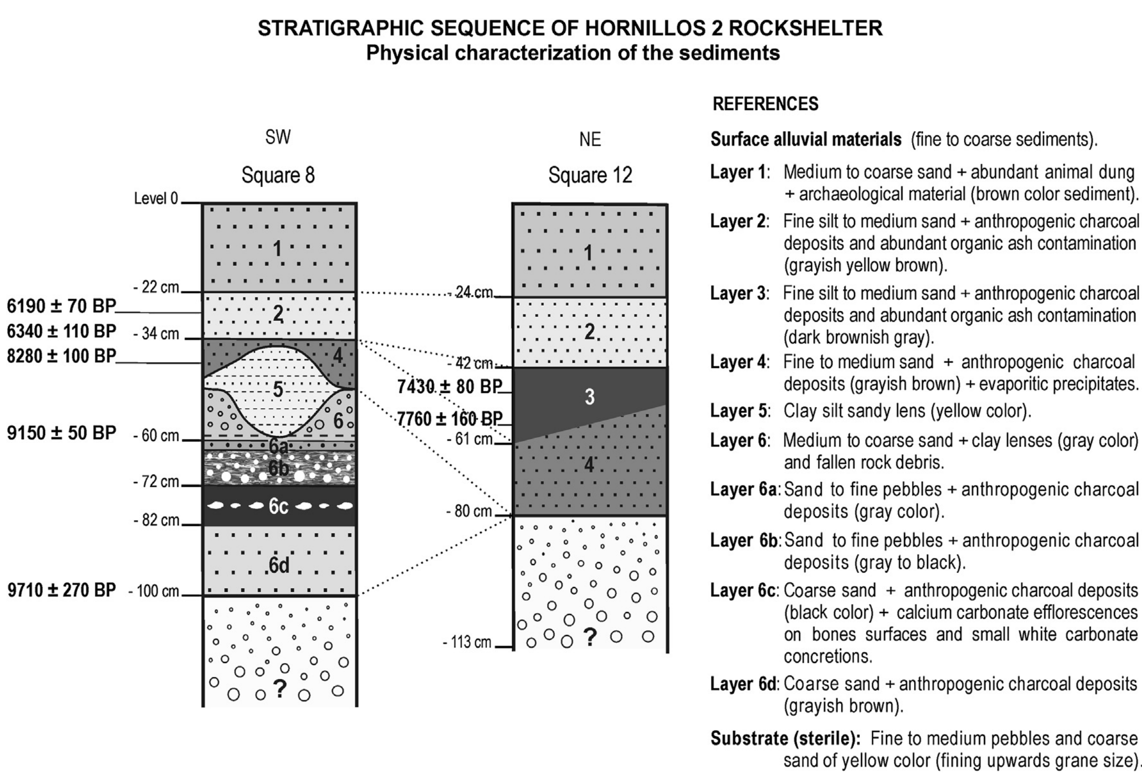

Fig. 3. Hornillos 2 stratigraphy indicating layers chronology, stratigraphic relationships between both squares (doted lines), contacts between layers (solid lines), and description of the nature of the sedimentary matrix of the layers.

Table 1
Hornillos 2 chronology. The calibrated ages ranges (1σ) were obtained with Calib 6.1 with the IntCal.09 curve (Reimer et al., 2009).

Layer	Lab code (Method)	Date (BP)	Date cal BP (±1σ)	Material
2	Beta-111392 (LSC)	6190 ± 70	6991–7172	Charcoal
2	UGA-7829 (LSC)	6340 ± 110	7167–7336	Charcoal
3	UGA-7830 (LSC)	7430 ± 80	8183–8340	Charcoal
3	UGA-8722 (LSC)	7760 ± 160	8387–8772	Charcoal
4	LP-757 (LSC)	8280 ± 100	9134–9407	Charcoal
6	UGA-8723 (AMS)	9150 ± 50	10,238–10,300	Charcoal
6	UGA-8724 (AMS)	9590 ± 50	10,787–10,908	Wood
6d	UGA-13550 (LSC)	9710 ± 270	10,650–11,407	Charcoal

sequence which include early and mid-Holocene components. Several papers concerning certain aspects of the archaeological record of this site have been published (Yacobaccio et al., 2000, 2008, 2010; Joly, 2008; Vázquez et al., 2008; Hoguin and Yacobaccio, 2012; Hoguin et al., 2012; Restifo and Hoguin, 2012).

Table 2
Chronology and sedimentary matrix of the layers of Hornillos 2.

Period	Date BP	Layers	Sedimentary matrix – depositional processes
Pleistocene–early Holocene	9710 ± 270 8280 ± 100	6d, 6c, 6b, 6a, 6	Sand + fine gravels – alluvial and fluvial sediments – (graded stratification with fining upward grain size – flood situations – humidity environmental conditions).
		5	Clay silt sandy lens (channel filling – shallow flooding during a wettest period).
		4	Alluvial and eolian sands (more arid conditions than previous ones).
Mid-Holocene	7760 ± 160 6190 ± 70	3, 2	Fine to medium floodplain sands + silts, particularly layer 2 (probably with eolian input). This depositional environment coincides with the driest conditions described for the period.
Late Holocene to present	–	1, surface level	Coarse to fine sands + animal dung (regime with strong seasonality, summer rains). Outside the rockshelter: convex floodplain, heterogeneous coarse sediments in longitudinal single bar of vertical accretion, fine sediments filling braided channels.

The rockshelter stratigraphy is signed by geomorphic and hydro-geological processes, and its location on the bank of the course of the Agua Dulce creek produced unique depositional situations. The site stratigraphy is intimately related with the hydrologic dynamic of the seasonal stream, and with the drought periods where the eolian contribution prevailed (Fig. 3, Table 2).

In transverse section, the floodplain of the creek shows a convex lobular topography due to the formation of a vertical accretion bar, with graded bedding structure (upward fining) and some isolated blocks. During most of the time of site formation, the base level of the site must have remained below the level of the present alluvial plain, at least since the onset of the late Holocene (Hoguin et al., 2012). Thus, the site was affected by consecutive episodes of aggradation and erosion depending on the energy of the water system and eolian activity. The variability of the processes involved in the sedimentary origin of the archaeological layers requires a detailed compositional analysis in the future. In Fig. 3, two profiles corresponding to both opposite extreme squares of the excavated area illustrate the general stratigraphy of the site. All the described stratigraphic contacts are well defined because the archaeological layers present suitable and abrupt colors, grain size and archaeological content changes.

4. Analytical techniques employed for the analysis of the archaeological record

In addition to the classic methods of lithic and faunal remains analysis, some materials of the archaeological record of Hornillos 2 were subjected to several physico-chemical analyses as described below. Obsidian samples recovered from the site (78 in total) were subjected to instrumental neutron activation analysis (INAA) at the Missouri University Research Reactor (MURR) using procedures described previously in detail in Cobean et al. (1991), to determine up to 27 elements.

For isotopic studies, camelids bone samples were processed and measured in the Environmental Isotope Laboratory (University of Waterloo, Canada) following the procedures described by Cormie et al. (1994) and Cormie and Schwarcz (1996). The treatment of modern samples was carried out in the Instituto de Geocronología y Geología Isotópica (INGEIS-CONICET, Buenos Aires University, Argentina) following the protocol published by Tykot (2004). The $\delta^{13}C_{col}$ measurement was made in a Finnigan MAT triple collector Mass Spectrometer in the latter institution, whereas the $\delta^{15}N_{col}$ values were obtained in the EILAB.

The inorganic components of the rock art were analyzed by an X-Ray Diffractometer Philips 1130 (Co tube) and an X-Ray Diffractometer Siemens D5000 (Cu/Ni radiation); an Energy Dispersive X-Ray Spectrometer Falcon PV 8200 and Scanning Electron Microscopy Philips 515 (CNEA, Argentina) and an X-Ray Fluorescence Spectrometer with a Philips generator (Mo X-Ray tube), and total reflection was achieved by a TXRF module designed by the Atominstitut der Österreichischen Universitäten (Vienna). The organic components of the pigments and paints were analyzed using a Chromatographer Hewlett–Packard 5890A and Trio-2 VG Mass Spectrometer, and the infrared spectra were obtained by a Nicolet Magna 550 Fourier Transform Spectrometer (FT-IR) (Buenos Aires University, Argentina).

5. Archaeological record of Hornillos 2

5.1. Lithic evidence

This section presents a review of the main trends observed in the analysis of 3122 debitage and 60 artifacts recovered from the mid-Holocene layers at Hornillos 2 (layers 3 and 2), representing only a part of the whole sample recovered at the site (9142 debitage, 118 artifacts). The focus is on five key aspects of the lithic record which allow to understand human organizational patterns regarding lithic technology: 1) raw material abundances, 2) obsidian source, 3) core description, 4) characteristics of blanks in terms of nature, size and module, and 5) the main patterns in retouch and shaping.

Several raw materials such as quartzites, andesites, obsidians and different siliceous rocks (chert, chalcedony, and opals) have been recovered from Hornillos 2. Previous papers presented the characteristics of local (Restifo and Hoguin, 2012) and long distance sources (Yacobaccio et al., 2004). A sustained reduction in the presence of quartzites through time was observed, except for layer 2, where this raw material increases to nearly 40% (Fig. 4). A similar trend was evident in the frequencies of andesites with a marked fall during the mid-Holocene layers. In contrast, long distance raw materials such as obsidians showed a rising pattern through time with a marked peak at layer 3 (Fig. 4). To confirm these observations, the lithic materials of Hornillos 2 were merged in two chronological groups: the early Holocene group, represented by layers 6d, 6c, 6b, 6a, 6 and 4, and the mid-Holocene group by 3 and 2, and an χ^2 test was applied. The result showed a significant difference ($\chi^2 = 151.36$, $p = <0.01$) between both chronological groups.

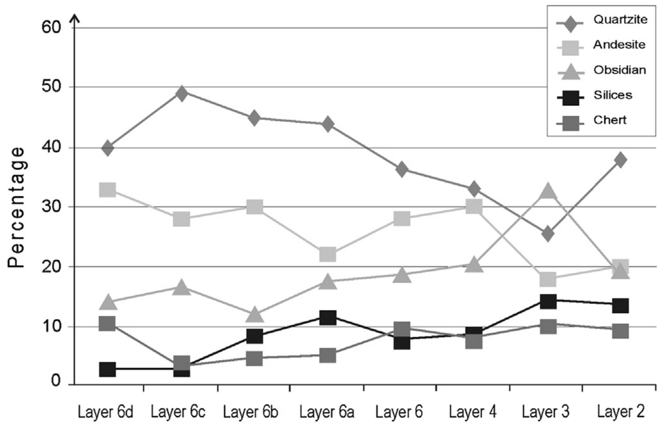

Fig. 4. Raw material proportions through time at Hornillos 2.

Regarding obsidians, twenty samples from layer 3 and 2 were subjected to INAA (ten of each layer). Layer 3 shows more variability, with 5 samples from Zapaleri/Laguna Blanca, 2 from Caldera Vilama 1, 1 from Tocomar, and 2 from an unknown source (unk-B). Layer 2 had 5 samples from Zapaleri/Laguna Blanca, 4 from Caldera Vilama 1, and 1 from Caldera Vilama 2. Except for the only sample from Tocomar, all the other known sources are located some 100 km to the northwest of the site. The greater source variation in layer 3 may be related to the dominance of "San Martín" projectile points (Fig. 7: 11–15) which have a huge dispersion in the western side of the Puna, and in the salt lake margins of the Puna de Atacama and Río Loa basin.

Five different cores were recovered from the mid-Holocene layers. One of them shows a long and contiguous sequence of unidirectional removals (Fig. 5: 4). Other two cores evidence: a) a core knapped by opportunistic alternation between platforms and the flaking surface (Fig. 5: 6), and b) a laminar core with the typical feature of the removals obtained turning on the edge of the platform (Fig. 5: 5). The remaining two cores have too few removals to identify any clear pattern.

In terms of the blanks, mid-Holocene occupations showed that extractive tools were made on a wide diversity that included: a) bifacial pre-forms (Fig. 6: 23, Fig. 7: 19, 20, 21, 24 and 25), b) blades (Fig. 6: 22), c) wider than long flakes (Fig. 6: 18, 19, 20 and 21), and d) evidence of platform preparation (Fig. 6: 15). Taking into account the size of quartzite tools, mid-Holocene occupations show more homogeneous sizes for this raw material (although in layer 2 the variation range is larger, if we include the outliers). In the andesite case, the largest diversity was presented in layer 4, a transitional layer of the end of the early Holocene, that also shows the appearance, for the first time at the site, of laminar blanks ($N = 4$) (Fig. 6: 9, 13, and 14). However, layer 2 also shows a wide range of sizes, if outliers are considered. A wide diversity in obsidian tool sizes is also shown by layer 2, but this variation is quite exiguous compared with the rest of raw materials. The mid-Holocene also has larger diversity in the size of the tools made on siliceous rocks, such as chert. Notwithstanding, the range of sizes is larger in layers corresponding to the early Holocene. In general terms, a trend towards the utilization of larger sizes during the early Holocene has been observed.

Regarding the module of quartzite tools, those from the end of early Holocene (layer 4) show a wide variety, including blades. In the andesite case, the more significant diversity in the modules is observed in layer 2, followed by layer 4. Even though, the trend is

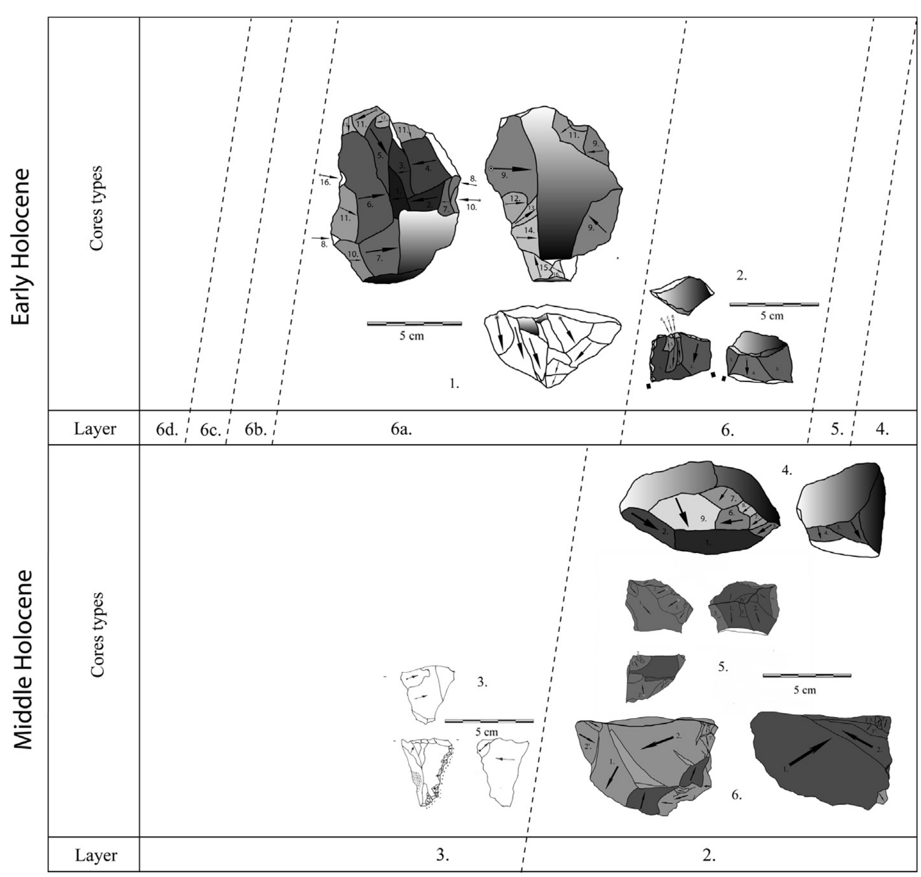

Fig. 5. Cores recovered at Hornillos 2 arranged by layers and grouped by those corresponding to early Holocene (above) and mid-Holocene (below).

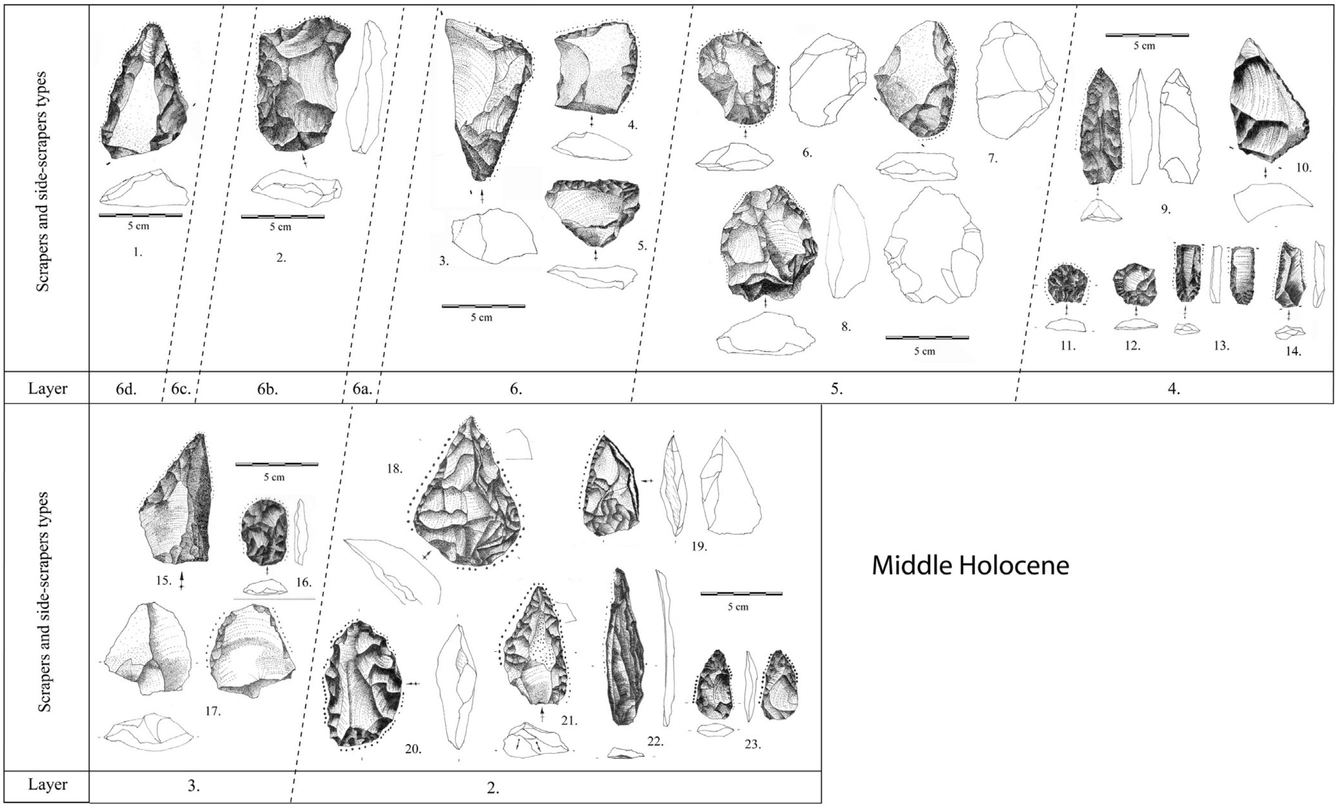

Fig. 6. Artifacts from Hornillos 2 arranged by layers and grouped by those corresponding to early Holocene (above) and mid-Holocene (below).

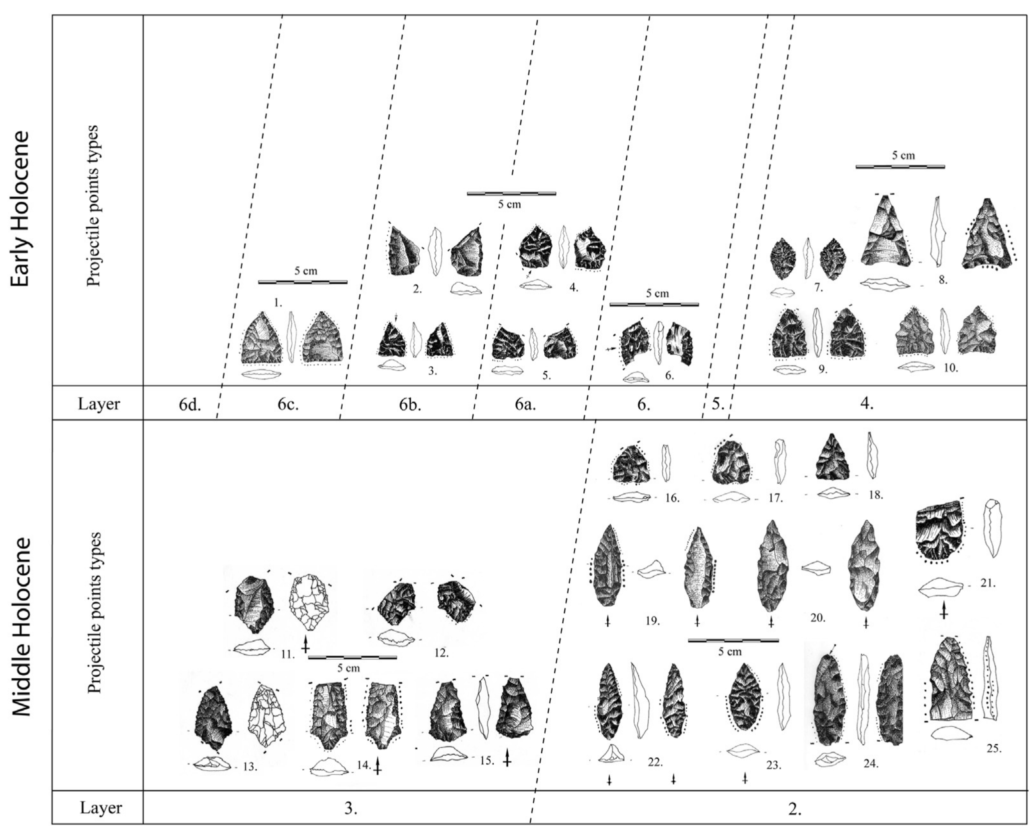

Fig. 7. Hornillos 2 projectile points and pre-forms arranged by layers and grouped by those corresponding to early Holocene (above) and mid-Holocene (below).

not significant in obsidians, a slight reduction in modules towards the mid-Holocene is observed, possibly due to the fragmentation of the tools. In the same way, although the early Holocene layers show a great variation in the modules of siliceous rocks, larger diversity was observed in layer 2.

In terms of retouch and shaping, an exclusive technical mode of the mid-Holocene applied to projectile points was detected. It consists of bifacial shaping involving several sequences followed by a parallel marginal retouch by pressure (Fig. 7: 11 to 15 and 25). Depending on the initial blank, several other retouch techniques were used, particularly in the small lanceolated points (Fig. 7: 19 and 20, 22–24). As mentioned in a previous paper (Restifo and Hoguin, 2012), layer 2 shows diverse and elaborated technical processes oriented to obtain laminar blanks. Other features include the use of blades, null formatization, invasive pressure, and manufacturing of bifaces in several sequences. The large extractive instrument of the mid-Holocene was made by several sequences of shaping and a final braked retouch, with the intention of forming different edges as active or transformative parts (Fig. 7: 18–21).

5.2. Zooarchaeological record

The zooarchaeological analysis of Hornillos 2 involved a total of 9671 faunal remains recovered from all the layers. Nearly 40% (3885) was taxonomically identified. The mid-Holocene layers (3 and 2) only comprise 28.4% of the NISP (Number of Identified Specimens per Taxon) (N = 1105) (Table 3). The bone remains were well preserved but present high degrees of fragmentation. The bones also show: a) a high frequency of elevated and medium states of thermo-alteration, b) a significant presence of cultural fractures and cut marks, and c) low frequencies of other kinds of marks such as those from carnivores. The identified specimens were merged in five groups: 1) Artiodactyla, 2) Camelids, 3) Cervids, 4) Chinchillidae (large rodents) and 5) Others (micro-mammals, mainly small rodents, carnivores, sparse birds, and one reptile, but none of these had cultural marks). Table 3 displays the NISP values of each of the groups for layers 2 and 3 of Hornillos 2.

Table 3
NISP values and frequencies by taxa of mid-Holocene layers at Hornillos 2.

Layer	NISP	NISP %				
		Artiodactyla	Camelids	Cervids	Chinchillidae	Others
2	747	34.1	25.9	0.8	30.1	9.1
3	358	62	14.2	0.8	19.1	3.9
Mean Values	–	48.05	20.05	0.8	24.6	6.5
Total	1105					

The sample recovered from layer 2 includes 747 specimens that evidenced similar values of Artiodactyla (34.1%), Chinchillidae (30.1%), and Camelids (25.9%). The sample from layer 3 (N = 358) is clearly dominated by Artiodactyla (62%) over Camelids (14.2%), because its higher degree of fragmentation, and Chinchillidae (19.1%) frequencies. These data indicate that layer 2 is more diverse, a fact also indicated by higher values of rare taxa. The cervids show the same low frequency in both layers, and these values were also comparable with the rest of the layers at the site. However, plotting the frequencies by taxa obtained for the mid-Holocene in the time series of faunal remains at the site, the abundance of camelids shows a sustained rise through time, evident particularly in the mid-Holocene values that almost triple those from the early Holocene. Fig. 8 displays the trends and pattern in zooarchaeological remains. Osteometric analysis of camelids specimens from layer 2 shows the presence of vicuñas, guanacos, and "llama" size camelids (phalanges and one scapula).

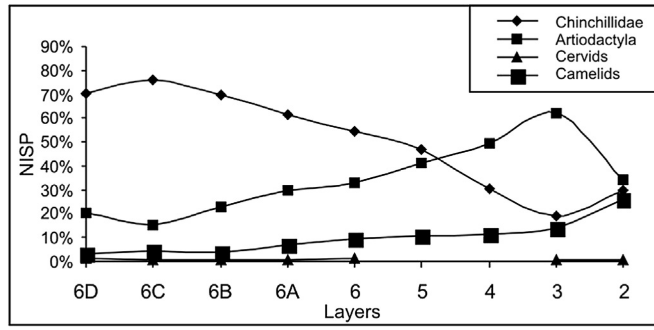

Fig. 8. Frequencies of taxa of the faunal remains of Hornillos 2 chronologically arranged by layer.

5.3. Isotopic data on camelid bones collagen

The isotopic analysis carried out at Hornillos 2 includes 33 values of $\delta^{13}C$, $\delta^{15}N$ and C:N measured on the collagen fraction of camelids bones recovered from the early ($N = 17$) and mid-Holocene ($N = 16$) layers at the site (Table 4). The following paragraphs briefly summarize the Hornillos 2 results and outline the main trends and patterns regarding two general aspects of the samples: their chronology and taxonomy. In previous works (Yacobaccio et al., 2010; Samec, 2011) reference values from modern camelids have been presented in order to discuss archaeological implications. These included 26 values of $\delta^{13}C_{col}$ and 13 of $\delta^{15}N_{col}$ obtained from llamas, vicuñas and guanacos located between 3900 and 4200 m asl in the Dry Puna of Jujuy (Fernández and Panarello, 1999-2001b, 1999-2001a; Yacobaccio et al., 2009, 2010; Samec, 2011).

In chronological terms and considering the $\delta^{13}C_{col}$ values presented in Table 5 and Fig. 9, whereas isotopic values of the early-Holocene and modern samples are not statistically different (One

Table 4
The thirty three $\delta^{13}C_{col}$ and $\delta^{15}N_{col}$ values of camelids bones included in this study.

Sample	Layer	Skeletal part	Camelid size	$\delta^{13}C$	$\delta^{15}N$	C:N
H2 02	2	Proximal Metacarpal	Large camelid	−18.79	10.16	3.68
H2 03	2	First Phalanx diaphysis	Large camelid	−16.79	10.25	3.01
H2 04	2	Phalange 1 proximal end	Large camelid	−16.90	8.69	2.98
H2 05	2	Metapodial diaphysis	Large camelid	−12.38	10.74	2.98
H2 06	2	Metapodial diaphysis	Large camelid	−17.20	9.25	2.91
H2 07	2	Metapodial diaphysis	Small camelid	−15.80	10.02	3.04
H2 08	2	Metapodial diaphysis	Large camelid	−18.70	6.22	3.03
H2 09	2	Phalanx 1 proximal end	Large camelid	−18.80	6.03	3.04
H2 10	2	Phalanx 1 proximal end	Large camelid	−19.02	6.18	3.06
H2 11	2	Phalanx 1 proximal end	Small camelid	−18.23	7.83	3.70
H2 12	2	Scapula	Large camelid	−17.45	7.26	2.95
H2 16	2	Mandible	Small camelid	−16.73	7.05	2.93
H2 18	2	Teeth incisive 3	Large camelid	−19.00	9.01	3.63
H2 20	2	Teeth incisive 1	Large camelid	−18.10	9.18	2.90
H2 25	2	Long bone fragment	Small camelid	−16.38	9.91	3.04
H2 14	3	Long bone fragment	Small camelid	−17.03	7.25	3.03
H2 21	4	Metapodial distal end	Large camelid	−16.68	10.54	3.01
H2 27	4	Proximal Phalanx	Large camelid	−17.49	8.18	2.89
H2 28	4	Long bone fragment	Small camelid	−19.32	5.58	3.08
H2 29	4	Proximal Phalanx	Small camelid	−17.39	5.59	2.89
H2 43	5	Long bone fragment	Large camelid	−18.34	6.86	3.22
H2 45	5	Long bone fragment	Small camelid	−18.40	7.08	3.22
H2 47	6	Femur	Large camelid	−19.09	6.09	2.93
H2 50	6	Long bone fragment	Small camelid	−17.65	5.02	2.92
H2 51	6	Teeth incisive	Large camelid	−17.56	10.02	2.99
H2 52	6A	Radius ulna	Large camelid	−16.67	7.64	2.84
H2 53	6A	Long bone fragment	Small camelid	−17.18	4.91	2.86
H2 24	6B	Phalanx indeterminate	Indeterminate	−17.83	5.94	2.97
H2 31	6B	Long bone fragment	Large camelid	−18.44	4.46	2.84
H2 33	6B	Teeth incisive	Large camelid	−19.23	3.67	2.93
H2 35	6C	Metapodial shaft	Small camelid	−16.68	5.87	2.87
H2 37	6C	Rib proximal	Large camelid	−18.63	5.19	2.99
H2 41	6D	Metapodial	Indeterminate	−16.01	8.11	2.81

Way ANOVA $F = 3.515$, $p = 0.06795$), modern values are depleted in comparison with those of mid-Holocene (One Way ANOVA $F = 6.59$, $p < 0.01$). Secondly, no statistically significant difference was found between early and mid-Holocene $\delta^{13}C$ values from Hornillos 2 camelids (One Way ANOVA $F = 0.9755$, $p = 0.331$). The $\delta^{15}N_{col}$ values from these samples exhibit another picture, because clear differences between early and mid-Holocene values have been detected (Table 6 and Fig. 10). The early Holocene values show a wide dispersion and not significant statistical differences in comparison with modern samples (One Way ANOVA $F = 1.688$, $p = 0.2044$). The mid-Holocene values exhibit remarkable differences with both data sets, those from early Holocene (One Way ANOVA, $F = 9.883$, $p < 0.01$) and the modern ones ($F = 28.55$, $p < 0.01$).

Table 5
Statistical data of $\delta^{13}C_{col}$ values of both, camelids from Hornillos 2 and modern reference samples.

	Early Holocene	Middle Holocene	Modern
N	17	16	26
Min	−19.32	−19.02	−20.10
Max	−16.01	−12.38	−16.90
Mean	−17.80	−17.33	−18.27
Median	−17.65	−17.33	−18.10
Standard error	0.24	0.42	0.13
Variance	0.97	2.79	0.46
Standard deviation	0.98	1.67	0.68

Table 6
Statistical data of $\delta^{15}N_{col}$ values of both, camelids from Hornillos 2 and modern reference samples.

	Early Holocene	Middle Holocene	Modern
N	17	16	13
Min	3.67	6.03	3.97
Max	10.54	10.74	7.56
Mean	6.51	8.44	5.78
Median	5.94	8.85	5.71
Standard error	0.46	0.40	0.24
Variance	3.57	2.58	0.78
Standard deviation	1.89	1.61	0.88

In taxonomical terms, mid-Holocene camelids isotopic values correspond to one of 3 alternative group sizes, assigned by osteometry and superimposed on modern camelids species that inhabit the studied area: vicuñas, guanacos, and llamas. The 14 bone

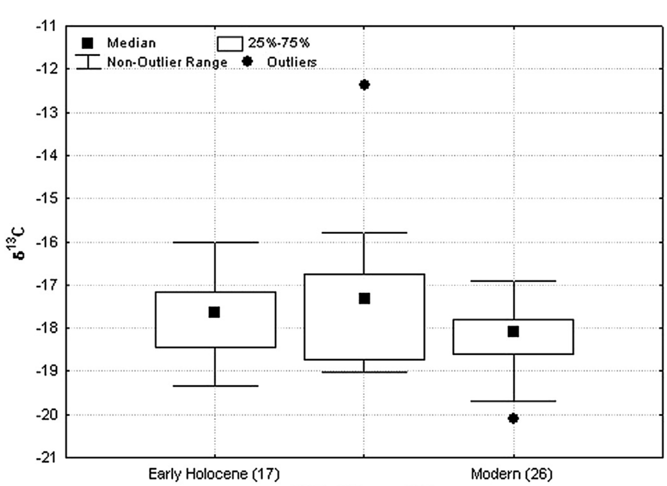

Fig. 9. Box plot of the $\delta^{13}C_{col}$ values segmented by taxa.

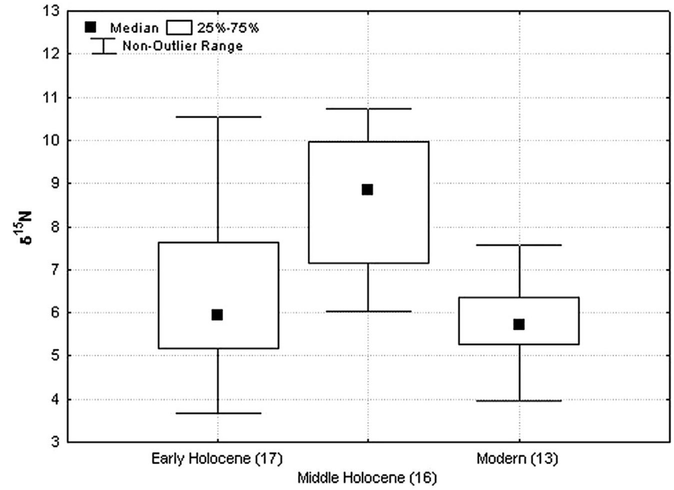

Fig. 10. Box plot of the $\delta^{15}N_{col}$ values segmented by taxa.

samples included in this analysis (no teeth included) were represented by: 4 individuals assigned to the guanaco group, 5 to the vicuña group, and 5 that correspond to the “llama” size recovered from layers 2 and 3 (Figs. 11 and 12). Due to the scarcity of the values involved in this taxonomic analysis, only some preliminary observations can be mentioned. In relation to $\delta^{13}C_{col}$, the values assigned to guanaco exhibit a great dispersion and seem to have been slightly depleted in comparison with the other two groups when comparing medians (Fig. 11). On the other hand, $\delta^{15}N_{col}$ values do not show clear differences between the three groups (Fig. 12). However, comparing the median values, a slight enrichment in the “llama” group seems evident, even though the “guanaco” group exhibits a greater dispersion. Further analyses are required to test this pattern and interpret its importance in ecological terms in the future.

5.4. Rock art

The rock paintings of Hornillos 2 consist of figurative motifs painted over the ignimbritic wall rock on the right sector of the rockshelter. The paintings include 28 wild camelids, 5 anthropomorphic figures, one bird-like design and a line of dots, all in black and different ocher reddish tones (Fig. 13) (Yacobaccio et al., 2008). Physical and chemical analysis of

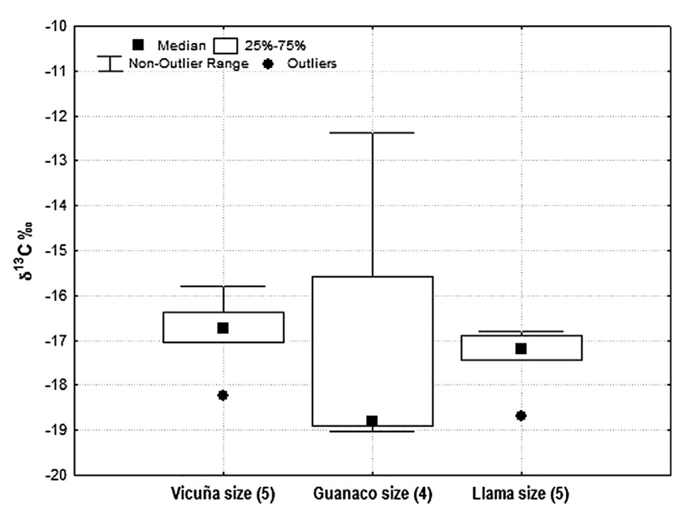

Fig. 11. $\delta^{13}C_{col}$ values arranged by morphometric group size.

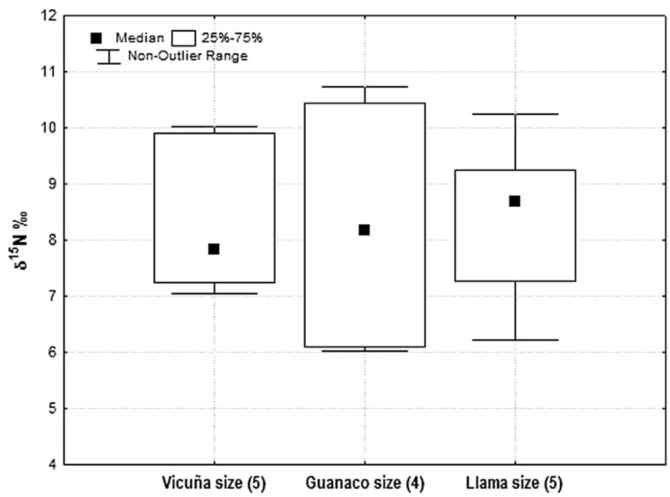

Fig. 12. $\delta^{15}N_{col}$ values arranged by morphometric group size.

several paints and red pigments recovered from the site stratigraphy showed that both, the black and red paints, were prepared with the same recipe, that included the grinding and mixture of at least three components: 1) hematite (red pigment) and probably iron and manganese oxide (black pigment), 2) gypsum, and 3) animal fat (Vázquez et al., 2008; Yacobaccio et al., 2008, 2012).

The evidence obtained from some layers suggests that the paintings were produced during the first occupations of the rockshelter in the early Holocene. For example, a wall fragment with red paint and a pestle with red pigments, but also with gypsum and bone relicts attached, are included in layers dated at least 9150 ± 50 BP. In terms of the painting events, the style and compositional similarities of the different groups represented on the panel and the detected superimpositions suggest five times of execution of the paintings as a minimum (Yacobaccio et al., 2012). The quantity of red pigment fragments found in the stratigraphic layers declines towards the mid-Holocene, indicating a reduced intensity in painting activity, particularly at the end of this period (31 fragments in layers 6d to 6, 20 in layer 4, only 2 in layer 3, and 8 in layer 2). The potential range of acquisition of these pigments (including the other components mentioned in paint recipes) covers a radius of almost 80 km. This range possibly imbricates with other raw material sources such as obsidians (Yacobaccio et al., 2004).

5.5. Spatial analysis of the mid-Holocene layers

The intra-spatial analysis of the remains of Hornillos 2 during mid-Holocene layers was fully presented in a recent paper (Hoguin et al., 2012). However, a brief summary of its outcomes should be mentioned in order to discuss the information available for the site (Fig. 14).

The evidence shows that the activities represented in the layer 3 were diachronic. For instance, bone and lithic remains located in square 12 do not showed any signs of fire which could indicate the relation with the hearth of the same grid. The lack of patina in lithic debris and the absence of weathering and natural marks of canids and rodents on the bones point towards a rapid burial. The burned material in layer 3 was found outside the combustion zone, concentrated in the adjacent square 5. This pattern is compatible with a trash heap area of anthropogenic origin. Grids 4 and 6 showed evidence of different tasks related to the knapping of raw material, especially bifacial shaping and pressure on silicified and obsidian rocks (Fig. 14).

In layer 2, square 3 and 4 are bounded by several hearths showing a great concentration of remains which were differentially distributed (by raw material in the case of the lithic debris) (Fig. 14). These distributional patterns correspond to an anthropogenic selection, even though some post-depositional bioturbation was detected. Taking the evidence of this layer as

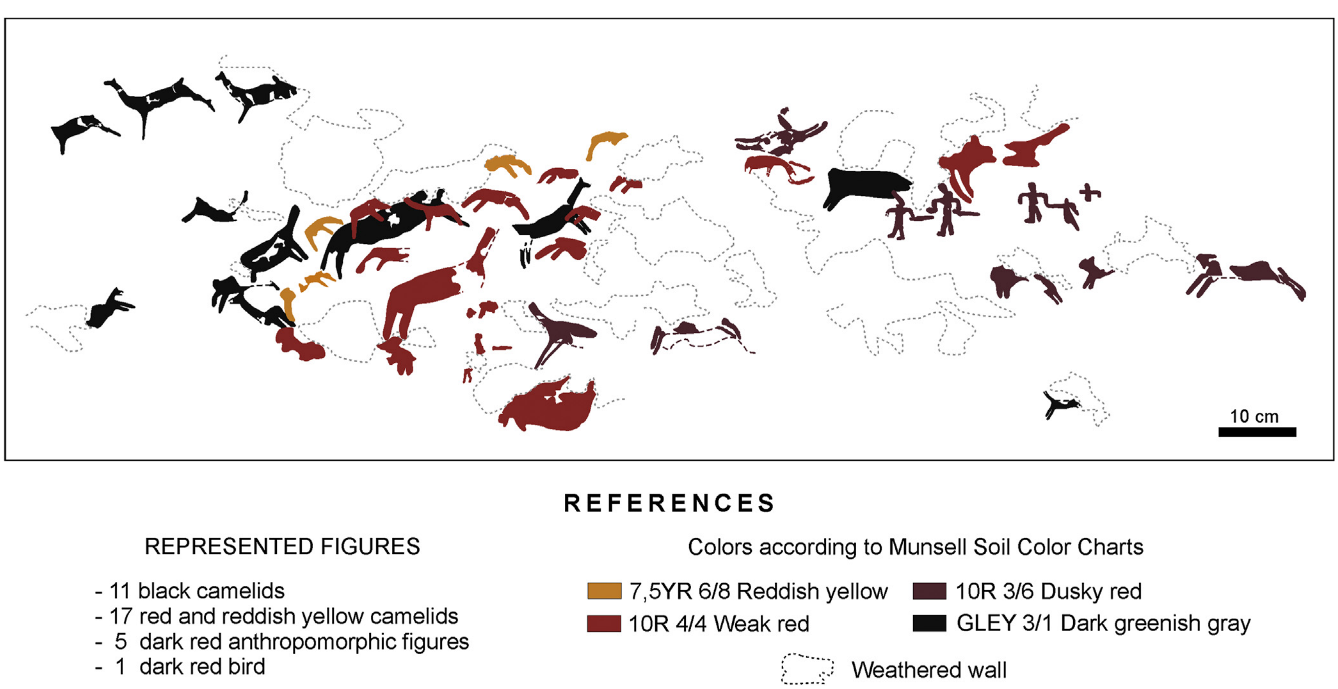

Fig. 13. Scheme of Hornillos 2 rock art, including color references of the motifs and the areas with weathered wall. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

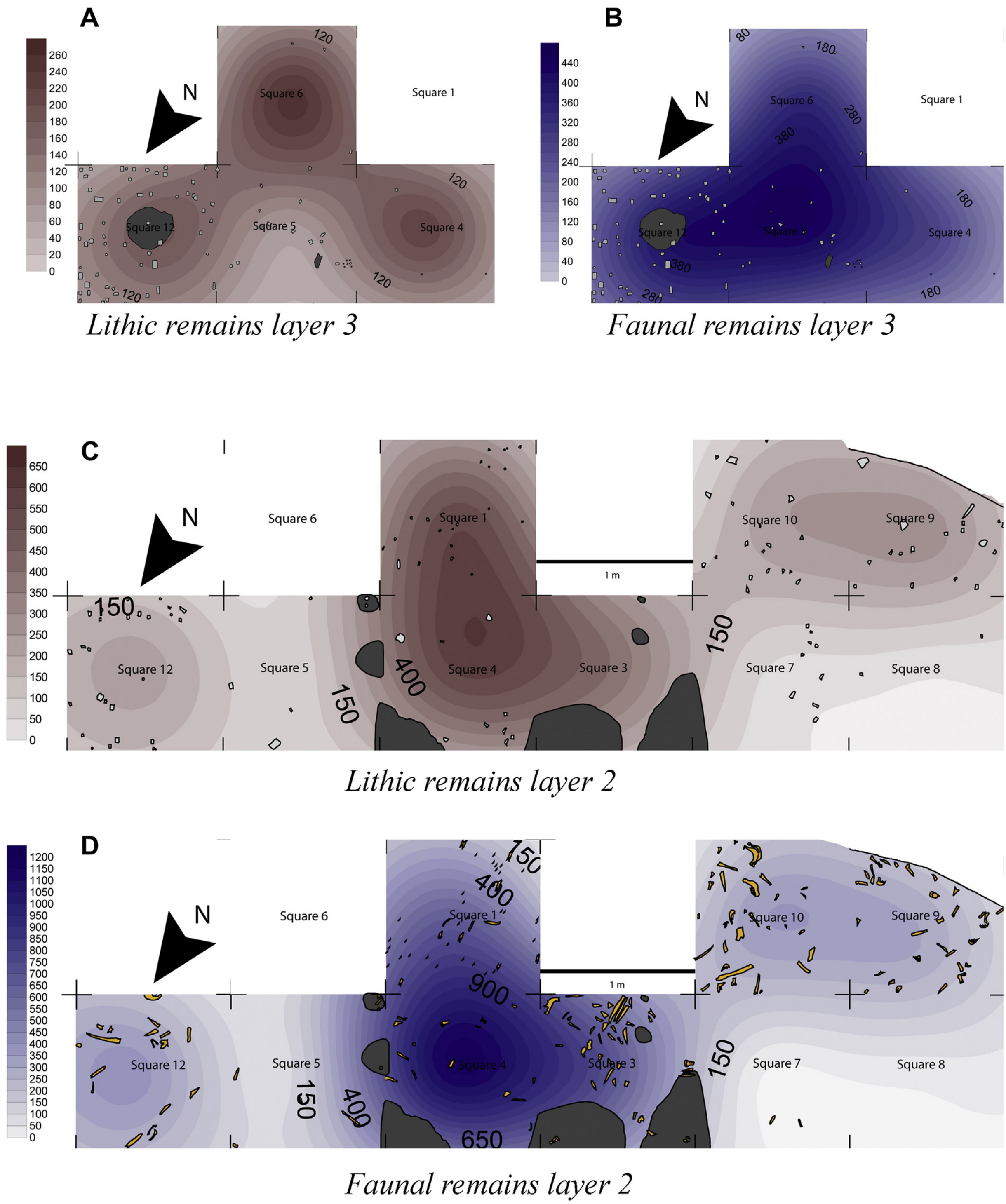

Fig. 14. Spatial distribution of lithic and faunal remains in the mid-Holocene layers 2 and 3 at Hornillos 2 site.

a whole, the area bounded by hearths could be interpreted as one of the main zones of activity, where tasks such as the final shaping of instruments and the processing of ungulates and rodents for consumption were carried out. Moreover, three alternative but not exclusive hypotheses could explain the patterns observed in this layer: 1) a sustained occupation, 2) a recurrent, perhaps seasonal, reoccupation, or 3) an occupation by larger human groups (compared with layer 3).

6. Discussion

The trends and patterns observed in the results of the analysis of the evidence recovered from Hornillos 2, conjoined with the site location features, the known raw materials sources and regional archaeological evidences let us discuss some aspects related to social strategies such as mobility patterns, resource use, and site function during the mid-Holocene.

A great difference in the extent and the average density of the materials per m^2 was observed between the two layers of the mid-Holocene. This could be linked to a different intensity in the use of the rockshelter. Whereas layer 3 seems to have been the byproduct of short term specific events, layer 2 suggests a more extensive and intensive occupation of the rockshelter. However, both layers exhibit a broader extent and intensity than those from the early Holocene.

The lithic technology recovered from layers 3 and 2 showed clear differences with early Holocene layers at the site, such as the frequencies of different kinds of raw materials and the technological organization as a whole. For example, during the mid-Holocene, new kinds of tools, such as blades and new types of projectile points, were recorded. Some of these changes seem to have started somewhat earlier, at the end of early Holocene. For instance, pre-determined blanks applied to make processing artifacts were present in layer 4 and in the following mid-Holocene layers 3 and 2. In the same way, the manufacturing sequence of the tools recovered from these layers (projectile points, side scrapers or multifunction instruments), showed a more structured and strict knapping schemes. In sum, the most conspicuous changes in lithic technology were: a) the rise in the utilization of medium and long distance raw materials in detriment of local ones, b) the addition of new types of projectile points (lanceolated and the "San Martín" type points that were exclusive of layer 3) to the previously available (*i.e.* triangular), c) new laminar artifacts (including blades), and d) more structured and strict schemes in artifact manufacturing. These changes seem to have started ~8300 BP, in close relationship with a regional environmental reorganization that involved a drop in resource abundance and availability (fragmentation of landscape).

The $\delta^{15}N$ and $\delta^{13}C$ isotopic values of the bones collagen recovered from Hornillos 2 were coherent with the environmental changes during the mid-Holocene in the area. The $\delta^{15}N$ values showed enrichment in mid-Holocene specimens, possibly associated with the rise of N values in the soils or to the water/protein stress of the sampled animals. On the other hand, the absence of significant variations in $\delta^{13}C$ values suggests similar C_3 and C_4 vegetation proportions in animal diet over time. Moreover, the isotopic values of bone remains showed that the composition of consumed vegetation was similar to that available in the vicinity of the site at present, suggesting that the animals could have been hunted nearby (Yacobaccio et al., 2010).

The location of both pigments and obsidian sources suggests a mobility radius restricted to the western part of the Puna of Jujuy. This mobility radius has been illustrated as an ellipse with its larger axis N–S oriented (Yacobaccio et al., 2012). This fact becomes clear taking into account the sources of red and black pigments recovered from other sites such as Inca Cueva Cueva 4 (Aschero, 1983-85; Rial and Barbosa, 1983-85) coming from different sources to those from Hornillos 2. The pigments recovered from the former were obtained from a basin located far to the east of the mobility radius of Hornillos 2. This observation fostered the hypothesis that the hunter–gatherers that occupied Hornillos 2 might have established some boundaries in relation with NNE–SSW oriented geographical features (Yacobaccio et al., 2012). This hypothesis is based on the idea that rock art has to do with marking and negotiating boundaries as suggested by diverse ethnographic contexts of contemporary hunter–gatherers (Bahn, 2010: 103). These boundaries could have been reinforced during periods of shortage or unpredictability of resource abundance such as the mid-Holocene.

The camelids depictions in Hornillos 2 also show the close relationship between people and wildlife which was intensified through time. This can be appreciated in the rise of camelid bone remains by the mid-Holocene. This pattern is common to other sites located in both chilean and argentinean slopes of the Puna de Atacama, such as Quebrada Seca 3, Tulán 67, Huasco 2, Puripica 13-14, Pintoscayoc (layer 5), and Alero Cuevas, all having punctuated occupations during the first part of the mid-Holocene. Eventually, this intensification in camelid utilization led to their domestication. This context includes the "llama" size bones from layer 2 of Hornillos 2.

In sum, mid-Holocene climatic conditions set a new and challenging environmental scenario for hunter–gatherers in the Dry Puna. They must have faced a drop in the regional primary productivity with an unstable and scattered offer of resources, but in general a more predictable availability in spatial terms (*i.e.* above 4000 m asl and associated with the larger and permanent basins). These changes in resource structure favored a cascade of innovations in several aspects of their organization such as: a) new techniques and artifact types (as indicated by projectile points diversity) and more structured and strict schemes in artifact manufacturing in the lithic technology, b) the rock art that possibly reinforced social boundaries or territories, and c) in the archaeofaunas which indicate a rising importance of camelids as a food staple during mid-Holocene in the whole area, eventually resulting in their domestication.

7. Concluding remarks

The mid-Holocene was not homogeneous from an environmental point of view. Hunter–gatherers modified their social strategies throughout the period. During the first part of the mid-Holocene, the archaeological record suggests short term occupations in layer 3 (*ca.* 7500 BP). This evidence is characterized by the dominance of stemmed projectile points, known as "San Martín"; this type have a broad distribution in the salt-lake margins of eastern Chile, such as Huasco, Coposa, Ascotán, and San Martín. This area includes the High-Andean region above 4200 m asl, which seem to have had better environmental conditions during mid-Holocene. These characteristics seem to have been completely replaced in layer 2, dated at 6340 ± 110 and 6190 ± 70 BP. In this layer, a greater diversity of projectile point types was recorded, together with other technological innovations. A more extensive and intensive use of the rockshelter is documented, revealing a decreasing mobility of hunter–gatherer groups. The appearance of "llama" size bones is explained by the development of protective herding as the first step to guanaco domestication. This is also supported by the intensification in the use of camelids and the reduced residential mobility of human groups. During this period, hunter–gatherer society changed in several ways, although there is insufficient evidence to have in-depth knowledge about their trajectory. Hopefully, future research will fill these gaps.

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