International Journal of Osteoarchaeology
Int. J. Osteoarchaeol. 24: 149–165 (2014)
Published online 4 November 2013 in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/oa.2351

SPECIAL ISSUE PAPER

Llamas in the Cornfield: Prehispanic Agro-Pastoral System in the Southern Andes

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ABSTRACT We report a study of the organisation of camelid production at the Ambato Valley, northern Argentine Andes, between the 6th and 11th centuries AD. We aim to contribute to the understanding of the different modes of economic production adopted in the past within non-egalitarian social contexts.

In view of this, information collected from previous studies is analysed from multiple perspectives, centering on the application of different analytical techniques to the assemblage of camelid bones (anatomical and taxonomical identification, osteometry and stable isotopes), to their diverse archaeological contexts and architectural and agricultural units, together with the implementation of frames of reference and ethnoarchaeological models. The results support the presence of an organisational mode for the production of plants and animals on the basis of a combination of different agrarian and livestock productive strategies under a unique new integrated agro-pastoral practice, differing from both previous ones. This new practice combined, in the very same land, the use of pens and agriculture terraces in an annual productive cycle adjusted to the seasonal calendar, where maize production was used as stubble for llamas during the dry season, at the same time those fertilised corn fields during fallow.

Although this new practice suggests an intensification in production, the bond and synergy of animal and plant productive strategies in a single practice could be considered risky because it decreases the range of possible responses to external fluctuation, to the extent that these could have influenced simultaneously or indirectly on both resources. This might have implied an extra factor contributing to the destructuration of the Ambato societies around 1000 AD. Copyright © 2013 John Wiley & Sons, Ltd.

Key words: agro-pastoral practices; herding; agriculture; South American camelids; maize

Introduction

One of the questions raised in connection with the archaeology of Ambato Valley, Catamarca, Argentina, involved understanding the organisation of camelid production in the particular context of Aguada, between the 6th and 11th centuries AD. In this regard, one of the first hypothesis postulated considered a model of animal and plant production characterised by a broad area of farmlands in foothills and on slopes, in addition to some scattered settlements among them, whereas grazing was held at higher elevations, more precisely in the high grasslands on the hilltops of both valley slopes (Kriscautzky, 1996/1997; Laguens, 2004). Similarly, the possibility of a system of complementarity of broader spatial scope was also proposed, ranging from the Eastern rainforests (area of exotic woods, hallucinogens and snails) to the high grasslands in the northern valley and western Puna, with access to products and/or grazing areas (Perez Gollán *et al.*, 1996/1997; Marconetto, 2008). In both cases, livestock production was understood as autonomous and complementary strategies to agricultural production, both performed in different and mutually exclusive spaces, according to a productive landscape zoning, either on a local valley scale or a larger extra-local scale (Laguens, 2004).

However, our most recent research departs substantially from such interpretations and allows us to discuss the feasibility of the said model, as well as the possibility of no geographical and seasonal separations between

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Received 26 October 2012
Revised 1 October 2013
Accepted 4 October 2013

agricultural and pastoral practices; instead, both strategies may have evolved in the same space and with a single infrastructure, resulting in an integrated agro-pastoral production.

Thus, to test these hypotheses, this paper reviews some of the main results obtained from different lines of inquiry. First, studies of zooarchaeological materials (i.e. anatomical and taxonomical identifications, osteometric studies) from different sites located in the depressed area of the valley are considered. Then, analyses of stable isotopes of camelid bones are examined, in order to determine feeding management and procurement areas. Finally, other lines of evidence are discussed, including microfossil analysis (silica phytoliths, starch grains, etc.), chemical studies of soil (phosphorus, organic matter, pH), spatial analysis and experimental archaeology, along with the application of frames of reference and ethnoarchaeological models.

Aguada of Ambato

Between the 6th and the 11th centuries AD, in the Ambato Valley, a complex society focused on maintaining social inequalities was developed (Laguens, 2006). This new way of life, archaeologically characterised as Aguada of Ambato (Gonzalez, 1998), was based on an intensification in the exploitation of resources, associated with population growth, diversification of social roles and marked economic, social and political inequalities. From the onset, this society came to interact with population in surrounding areas, which were integrated into a single supra-regional sphere, each with its own characteristics (Perez Gollan, 1991; Laguens, 2004).

This social configuration was grounded in a surplus base of cultivated and natural products (Laguens, 2004), a hierarchical system of rights and opportunities for housing and community land use (Laguens and Bonnin, 2005), along with an organisation of ceramic production with some degree of specialisation and standardisation (Laguens and Juez, 2001; Fabra, 2007) and differential access to material goods and natural resources (Marconetto, 2008). This organisation was reinforced by an ideology and a hitherto unknown display of ceremonialism, materially expressed in the ceremonial complex of squares and pyramids, and an iconography centred on representations of felines or jaguars, elements that are part of an extensive geographic area of the Southern Andes (Perez and Heredia, 1987; Gonzalez, 1998; Gordillo, 2003; Laguens, 2004, 2006).

With regard to subsistence, it was based on farming in agro-pastoral systems on both sides of the valley (Figueroa, 2010), supplemented, to a lesser extent, by hunting and gathering (Laguens, 2004). The resource catchment area covered ecological zones located more than a day away, from the Yungas in the east (an area of forest, tropical products and hallucinogens) to the highland plains in the west (possible grazing area) (Pérez Gollán *et al*., 1996/1997; Marconetto, 2008).

In the centre of the valley, up to 1100 m a.s.l., in an environment characterised by mountain forest (Morláns, 2007), the highest density of occupation surveyed to date registers 292 sites. These sites have a complex residential pattern, differentiated by the density and variety of domestic and public sites, as well as the monumentality of some buildings (Assandri, 2007). Residential sites

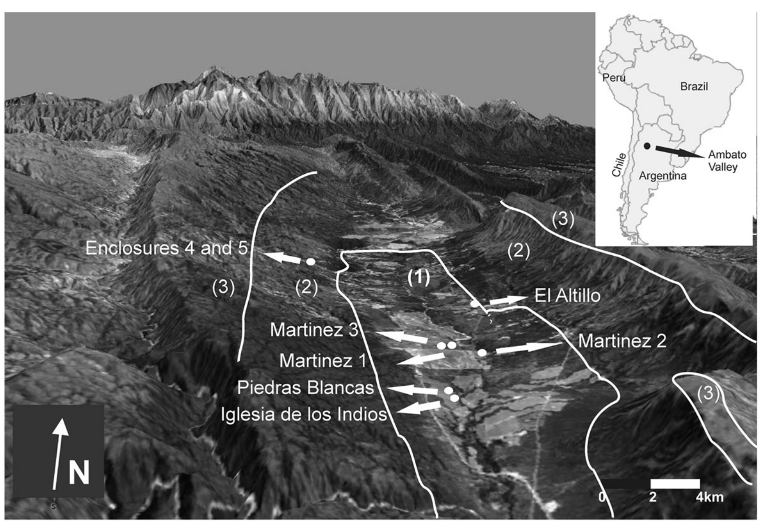

Figure 1. Ambato map with site locations. References: (1) central sector of the valley with highest density of residential sites; (2) area of agro-pastoral production; (3) sector of high grassland vegetation.

resembling villages were grouped into at least three sets, with a similar spatial hierarchy and structuring. In each of these groups, the presence of a particularly large main site is highlighted, characterised by a stepped mound, a central square and surrounding enclosures (e.g. Iglesia de los Indios, Gordillo 2003 and Bordo de los Indios), surrounded nearby, for some residential sites of multiple enclosures and patios. At the periphery of these sets, smaller sites are distributed, which are larger in number than the previous ones (Laguens and Bonnin, 2005; Assandri, 2007).

Higher up, between 1100 and 1600 m a.s.l., lies an extensive area of about 800 ha devoted to animal and plant production, which includes varied agricultural terraces and enclosures, and irrigation and water storage structures (Figueroa, 2008, 2010). This entire infrastructure lays at the confluence of two main ecological environments, such as the mountain forest and the shrub-grassland (Morláns, 2007).

Above this area, more precisely from 1600 m a.s.l., high grassland vegetation develops (Morláns, 2007). There, the archaeological structures are meagre (Figure 1).

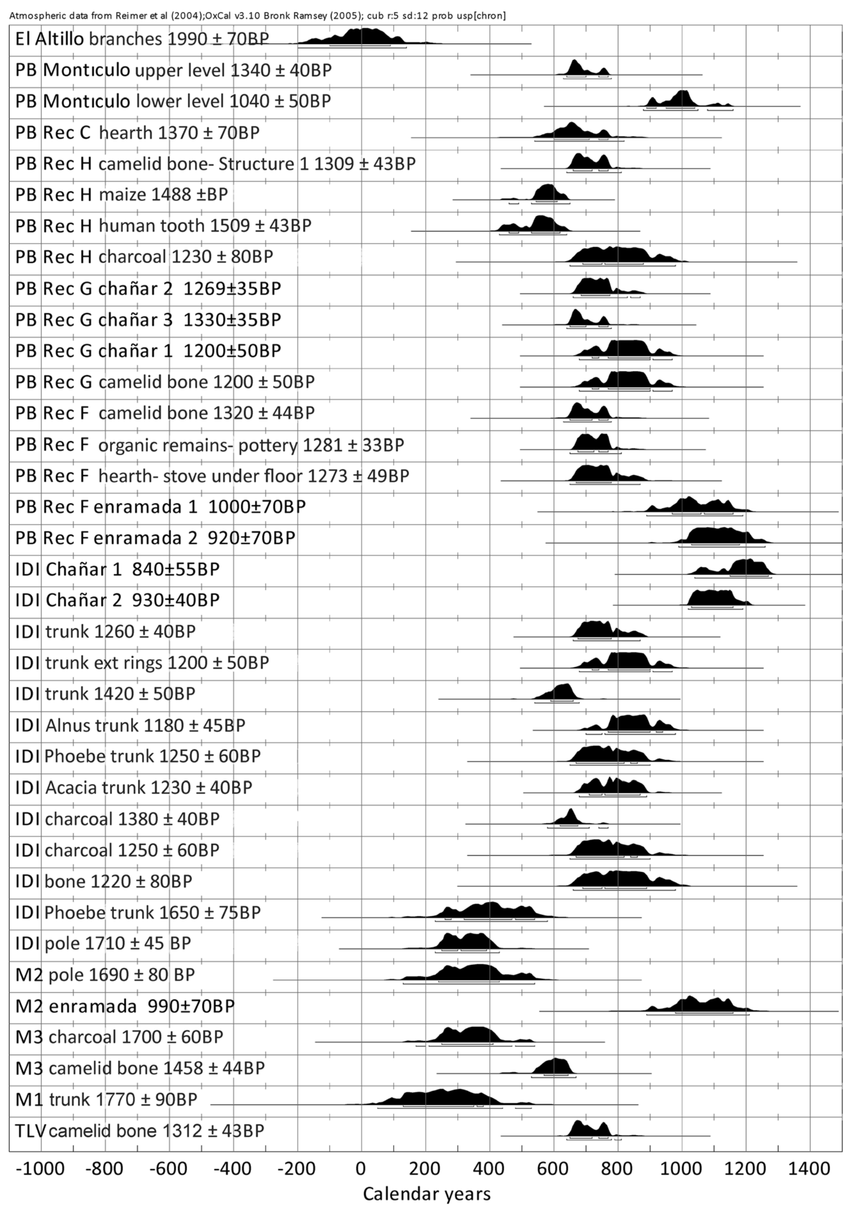

Figure 2. Radiocarbon datings of Ambato Valley (PB = Piedras Blancas; IDI = Iglesia de los Indios; M2 = Martinez 2; M3 = Martinez 3; M1 = Martinez 1; TLV = Enclosures 4 and 5 Terraza de los Varela) (data taken from Bonnin and Laguens, 1997; Gordillo, 2003; Laguens and Marconetto, 2010; Marconetto, 2008).

Evidence for agro-pastoralism

On the basis of the questions raised at the beginning of the work, this section presents the results of zooarchaeological and stable isotope analyses, surveys and excavations in the valley slopes, allowing us to distinguish between the different hypotheses postulated.

Zooarchaeological evidence for agro-pastoralism

The archaeofaunal materials studied come from four sites placed at the bottom of the valley: Piedras Blancas, Martinez 1, Martinez 2 and Martinez 3 (Figure 1).

Piedras Blancas has two different sectors: a mound and one with constructions, which was defined as an elite residence of large dimensions (Assandri, 2007). The archaeofaunal material studied consists of 5895 specimens: 2739 (46.5%) were identified anatomically and taxonomically; 3156 (53.5%) were classified as indeterminate.

Martinez 1 consists of a room-unit and a mound dump; it served the function of a workshop, where various handcrafts were developed (Assandri, 1991). Heredia (1998) has suggested that this site might have been occupied by a small domestic group. Recovered faunal skeletal remains comprise 98 specimens, of which 62.3% (61 specimens) were identified.

Martinez 2 is a site surrounded by a double stone perimeter wall, with two sections of rooms separated by a central courtyard and terraced galleries. The total sample consists of 96 specimens, out of which 36 (37.5%) were identified anatomically and taxonomically.

Finally, Martinez 3 was characterised as an outdoor isolated mound site (Assandri, 2007), composed of an accumulation of various archaeological materials. On the basis of the analysis of ceramic materials and their stratigraphic position, Avila and Herrero (1991) identified two stages in the formation of the site: its lower levels correspond to pre-Aguada occupations, whereas the upper ones belong to Aguada culture. Bone material recovered in Aguada levels totaled 457 specimens, of which 57.6% were identified [number of identified specimens (NISP) 263].

Radiocarbon dates locate the occupation of these sites between the 4^{th} and 11^{th} centuries AD (Bonnin and Laguens, 1997; Marconetto, 2008; Laguens and Marconetto, 2010) (Figure 2).

The methodology followed for the analysis of these assemblages consisted, first, in the anatomical and taxonomic identification of faunal remains and their subsequent quantification using the following measures: number of identified specimens, minimum number of elements and minimum animal units (MAU and %MAU) (Klein and Cruz-Uribe, 1984; Lyman, 1994; Mengoni Goñalons, 1999; Mondini, 2003). In addition, in the case of specimens identified as Camelidae, %MAU was correlated with meat utility index, marrow index and drying index, developed by Mengoni Goñalons (1991, 1996, 2001) and De Nigris and Mengoni Goñalons (2004).[1]

As a result, it was determined that bone assemblages show a good state of preservation not greatly altered by natural processes such as weathering, chemical precipitation and the action of carnivores, rodents and roots. At the same time, the correlation between bone density values and frequency of anatomical parts of camelids showed, in no case, significant values (Dantas, 2010).

In all faunal assemblages, there was a clear dominance of camelids in comparison with other identified taxa (Figure 3). At a family level, in Piedras Blancas, camelids comprise 77.4% of all identified taxa, 93.3% of Martinez 1, 96.9% of Martinez 2 and 87.4% of Martinez 3 (Dantas, 2010). The remaining taxa not only show very low percentages but also small body size, representing a very low meat intake, and even some of them entered the site after its abandonment (i.e. Didelphidae, Cricetidae, Caviidae, Ctenomyidae, Mephitidae and Lacertilia).

The implementation of osteometric studies[2] allowed discriminating three groups: one that gathers vicuñas[3] (12.8%), another comprising llamas (46.8%) and a third one composed of reference guanacos (40.4%) (Dantas, 2010). In the last case, due to the fact that the size range of the Andean guanaco overlaps with the smaller one of llamas, as already mentioned by Mengoni Goñalons (2007), we decided to assign those specimens to the category of 'llama-guanaco', according to Lopez (2003) and Olivera and Grant (2009), among others.

[1] For a detailed description of the methodology followed in this paper, see Dantas (2010).
[2] The methodology followed is the one proposed by Menegaz *et al*. (1988), summarised and used by Cardich and Izeta (1999–2000) and Izeta (2004, 2007). Thus, quantitative multivariate analyses were performed (cluster analysis and principal component analysis) to bones of the postcranial skeleton, using the characters given by Izeta (2004) and Kent (1982).
[3] The vicuña is a foreign species into the valley, as its current distribution corresponds to Puna and Andean ecosystems, 3000 m a.s.l. (Laker *et al*., 2006; Wheeler, 2006). Through osteometric and morphological comparative, analysis could only be ascribed proximal and medial phalanges and a metapodial to this taxon. For this reason, we believe that these specimens must have mainly entered the sites along with the hides of these animals, because as noted by Haber (1999, 2007) and Silveira (1979), the phalanges usually remain in the hides after skinning of the animals. As for how these resources were obtained, for the moment, it is not possible to establish whether they were acquired by exchange or direct access.

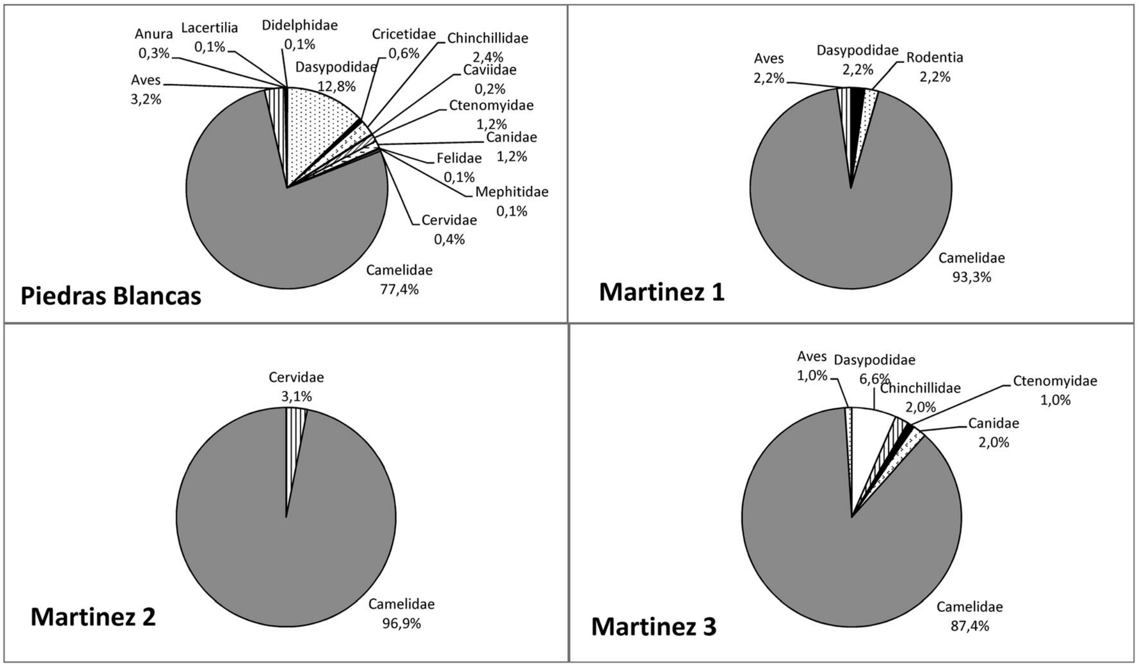

Figure 3. Percentage of identified specimens per site, grouped by family.

With regard to age classes,[4] there are individuals ranging from newborns to those exceeding their 10 years, providing possible indicators of the development of management activities and the use of herds (Browman, 1989). In Piedras Blancas, adults, juveniles and young groups are represented, adults showing a higher percentage. In Martinez 1 the adult category reveals a greater number of individuals, while in Martinez 3 adults show the highest number of individuals (Table 1).

At all sites, the relative frequency of adult and juvenile young animals remains around 50%: it is the case of Martinez 1 and Martinez 3 sites (50% young and juveniles and 50% adults) and somewhat higher in Piedras Blancas (56.7% young and juveniles compared with 43.4% adults) (the size of the sample from Martinez 2 site precluded this type of analysis). These patterns in animal mortality are similar to those expected in a model of meat production (Yacobaccio *et al.*, 1998; Dantas, 2010).

Whole carcasses are largely represented at all sites albeit with dissimilar proportional distribution. In Piedras Blancas, a higher hierarchy residential site, entire carcasses are mostly represented for all age classes, expressing, except for juveniles, an imbalance in favour of the extremities. These show certain variability in different structures of the site, which tends to balance both regions of the skeleton. The correlations of the economic utility indexes made it possible to identify a selection of anatomical parts containing higher proportions of marrow in the adult and the young groups (Dantas, 2010).

At the other sites, all smaller than Piedras Blancas, some variations between them were also found. For example, in Martinez 1, most elements in the adult category were from the appendicular region, whereas in the remaining age classes, elements of only one of the anatomical regions were identified. By correlating this with the economic utility indexes, it could be observed that although elements having high meat content or showing more suitability for drying were

Table 1. Percentage of adults, juveniles and young camelids discriminated by sites

Site	Young	Juveniles	Adults
M1	16.7%	33.3%	50.0%
M3	33.3%	16.7%	50.0%
PB	30.0%	26.7%	43.4%

[4] In this analysis, three age categories were established: young, juveniles and adults. The age limit between the first and second category is 12 months (Puig, 1988) and between juveniles and adults is 36 months, which is the age at which almost all bones of the skeleton are fused (Yacobaccio *et al.*, 1997/1998). For the differentiation between age classes, epiphysial fusion status of the bones, size of specimens, bone tissue characteristics and sequence of eruption and tooth wear were taken into account (Kent, 1982; Wheeler, 1982, Herrera, 1988; Puig, 1988; Kaufmann, 2004).

underrepresented in a particular sector of the site, in another sector, the presence of anatomical parts was not mediated by economic selectivity criteria.

In Martinez 3, however, the elements of the whole carcass were found within each age group, suggesting an imbalance in adults and young in favour of the extremities and a correspondence in juveniles between the two regions. In adult and juvenile categories, the frequency of anatomical parts corresponds to their proportions in the carcass, without having been selected by an economic criterion; in the young, those parts with a high marrow index are more frequent.

The location and frequency of cut marks, in conjunction with the proportion of anatomical parts, allow us to infer that some camelids were brought complete to the sites whereas other animals entered already butchered. In general, it seems that the whole range of activities had been developed within the site, from primary butchery to consumption and final disposal, using animals integrally and intensively.

In La Rinconada or Iglesia de los Indios, a large ceremonial site located near Piedras Blancas, similar results were obtained not only in terms of frequency and distribution of camelids but also in terms of their osteometry. Among the identified taxa, camelids were found to be prominent and almost all skeletal parts were represented, parts with high nutritional yield (mainly axial postcranial bones and hind legs) being predominant. In those cases where the specific identification of camelids was feasible, the presence of vicuñas and small llamas and/or guanacos was determined (Olivera, 1999; Fernandez Varela *et al.*, 2002; Gordillo, 2003; Svoboda, 2010a; Svoboda and Eguia, 2010).

Isotopic evidence for agro-pastoralism

The analysis of stable carbon isotopes was performed at the Instituto de Geocronología y Geología Isotópica-CONICET (AIE). Fifteen samples from Piedras Blancas were processed: 10 from the 'llama' group, four from 'llama-guanaco' and a long bone splinter from *Lama* sp. In order to compare them with pre-Aguada occupations, seven samples of long bones from the El Altillo site (dated 1990 ± 70 BP) were also analysed: one from *Lama* sp. and the rest from the 'llama' group (Izeta *et al.*, 2009, 2010). The methodology used for stable isotope analysis followed the procedures described by Tykot (2004). In the first place, the sample was cleaned with a mechanical drill, followed by an ultrasonic wash with bidistilled water. Secondly, the bone was demineralised in 2% hydrochloric acid for 72 h, renewing the acid every 24 h. With the purpose of eliminating postdepositional organic compounds, the material was soaked in sodium hydroxide at 0.1 M dilution for 24 h, before and after the process of demineralisation. Finally, the sample was rinsed and dried at < 60°C. The isotopic ratio ($^{13}C/^{12}C$) determination was performed on the CO_2 obtained by combustion of the collagen with CuO for 8 h at 550°C. The cryogenically purified carbon dioxide was measured in a Finnigan Delta-S mass spectrometer with triple collector and multiple introduction system.

To interpret the results obtained, modern llamas, alpacas, guanacos and vicuñas $\delta^{13}C$ values were used as a frame of reference (Fernández *et al.*, 1991; Fernandez and Panarello, 1999-2001a, 1999-2001b; Yacobaccio *et al.*, 2009, 2010; Thornton *et al.*, 2010; Samec, 2011). The samples with more enriched $\delta^{13}C$ values (above −14.5‰) correspond, in the modern samples, to domestic camelid grazing in environments below 3900 m a.s.l. The guanaco and vicuña show values ranging from −19.0‰ to −20.4‰ in environments above 3900 m a.s.l. At lower elevations, vicuñas show results ranging from −14.6‰ to −18.7‰, averaging −16.4‰ (Fernández and Panarello, 1999-2001b; Samec, 2011) (Figure 4). Tykot (2006) reports that in the case of animals, a diet focused exclusively on C_3 plants, transference to collagen of $\delta^{13}C$ is about −21.5‰; at the other extreme, however, those fed exclusively on C_4 plants exhibit values of −7.5‰. Thus, a diet consisting of a mixture of 50% C_3 plants and 50% C_4 produces a $\delta^{13}C$ value of ≅ −14.5‰.

Regarding the isotopic ecology of the Ambato Valley, Izeta *et al.* (2009) recorded plant species with forage capacity, in addition to their distribution and photosynthetic pathway (Table 2). Thus, they noticed the presence of species with C_3 and C_4 photosynthetic patterns, equally distributed across the different vegetation floors of the valley, showing no correlation between altitude and vegetation patches. That is to say, mountain forest, shrub-grassland and hilltop grassland have the same range of C_3 and C_4 plants, regardless of altitude.

The $\delta^{13}C$ values obtained from the Piedras Blancas site range from −9.5‰ to −13.1‰ (mean −11.15‰ ± 1.15‰); in El Altillo, they display more variation: between −11.8‰ and −17.1‰ (mean −14.00‰ ± 2.21‰) (Table 3). The statistical significance was tested by *t*-test, and the result shows a significant mean difference in the values of the samples of both sites ($t = 3.2251$, $p = 0.0121$). These data show that camelids from the earliest site were fed on plants with C_3 and C_4 photosynthetic pathways, distributed across the various vegetation floors of the valley; in Piedras Blancas, enriched $\delta^{13}C$ values represent a high intake of C_4 plants.

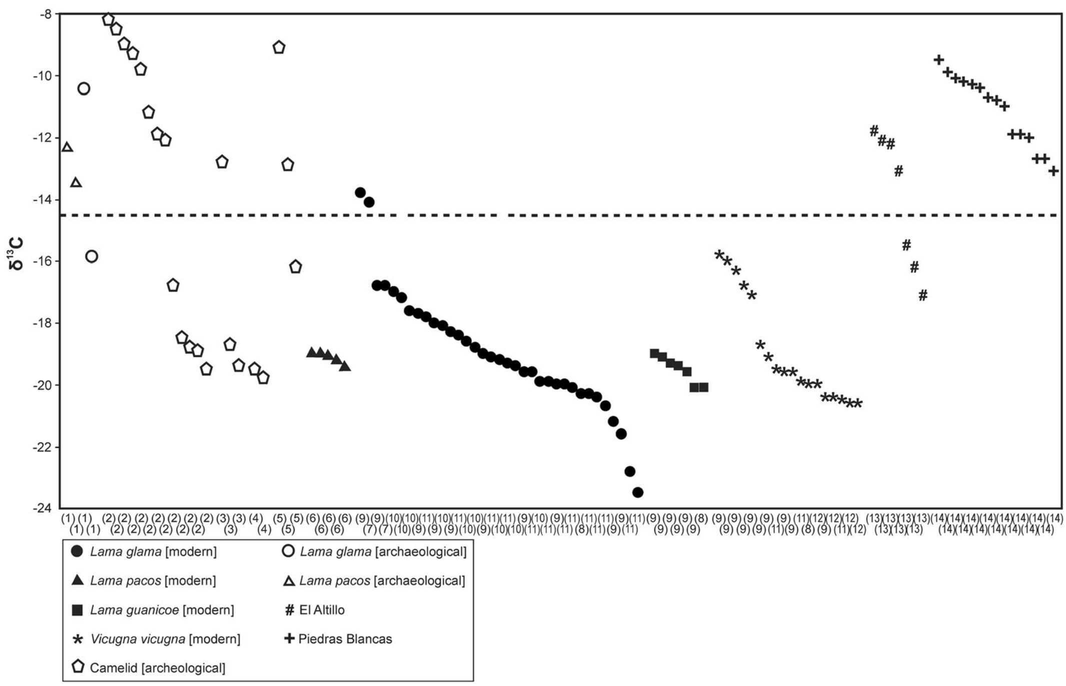

Figure 4. Carbon isotope values results. References: (1) data from Vásquez Sánchez et al. 2012, Zona Urbana Moche, Peru; (2) data from Finucane et al. 2006, Conchopata, Peru; (3) data from Burger and Van Der Merwe 1990, Chavin de Huantar, Peru; (4) data from Aufderheide et al., 1988 cited in Thornton et al., 2010, Pachamachay and Wari, Peru; (5) data from Verano and DeNiro, 1993, Pacatnamu, Peru; (6) data from Thornton et al., 2010, Chilligua, Peru; (7) data from Fernández et al., 1991, Puna of Jujuy, Argentina; (8) data from Fernández and Panarello, 1999-2001a, Puna of Jujuy, Argentina; (9) data from Fernández and Panarello, 1999-2001b, Puna of Jujuy, Argentina; (10) data from Yacobaccio et al., 2009, Puna of Jujuy, Argentina; (11) data from Yacobaccio et al., 2010, Puna of Jujuy, Argentina; (12) data from Samec, 2011, Puna of Jujuy, Argentina; (13) data from El Altillo; (14) data from Piedras Blancas.

At the same time, the $\delta^{13}C$ values of the 'llama' group in Piedras Blancas markedly differ from those recorded for local plant resources. The $\delta^{13}C$ values of the four specimens in Piedras Blancas, under the 'llama-guanaco' category, range between −9.9‰ and −13.1‰. These results diverge from those expected for wild animals (guanacos) and are similar to those recorded for specimens in Piedras Blancas, osteometricaly determined as llamas; even one of them has one of the most positive results of the sample (−9.9‰). We consider that if both groups, 'llama' and 'llama-guanaco', were feeding with the same restricted range of plants, having a high component of C_4 plants, probably, they could have been domestic animals of smaller size, that is, small llamas (Dantas, 2012).

It is worth noting the high consumption of C_4 species in Aguada samples compared with the earliest ones from El Altillo, depicting a more varied diet in the open field. Considering the mean values of Piedras Blancas (i.e. −11.1‰), the diet would have included 74.8% of C_4 and 25.2% of C_3 plants (70.2% based on the maximum value and 77.5 % based on the minimum $\delta^{13}C$ value, from a mean value of −14.5‰ in a balanced diet between C_3 and C_4)[5] ; in El Altillo (i.e. −14.0‰), it would have been 51.7% of C_4 and 48.3% of C_3, percentages consistent with the natural supply. The results from Piedras Blancas can also be seen to differ from reference values for llama, alpaca, guanaco and vicuña (Figure 4).

Although C_3 and C_4 palatable plants to camelids are distributed uniformly and in similar proportions (7/9, respectively) in the different vegetation units of the valley, we believe that by focusing on an intake of C_4 could be pointing to a directed feeding of the animals, because there is no specific patch with dominance of the latter, and even tree species suitable for grazing are all C_3 (Nogues *et al.*, 2001). It is feasible, then, that there was a controlled management in the animal feeding mode. Considering that the known

[5] This percentage of C_4 plant intake would increase even more if we consider what was observed recently by Andrew Ugan (pers. comm. 2012), who, by analysing the apatite-collagen difference from guanaco specimens (mostly archaeological) from Central South of Mendoza, Argentina, noted a collagen-diet difference of +2.1‰, which is similar to +3.5‰ registered by Sponheimer *et al.* (2003) for fractionation between hair and diet in multiple herbivore taxa (including llamas and alpacas) and distance from the generally considered +5‰ (Tykot 2004).

Table 2. Los Puestos river basin forager potential and photosynthetic pathways (taken from Izeta et al. 2009)

Taxa	C3	C4	δ13C	Environment	Altitude
Alchemilla pinnata (ROSACEAE)	X	—	−24.0	Hilltop grassland	2010 m a.s.l.
Botriochloa barbinodis (POACEAE)	—	X	—	Mountain forest	1100 m a.s.l.
Bouteloua sp. (POACEAE)	—	X	−12.2	Hilltop grassland/shrub-grassland	2010 m a.s.l. 1300 m a.s.l.
Bromus sp. (POACEAE)	X	—	−28.5	Hilltop grassland	2010 m a.s.l.
Cenchrus echinatus (POACEAE)	—	X	—	Shrub-grassland	1300 m a.s.l.
Cologania broussonetii (FABACEAE)	—	—	—	Hilltop grassland	2010 m a.s.l.
Cynodon dactylon (POACEAE)	—	X	−12.4	Hilltop grassland/shrub-grassland/ mountain forest	2010 m a.s.l. 1300 m a.s.l. 1100 m a.s.l.
Festuca sp. (POACEAE)	X	—	−27.5	Hilltop grassland/shrub-grassland	2010 m a.s.l. 1300 m a.s.l.
Glandularia peruviana (VERBENACEAE)	X	—	−28.1	Hilltop grassland	2010 m a.s.l.
Macroptilium panduratum (FABACEAE)	—	—	—	Mountain forest	1100 m a.s.l.
Neobouteloua lophostachia (POACEAE)	—	X	—	Shrub-grassland	1300 m a.s.l.
Paspalum unispicatum (POACEAE)		X	—	Mountain forest	1100 m a.s.l.
Paspalum malacophyllum (POACEAE)		X	—	Shrub-grassland	1300 m a.s.l.
Piptochaetium sp. (POACEAE)	X	—	—	Hilltop grassland	2010 m a.s.l.
Prosopis nigra (FABACEAE)	X	—	—	Mountain forest	1100 m a.s.l.
Setaria sp. (POACEAE)	—	X	—	Hilltop grassland/shrub-grassland/ mountain forest	2010 m a.s.l. 1300 m a.s.l. 1100 m a.s.l.
Sporobolus indicus (POACEAE)		X	—	Shrub-grassland	1300 m a.s.l.
Stipa sp. (POACEAE)	X	—	—	Hilltop grassland/shrub-grassland/ mountain forest	2010 m a.s.l. 300 m a.s.l. 1100 m a.s.l.
Zea mays (POACEAE)	—	X	−11.2	Cultivated	—

$\delta^{13}C$ value for South-Andean maize (*Zea mays*) is −11.2‰ (Falabella *et al.*, 2007: 9), it is very likely that the values obtained are the outcome of the consumption of maize by llamas in a high proportion, either from agricultural residues or from stubble (Dantas and Figueroa, 2009; Izeta *et al.*, 2009, 2010; Figueroa *et al.*, 2010).

Similar findings were reported in other camelid samples from northwestern Argentina: in one case, a large camelid from Pucará de Volcán with a $\delta^{13}C$ value of

Table 3. Stable isotope results

Sample	Group	Element	δ13C (‰)	±	Laboratory code
PB99 C15 39	Llama	Metapodial	−9.5	0.3	AIE 21565
PB00 RH N104 41	Llama-guanaco	Femur	−9.9	0.3	AIE 21564
Piedras Blancas	*Lama* sp.	Long bone	−10.1	0.3	AIE 13249
PB96 C1 N12 C`01	Llama	Metapodial	−10.2	0.3	AIE 21555
PB99 C56 N3 300	Llama-guanaco	Metapodial	−10.3	0.3	AIE 21561
PB00 RH N107 62-B	Llama	Metapodial	−10.4	0.3	AIE 21557
PB99 TM CE N1 021	Llama	Metapodial	−10.7	0.3	AIE 21554
PB99 C8 N19 h.36	Llama	Metacarpus	−10.8	0.3	AIE 21566
PB00 RH N106 17	Llama-guanaco	Tibia	−11.0	0.3	AIE 21556
PB00 RH N107 15-B	Llama	Metapodial	−11.9	0.3	AIE 21553
PB96 C1 N11 A`00	Llama	Femur	−11.9	0.3	AIE 21559
PB96 C1N12 C`79	Llama	Humerus	−12.0	0.3	AIE 21558
PB99 C56 N3 303	Llama	Metatarsal	−12.7	0.3	AIE 21560
PB96 C2 N22 A63	Llama	Metacarpus	−12.7	0.3	AIE 21563
PB99 C15 44	Llama-guanaco	Femur	−13.1	0.3	AIE 21562
El Altillo	*Lama* sp.	Metapodial	−16.2	0.3	AIE 13248
EA S2 N10600	Llama	Radio-ulna	−11.8	0.3	AIE 21550
EA S2 N13844	Llama	Humerus	−13.1	0.3	AIE 21549
EA S2 N13841	Llama	Tibia	−15.5	0.3	AIE 21548
EA S2 N13826	Llama	Unciform	−17.1	0.3	AIE 21547
EA S2 N16046	Llama	Metacarpus	−12.1	0.3	AIE 21551
EA S2 N16040	Llama	Humerus	−12.2	0.3	AIE 21552

PB, Piedras Blancas; EA, El Altillo.

−9.0‰, interpreted by Mengoni Goñalons (2007: 138) as extremely positive, indicating a C_4 plant-based diet, probably maize or a special type of pasture. Another case, reported by Fernandez and Panarello (1999-2001b: 81), comprises a llama from the Puna, below 4000 m a.s.l., with $\delta^{13}C$ values of −13.8‰, with 54% of the diet largely dependent on C_4 plants. Yacobaccio and colleagues view this as a human intervention in food intake, probably with maize (Yacobaccio *et al*., 2009: 152). In the case of Iglesia de los Indios, another Aguada site of Ambato valley, the results of three phalanges of camelids analysed by Svoboda (2010a, 2010b) yielded values of −11.2‰, −11.8‰ and −13.1‰, which were interpreted as belonging to a directed feeding, with high proportions of maize.

Finucane and colleagues (2006) found, in the central Andes, that for the Middle Horizon at the Conchopata site, the remains of alpaca and llama have different $\delta^{13}C$ values, −18.6‰ and −10.0‰, respectively. They interpreted them not only as two dissimilar feeding strategies in different environments, but also, in the case of the latter, as having an artificial diet restricted to maize. This differs from other Peruvian sites, such as the sierra and the coast, where foddering of domestic camelids in open fields was registered, with $\delta^{13}C$ values that reflect those from the natural forage of each zone (e.g. Vásquez Sánchez *et al*., 2012; Aufderheide *et al*., 1988: cited in Thornton *et al*., 2010). Exceptions include Chavin de Huantar (Burger y Van Der Merwe, 1990) and Pacatnamu (Verano and DeNiro, 1993), where the presence of some maize-fed animals (Figure 4) was also suggested.

Archaeological evidence for agro-pastorlism

As a result of the systematic survey, mapping and excavation on the foothills and mountain slopes of both sides of the valley (Figueroa, 2008, 2010; Dantas and Figueroa, 2009), between 1100 and 1600 m a.s.l., we identified a large area of about 800 ha devoted to the production of plants. This includes different agricultural terraces and enclosures made of stone walls, irrigation and water storage structures, as well as ceramic and lithic artefacts on the surface. Above this altitude range, only a few small semicircular stone structures, about 3 or 4 m in diameter, in the manner of parapets, were found (Figueroa, 2008, 2010).

Regarding specifically the farming terraces, three classes were recorded: hillside terraces on the mountain slopes, stream terraces and boxes situated on the beds of the tributary streams of the river Los Puestos (Figueroa, 2008, 2009). Additionally, among some terraces, there are small circular enclosures made of stone walls, of about 2 to 3 m in diameter, whose excavation yielded no results (Cruz, 2004).

From the excavation of six of these terraces, silica phytoliths and organic matter were obtained for study. It was notable to find, among silica phytoliths, the presence of maize (*Z. mays*) in the stabilisation level of the profiles, marked by the abundance of cross-shaped phytoliths from the group of morphotypes with panicoid affinity, along with some types of halteriform phytoliths that indicated that maize was one of the elements grown in these structures (Figueroa, 2010; Zucol *et al*., 2012). The presence of maize was also determined by carbonised macroremains of cobs and grains from the Microsperma race (popcorn) and Oryzaea race (rice popcorn), found in different contexts of valley floor households (Pochettino, 2000; Gordillo, 2003; Laguens, 2004; Marconetto, 2008).

A special consideration deserves the presence of bambusoid phytoliths, represented by *Chusquea lorentziana*, a species that, in the regional flora, is found only in the area of the mountain jungles of the Yungas Province (Morláns, 2007), particularly prolific in the shrub stratum. In three of the farming structures, the presence and amount of this element showed varying degrees, allowing us to estimate its presence as a result of an activity associated with these structures, for the purpose of repair or use of the own canes (Zucol *et al*., 2012).

On the other hand, a high amount of organic matter content was found in the sedimentary profiles, with little shrinkage along the whole profile. This may be due to natural factors (the arrangement of terraces in the landscape and their environmental variation), management practices and/or differential use of the terraces (Figueroa, 2010). In this sense, the fertilisation of these lands through the use of camelid dung would prove a viable alternative to this high amount of organic matter, especially if we consider the context in which these structures are placed.

Directly attached to the hillside terraces, or in close proximity, we found circular or rectangular double-walled stone enclosures (Figure 5). The results obtained from the excavation of two of these (enclosures 4 and 5; 1312 ± 43 BP, camelid bone, AA93890) allowed confirming that they would have served as pens. The possibility of their functioning as pens is suggested by the architectural morphology, the absence of structures within the precincts, the scarcity of artefacts on the occupancy floors, their functional analysis and the results of the chemical analysis of the soil (Dantas and Figueroa, 2009; Figueroa, 2010). Particularly, the values of organic matter recorded in the floors of the excavated structures are nine to 12 times higher than those recognised outside of the enclosure (Figure 6). A similar situation takes place in relation to the levels of total phosphorus, between six and ten times higher

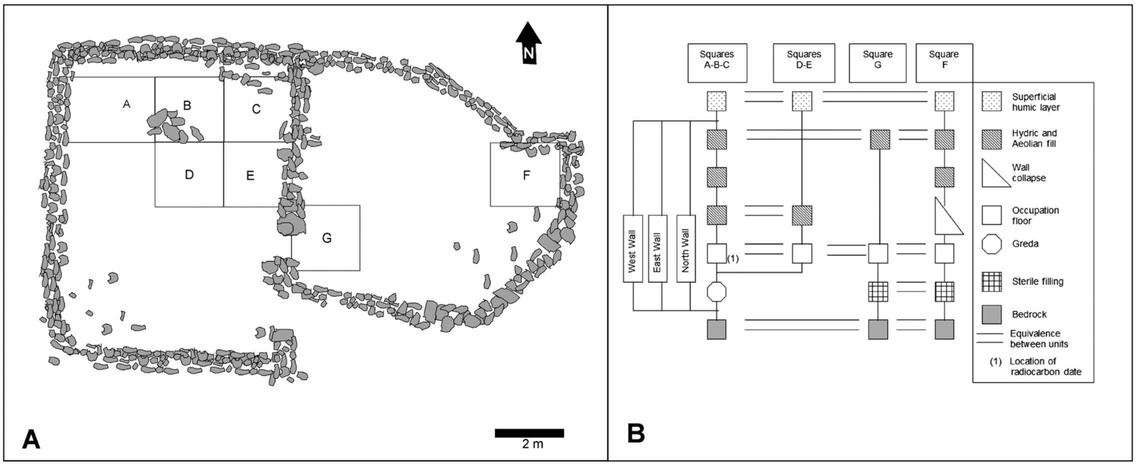

Figure 5. (A) Plan view of enclosures 4 and 5, including excavated areas; (B) stratigraphic matrix of excavated areas (modified from Figueroa, 2010).

within—rather than outside—the structures. Furthermore, it should be noted that these values show no logical pattern in the distribution of organic matter and phosphorus, as they would have to decrease gradually with soil depth, a situation which, as can be noted in Figure 6, does not occur. In summary, these results would indicate the presence, in both enclosures, of areas where animal activity was concentrated.

Functional and experimental analyses on microscopic basis of lithic artefacts (four front scrapers, a side scraper and a natural edge with complementary traces), all in milky quartz found within the stone enclosures, suggest that these instruments would have been used in animal processing, more precisely in fresh bone and leather, tasks that can be linked to livestock activity (Figueroa, 2010). Two of the front scrapers exhibited damages consisting in micro-polishing, similar to those found in experimental artefacts that worked on fresh and dry leather. In addition, we identified, in a side scraper, a combination of damage involving micro-polishing and striations, similar to those found in experimental samples used for cutting fresh

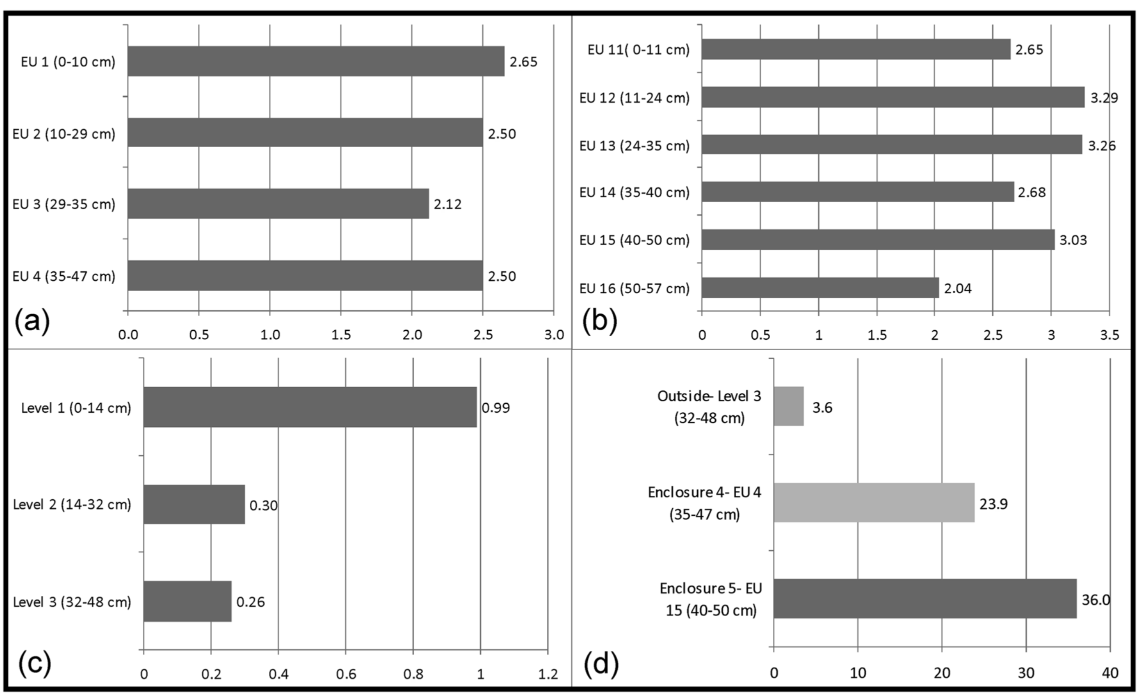

Figure 6. (a) Percentage of organic matter in enclosure 4; (b) percentage of organic matter in enclosure 5; (c) percentage of organic matter outside the site; (d) percentage of total phosphorus in enclosures 4, 5 and outside the site.

bone. Regarding the natural edge with complementary traces, the analysis allowed recognising the presence of damage consisting of micro-polishing similar to those identified in experimental instruments that worked on animal skin despite the fact that due to the low resolution of the sample, it was not possible to establish whether it was used for fresh or dry leather (Figueroa, 2010).

Through analysis of microfossils from the soil of these enclosures, the presence of maize in association with these structures was successfully detected. On the one hand, in a *conana* recovered in the wall of one of the excavated pens, the presence of starches related to maize was identified (Pazzarelli, 2012); on the other hand, in the sediments of the occupancy floor level, the presence of that species was determined through silica phytoliths analysis.

In addition to these structures, the presence of water infrastructure was also confirmed: six dams with double walls that cross the beds of the tributary streams and 11 sections of stone channels leading to the valley floor.

Near this productive infrastructure, it is common to find rectangular plan buildings with a simple stone wall and mud walls with stone columns, subdivided into at least two enclosures. Because of their morphology and similarity to other structures in the valley bottom, they may be interpreted as individual households.

This combination of hillsides and stream terraces, pens, households, channels and dams constitutes a recurring pattern in both sides of the valley. This pattern is also commonly found in the various sub-basins of the main river valley, developed as structural units. These would have served the purpose of productive units of plant and animal resources, located in the vicinity of the residential villages at the valley floor, with which they are articulated spatially through the drainage network.

Regarding the chronology of this productive system, it should be noted that, except for enclosures 4 and 5 previously mentioned, it was not possible to perform radiocarbon dating because of unavailability of material that could be used for direct measurement. Furthermore, it was not possible to identify stone clearing heaps (or 'despedres') that would have enabled dating the soils buried there, as proposed by Korstanje *et al.* (2010). For this reason, we mostly worked with a relative chronology, used by archaeologists in different regions of the Americas (Erickson, 1980; Treacy, 1994; Quesada, 2001; Muñoz Ovalle, 2005; Albeck, 2003/05; Cruz, 2006 among others). In this sense, elements such as the preeminence of Aguada pottery in the area, the similarity between the surveyed households and those located on the valley floor, the recurrent spatial arrangement of the different types of buildings and the similarity noticed in the raw materials and construction techniques used, allowed us to assign them to the period of Aguada occupation of the valley, between 300 and 1000 AD. This timing could be subsequently adjusted through radiocarbon dating performed on the occupancy floor of enclosure 4, dated 1312 ± 43 year BP. Therefore, although it is fairly unlikely to determine exactly whether the buildings identified were developed by a single human group or by different groups at different times, we can argue that at some point in the past they could have worked simultaneously, perhaps coinciding with the maximum extension of Aguada in the area (Figueroa, 2010).

Discussion

As we previously stated, we are interested in understanding the organisation of the production of camelids in the particular context of Aguada. Previous research viewed livestock production as an autonomous strategy, complementary to agricultural production, both performed in different and exclusionary areas within a productive landscape, either local or extra-local (Laguens, 2004). Yet, from the results presented here, we believe, by contrast, that such production made up a single system of agro-pastoral production that included and articulated, simultaneously, plant and llama breeding in the same space and sharing the same infrastructure. It was adopted as a single integral practice of animal, vegetable and fodder production. This economic practice combined in a mutual manner, in a same network of relationships, two different ways of doing what is usually understood as autonomous economic strategies, with independent historical trajectories in the Andean area.

The definitions of agro-pastoralism are varied, and although all acknowledge the presence of both forms of production, they differ in the relative weight of each of these strategies as a basis for subsistence, either in an even balance or in a predominance of one side of the relationship, which in turn imposes in each case a certain way of life (e.g. Webster, 1973; Brandström *et al.*, 1979; Sandefur, 2001; Lane, 2006). In all of these perspectives, there are two important aspects in common: firstly, they understand agro-pastoralism as a combination or sum of forms of production, and secondly, although they involve the same production unit, they do not necessarily involve the same space. Our perspective is different: in Ambato, agro-pastoralism does not combine two forms of production or two strategies, and they do not even complement each other in a mixed production system (Figueroa *et al.*, 2010). This was one single productive practice that articulated simultaneously multiple material and social components, resources, times and places, among other dimensions, in an extensive network of relationships. Thus, it was not a combination of economic strategies where one of them—either farming or grazing—imposed a calendar, on the basis of which, to some extent, life was organised, but a simultaneous overlap and/or alternation of activities, natural cycles and species in a same way of doing and certainly not necessarily limited to the same space. There are some Andean ethnographic cases, particularly in intermediate ecological zones such as the *qeshua*, in which agro-pastoralism is shown as a single practice (McCorkle, 1987; Aldenderfer, 2001, among others), without one being governed by the other; there are cases where llamas are raised as people and fed with agricultural products, like humans (e.g. Göbel, 2001). Archaeologically, for the Middle Horizon, Finucane and colleagues interpret the results obtained in Conchopata as an intentional feeding of llamas with maize within an agro-pastoral complex, characterised by low mobility patterns due to confinement pens (Finucane *et al.*, 2006: 1773).

In these terms, the organisation of agro-pastoral production in the case of Ambato was integrated as a unilocal practice,[6] that is, held in the same space, constituting a synergy of different elements articulated in a network of interrelationships: a single altitudinal space, the llamas production cycle, the maize production cycle, the seasonal calendar, the infrastructure of terraces and pens, water dams in streams, the reproductive technology of both species, the knowledge or know-how and the people, among others. All this formed a new object, with emergent properties, whose result took advantage of and maximised the qualities of each of the previously independent elements, where the products and benefits derived from each could not be achieved independently, rather, all contributed to mutual maintenance and reproduction.

Figure 7 describes the annual cycle of the agro-pastoral work derived from our data, combining ethnoarchaeological and ethnographic information of the Puna and the valley (Flannery *et al.*, 1989; Yacobaccio *et al.*, 1998; Göbel, 2001; González, 2001; Sandefur, 2001; Figueroa, 2010; Figueroa *et al.*, 2010)

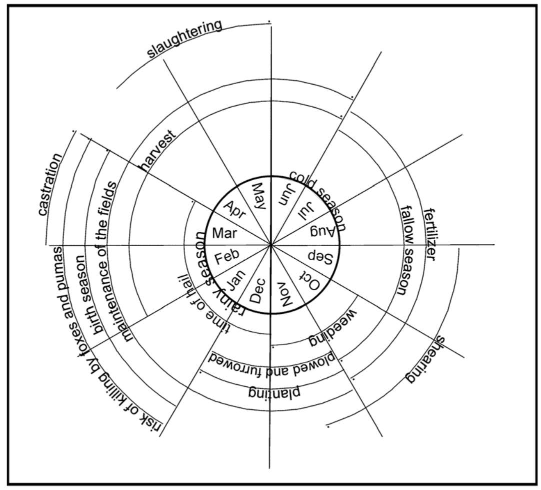

Figure 7. Agro-pastoral calendar (design adapted from Göbel, 2001).

and taking account of the distribution of tasks during the year according to thermal station. Summer is the rainy and hail season. January is the time when camelids give birth and newborns are more vulnerable to the attack of predators, thus much of the herd—at least females and the young—are enclosed in pens. It is also the time of fruit ripening and the time during which activities of maintenance, weeding and irrigation management in the fields are developed, thus animals are kept out of the terraces (perhaps using the protection with solid cane fences). In early February, the first maize begins to be reaped (stage that extends nearly to the end of May or June). During this period, part of the herd may be locked in pens and fed with maize stubble—perhaps stored in the small circular enclosures between the terraces—whereas another part may be in the pastures nearby.

The early fall coincides with the time of the castration of young males, an activity also performed inside the pens. The end of this season is usually the time of greatest slaughter, when animals are fatter and their meat is used in the preparation of *ch'arki*, activities in which stone artefacts, as those found, could have been used. Autumn also marks the beginning of the dry season, which peaks in late winter, when water and pastures are scarce throughout the region. It is also the fallow land season when camelids could survive with the stubble of the cornfields and the water stored in dams, while fertilising the land with their dung. Once the stubble is finished, the animals could be fed with maize, a current common practice to feed herds of young goats and llamas in different parts of the Andean world.

The arrival of spring correlates with the shearing of llamas for fibre production, a task also involving

[6] Brandstrom and colleagues (1979) distinguish at least three practices from the size of space and on how the animals are located in the annual cycle: unilocal, when the herd graze around the house and is taken every night to the pen; bi-local, when part of the year is unilocal and the rest of the year the animals are taken to places of pasture, or when part of the herd is unilocal and the rest is maintained throughout the year elsewhere; and multi local, when only a part of the herd is near the house and the rest pasture all year around.

confinement, which runs until the beginning of summer. Simultaneously, the activities for preparation of agricultural land are undertaken, to begin sowing at the early thermic local summer, in early November, when rain begins and frosts end. This stage is linked to land preparation, sowing and plant growth during summer. It is a period of exclusion of animals from the fields and probably confined to their pens or to partial grazing in the meadows of the hills, when the grasses reach their greatest extent.

At some point—or perhaps many—of this cycle, the camelids would be taken to residential sites in the valley bottom for consumption, where, as we have seen, one part would come already fractioned into large anatomic units and differentially distributed into residential and ceremonial sites. That is, these places for breeding and reproduction may have also served as spaces for slaughter and primary butchering of animals. In turn, these camelids could have been used to transport agricultural production to residential units in the valley bottom.

Conclusions

So far, we have seen how llama production in the Ambato Valley was integrally formed through one production strategy with maize cultivation, with a single infrastructure in the same production space, organised around an induced mutualism between plants and animals in a single annual cycle, described by us under the concept of agro-pastoralism and conceptualized as a multidimensional network of relationships, a particular entanglement (Hodder, 2011).

On the basis of these results, the innovative aspect of this kind of production can be sustained on a local scale. It was typical of the Aguada times and consistent with another series of profound changes, which occurred from 4th century AD in the way of life of local societies (Laguens, 2004, 2006). Although we cannot exactly determine the moment of its implementation as a general productive strategy, its existence is confirmed by radiocarbon dates, leading to the last centuries of occupation of the valley until around 1000 or 1100 AD.

No doubt it meant an intensification in production in a variety of ways (from the yields to the use of surplus, including, work, time and space) and implied a synergy between all the components of the network, which must have had several advantages for the maintenance and reproduction of the system, as well as for the society itself.

However, this synergy and unification of strategies could have been risky. Although from the standpoint of raising llamas and plants, this strategy increases carrying capacity and diversifies the diet and increases production capacity, respectively. From the perspective of humans beings, it would be a system more sensitive or vulnerable to external changes (climate, water and pests, for example), which would impact simultaneously—or indirectly—on both kinds of resources. Yet, on the other hand, it can also be viewed in terms of the efficiency in the use of resources because, in the presence of an environmental crisis, the integrated management of the species can mitigate the individual impact on each species. Indeed, towards the end of the Aguada occupation in the Ambato Valley, environmental degradation (Marconetto, 2009) and social crisis were registered, ending in the breakdown of society in the 11th century AD. We do not know yet if the implementation of an agro-pastoral productive system may have been both a response to this situation and a contribution to their vulnerability. What we do know is that llamas, maize and people in Ambato were entangled in the same network of social life.

Acknowledgements

We wish to express our sincere gratitude to the organisers of the special issue 'Zooarchaeology and Stable Isotope Analysis: Methodological Approaches and Case Studies in southern South America' for inviting us to present this paper and for their support throughout the editorial process. To Andrew Ugan and two anonymous reviewers for the comments that have helped in improving the work, to Martín Giesso and Carolina Mosconi for language assistance and to Andrés Izeta, Mariana Mondini, Alejandra Kornstanje, Alejandro Zucol, Milagros Colobig, Eduardo Pautassi and fellows from Ambato Project for their contributions to the development of the themes of this investigation. This research was financed by grants from Fondo para la Investigación Científica y Tecnológica (PICT 2005 Nº 34558) and Secretaría de Ciencia y Tecnología, Universidad Nacional de Córdoba.

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