



Of Hunting and Herding: Isotopic evidence in wild and domesticated camelids from the Southern Argentine Puna (2120–420 years BP)



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ABSTRACT

Using stable isotope analysis, this paper studies the interaction between Prehispanic camelid herding and hunting practices in agropastoralist societies of the Antofagasta de la Sierra Basin (Southern Argentinean Puna) between 2120 and 420 years BP. Stable carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) isotope ratios were measured on 45 archaeological wild (*Vicugna vicugna*) and domesticated (*Lama glama*) camelid bone samples from the Early and Late Formative Period (3000–1000 years BP) site of Casa Chavez Montículos, and from the Regional Late Period (1000–420 years BP) sites of Corral Alto, Bajo del Coypar, Real Grande 1 and Real Grande 6. The isotopic analysis showed that domestic camelids at the sites segregated into two groups according to $\delta^{13}\text{C}$, reflecting two distinct animal management strategies. This could have involved differences in foddering practices or altitudinal herding ranges. In the case of wild camelids, $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values indicated that the distances travelled in their hunting varied depending on the site. The observed variability in the management strategies of herding resources, and in the mobility circuits linked to the exploitation of wild camelids, presents the case for puna groups relying on an ongoing re-organisation of longstanding local economic practices to mediate the socio-political and environmental factors that arose through time.

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1. Introduction

South American camelids occupied a central role in the economic, social and ritual lifeways of past Andean hunter-gathers, herders and farmers. The llama and alpaca were the only medium to medium-large domesticated animal of the Americas. Their exploitation presaged the development of the only autochthonous herding strategy in the New World (Bonavia, 2008; Mengoni Goñalons, 2007; Wheeler, 1995; Yacobaccio, 2001). The domestication of camelids was especially important for the highland regions, such as the Southern Argentine Puna, where critical resources – water, forage, fertile soil, etc. – were limited for both humans and animals. Likewise, agriculture played an important role in the variety of economic systems adopted by the agro-pastoralist societies of the highlands (Erickson, 2006; López, 2003; Olivera, 1997; Stanish, 2006). Nevertheless, the means by which subsistence agriculture and camelid herding interacted at this ecological juncture is a long understudied theme.

Archaeological research shows that by 1000 years BP, the South-Central Andes saw an intensification in both agricultural and pastoralist production. This pastoralist intensification would have engendered a specialised use of domesticated camelids for diverse functions, such as meat, fibre and as load-bearing animals (Mengoni Goñalons, 2007; Nielsen, 2001; Olivera, 1997; Olivera and Grant, 2008; Reigadas, 2008;

among others). In spite of these profound changes, to date, there have been no studies into the impact that this economic intensification had on the transhumant mobility practices of pastoral people, linked to live-stock management and the productivity of a given study area (Olivera, 2006; Grant, 2014).

In addressing these lacunae, I study the trajectory of Andean Prehispanic pastoralism in a particular sector of the South-Central Andes – Antofagasta de la Sierra (Southern Argentine Puna) – where hunting, herding and agriculture occupied shifting social and economic roles across time. The archaeological and zooarchaeological data from Antofagasta de la Sierra (Southern Argentinean Puna) indicates that camelid pastoralism constituted, from around 3000 years BP, a fundamental element in the economy and lifestyle of these ancient Prehispanic communities. Even so, the adoption of pastoralist strategies, the final result of a process of domestication, did not mean the end of hunting; indeed, the evidence strongly suggests that hunting remained a much more important resource within the economies of these societies than previously acknowledged (Grant, 2010; Olivera and Grant, 2008; Ortiz and Urquiza, 2012; Urquiza and Aschero, 2006).

Concomitantly, agriculture from an initial small-scale endeavour at the commencement of the agropastoralist process grew in importance until it constituted a crucial link in the organisation of late societies (ca. 1000 years BP). In this article, I address the impact of this increase in scale and intensity of agricultural practices on the existing herding and hunting strategies, as well as the specific locations of their pasturelands.

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The aim of this paper then is to elucidate changes and continuities through time in animal management practices and the economic use of camelids, both domestic and wild, in the Antofagasta de la Sierra Basin of the Southern Argentine Puna. I do this through an analysis of carbon and nitrogen stable isotopes on bone collagen from archaeological camelid remains. The bones sampled are from five archaeological sites dating to between 2120 and 420 years BP, located at different altitudes within the Antofagasta de la Sierra Basin. Specifically, this study seeks to determine the characteristics of animal management practices, as well as the interplay between hunting, herding and agriculture in early and late agropastoralist societies of the study region.

This new data shows that the isotopic signature of bones can be used as a tool for identifying differences in the foddering practices and the elevational habitat in which camelid were pastured or hunted within short radial distances, such as those of the Antofagasta de la Sierra Basin. These results are discussed within a framework covering the political, social and economic changes that occurred in this sector of the Southern Argentine Puna across 1700 years Prehispanic history.

1.1. Environmental and archaeological setting

The Puna of Argentina is a highland desert located between 22° and 27°S and at 3000 to 5000 masl. This area is characterised by high solar radiation due to altitude, wide daily thermal variation, low atmospheric pressure and marked rainfall seasonality. Primary productivity is mainly concentrated on stable hydrological systems such as wetlands and primary basins. There are a few low-flow rate, permanent and semi-permanent watercourses that are distributed unevenly throughout the landscape. These are the only sources of fresh water (Olivera, 2006; Tchilinguirian, 2008). In terms of precipitation distribution, the Argentinean Puna exhibits a latitudinal gradient that determines two sub-regions: the Dry or Northern Puna and the Salt or Southern Puna. While both have similar vegetational compositions, the Salt Puna is dominated by salt-lakes and saline soils (Cabrera, 1976).

The Antofagasta de la Sierra Micro-region is located between 25° 50' and 26° 10'S, and 67° 30' and 67° 10'W and falls within the Salt Puna (see Fig. 1). It is characterised by extreme aridity (arid Andean Puna climate) with average summer rainfalls below 100–150 mm annually, sometimes failing altogether in given seasons. The hydrological network is endorheic, fed by scarce precipitation, ice-melt (November–March) and subterranean water sources. In keeping with the rest of the puna, the wide altitudinal range results in moisture variations that underpin the development of distinct plant communities.

Below 3800 masl there is the *Tolar* (shrub steppe) community, dominated by shrubs of the Asteraceae family and with a low proportion of herbs. The *Tolar* includes mainly C₃ (shrubs and grasses) and C₄ (mostly grasses) plant species. Between 3900 and 5000 masl extends the *Pajonal* ecozone (herbaceous grasslands), dominated by *Festuca* and other grasses, containing mostly C₃ plant species. At the interface between the two zones – 3800/3900 masl – there is an ecotone characterised by a mixed shrub and steppe community ecotone. These plant communities constitute 99% of the desert matrix. The remaining 1% is composed of poorly drained moorland known as *vegas* (wetlands). *Vegas* are found at different altitudes and represent densely vegetated areas containing several grass species (Haber, 1991; Tchilinguirian and Olivera, 2009).

Various archaeological studies undertaken in Antofagasta de la Sierra show that the Early Formative Period (3000–1800 years BP) was categorised by the presence of groups practicing agro-pastoralism. The life-cycle of these human groups was organised primarily around llama herding, with agriculture playing a minor role (Olivera, 1997, 2006). Nevertheless, vicuña hunting still played an important part in the economic strategies of these societies (Escola, 1996; Grant, 2010; Olivera and Grant, 2008). During the Late Formative period (1800–1000 years BP) there was a slow, human demographic increase among these agropastoral societies, and a concomitant rise in agricultural

production. This agricultural production was focussed around the improved use of those sectors best suited to agriculture (Olivera, 1997). At this stage, camelid hunting seems to have diminished in intensity, perhaps as a consequence of greater economic reliance on farming among these groups (Olivera and Grant, 2008).

Finally, during the Late Period (1000–420 years BP), there is another population increase, and the appearance of semi-urban habitational centres associated to increased social complexity. At this time, there seems to have been a marked tendency towards greater agricultural production, whereby the best lands are actively, extensively, and intensively cultivated (Tchilinguirian and Olivera, 2009). This increase in agricultural production is mirrored by an equal intensification in pastoralist production, reflected in the increasingly evidence for a more complex management of camelids, such as the rearing of specialised fibre and load-carrying llama types (Olivera, 1997; Olivera and Vigliani, 2000/2002; Olivera and Grant, 2008; Reigadas, 2008). Likewise, by this stage, hunting has again regained its importance within the existing economic set-up (Grant, 2010; Olivera and Grant, 2008; Ortiz and Urquiza, 2012; Urquiza and Aschero, 2006).

1.2. Camelids and Andean pastoralism

At present there are four camelid species in South America: guanaco (*Lama guanicoe*) and vicuña (*Vicugna vicugna*) both wild, and llama (*Lama glama*) and alpaca (*Vicugna pacos*) both domesticated. Here, I concentrate on the characteristics of llamas and vicuñas given that these two species dominate the analysed archaeological record of Antofagasta de la Sierra. The alpaca is a rare presence in the Argentinean Puna, given that this dry region is environmentally unsuited to this animal. Likewise, there is no strong evidence to suggest its presence in the study area in the Prehispanic period (Grant, 2014; Olivera and Grant, 2008). In the case of the guanaco, although currently not present in the study area (Olivera, 2006), osteometric and contextual evidence suggests their presence in different archaeological sites of Antofagasta de la Sierra until the end of the Formative Period, although in ever decreasing frequency through time (see Section 2 below).

The vicuña is the smallest camelid. In the Argentine Puna, vicuñas have been classified as variable graziers, implying that they feed preferably on herbs and grasses, but sometimes vary their diet by feeding on steppe shrubs (Benítez et al., 2006). Despite this dietary flexibility, they register higher consumption of C₄ plants relative to most ungulates (Borgnia et al., 2008, 2010). In spatial terms, individual vicuñas organise themselves into stable family groups that dominate a given territory (Franklin, 1982; Vilá, 2000). The llama is the largest domesticated camelid and it is adapted to a great variety of environments. It has the capacity to eat a wide range of different plants and is thus known as a generalist species (Gundermann, 1984; Yacobaccio, 2001). Insofar as its spatial range is concerned, its social behaviour in these circumstances, as in others, is circumscribed by human intervention.

In this sense, there are a number of studies on contemporary Andean pastoralism noting that the spatial separation and temporal availability of pasturelands is managed by the mobilisation of herds and people (e.g. Göbel, 1994; Gundermann, 1984; Yacobaccio et al., 1998). These migrations usually follow a seasonal vertical movement – transhumance – that results in a dispersed human settlement pattern across the landscape (Yacobaccio et al., 1998).

In modern-day Antofagasta de la Sierra, because of a range of different factors, including work migration to cities, and the introduction of exotic animals into the herds (e.g. *Ovis aries*), these transhumant mobility patterns have been further modified, such that herders show a preference for maintaining llamas at the valley basin for the whole of the year, as opposed to yearly migrations. Here, close to the modern village, the llamas pasture freely in the *vegas* and fields, complementing their diet with fodder, mainly alfalfa (*Medicago sativa*), an Old World C₃ plant (Grant, 2016).

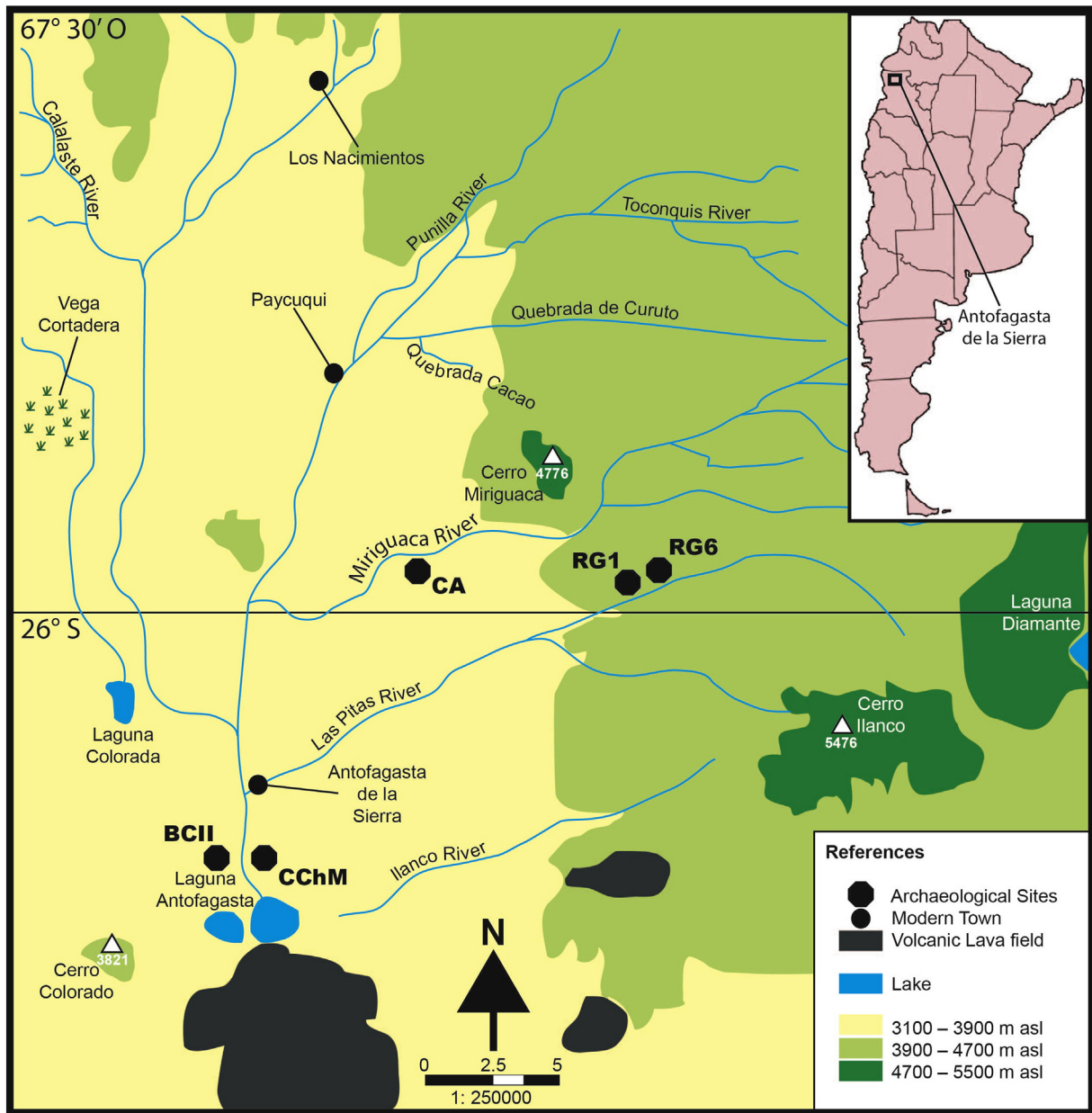


Fig. 1. Map of the Antofagasta de la Sierra Basin, Argentina, showing elevation, study sites and modern town. Adapted from Aschero et al., 2012.

1.3. Stable isotope analysis

In the Andean region, isotopic analyses on camelid remains have been applied successfully to pastoralism and animal diet research (e.g. Dantas et al., 2014; Dufour et al., 2014; Finucane et al., 2006; Goepfert et al., 2013; Mengoni Goñalons, 2007; Samec et al., 2013; Szpak et al., 2014; Thornton et al., 2011; Yacobaccio et al., 2010). These studies have explored different aspects of pastoralism and diet such as types of animal husbandry, mobility, foddering zones, wild resource capture areas, among others. In addressing these themes it is important to understand the variables that influence the isotopic signature of these animals within a particular study area (Samec et al., 2013).

In the case of the Argentine Puna, research undertaken in the Salt and Dry Puna have shown that altitude is a key variable in the $\delta^{13}\text{C}$ values of camelids, given the differential distribution of C_3 and C_4 plants along the vertical gradient (Fernández and Panarello, 1999–2001; Grant, 2014, 2016; Samec et al., 2013; Yacobaccio et al., 2009). These studies, noted the tendency towards an impoverishment in $\delta^{13}\text{C}$ values

from wild and domesticated camelid bone collagen as altitude increased. Meanwhile, animals that grazed at lower altitudes had higher $\delta^{13}\text{C}$ values, due to greater amount of C_4 in their diet.

This trend was even more noticeable in the case of vicuñas, given that the $\delta^{13}\text{C}$ values of vicuñas feeding at a height below 3900 masl, reflected a diet richer in C_4 plants than in those of llamas at the same altitude (Grant, 2016; Samec et al., 2013). The existence of certain selectiveness in the feeding behaviour of vicuñas, showing a higher consumption of C_4 plants when these are available, is supported by ethological evidence (Borgnia et al., 2010).

Similarly, $\delta^{15}\text{N}$ values on vicuñas and llamas have also demonstrated that altitude is a key variable (Grant, 2016; Samec et al., 2013). In this case, the variability in values is probably related to variations in water availability (Ambrose and DeNiro, 1986; Amundson et al., 2003; Swap et al., 2004), with higher values being registered in drier areas located below 3900 masl, while the lower values are found above this height, among the highland *pajonal* plant communities where there is a greater availability of water (Samec et al., 2013).

The variables that influence the isotopic signature of these animals in the Argentine Puna have also been registered in other areas of the Andes. For instance, Thornton et al. (2011) show that, even though there is no comparable modern data for camelids feeding on natural forage at coastal or very low elevations (<1000 masl), vegetation surveys indicate a general pattern of higher carbon and nitrogen isotopic compositions in plant tissues on average at coastal and low altitude sites relative to high altitude sites (see also, Szpak et al., 2014). This suggests that camelid $\delta^{13}\text{C}$ values would be less negative with decreasing altitude, and that camelids feeding extensively on coastal or low elevation forage should therefore have high $\delta^{15}\text{N}$ values in comparison to animals feeding primarily in the high sierra or puna (Thornton et al., 2011). Therefore, it is possible, based on a proportional analysis of $^{13}\text{C}/^{12}\text{C}$ and $^{15}\text{N}/^{14}\text{N}$ values from camelid bone collagen, to interpret which altitudinal zones were used by these animals for grazing.

1.4. Analysed sites

The material analysed here came from five different sites within the study area. For the Early Formative period, I studied the lower layers of the Casa Chávez Montículos (CCh1i) site, a multi-activity residential base located on the valley bottom at 3360 masl. For the Late Formative Period, I analysed material from the top levels of the same site (CCh1s/4). On the Late Period, sampling was extended to take in a series of sites, such as the valley bottom residential base site of Bajo del Coypar II (BCII), located at a height of 3349 masl, the residential base of Corral Alto (CA), located in the middle sector of the Miriguaca River, at 3680 masl, and finally, the upper levels of the Real Grande 1 and 6 sites (RG1 and RG6), both being hunting and herding posts located at high altitude, 4050 masl (Table 1).

2. Materials and methods

A sample of 45 archaeological camelids were analysed for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ derived from bone collagen. Bone from five archaeological sites, and three culture periods were included in the study, thereby assessing camelid dietary variation between different time periods and sites located at varying altitudes within the Antofagasta de la Sierra Basin.

Prior to selecting the samples for isotopic analysis, osteometry was used for species determination (Grant, 2014). In doing so, the standard methodology proposed by Menegaz et al. (1988), and used by several authors – Capriles Flores, 2011; Izeta, 2007; Gasco, 2013; Grant, 2010; Dantas et al., 2014; among others – was followed. Thus, quantitative multivariate analyses – cluster analysis and principal component analysis – were performed on postcranial bones from archaeological camelid samples as well as modern reference specimens of llama, guanaco and vicuña, using the metrics provided by Kent (1982), Menegaz et al. (1988) and Von den Driesch (1976).

Osteometric studies allowed for the discrimination of three groups: one comprising llamas (28.3%), another vicuñas (63.7%), and a third of guanacos (8%) (Grant, 2014). Nevertheless, given that the size range of the Andean guanaco overlaps with that of small llamas (Mengoni Goñalons, 2007), here I opted to disregard the guanaco group, because of the risk that it could correspond equally to guanaco or small llamas (classified as guanaco-llama category in; López, 2003; and, Grant, 2010). Therefore, I focussed on the archaeological specimens that

group around the modern vicuña and llama elements from the study area, given that respectively they occupy both extremes of the North Andean camelid body-size gradient. This being, from smaller to larger: vicuña, alpaca, guanaco and llama (Mengoni Goñalons, 2007).

Likewise, during the selection process I was careful to avoid sampling the same individual more than once. Therefore, the sampling of two individuals from the same level and sector of a site only occurred when, on the basis of osteometric identification, I was sure that the samples were from different species and hence individuals. On this basis, the samples used for isotope analysis were conformed of 16 specimens assigned to llama, and 29 to vicuñas (Table 1).

Sample preparation and analysis were conducted at the Instituto de Geocronología y Geología Isotópica (INGEIS), Argentina. Sample preparation for isotope analysis followed the standard procedures set by Tykot (2004), with some modifications. After abrasive cleaning and an ultrasonic wash with bi-distilled water, approximately a gram from each bone element (one per individual) was selected; humic acids were then eliminated using sodium hydroxide at 0.1 M dilution for 24 h. To obtain collagen, the bone was demineralised in 2% chloric acid solution for 72 h, the solution was changed every 24 h. Finally, each sample was soaked in sodium hydroxide for another 24 h. The final material was rinsed and dried at 60 °C (Tykot, 2004; Yacobaccio et al., 2010).

The bone collagen was weighed on an analytic balance, and placed within a silver capsule. These capsules were then positioned, using an automatic sampler, into a CARLO ERBA EA1108 elemental analyser, that was linked to a (IRMS) Thermo Delta V Advantage isotope mass spectrometer, using a CONFLO IV™ interface. The results were displayed as $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ isotopic deviations in respect to the international referents VPDB and AIR respectively. The standard error (1σ) margin was $\pm 0.2\%$ for both isotopes.

In order to interpret the isotope values obtained from archaeological camelid remains, these were compared against the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values from modern camelids from the study area, as well as against present-day llamas and vicuñas from the Dry Puna (Fernández and Panarello, 1999–2001; Grant, 2014, 2016; Yacobaccio et al., 2009, 2010). All modern $\delta^{13}\text{C}$ values were adjusted by +1.5% to account for the fossil fuel effect.

3. Results and interpretation

The resulting $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of 45 wild and domesticated camelid bone samples are listed in Table 2 and illustrated in Fig. 2. All samples met published collagen quality controls (e.g. C:N ratio between 2.9 and 3.6 – De Niro, 1985) (Table 2). When taken together, the Antofagasta de la Sierra camelids exhibit important variations in their isotopic values, with $\delta^{13}\text{C}$ values ranging from -19.7% to -11.6% (Mean -17.4% , $\sigma \pm 1.7$) and $\delta^{15}\text{N}$ values ranging from 3.4% to 7.9% (Mean 5.9% , $\sigma \pm 1.08$). This variation also carried through to the intra-taxonomic group values: llamas ($\delta^{13}\text{C} = -19.3\%$ to -11.6% ; $\delta^{15}\text{N} = 4.1\%$ to 7.7%) and vicuñas ($\delta^{13}\text{C} = -19.7\%$ to -14.2% ; $\delta^{15}\text{N} = 3.4\%$ to 7.4%) (Fig. 2: closed and open symbols, respectively).

In studying this variability, the isotope values were compared against the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of present-day camelids. The llamas and vicuñas analysed here were taken separately given the expectation that the isotopic signature for each of the species would respond to different variables.

Table 1
Summary of sites, radiocarbon dates and archaeological camelid bone samples.

Site	Level	Radiocarbon dates (years BP)	Elevation (masl)	Assigned to <i>Lama glama</i>	Assigned to <i>Vicugna vicugna</i>	Total
Casa Chaves Montículos 1	VI to VIII	2120 ± 60–1740 ± 60	3360	5	7	12
Casa Chaves Montículos 1/4	III to Vc	1740 ± 100–1530 ± 70	3360	9	3	12
Bajo del Coypar II	IV to VI	920 ± 80–670 ± 60	3349	1	3	4
Corral Alto	II	720 ± 40–660 ± 60	3680	1	3	4
Real Grande 1	II	980 ± 60–680 ± 70	4050	–	6	6
Real Grande 6	II to III	670 ± 100–420 ± 70	4050	–	7	7

Table 2
Stable isotope ratios of archaeological camelid samples from the Antofagasta de la Sierra Basin, Argentina.

Site	Sample	Level	Assigned specie	Laboratory code	Skeletal element	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	C:N
Casa Chávez Montículo 1	16 1 335	VIII	<i>Lama glama</i>	AIE 25465	Humerus	-17.1	7.9	3.2
Casa Chávez Montículo 1	16 1 26	VII	<i>Lama glama</i>	AIE 25496	Metapodial	-19.3	7.3	3.3
Casa Chávez Montículo 1	16 1 102	IX	<i>Lama glama</i>	AIE 25500	Metapodial	-17.3	7.6	2.9
Casa Chávez Montículo 1	16 1 82	VI	<i>Lama glama</i>	AIE 25501	Metapodial	-17.0	6.4	3.3
Casa Chávez Montículo 1	16 1 10	VIII	<i>Lama glama</i>	AIE 25498	Phalange 1	-19.0	4.1	3.2
Casa Chávez Montículo 1	16 1 120	II	<i>Lama glama</i>	AIE 25510	Phalange 1	-18.0	5.1	3.0
Casa Chávez Montículo 1	16 1 140	IV	<i>Lama glama</i>	AIE 25475	Scapula	-16.2	7.7	3.0
Casa Chávez Montículo 1	16 1 121	III	<i>Lama glama</i>	AIE 25495	Phalange 1	-17.9	4.9	3.0
Casa Chávez Montículo 1	16 1 141	V a	<i>Lama glama</i>	AIE 25508	Phalange 2	-16.3	6.2	3.0
Casa Chávez Montículo 4	16.4 3	III	<i>Lama glama</i>	AIE 28459	Radio-ulna	-17.2	6.1	3.3
Casa Chávez Montículo 4	16.4 6	IV	<i>Lama glama</i>	AIE 28446	Scapula	-17.3	6.5	3.3
Casa Chávez Montículo 4	16.4 205	V	<i>Lama glama</i>	AIE 25497	Phalange 1	-18.5	4.9	3.5
Casa Chávez Montículo 4	16.4 80	IV a	<i>Lama glama</i>	AIE 25502	Phalange 1	-13.1	7.6	3.0
Casa Chávez Montículo 4	16.4 184	IV	<i>Lama glama</i>	AIE 25509	Phalange 1	-11.6	7.1	3.0
Corral Alto	CA0	II	<i>Lama glama</i>	AIE 27375	Phalange 1	-17.1	6.7	3.2
Bajo del Coypar II	BCII 264	III	<i>Lama glama</i>	AIE 25488	Phalange 1	-13.7	5.4	3.0
Casa Chávez Montículo 1	16 1 74	VIII	<i>Vicugna vicugna</i>	AIE 25494	Phalange 1	-18.6	6.1	2.9
Casa Chávez Montículo 1	16 1 100	IX	<i>Vicugna vicugna</i>	AIE 25503	Phalange 1	-18.2	5.1	2.9
Casa Chávez Montículo 1	16 1 99	IX	<i>Vicugna vicugna</i>	AIE 25504	Metapodial	-18.2	5.4	3.1
Casa Chávez Montículo 1	16 1 155	VII	<i>Vicugna vicugna</i>	AIE 25506	Phalange 1	-18.0	4.5	3.0
Casa Chávez Montículo 1	16 1 129	VII	<i>Vicugna vicugna</i>	AIE 25507	Phalange 2	-17.5	5.6	3.2
Casa Chávez Montículo 1	16 1 156	VI	<i>Vicugna vicugna</i>	AIE 25511	Phalange 1	-16.6	6.2	2.9
Casa Chávez Montículo 1	16 1 57	VII	<i>Vicugna vicugna</i>	AIE 25512	Metapodial	-17.3	6.0	3.0
Casa Chávez Montículo 1	16 1 58	III	<i>Vicugna vicugna</i>	AIE 25476	Scapula	-16.8	5.5	3.3
Casa Chávez Montículo 1	16 1 138	IV	<i>Vicugna vicugna</i>	AIE 25505	Phalange 2	-18.4	4.3	3.2
Casa Chávez Montículo 4	16.4 186	IV	<i>Vicugna vicugna</i>	AIE 25499	Phalange 1	-16.1	7.0	3.3
Bajo del Coypar II	BCII 211	VI b	<i>Vicugna vicugna</i>	AIE 25468	Phalange 1	-17.9	3.4	3.1
Bajo del Coypar II	BCII 265	I	<i>Vicugna vicugna</i>	AIE 25472	Phalange 1	-17.5	6.9	3.2
Bajo del Coypar II	BCII 210	III	<i>Vicugna vicugna</i>	AIE 25487	Metapodial	-17.8	4.5	3.4
Corral Alto	CA 102	II	<i>Vicugna vicugna</i>	AIE 27377	Phalange 1	-15.4	7.4	3.3
Corral Alto	CA 90	II	<i>Vicugna vicugna</i>	AIE 27379	Phalange 1	-14.2	6.6	3.1
Corral Alto	CA 108	II	<i>Vicugna vicugna</i>	AIE 27381	Phalange 1	-15.6	7.1	3.1
Real Grande 1	RG 1 64	I	<i>Vicugna vicugna</i>	AIE 25480	Metapodial	-18.5	5.4	3.1
Real Grande 1	RG 1 62	I	<i>Vicugna vicugna</i>	AIE 25482	Metapodial	-19.0	5.7	3.3
Real Grande 1	RG 1 183	II	<i>Vicugna vicugna</i>	AIE 25470	Metapodial	-18.6	7.0	3.0
Real Grande 1	RG 1 177	II	<i>Vicugna vicugna</i>	AIE 25474	Metapodial	-18.7	5.7	3.1
Real Grande 1	RG 1 72	II	<i>Vicugna vicugna</i>	AIE 25477	Humerus	-18.2	5.1	2.9
Real Grande 1	RG 1 3	II	<i>Vicugna vicugna</i>	AIE 25491	Phalange 1	-19.7	4.7	3.2
Real Grande 6	RG 6 241	II	<i>Vicugna vicugna</i>	AIE 25479	Metapodial	-17.9	6.5	3.2
Real Grande 6	RG 6 259	III	<i>Vicugna vicugna</i>	AIE 25467	Metapodial	-18.5	4.9	3.3
Real Grande 6	RG 6 213	III	<i>Vicugna vicugna</i>	AIE 25478	Phalange 1	-19.0	5.4	3.2
Real Grande 6	RG 6 219	III	<i>Vicugna vicugna</i>	AIE 25481	Metapodial	-18.3	5.4	2.9
Real Grande 6	RG 6 217	III	<i>Vicugna vicugna</i>	AIE 25492	Phalange 1	-18.0	5.4	3.0
Real Grande 6	RG 6 256	III	<i>Vicugna vicugna</i>	AIE 25493	Metapodial	-18.1	6.1	2.9
Real Grande 6	RG 6 230	IV	<i>Vicugna vicugna</i>	AIE 25483	Phalange 1	-18.3	4.6	3.0

3.1. Rangelands used by domesticated and wild camelids

3.1.1. Archaeological and modern llamas

The llamas segregated into two discreet subgroups according to $\delta^{13}\text{C}$ values (Fig. 3). The first group aggregated the majority of the samples analysed and showed an average value of -17.6% . These values were close to those of four modern-day llamas from Antofagasta de la Sierra

that grazed on natural pastures, located at different altitudinal levels. Their diet was markedly different to that of llamas foddered on alfalfa, an allochthonous C_3 plant.

The second group, represented by samples 16.4 10, 16.4 184 and BCII 264, averaging $\delta^{13}\text{C}$ values of -12.3% , were considerably more enriched than those of the previous group. The difference between the carbon isotope values of these two groups was also statistically

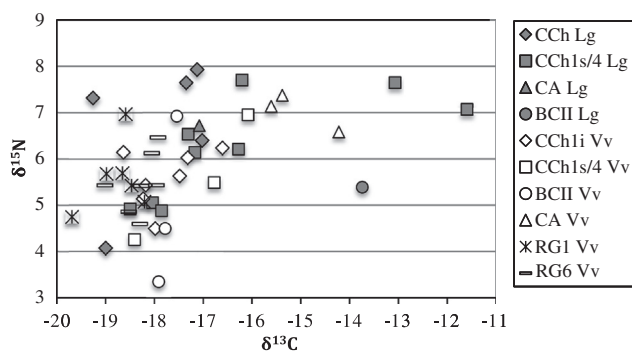


Fig. 2. Carbon and nitrogen stable isotope values of archaeological llamas (Lg) and vicuñas (Vv) bone collagen from Antofagasta de la Sierra sites.

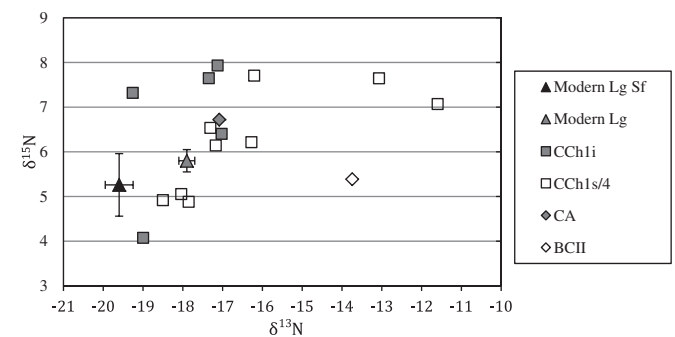


Fig. 3. Carbon and nitrogen stable isotope values of archaeological llamas compared to the isotopic signatures of modern llamas (averages and S.D.) of Antofagasta de la Sierra. Lg Sf: llama with supplementary foddering; Lg: llamas grazing on natural pastures.

significant (t -test, $P < 0.005$), even though this difference was not observed in the $\delta^{15}\text{N}$ values (t -test, $P > 0.005$), given that the samples with the highest $\delta^{13}\text{C}$ values had $\delta^{15}\text{N}$ values within the range observed in the rest of the samples in the assemblage.

With the object of understanding the general tendencies marked by the analysis, in Fig. 4, the sample was expanded by adding 46 published modern llama carbon values from different altitudinal levels within the Northern Puna (Fernández and Panarello, 1999–2001; Yacobaccio et al., 2009, 2010). Once again the values segregate into two distinct groups.

In respect of the first group, which had more impoverished $\delta^{13}\text{C}$ values, the majority of the samples, especially those corresponding to the Early Formative, were close to the modern values for llamas herding on natural pastures located above 3900 masl. Conversely, the convergence of the archaeological values for llamas located below 3900 masl was much less, generally belonging to samples from the Late Formative and Late Period.

In the second group, two samples from the Late Formative, and one from the Late Period, aggregated themselves around a single modern $\delta^{13}\text{C}$ value, that of a Northern Puna llama. This last value, recorded in the study of Fernández and Panarello (1999–2001), was viewed by Yacobaccio et al. (2009: 152) as evidence of human intervention in the animal's diet, possibly through foddering on maize.

3.1.2. Archaeological and modern vicuñas

Turning to the wild camelid samples (Fig. 5), 6 of the archaeological samples showed relatively enriched values in both isotopes, averaging for $\delta^{13}\text{C}$ -15.8‰ , and for $\delta^{15}\text{N}$ at 6.6‰ . Said values converge well with the average values for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ registered in modern-day vicuñas of the study area whose territorial range was located below 3900 masl, within the *tolar* plant communities.

The rest of the samples exhibited more impoverished $\delta^{13}\text{C}$ values, averaging -18.3‰ , thus showing a closer correlation to modern-day vicuñas grazing above 3900 masl and associated to the *pajonal* plant communities, although some of the values occupied an intermediate position between *pajonal* and *tolar* plant communities. The $\delta^{15}\text{N}$ values belonging to this assemblage averaged 5.4‰ , presenting a higher than expected level of enrichment for samples at this altitudinal range. Likewise, the difference between the carbon isotope values of these two groups was statistically significant (t -test, $P < 0.001$).

In Fig. 6, 19 $\delta^{13}\text{C}$ values from modern vicuñas located in the Northern Puna (Fernández and Panarello, 1999–2001; Yacobaccio et al., 2009, 2010) were added to the analysis. On this basis, three of the samples from the CA site had values analogous to those registered for modern-day vicuñas fed on *tolar* plant communities. Meanwhile, the samples

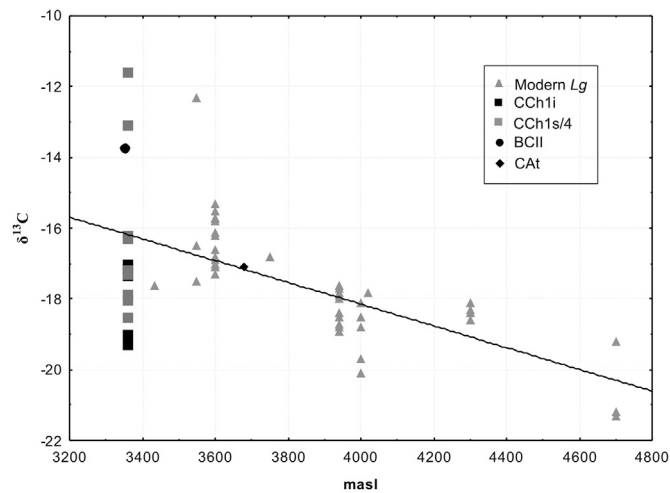


Fig. 4. Carbon stable isotopic values of modern llamas from the Northern and Southern Puna compared to the isotopic signatures of archaeological specimens from Antofagasta de la Sierra sites.

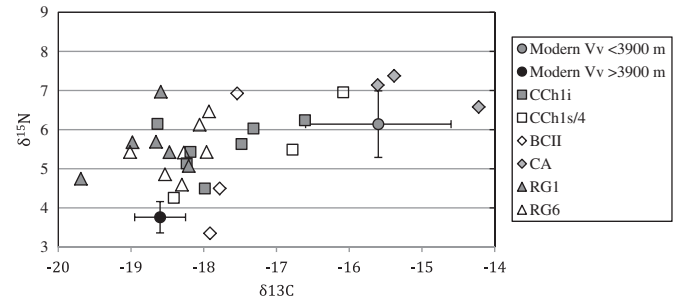


Fig. 5. Carbon and nitrogen stable isotope values of archaeological vicuñas compared to the isotope signatures of modern vicuñas (averages and S.D.) of Antofagasta de la Sierra.

from high altitude sites RG1 and RG6 presented impoverished values that converged with those obtained for vicuñas located in *pajonal* plant communities.

At the site of Casa Chavez Montículos, an Early Formative and two Late Formative values were close to the more impoverished values obtained for modern-day vicuñas grazing on *tolar* plant communities. The rest of the archaeological samples showed values that converged with those of the more enriched modern-day vicuñas from high altitude *pajonal*. This also seemed to be the case for the samples from the Bajo del Coypar site. It is important to note, that we do not have present-day values for vicuñas located in the *tolar/pajonal* ecotone (3800–3900 masl). Therefore, it is possible that certain archaeological values, in particular those clustering around -17.4‰ , could correspond to archaeological vicuñas from that ecotone, and not from the more distant high altitude *pajonal*.

Finally, I should mention that to date there are no clear patterns within the $\delta^{15}\text{N}$ values, aside from the fact that the values are within the expected parameters for herbivores living in arid environments. This would indicate that other variables, beyond those of altitude, such as variations in precipitation through time, or in soil salinity of pastures (e.g. pastures near to salt-pans) (Pate, 1994), have to be considered in any future studies.

4. Discussion: diachronic trends in herding and hunting strategies

Isotopic variation in archaeological camelids from the Antofagasta de la Sierra Basin, especially in $\delta^{13}\text{C}$ values, indicated heterogeneity in Prehispanic camelid diet through time. This in turn, suggested the

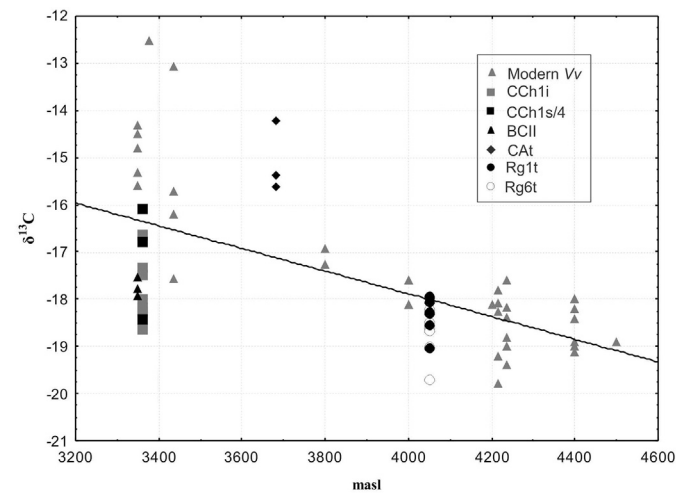


Fig. 6. Carbon stable isotopic values of modern vicuñas from the Northern and Southern Puna compared to the isotopic signatures of archaeological specimens from Antofagasta de la Sierra sites.

existence of variability in the forms of animal husbandry and in the mobility circuits linked to the exploitation of wild camelids.

4.1. Early and Late Formative Period

The $\delta^{13}\text{C}$ values of the archaeological *Lama glama* specimens analysed for the Early Formative site (CChM1i) showed variation ranges suggesting that, during this period, there was a strategy of animal management based on range-stock grazing on puna pasture characterised by a predominance of C_3 flora, with an emphasis on high altitude *pajonales*. For the Late Formative Period site (CChM1s/4), most of the individuals analysed had $\delta^{13}\text{C}$ values consistent with a diet of mainly C_3 vegetation, although in general exhibiting more enriched values than the samples from the Early Formative. Nevertheless, two llamas had values significantly more enriched than those expected for camelids feeding on puna pastures. This would indicate a major C_4 plant input in the animal's diet.

Based on this data, I propose that two different types of pastoralist strategies were at play during this time. At one end, the individuals with relatively impoverished $\delta^{13}\text{C}$ values would seem to indicate a continuation of the strategy observed in the Early Formative Period. That is, one based on range-stock grazing of high altitude puna *herbaceous grasslands*.

Conversely, the individuals with enriched values suggests the emergence of a new pastoralist strategy characterised by a contraction in mobility, thereby maintaining the herds nearer to the lower basin settlement where there was greater availability of C_4 plants, and/or the complementing of their diet through the use of a C_4 plant as fodder, possibly maize. Maize is a C_4 plant that in Antofagasta de la Sierra has an average isotopic value of $\delta^{13}\text{C}$ de -11.2‰ (Killian Galvan et al., 2014).

Although the use of maize for fodder is a possible dietary strategy, we should bear in mind that a direct correlation between high $\delta^{13}\text{C}$ values – when not substantiated by high $\delta^{15}\text{N}$ values – and a maize diet is not a foregone conclusion, especially in ecological settings where wild C_4 plants also grow (Thornton et al., 2011). In the case of Antofagasta de la Sierra though, the predominance of wild C_3 plants, coupled to the general absence of specific patches with a predominance of wild C_4 plants, and the ethology of llamas does suggest that the controlled management of these camelids through maize foddering from agricultural residues is a distinct possibility. This rationale gains further support when we consider that this increase in $\delta^{13}\text{C}$ values in camelids coincides with the expansion of agriculture in the area. Studies demonstrating a similar tendency, that is the use of maize as supplementary fodder, have been reported in other Northwestern Argentina and Central Peruvian Andean camelid samples (e.g. Dantas et al., 2014; Izeta et al., 2009; Finucane et al., 2006; Mengoni Goñalons, 2007).

Meanwhile, the $\delta^{13}\text{C}$ values obtained from Formative Period wild camelids suggest that even though some resources were hunted near to the lower basin settlement – especially during the Late Formative – the majority were killed in areas far from this site. These hunting areas would have been high altitude environments with *pajonal*-type vegetation, with the added possibility of vicuña hunting in the *tolar/pajonal* ecotone (3800–3900 masl). Both these sectors are located a distance of between 15 and 20 km from the lower basin.

Therefore, it is probable that the exploitation of wild resources throughout the Formative Period took place within the framework of pastoralist transhumant patterns. The annual herding cycle would have conditioned movement to, and from, the lower basin for herders seeking pastures for their domesticated animals. Wild animal hunting would have been a by-product of herding at different altitudes, thereby forming part of an active economic diversification strategy that allowed herders to ameliorate the risks associated with herding small groups of llamas in unstable environments such as the puna (Escola, 1996). Nevertheless, towards the end of this period there is a decrease in the relative importance of hunting. This decrease could be associated to the

increase in agriculture detected in different sectors of the basin (Grant, 2014; Olivera and Grant, 2008).

4.2. Late Period

For the Late Period, we have two samples of *Lama glama*; the one from the BCII site gave a relatively enriched $\delta^{13}\text{C}$ value, while the value for the specimen from the CA site was more impoverished. Given that both samples came from sites located below 3900 masl it is possible that these values indicate the coexistence of the different herding strategies described previously. In this sense, the case of BCII could be demonstrating the consolidation of this new strategy in which the diet of the herds is more strictly controlled; while at CA, the values correspond to that of herds grazing on natural pastures near to the site, or on the *tolar/pajonal* ecotone.

Crucial to these varied herding strategies are the emergent differences in the distances travelled to obtain wild resources; so, while at BCII the vicuñas were being obtained from areas far from the settlement, at CA, vicuñas were being hunted in the nearby *tolar*. As previously noted, it is during this time that hunting resumed its importance within the economy of the communities in the area. This is highlighted by the appearance in the archaeological record of hunting and herding stations such as RG1 and RG6, the second of which was dedicated exclusively to hunting (Grant, 2014), and were the isotope signature of the vicuñas shows that these were being killed near to these sites. An increase in the importance of hunting could indicate a degree of specialisation within the economic landscape for this later period (Grant, 2014; Urquiza and Aschero, 2006).

Therefore, while the isotope sample size for domesticated camelids from the Late Period may be limited, when analysed in context it is possible to infer certain trends from the evidence. By this period, agriculture anchored in the lower basin and involving significant hydraulic investment was both intensive and extensive, probably requiring a greater degree of sedentism (Elías, 2014). This increased sedentism would have had repercussions on what type of herding strategies could have been implemented. In this scenario, a decrease in transhumance might have led to the need for complementing the diet of animals with agricultural residues.

At the same time, this new type of agropastoralism would have allowed a dual intensification of agriculture and herding. In turn, this would have opened up the possibility for certain sectors of society to abandon this type of mixed economy in favour of a specialisation in hunting. This might have meant that for this period the exploitation of wild animals was not restricted solely to their meat, but also to other by-products such as fibre, leather, etc. (Grant 2014; Olivera and Grant, 2008; Moreno and Revuelta, 2010).

In summary, the products produced by these various strategies – fibre and meat from hunting, and fibre and transport from specialised herding – would have been a crucial element in exchange, and an important conduit for social interaction within a context of inter-regional trade, emergent elites, tribute and/or a combination of these, against a background of ever increasing integration by this region into the political economy of the South-central Andes (Grant, 2014). In these circumstances, some of these groups would have bet on long established subsistence strategies for this area – hunting, herding and agriculture – and reorganised them to form a new socio-economic system. Similar processes have been identified across the Andes, such as at Conchopata (Finucane, 2007), the Cordillera Negra of the Ancash Province, Peru (Lane, 2006), as well as the Ambato Valley (Dantas et al., 2014), the Vocavil Valley and the Quebrada de Humauaca (Mengoni Goñalons, 2007) in Northeastern Argentina.

Nevertheless, this new mode of economic organisation seems to have functioned in parallel with the existing, deep time, local tradition epitomised by sites such as Corral Alto (CA). Here we have a continuation of small-scale modes of production in certain sectors of the Antofagasta de la Sierra Basin (Elías, 2014; Escola et al., 2013; Grant and Escola,

2015). This in turn, serves to emphasize the inherent variability in economic strategies employed in the area, set against a backdrop of growing social and political complexity.

5. Conclusions

The results of stable carbon isotope ratios on domestic camelid remains from five archaeological sites dating from the Formative through to the Late Period in the Antofagasta Sierra Basin suggest the existence of at least two different types of camelid herd management strategies in the area.

A first, consistent with the exploitation of natural pastures present in different environmental sectors of the basin, and a second, characterised by a reduction in mobility and the possibility of complementing the llama's diet through the use of supplementary fodder. Although this last strategy has been detected in other Andean areas (Dantas et al., 2014; Izeta et al., 2009; Finucane, 2007; Mengoni Goñalons, 2007), the case analysed here constitutes the first time that this has been supported through recourse to stable isotope ratios for the puna area. As such this research challenges the traditional models that suggest that only one type of pastoralism was practiced in the puna, that of a camelid range-stock strategy with little, if any foddering (Gundermann, 1984; Flannery et al., 1989; Flores-Ochoa, 1979; Yacobaccio et al., 1998).

Likewise, the $\delta^{13}\text{C}$ values in wild camelids serve to demonstrate the varying distances travelled to obtain these resources. These hunting patterns could also be linked to the different herding strategies described above. In this manner, the new agropastoralist modality would have allowed, to certain sectors of the society, the possibility of abandoning a mixed agropastoralist model, opting and permitting the rise of a specialisation in hunting. In essence, the emergence during the Late Formative of a new agropastoralist mode of production and its consolidation during the Late Period, alongside the more traditional range-stock strategy, highlights how local groups responded to the economic and political challenges detected for this period in the South-central Andes.

To conclude, the isotopic data for wild and domestic camelids shown here represents one of the first such studies on the Prehispanic agropastoralist societies that inhabited the Antofagasta de la Sierra Basin. Further isotope analyses on camelid skeletal material is necessary. Nevertheless, this preliminary work has demonstrated that isotope analysis is a crucial tool towards understanding continuity and change in the livelihood of these Prehispanic highland communities. In particular, isotope analysis has shown that even in areas considered traditional, and almost exclusive, to natural high altitude pastureland camelid pastoralism, varying economic, social and political conditions through time engendered different combinations of farming, herding and hunting management strategies across these varied geographical areas.

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