

Camelid domestication on the western slope of the Puna de Atacama, northern Chile

Isabel CARTAJENA

Departamento de Antropología
Universidad de Chile
Ignacio Carrera Pinto 1045, CL-Santiago Chile (Chili)
icartaje@uchile.cl

Lautaro NÚÑEZ

Instituto de Investigaciones Arqueológicas y Museo R.P. Gustavo Le Paige
Universidad Católica del Norte
Le Paige s/n, CL-San Pedro de Atacama Chile (Chili)
lautanunez@netline.cl

Martin GROSJEAN

Nacional Center of Excellence in Research on Climate (NCCR) and Institute of Geography
University of Bern
Erlachstrasse 9a, CH-Bern 3012 (Switzerland)
grosjean@giub.unibe.ch

Cartajena I., Núñez L. & Grosjean M. 2007. – Camelid domestication on the western slope of the Puna de Atacama, northern Chile. *Anthropozoologica* 42 (2): 155-173.

ABSTRACT

Archaeofaunal records from the Early Archaic to the Early Formative sites (11000-2400 BP) on the western slope of the Puna de Atacama region (22°S-24°S) were analysed in order to understand the process of camelid domestication. The remains were recovered from rock shelters and open sites reflecting an extended occupational sequence, starting with the first human occupations in the Early Archaic (11000-8000). During the Late Archaic (5000-3800 BP), the mobile hunting/gathering tradition had changed into a cultural system characterised by large campsites, hunting activities being present along with the first evidence of camelid domestication in favourable mid-Holocene sites (Quebrada Tulán and Puripica), which evolved during the Early Formative to complex camelid husbandry-based societies about 3100 BP. Although osteometrical evidence is mainly used, we incorporate pathologies, palaeoenvironmental information, the material culture and the archaeological context. Our intent is to identify the environmental scenario and the importance of environmental variables in desert areas, as well as to understand the emergence of camelid domestication in relation to

KEY WORDS

Puna de Atacama,
South-American camelids,
domestication,
Late Archaic,
Early Formative.

subsistence, transport and sources for raw material, and also, the continuity of camelid hunting activities during the Early Formative. The results sustain the hypothesis of domestication taking place around Puna independent from the Central Andes in a context of complex archaic societies which consolidate during the Early Formative.

RÉSUMÉ

La domestication des camélidés sur le versant occidental de la Puna de Atacama, Chili du Nord.

Les restes fauniques de sites de l'Archaïque Ancien au Formatif Ancien (11000-2400 BP) du versant occidental de la Puna de Atacama (22°S-24°S) ont été analysés afin de comprendre le processus de domestication des camélidés. Les restes proviennent d'abris-sous-roche et de sites de plein air reflétant une longue séquence d'occupation, depuis les premières occupations humaines de l'Archaïque Ancien (11000-8000). Pendant l'Archaïque récent (5000-3800 BP), la traditionnelle chasse/cueillette itinérante s'est transformée en un système culturel caractérisé par de grands sites de plein air, des activités de chasse perdurantes avec, simultanément, la première mise en évidence de la domestication de camélidés dans des sites holocènes (Quebrada Tulán et Puripica). Ces sites ont évolué pendant le Formatif Ancien vers des sociétés pratiquant un système d'élevage complexe des camélidés, aux environs de 3100 BP. Notre étude exploite essentiellement les données de l'ostéométrie, mais également celles de la paléopathologie, du paléo-environnement, de la culture matérielle et du contexte archéologique. Notre intention a été, d'une part, de mettre en évidence le « scénario » environnemental et l'importance des variables environnementales dans des zones désertiques, d'autre part de comprendre l'émergence de la domestication des camélidés en relation avec la subsistance, le transport et les sources de matières premières, et enfin de saisir la continuité des activités de chasse des camélidés pendant le Formatif Ancien. Les résultats soutiennent l'hypothèse d'une domestication dans la Puna chilienne indépendante de celle des Andes centrales, dans un contexte de sociétés archaïques complexes qui se consolident pendant le Formatif Ancien.

MOTS CLÉS

Puna de Atacama,
camélidés sud-américains,
domestication,
Archaïque Ancien,
Formatif Ancien.

RESUMEN

Domesticación de camélidos en la vertiente occidental de la Puna de Atacama, norte de Chile.

Registros arqueofaunísticos de sitios comprendidos entre el Arcaico Temprano hasta el Formativo Temprano (11,000-2400 AP) de la vertiente occidental de la región de la Puna de Atacama (22°S-24°S) fueron analizados con el fin de entender el proceso de domesticación de los camélidos. Los restos fueron recuperados tanto de abrigos bajo roca como de sitios a cielo abierto que reflejaron una extendida secuencia de ocupación, comenzando con las primeras ocupaciones humanas en el Arcaico Temprano (11,000-8000 AP). Durante el Arcaico Tardío (5000-3800 AP), la tradición de caza y recolección móvil cambió hacia un sistema cultural caracterizado por grandes campamentos y actividades de caza junto a las primeras evidencias de domesticación de camélidos en hábitats favorables del Holoceno Medio (Quebrada Tulán y Puripica), evolucionando hacia sociedades basadas en un complejo manejo de los camélidos durante el Formativo Temprano alrededor de 3100 AP. Aunque principalmente se emplea evidencia osteométrica, también incorporamos datos de patologías, información paleoambiental,

PALABRAS CLAVE
 Puna de Atacama,
 camélidos sudamericanos,
 domesticación,
 Arcaico Tardío,
 Formativo Temprano.

cultura material y contexto arqueológico. Por una parte, buscamos identificar el escenario ambiental y la importancia de las variables ambientales en áreas desérticas. Por otro lado, entender la emergencia de la domesticación de camélidos para la subsistencia, transporte y fuente de materias primas, pero también la continuidad de las actividades de caza durante el Formativo Temprano. Los resultados apuntalan la hipótesis de un centro de domesticación circumpuneño independiente al de los Andes Centrales dentro de un contexto de sociedades arcaicas complejas, las cuales se consolidan durante el Formativo Temprano.

INTRODUCTION

A summary on camelid domestication evidences from the western slope of the Puna de Atacama is presented. The results form part of a multidisciplinary research aimed towards the understanding of the transition between Late Archaic (*ca.* 5.000-3.800 BP) and Early Formative societies (*ca.* 3.100-2.400 BP), characterised by camelid domestication and the beginning of livestock husbandry, among others (Núñez *et al.* 2006a). One part of the project was a research on Quebrada Tulán. Together with previous work, it allows an approach to the problem over a long chronological sequence that starts from the first human occupations in the highlands around 11.000 BP (Núñez *et al.* 2001, 2002; Grosjean *et al.* 2005a). Results obtained through palaeoclimatic reconstructions have remarkable significance since they have provided a sequence from Late Pleistocene to Late Holocene giving a powerful insight to palaeoclimatic changes and its cultural responses (Grosjean *et al.* 1997, 2001, 2005b).

First studies were made as part of a research aiming to document the domestication process in the Puna de Atacama at the end of the 70's (Hesse & Hesse 1979; Núñez 1981; Hesse 1982a, 1982b, 1986) where local camelid domestication during the Late Archaic was suggested (Hesse 1982a: 210). Further studies in the Atacama Basin and Middle Loa river have supported this hypothesis (Cartajena 1995a, 1995b, 2003, 2005; Yacobaccio 2003). Most recently, Mengoni and Yacobaccio (2006) have summar-

ized part of these studies. They present a view of camelid domestication in the South Central Andes and a state-of-art of zooarchaeological research in the Circumpuna compared with the Central Andes area (*ibid.*).

This work emphasises on evidence recovered from excavations of archaeological sites located on the western slope of the Puna de Atacama. These allow a clear definition on settlement nature, palaeoenvironmental conditions and contextual intra and inter relationships. In fact, Archaic sites under study belong to the same cultural tradition called Puripica-Tulán (Núñez 1992) in which some of the cultural indicators transfer to the Early Formative phase, entailed to the emergence of pottery, metalwork and ceremonial architecture, among others (Núñez *et al.* 2006a).

Zooarchaeological analysis emphasises on osteometry, age profiles, osteopathologies, fiber analysis and taxonomic diversity. All these indicators are traditionally used to identify domesticated forms. Especially relevant are palaeoenvironmental data, which allow to build up a scenario in which this process could have developed. Of major importance are contextual pieces of information, particularly those referring to the presence of rock art and possible pens.

ARCHAEOLOGICAL SITES

The geographic area in which archaeological sites are located corresponds to the western slope of the Puna de Atacama (22°-24°S), in an altitude



FIG. 1. — Studied Area. Designer: Patricio López.

gradient of intermediate ravines between the highlands and the oasis piedmont (*ca.* 2.500 to 3.600 m above sea level).

The sites are placed in Quebrada Puripica -30 km northwest of San Pedro de Atacama- and Quebrada Tulán situated on the southeastern border of the Salar de Atacama (Fig. 1). The assemblage studied here come from the sites of Tambillo-1 from the Early Archaic (*ca.* 11.000-8.000 BP), from Puripica-1 and from Tulán-52 from the Late Archaic (*ca.* 5.000-3.800 BP); and Tulán-54-55-85-94-109-122 from the Early Formative Period (*ca.* 3.100-2.400 BP) (Table 1).

The Early Archaic corresponds to the transition between the Late Pleistocene (Late-Glacial) and the Early Holocene coincident with first human occupations in the Puna de Atacama. Palaeoenvironmental data show that this period is characterized by a humid phase with an

increase in summer rains and higher water level in lakes; nevertheless these levels show rapid decreases around 8.100 ^{14}C yr BP announcing the start of the arid stage (Núñez *et al.* 2002). High level of mobility is observed in the human groups as denoted by the location of settlements in low lands, intermediate altitudes and in the highlands. However, at the end of this period a higher population density is observed at Tambillo-1, located at the edge of the Salar de Atacama, characterized by circular structures nucleated around a fireplace (Núñez 1983).

The Late Archaic Puripica-Tulán tradition is characterised by large campsites, the development of solid architecture formed by multiple agglutinated circular structures, a diversification and innovative lithic industry with microliths and perforators, more sedentary populations compared to the Early Archaic, the appearance of rock art, long distance interactions and a subsistence strategy both including hunting and camelid domestication. All this suggests the development of an increasing sociocultural complexity (Núñez 1992; Grosjean *et al.* 2005b).

The Early Formative is characterized by the emergence of large settlements with a complex and planned ritual architecture along with the intensification and expansion of productive practices, an emphasis on ritual expressions, the appearance of new technologies such as pottery, and the presence of numerous settlements in Quebrada Tulán denoting sedentary populations. This occurs in a time span between 3.080 and 2.380 BP (Núñez *et al.* 2006a).

Archaeological collections from sites Tambillo-1, Puripica-1, Tulán-52 and Tulán-54 had been previously studied by Hesse & Hesse (1979), whose results are found in an unpublished preliminary report and in Hesse (1982a, 1982b y 1984). Later, Yacobaccio (2003) and Cartajena (2003, *et al.* 2003) also developed osteometric studies. In the present work these collections are re-evaluated and new results from Quebrada Tulán, obtained during 2002-2005 are incorporated (Núñez *et al.* 2006a) (Table 2).

TABLE 1. – Studied sites.

Site	Location	Period	Dates	Description	References
Tambillo-1	Eastern border of the Salar de Atacama 27 km south from San Pedro de Atacama (2.300 m. a.s.l.)	Early Archaic	8.870±70 BP 8.590±130 BP	Open campsite with circular semi-subterranean structures	Núñez <i>et al.</i> 2002
Puripica-1	Higher border of Quebrada Puripica, 30 km northeast of San Pedro de Atacama (3.500 m. a. s. l.)	Late Archaic	4.050±95 BP 4.815±70 BP	Formed by multiple agglutinated circular structures.	Núñez <i>et al.</i> 1999
Tulán-52	Southern border of Quebrada Tulán (3.000 m. a. s. l.)	Late Archaic	3.860±60 BP 4.580±90 BP	Agglutinated circular and subcircular structures built with vertical blocks.	Núñez <i>et al.</i> 2006a
Tulán-94	Southern border of Quebrada Tulán (2.620 m. a. s. l.)	Transitional (Archaic to Formative)	3.400±40 BP 3.110±60 BP	Formed by two clusters of circular and subcircular structures, with a total of 19. early pottery was recovered.	Núñez <i>et al.</i> 2006a
Tulán-54	Located on the southern border of Quebrada Tulán, 300 m west of Tulán-52. (3.000 m. a. s.l.)	Early Formative	2.380±70 BP 3.080±70 BP	Central semi-subterranean temple structure delimited by a perimetral wall built with big vertical blocks, that also form internal structures. Twenty four human newbornburials with their offerings were found in pits at the beginning of occupation. The temple is surrounded by possibly dwelling structures. The site has been completely covered by stratified deposits.	Núñez <i>et al.</i> 2005, 2006a
Tulán-122	Located on the southern border of Quebrada Tulán, (2.680 m. a. s. l.)	Early Formative	2.740±40 BP	Agglutinated and isolated clusters of structures, built mainly from vertical flat rocks, that form a total of 153 structures.	Núñez <i>et al.</i> 2006a
Tulán-85	Located near to the lowland vega on the Salar de Atacama border (2.318 m. a. s. l.)	Early Formative	3.140±70 BP 2.660±80 BP	Extended monticular stratified deposit, associated to human newborn burials and structures.	Núñez 1992
Tulán-109	Located on the northern border of Quebrada Tulán (3.000 m. a. s. l.)	Early Formative	3.140±80 BP 2.410±70 BP	Small rock shelter associated to rock art and offerings.	Núñez <i>et al.</i> 2006a
Tulán-55	Located on the southern border of Quebrada Tulán (2.680 m. a. s. l.)	Early Formative	3.010±40 BP 2.700±100 BP	Cave associated with rock art.	Núñez <i>et al.</i> 2006a

TABLE 2. — Identified camelid bones per site (NISP and MNE). Diaphysis fragments, splints and minimal bones are not included.

Period	Site	NISP	MNE
Early Archaic	Tambillo-1	1048	456
Late Archaic	Tulán-52	7874	3989
	Puripica-1**	3426	—
Early Formative	Tulán-54	3921	2169
	Tulán-55	116	69
	Tulán-85	595	503
	Tulán-109	166	132
	Tulán-122	93	85

** Source: Hesse (1982a: Table 2)

OSTEOMETRY

The methodology used in this study aims to characterise faunal assemblages according to osteometric criteria seeking for the best possible taxonomic determination of remains, especially between both wild species (*Lama guanicoe* y *Vicugna vicugna*), which have big differences in size with no overlapping measurements (Wing 1972, Kent 1986, Elkin *et al.* 1991, Cartajena 2003). On the other hand, there are only few morphological differences being one of them the incisors of the vicuña (Wheeler 1984). Zooarchaeological and genetic evidence suggest that wild camelid species belong to two different genera (*Lama* and *Vicugna*), where the llama descended from the guanaco while the alpaca from the vicuña (Wheeler 1995, Kadwell & Wheeler 2001).

Osteometric techniques applied to current camelids have been matter of debate since the beginnings of last century (Herre 1952: 75). Nevertheless, problems on taxonomic assignation through osteologic measurements persist due to the lack of significant size differences between domestic and wild animals (*Lama glama/Lama guanicoe* and *Lama pacos/Vicugna vicugna*). However, multivariate statistical methods had easily lead to a separation between big and small size camelid groups (Wheeler 1991: 37),

although there are difficulties inside each group (Kent 1986) demanding more sophisticated statistical techniques (Izeta & Cortés 2006). Along with this, in the application of models based on modern species dimensions, the large period of selection and change is being ignored, and cannot be recognized through current standards (Moore 1989: 317). Finally, there are wide intersection areas due to intraspecific variability; in some cases subspecies have been defined with important size differences which get confused interspecifically (Novoa & Wheeler 1984: 121, Elkin *et al.* 1991: 5). In the case of the Northwest of Argentina, llama is the biggest morphotype; vicuña the smallest and guanaco would be in an intermediate range (Yacobaccio *et al.* 1994: 28). In addition, founder herds should only be detected in the faunal record if they are separated spatially from the wild population since this would bring about shifts in selection pressures, reflected in skeletal size and/or morphology (Peters *et al.* 1999). Yet in this area domestic species cohabit with wild ones.

This shift in the measurements trough time can be interpreted as an indicator for animal domestication. In order to compare assemblages from different periods and sites the Logarithmic Size Index (LSI) was used. This allows considering jointly measurements from different skeletal parts in an assemblage (Meadow 1999). For the case of big size camelids a guanaco¹ with a length of 181 cm (nose- base of the tail) was used, which corresponds to the lower range defined for Patagonian guanaco (Raedecke 1979 in Wheeler 1995: 275). Given the lack of archaeological nor actual skeletons from the region, this animal was used for which known body measurements (length) were available. Smaller to other Patagonian guanaco, it is not that different to those commonly used as a standard in closer areas (Northwestern Argentina) with differences between 5-10% in first phalanx, second phalanx, and metapodials measurements (Elkin *et al.* 1991, Izeta & Cortés 2006, Mengoni &

1. Zoologische Staatssammlung Muenchen 1956/89.

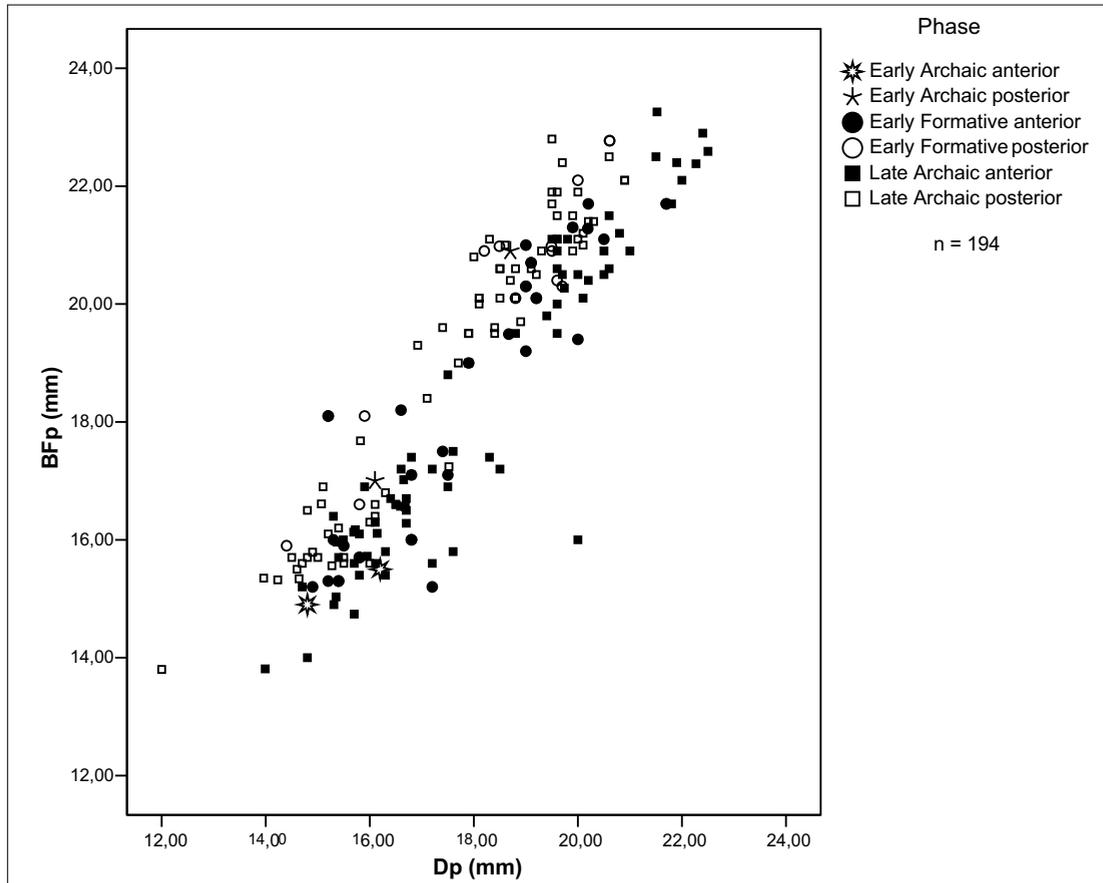


FIG. 2. – Measurements (Bfp and Dp) of anterior and posterior first phalanx of camelids by archaeological phases. Early Archaic (8.900 BP), Late Archaic (4.850-3.850 BP) and Early Formative (3.080-2300 BP).

Yacobaccio 2006). On the other hand, measures obtained from an actual guanaco skeleton attributable to an even closer area resulted larger compared to one finally used here as standard. For small camelids a vicuña² was used as a standard animal, with a total length of 170 cm. Used measurements and nomenclature were based on von den Driesch (1976).

First phalanx was selected due to its high frequency in most of the sites. Given its morphological pattern it is easy to separate between anterior and posteriors. Bfp and Dp. measurements were put on

scatter plots (Fig. 2). The presence of two different groups “small size” and “big size” camelids can be easily distinguished from the Figure 2. It is interesting to note the presence both of anterior and posterior phalanxes in each group discarding that observed size differences are due to this fact. In addition, sexual dimorphism does not affect both groups in the case of Southamerican camelids since there are no significant size differences between sexes (Moore 1989, Cartajena 2003).

Although the scarce number of measurements, in Tambillo-1 both groups of size are present.

2. Zoologische Staatssammlung Muenchen 1979/186.

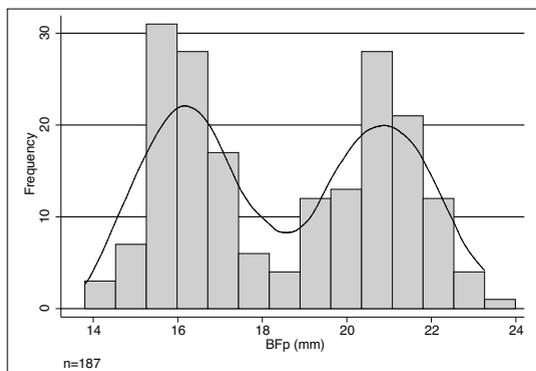


FIG. 3. – Sample and empirical distribution of first phalanx measurements (BFp) of all camelids from studied sites covering the Early Archaic, Late Archaic, and Early Formative periods.

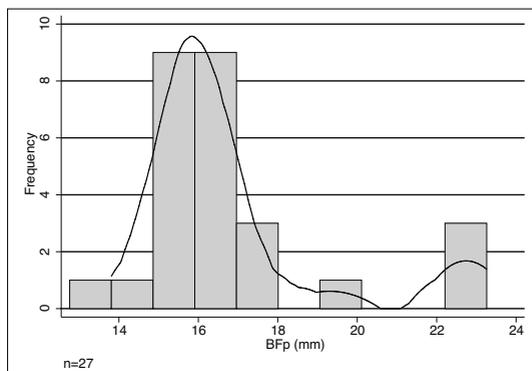


FIG. 5. – Sample and empirical distribution of first phalanx measurements (BFp) of all camelids first phalanx measurements (BFp) from Late Archaic site Puripica-1.

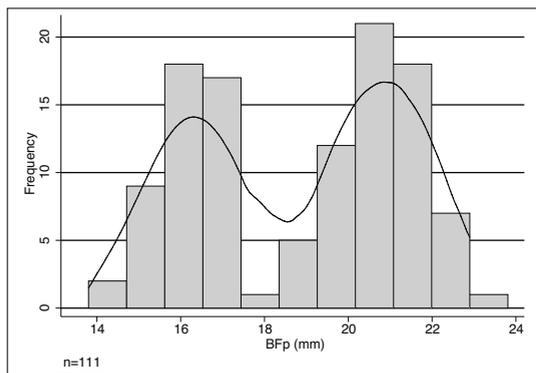


FIG. 4. – Sample and empirical distribution of first phalanx measurements (BFp) of all camelids from Late Archaic site Tulán-52.

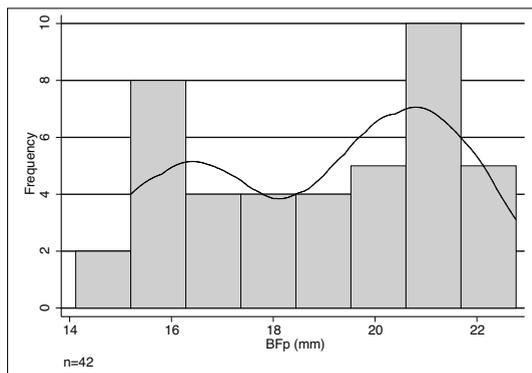


FIG. 6. – Sample and empirical distribution of first phalanx measurements (BFp) of all camelids first phalanx measurements (BFp) Early Formative sites located at Quebrada Tulán (Tulán-54, 85 and 122).

Given the early dates obtained for this site it could be assumed that the smaller and larger groups are wild species, vicuña and guanaco respectively. Anterior and posterior phalanxes could be easily separated for each one of the stages (Late Archaic and Formative).

In order to set a metric criteria to discriminate between size groups, in Figure 3 we present the

sample and empirical³ distribution of BFp. Although other authors (Hesse 1982a) have used different cutting points, in this case 18 mm was proposed to separate between small and big size camelids. In order to statistically assess differences between groups, Wilcoxon test was applied. Results express two differentiated assemblages ($Z = -7.78$, $p = 0.00$).

3. An Epanechnikov Kernel based distribution using an optimal bandwidth as suggested in Silverman (1986). The empirical distribution represents the most likely population distribution of measurements obtained from the available sample.

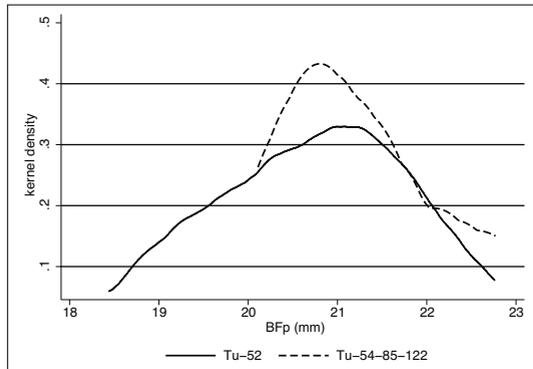


FIG. 7. – Posterior First Phalanx measurements (BFp) empirical distribution of big size camelids from Late Archaic sites (Puripica-1 and Tulán-52) and Early Formative sites located at Quebrada Tulán (Tulán-54, 85 and 122).

BFp distribution was evaluated for each site with the suggested cut measurement. This was plotted and Wilcoxon test was applied to them (Figs 4-6)⁴. Results effectively show two distinct groups in each site.

In order to have a more accurate analysis, phalanges were separated between anterior and posteriors, and given their higher representation, only the posterior were considered. Empirical measurement distribution in the big size camelid group (Fig. 7) suggests larger heterogeneity for Archaic site Tulán-52. During the Formative situation changes since measurements tend to concentrate in the middle trend; especially inferior segments common in Archaic sites do not appear represented, which could be due to initial husbandry development.

Aiming towards the comparison of bigger measurements samples, LSI was used for both groups. It has to be noted that relative size differences are not affected by changing the animal used as standard. However, the absolute values measured in the vertical axis may change.

In the case of big size camelids (Fig. 8), from the Early Archaic onwards size decreases, although the assemblage is small and probably does not

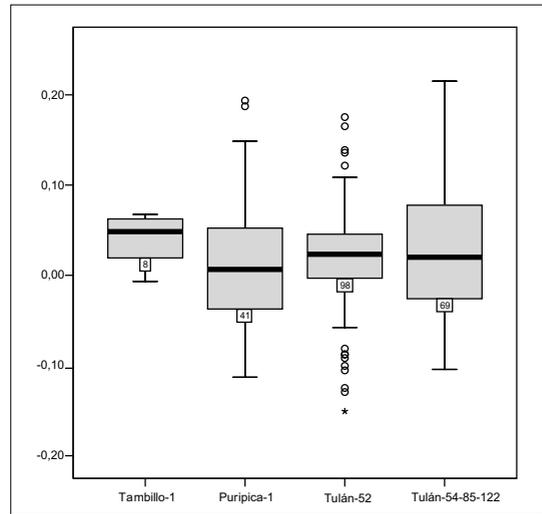


FIG. 8. – LSI boxplots for big size camelids from Early Archaic site Tambillo-1, Late Archaic sites (Puripica-1 and Tulán-52), and Early Formative sites located at Quebrada Tulán (Tulán-54, 85 and 122).

register the complete range of variation properly. Despite the fact of the scarce number of measurements, the size of the guanacos could be solidly characterized since at this period no human manipulation should be observed.

In the case of Late Archaic sites Puripica-1 and Tulán-52 the median decreases and variation in relation to earlier (Tambillo-1) and to later sites increases, especially in the lower bound (Tulán-54, 85 and 122). It is interesting to note that the upper bound of Tulán-54 rises compared to Late Archaic sites, suggesting the presence of larger animals.

This situation suggests the presence of domestic camelids in the analysed sites, which is supported by the smaller size of the big camelid group found in Late Archaic sites according to specimens collected. This follows the pattern proposed for the domestication of Old World herbivores like *Bos*, *Capra* and *Ovis* such as a reduction in the mean body size, the lower minimum size and the increased variability

4. PU-1 $Z=-1,82$ $p=0,068$; TU-52 $Z=-5,99$ $p=0,00$; TU-54-85-122 $Z=-3,41$ $p=0,001$.

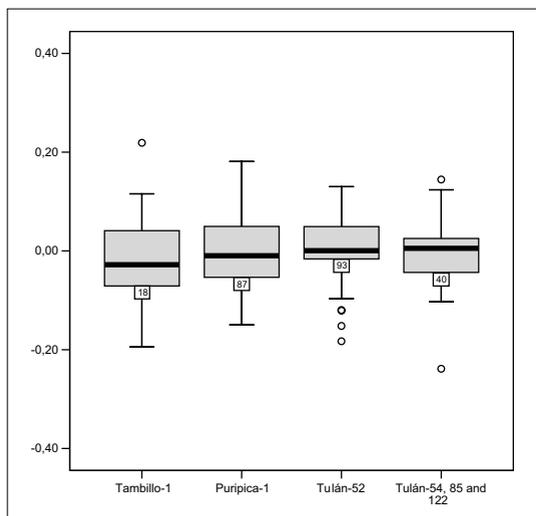


FIG. 9. – LSI boxplots for small size camelids from Early Archaic site Tambillo-1, Late Archaic sites (Puripica-1 and Tulán-52), and Early Formative sites located at Quebrada Tulán (Tulán-54, 85 and 122).

(Peters *et al.* 1999, figs. 7-9), especially in the case of the horse where size decrease and variability increase are simultaneously observed (Uerpmann 1990, Benecke 1994). If these indicators are considered, this could be symptomatic of the camelid domestication at the Late Archaic sites in the western slope of the Puna de Atacama. However, camelids show higher levels of variability in the upper range of measurements.

In contrast, small size camelid group show no significant difference in the median and variation range (Fig. 9). In this case, samples come from sites located in the same area, ideal condition to measure palaeoenvironmental induced changes. A comparison between vicuña bone measurements (small size camelids) by means of LSI method did not reveal a major difference in size between the Early, Late Archaic and Early Formative periods. It has to be noted that we assume that for the Early Archaic period small camelids correspond to vicuñas.

These results have remarkable significance since a reduction in body size cannot be related to a change in palaeoenvironmental conditions in the case of the big size camelids, thus the occurrence

of significant changes in body size can be associated to human manipulation.

In Tulán-54 site, three incisors were registered with a similar pattern as proposed by Wheeler for the alpaca (Wheeler 1984: 78-79, 80: fig. 3). Similar evidences were registered at the Tomayoc site (Northwestern Argentina) with almost contemporary dates (Lavallée *et al.* 1997). However, these indicators should be taken with caution (Kent 1986, Mengoni & Yacobaccio 2006). Although osteometric measurements for the smaller group of camelids is slightly bigger than those obtained for the archaic site Tulán-52, they do not show big changes in this assemblage related to the presence of alpaca.

AGE PROFILE

Age profiles were calculated from epiphyseal fusion frequency (% MNE) (Fig. 10). Frequency of juveniles (absence of epiphyseal fusion) reaches almost 40% in Late Archaic site Tulán-52. Tendency observed during the Early Formative corresponds mostly to adult assemblages, exception made by sites Tulán-54 and Tulán-109. It is important to mention that both sites have ritual connotations; the former for its temple structure and the latter for its association with rock art panels and for the presence of an offering composed by bone dart-throwers. These special connotations could be acting as selection criteria for younger specimens and would explain the difference between these and the other sites located in the Quebrada Tulán.

TABLE 3. – Cumulative percentage of non fused epiphysis (immature), sites Tulán-52 (B5) and Tulán-54 (H2 and H4). Fusion criteria based on Wheeler & Mujica (1981).

Immature	Tulán-52	Tulán-54
< 3.9 years	100,0	100,0
< 2.9 years	98,0	98,1
< 1.9 years	21,1	73,2
< 9 months	11,6	29,1
< 3 months	8,2	3,8

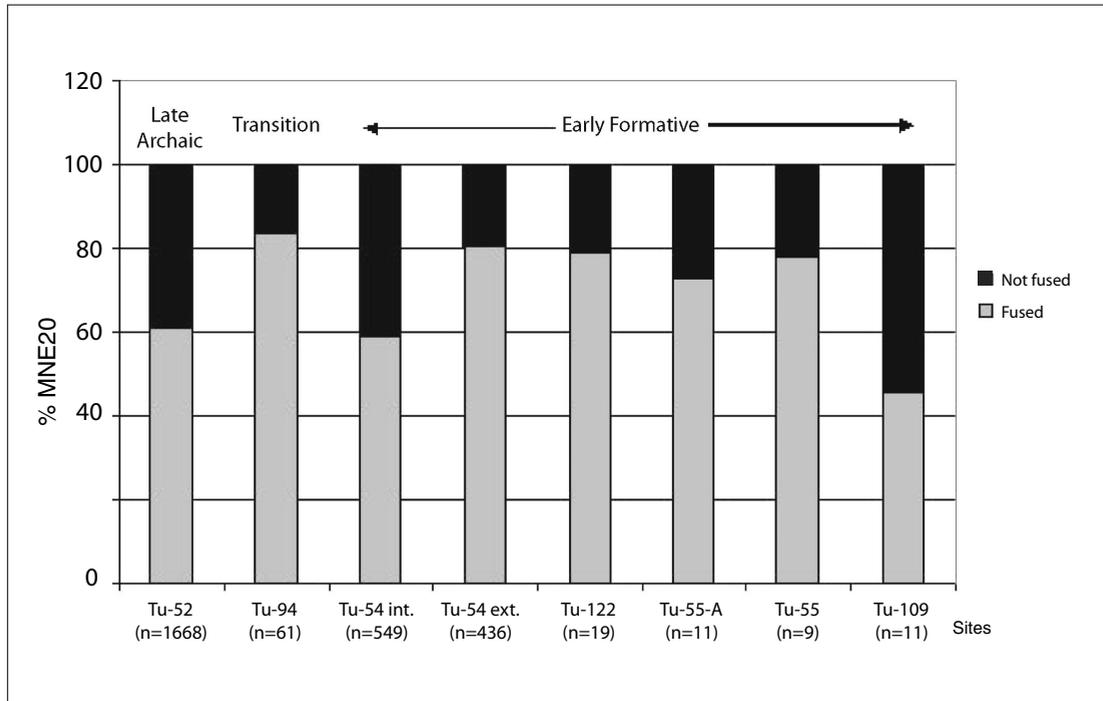


FIG. 10. – Age profile. Comparison between fused and non fused epiphysis from Late Archaic sites (Puripica-1 and Tulán-52), transitional site Tulán-94 and Early Formative sites located at Quebrada Tulán (Tulán-54, 85 and 122).

By analysing Tulán-52 and Tulán-54 (temple structure), despite the similar frequencies of juveniles in both periods age range distribution varies considerably (Table 3). In the former settlement, juveniles concentrate in the 2.9-1.9 year old age trend which corresponds to camelid sexual maturity, reached at the age of 2 for guanacos. In Tulán-54 on the other hand, frequencies concentrate between 9 months and 1.9 years, yet in neither sites high newborn mortality is observed, which has been suggested as a domestication indicator (Wheeler *et al.* 1977).

PATHOLOGIES

Camelid remains from Late Archaic sites of Puripica and Quebrada Tulán show numerous pathologies in contrast to bones from earlier sites in which are not found. Most pathologies are

related to distal metapodial and phalanx exostosis, which possibly developed as a consequence of long term periosteum irritation that led to bone proliferation (Levine *et al.* 2000, Fabis 2004) (Fig. 11C and D). Numerous factors can lead to phalanx periostitis consisting in the inflammation with proliferative growth of the bone tissue (Fabis 2004). Moreover, this pathology can be seen in metapodial bones of animals kept in captivity through strain friction (Benecke 1994: 33). On Figure 11B a camelid metapodial bone from the big size group with a strangle mark is shown that suggests that the animal was kept tied up. Presence of arthropathy (a degenerative articular disease), which is a marked extension of the articular surface, also occurs (Fig. 11A). These pathologies are generally related to domesticated animals either due to a poor diet, to long periods of exercise or to movement restrictions, although they have also been reported for wild animals

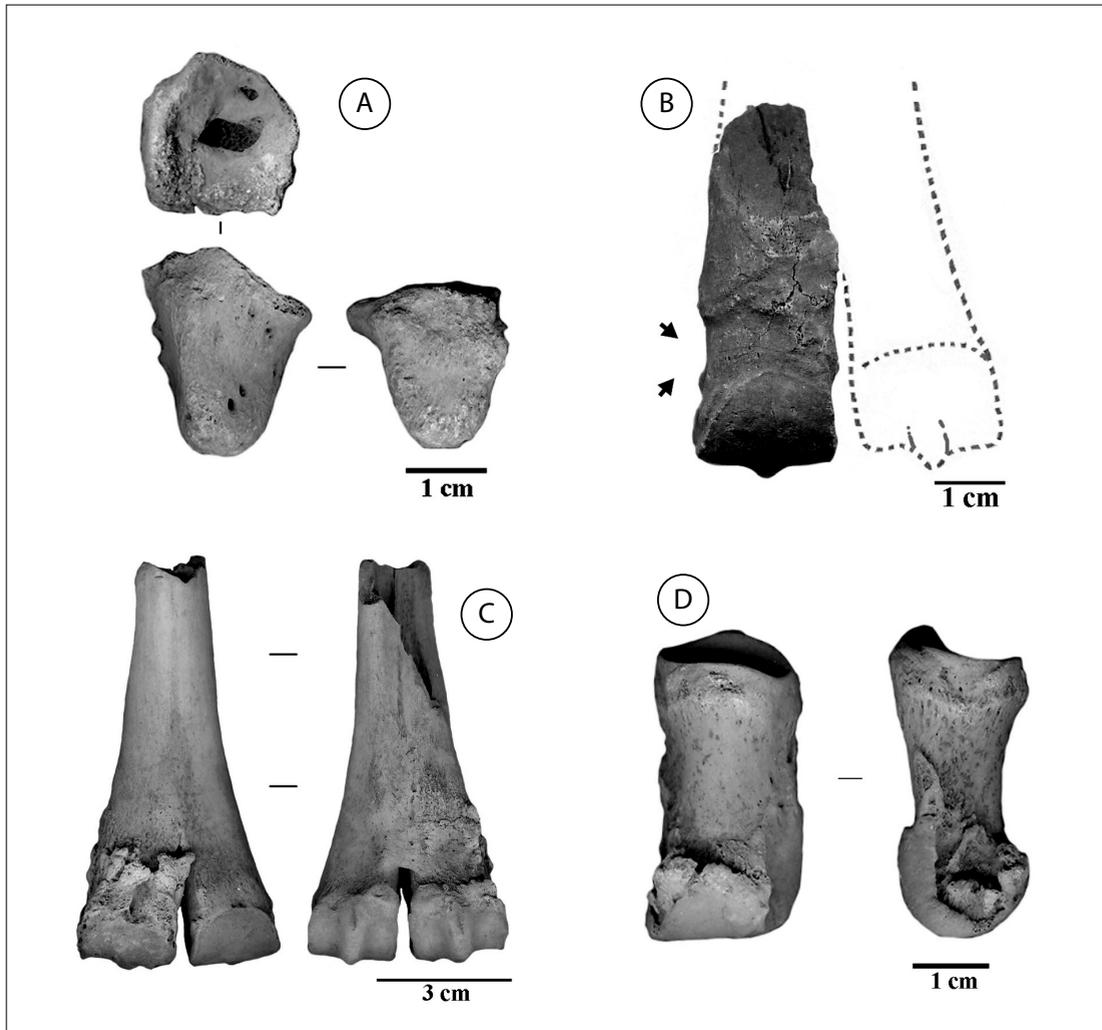


FIG. 11. – Bone pathologies in Late Archaic sites. A. Arthropathy in the articular surface of a third phalanx (Tulán-52). B. Distal metapodial with a strangle mark suggesting that the animal was tied up (Puripica-1). C. Metapodial, anterior and posterior view, with periostitis ossificans (Tulán-52). D. Second phalanx with periostitis ossificans at the distal end, anterior and axial view (Tulán-52). Photographer: Patricio López.

(Wobeser & Rung 1975). Several factors can contribute to the development of these pathologies, nevertheless their presence in this period indicates stress conditions which can be considered as an indirect evidence of human control over camelids, as an alternative approach for evidencing domestication processes specially in their first stages (Levine *et al.* 2000). These pathologies occur only on big size camelids yet not on the small ones (vicuñas).

FIBRES

Fibre analysis took into account some macroscopic features such as colour, texture and nature of the identified pieces, and microscopic ones such as the absence or presence of the medullar channel, the nature of medullar structure, average thickness, fiber diameter (μ) and comparison with current patterns (Benavente *et al.* 1993).

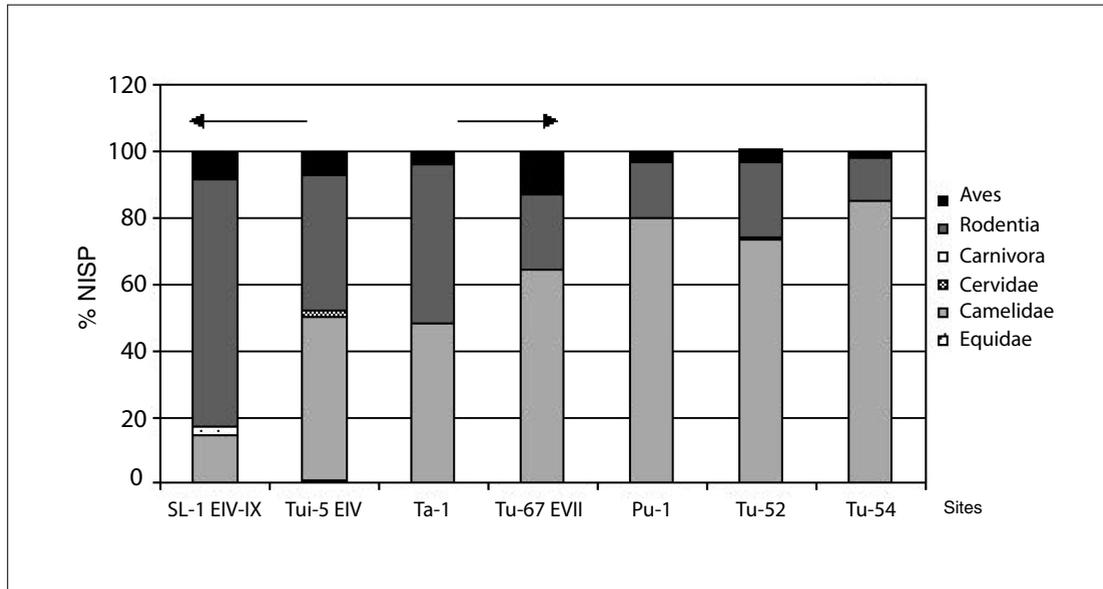


FIG. 12. – Taxonomic diversity. Comparison between Early Archaic sites located in the western slope of the Puna de Atacama (San Lorenzo-1 Stratum IV-IX, Tuina-5 Stratum IV, Tambillo-1 and Tulán 67 Stratum VII), Late Archaic sites (Puripica-1 and Tulá-52), and Early Formative site (Tulán-54).

TABLE 4. – Fleece identification at Tulán-52 and 54 sites (based on Benavente 2005-2006)

Taxa	Tulán-52	Tulán 54
<i>Vicugna vicugna</i>	37 (52.2%)	61 (48.8%)
<i>Lama guanicoe</i>	13 (18.6%)	36 (28.8%)
<i>Lama glama</i>	8 (11.4%)	15 (12.0%)
<i>Lama pacos</i>	–	1? (0.8%)
<i>Chinchilla sp.</i>	12 (17.1%)	7 (5.6%)
<i>Lagidium viscacia</i>	–	5 (4.0%)
Total	70	125

Although the possible presence of domestic animals in Tulán-54 had been suggested in previous analysis based on fibre colours (Dransart 1991), more recent studies identified domestic animals (llama) at Archaic settlement Tulán-52 and pointed out an important occurrence of wild species, especially of vicuña during Late Archaic as well as in Early Formative times with a low percentage of llamas (Benavente 2005-2006) (Table 4) showing no selection of domesticated camelids in this direction.

TAXONOMIC DIVERSITY

Taxonomic diversity is another common indicator, especially for the Central Andes (Mengoni & Yacobaccio 2006). During the Archaic in the Puna Salada, major biomass came from wild camelids since no other herbivores have been registered; exception made at Tuina-5 site where cervid remains were found associated to Early Holocene favourable conditions (Cartajena 2003). In this sense, there is an increasing reduction of microfaunal remains (birds and rodents) starting in the Early Archaic, which in Late Archaic and Early Formative sites find a very low frequency (Fig. 12).

On the other hand, no increase is observed in buffer resources which as Hesse (1986) points out, should be present in pastoralist settlements due to a resistance to sacrifice animals from the herd. In the settlements of Puripica and Quebrada Tulán an intensive wild animal hunt is observed, which is maintained all through the Early Formative and that would be fundamental for subsistence and

fleece procurement. Low presence of microfaunal remains could be related to the introduction of crops during the Early Formative, which would allow diet diversification (McRostie 2006). The presence of microfaunal remains in low quantities in Archaic and Formative settlements could be related to raw material procurement, as the high occurrence of *chinchilla* fleece indicates (Benavente 2005-2006), or to ritual purposes, among others (Labarca 2005).

PALAEOENVIRONMENT INFORMATION

Around 12.000 years BP a rapid change from extremely arid to a more humid environment, in which effective moisture increased more than three times compared with modern times (~200 mm precipitation) occurred. This was followed by a dramatic shift to arid conditions and a general paleolake regression in the highlands above 3.600 m around 8.000 BP, prevailing during the mid-Holocene until 3.600 BP, when lakes arose to modern levels and modern climatic conditions were established. Despite human dispersal during the mid-Holocene, people did not completely disappear from the area but moved to alternative newly created habitats in wetlands, in step valleys such as Quebrada Puripica and Tulán, newly formed in wetlands in the flat bottom areas of former palaeolakes or remained in places with large springs or regional river systems where resources remained stable through time. The end of favorable ecological refuges in wetlands at the *quebradas* was triggered by the onset of modern climatic conditions at about 3.000 years BP. This saw the beginning of river down cutting as a result of more humid climate, drying out and erosion of the wetlands and dry lake basins were flooded again (Grosjean *et al.* 2001, 2005b).

The presence of coprophilous fungal spores (Cercophora-type) and mire and wetland vegetation pollen in the mid-Holocene sediments of Laguna Miscanti (Fig. 1) suggest that with increasing aridity, the lake evolved into a wetland that provided excellent grazing areas for camelids on the newly exposed lake bed (Grosjean *et al.*

2001, 2005b). Thus regional climatic aridity did not necessarily turn into local environmental stress with water, animal and vegetation resources shortage, creating a positive scenario for camelid domestication.

CORRALS

Following the Quebrada Tulán stream, large fence structures are found, which might have been used as big pens that take advantage of the maximum foraging space along the ravine (Fig. 13). High and rocky slopes are used as natural boundaries on both borders; on softer slopes big regular boulders have been arranged to enclose pens. Boundary lines that cross the ravine are interrupted in the stream part to avoid holding back the water; palisades or similar solutions were probably used to bound areas close to the stream, allowing the enclosure of extended areas with water and forage, in contrast to later periods, with smaller and closed pens. Pen areas are close to Tulán-54 site, even though there are also Late Formative and historic settlements that could be associated to pen use. Pen dimensions (*ca.* 300 × 80 m) suggest a considerable amount of labour, consistent with the complexity observed in Tulán-54.

We have stressed the relationship between the Holocene landscape evolution and stone structures



FIG. 13. – Corral structures located over the palaeowetlands sediments at the valley bottom of Quebrada Tulán. Photographer: Lautaro Núñez.

(fences). Mid-Holocene wetland formation in the valley bottom has started around 7.400 BP and ending after ca. 3.140 BP (Rech *et al.* 2002). After ca. 3.100 BP a phase of rapid river incision and linear erosion took place. Following the interpretation by Grosjean (2001) the phase of linear erosion was due to an increase in river runoff and precipitation. Rech *et al.* (2002) noted in the Tulán river valley incision on the order of 10 m, which resulted in a local lowering of the groundwater table and drying of the mid-Holocene wetlands. The stone fence lies on the hard and dry surface, the boulders stick up to 10 cm deep in the sediments suggesting that the wetlands were still active and the sediments were soft at the time when the boulders were put in place. Therefore, the maximum age is unknown, yet certainly younger than 3.100 BP (Grosjean 2006) and may be as young as

1.600 A.D. It is important to define the relationship between pens and Formative settlements in Quebrada Tulán, due to their importance as early evidences on corral architecture, associated to the complexity observed during the Early Formative. In relation to corrals evidences, a fragment of dung derived soil was found over the occupational floor of Tulán-55, reinforcing the idea that corrals were in use by the Early Formative.

ROCK ART

Eight continuous panels totalling a 20 m extension located on the northern border of Quebrada Tulán compose Tulán-60 site, with large naturalist camelids of Taira-Tulán style (Berenguer 1995, 1999; Núñez *et al.* 2006b) (Fig. 14). In the

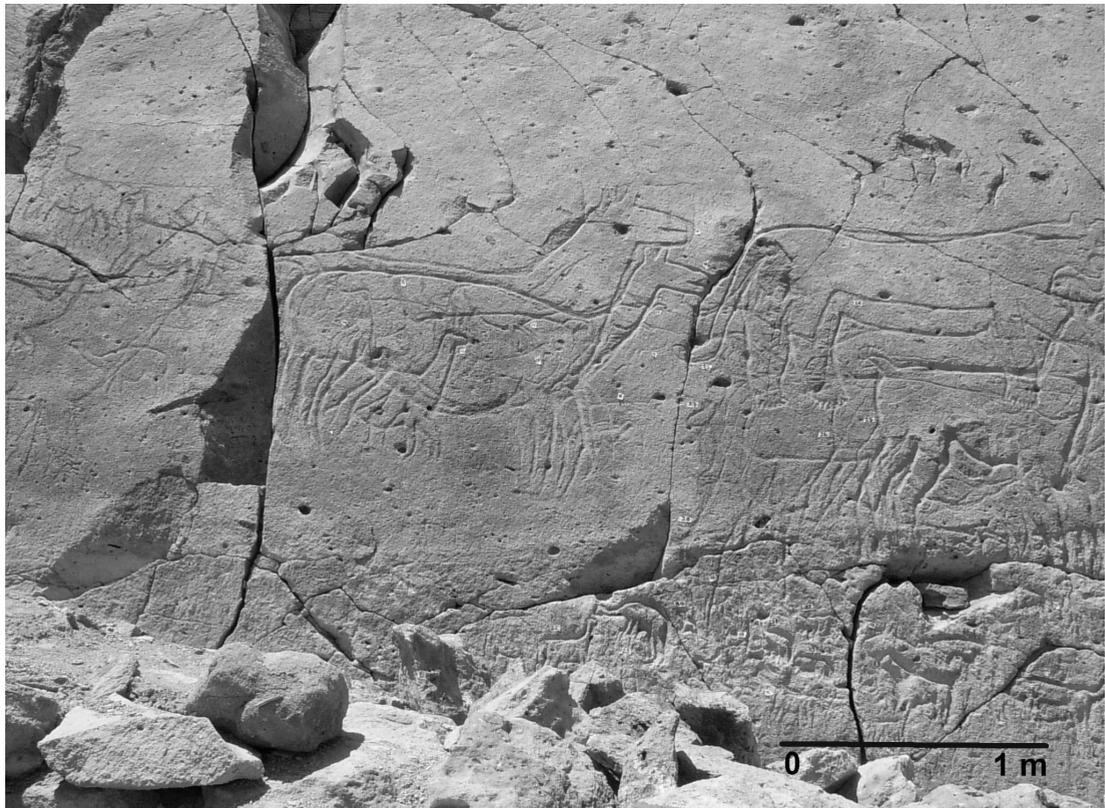


FIG. 14. – Rock art panels (Tulán-60) with big naturalist camelid representations of Taira-Tulán style. Photographer: Ignacio Torres.

interior of Tulán-54, different rock art representations are found; boulders with inverted camelid heads, a smaller camelid tied down and a dynamic anthropomorphic figure with a dart in its hands, similar to Confluencia style motifs (Gallardo *et al.* 1999). Additionally, a dart-thrower fragment was registered in the interior of Tulán-54 and also complete as offerings at Tulán-109 dated at 2.410 ± 70 B.P associated to the panels (Núñez *et al.* 2006a). A distinctive graphic representation of wild (Confluencia style) as opposed to domesticated camelids (Taira-Tulán style) has been proposed, as well as correspondence of these representations to different subsistence modes, one of hunters and other of husbandry-pastoralist societies which may have coexisted during the Early Formative (Gallardo & Yacobaccio 2005). Presence of both styles in Quebrada Tulán would represent the coexistence of hunting and pastoral practices, which is also supported by osteologic and fleece evidence (Cartajena *et al.* 2003, 2005; Benavente 2005-2006). In consequence, rock art of Tulán-54 site would represent a wild camelid hunting scene, while as Taira-Tulán style found all through the ravine would represent domesticated camelids (Gallardo & Yacobaccio 2005, Núñez *et al.* 2006b).

CONCLUSIONS

Different lines of evidence allow us to have a better comprehension of the domestication process in the western slope of the Puna de Atacama.

Osteometric results show higher levels of heterogeneity in measurements from Puripica-1 and Tulán-52 compared to those from the early site of Tambillo-1 (Early Archaic) and to the later Tulán-54 (Early Formative). However, for the earlier site we only have few measurements which may not represent the whole range of variation from early groups.

It has been suggested that possibly during the process of domestication, larger camelids than present guanacos (*i.e.* llamas) appeared in sites of northwestern Argentina and in northern Chile

dated around 4.400 BP, which have been interpreted as the initial steps of camelid domestication (Mengoni & Yacobaccio 2006: 238). Although the existence of size differences between domestic and wild species is discussed, the presence of domestic animals of the same size or larger than their wild ancestor is the result of conscious breeding process (Uerpmann & Uerpmann 2002: 252), which may not correspond to initial stages of domestication. Larger form sizes were already present during the Mid Holocene (Mengoni & Yacobaccio 2006: 237, fig. 16.5) showing high variation before the Late Archaic.

On the other hand, although a smaller Patagonian guanaco was used as a standard form, results show that site's medians were larger than the standard, suggesting the presence of wild animals in the Early Archaic, all of them guanacos.

Although the observed decrease in size of larger animals after the Early Holocene may be due to arid conditions, we suggest that major shifts at the Late Archaic are the consequences of a domestication process. On contrary, small size camelids attributable to vicunas during the Early Archaic, do not present the same shift during Late Archaic.

In general, ungulates tend to decrease in their size due to changes imposed by the domestication process (Peters *et al.* 1999: figs 7-9), including the camelid (Uerpmann & Uerpmann 2002). However, studied samples show a great variability in the upper size range which is not observed in domesticated animals in the Old World. At the same time, during the Late Archaic we observe higher variability in the lower size range of larger camelids. This heterogeneity is later reduced during the Early Formative, suggesting the disappearance of smaller animals in this size group. This may reflect more consolidated livestock husbandry practices.

The constant presence of small size camelid bones and vicuña fibres during the Late Archaic and Early Formative denotes the importance of wild animal hunting practices. Despite the fact that vicuñas are present in this territory, domestication of this specie is not observed. On the other

hand, we did not identify certainly alpaca contrary to what has been proposed for the Central Andes (Wheeler 1984). At the same time, measurements variability inside the group of large animals could be associated to guanacos and llamas as reflected by the presence of fleece attributable to both species. We proposed that the domestication process may have respond mainly to transport and meat motivations.

The use of wild animals for meat and fibre is still relevant as a symbolic aspect as well, denoted by the presence of dart-throwers as offerings and Confluencia style rock art.

Size differences between contemporaneous sites may also be due to distinct populations or slightly different environmental conditions or to site functionality. The ritual character of Tulán-54 (temple's interior) may influence the selection of camelids similar in size related to ritual practices. When comparing large size camelids measurements from the temple's interior with those from other sites at the *quebrada*, they appear to be smaller.

Other indicators like the presence of pathologies indirectly suggest human intervention or manipulation, especially camelid captivity during the Late Archaic. The age pattern, similar to that observed in other sites from the Central Andes and the Circumpuna does not show a shift in mortality patterns that might mark the onset of domestication (Kent 1982, Cartajena 1995a, Mengoni & Yacobaccio 2006, among others). In this case, age pattern in Formative sites (Tulán-54 and 109) may be related to ritual activities since most of immature individuals are concentrated here.

On the other hand, environmental conditions favour water and feeding resources conforming a propitious scenario for the domestication of camelids despite the general arid conditions. In this sense, it is important to define the relationship between pen structures and the Early Formative settlements; this by optimizing feeding and water resources using the natural border of the palaeowetlands at bottom of the valley.

Finally, the process of camelid domestication is part of an increasing socio-cultural complexity process, possibly providing the cultural background against which camelid domestication took place. We argue

that the location of Archaic and Formative settlements in Quebrada Tulán are explained by favourable cultural, social and environmental conditions, that allowed the transformation from a hunter gatherer society to a livestock husbandry based one (Núñez *et al.* 2006a).

Acknowledgments

We acknowledge comments by Prof. Dr. Angela von den Driesch, to Patricio López and Fernanda Kalazich for their valuable help in the preparation of this manuscript, and to anonymous referees for their comments.

REFERENCES

- BENAVENTE M. A. 2005-6. — *Análisis lanimétrico de fanéreos de los sitios Tulán-52 y 54*. Final Project Report FONDECYT 1020316. Ms.
- BENAVENTE M. A., ADARO L., GECELE P. & CUNAZZA C. 1993. — *Contribución a la determinación de especies en arqueología: Familia Camelidae y Taruca del norte*. Serie Programas de Desarrollo 3. Universidad de Chile, Santiago.
- BENECKE N. 1994. — *Der Mensch und seine Haustiere. Die Geschichte einer jahrtausendealten Beziehung*. Theiss, Stuttgart.
- BERENGUER J. 1995. — El arte rupestre de Taira dentro de los problemas de la arqueología atacameña. *Chungara* 27 (1): 7-43.
- BERENGUER J. 1999. — El evanescente lenguaje del arte rupestre en los Andes atacameños, in BERENGUER J. & GALLARDO F. (eds), *Arte Rupestre en los Andes de Capricornio*. Museo Chileno de Arte Precolombino, Santiago de Chile: 10-56.
- CARTAJENA I. 1995a. — Determinación de restos de camélidos en dos yacimientos del Loa Medio (II Región). *Estudios Atacameños* 11: 25-52.
- CARTAJENA I. 1995b. — Determinación de restos óseos de camélidos en dos registros mixtos, Chiu-Chiu Cementerio. *Hombre y Desierto* 9: 291-308.
- CARTAJENA I. 2003. — *Los conjuntos arqueofaunísticos del Arcaico Temprano en la Puna de Atacama, Norte de Chile*. Ph. D. thesis. Freie Universität Berlin, Berlin. Printed in microfilm.
- CARTAJENA I., NUÑEZ L. & GROSJEAN M. 2003. — *Los camélidos en la vertiente occidental de la Puna de Atacama: una visión desde el Arcaico Temprano al Formativo Temprano*. III Taller Internacional de Zoológico de Camélidos Sudamericanos, Tilcara, 21-24 August 2003. Ms.
- CARTAJENA I., NUÑEZ L. & GROSJEAN M. 2005. — *Animal utilization and camelid domestication in the*

- Atacama Desert 13000-3500 cal. BP 2nd Southern deserts conference: Human-environment interaction in southern hemisphere deserts.* Past, present and future, Arica, 10-14 October 2005. Ms.
- DRANSART P. 1991. — Llamas, herders and the exploitation of raw materials in the Atacama Desert. *World Archaeology* 22(3): 304-319.
- DRIESCH A. VON DEN 1976. — *A guide to measurement of animal bones from archaeological sites.* Peabody Museum Bulletin 1. Peabody Museum, Cambridge, MA.
- ELKIN D., MADERO C. M., MENGONI GOÑALONS L. G., OLIVERA D. E. & YACOBACCIO H. D. 1991. — *Avances en el estudio arqueológico de los camélidos en el noroeste argentino.* Actas de la VII Convención Internacional de Especialistas en Camélidos Sudamericanos. S.S. de Jujuy, Argentina 17-20 April 1991. Ms.
- FABIŠ M. 2004. — Palaeopathology of findings among archaeofaunal remains of small Seminar Site in Nitra. *Acta Veterinaria Brno* 73(1): 55-58.
- GALLARDO F., SINCLAIRE C. & SILVA C. 1999. — Arte rupestre, emplazamiento y paisaje en la cordillera del desierto de Atacama, in BERENQUER J. & GALLARDO F. (eds), *Arte Rupestre en los Andes de Capricornio.* Museo Chileno de Arte Precolombino, Santiago de Chile: 58-96.
- GALLARDO F. & YACOBACCIO H. D. 2005. — Wild or domesticated? Camelids in Early Formative rock art of the Atacama Desert (Northern Chile). *Latin American Antiquity* 16(2): 115-130.
- GROSJEAN M. 2001. — Mid-Holocene Climate in the South-Central Andes: Humid or Dry? *Science* 292 (5526): 2391.
- GROSJEAN M. 2006. — Cross-section profile Quebrada Tulán, in *Final Project Report FONDECYT 1020316.* Ms.
- GROSJEAN M., NUÑEZ L. & CARTAJENA I. 1997. — Mid-Holocene climate and culture change in the Atacama Desert, Northern Chile. *Quaternary Research* 48: 239-246.
- GROSJEAN M., LEEUWEN J. VAN, KNAAP W. O. VAN DER, AMMANN B., TANNER W., MESSERLI B., NUÑEZ L., VALERO-GARCES B. & VEIT H. 2001. — A 22,000 ¹⁴C years BP sediment and pollen record of climate change of Laguna Miscanti (23°S), Northern Chile. *Global and Planetary Change* 28: 35-51.
- GROSJEAN M., NUÑEZ L. & CARTAJENA I. 2005a. — Paleoindian occupation of the Atacama Desert, Northern Chile. *Journal of Quaternary Science* 20: 643-653.
- GROSJEAN M., NUÑEZ L. & CARTAJENA I. 2005b. — Cultural response to climate change in the Atacama desert, in SMITH M. & HESSE P. (eds), *23° South: Archaeology and environmental history of the southern desert.* National Museum of Australia, Canberra: 156-171.
- HERRE W. 1952. — Studien über die wilden und domestizierten Tylopoden Südamerikas. *Der Zoologische Garten (N.F.)* 19(2/4): 70-98.
- HESSE B. 1982a. — Archaeological evidence of camelid exploitation in the Chilean Andes. *Säugetierkundliche Mitteilungen* 30(2): 201-211.
- HESSE B. 1982b. — Animal domestication and oscillating climates. *Journal of Ethnobiology* 2(1): 1-15.
- HESSE B. 1986. — Buffer resources and animal domestication in prehistoric Northern Chile, in DUCOS P. (ed.), *Archaeozoologia. Mélanges publiés à l'occasion du 5^e Congrès International d'Archéozoologie.* La Pensée Sauvage, Bordeaux ; Grenoble: 73-85.
- HESSE B. & HESSE P. 1979. — *Archaic animal exploitation in inland northern Chile. Preliminary Report.* Ms.
- IZETA A. D. & CORTES L. I. 2006. — South American Camelid Paleopathologies: Examples from Loma Alta (Catamarca, Argentina). *International Journal of Osteoarchaeology* 16: 269-275.
- KADWELL M., FERNANDEZ M., STANLEY H. F., BALDI R., WHEELER J. C., ROSADIO R., & BRUFORD M. W. 2001. — Genetic analysis reveals the wild ancestors of the llama and the alpaca. *Proceedings Royal Society London* 268: 2575-2584.
- KENT J. 1986. — *The domestication and exploitation of South American camelids: Methods of analysis and their application to circumlacustrine archaeological sites in Bolivia and Peru.* Ph. D. thesis. Department of Anthropology, Washington University, Washington. University Microfilms International, Ann Arbor.
- LABARCA R. 2005. — *Zoarqueología de fauna menor en la Puna Salada: El caso de Quebrada Tulán (II Región, Chile).* Undergraduated thesis. Departamento de Antropología, Universidad de Chile, Santiago de Chile.
- LAVALLÉE D., JULIEN M., KARLIN C., GARCIA L. C. & POZZI-ESCOT D. 1997. — Entre desiertos y quebradas: Primeros resultados de las excavaciones realizadas en el abrigo de Tomayoc (Puna de Jujuy, Argentina). *Bulletin de l'Institut Français d'Études Andines* 26(2): 141-175.
- LEVINE M. A., BAILEY G. N., WHITWELL K. E. & JEFFCOTT L. B. 2000. — Palaeopathology and horse domestication: The case of some Iron Age horses from the Altai Mountains, Siberia, in BAILEY G., CHARLES R. & WINDER N. (eds), *Human Ecodynamics and Environmental Archaeology.* Oxbow, Oxford: 123-133.
- MCROSTIE V. 2006. — *La transición Arcaico-Formativo en la quebrada de Tulán, sur del Salar de Atacama, Chile. Evidencias arqueobotánicas.* Final Project Report FONDECYT 1020316. Ms.
- MEADOW R. H. 1999. — The use of size index scaling techniques for research on archaeozoological collections from the Middle East, in BECKER C., MANHART H., PETERS J. & SCHIBLER J. (eds), *Historia Animalium ex Ossibus. Beiträge zur Paläoanatomie, Archäologie, Ägyptologie, Ethnologie und Geschichte der Tiermedizin. Festschrift für Angela*

- von den Driesch zum 65. Internationale Archäologie Studia honoraria 8. VML VIg Marie Leidorf, Rahden/Westfalen: 285-300.
- MENGGONI GOÑALONS G. L. & YACOBACCIO H. D. 2006. — The domestication of south american camelids. A view from the South-Central Andes, in ZEDAR M. A., BRADLEY D. G., EMSHWILLER E. & SMITH B. D. (eds), *Documenting domestication. New genetic and archaeological paradigms*. University of California Press, Berkeley; Los Angeles; London: 228-244.
- MOORE K. 1989. — *Hunting and the origin of herding in Peru*. Ph. D. thesis. University of Michigan, Ann Arbor. University Microfilms International, Ann Arbor, Michigan.
- NOVOA C. & WHEELER J. C. 1984. — Llama and alpaca, in MASON I. L. (ed.), *Evolution of domestic animals*. Longman, London: 116-128.
- NUÑEZ L. 1981. — Asentamiento de cazadores recolectores tardíos en la Puna de Atacama: Hacia el sedentarismo. *Chungara* 8:137-168.
- NUÑEZ L. 1983. — *Paleoindio y Arcaico en Chile*. Series Monográficas 3. Ediciones Cuicuilco, México.
- NUÑEZ L. 1992. — Ocupación arcaica en la puna de Atacama: secuencia, movilidad y cambio, in MEGGERS B. J. (ed.), *Prehistoria sudamericana. Nuevas perspectivas*. Taraxacum, Washington: 283-307.
- NUÑEZ L., CARTAJENA I. & GROSJEAN, M. 1999. — Un ecorefugio oportunístico en la Puna de Atacama durante eventos áridos del Holoceno Medio. *Estudios Atacameños* 17: 125-174.
- NUÑEZ L., GROSJEAN M. & CARTAJENA I. 2001. — Human dimensions of late Pleistocene/Holocene arid events in southern South America, in MARKGRAF V. (ed.), *Interhemispheric Climate Linkages*. Academic Press, Burlington: 105-117.
- NUÑEZ L., GROSJEAN M. & CARTAJENA I. 2002. — Human occupations and climate change in the Puna de Atacama, Chile. *Science* 298(5594): 821-824.
- NUÑEZ L., CARTAJENA I., CARRASCO C. & DE SOUZA P. 2005. — El Tempete de Tulán y sus relaciones formativas panandinas (norte de Chile). *Bulletin de l'Institut Francais d'Études Andines* 34(3): 299-320.
- NUÑEZ L., CARTAJENA I., CARRASCO C., DE SOUZA P. & GROSJEAN M. 2006a. — Emergencia de comunidades pastoralistas formativas en el sureste de la Puna de Atacama. *Estudios Atacameños* 32: 93-117.
- NUÑEZ L., CARTAJENA I., CARRASCO C., DE SOUZA P. & GROSJEAN M. 2006b. — Patrones, cronología y distribución del arte rupestre arcaico tardío y formativo temprano en la cuenca de Atacama, in FIORE D. & PODESTA M. M. (eds), *Tramas en la Piedra. Producción y Usos del Arte Rupestre*. World Archaeological Congress; Asociación Amigos del INA; Sociedad Argentina de Antropología, Buenos Aires.
- PETERS J., HELMER D., DRIESCH A. VON DEN, SAÑA SEGUI M. 1999. — Early Animal Husbandry in the Northern Levant. *Paléorient* 25(2): 27-48.
- RECH J. A., QUADE J. & BETANCOURT J. L. 2002. — Late Quaternary paleohydrology of the central Atacama desert (lat 22-24°S), Chile. *GSA Bulletin* 114(3): 334-348.
- SILVERMAN V. W. 1986. — *Density estimation and data analysis*. Chapman & Hall, London.
- UERPMANN H. P. 1990. — Die Domestikation des Pferdes in Chalkolitikum West und Mitteleuropas. *Madridrer Mitteilungen* 31: 109-153.
- UERPMANN H. P. & UERPMANN M. 2002. — The appearance of domestic camel in South-east Arabia. *Journal of Oman Studies* 12: 235-260.
- WHEELER J. C. 1984. — La domesticación de la alpaca (*Lama pacos* L.) y la llama (*Lama glama* L.) y el desarrollo temprano de la ganadería autóctona en los Andes Centrales. *Boletín de Lima* 6(36): 74-84.
- WHEELER J. C. 1991. — Origen, evolución y status actual, in FERNÁNDEZ-BACA S. (ed), *Avances y perspectivas del conocimiento de los camélidos sudamericanos*. FAO, Santiago: 11-48.
- WHEELER J. C. 1995. — Evolution and present situation of the South American Camelids. *Biological Journal of Linnean Society* 54: 271-295.
- WHEELER J., PIRES-FERREIRA E., & KAULICKE P. 1977. — Domesticación de los camélidos en los Andes centrales durante el período precerámico: un modelo. *Journal de la Société des Américanistes* 64: 155-165.
- WHEELER J. & MUJICA E. 1981. — *Prehistoric pastoralism in the Lake Titicaca basin, Perú*. Final Project Report. National Science Foundation, Arlington, Virginia.
- WING É. 1972. — Utilization of animal resources in the Peruvian Andes, in IZUMI S. & TERADA K. (eds), *Andes 4. Excavations at Kotosh, Peru, 1963 and 1969*. University of Tokyo Press, Tokyo: 327 - 350.
- WOBESER G. & RUNGE W. 1975. — Arthropathy in white-tailed deer and a moose. *Journal of Wildlife Diseases* 11(1) :116-121.
- YACOBACCIO H. D. 2003. — *Procesos de intensificación y de domesticación de camélidos en los Andes Centro-Sur. III Congreso Mundial sobre Camélidos. Taller internacional de DECAMA. Potosí, 15-18 october 2003*. UNEPACA, Potosí: 211-216.
- YACOBACCIO H. D., ELKIN D. & OLIVERA D. 1994. — El fin de las sociedades cazadoras? El proceso de domesticación animal en los Andes centro-sur, in LANATA J. L. & BORRERO L. A. (eds), *Arqueología de cazadores recolectores. Límites, casos, aperturas. Arqueología Contemporánea* 5, Edición Especial: 23-31.

Submitted on 2 January 2007;
accepted on 9 June 2007.

