

# Hunting, Herding, and Caravanning: Osteometric Identifications of Camelid Morphotypes at Khonkho Wankane, Bolivia

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**ABSTRACT** Khonkho Wankane is a ceremonial center located in the southern Lake Titicaca Basin, Bolivia. During the Late Formative period (AD 1–500), its residents practiced agropastoral lifeways and participated in the rise of the state at Tiwanaku. Like at many Andean sites, bones from the family Camelidae are the most abundant large mammal in domestic contexts. Identifying camelid morphotypes represented by these bones carries far-reaching implications for understanding past hunting, herding, and caravanning practices, and their roles in larger social and economic webs. Identifications were based on a locally focused reference collection, including llamas (*Lama glama*) from the immediate vicinity of the site, as well as Andean guanacos (*Lama guanicoe*), a much smaller morphotype than the Patagonian guanacos used in many osteometric studies. Multivariate statistical analyses and incisor morphology identified all four camelid. Different analyses suggest that the crux of osteometry lies in the reference collection, not the statistical test. An additional, very large morphotype likely corresponds to a castrated llama, the preferred cargo animal among modern drovers. The presence of these animals is interpreted as evidence that groups hunted vicuña (*Vicugna vicugna*) and guanaco, which are not currently present around the site, herded llamas and alpacas (*Vicugna pacos*), and perhaps organized caravans with castrated llamas. Copyright © 2013 John Wiley & Sons, Ltd.

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## Introduction

Hunting, herding, and caravanning are among the most widespread, enduring, and socially embedded practices in Andean societies. They are produced and reproduced through relationships and interactions with a variety of South American camelids, still the single most important domesticated animal in the Andes. It is difficult to understand the role of camelids in ethnographically and ethnohistorically documented communities from Quito to Tierra del Fuego, ranging from hunter-gathers, later agropastoralists, and even the Inca empire. Rich descriptions have provided archaeologists with a robust starting

point for understanding the role of camelids in past societies. In many cases, there seems to be good reason to suppose that there has been a strong degree of historic continuity in these cultural practices (Lynch, 1983; Browman, 1990; Tomka, 1992; Wheeler, 1995; Kuznar, 2001; Dransart, 2002; Yacobaccio, 2007; Mengoni Goñalons, 2008).

Different cultural practices are associated with different types of camelids, so understanding them better requires identifying wild or domestic camelids in the archaeological record. In many cases, clear species or morphotype identifications have been limited to unusual cases of incisors, preserved fiber and wool, or indirect indications from images on pottery or rock art, corrals, and bone pathologies (e.g. Wheeler *et al.*, 1995; Gallardo and Yacobaccio, 2005; Cartajena *et al.*, 2007). The most abundant material signature are postcranial bones, whose measurements have been used in attempts

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to distinguish wild and domestic camelids through comparisons to modern reference collections (e.g. Kent, 1982; Miller and Gill, 1990; Elkin, 1996; Izeta, 2004; Cartajena, 2009). This paper continues the tradition of osteometry, using a recently developed reference collection more appropriate to Andean contexts than those previously employed (Gasco, 2013).

The goal of this paper is to use osteometry to identify camelid morphotypes and document-related cultural practices at the archaeological site Khonkho Wankane, located in the southern Lake Titicaca Basin (Figure 1). There is an abundance of camelid bones, but it remains unclear which species were exploited, and how relationships with different camelids were intertwined in a community that participated in the rise of a first generation state at Tiwanaku (Janusek, 2004; Marsh, 2012).

Our sample of first phalanges from domestic contexts allows us to confidently identify the presence or absence of different morphotypes, though it is too small to speak to relative diet contributions. Identifying which camelids were present at Khonkho Wankane can shed light on the inhabitants' past practices of hunting, herding, and caravanning. The material expectations for each are as follows. Hunting practices are indicated by the bones of wild camelids, guanacos (*Lama guanicoe*), and vicuñas (*Vicugna vicugna*), often in combination with projectile points. Herding practices

are indicated by the bones of the domestic camelids, llamas (*Lama glama*), and alpacas (*Vicugna pacos*). Artificial selection and castration are herd management practices that may generate breeds or size classes. Caravanning is indirectly suggested by the bones of castrated llamas, the ethnographically preferred pack animal, in combination with the presence of imported goods (Nielsen, 2000; Tripcevich, 2007).

### Khonkho Wankane: a ceremonial center in the southern Titicaca Basin

Khonkho Wankane (hereafter Khonkho) was brought to the attention of archaeologists in the 1930s, attracted by a set of sandstone monoliths measuring around 5 m in height, carved in low relief with elaborate iconography (Portugal Zamora, 1941; Rydén, 1947). Since 2001, John Janusek has directed a multi-disciplinary research project, *Jach'a Machaca*, focused on the Late Formative occupation (Pérez Arias, 2004, 2005; Gladwell, 2007; Smith, 2009, 2011; Janusek, 2011; Lémuz Aguirre, 2011; Marsh, 2011, 2012; Ohnstad, 2011; Pokines, 2012). A large community lived at Khonkho from around AD 150 to 450. At this time, the principal mound was built, which includes a

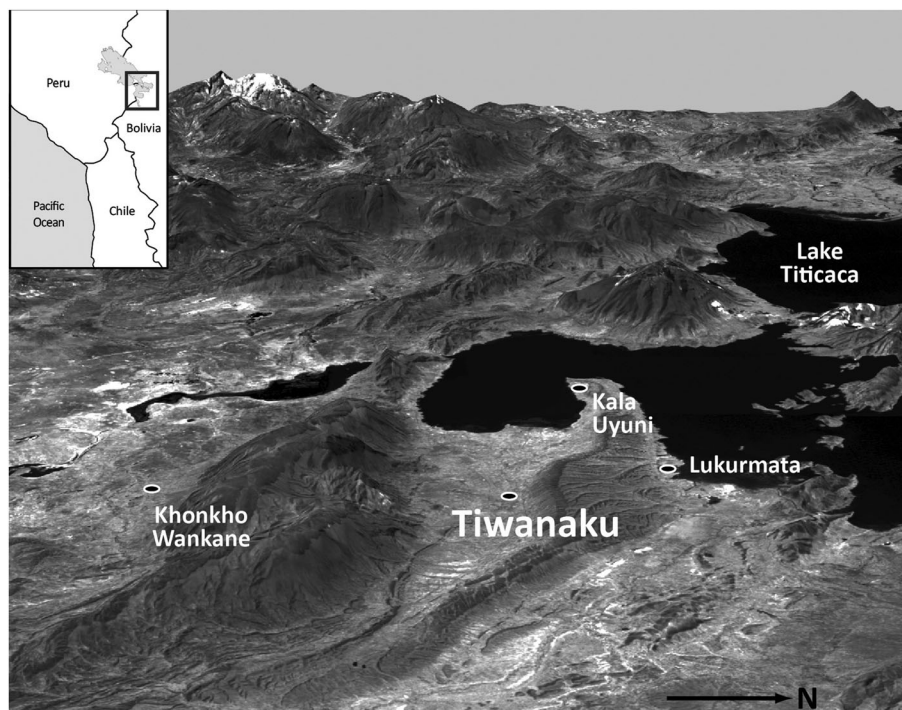


Figure 1. Perspective map of the southern Titicaca Basin, looking northwest, modified from Marsh (2012: Figure 1.1). Based on a composite map by Arik Ohnstad, using LANDSAT and SRTM topographic data.

monumental complex of three trapezoidal temples surrounding a central plaza, and large rectilinear residential complexes (Figures 2 and 3). An underground stone and clay canal of more than 100 m originates below the central plaza. It was designed to channel rain water from the central plaza atop the mound to a low moat.

Prior to the Late Formative, communities in the region were small and dispersed, and occasionally gathered to venerate ancestors or for other festivals, at centers such as Chiripa (Hastorf, 2008: 554–557; Marsh, 2012: 62–69). Beginning in the Late Formative, residents built and lived at much larger ceremonial centers. While other similar contemporary ceremonial centers are known, Khonkho stands out for its elaborate architecture and residential complexes (Janusek, 2004: 115–117). Interactions among regional communities resulted in the emergence of a primary Andean state centered at Tiwanaku, 30 km to the north. Many of Tiwanaku's enduring architectural canons and domestic traditions were pioneered at Khonkho (Marsh, 2012: 470–478).

It has been suggested that these major social changes were closely related to expanding llama caravan networks, based on the presence of imported items (Browman, 1980: 114–117; Tripcevich, 2007: 245–251). Major regional shifts are known in general terms, but they were produced and reproduced through daily practices, traditions, and interactions. The economic livelihoods of the families who lived at Khonkho seemed to have involved close relationships with camelids. Like at many Andean

sites, the representation of camelid bones is overwhelming, in some cases approaching 100% of recovered bone specimens (see Mengoni Goñalons and Yacobaccio, 2006: 235–237). The economic activities related to camelids can be clarified through osteometry.

### Discriminating camelid species and osteometry

Camelid species can be discriminated on the basis of fiber and incisors (Wheeler, 1982; Wheeler *et al.*, 1995), but they are rarely present in the archaeological record. Wing (1972: 329–330, Figures 1, 3) initiated attempts to discriminate them on the basis of size differences in postcranial bones. With little to no sexual dimorphism, this osteometric approach is a promising means of distinguishing the four extant species, which are osteologically very similar (e.g. Yacobaccio, 2006: Table 4; Cartajena, 2009: 204–205; Kaufmann and L'Heureux, 2009: 195; Miller, 1979: 139–141). The first osteometric studies used reference collections from the La Raya research station in highland Peru, which included llamas, alpacas, and vicuñas from the region, as well as guanacos from Patagonia. There were few data to approach the acknowledged problem of overlapping size ranges, resulting in a 'low-resolution window into the taxonomic identity of archaeological camelids' (Miller and Burger, 1995: 432).

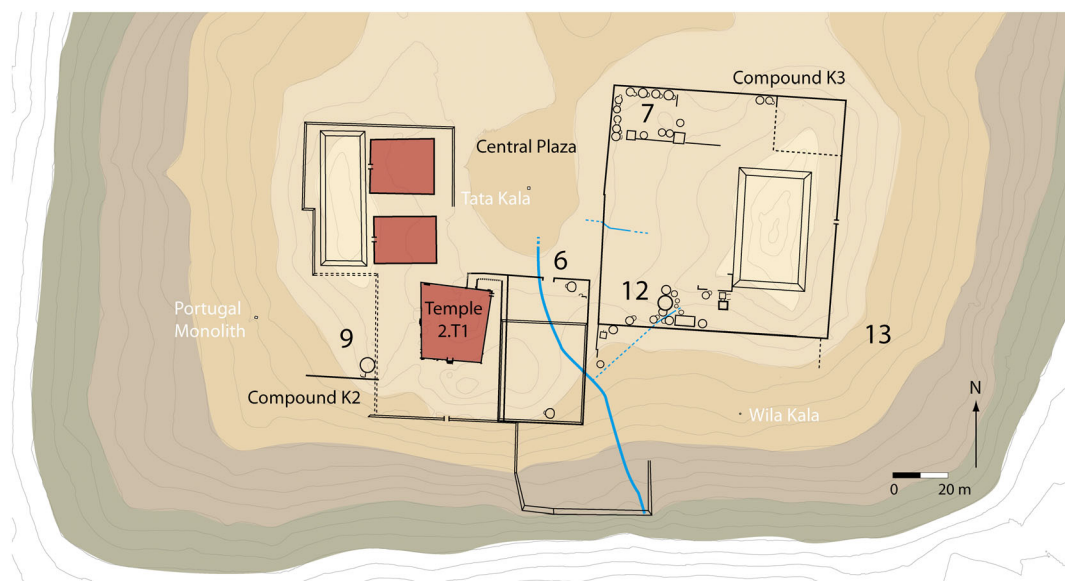


Figure 2. Map of Khonkho Wankane located at 16.80°S, 68.67°W, modified from Marsh (2012: Figure 1.3). Numbered areas indicate excavation sectors. Contour lines every 0.5 m, shading every 2 m. Based on a topographic map by Scott Smith and Arik Ohnstad. This figure is available in colour online at [wileyonlinelibrary.com/journal/oa](http://wileyonlinelibrary.com/journal/oa).



Figure 3. Stone foundations of circular residences in sector 7, facing west. Photo by Wolfgang Schüler. This figure is available in colour online at [wileyonlinelibrary.com/journal/oa](http://wileyonlinelibrary.com/journal/oa).

Further research proposed additional and more standardized measurements, more robust statistical treatments, and principally, expanded reference collections (Kent, 1982: Chapter 4; Miller, 1979: 140–159; Menegaz *et al.*, 1988; Moore, 1989: Chapter 8; Miller and Gill, 1990: 57; Gasco, 2013). These tools allowed researchers to better distinguish wild and domestic camelids (e.g. Elkin, 1996; Izeta, 2004; Cartajena, 2009; Vásquez Sánchez and Rosales Tham, 2009; Yacobaccio, 2010; Gasco *et al.*, 2011). While often supposed that each species corresponds to a single morphotype, recent biological and osteometric research has begun to identify multiple morphotypes within each species (e.g. González *et al.*, 2006; Izeta *et al.*, 2009; L'Heureux, 2010; Yacobaccio, 2010; Gasco, 2013). Morphometric data more directly reflect morphotypes than species, so morphotypes are the more relevant category for identifying past camelids.

### Modern guanacos and llamas

Guanacos have a very wide geographic distribution and significant variability in body size (Wheeler, 1995:

273–277; González *et al.*, 2006; Mengoni Goñalons and Yacobaccio, 2006; Marín *et al.*, 2008). The tendency for guanacos to be larger in more southern and colder environments seems to be a response to selective pressures, perhaps following Bergmann's rule (González *et al.*, 2006: 170; L'Heureux, 2008: 24). Measurements of a guanaco cranium from highland Peru suggest that this northern morphotype may be as much as 20% smaller than its Patagonian cousins (Lönnberg, 1913: 2, 8; Kent, 1982: 18, 30). This difference bears out in the maximum length of the first phalanx, the element in question in this paper. Four Patagonian guanacos average  $82.14 \pm 3.4$  mm (Kent, 1982: Appendix IV.2), while 27 Andean guanacos in this paper's reference collection average  $76.0 \pm 3.5$  mm. Hence, there are at least two guanaco morphotypes, Andean and Patagonian (Mengoni Goñalons and Yacobaccio, 2006: 231, Figure 16.2).

Llamas can be as large as 130–150 kg, but most are much smaller (Miller and Gill, 1990: 61; Wheeler, 1995: Table 3). Llama breeds have been identified on the basis of fleece differences, but it remains unclear if these breeds are correlated with body size differences (Wheeler *et al.*, 1995; Iñiguez *et al.*, 1998: 62). A more significant source of body size variation results from castration, which prolongs bone growth (Fowler, 2010: 158). This routine technique is essential for herd management and enables herders to control reproduction and aggression between males (see below). The domestication process probably resulted in animals that were smaller than their wild progenitors, Andean guanacos. Body size reduction is a common unanticipated effect in almost all other cases of domestication (Tchernov and Horwitz, 1991: 55–57). This expectation is borne out by the data from the reference collection (see below). Hence, guanaco and llama morphotypes seem to follow this size gradient: Patagonian guanacos, castrated llamas, Andean guanacos, and uncastrated llamas (see discussion in Gasco, 2013: Chapter 7).

### Modern alpacas and vicuñas

There is substantial size variation within alpacas, and it is unknown if this corresponds to differences between the two recognized breeds (*suri* and *huacaya*), which are defined by differences in fiber. Their distribution is generally limited to at least 4000 masl, and most are found within 150 km of Lake Titicaca (Wheeler, 1995: 284). They prefer the softer grasses of bofedales (i.e. high altitude marshes). Alpacas do not fare well outside of their narrow, preferred ecological zone, where the quantity and quality of wool suffers considerably (Forbes, 1870: 76; Topic *et al.*, 1987: 832; Browman, 1990: 398). As these animals are valued for

their wool, it would be unusual, though certainly not impossible, to find them at low altitudes or in dry climates (see Shimada and Shimada, 1985; Crossley *et al.*, 1994).

Size differences are clearer in vicuñas, which generally inhabit areas over 3700 masl (Wheeler and Laker, 2009: 21). There are two subspecies with restricted geographic ranges: *Vicugna vicugna mensalis*, located between the southern latitudes 9° and 18°, and *Vicugna vicugna vicugna*, located between 18° and 29°. The Dry Diagonal in the south-central Andes may geographically and genetically separate the subspecies (Wheeler and Laker, 2009: 24–25). The southern subspecies is larger, and it seems that each subspecies corresponds to a separate morphotype, but there are few metric data available (Izeta *et al.*, 2009: 170; Yacobaccio, 2006: Table 4). For the moment, the size gradient, from largest to smallest, is as follows: alpaca, southern vicuña, and northern vicuña.

### Archaeological applications

The most straightforward means of identifying the most probable morphotype of an archaeological specimen is process of elimination, considering geographic and environmental limitations (see Miller and Gill, 1990: 56–63). This is difficult in the case of domestic animals, as herders may move animals to different places, exploiting or creating microclimates suited to their herds. Their past and present distributions were not identical, though perhaps similar. The animals themselves were probably different, given thousands of years of controlled breeding.

However, for wild camelids, geographic and environmental distributions are not likely to have changed much from the beginning of the Late Holocene to the arrival of the Spanish. At most central Andean archaeological sites, it is very unlikely that Patagonian-sized guanacos ever co-existed with humans. Hence, using Patagonian guanacos as metric references can impede proper identifications (Mengoni Goñalons and Yacobaccio, 2006: 231–232). A great deal of size variability depends on geography, best documented in wild camelids, and an effective reference collection should include animals from the same region as the archaeological site (L'Heureux, 2010: 44).

### Reference collection and archaeological specimens

In general, comparative collections of South American camelids remain very limited (L'Heureux, 2010). In this

paper, we use published and unpublished measurements toward better comparisons and more reliable identifications, described in detail by Gasco (2013). We use a reference collection of 50 individuals, much larger than others used in similar studies (Table 1). The collection of llamas and guanacos is adequate for our purposes; that of vicuñas and alpacas remains preliminary.

The reference collection includes 10 llamas: three from the Provinces of Mendoza and Jujuy, Argentina, and two from the Province of Oruro, Bolivia; the remaining five are from the modern agropastoral community of Khonkho Liqiliqi, whose central plaza is located 1.5 km north of the archaeological site (Table 2). These llamas seem to be the best possible analogs for pre-Hispanic llamas at Khonkho because they are from the same environment, probably had similar diets, and perhaps were even subject to similar management techniques. Statistically, measurements from these llamas group well with those from the other five llamas.

Published measurements for one individual from the region were excluded (codes ll1-4 in Izeta *et al.*, 2009: Table 1) because the skeleton shows evidence of osteoarthritis and eburnation (P. Novellino, personal communication, 2012). These pathological conditions seem to have resulted in larger than normal bones in this seven-year old female, purchased in Jesús de Machaca (16.74°S, 68.80°W).

The llamas are all smaller than the 29 Andean guanacos used in the analysis, which are from the high altitude parts of western Argentina, in the Provinces of Mendoza, San Juan, and La Rioja (Gasco, 2013: Chapter 7). The animals are all from Andean environments well north of Patagonia. One particular case is from Peru, east of Lake Titicaca (Lönnberg, 1913), whose post-cranial elements are curated as specimen 22879 at the University of California's Museum of Paleontology, Berkeley (Gasco, 2013: 292, Figure 7.25). The similarity in environments may explain the morphometric similarity between the Lake Titicaca guanaco and the other Andean guanacos from Argentina. This guanaco falls within the

Table 1. Summary of reference individuals and bone specimens

	Fore phalanx		Hind phalanx	
	Individuals	Specimens	Individuals	Specimens
<i>Lama guanicoe</i>	29	76	26	62
<i>Lama glama</i>	10	25	7	24
<i>Vicugna vicugna</i>	9	29	6	23
<i>Vicugna pacos</i>	2	8	2	7
Total	50	138	41	116

Table 2. Measurements (mm) of first phalanges of llamas from Khonkho Liqiliqi (16.79°S, 68.67°W)

Individual	Age	Sex	Fore phalanges					Hind phalanges				
			V1	V2	V3	V4	V5	V1	V2	V3	V4	V5
Lgl-04	3 years	Female	66.19	18.79	18.49	15.87	14.87	58.31	18.72	16.09	15.30	13.73
			66.42	19.18	18.35	16.31	15.06	58.52	18.70	16.11	15.24	13.44
			67.73	19.32	18.18	16.28	15.02	59.10	18.72	15.84	15.23	13.88
Lgl-05	3 years	Uncastrated Male	67.41	19.40	18.29	16.13	14.69	59.36	18.19	16.04	15.16	13.82
			67.15	19.61	18.52	16.67	15.48	58.45	19.65	17.05	15.29	13.52
			66.27	19.84	18.48	16.76	15.15	58.52	19.37	16.40	15.28	13.63
Lgl-06	adult	Uncastrated Male	67.56	19.92	18.91	16.73	15.72	59.22	19.44	16.45	15.30	14.04
			66.26	19.98	18.60	16.56	15.79	59.63	19.42	16.39	15.32	13.98
			64.74	18.41	17.44	15.77	13.49	57.44	17.62	15.99	14.45	12.77
Lgl-07	adult	Uncastrated Male	64.45	18.58	17.49	15.82	13.95	57.55	17.69	15.96	14.64	12.76
			66.50	18.60	17.70	15.92	14.41	57.95	17.99	15.73	14.42	12.90
			65.90	18.76	17.76	16.18	13.98	57.97	18.14	15.76	14.50	12.89
Lgl-08	adult		66.73	19.16	17.60	16.40	15.28	60.24	18.06	15.41	15.25	13.15
			67.27	19.41	17.36	16.59	15.07	61.03	17.99	14.88	15.01	13.26
Lgl-08	adult		66.07	18.95	18.58	16.95	14.88					

These 29 phalanges are from skeletons currently housed in Bolivia, at the Laboratorio de zooarqueología, at the Universidad Mayor de San Andrés, La Paz, and the laboratory of Project *Jach'a Machaca*, in Khonkho Liqiliqi.

group but is slightly smaller, in line with Bergmann's Rule (González *et al.*, 2006: 170). All the guanacos are statistically grouped as a distinct population from the llamas.

Although most of these guanacos are from regions far from Khonkho, they seem to represent the potential morphometric variability of past Andean guanacos near Khonkho. Compared to Patanogian guanacos, the Andean guanacos in the reference collection are certainly more morphometrically similar to past Lake Titicaca guanacos (González *et al.*, 2006: 164–166, Table 2). While it would be ideal to use a collection of guanacos living closer to Khonkho, these animals no longer inhabit the region. They were present until recently and probably earlier: 16th century documents mention guanaco hunting in central Peru (Custred, 1979: 13–14), guanacos were reported near Lake Titicaca by early ethnographers (Forbes, 1870: 70; Bandelier, 1910: 26, 35; Tschopik, 1946: 503; Franklin, 1982: 468), and the sole Lake Titicaca guanaco in the reference collection was hunted a century ago (Lönnerberg, 1913: 2).

There are two alpaca individuals: one from the collections of the Museo de Historia Natural, San Rafael, Mendoza, and one from published data (Izeta *et al.*, 2009: Tables 1 and 2). Vicuñas are represented by nine individuals with incomplete provenience information: one from a private collection, one housed at the Bolivian Collection of Fauna, La Paz, four from the museum in San Rafael, and three from a published source (Izeta *et al.*, 2009: Tables 1 and 2). To date, measurements from alpacas remain a weak point of the comparative

collection, where more individuals with better provenience data are necessary for future studies.

The archaeological sample is comprised of 21 Camelidae first phalanges from domestic contexts at Khonkho (Figure 4, Tables 1 and 2; see Marsh, 2012: Chapters 5 and 6). The majority of the phalanges are from sectors 7 and 9, where occupations date to around AD 300 to 450 (Figure 2). Residents who lived in these sectors dwelt in adobe structures with circular, cut stone foundations



Figure 4. First fore phalanges from castrated llamas (a, b) and an Andean guanaco (c), from excavation context 9.7.3.R2. Scale bar measures 10 cm. This figure is available in colour online at [wileyonlinelibrary.com/journal/oa](http://wileyonlinelibrary.com/journal/oa).

(Figure 3). Material evidence suggests a variety of domestic practices, including cooking, making pottery, butchering animals, grinding food, and making and using lithic and bone tools (Marsh, 2012: 299, 499).

Phalanges were measured using Kent's guide, designed specifically for South American camelids (Kent, 1982: 162, Appendix IV.2, Figure IV.1; Gasco *et al.*, 2013). To control for possible size differences due to age or pathological conditions, only fused bones from adults with no indication of pathological conditions were measured. To control for the effects of taphonomic processes, only bones without evidence of thermal alteration or significant weathering were measured; archaeological specimens used here were classed as 1 or 2 on Behrensmeyer's (1978) scale.

The first phalanx is an especially appropriate element for osteometry. It is relatively common in archaeological assemblages. It has high bone density and preserves well. It has clear centers of ossification, making it easy to distinguish between juvenile and adult bones, and potential effects of pathological conditions or castration are apparent. Its measurements are straightforward, replicable, comparable, and discriminate well between species (see below), making it the most widely studied element. First fore phalanges are larger than hind ones, so it is important to identify them correctly (Kent, 1982: 164–164; Moore, 1989: 326; Webster, 1993: 203). We crosschecked identifications as fore or hind phalanx using morphological and statistical criteria (Kent, 1982: 165, Figure IV.12; L'Heureux, 2008: 243–245; Cartajena, 2009: 202, 205, Annex 2).

Measurements were taken to nearest 0.01 mm with digital calipers and processed with the program PAST (Hammer *et al.*, 2001). Four methods were contrasted: (i) bivariate plots of raw data, (ii) Cluster Analysis using Unweighted Pair Group Using Arithmetical Averages (UPGMA), (iii) Principal Components Analysis (PCA), and (iv) Discriminant Analysis. UPGMA uses the paired group algorithm and euclidean distances; PCA uses a

variance–covariance matrix, and the few missing values were estimated with iterative imputation, an advantage when working with fragmented specimens. These analyses offer many possible types of algorithms, matrices, and distances, and those used here are most appropriate for morphometric data (Lele and Richtsmeier, 1991; Hammer, 2012: 76, 79, 89). UPGMA emphasizes similarities among data, while PCA stresses differences, making them complementary. Both are useful in identifying the number of groups in the data, and the degree to which they are similar or different.

Finally, we applied a stepwise Discriminant Analysis in SPSS (IBM, 2011) using Wilk's Lambda, following Kent (1982:167–168); prior probabilities were based on group size and the results were cross validated. This test indicates strong and significant separation between the reference data for each species. It provides a statistical probability that an archaeological specimen (of unknown morphotype) is associated with a group (each defined by species). Groups are defined a priori, making it difficult to identify unexpected groupings or the presence of a group not in the reference collection. Overall, the most robust approach seems to be comparing and contrasting different tests before making a morphometric assignment.

Statistical comparisons were made between archaeological and reference specimens (e.g. Izeta, 2004; Aschero *et al.*, 2012), and also between archaeological specimens and average values for each reference individual (e.g. Kent, 1982). We ran all tests with both sets of data, which showed no difference in the final identifications. On one hand, it is more appealing to use raw data, which better represent the full range of variability, and to compare the same unit of analysis; the appropriate archaeological unit of analysis is the specimen. On the other hand, this artificially inflates the sample size of the reference collection. Results of both sets of data for the Discriminant Analysis are presented in Table 3. Using averages rather than specimens resulted in

Table 3. Results of stepwise Discriminant Analysis

Specimens	N	% of variance explained by first function	Variables used in analysis (in order of selection)	% of correctly classified cases, cross validated	% of correctly classified cases (excluding alpaca-llama misclassifications)
Complete fore phalanx	134	95.5	V1, V3, V4, V5	92.5	96.3
Distal fore phalanx	138	99.1	V4, V5	87.1	92.1
Proximal fore phalanx	134	96.2	V2, V3	83.7	89.6
Distal hind phalanx	110	99.7	V4, V5	85.5	91.8
Individual averages					
Complete fore phalanx	48	95.3	V5, V3	91.7	95.8
Distal fore phalanx	50	100	V5	92.0	96.0
Proximal fore phalanx	48	95.6	V2, V3	87.5	91.6
Distal hind phalanx	41	100	V5	87.8	92.3

functions with fewer variables that predicted a few more cases correctly, but the difference is minor and did not affect the identifications. Future research will be able to better define the most appropriate methods of comparison.

## Results and discussion

Statistical treatments identified clear groups in the modern reference collection. Nearly all of the variance is explained by the first function in the PCA and Discriminant Analysis, which correctly classified most of the cases (Table 3). The least clear distinction is between llamas and alpacas, an issue that may be resolved with a better reference collection, especially of alpacas. While these two morphotypes overlap in some measurements, Discriminant Analysis did still separate and correctly classify them. In any case, archaeological specimens in this range can safely be considered domestic animals, the principal distinction, which allows us to argue for herding practices.

Comparing and contrasting results from all four analysis resulted in the morphotype identifications for each archaeological specimen (Table 4). For example, a bivariate plot of measurements from the proximal articular surface shows the associations of reference phalanges averages and nine archaeological specimens (Figure 5). A PCA of complete phalanx measurements reinforces the clear grouping of the modern reference specimens, as well as the associations of the archaeological ones (Figure 6). The Discriminant Analysis made some associations with very large distances from the nearest centroid, potential outliers, which were re-evaluated with UPGMA and PCA. We treated fore and hind phalanges and distal and proximal epiphyses separately and included portions of complete phalanges when appropriate.

### Identification of vicuñas and alpacas

Three archaeological specimens are morphometrically similar to modern vicuñas (Table 4). Two specimens from context 9.20.5 are so similar they may be from a single individual. Based on the current reference collection, they are most likely vicuñas (Table 4). The identification of alpacas is not clear. The specimen from context 9.22.2 is statistically grouped with llamas, but similar to one alpaca. This particular alpaca is quite large compared to Kent's averages (1982: Appendix IV.2) and may not be representative of the morphotype. In face of this uncertainty, we looked at camelid incisors from the same contexts. Both vicuñas and alpaca incisors were identified

based on morphological differences (Wheeler, 1982; Riviere *et al.* 1997).

Osteometric data and incisors confirm that vicuñas and alpacas were both present at Khonkho, leading us to suggest that the former was linked to hunting and the latter to herding. The presence of vicuñas suggests that these animals were hunted by residents of Khonkho during the Late Formative, as they have been by more recent inhabitants of the area (Forbes, 1870: 700; Bandelier, 1910: 25; Tschopik, 1946: 503; Custred, 1979: 12–17).

The presence of alpacas suggests that residents herded these animals, even though the site is located in a dry part of the altiplano. Modern herders create microclimates by building and maintaining bofedales, resulting in healthier animals with more and better wool (Flores Ochoa, 1977: 136–139; Palacio Ríos, 1977: 156–157; Browman, 1990:398; Tomka, 1992: 426). At Khonkho, two natural streams were channeled to the northern edge of the site, which would have created an artificial bofedal (A. Ohnstad, personal communication, 2008; Marsh, 2012: 65–67). These conditions would have made it possible to raise healthy flocks with healthy wool. Alpaca herding may have been linked to textile production with high quality wools (Dransart, 2002). This possibility is supported by the archaeological association of bone tools that seem to have been made for spinning and weaving (Gladwell, 2007: 84, Figure 3). Even higher quality wool would have been available from wild vicuñas, who would also have been attracted to a wetland microclimate in the dry altiplano.

### Identification of guanacos and llamas

Osteometry identified three guanaco and llama morphotypes: llamas, Andean guanacos, and a significantly larger and statistically distinct morphotype (Table 4). Llamas were a valuable domestic animal, providing wool, meat, leather, manure, and labor. The notable presence of Andean guanacos demonstrates the continuity of hunting as an economic strategy.

The small sample size only allows us to briefly speculate on relative contributions to the diet, but the frequency of guanacos (11 of 21 specimens) suggests that hunting was not merely an occasional complement to local diets. Including the three vicuñas, this sample suggests that the majority of meat in the diet came from hunted animals. Additional evidence for hunting comes from projectile points and Andean deer, *Hippocamelus* sp., identified in the same domestic contexts.

There are fewer llamas that might be expected for a complex society in the altiplano, often thought to have maintained large herds. However, the osteometric



Table 4. Measurements and identifications of archaeological first phalanges

Excavation context (specimen)	Fore or hind	Variables (mm)								Stepwise Discriminant Analysis with individual averages ( <i>p</i> )				Identification
		V1	V2	V3	V4	V5	V1-V5	V2-V3	V4-V5					
6.22.3.R1a(a)	Fore				14.69	13.76							Vv (.55), Lgl (.41)	Vicuña
6.22.3.R1a(b)	Hind				17.34	15.20							Lg (.99)	Andean guanaco
7.17.4	Fore	22.58		21.24										Andean guanaco
7.19.10	Fore				15.70	15.44							Lgl (.62), Lg (.21)	Llama
7.19.4	Fore				19.05	18.58							Lg (1.0)	Andean guanaco
7.19.5(a)	Fore				19.80	18.79							Lg (1.0)	Andean guanaco
7.19.5(b)	Fore				17.79	17.20							Lg (.99)	Andean guanaco
7.19.5(c)	Fore				20.64	20.03							Lg (1.0) <sup>a</sup>	Castrated llama
7.19.5(d)	Hind				17.35	17.55							Lg (1.0)	Andean guanaco
7.19.7	Hind				17.47	17.74							Lg (1.0)	Andean guanaco
7.39.2S	Fore	21.84		19.75									Lg (.99)	Andean guanaco
7.75.2	Fore				16.53	15.57							Lgl (.54), Lg (.30)	Llama
7.76.6	Fore	24.11		23.13									Lg (1.0) <sup>a</sup>	Castrated llama
7.83.8	Fore				18.35	18.31							Lg (1.0)	Andean guanaco
9.7.3.R2(a)	Fore	76.34		21.20					Lg (1.0)				Lg (1.0) <sup>a</sup>	Castrated llama
9.7.3.R2(b)	Fore	87.78		21.17					Lg (1.0) <sup>a</sup>				Lg (1.0) <sup>a</sup>	Castrated llama
9.7.3.R2(c)	Fore	80.51		22.25					Lg (1.0) <sup>a</sup>				Lg (1.0) <sup>a</sup>	Andean guanaco
9.20.5(a)	Fore			19.74					Lg (.87), Lgl (.13)				Vv (.88), Vp (.05)	Vicuña
9.20.5(b)	Fore			15.64					Vv (.88), Vp (.05)				Vv (.88), Vp (.05)	Vicuña
9.22.2	Fore	67.87		15.69					Lgl (.69), Vp (.18)				Lgl (.70), Vp (.17)	Llama
14.1.10	Hind			17.51					Lg (.45), Lgl (.41)				Lg (.99)	Andean guanaco

Lg = *Lama guanicoe*, Lgl = *Lama glama*, Vv = *Vicugna vicugna*, Vp = *Vicugna pacos*

<sup>a</sup>These very large phalanges are markedly distant from the guanaco centroid, so they were evaluated using UPGMA and PCA. They form separate groups from the Andean guanacos at large euclidean distances and are most likely from castrated llamas.

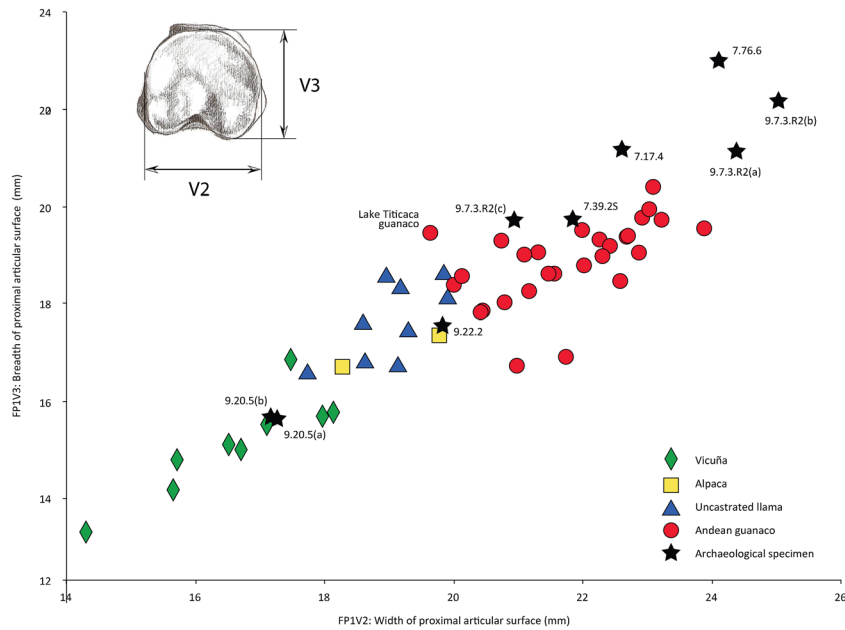


Figure 5. Bivariate plot of first fore phalanges, measurements V2 and V3. Comparative data points are averages for each individual. This figure is available in colour online at [wileyonlinelibrary.com/journal/oa](http://wileyonlinelibrary.com/journal/oa).

sample probably does not represent the size of herds or their relative importance to the community. This may be explained by two effective strategies practiced by modern pastoralists, and also perhaps at Khonkho in the past. First, while herds can be controlled by castrating males, this can also be accomplished by consuming juveniles. This would result in few juvenile domestic animals in the osteometric sample, which is limited to

adults. Second, Khonkho's residents most likely preferred to consume hunted meat and keep domestic animals 'on foot', a more efficient way to take advantage of secondary products and uses. This walking larder would have helped maintain stocks of meat and resources in case of droughts or lean years, an effective and enduring risk management strategy in the unpredictable altiplano.

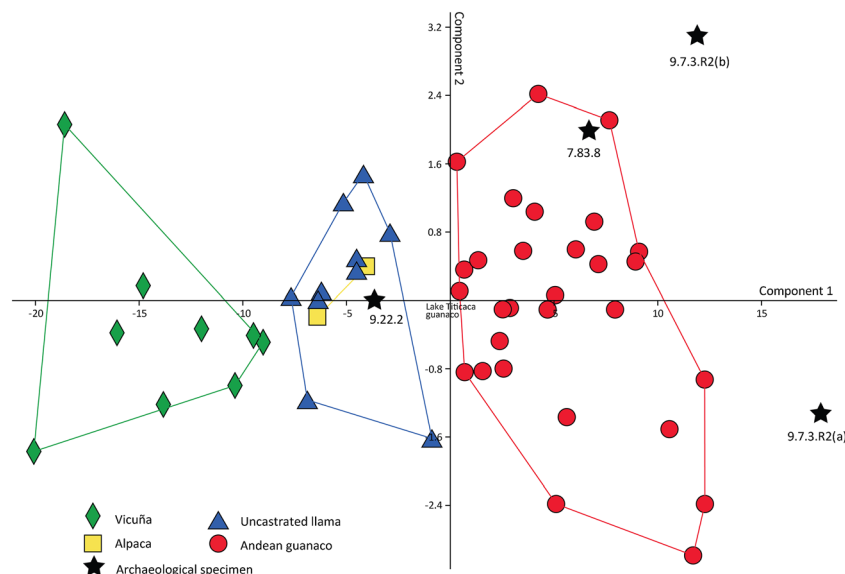


Figure 6. Principal components analysis of complete first fore phalanges. This figure is available in colour online at [wileyonlinelibrary.com/journal/oa](http://wileyonlinelibrary.com/journal/oa).

### *Castrated llamas and herd management*

The largest morphotype is much larger than the others and may represent llamas selectively bred for size, or more likely, castrated llamas. Unfortunately, there are no reference data available for castrated llamas, a priority for future research. That being the case, if we exclude Patagonia guanacos from the possibilities, the most feasible conclusion is that the especially large phalanges are from castrated llamas. Castration results in an absence of hormones that affects bone structure, particularly in the long bones (Fowler, 2010: 158). In rams (*Ovis aries*), castrates' long bones are 5–8% longer than those of non-castrated males and 10–20% longer than those of females (Davis, 2000: 862). The measurements from the largest morphotype at Khonkho are around 20% larger than those of uncastrated reference llamas. Similarly, large phalanges have been reported at other sites, suggesting that the presence of this large morphotype was not an isolated occurrence (Miller, 1979: 147; Kent, 1982: Appendix VI.1; Webster, 1993: 205; Yacobaccio, 2010; Gasco *et al.*, 2011; Aschero *et al.*, 2012; Labarca Encina and Gallardo, 2012; Gasco, 2013).

Among modern herders, castration is a routine management technique that is necessary to control aggression between males and maintain order in the herd (Göbel, 2001: 103–104; Cardozo González, 2007: 124). Herds are usually organized into groups with breeding or castrated males (Tomka, 1992: 416–419; Nielsen, 2000: 171–173). It is also an effective means of selecting animals for wool color, size, or other characteristics (Cardozo González, 2007: 82). Families may keep a significant number of castrates, especially for larger herds and in communities who specialize in trade (Browman, 1990: 399–401; Tomka, 1992: 416). Based on these ethnographic comparisons, we would expect bones from castrates to be fairly common in the archaeological record; phalanges from castrates represent about a fifth of the small sample at Khonkho.

Clearly identifying castrated llamas has profound implications for camelid osteometry and Andean archaeology. Compared to the small and often overlapping size differences between other morphotypes, the identification of large castrates is based on very clear metric differences. The presence of castrated llamas is a direct indicator of human management of domestic animals and provides one line of evidence in support of caravanning.

### *Caravans*

Ethnographic studies consistently report that drovers prefer castrates for caravans because they are taller,

stronger, and more docile (Browman, 1990: 398; Tomka, 1992: 427; Nielsen, 2000: 410). Khonkho's residents may also have participated in or organized llama caravans with castrates. This possibility is supported by the presence of imported ceramics, gold, and obsidian. Most obsidian at Khonkho comes from Chivay, a source 325 km to the northwest. The site's residents were Chivay's most distant consumers (Giesso, 2000: 346; Tripcevich, 2007: 275). Castrated llamas may have carried this obsidian, which comes from the same domestic contexts as the phalanges, hinting that caravans were organized at the household level (Tripcevich, 2007: 157–159).

During the Late Formative period, expanding trade networks are suggested by an increase the movement of exotic or prestige goods, possibly by caravans (Browman, 1980; Dillehay and Núñez, 1988). This probably led to wider social networks related to emerging social complexity at Khonkho and other nearby centers. Caravans remained important as the state emerged at Tiwanaku around AD 500. Members of this first generation state maintained prior trade routes and domestic economic practices, such as hunting and herding wild and domestic camelids (Webster, 1993: 259–268).

## **Conclusion**

The admittedly small sample of first phalanges from Khonkho, in combination with incisors, allows us to conclude that there were five camelid morphotypes present at Khonkho: vicuñas, alpacas, guanacos, uncastrated llamas, and castrated llamas. Future research with larger samples may begin to speak to the relative presence of each morphotype. The simple presence of these camelids responds to this paper's research questions, allowing us to argue that Khonkho's residents processed wild and domestic camelids, probably for food and perhaps textiles, and that their cultural practices included hunting, herding, and possibly caravanning.

The results of osteometric studies are heavily dependent on the reference collection and less so on statistical tests. In this case, using llamas from Khonkho Liqiliqi and Andean guanacos resulted in reliable identifications of large morphotypes. Incisors confirmed the presence of alpacas and vicuñas. The full array of modern and pre-Hispanic camelid morphotypes remains unclear (Wheeler *et al.*, 1995), so improving results will rely on more complete data for reference animals, including measurements, specific provenience, subspecies, age, sex, diseases, diet, associated breeding practices, and other pertinent information (L'Heureux, 2010: 44; Yacobaccio, 2010: 72).

Improved reference collections may allow for more direct assessment of camelids and related practices at different times and places throughout the Andes. Correlated with other data, osteometric data can contribute to understanding trade caravans and managing economic or environmental risks. Domestic herds may have played a central role in the initial development of wealth and power inequalities as societies became more complex. These and other profound changes in the history of Andean societies can be clarified by more confidently identifying camelid morphotypes.

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