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Archaeological silence and ecorefuges: Arid events in the Puna of Atacama during the Middle Holocene

Lautaro Núñez [a,*], Isabel Cartajena [b], Martin Grosjean [c]

[a] Instituto de Investigaciones Arqueológicas y Museo, Universidad Católica del Norte, Le Paige 380, San Pedro de Atacama, Chile
[b] Departamento de Antropología, Universidad de Chile, Santiago, Chile
[c] Oeschger Centre for Climate Change Research, University of Berne, Switzerland

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ABSTRACT

This paper briefly summarizes presearch concerning the mid-Holocene in the western slope of the puna de Atacama (20–25°S). Proxy data and dates from palynological, limnological, geomorphological archives were compared with data recovered from the archaeological sites in high altitude basins, intermediate ravines and piemontane paleowetlands. Due to exceptionally favorable conditions, numerous Early Holocene archaeological sites were found. In contrast, the lack of occupations in previously populated areas suggests a decline in human activity during the arid mid-Holocene. In this context, two key concepts are introduced: ecorefuge or ecological refuge, and archaeological silence (*silencio arqueológico*). The first refers to the particular favorable locations occupied by human groups during the mid-Holocene. The second provides a better understanding about the impact of the arid interval during this period on human adaptations in the most barren territories of the New World.

1. Introduction

Well-preserved archaeological and climatic archives constitute an appropriate scenario in which the relation between environments, Holocene climate change and human occupation can be understood. Today, there exists increasing interest to understand the relationship between economic, social, political and environmental factors in the South-Central Andes (Byrne, 1988; Fernández et al., 1991; McCorriston and Hole, 1991; Browman and Gundersen, 1993; Grosjean and Núñez, 1994; Grosjean et al., 1997a; Sandweiss et al., 1998; Aldenderfer, 1999; Núñez et al., 1999a,b). This paper summarizes pioneering work started twenty years ago in Quebrada Puripica. By using a multidisciplinary approach allowed a comprehensive understanding about the relation between human occupations and the environment in this area. Especially surprising was the identification of a highly dynamic scenario and the different responses from human groups during the Holocene (Grosjean and Núñez, 1994; Grosjean et al., 1997a; Núñez et al., 1999a,b). At the beginning of this research, it was proposed that early groups would have responded most sensitively to climate changes in dry, high-elevation environments, where local to regional water availability was a limiting factor, especially in the Atacama Desert.

During the 1990s further work integrated a broader area, including the survey of 20 altiplano lake basins (20–25°S) above 3600 m, intermediate ravines between 3000 and 3600 m and lowland basins (2300–2000 m) (Núñez et al., 1999a). As a result, numerous open campsites along fossil shorelines of paleolakes were found. Open campsites and caves at intermediate elevations such as Quebrada Puripica, San Lorenzo and Quebrada Tulán, located in the northeast, mid-east and southeast of the Salar de Atacama basin respectively, are reevaluated. Finally, at the Salar de Atacama and Punta Negra, low-altitude paleo-wetlands were identified, associated with extensive open campsites (Núñez et al., 2005).

The comparison of proxy data and dates from palynological, limnological, geomorphological archives with data recovered from the archaeological sites, led to the postulate od the existence of arid conditions during the mid-Holocene. Previously reported results (Núñez et al., 1999b, 2002, 2005) are summarized in the context of the discussion about human occupations and environments during the Middle Holocene in the South–Cental Andes.

The Atacama Desert is situated between the Loa and Copiapó valleys at the southern end of the great desert that straddles Chile and Peru and is one of the most barren areas of the world (Bowman, 1924). The core area of the Atacama Desert and highland (Puna de Atacama, 20°S–25°S, 2300–4500 masl) was selected for

* Corresponding author.
E-mail addresses: lautaro.nunez@hotmail.com (L. Núñez), icartaje@uchile.cl (I. Cartajena), grosjean@giub.unibe.ch (M. Grosjean).

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geoarchaeological research (Fig. 1). Modern precipitation, mainly during the southern summer, ranges between less than 20 mm per year in the Salar de Atacama to less than 200 mm per year on the *altiplano*. The annual 0° Celsius isotherm is at 4400 m, vegetation is extremely weak with a maximum of about 30% grass and shrub cover between 3800 and 4000 m. Springs and a few perennial creeks are focal points for biologic resources (Grosjean et al., 2005a).

Paleoecological data showed that this area changed dramatically from very arid environments at the Last Glacial Maximum (LGM) to relatively humid conditions during late glacial and early Holocene times (Geyh et al., 1999; Grosjean et al., 2001; Latorre et al., 2002; Núnez et al., 2002). This change began around 14,000 cal BP and culminated between 13,000 and 9500 cal BP. The shorelines of late glacial paleolakes were up to 70 m above those of the current salt lakes due to the increase of summer precipitation (Grosjean, 1994; Geyh et al., 1999; Grosjean et al., 2001; Núñez et al., 2002; Rech et al., 2002).

The identification of a more humid phase is coincident with available records of continental climate change for the Central Andes as summarized by Latorre et al. (2007:314) "[……] lake and salt cores from Lake Titicaca and Salar de Uyuni (Baker et al., 2001a,b; Fornari et al., 2001), chronostratigraphic work on shoreline deposits throughout the Altiplano (Clapperton et al., 1997; Clayton and Clapperton, 1997; Sylvestre et al., 1999; Placzek et al., 2006), ice cores from Nevado Sajama (Thompson et al., 1998) and Illimani (Ramirez et al., 2003), salt cores from Salar de Atacama (Bobst et al., 2001; Lowenstein et al., 2003), and Hombre Muerto (Godfrey et al., 2003)".

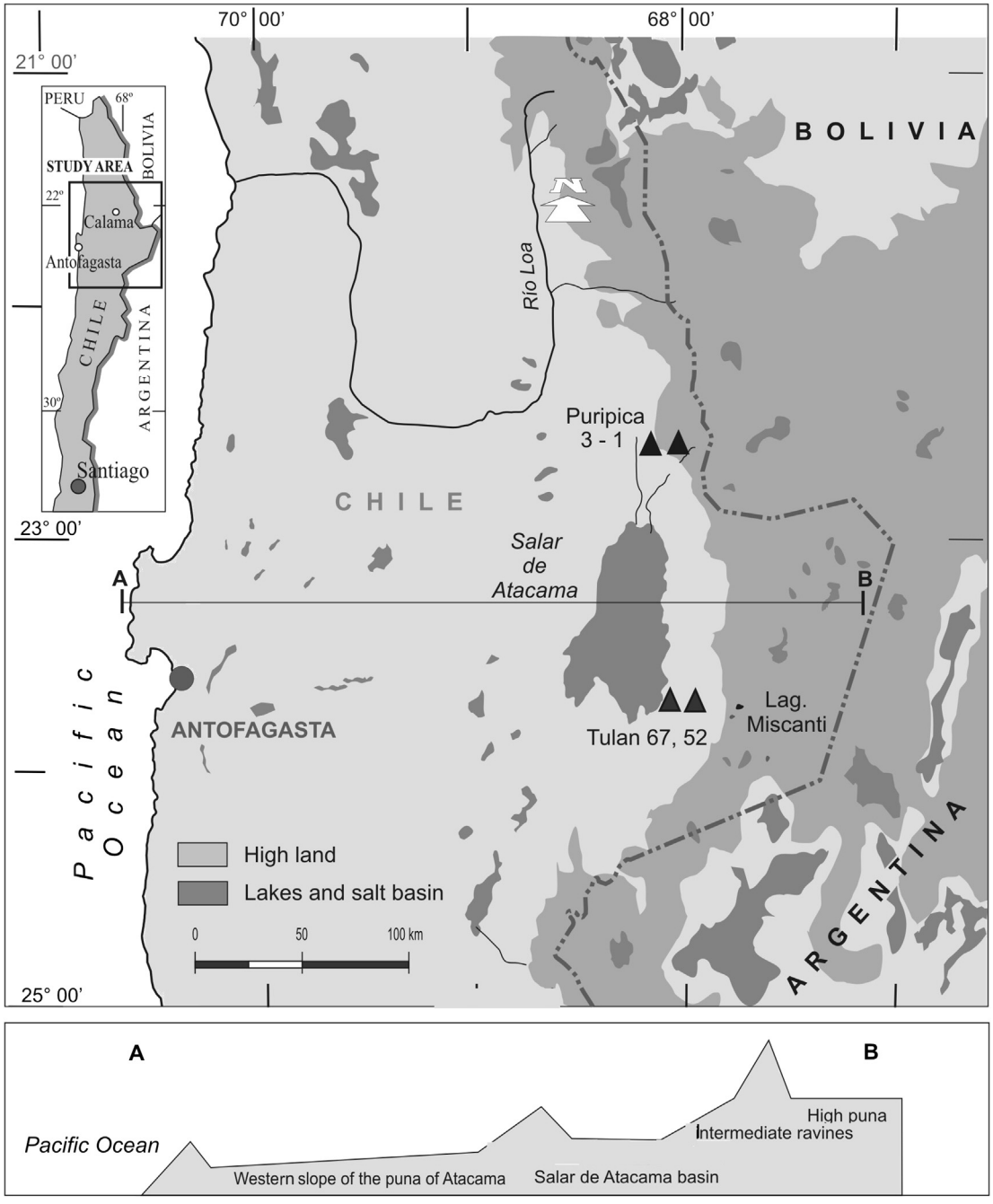

Fig. 1. Study area and location of the main sites cited in the text.

In northern Chile, this wet phase has also been called the Central Atacama Pluvial Event (Latorre et al., 2006; Quade et al., 2008). The abundance of sites during this period reflects exceptionally favorable conditions for human habitation and widespread early occupations during the existence of paleolakes in the highland and paleowetlands in the lowlands (Santoro et al., 2011).

The Early Holocene lake transgressions were followed by lakes collapse ca. 9600 cal. BP (Geyh et al., 1999; Grosjean et al., 2001). Evidence based on lake sediments and ice cores suggests that paleoclimate was generally dry during the mid- and late Holocene (Seltzer et al., 1998; Thompson et al., 1998; Baker et al., 2001a,b; Grosjean, 2001; Grosjean et al., 2001). The aquatic system (limnology and aquatic plants) of Laguna Miscanti suggests generally dry conditions during the mid-Holocene (Valero et al., 1996; Grosjean et al., 2003). However, there are discrepancies about the magnitude and the scale of aridity events during the mid-Holocene. Local proxies suggest an extremely arid period interrupted only by low-frequency heavy storms (Geyh et al., 1999) consistent with low lake levels in the south-central Andes and the Titicaca basin, low accumulation rates and elevated Cl concentrations in the Sajama ice core, and with other pedological and geomorphological features indicative of long-term dry climates (Seltzer et al., 1998; Thompson et al., 1998; Baker et al., 2001a,b; Grosjean, 2001; Grosjean et al., 2001, 2003, 2005a; Abbott et al., 2003, 2005a). However, other investigations have identified well-defined arid and wet events during the mid-Holocene (Latorre et al., 2005, 2007). Surrounding terrestrial vegetation, and plant macrofossil records in rodent middens, suggest more humid conditions during the mid-Holocene compared with the early-Holocene (Betancourt et al., 2000; Latorre et al., 2002). Although rodent middens record climate variability at higher resolution, they may reflect rather (sub-) decadal or even interannual climate variability. This is very different from lake records that integrate climate over decades to centuries and thus show low-frequency variability (Grosjean et al., 2003). Despite the sensitivity of the proxies used, climate variability during the mid-Holocene is more complex and heterogeneous than previously thought (Grosjean et al., 2003; Yacobaccio and Morales, 2005; Latorre et al., 2007).

The regional extent of an arid mid-Holocene has been discussed. A decline of human occupations is observed in the eastern border of the Dry Puna of Argentina and probably in southwest Bolivia (Albarracin-Jordan and Capriles, 2011). However, recent research in northeastern Argentina denotes the occupation of favourable places during more humid phases or throughout the mid-Holocene, such as Hornillos-2 (Susques Dry Puna), Quebrada Seca 3 and Cueva Salamanca in the Salty Puna (Aschero et al., 1991, 2000; Yacobaccio and Morales, 2005; López, 2008; Pintar, 2009; Yacobaccio et al., 2012). In contrast, in the western Puna slope, human groups would have abandoned broader areas, remained or relocated in smaller scale occupations at few favourable places, whilst other groups decided to move to the nearby coastline (Grosjean et al., 2007). Certainly, new explorations could identify other ecorefuges or patches that could have been used during the arid interval along with those identified in Puripica and Tulán.

2. Early Holocene

In the Atacama Desert, favourable environments were established in the period between 13,000 and 9000 cal BP, during the relatively humid Early Holocene. Highly mobile groups of hunter-gatherers occupied different habitats from the Pacific coast up to high elevation palaeolake sites above 4000 masl. During this period, diverse and synchronous occupations can be observed in the Central-Southern Andes. They include maritime adaptations on the coastline near the western valleys in Southern Peru (Tacahuay pattern; De France and Alvarez, 2004), along the coastline of the Atacama Desert (Huentelauquen pattern; Llagostera et al., 1997), inland hunter-gather occupations at the low basin of the Pampa del Tamarugal (Ugalde et al., 2012), the Meridional Altiplano (Albarracin-Jordan and Capriles, 2011), and the Circumpuna area (Aschero, 2000; Nuñez et al., 2005; Yacobaccio and Morales, 2005).

In the puna, they preferentially exploited palaeolake shorelines on the *altiplano*, rock-shelters at intermediate elevations, and palaeolake wetlands at lower elevations (Salar de Atacama and Salar Punta Negra). Groups from the early occupational pattern Fell-Tuina (ca.12,100–9100 cal BP) established open campsites on the edges of the paleo wetlands located in Punta Negra basin. Hunter-gatherers used triangular and fishtail projectile points, the latter similar to those commonly recorded at sites in Central and Southern Chile (Grosjean et al., 1997b; Núñez et al., 2005). In the site SPN-1 (12,600 and 10,200 cal. BP) located in the eastern border of the Salar de Punta Negra, different types of projectile points were found, among them, the triangular Tuina and Fell fishtail ones, suggesting the coexistence of these two technological traditions. Animal bones also were recovered, and by using osteometric methods the presence of *Lama guanicoe* and *Vicugna vicugna* was identified (Grosjean et al., 2005b).

The Tuina occupations also include several Andean hunter-gatherer settlements located in caves along intermediate ravines and in open campsites on shoreline of highlands. The sites are strongly associated with circum-puna highland resources (Núñez, 1992; Núñez et al., 2002). The zooarchaeological record from Tuina-5 (11,420–11,810 cal. BP) indicates that these groups hunted camelids (*L. guanicoe* and *Vicugna vicugna*), to a lesser extent, deer (*Hippocamelus antisensis*), a Pleistocene equid (*Equus* sp.), and abundant microfauna (*Lagidium viscacia*, *Chinchilla* sp., *Abrocoma* sp. *Nothroprocta* sp., *Anas*, sp., *Fulica* sp., *Metriopelia* sp., Passeriformes and *Anfibia*). In other sites, the collection included gathered plants for grinding in intermediate ravines and lowlands on the eastern border of the Salar de Atacama (Núñez et al., 2005, 2010).

Given their wide distribution, these groups have lived in the circum-Puna highlands, above 2000 masl, moving around rich resource areas. Their movements are closely associated with high Andean hunting and gathering resources in environments such as meadows, groves and foothill scrublands on the eastern and western slopes of the high puna (Aschero, 2000; Yacobaccio and Morales, 2005). With this occupational pattern, exploitation of lake resources and high Andean foraging commenced, in parallel with the use of resources from the Loa River and the streams of the Atacama basin, including those in the mountains, spring-fed ravines, meadows and small lagoons on the eastern edge of the present-day Atacama Salt Flat (Fig. 2).

Recent findings on the coast contemporaneous to the Tuina pattern confirm the existence of different occupational traditions during the initial settlement of the circum-puna desert region (Castelleti, 2005; Núñez et al., 2005). Although the dates of the Tuina sites are slightly older, the abundance of coastal resources suggests that the first explorers arrived at the end of the Pleistocene along the coastline and occupied the coast not only in southern Peru (e.g. Sandweiss et al., 1998), but also near Taltal and the Atacama Desert (Castelleti, 2005).

During the mid-Holocene, there is evidence for a significant decline and in some cases even a hiatus of human occupation due to aridity stress in highland lakes as well as intermediate ravines and low elevation wetlands from 9600 to 4500 cal BP. The lack of occupations in previously populated areas in the Atacama Basin and the presence of large sterile mid-Holocene sediments in most of the caves separating the early and late occupations led to the postulate of the decrease of human occupations (Fig. 3). This time is known as the archaeological silence (*silencio arqueológico*) (Núñez et al., 2002).

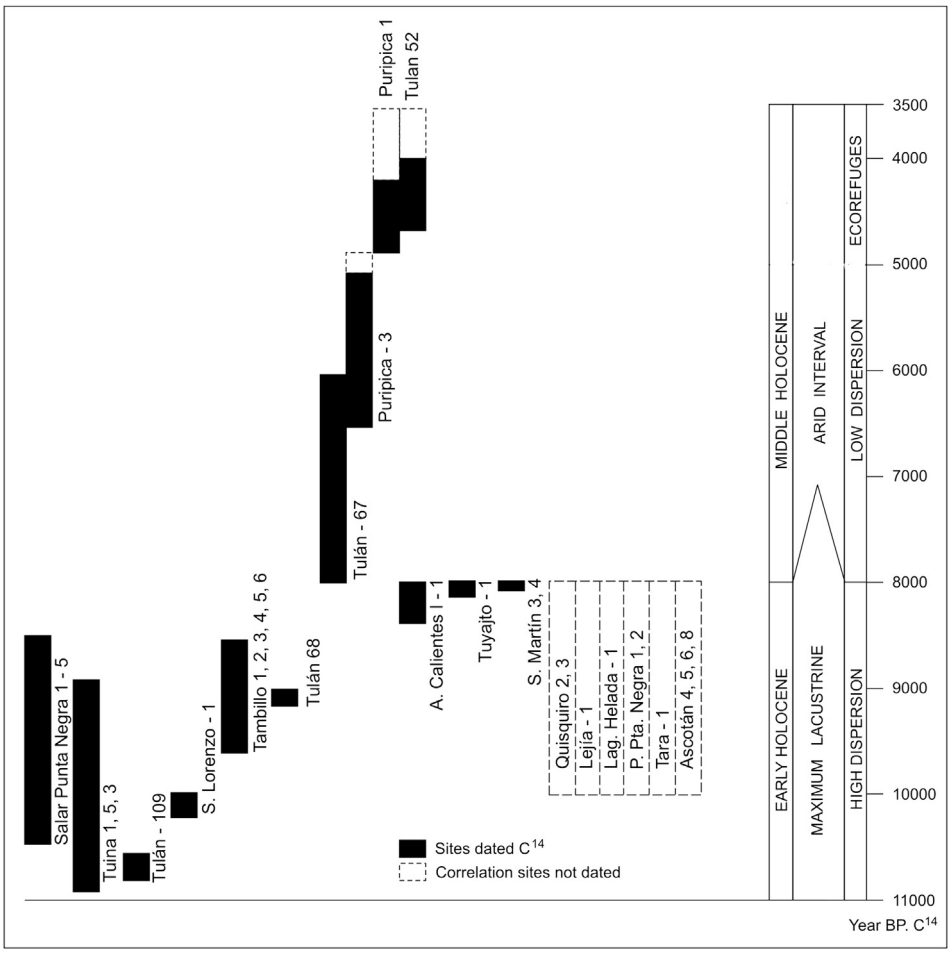

Fig. 2. Early and Middle Holocene sites in the western slope of the Puna de Atacama.

3. Tulán and Puripica ecorefuges

During the arid Middle Holocene, groups of inland hunter-gatherers lived in camps in the pre-Puna ravines, where resources were concentrated in the floors of valleys (ecological refuges) such as Puripica and Tulán. The movements of these groups distributed them around the lakeside beaches of the highland basins, including intermediate ravines such as Tulán, Puripica and Chulqui, and throughout the Loa and Atacama basins. The arid conditions that prevailed during the Middle Holocene

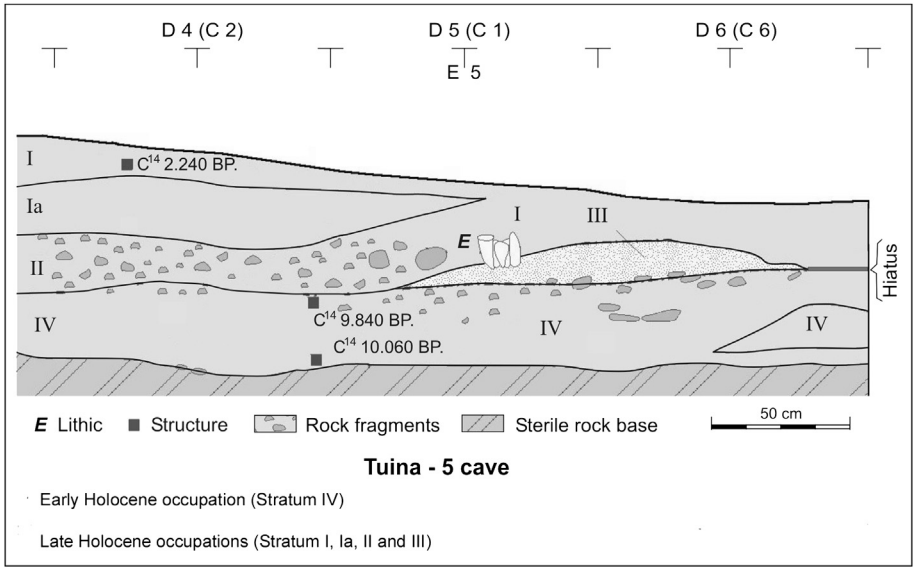

Fig. 3. Early Holocene Tuina-5 cave showing an occupational hiatus during the Middle Holocene.

Fig. 4. Quebrad Tulán view.

seem to have prompted the groups' movement to other productive zones, specifically microhabitats, making the frequency of dated sites much lower than in the earlier periods. Habitats were predominantly found in the eco-refuges (Grosjean et al., 1997a; Núñez et al., 1999b, 2005; Grosjean et al., 2005a). Without doubt, the isolated concentration of flora and fauna, especially around year-round springs and meadows, enabled the establishment of archaic settlements in the pre-Puna sectors of the Loa and Atacama basins (including the adjacent high Puna). These groups hunted wild camelids, developed camelid domestication, collected plants, and maintained contact with the Pacific coast (Núñez et al., 2010).

This decline in human activity is seen in most caves, with early and late occupations separated by largely sterile mid-Holocene sediments as noted before. However, a few sites, including the cave of Tulan-67, show that people did not completely abandon the area. All of the sites of sporadic occupation are located near wetlands in valleys, near large springs, or where lakes turned into wetlands and subsistence resources were locally still available despite a generally arid climate (Grosjean et al., 1997a; Betancourt et al., 2000; Grosjean et al., 2001). In Laguna Miscanti, paleolakes were replaced with mid-Holocene wetlands and grazing areas in the flat bottom area of the former lake, and thus more favorable habitats were created in a drier climate (Grosjean et al., 2001).

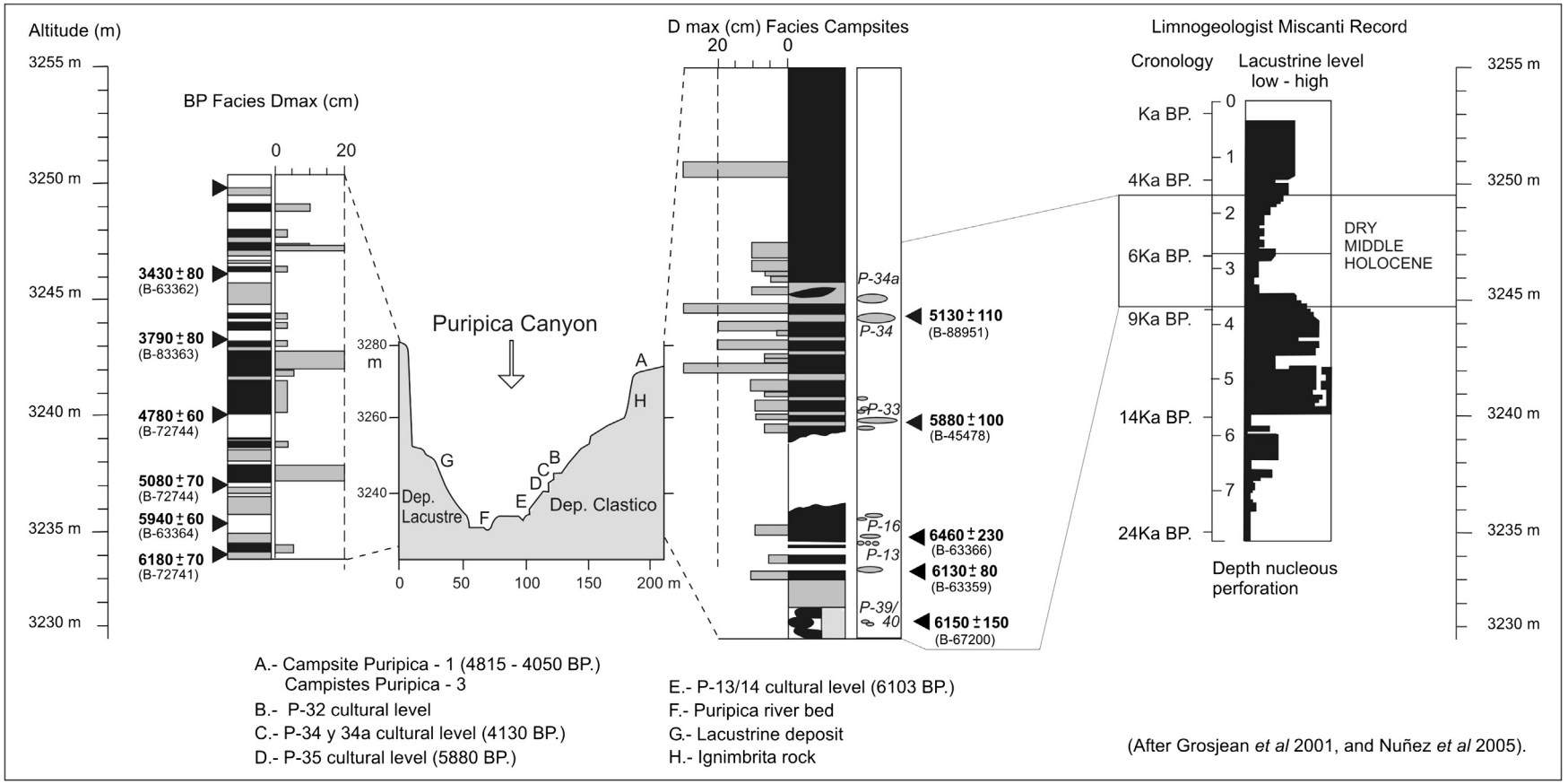

Fig. 5. Middle Holocene cultural and sedimentological profile from Puripica-3 on the left. On the right, the limnological profile from Laguna Miscanti (after Grosjean et al., 2001; Núñez et al., 2005).

During the Middle Holocene, only a small archaic occupation was registered in Quebrada Tulán (Fig. 4) recorded in the stratigraphic profile of the rockshelter Tulán-67. This site is a small rockshelter located on the southern side of the Tulán ravine (S 23°42′12″/W 68°04′36″) at 2669 masl. Inside the shelter (21 m^2), the rockwalls bear linear geometric designs painted in red including a human figure. The site was modified by modern hearders who build a stone wall around the shelter. A large scatter of surface material, mostly lithic, covers the ground. Seven stratigraphic units were recognized; all excavated levels contained animal bones and lithic material.

The early stratigraphic zone (EVII) corresponds to the beginning of the occupation dated 8190 ± 120 B.P (9426–8656 cal BP) (Núñez, 1992; Núñez et al., 2005). Early archaic groups exploited mainly camelids (*L. guanicoe* and *Vicugna vicugna*) and, to a lesser extent birds and rodents (*Lagidium* sp., *Chinchilla* sp., *Phoenicopetridae*, *Metriopoelia* sp., *Passeriformes* y *Accipitridae*). Pacific shells were found (*Agropecten purpuratus*), suggesting contact with the coast (Cartajena, 2003). The middle stratigraphic zone (EVI and EV) dated 5320 ± 90 B.P. (6281–5769 cal BP) (Hedges et al., 1989 in Dransart, 1991:296) and 5940 ± 50 B.P. (6855–6552 cal BP) (Núñez et al., 2005) corresponds to a mid-Holocene occupation. The faunal assemblage is very similar to the former level (*L. guanicoe*, *Chinchillidae*, *Phonicopteridae* and Passeriformes), and some bone remains exhibit red pigments. Blades became common and greater artifact diversity is observed (Cartajena, 2003). Finally, the stratigraphic levels EIV and EIII dated 3640 ± 120 B.P. (4239–3572 cal BP) (Núñez et al., 2005) correspond to Early Formative occupations.

The lacustrine, fluvial and torrential sediments in Quebrada Puripica (22°48′S, 68°04′ W, 3250 masl) give a detailed record of environmental and climatic conditions during the Holocene ca. 7400 to 3300 cal BP This was the first paleoenvironmental archive covering this period in this area. The mid-Holocene was significantly drier than the early Holocene: evidence was found for low frequency, heavy storms and for moderate and small flood events. The accumulation of 18 m of sediment and the subsequent erosion took place in a short time and is interpreted as a function of change in the moisture regime of climate (Fig. 5).

The gradual onset of the ecological refuge in the confluence area of the Puripica stream and the Quebrada Seca formed a shallow lake and wetland environment in the backwaters of the emerging alluvial cone (Fig. 6). Sterile fluvial sands preserved the oldest small fireplace P-39/40 (7409–6569 cal BP) containing basalt, obsidian and flint flakes and camelid bone remains, suggesting a short term, single occupation by a small highly mobile group. A second campsite (P13, 7167–6737 cal BP) contains few bone artifacts and a large number of lithic artifacts and bone remains (*L. guanicoe*), showing a foliacean industry. Around 6886–6406 cal BP, a more diversified technology and occupational pattern is found, reflecting a transitional phase in which elements of the earlier cultural phase were still present (obsidian multifunctional blades and projectile points), and components of the Late Archaic were appearing (discoidal microliths and microperforators) (Grosjean et al., 1997a).

The sites in the Puripica canyon suggest that the transformation and the increasing complexity of the early archaic hunting tradition towards the middle and later archaic societies was a gradual process. The old tradition (7400 cal BP) changed around 6800 cal BP towards a pattern of settlement with denser campsites, an intense exploitation of camelids (*L. guanicoe and Vicugna vicugna*) and innovations in the lithic industry (use of microliths and drilling), where the high mobility and the utilization of exotic materials continued to be important. In effect, in Puripica this socio-cultural

Fig. 6. Quebrada Puripica view.

process culminates in the Late Archaic period (between ca. 5600 and 4500 cal. BP) with the domestication of camelids, more complex architecture associated with semi-sedentary adaptations, the utilization of local lithic material and the innovation and diversification of the lithic technology with the apparition of microliths and perforators, related to a more extended bead production. The appearance of rock art and long distance interactions are observed. Productive practices were intensified during this period based on subsistence strategy, including hunting and camelid domestication and grinding practices (high frequency of conic mortars) (Hesse, 1982; Núñez 1982; Grosjean et al., 1997a; Núñez et al., 2006).

Large campsites and the development of solid architecture formed by multiple agglutinated circular structures dated at approximately 5600–4500 cal BP appear in the Puripica sector. These settlements were contemporaneous with the Tulán ravine camps, and are associated with the first osteological evidence of camelid domestication in the context of complex hunting societies (Mengoni and Yacobaccio, 2006; Cartajena et al., 2007;Cartajena, 2013). These mid- to late Archaic events are associated with the use of restricted spaces at moderate altitudes (3000–2000 masl) in ravines, suitable for subsistence strategies based on hunting and camelid breeding rather than on horticultural activities (Núñez et al., 1999b).

Many of these sites were close to local raw material sources and near obsidian outcrops in the high Puna. However, groups not only move from these sites up into the highlands but also down to the adjacent coast, as the arid climate did not affect marine resources. It has, therefore, been suggested that during the Middle Holocene, the coastal population increased considerably as people moved from inland areas to coastal sites with freshwater springs and protected beaches (Nuñez and Santoro, 2011).

Thus, it is possible to affirm that the desert coastline was inhabited temporarily or permanently by groups of inland hunter-gatherers who seem to have lived from hunting and camelid raising and who increased their contact with the coast during arid climatic events (Núñez et al., 1999a; Grosjean et al., 2007). It is generally accepted that a combination of favourable environmental and cultural conditions led to increasing social complexity and the specialized exploitation of sites where natural resources were abundant (ecorefuges) (Núñez et al., 2010).

4. Conclusions

Based on of the evidence of Quebrada Puripica and Tulán, we propose a more differentiated view and a more comprehensive concept of the *silencio arqueológico*, the regional response of cultures in the Atacama Desert to prolonged mid-Holocene drought between 9000 and 4200 cal BP. People did not completely abandon this area, but moved to alternative, newly created habitats in wetlands in steep valleys (such as Quebrada Puripica and Quebrada Tulán), newly-formed wetlands in the flat bottom areas of former palaeolakes, or remained in places with large springs or regional river systems, where resources remained stable. Now, there is abundant evidence that sporadic human occupation persisted in ecological refuges throughout the Holocene, while widespread Early Archaic occupation of open palaeolake sites collapsed as a result of climatic stress and environmental change. This in turn led to a general mid-Holocene decrease and in some loci even to a gap of human occupation and, simultaneously, to a concentration of human activities in the few still favourable habitats, ecorefuges (Grosjean et al., 2005a).

The *silencio arqueológico* (Núñez and Santoro, 1988) is to be understood as a conceptual framework of adaptation and not as an absolute hiatus. It accounts for the complex environmental evolution of microhabitats and allows for continuing sporadic human occupation in particular sites of oases and ecological refuges, wherever resources were available or newly created, despite general climatic aridity stress. Thus, the concept of the *silencio arqueológico* as an environmentally driven adaptation applies best to the most arid area of the central Atacama and to the most vulnerable sites, where aridity thresholds for the persistence of hunting and gathering groups were exceeded (Grosjean et al., 2005a).

For instance, a shift towards more arid climatic conditions does not lead in all localities to environmental stress and shortage of resources; but instead can result in some places in locally quite favourable habitats, oases and ecological refuges, and thus bring about a distinct spatial pattern with favourable and hostile places as is observed today. It is important to understand ecological refuges or ecorefuge as sites that are not susceptible to climate change, i.e. where natural resources are not affected by climate change and remained available during general regionally dry climates.

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