POLLEN ANALYSIS OF PASTOS CHICOS: PALEOENVIRONMENTAL AND ARCHEOLOGICAL IMPLICATIONS DURING THE HOLOCENE IN THE DRY PUNA OF ARGENTINA

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Abstract

Historically, the models accounting the human colonization of the Puna were based on assumptions and broad generalizations about the environmental context in which human groups had developed. In this sense, the main objective of this paper is to characterize and precise the environmental scenario of the earliest human occupations in the Dry Puna of Argentina. For this purpose, we provide the results of the pollen analyses from different Early and Middle-Holocene profiles located in Pastos Chicos - Las Burras river basin (23° 40' S; 66° 25' W; 3890 m a.s.l.). The comparison with another sequence from the sedimentary profile located in Lapao ravine, Lapao 5 profile (23º 36' S, 66º 36' W; 3650 m a.s.l.), assists to understand the variability in the performance of the climate system in different temporal and spatial scales. These results show two paleoenvironmental moments: a) ~ 9300 - 7300 yr BP, a moist and stable period represented by a vegetation composed for grasses, and b) ~ 7300 - 6300 yr BP, a drier environment interrupted by a short-time events of moisture. The comparison with Lapao 5 sequence shows similar trends, although with some chronological discrepancies. More moisture events are recorded towards ~ 7700 yr BP; after this date and until the beginning of the Late Holocene, drier conditions were installed. Based on this information, the models proposed were evaluated and new hypothesis are generated about the subsistence patterns of hunter-gatherers who had inhabited the area during that period and then are evaluated with the presently known archaeological record.

Key words: *Pollen - Paleoenvironment - Hunter-gatherer groups - Holocene - Puna*

Many laws regulate variation, some few of which can be dimly seen...
Charles Darwin, The Origin of Species (1859)

INTRODUCTION

At present, the evidence of early human occupation in the Dry Puna comes mainly from caves and rockshelters, located in gorges and protected valleys, dating around 11,000 yr BP (Table 1).

Site	Radiocarbon Age BP	Calibrated Range one sigma BP(*)	Reference
Cueva Yavi	9.760 ± 160	11.061 - 11.348	Krapovickas 1987-88
Inca Cueva 4	10.620 ± 140	12.564 - 12.817	Aguerre *et al*. 1975
Huachichocana	10.200 ± 420	11.267 - 12.400	Fernández Distel 1986
Pintoscayoc 1	10.720 ± 150	12.409 - 12.451	Hernández Llosas 2000
Alero Cuevas	9.650 ± 100	11.005 - 11.025	López 2008
León Huasi 1	10.550 ± 300	12.044 - 12.843	Fernández Distel 1989
Hornillos 2	9.710 ± 270	10.650 - 11.407	Yacobaccio *et al*. 2009

Table 1. Earliest radiocarbon dates from archaeological sites for Early Holocene in the The Dry Puna Argentina. (*) Calib 5.01 INTCal 4.0.

Scholars from different theoretical frameworks (Human Ecology and Processual perspective, among others) tried to explain the diversity in use and function of the early archeological sites during the colonization of the region. In general terms, there are two tendencies:

- First, there are some authors who use the Optimal Foraging Theory. Within this group, two different hypotheses can be discriminated. One is the idea that during the Early Holocene hunter-gatherer groups developed a long-term strategy, in order to include as many potential ecological patches as possible, located at different altitudes (Yacobaccio 1990). From this perspective, the maximum diversity of archaeofaunas is expected (camelids and rodents; among others). The other idea, derived from Darwinian archeology, considers that the high consumption of small mammals could be understood as a "sub-optimal or bad adaptive responses", in terms of the investment and energetic ratio return (Muscio 1999).

- Second, another group of authors endorse the ecological model of land use proposed by Borrero (1994-1995) for the Patagonian region. This model consists of three stages employing biogeographical categories: Exploration - Colonization - Effective Occupation of the Space. The exploration is characterized as a stage in which small bands make casual headings to know the availability of the surrounding environment. The expected archeological record for this moment is sparse, spread out in the regional space. Colonization implies that several bands or groups settled in certain areas, which would generate an archeological concentration of evidences related to patches of available resources. The stage of effective occupation of the space assumes planning management of resources from residential sites to specific locations, according to the structure of available resources. This model has been used by Hernández Llosas (2000) to explain the archeological record of Pintoscayoc I site. She understands the temporal sub-segment dated in *ca*. 10,000 yr BP, where she explained some remains of rodents (mostly Chinchillidae and Caviidae), artiodactyls (mostly camelids), associated with lithic artifacts showing an expidiency technique of manufacture, as an exploration stage (Hernández Llosas 2000). On the other hand, Aschero (2000) from Inca Cueva 4 and Huachichocana III evidence argues that the use and exploitation of lithic raw materials, and functional complementation and re-use of sites, suggests some stability in the use of resources in certain areas for the Early Holocene. This evidence would be consistent with the expectations developed in the model proposed by Borrero (1994-1995) for the advanced stage of initial colonization (Aschero 2000). This does not mean that the area had not been explored earlier, but that the archaeological evidence we have today suggests that the early occupations of the Puna do not fit in an exploration phase, but in a colonization which implied the redundant use of more productive areas (Aschero 2011).

In this context, the incorporation of paleoenvironmental studies helps to evaluate the proposed models. The scarcity of systematic paleoenvironmental studies in the area has turned it difficult to understand the environmental scenario in which human groups developed the colonization of the Puna. In this way, this study contributes to the demystification of the Puna as an unattractive area for human occupation, and achieves a better understanding of the strategies developed by human groups within certain specific contexts. For this reason, this research fulfills the need to develop a broader database on the particular conditions of this environment.

In regard to the paleopalynological background in the Argentine Dry Puna, from evidence of El Aguilar (Markgraf 1985), Yavi (Lupo 1998) and Barro Negro (Fernández *et al*. 1991), three phases can be suggested, although with some chronological discrepancies: a) a cold and wet phase between 10,000 and 7500 yr BP, with a dominance of the Poaceae represented in a Herbaceaous steppe and b) a dry phase between 7500 and 4000 yr BP, with elements of the Shrub steppe (Asteraceae, Chenopodaceae, *Ephedra* sp., among others) and c) *circa* 4000 yr BP the present conditions were established.

Fortunately, in the last few years the number of paleoenvironmental studies, carried out from different lines of evidence (such as pollen, diatoms, sediment analysis, among others), has increased our knowledge about the variability of the impact of global climate changes in different spatial scales (Morales 2004, 2011; Morales and Schitteck 2008; Oxman 2010; Tchilinguirián 2009; Yacobaccio and Morales 2005). The goal of this paper is to continue with this way of research and advance in the study of the paleoenvironmental conditions that may have influenced the use of space during the Holocene by hunter-gatherer groups.

Within this framework, the pollen analysis can provide information about changes in the composition of the regional vegetation and even in some cases it is possible to define the conditions of humidity and temperature in which different species had developed. At the same time, the composition of the vegetation is a principal component in the conformation of environmental scenario, thus conditioning the behavior of a variety of living organisms. These studies contribute to the task of building an ecological framework in which different organisms interact with each other.

THE STUDY AREA

The study area is located in the Puna of Jujuy, which comprises the arid highlands of NW Argentina, between 22° and 24° S, and from 3000 to 4500 m a.s.l. (Figure 1). This area is defined as a highland desert biome, where several NE-SW oriented mountain ranges are observed. This biome includes an altitudinal variation of the "tolar" (shrub steppe) ubicated between 3600 - 3900 m a.s.l., "pajonal" communities (highland grasslands) ubicated between 4100 - 4700 m a.s.l. (Cabrera, 1976), mixed steppe (ecotone) between 3900 - 4100 m a.s.l., with patchy wetlands ("vegas") occurring in both of them (Borgnia *et al*. 2006). The Puna is characterized by high solar radiation due to its high altitude, wide daily thermal amplitude, marked seasonality of rainfall (but never more than 400 mm/year), and low atmospheric pressure. Primary productivity is mainly focused on stable hydrological systems such as primary basins, high valleys (Olivera 1997), and wetlands. Several permanent freshwater basins, salt lakes, pans and playas constitute the general hydrological net. A few rivers and several springs, irregularly distributed all over the landscape, are the main freshwater sources, which are a critical resource for human and ungulate populations. Summer precipitation in Northern Argentina is largely governed by the so-called South American Monsoon-like System (Garreaud *et al*. 2009). This system produces about 80% of the annual precipitation falling in the Andean highlands between December and February (Vuille and Keimig 2004). In turn, these conditions determine a heterogeneous distribution of plant and animal resources. Some patches defined as "nutrient concentration zones" (NCZ) (Yacobaccio 1994) contain the majority of the available regional biomass. The most important animal food sources for humans in the Puna included several medium-sized mammals, the vicuña (*Vicugna vicugna*) and the guanaco (*Lama guanicoe*); and some rodents, vizcachas (*Lagidium viscacia*) and chinchillas (*Chinchilla laniger*), and a cervid, the Taruca (*Hippocamelus antisensis*).

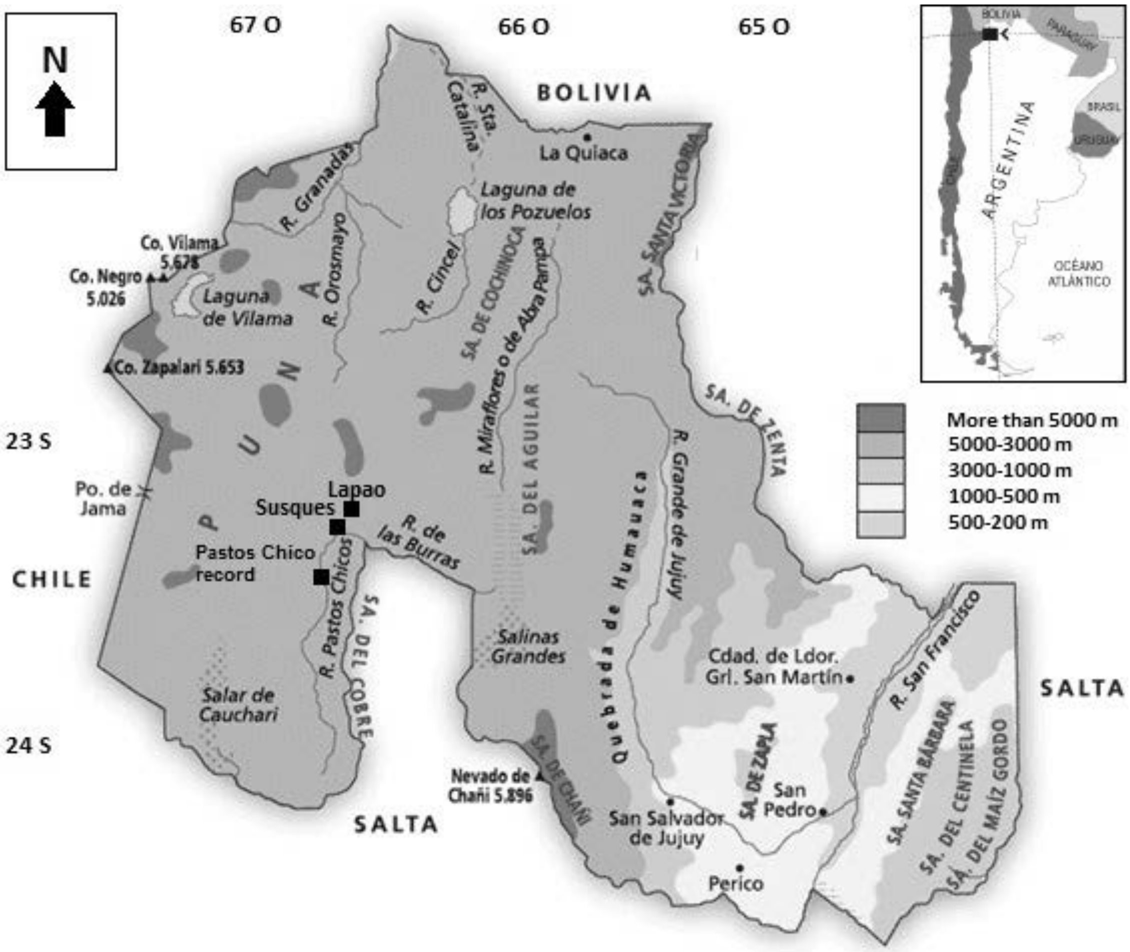

Figure 1: Location map of the Pastos Chicos River in the Jujuy Province, Argentina.

DESCRIPTION OF THE PROFILES

Fieldwork for this study has been conducted in the area of Pastos Chicos River, the main watercourse of a larger hydric system, called Pastos Chicos - Las Burras (Figure 2). The geomorphology report of the Pastos Chicos River (Tchilinguirian 2008) described the area as steady all over the year, although with significant variations in water volume due to rain falling in the upper basin. Pastos Chicos River catchment covers 988 km^2 and occupies a north-south oriented tertiary tectonic depression bounded on the west by the Taire mountain range (5120 to 4200 m a.s.l.) and the Los Cobres Mountains (4200 to 4500 m a.s.l.) in the East.

Detailed field studies of the Holocene deposits were performed on outcrops exposed over an area of more than 20 km through longitudinal Pastos Chicos river profile in order to indentify lithofacies and lithofacies associations. The Pastos Chicos valley has two different geomorphic sections along its North-South axes. The northern section is occupied by a Playa-lake system composed by very fine sediment, reddish sands and mud with parallel lamination, whereas in the middle section, the Pastos Chicos valley is excavated in Tertiary sedimentary and pyroclastic rocks. The profile selected for this investigation is located in this section. Into the Pastos Chicos River, three levels of fluvial terraces were developed on both sides of the river (TI, TII and TIII). In this opportunity, we only describe the Holocene deposits of the TI Alloformation II (Figures 2 and 3).

The geomorphologic description of the profile separates different deposition events based on the presence of erosive discontinuities. Terrace I is + 6 m above the current level of the river watercourse; sedimentary deposits are quaternary aged and they are called: "Alloformation Pastos Chicos II". This Alloformation is separated from others by means of higher level erosive discontinuities. Four sub-sedimentary units have been distinguished within the Alloformation Pastos Chicos II, separated by erosive discontinuities of minor importance called Unit A, B, C, D and E. Further, within each Unit there are different types of sediments and sedimentary structures that can be grouped into sedimentary lithofacies. Several distinctive lithofacies were defined in terms of relative scales of strata thickness and internal structures, generally allowing gathering information regarding depositional form and process in relatively small scales (Bridge 1993; Tchilinguirian 2008).

Twenty-eight samples from two different profiles of Pastos Chicos record were taken for geological, pollen and diatoms analyses and only half of them were processed (distributed along the whole profile) in this first stage of the investigation for the pollen analysis.

Figure 2. Geomorphology of Pastos Chicos River Valley. 1: Terrace level with outcrops of Quaternary age 2: Terrace lower level, 3: Permanent River channel (Tchilinguirian 2008).

For chronological purposes three samples were selected for dating. The bulk organic matter of two of these samples -PCH2-M2 and PCH1-M3- were dated to 7900 ± 100 and 8900 ± 130 yr BP using conventional 14C, respectively. Another age of 6935 ± 69 yr BP was obtained from a bird bone (PCH2-M15). Based on These dates and the strong stratigraphic correlation, between profiles, a linear interpolation age-depth model (Bennett 1994) was created to estimate the relative age of each analyzed sample (Table 2) (Oxman 2010). This model have been applied -assuming a constant sedimentation rate between dates- due to the similarities observed in sedimentary accumulation and in pollen counts in the chronological packages (11.49 yr/cm between both peat dates, and 6.34 yr/cm between the 7900 ± 100 peat sample and the 6935 ± 69 date of the bone sample) of this sequence (unit A). The chronology of the samples placed in units B and C have been considered as post 4200 yr BP due to the stratigraphic correlation with other dated sequences in the locality (Tchilinguirian *et al.* 2012).

MATERIALS AND METHODS

As mentioned above, this paper uses pollen analysis as proxy data to infer particular types of vegetation and, indirectly, the climatic conditions (temperature and relative humidity) under which plant communities developed. This kind of paleoenvironmental information is complementary with other lines of evidence, such as the studies of sediments, fluvial geomorphology and analysis of diatoms, which also allow inferring moisture conditions, though on a more restricted scale (Dincauze 2000).

The fossil samples were processed according to the Standard Protocol for Quaternary Pollen (Faegri and Iversen 1989). The laboratory stage consisted in the observation of the samples under Zeiss-Axiolab biological microscope and due to low pollen concentration in general of all samples, at least 200 grains per sample were counted. The quantification and statistical treatment of the species described were performed using TILIA software (Grimm 1987, 2004). The identification of pollen types was carried out using the existing Atlas (Heusser 1971; Markgraf and D' Antoni 1978) and the pollen reference catalog of the Palynology laboratory of the Facultad de Ciencias Agrarias UNJu/Conicet (Lupo 1998).

RESULTS

Of the 14 extracted samples for pollen analysis, four of them were sterile and 10 were fertile and could be subjected to pollen analysis. The identification of pollen grains usually was performed at the family level, except in cases in which it was possible to reach a greater degree of precision allowing identification to a genera level. In this case has been identified: one genus (Pteridophyta), six families (Poaceae, Asteraceae, Fabaceae, Chenopodiaceae, Solanaceae and Mimosaceae) and two species (*Carex* sp. and *Ephedra* sp.).

In general terms, Poaceae family dominates most of the pollen samples, followed by Asteraceae. The other taxa are significantly less frequent. The only exception is a sample around 6300 yr BP (M16) where Pteridophyta spores are highly abundant.

Based on the changes in the relative frequency of pollen types, two major environmental phases were identified. The first part of the record, between ~ 9200 and 7300 yr BP shows a clear evidence of a moist environment - possibly a paleowetland- with clear dominance of herbaceous species (Poaceae). In ~ 7300 yr BP (M10) an important change in the pollen spectra composition was detected. This change was represented by an increase in the diversity of pollen types. However, the Poaceae family still dominates over other taxa. Towards ~ 7300 yr BP (M10), the sequence showed a gradual and steady increase in the frequency and diversity of the regional vegetation represented by shrub steppe species represented by Asteraceae, Chenopodiaceae, Fabeaceae, Solanaceae and Verbenaceae over the local vegetation which is represented by moist condition indicators such as fern spores and grasses (Poaceae). Around 6300 yr BP (M16), the pollen spectra change in the composition species with a marked presence of the herbaceous steppe mainly composed by Asteraceae, *Ephedra* sp., Mymosaceae plus Poaceae and Pteridophyta spores. This composition that had not been previously recorded, is interpreted as an increase in local moisture conditions within a shrub steppe context. Post 4200 is the only case in which the Asteraceae dominate the composition of the sample, which represents a more arid environment than previously presented (Figure 4).

Sample	Depth	Chronology	Sample analyzed
PCH2 M20	402		X
PCH2 M19	362		
PCH2 M18	331	Post 4200	X
PCH2 M17 Bis	311		
PCH2 M17	308		
PCH2 M16	280	6319	X
PCH2 M15	270	**6935 ± 69**	
PCH2 M14	260	6998	X
PCH2 M13	250	7062	
PCH2 M12	240	7125	X
PCH2 M11	230	7189	
PCH2 M10	220	7252	X
PCH2 M9	210	7316	
PCH2 M8	200	7379	X
PCH2 M7	190	7443	
PCH2 M6	180	7506	X
PCH2 M5	170	7570	
PCH2 M4	168	7583	X
PCH2 M3	142	7748	
PCH2 M2	118	**7900 ± 100**	X
PCH1 M8	118	7900	
PCH1 M7	108	8015	X
PCH1 M6	91	8210	
PCH1 M5	63	8532	X
PCH1 M4	33	8877	
PCH1 M3	31	**8900 ± 130**	X
PCH1 M2	20	9130	
PCH1 M1	0	9256	X

Table 2. Ages and radiocarbon dates (those with 1σ) of the model and samples analyzed.

In sum, the interpretation of the pollen analysis indicated two different paleoenvironmental moments: a) the first one, between ~ 9200 yr BP and 7300 yr BP (PCH1-M1 to PCH2-M8), shows dominance of a herbaceous steppe, this could indicate colder and moister conditions, which might have produced by a down-slope displacement of the herbaceous steppe vegetation towards a shrub steppe landscape that currently dominates; b) the second phase, after ~ 7300 yr BP and post 4200 yr BP (M10 to M18), shows a subtle increasing diversity in the composition around 7300 yr BP (M10) and a subsequent increase in the abundance of the elements related to the shrub steppe; suggesting a gradual settlement of a dry landscape.

EVIDENCE FROM OTHER PROXY DATA

Complementation with other lines of evidence on the same samples assists in specifying our paleoenvironmental interpretations (Dincauze 2000). Following these criteria, the diatom, geological and sediment analysis have been included in this analysis (Morales 2004, 2011; Tchilinguirián 2008, 2009).

In general terms, the geological analysis indicate that at the base of the Holocene deposits, the presence of an extended thick alluvial organic-fine sediment (units A, Figure 4) outcrops on the border of the valley. This is a prominent unit feature of the stratigraphic scheme, representing an important Early to Middle Holocene low energy fluvial system with organic paleowetlands, oxbow lakes and backswamp muds (Tchilinguirian *et al*. 2009).

In Pastos Chicos I profile, the base of unit A is overlaid by tertiary limestones, whereas the upper contact with unit B is a channel scoured. The lowermost unit A is up to 1 to 3 m thick over hundred meters long an outcrop and is dominated by greyish green colors. The lower section of the sequence (subunit A1) consists of a horizontally bedding, pale green medium and massive sand of the river channel. Unit A2 consists of fine laminated, hard, black, organic layers interbedded with thin light gray laminated diatomaceous silt. The organic material contains uncharred, well-preserved plant epidermis and vascular plant bundles of 1 to 2 mm length. These organic layers represent backswamps with organic soils development. Unit A3 is composed of massive, grey light, very fine sand and diatomaceous silt interbedded with laminated dark grey medium organic sand. The subunit A4 (2 m) is characterized by fine laminated, green mud and clays interbedded with thin (2 cm) layers of massive and white diatomite. No organic matter found, and thus remains undated.

Unit B is composed of channel facies in the lower section (subunit B1), overbank facies in the middle section (subunit B2) and carbonate pond deposits of facies, located in the uppermost section of the sequence (subunit B3).

The diatom's assemblages in Pastos Chicos record (Morales 2004, 2011) suggest two paleoenvironmental moments. The first one, between ~ 9200 and 7300 yr BP could be interpreted as a moist and relatively stable environment. This moment would resemble a wetland with broad vegetated littoral areas presenting extensive littoral forms of the Fragilariaceae group -usually a species with broad tolerance to salinity fluctuations- interrupted by one drier pulse around 8000 yr BP, as evidenced by the negative anomalies in the moisture index. The conditions inferred from diatom analysis are coincident with those suggested by the geomorphologic analysis, which suggests a floodplain environment that is moist during most part of the year and with development of paleo-soils. The second moment, between ~ 7300 and 6000 yr BP, suggests a wetland environment which is much drier and more salty due to the arid conditions, but episodically interrupted by some moister pulses. From ~ 7300 to 6000 yr BP drier conditions have prevailed, characterizing the second environmental moment. At least two events with moister conditions were detected under these dry conditions, the first one at ~ 7000 yr BP and the second at ~ 6300 yr BP. It is also detectable the presence in this particular alofacie dry conditions - probably the drier moment in the studied sequence- between ~ 7500 and 7000 yr BP, as suggested by the rise in aerophilic diatoms and the values of the salinity index obtained from diatom's ecological affinities (Morales 2004, 2011).

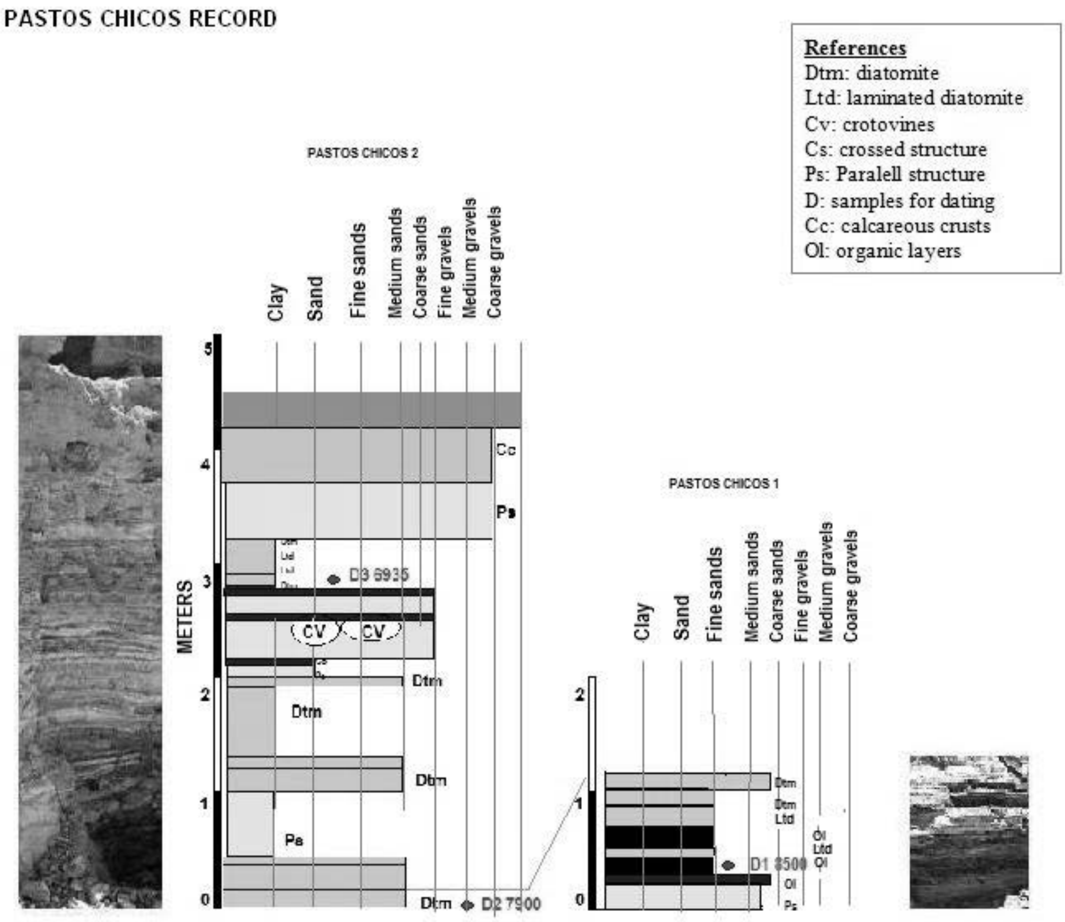

Figure 3. Photographs and drawings of PCh1 and PCh2 profiles (modified from Morales 2011).

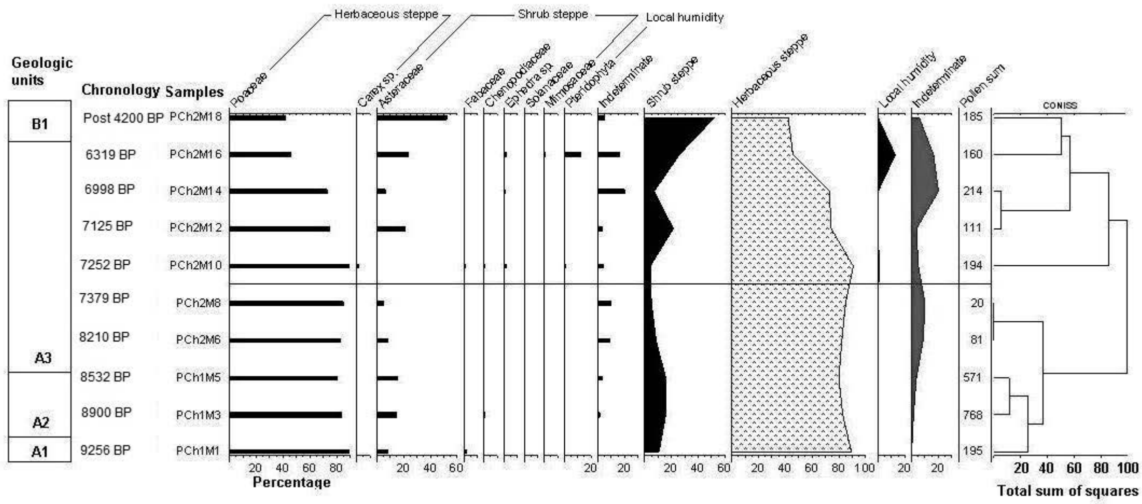

Figure 4. Pollen diagram from Pastos Chicos record.

The comparison of Pastos Chicos record with one of his tributaries, Lapao 5 (L5) (Tchilinguirian *et al.* in this volume), allows the generation of some hypotheses about the response of different catchment environments to the global environmental changes. In the case of L5 the information generated by pollen analysis, indicates an extent of the highland grasslands (Poaceae) between ~ 9000 and 7770 yr BP, which would evidence wetter conditions than today. This was followed by the formation of a mixed steppe (ecotone) and drier conditions than the ones that were present in the previous period, similar to the present. In regard to the diatoms analysis, three paleoenvironmental zones were identified: 1) Between ~ 9300 and 8900 yr BP, characterized by the presence of wetland with broad vegetated littoral areas represented by the high frequencies of Littoral species with a minor percentages of the benthic species; 2) Between ~ 8900 and 7770 yr BP, installed wetter conditions than the previous period, although some variations. Between ~ 8500 and 8100 yr BP the peak of moisture throughout the profile is registered, and is characterized by the development of a palustre system, interrupted by a considerably drier moment around 8400 yr BP; and 3) between ~ 7700 and 7400 yr BP again are installed drier conditions than the previous period, represented by the dominance of species of benthic and epiphyte that indicate the conditions of the wetland, that remained until 7400 yr BP (Oxman 2010).

The result of the study of these cases (PCH and L5) show that the paleoenvironmental conditions between ~ 9300 and 7700/7300 yr BP would have been more stable and moister than the current conditions. Meanwhile, during the period ranging from ~ 8000/7300 to 6300 and post 4200 yr BP, the conditions were drier and more unstable, though with punctual moisture episodes, which can be described as a wetland considerably drier than the one of the previous period.

On the other hand, when we compare the sites, two different situations emerge. First, the Pastos Chicos record shows that the changes seem to initiate before and disappear afterwards in the extended area systems, while presenting higher stability in the long term. We think that this could be due to the geomorphological control of the broad moisture catchments area (~ 1000 km^2) that generates an average signal of the tributaries, reflecting mostly a signal of regional scale. Second, in the case of L5, the system responds to short-term changes with particular intensity, as the small area basins (~ 17 km^2) tend to reflect the changes locally produced with higher intensity (Tchilinguirian 2009; Tchilinguirian *et al.* 2009).

This information agree with the model proposed by Morales (2011), which points out that during the period ranging from 10,000 to 8000 yr BP, resources would have become abundant in most sectors of the dry Puna, with the exception of those areas above 4000 m a.s.l. to the West of the Pastos Chicos river basin, to the West of Olaroz - Cauchari basin, Rosario de Susques river high basin and around Laguna Vilama. On the contrary, the area located north of Guayatayoc lagoon, would gather most of the Dry Puna resources. Though more abundant during the period from 10,000 to 9000 yr BP, wherein the NCZ (Yacobaccio 1994) would be much more frequent and concentrated in basins without snowmelt water input, with different catchments than during the next period. From 9000 to 8000 yr BP it was possible for the minor catchments basins to have presented water deficit events and for NCZ to become more frequently available in basins with snowmelt water input of elevations higher than 4000 m a.s.l. Those areas located above 5000 m a.s.l. would have been covered by snow during most part of the year, so they would not have involved an important supply of resources (Morales 2011).

CONCLUDING REMARKS

Regarding the regional archeological record from the Early and Middle Holocene, some patterns may be delineated in order to evaluate the different models proposed for explaining the first occupations of the Dry Puna Argentina (Aschero 2000; Grosjean 1994; Olivera 1997; Yacobaccio 1991, among others).

During the Early Holocene has been recorded a more humid environment, less fragmented and more stable than nowadays, whereas the Middle Holocene had regional drier conditions (in these cases after 8000/7000 yr BP), more fragmentation of the environment with restricted loci of productive patches which were the focus of main amount of resources (Fernández *et al.* 1991; Lupo 1998; Markgraf 1985; Yacobaccio and Morales 2005, among others).

Regarding to the Early Holocene, the archaeological record shows:

- Strategic site location, near water sources, firewood and animal resources.
- Most part of the sites are located in caves or rocksheltters, in gorges covered from the wind, near water resources and generally in ecotone sectors.
- Resources are used with relation to their local abundance (according to the reference site); zooarcheological remains differ from site to site following the specific availability of local resources.
- Some variability is also observed in the use of wild plants, such as tubers, tuberous roots, grasses, etc either for feeding purposes or for technological use.
- Lithic raw materials are generally local, the projectile points are triangular, and the artifacts show a low to medium energy investment.

In contrast, the Middle Holocene archaeological record shows:

- An increase in the relative abundance of camelids in most of the sites, and a decrease in the other animal resources.
- The lithic technology shows an increase of the morphological types of projectile points, which more

diversity than in the earlier period (new forms appear, like lanceolate or stemmed). There is also a greater diversity of other artifact types such as milling stones. There is also an increase in the use of obsidians from the Zapaleri/Laguna Blanca source.

Based on the paleoenvironmental data generated, the archeological evidences compiled and the available information referring to mobility and subsistence strategies by hunter-gatherer groups (Bettinger 1987; Binford 1980, 2001; Bousman 1993; Kelly 1995), now we can return to the discussion of the models proposed in order to explain the first occupations of the Dry Puna.

We argue that the extension of the high grasses (Herbaceous steppe) to lower elevation, controlled by humidity, was the result of the increase in precipitation (Betancourt *et al*. 2000). Consequently, the increase of the environmental primary yield would have allowed a higher amount of animal biomass. Related to this, the distance between patches would have diminished, which in turn would have provided hunter-gatherer groups with a higher energetic supply of resources in shorter distances. Also, it has been observed climatic changes impacts on the environment in different spatial and temporal scales, leading to variability, sometimes shortages, in resources supply. In this sense, it is also expected some variability in the management of animal and plant resources, whose availability depends on environmental and climatic factors (rainfall patterns, humidity and temperature; among others). A high mobility is the strategy for obtaining resources from different ecological patches. For this reason, we interpreted that the consumption of small mammals, for example, should not be seen as bad adaptive responses (as argued from Optimal Foraging Theory), but as short-term responses in a stage of recognition of the dynamics of the environment, in which better environmental conditions allowed the opportunistic strategy of obtaining local resources, thus explaining the high variability observed in the abundance of animal resources in different sites. These short-term responses would be the beginning of the designing of the long-term responses, the planned circuit and the typical Andean complementation of the resources from different altitude levels (proposed by Yacobaccio 2010).

In relation to the model proposed by Borrero (1994/1995), and used by Hernández Llosas (2000) and Aschero (2000), we argue that the characteristics of the archaeological record of the Argentine Puna make difficult, not only to recognize, but also to accept the idea of an “exploration stage” (Aschero 2011), which is contradicted on environmental and archeological grounds. In short, the evidence indicates the presence of hunter-gatherer groups with high residential mobility. The great productivity of many vegetation patches allowed an opportunistic exploitation of animal resources (Binford 1980). For that reason, we propose to use the concepts of “Dispersal” in order to denote the spreading out of individuals or groups which filled up the available vacant habitat, and the term “Colonization” as to the major extension of a population habitat or range that includes an established occupation of areas previously unoccupied or occupied (Dillehay 2000; Yacobaccio 2010). Thus, although we can hardly find evidence of this initial dispersion, we may assume that some knowledge in the management of resources is the result of previous experiences developed in the area. The record indicates some degree of knowledge and transmission of information on the management of environmental resources, a process that exceeds the capacity of a single generation (Meltzer 2002). For this reason, we interpret that the earliest known archaeological record in the Argentine Puna as befits a time of colonization.

Based on the conclusions derived from paleoenvironmental data and the knowledge of how different environments respond to broader climate change, we may derive some new hypotheses. On a broader scale, we can consider altitudinal divisions, which have a range of differential production areas. Regarding the altitude, three geo-environments could be ranked: valleys and ravines, pre-Puna and highlands or Altiplano. With these parameters established, we propose an initial period of dispersion of people, which could be moving either from the South Bolivian lowlands or the valleys and ravines, into a vertical direction to the other environments. These new areas would result from an extension of the circuitry of mobility, which included also the Puna of Chile. Each region collects various ecological attributes that might influence hunter-gatherer settlement patterns and decisions concerning hunting (Muscio 1999; Oxman 2010). The higher areas (above 4000 masl) were available for human occupation later in time than the lower ones (between 3800 and 3200 m a.s.l) (Morales and Schitteck 2008). However, the evaluation of paleoenvironmental and archaeological evidence reveal that when the highest areas were available they were rapidly occupied. This also reveals to us that those areas were unfit for long-term human´s occupation, but were known and visited by hunter-gatherer groups, as seen from the obsidian distribution, because this raw material ´s source is located in the high Altiplano area.

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