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Early Horizon Camelid Management Practices in the Nepeña Valley, North-Central Coast of Peru

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Abstract

South American camelids (llamas and alpacas) were of great economic, social, and ritual significance in the prehispanic Andes. Although these animals are largely limited to high altitude (>3,500 masl) pastures, it has been hypothesized that camelids were also raised at lower altitudes in the arid coastal river valleys. Previous isotopic studies of Early Intermediate Period (c. 200 BC to AD 600) and Middle Horizon (c. AD 600 to 1100) camelids support this argument. Here, we utilize carbon and nitrogen isotopic analyses of camelid bone collagen from the Early Horizon (c. 800 to 200 BC) sites of Caylán and Huambacho on the north-central coast of Peru to examine the management of these animals during the first millennium BC. Most of the camelid isotopic compositions are consistent with the acquisition of animals that were part of caravans, moving between the coast and the highlands. A small number of the animals may have been raised on the coast, suggesting that the practice of coastal camelid husbandry was in the experimental phase during the Early Horizon before growing into a more established practice in the Early Intermediate Period. These results echo zooarchaeological studies from the region that have revealed a paucity of camelid remains in refuse deposits prior to 800 BC, followed by an increase in abundance after 450 BC.

Keywords: Stable isotopes; Carbon; Nitrogen; Animal husbandry; Andes; Llama; Caravan; Exchange

Introduction

In the Americas, the South American camelids (llama [*Lama glama*] and alpaca [*Vicugna pacos*]) were the only large mammalian species to be domesticated. While there was temporal and regional variability, these animals were utilized for their meat (Pozorski 1979a; Miller and Burger 1995; Marcus *et al.* 1999), wool (Murra 1962; Boytner 2004; Millaire 2008), dung (for fuel and fertilizer) (Winterhalder *et al.* 1974; Grossman 1983; Bruno 2014), and as pack animals (Browman 1975; Stahl 1988; deFrance 2010). Camelids figured prominently in iconographic representations (Shimada and Shimada 1985; Stone-Miller 1992) and ceremonial events (Donnan and Foote 1978; Millaire 2002; Goepfert 2012; Szpak *et al.* 2014; Millaire 2015; Szpak *et al.* In Press). They permeated every aspect of life in the pre-Hispanic Andes and were thus intimately intertwined with political, religious, and social developments in the region. Accordingly, understanding camelid management practices, as well as the interactions between people and these animals is critical in the context of Andean prehistory.

After the arrival of the Spanish in the sixteenth century various aspects of camelid management were recorded (Murra 1965, 1968, 1980). Yet, many questions remain surrounding the broader applicability of these models across both time and space. Overall, animal management practices prior to the Late Horizon (A.D. 1476 to 1532) are particularly poorly understood. This is due largely to the fact that traditional agro-pastoral systems were severely disrupted by the Spanish conquest in the sixteenth century (Gade 1992). Moreover, the number of camelids, as well as their range was substantially reduced and, in many places, European domesticates (pig, sheep, and donkey) began to overshadow camelids in terms of economic importance (Wheeler 1995).

On the basis of ethnographic and ethnohistoric accounts, camelid herding was principally associated with the high altitude (>3,500 masl) pastures of the *altiplano* and *puna* (Gilmore 1950; Murra 1962, 1965, 1968; Browman 1974; Winterhalder *et al.* 1974; Orlove 1977b; Flores-Ochoa 1979; Murra 1980; Orlove 1982; McCorkle 1987; Flannery *et al.* 1989; Browman 1990a, b; Kuznar 1991). This is the environment in which camelid pastoralism originated (Wheeler 1985; Browman 1989; Kuznar 1989; Moore 1989; Wheeler 1995; Aldenderfer 2001) and the nature of management in the highlands has been widely examined in archaeological contexts (Browman 1984; Moore 1988; Webster 1993; Moore *et al.* 1999; Duncan 2003; Webster and Janusek 2003; Aldenderfer 2006; Beaule 2012; Knudson *et al.* 2012; Vallières 2012). Camelids are, however, regularly present in refuse and ceremonial deposits at sites on the north, central, and south coasts of Peru from at least the Early Horizon (c. 800 BC) and through to the Late Horizon (c. AD 1476 to 1532) (Pozorski 1979a; Pozorski 1979b; Reitz 1979; Shimada and Shimada 1985; Marcus *et al.* 1999; Bonavia 2008; Chicoine 2011; Goepfert 2012; Millaire 2015). Some scholars have argued that camelids (specifically llamas) were raised locally along the coast, rather than being imported from higher altitudes either as dried meat (*ch'arki* or jerky) or meat on the hoof via coast-highland networks of llama caravans. In the most comprehensive summary of various lines of evidence for coastal camelid herding, Shimada and Shimada (1985) argued that this practice was established by the onset of the Middle Horizon (c. AD 600) on the north coast of Peru and suggested it may have started as early as the Early Horizon (c. 800 BC). With the exception of neonates, however, the presence of camelid remains at coastal sites can be difficult to interpret as unambiguous evidence for local herding. Hence, the presence of camelid skeletal remains on the coast alone cannot be used as definite indicator of local herding.

Because of the large environmental and phytogeographic differences between the coastal and high altitude regions of Peru and associated differences in plant isotopic compositions (Szpak *et al.* 2013), stable isotope analyses have been employed to assess the question of camelid husbandry outside the highlands (DeNiro 1988; Verano and DeNiro 1993; Thornton *et al.* 2011; Dufour *et al.* 2014; Szpak *et al.* 2014; Szpak *et al.* 2015; Szpak *et al.* In Press). Generally, a pattern emerges in which animals recovered from coastal contexts are characterized by significantly higher dietary contributions of C_4 plants (likely maize) relative to camelids from the highlands, as well as greater inter-individual isotopic variability. This pattern is clearly manifested at several sites on the north coast of Peru during the Early Intermediate Period (beginning c. 200 BC), which strongly suggests coastal based camelid husbandry by this time (Dufour *et al.* 2014; Szpak *et al.* 2014; Szpak *et al.* In Press). It is, however, unclear whether or not coastal camelid husbandry predates the EIP and the emergence of what have been characterized as archaic states on the north coast of Peru (Fogel 1993; Millaire 2010; Chapdelaine 2011). Presently, the only pre-EIP isotopic data that exist for coastal camelids come from three individuals from La Paloma (5800−1800 BP) on the southern central coast of Peru (DeNiro 1988) but their precise context is not clear. The purpose of this study is to analyze the isotopic compositions of camelid bone collagen from Caylán and Huambacho, two Early Horizon settlements located in the coastal portion of the Nepeña Valley to assess whether or not the previously observed isotopic patterns of coastal camelid management can be traced back to the first millennium BC.

Isotopic Context

The western slope of the Peruvian Andes is a region of marked environmental variation. As altitude increases moving from the arid coastal desert, mean daily temperature decreases and mean annual precipitation increases (Troll 1968; Sandweiss and Richardson 2008). Consequently, the carbon and nitrogen isotopic compositions of vegetation vary in accordance with altitude, and the low (coastal) and high altitude regions are isotopically distinct (Szpak *et al.* 2013). This is true in terms of wild plants and to a lesser extent for domestic plants. On the coast and at low altitudes, where conditions are relatively warm and dry, C_4 plants occur regularly. The high altitude habitats associated with modern camelid herding are generally devoid of C_4 species, with the exception of *Muhlenbergia* sp., which has been recorded in some highland pastures. Nevertheless, these plants are not especially abundant (Wilcox *et al.* 1987) and constitute a relatively minor fraction (no more than 15% and usually much less) of camelid forage today (Bryant and Farfan 1984; Reiner and Bryant 1986).

On the basis of the isotopic ecology of the western slope of the Andes (Szpak *et al.* 2013), as well as previous isotopic studies of camelids, we can generate a series of expectations with respect to camelid isotopic compositions to assess whether or not they were herded in a particular ecological zone, which are summarized in Figure 1. These approximations are intended to represent isotopic data derived from bone collagen, which continuously turns over and therefore represents an average of the long-term diet (Wild *et al.* 2000). As with nearly all species, controlled studies examining the turnover rates of bone collagen in camelids have not been performed. Based on estimates of turnover rates in human bone collagen (upwards of 20 years; Stenhouse and Baxter 1979; Wild *et al.* 2000; Hedges *et al.* 2007), however, it is reasonable to assume that the isotopic composition of camelid bone collagen reflects a lifetime average of diet. Therefore, collagen lacks the ability to resolve more precise life histories relative to tissues that grow continuously such as hair (Szpak *et al.* 2014) or tissues that may be sampled along growth axes such as teeth (Dufour *et al.* 2014).

For camelids herded on the high altitude pastures of the puna and altiplano, we expect low carbon isotopic compositions, consistent with diets composed principally (>80%) of C_3 plants. Nitrogen isotopic compositions are relatively difficult to predict because the pastures on which camelids graze in the Andean highlands may be relatively wet (e.g., the *bofedales* [cushion-peat bogs] and moist *punas* that occur in the central Peruvian highlands) or dry (e.g., the dry and salt *punas* that occur primarily in southern Peru and further south, east of the Atacama) (Baied and Wheeler 1993). Given that plant tissue δ^{15}N values tend to be higher in under conditions of limited water availability (Handley *et al.* 1999; Amundson *et al.* 2003; Craine *et al.* 2009), we would expect high δ^{15}N values in dry relative to moist highland pastures, although this requires experimental verification.

While comparatively few modern camelids from high altitude contexts (both modern and archaeological) have been subjected to isotopic analysis, none have been characterized by the high (>8‰) nitrogen isotopic compositions that have been recorded for some camelids from coastal and low altitude sites (DeNiro 1988; Verano and DeNiro 1993; Thornton *et al.* 2011; Dufour *et al.* 2014; Szpak *et al.* 2014; Szpak *et al.* 2015). A pattern of camelid diets dominated by C_3 plants has been recorded for modern camelids from high altitude contexts throughout much of Peru (Schoeninger and DeNiro 1984; Thornton *et al.* 2011; Dufour *et al.* 2014; Szpak *et al.* 2014), as well as archaeological camelids from Chinchawas (3,850 masl) (Szpak *et al.* 2015) and Tiwanaku (3,800 masl) (Szpak 2013). For camelids that were herded on the coast, we predict three different patterns depending on whether the principle forage was agricultural fodder (e.g., maize and other byproducts) or wild plants, and the scale at which herding was practiced (large or small herds).

For camelids herded on the coast or at low altitudes that grazed on wild vegetation, we expect high carbon isotopic compositions (due to a higher proportion of C_4 plants in the diet) and much higher nitrogen isotopic compositions (due to the consumption of vegetation growing under water-limited conditions) relative to high altitude camelids. Because the coastal and low altitude regions still contain appreciable quantities of C_3 plants, relatively low carbon isotopic compositions are still feasible, although most of these plants should still be characterized by high nitrogen isotopic compositions because of the aridity effects on vegetation (Szpak *et al.* 2013). These patterns have been observed in camelids from several sites, although not necessarily interpreted in this manner: Cerro Baul in the Moquegua Valley (2,500 masl) (Thornton *et al.* 2011), as well as Chilca and La Paloma on the southern central coast of Peru (DeNiro 1988).

The coast of Peru is essentially a desert environment with areas of herbaceous vegetation being more common in coastal river valleys, which today may support small numbers of grazing goats in some areas (Rundel *et al.* 1991). The lack of substantial vegetation on the coast is, however, a potential limitation to the herding of camelids. Accordingly, it has been suggested that coastal camelids would have been provided with principally, or entirely, fodder from agricultural products or byproducts. This is an important distinction in terms of animal management practices, and the consumption of coastal cultigens should manifest itself differently in camelid tissue isotopic compositions relative to the consumption of wild coastal vegetation.

On the coast of Peru rainfall occurs only under exceptional circumstances and agriculture is entirely dependent on irrigation (Rauh 1985). Because of this, cultigens are not subjected to the water-limited conditions characteristic of wild coastal vegetation and the influence of local environmental conditions on plant δ^{15}N values is mediated (Szpak *et al.* 2012a). Therefore, coastal camelids provided with agricultural fodder will not be characterized by unusually high δ^{15}N values. Nevertheless, C_4 cultigens are much more common at lower altitude and coastal sites relative to those in traditional camelid herding areas, which instead focus on tuber (all of which are C_3 plants) cultivation (Orlove and Godoy 1986). Therefore, unlike low altitude camelids grazing on wild vegetation, coastal camelids foddered with agricultural byproducts should be characterized by relatively high, but variable, carbon isotopic compositions (due to the importance of maize foddering), but nitrogen isotopic compositions that are comparable to camelids herded in highland pastures. Such a pattern has been observed at many sites along the north coast of Peru including Huaca Gallinazo, Huaca Santa Clara, and Huancaco in the Virú Valley (Szpak *et al.* 2014), Pacatnamú in the Jequetepeque Valley (Verano and DeNiro 1993), and El Brujo in the Chicama Valley (Dufour *et al.* 2014). It is important to point out that the sample sizes for the latter two sites were quite small, making it difficult to formulate any broad generalizations about camelid diets.

A third pattern involves intensive foddering of camelids with maize. In this case, camelids are still fed agricultural products or byproducts but consume a markedly less varied diet at the group or population level and would be characterized by consistently high δ^{13}C values. Evidence for intensive maize foddering has been recorded at Conchopata (2,700 masl) where several camelids (interpreted to be llamas) had δ^{13}C values of c. −10 ‰ (Finucane *et al.* 2006). This pattern is not necessarily specific to any particular region, but the fact that maize is not cultivable above c. 3,500 masl (Sandweiss and Richardson 2008) and C_4 plants are also sparsely distributed above this altitude (Szpak *et al.* 2013) precludes this camelid management strategy from the *puna.* To date Conchopata is the only site where these isotopic compositions have been observed, although it is important to note that the δ^{13}C values were bimodally distributed and it is unclear whether a larger sample from the site would have obscured this pattern and produced a dataset more similar to others from sierra and coastal sites.

Archaeological Context and Materials

Nepeña is a small coastal oasis located 400 km north of Lima (Figure 2). The valley is perhaps most famous for its strong human presence and dynamic cultural innovations during the first millennium BC (Proulx 1982; Daggett 1983, 1984). During the local Nepeña Phase (800-450 cal BC, Figure 3) (see Shibata 2011), late Initial Period ceremonial centers such as Cerro Blanco and Huaca Partida were abandoned and populations gradually nucleated at urban-like settlements on the north and south margins of the valley. Survey and excavation work over the last decade indicate that these developments were associated with the rise of an Early Horizon polity based at the primary center of Caylán, the largest archaeological complex in Nepeña (Chicoine and Ikehara 2010, 2014).

Caylán is located on the northern margin of the lower valley, some 15 km from the Pacific coastline. The site appears strategically located at the center of the catchment area of the lower valley polity. Meanwhile, secondary satellite communities in the lower valley have been recorded at Huambacho (Chicoine 2006), Sute Bajo (Cotrina *et al.* 2013), Samanco (Helmer and Chicoine In Press), and perhaps Cerro Blanco (Shibata 2010, 2011). Radiocarbon dates indicate that the polity reached its climax during the local Samanco Phase (450-150 BC), before giving way to outside influences at the turn of the first millennium AD (Chicoine 2011).

Combined with settlement pattern data, the analysis of faunal and botanical remains from secure excavated contexts at Cerro Blanco (Ikehara *et al.* 2013), Huambacho (Chicoine 2011; Chicoine and Rojas 2012), and Caylán (Chicoine and Rojas 2013; Chicoine *et al.* In Press) have provided insight into the profound socioeconomic transformations experienced by Early Horizon groups in coastal Nepeña. Most salient among these transformations are the extension of irrigation networks, the intensification of maize cultivation, and the increased reliance on highland animal domesticates − namely guinea pigs and camelids. Previous research suggests that these innovations were closely tied to a reorganization of exchange networks, shifts in leadership strategies, heightened elite competition as materialized in the acquisition of prestige items, the construction of more exclusive ritual settings, and the sponsoring of feasts and alcohol production (Chicoine 2011; Ikehara *et al.* 2013). While camelids and their use as caravan animals likely played a crucial role in the realignment of political and economic strategies during the Nepeña and Samanco phases, little is currently known about the actual movements of these animals and their management.

Between 2003 and 2010, Chicoine directed a combined 39 weeks of fieldwork at Huambacho and Caylán to investigate Early Horizon cultural developments in coastal Nepeña. Mapping and excavation results from Caylán indicate that the Early Horizon settlement was organized into more than 40 monumental house compounds agglutinated into a dense urban core and articulated through a complex network of streets and alleyways. Excavations sampled more than 560 m^2 and yielded information on different types of primary and secondary discard contexts including floor scatters, open air middens, and construction fills (Figure 4). A total of six excavation areas (UE1-6), and sixteen test units (HP1-16) were excavated, along with the clearing of a looter's pit (PH1). Overall, the excavated contexts and associated structures and materials allow for a preliminary consideration of (1) a monumental platform complex (Main Mound Complex, UE1, 4), (2) a public space (Plaza-A, UE2, 5), (3) a multi-functional residence (Compound-E, UE6), and (4) several other discard areas located throughout the site and sampled through UE3, the test pits (HP), and PH1. The samples of camelid remains analyzed in this article come the Main Mound Complex (n=8), Plaza-A and one of its adjacent patios (n=6), the residential portion of Compound-E (n=5), as well as peripheral open-air middens (n=3). Overall, the samples from Caylán appear to correspond to discard episodes associated with the ceremonial use of plaza and mound spaces (Main Mound, Plaza-A), the more domestic or daily consumption of camelids (Compound-E), as well as the secondary transport of skeletal remains away from the urban core. Stylistic evidence and radiocarbon measurements suggest that all the sectors sampled were occupied contemporaneously.

Meanwhile, excavations at Huambacho sampled more than 4,500 m^2 and yielded insights into the occupation of a small elite center located on the southern margin of the coastal plain, some 8 km from the shoreline. Here, materials mainly came from the clearing of plazas and patio halls associated with feasting practices and ceremonial gatherings. More specifically, the camelid remains analyzed in this study are associated with the use of a monumental plaza (Plaza-B, n=1), as well as a small mound complex interpreted as an elite residence (Huaca-A, n=2). Radiocarbon measurements securely place the excavated contexts at Caylán and Huambacho within the Early Horizon (Chicoine 2010a; Chicoine and Ikehara 2010, 2014).

The excellent organic preservation at both sites allowed the recovery of a rich faunal assemblage. Taxonomic analyses of the vertebrate remains indicate that the dwellers of these two Early Horizon settlements interacted with, used, ate, and processed a vast array terrestrial, marine, riverine, and lacustrine vertebrates including amphibians, reptiles, fish, birds, and mammals. The role of camelids was likely diverse, serving as pack animals, sources of meat and bones, and perhaps fibers. Yet, solid conclusions about local herding practices remain out of reach since no corrals, dung, or other indications of *in situ* husbandry were detected at Caylán or Huambacho. It is significant, however, that recent fieldwork at Samanco, an Early Horizon site located 2 km from the coast on the northern margin of the lower Nepeña, revealed a series of rectangular rooms with large amounts of compacted camelid dung (Helmer and Chicoine In Press). With a surface area of more than 800 m^2, the structure could have easily housed up to 200 llamas, possibly more. More research is needed on the Samanco assemblage, but it appears possible that llama caravans were travelling to the coastal center to move marine resources. Differences, for instance, in the composition of the shell assemblages from Samanco and Caylán suggest that a limited number of select bivalve species supplied inland populations, in particular the small intertidal clam *Donax* spp. (Chicoine and Rojas 2013). In contrast, deposits at coastal settlements contain a richer and more diverse corpus (Matthew Helmer, personal communication 2014).

Nineteen camelids from Caylán and three from Huambacho were sampled for stable isotope analysis (Table 1). The vast majority of the samples consisted of first phalanges, as well as three astragali (although these failed to produce acceptable collagen and are not included in the analysis) and a single mandible (Table 1). The same non-repetitive elements were sampled from each context (i.e. Main Mound, Plaza-A, Compound-E at Caylán) to avoid sampling the same individual. Based on the epiphyseal fusion data provided in Kent (1982), the animals sampled were all >2 years of age.

Methods

Because it is exceptionally difficult and in most cases impossible to accurately differentiate South American camelid species on the basis of postcranial skeletal elements (Shimada 1982), the samples analyzed in this study could only be identified as camelids and not to any particular species. Based on limited osteometric analyses conducted on camelids recovered from Early Horizon contexts, these individuals are more similar to modern llamas than they are to alpacas (Vásquez and Rosales 2012).

Bone collagen was extracted using previously described methods (Szpak *et al.* 2014). Isotopic and elemental compositions (δ^{13}C, δ^{15}N, % C, % N) were determined using a Thermo Finnigan Delta V continuous flow mass spectrometer coupled to a Costech Elemental Analyzer at the Laboratory for Stable Isotope Science (University of Western Ontario). Carbon and nitrogen isotopic compositions were calibrated to VPDB and AIR with USGS40 (glutamic acid, accepted values δ^{13}C = −26.39 ‰, δ^{15}N = −4.52 ‰) and USGS41 (glutamic acid, accepted values δ^{13}C = 37.63 ‰, δ^{15}N = 47.6 ‰). Details on analytical accuracy and precision are summarized in the Supplementary Material.

All statistical analyses were performed with the open source statistical package R (R Development Core Team 2007) for Mac OS X. Relative contributions of C_3 and C_4 plants were quantified using a single isotope Bayesian mixing model with the SIAR package (Parnell *et al.* 2010). The following parameters were used in the mixing model:

Sources: C_3 plants (−26.12±1.75 ‰) and C_4 plants (−12.01±0.95 ‰). These values represent means ± one standard deviation of wild and cultivated plants sampled in northern Peru (Szpak *et al.* 2012a). The values presented above have been adjusted by +1.50 ‰ to account for the Suess Effect (Yakir 2011).

Corrections: Trophic level fractionation for bone collagen was obtained from a survey of published literature (Szpak *et al.* 2012b): $\Delta^{13}C_{\text{collagen−diet}}$ = +3.6±1.7 ‰.

Results

Isotopic and elemental compositions for all specimens analyzed are presented in Table 1. Nineteen of the twenty-two specimens from which collagen was extracted produced atomic C:N ratios within the range of accepted values for well-preserved bone collagen (2.9−3.6) as reported by DeNiro (1985). For the 19 samples with acceptable C:N ratios, collagen yields were >1%, while the 3 samples with unacceptable C:N ratios were also characterized by collagen yields <1% (AIS−1299, AIS−1313, AIS−1314). Accordingly, results for these three samples have been omitted from all summary statistics, plots, and analyses (Ambrose 1990).

Individual carbon and nitrogen isotopic compositions for the Nepeña camelids are plotted in Figure 5A and Figure 5B. These data are overlain atop heat plots generated on the basis of isotopic datasets for camelids from coastal archaeological sites (*n*=160) and highland archaeological sites as well as modern highland (>3,200 masl) camelids (*n*=155) (compiled by Szpak 2013). The majority (16/19) of the Nepeña camelids (those with $\delta^{13}C$ values <−16 ‰) fit generally with the isotopic compositions of high altitude camelids, although three individuals from Caylán (those with $\delta^{13}C$ values > −16 ‰) have isotopic compositions inconsistent with high altitude pasturing.

The results of the two-source (C_3/C_4) Bayesian mixing model (SIAR) are presented in Figure 6. Two comparative camelid datasets are also presented in: a group of Middle Horizon camelids from a high altitude herding site (Chinchawas in the Callejón de Huaylas) and a group of Early Intermediate Period camelids from a coastal site (Huaca Gallinazo in the Virú Valley)

(Szpak *et al.* 2014; Szpak *et al.* 2015). On the basis of a growing body of isotopic measurements of camelids from coastal, highland, and intermediate altitudes in Peru (DeNiro 1988; Verano and DeNiro 1993; Finucane *et al.* 2006; Thornton *et al.* 2011; Szpak 2013; Dufour *et al.* 2014; Szpak *et al.* 2014; Szpak *et al.* 2015; Szpak *et al.* In Press), the two comparative datasets presented in Figure 6 are the largest and are representative of typical coastal and highland patterns.

Collectively, the Caylán camelids are characterized by intermediate carbon isotopic compositions relative to the comparative groups from the coast (Huaca Gallinazo) and highlands (Chinchawas). These comparisons do not take into account any intragroup complexities that may drive these patterns, which is somewhat problematic. The majority of the Caylán camelids have δ^{13}C values between −20 and −16 ‰ and a panel is included in Figure 6 that removes the three individuals with δ^{13}C values greater than −16 ‰. Even after removing these three values, the Caylán camelids still have diets consistent with significantly greater C_4 plant consumption than the Chinchawas (highland) camelids ($p<0.001$) suggesting some differences in camelid life histories between the two groups. Therefore, neither the coastal pattern of diversified camelid husbandry involving significant C_4 plant foddering (Szpak *et al.* 2014), the specialized urban pattern of almost exclusively maize foddering (Finucane *et al.* 2006), nor the highland pattern of pasturing (as is seen in the Chinchawas data) adequately characterizes the Caylán camelids.

Discussion

We posit that the isotopic data for the Caylán camelids are reflective of two economic strategies. The first involves the acquisition of camelid livestock traded in from higher altitude zones. These animals were likely born in the highlands and moved to the coast at some point in their lives prior to being killed and consumed. They may have been animals associated with or part of caravans that moved to and from the coast, consuming a more mixed C_3/C_4 diet than those animals living exclusively on the high altitude pastures of the puna, with maize fodder being provided to the animals at various points along the way, possibly in exchange for goods being moved by the caravans – this practice was recorded in ethnohistoric accounts (e.g. Zárate 1555).

While we cannot definitely rule out that the camelids with relatively low δ^{13}C values were not foddered with local C_3 forage – the practice of feeding camelids with the beans and pods of the algorrobo tree (*Prosopis* sp., a N_2-fixing C_3 species common in coastal Peru) has been observed in coprolites from coastal Late Intermediate Period specimens (Shimada and Shimada 1985) − this explanation seems unlikely given that this pattern (at the site level) has not been observed in over 200 camelid C and N isotopic measurements from 12 other coastal sites (DeNiro 1988; Verano and DeNiro 1993; Szpak 2013; Szpak *et al.* 2014; Szpak *et al.* In Press). Moreover, there is limited additional evidence supporting local camelid husbandry, such as the presence of structures resembling corrals or the accumulation of significant quantities of dung (for examples on the coast, see Shimada 1981; Wilson 1988; Szpak *et al.* 2014). This negative evidence has to be interpreted with caution, but the fact remains that most of the animals have δ^{13}C values that do not accord well with intensive patterns of local husbandry, but these camelids were consuming more C_4 plants than would be expected for animals raised in the *puna*. Instead, we suggest that these camelids were acquired via trade with caravans.

While no isotopic studies have been performed on modern or archaeological animals known or suspected (in the case of the latter) to have been associated with caravans, modern observations suggest that caravan animals begin training after two years of age (spending this time in the *puna*) and consist exclusively of castrated males between 2 and 8 years of age

(Nielsen 2001). In the course of their movements, caravan animals graze on locally abundant forage and in some cases are provided with fodder from agricultural products or permitted (sometimes encouraged) to graze field stubble, which typically includes maize at altitudes below 3,500 masl (Browman 1990b).

In southern Peru, modern llama herders often arranged trading trips to the coast at the end of the maize harvest, where animals could have grazed maize stubble intensively, but for a short period of time (Browman 1990a). Thus, animals acquired as adults that were part of caravans would likely show a predominantly C_3 diet, particularly if bone remodeling rates are such that the isotopic signature of the collagen disproportionately represents periods of accelerated bone growth early in life (Hedges *et al.* 2007), when the animals were still living in the *puna*. Interestingly, there is a strong positive correlation between δ^{13}C and δ^{15}N values for the Nepeña camelids consuming predominantly C_3 plants (Spearman's $\rho=0.76$, $p<0.001$), suggesting that the C_4 plants consumed by these camelids had significantly higher δ^{15}N values than the C_3 plants they consumed.

By way of comparison, the camelids from the high altitude herding site of Chinchawas (Szpak *et al.* 2015) show a *negative*, but not statistically significant correlation between bone collagen δ^{13}C and δ^{15}N values (Spearman's $\rho=-0.50$, $p=0.08$). These animals are believed to have been alpacas (Lau 2007), and hence would not have been caravan animals moving between altitudinal zones. There are two plausible scenarios for the correlation observed for the Caylán camelids, both of which fit with the consumption of maize from field stubble. They are, however, not mutually exclusive. First, if camelids regularly visited maize plots, they may have deposited significant quantities of dung as they grazed; recent accounts report this activity for modern camelids in agricultural fields after the harvest (McCorkle 1987; Mitchell 1991; Goland

1993). Indeed, Orlove (1977a) points out the importance of the addition of highland camelid dung for lowland crop growth. The addition of camelid dung to maize fields significantly increases plant tissue δ^{15}N values by between 2 and 4 ‰, even after a single season and at a relatively low rate of application (Szpak *et al.* 2012a). If caravan camelids consumed this fertilized maize, it would fit with the positive correlation between δ^{13}C and δ^{15}N values observed here for Caylán camelid bone collagen. An additional consideration is the type of plant tissue consumed.

The fact that animals are only permitted to graze on the leaves and stalks in maize fields is significant because there is consistent intraplant δ^{15}N variation in annual crops such as maize. Specifically, leaves and stems have consistently higher δ^{15}N values than grains because of reallocation and resultant discrimination against ^{15}N that occurs during grain filling; these differences may be on the order of several per mil, and significantly higher (>5 ‰) under conditions of high nitrogen availability, such as occurs with fertilization (Szpak 2014). Therefore, we would expect animals that had diets consistent with this pattern of seasonal, but relatively limited, fertilized maize leaf and stem consumption to be characterized by carbon and nitrogen isotopic compositions observed for the majority of the Early Horizon camelids.

Although marine fauna are both abundant and diverse at Caylán and Huambacho (Chicoine and Rojas 2012, 2013), camelids are the most abundant vertebrate taxon. At Caylán, they represent 13.3% of the total NISP (n=3,289), and 37.4% of the NISP for mammals (n=1,661). Similarly, at Huambacho, camelids comprise 39.8% of the vertebrate NISP (n=1,300). That most of the camelid remains analyzed have isotopic compositions consistent with a non-local origin suggests that the local population may have relied to a large extent on imported camelid meat, which implies a significant level of interaction between coastal and highland communities during the Early Horizon.

During the 1st millennium BC, many transformations can be evoked to account for increased contacts between coastal and highland communities. Technological advances were made, either through innovation or improvement of Initial Period traditions (Burger 1988; Kembel and Rick 2004), however, it is the development of Chavín de Huantar and the spread of the Chavín cult that have traditionally been seen as the main driving forces of change (Keatinge 1981). The Chavín cult was materialized in an iconography centered on images of felines, raptorial birds, caimans, and San Pedro cactus, and expressed the predominance of shamanistic beliefs. It is believed that ideological and religious ties were materialized in similar ritual paraphernalia, iconography, and ceremonial architecture (Burger 1992). In contrast to day-to-day interactions, these interregional interactions existed within the realm of elites.

Some scholars have emphasized the more socioeconomic and political aspects of interregional networks, outlining the limitations of considering the Chavín influence as solely religious (Burger and Matos 2002). They suggest that the circulation of valuables, from the extraction of special materials to the crafting of fine artifacts and the acquisition of non-local goods, primarily answered economic and sociopolitical concerns. From this perspective, groups with privileged access to prized resources and valuables would take advantage of the situation to position themselves within regional networks and increase their power and influence. Burger and Matos (2002) provide an example from the Early Horizon site of Atalla in the central highlands and suggest that the local availability of cinnabar, a mineral valued for its bright red color and used during the Early Horizon in burial rites and for decorating ceremonial objects and buildings, allowed local leaders to gain power. These interactions would have materialized in the identification of Atalla elites to Chavín precepts and materialized in the emulation of Chavín ceramic styles (Burger and Matos 2002).

In coastal Nepeña, recent research has questioned traditional connections with the Chavín phenomenon and the adjacent highlands (Chicoine 2006, 2010b; Shibata 2010, 2011); especially considering the reevaluation of the occupational history and chronology at Chavín de Huantar (Burger and Salazar-Burger 2008; Rick *et al.* 2011). While Chavín-related and Cupisnique stylistic features are evident at the late Initial Period ceremonial centers of Cerro Blanco and Huaca Partida, by the time of the emergence of urban communities at Caylán and associated settlements, coastal populations appear to have steered clear of Chavín imagery. Yet, it is precisely during this transition that camelids begin to be common in coastal Ancash. This is likely related to the intensification of bulk exchanges, likely of subsistence goods, along the coast, but perhaps more importantly – based on the results of our isotope study in Nepeña – between the coast and the adjacent highland regions. This suggests that coast-highland interaction networks survived the demise of Chavín-related phenomena, although these were likely substantially reorganized. Here, llama caravans appear to have been important in the transportation of goods between Early Horizon coastal populations and settlements in the more elevated highland regions, likely the Callejón de Huaylas. It is unclear at the moment if these extra-local interaction networks channeled exotic and prestige items, and/or more mundane subsistence staples, but the presence of a camelid corral at the Early Horizon fishing community of Samanco suggests that dried fish and other marine resources were being moved across Ancash. The presence of large amounts of select shell species at inland communities strengthens this assertion (Chicoine and Rojas 2012, 2013).

As mentioned previously, the three Caylán camelids with δ^{13}C values higher than −15 ‰ do not fit with the highland mode of pastoralism. Therefore, these individuals merit some additional discussion. There are three reasonable possibilities that might explain the Caylán camelids with relatively high δ^{13}C values. First, the local populace was beginning to experiment with camelid herding some time during the Early Horizon and supplied these animals with fodder that included significant quantities of C_4 plants, most likely maize byproducts, but wild local C_4 grass species (e.g., *Distichlis* sp.) may have formed an important part of the diet (Shimada and Shimada 1985). An additional source of wild forage with high δ^{13}C values may have been *lomas* (fog oases) located in the Andean foothills. These ephemeral formations occur sporadically throughout the Andes (Ono 1986) and today exist in relatively close proximity to both Caylán and Huambacho in the coastal portion of the Nepeña Valley. Thornton et al. (2011) interpret several individual camelids from Cerro Baúl with relatively high δ^{13}C and δ^{15}N values as possibly having grazed in *lomas* environments.

Second, these camelids may also have been caravan animals that for some reason happened to have consumed significantly higher quantities of C_4 plants than the other individuals despite occupying a similar economic role. Given the limited availability of C_4 plants throughout most of the year at high altitudes, however, this seems unlikely. A more plausible scenario is that these animals were foddered in a way that was distinct from the majority of the Early Horizon coastal camelids because they spent a significant portion of their lives in another location.

It is possible that the Caylán camelids with relatively high δ^{13}C values may have originated outside of the *puna* pastures above 3,500 masl, but were raised in the intermediate low or high sierra zones (c. 2,300 to 3,500 masl) where maize cultivation still occurs. The high δ^{13}C values recorded for the camelids from the Middle Horizon (c. AD 550 to 1000) occupation at

Conchopata, which is located at c. 2,700 masl demonstrate the possibility of camelids being foddered on large amounts of C_4 plants (Finucane *et al.* 2006), although this is the only instance in which such a pattern has been observed and relevant data are lacking from earlier periods. The C_3 consuming animals at Conchopata have been interpreted to be alpacas that grazed not locally, but in the *puna*, and the C_4 consuming animals were likely corralled and foddered with maize and/or allowed to graze maize stubble in local agricultural fields (Finucane *et al.* 2006). This latter pattern of camelid husbandry is very similar to what has been suggested for the north coast during the EIP and Middle Horizon (Dufour *et al.* 2014; Szpak *et al.* 2014; Szpak *et al.* In Press). In other words, while foddering camelids with significant quantities of maize is possible at intermediate altitudes, there is no basis to suggest that it would be any more likely than at low altitudes. There is evidence for corralling and the presence of maize in camelid dung at nearby Samanco in the Nepeña Valley, suggesting local herding of camelids at this site, although the broader regional importance and temporal scale of this activity is presently unclear. That there is some evidence of local corrals and the fact that these animals have isotopic compositions completely inconsistent with high altitude herding (Figure 5A), similarly do not fit with the other Caylán camelids that we have interpreted to be caravan animals. This leads us to hypothesize that people in the lower Nepeña Valley were experimenting with local camelid herding during the Early Horizon. The isotope results suggest dynamic human-animal relationships at the onset of the Early Horizon in which camelids were gradually being brought to and eventually corralled and raised on the coast. This is particularly significant in the context of incipient urban settlements, such as Caylán, where many human groups had the potential to become specialized and detached from primary subsistence activities. Indeed, urban dwellers can acquire meat and other animal products directly or indirectly through state-sponsored and other centralized systems (Zeder 1991). Traditionally, archaeologists have hypothesized that the development of state-like and other stratified societies led to increasingly efficient and centralized systems of animal management (i.e., increasing number of non-food producers are provisioned by centralized economic/redistributive mechanisms/institutions). In coastal Ancash, it appears that the introduction and increased reliance on camelids as beasts of burdens played a major role in the development of long-distance trade and its associated routes and networks.

That the isotopic data for the Caylán camelids are quite distinct from other coastal sites where husbandry appears much more established (Dufour *et al.* 2014; Szpak *et al.* 2014; Szpak *et al.* In Press) suggests that the activity of local raising camelids was not of great economic importance in Nepeña during the Early Horizon. Herd sizes collectively throughout the valley may have not have been large enough to sustain a local population and the addition of new animals was likely primarily through the acquisition of young animals from highland herds. Shimada and Shimada (1985) posited that llamas were successfully bred and maintained on the north coast of Peru from at least the Middle Horizon (c. AD 600) and possibly dating back to the Early Horizon (c. 200 BC). The results presented here suggest that the experimentation with coastal camelid husbandry through the occasional acquisition of caravan llamas may have begun during the Early Horizon, at least in Ancash, but this hypothesis requires testing through the collection of additional data from other sites, both in Nepeña and along the entire coast, that predate the EIP.

Conclusions

The principal source for camelid consumption at Caylán and Huambacho appears to have been the acquisition of llamas that were likely part of caravans moving between the coast and the highlands. These animals consumed significant quantities of maize, likely stems and leaves and probably fertilized maize plots as they grazed, but for relatively short periods of the year. A small number of camelids from Caylán have isotopic compositions consistent with being raised locally on the coast, suggesting that the local populace in Nepeña may have been experimenting with this activity during the Early Horizon. Although the data for Caylan is the third largest sample of camelids from a single site in Peru produced to date, additional data from contemporaneous sites are necessary before any clear picture of animal management during the Early Horizon can develop.

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References

Aldenderfer, M. 2001. Andean Pastoral Origins and Evolution: The Role of Ethnoarchaeology, pp. 19-30 in Kuznar, L.A. (ed.) *Ethnoarchaeology of Andean South America: Contributions to Archaeological Method and Theory*, Ann Arbor: International Monographs in Prehistory. Ethnoarchaeological Series 4.

Aldenderfer, M. 2006. Costly signaling, the sexual division of labor, and animal domestication in the Andean highlands, pp. 167-196 in Kennett, D.J., Winterhalder, B. (eds.), *Behavioral Ecology and the Transition to Agriculture*, Berkeley: University of California Press.

Ambrose, S.H. 1990. Preparation and characterization of bone and tooth collagen for isotopic analysis. *Journal of Archaeological Science* **17**: 431-451.

Amundson, R., Austin, A.T., Schuur, E.A.G., Yoo, K., Matzek, V., Kendall, C., Uebersax, A., Brenner, D., Baisden, W.T. 2003. Global patterns of the isotopic composition of soil and plant nitrogen. *Global Biogeochemical Cycles* **17**: 1031.

Baied, C.A., Wheeler, J.C. 1993. Evolution of High Andean Puna Ecosystems: Environment, Climate, and Culture Change over the Last 12,000 Years in the Central Andes. *Mountain Research and Development* **13**: 145-156.

Beaule, C. 2012. Wealth on the hoof: Camelid faunal remains and subsistence practices in Jachakala, Bolivia. *Research in Economic Anthropology* **32**: 259-289.

Bonavia, D. 2008. *The South American Camelids*. Los Angeles: Cotsen Institute of Archaeology, University of California.

Boytner, R. 2004. Clothing the social world, pp. 130-145 in Silverman, H. (ed.) *Andean Archaeology*, Malden, MA: Blackwell.

Browman, D.L. 1974. Pastoral nomadism in the Andes. *Current Anthropology* **15**: 188-196.

Browman, D.L. 1975. Trade Patterns in the Central Highlands of Peru in the First Millennium B.C. *World Archaeology* **6**: 322-329.

Browman, D.L. 1984. Tiwanaku: Development of Interzonal Trade and Economic Expansion in the Altiplano, pp. 117-131 in Browman, D.L., Burger, R.L., Rivera, M.A. (eds.), *Social and Economic Organization in the Prehispanic Andes*, Oxford: BAR International Series 194.

Browman, D.L. 1989. Origins and development of Andean pastoralism: an overview of the past 6000 years, pp. 256-268 in Clutton-Brock, J. (ed.) *The Walking Larder: Patterns of Domestication, Pastoralism, and Predation*, London: Unwin Hyman.

Browman, D.L. 1990a. Camelid pastoralism in the Andes: Llama caravan fleteros, and their importance in production and distribution, pp. 395-438 in Salzman, P.C., Galaty, J.G. (eds.), *Nomads in a Changing World*, Naples: Instituto Universitario Orientale.

Browman, D.L. 1990b. High altitude camelid pastoralism of the Andes, pp. 323-352 in Galaty, J.G., Johnson, D.L. (eds.), *The World of Pastoralism: Herding Systems in Comparative Perspective*, New York: The Guilford Press.

Bruno, M.C. 2014. Beyond Raised Fields: Exploring Farming Practices and Processes of Agricultural Change in the Ancient Lake Titicaca Basin of the Andes. *American Anthropologist* **116**: 130-145.

Bryant, F.C., Farfan, R.D. 1984. Dry Season Forage Selection by Alpaca [*Lama pacos*] in Southern Peru. *Journal of Range Management* **37**: 330-333.

Burger, R.L. 1988. Unity and Heterogeneity within the Chavín Horizon, pp. 99-144 in Keatinge, R.W. (ed.) *Peruvian Prehistory: An Overview of Pre-Inca and Inca Society*, Cambridge: Cambridge University Press.

Burger, R.L. 1992. *Chavín and the Origins of Andean Civilization*. New York: Thames & Hudson.

Burger, R.L., Matos, R.M. 2002. Atalla: a center on the periphery of the Chavin horizon. *Latin American Antiquity* **13**: 153-177.

Burger, R.L., Salazar-Burger, L. 2008. The Manchay Culture and the Coastal Inspiration for Highland Chavín Civilization, pp. 85-105 in Conklin, W.J., Quilter, J. (eds.), *Chavín: Art, Architecture, and Culture*, Los Angeles: Cotsen Institute of Archaeology Press.

Chapdelaine, C. 2011. Recent Advances in Moche Archaeology. *Journal of Archaeological Research* **19**: 191-231.

Chicoine, D. 2006. Early Horizon Architecture at Huambacho, Nepeña Valley, Peru. *Journal of Field Archaeology* **31**: 1-22.

Chicoine, D. 2010a. Cronología y secuencias en Huambacho, valle de Nepeña, costa de Ancash. *Boletín de Arqueología PUCP* **12**: 317-348.

Chicoine, D. 2010b. Elite Strategies and Ritual Settings in Coastal Peru during the 1st Millenium B.C., pp. 191-212 in Cutright, R., Lopez-Hurtado, E., Martin, A.J. (eds.), *Comparative Perspectives on the Archaeology of Coastal South America*, Pittsburgh: Center for Comparative Archaeology, University of Pittsburgh.

Chicoine, D. 2011. Feasting landscapes and political economy at the Early Horizon center of Huambacho, Nepena Valley, Peru. *Journal of Anthropological Archaeology* **30**: 432-453.

Chicoine, D., Ikehara, H. 2010. Nuevas evidencias sobre el Periodo Formativo del valle de Nepeña: Resultados preliminares de la primera temporada de investigaciones en Caylán. *Boletín de Arqueología PUCP* **12**: 349-370.

Chicoine, D., Rojas, C. 2012. Marine Exploitation and Paleoenvironment as Viewed through Molluscan Resources at the Early Horizon Center of Huambacho, Nepeña Valley, Peru. *Andean Past* **10**: 284-290.

Chicoine, D., Rojas, C. 2013. Shellfish Resources and Maritime Economy at Caylán, Coastal Ancash, Peru. *The Journal of Island and Coastal Archaeology* **8**: 336-360.

Chicoine, D., Ikehara, H. 2014. Ancient urban life at the Early Horizon center of Caylán, Peru. *Journal of Field Archaeology* **39**: 336-352.

Chicoine, D., Clement, B., Stich, K. In Press. Macrobotanical Remains from the 2009 Season at Caylán: Preliminary Insights into Early Horizon Plant Use in the Nepeña Valley, North-Central Coast of Peru. *Andean Past* **12**.

Cotrina, J., Peña, V., Tandaypan, A., Pretell, E. 2013. Evidencias Salinar: sitios VN-35 y VN-36, Sector Sute Bajo, valle de Nepeña. *Revista Arqueológica SIAN* **14**: 7-12.

Craine, J.M., Elmore, A.J., Aidar, M.P.M., Bustamante, M., Dawson, T.E., Hobbie, E.A., Kahmen, A., Mack, M.C., McLauchlan, K.K., Michelsen, A., Nardoto, G.B., Pardo, L.H., Peñuelas, J., Reich, P.B., Schuur, E.A.G., Stock, W.D., Templer, P.H., Virginia, R.A., Welker, J.M., Wright, I.J. 2009. Global patterns of foliar nitrogen isotopes and their relationships with climate, mycorrhizal fungi, foliar nutrient concentrations, and nitrogen availability. *New Phytologist* **183**: 980-992.

Daggett, R.E. 1983. The Early Horizon-Early Intermediate Period transition: a view from the Nepaña and Virù Valleys, pp. 41-66 in Kvietok, D.P., Sandweiss, D.H. (eds.), *Recent Studies in Andean Prehistory and Protohistory. Papers from the Second Annual Northeast Conference on Andean Archaeology and Ethnohistory*, Ithaca: Cornell University, Latin American Studies Program.

Daggett, R.E. 1984. *The Early Horizon Occupation of the Nepeña Valley, North Central Coast of Peru*. Unpublished Ph.D. Dissertation, University of Massachusetts.

deFrance, S.D. 2010. Paleopathology and health of native and introduced animals on Southern Peruvian and Bolivian Spanish Colonial sites. *International Journal of Osteoarchaeology* **20**: 508-524.

DeNiro, M.J. 1985. Postmortem preservation and alteration of *in vivo* bone collagen isotope ratios in relation to palaeodietary reconstruction. *Nature* **317**: 806-809.

DeNiro, M.J. 1988. Marine food sources for prehistoric coastal Peruvian camelids: isotopic evidence and implications. British Archaeological Reports, International Series 427, pp. 119-128 in Wing, E.S., Wheeler, J.C. (eds.), *Economic Prehistory of the Central Andes*, Oxford: Archaeopress.

Donnan, C.B., Foote, L.J. 1978. Appendix 2: Child and Llama Burials from Huanchaco, pp. 399-408 in Donnan, C.B., Mackey, C.J. (eds.), *Ancient Burial Patterns of the Moche Valley, Peru*, Austin: University of Texas Press.

Dufour, E., Goepfert, N., Gutiérrez Léon, B., Chauchat, C., Franco Jordan, R., Vásquez Sánchez, S. 2014. Pastoralism in northern Peru during pre-Hispanic times: insights from the Mochica Period (100-800 AD) based on stable isotopic analysis of domestic camelids. *PLoS One* **9**: e87559.

Duncan, N.A. 2003. *At the edge of the Puna: Archaeological test excavation and sampling for phytolith signatures of ancient corrals at Antibal, Peru*. Unpublished M.A. Thesis, University of Missouri.

Finucane, B., Agurto, P.M., Isbell, W.H. 2006. Human and animal diet at Conchopata, Peru: stable isotope evidence for maize agriculture and animal management practices during the Middle Horizon. *Journal of Archaeological Science* **33**: 1766-1776.

Flannery, K.V., Marcus, J., Reynolds, R.G. 1989. *The Flocks of Wamani: A Study of the Llama Herders on the Punas of Ayacucho, Peru*. San Diego: Academic Press.

Flores-Ochoa, J.A. 1979. *Pastoralists of the Andes: The Alpaca Herders of Paratía*. Philadelphia: Institute for the Study of Human Issues.

Fogel, H.P. 1993. *Settlements in time: A study of social and political development during the Gallinazo occupation of the north coast of Perú*. Unpublished Ph.D. Dissertation, Yale University.

Gade, D.W. 1992. Landscape, System, and Identity in the Post-Conquest Andes. *Annals of the Association of American Geographers* **82**: 460-477.

Gilmore, R.M. 1950. Fauna and Ethnozoology of South America, pp. 345-464 in Steward, J. (ed.) *Handbook of South American Indians, Volume 6*, Washington, D.C.: Smithsonian Institution Bureau of American Ethnology Bulletin 143.

Goepfert, N. 2012. New zooarchaeological and funerary perspectives on Mochica culture (A.D. 100-800), Peru. *Journal of Field Archaeology* **37**: 104-120.

Goland, C. 1993. Field Scattering as Agricultural Risk Management: A Case Study from Cuyo Cuyo, Department of Puno, Peru. *Mountain Research and Development* **13**: 317-338.

Grossman, J.W. 1983. Demographic change and economic transformation in the south-central highlands of pre-Huari Peru. *Ñawpa Pacha* **21**: 45-126.

Handley, L.L., Austin, A.T., Stewart, G.R., Robinson, D., Scrimgeour, C.M., Raven, J.A., Heaton, T.H.E., Schmidt, S. 1999. The ^{15}N natural abundance (δ^{15}N) of ecosystem samples reflects measures of water availability. *Australian Journal of Plant Physiology* **26**: 185-199.

Hedges, R.E.M., Clement, J.G., Thomas, D.L., O'Connell, T.C. 2007. Collagen turnover in the adult femoral mid-shaft: Modeled from anthropogenic radiocarbon tracer measurements. *American Journal of Physical Anthropology* **133**: 808-816.

Helmer, M., Chicoine, D. In Press. Seaside Life in Early Horizon Peru: Preliminary Insights from Samanco, Nepeña Valley. *Journal of Field Archaeology*.

Ikehara, H., Paipay, J.F., Shibata, K. 2013. Feasting with *Zea mays* in the Middle and Late Formative North Coast of Peru. *Latin American Antiquity* **24**: 217-231.

Jackson, A.L., Inger, R., Parnell, A.C., Bearhop, S. 2011. Comparing isotopic niche widths among and within communities: SIBER – Stable Isotope Bayesian Ellipses in R. *Journal of Animal Ecology* **80**: 595-602.

Keatinge, R.W. 1981. The Nature and Role of Religious Diffusion in the Early Stages of State Formation: An Example from Peruvian Prehistory, pp. 172-187 in Jones, G.D., Kautz, R.R. (eds.), *The Transition to Statehood in the New World*, Cambridge: Cambridge University Press.

Kembel, S.R., Rick, J.W. 2004. Building Authority at Chavín de Huántar: Model of Social Organization and Development in the Initial Period and the Early Horizon, pp. *Andean Archaeology*, Oxford: Blackwell.

Kent, J.D. 1982. *The Domestication and Exploitation of the South American Camelids: Methods of Analysis and their Application to Circum-lacustrine Archaeological Sites in Bolivia and Peru*. Unpublished Ph.D. Thesis, Washington University in St. Louis.

Knudson, K.J., Gardella, K.R., Yaeger, J. 2012. Provisioning Inka feasts at Tiwanaku, Bolivia: the geographic origins of camelids in the Pumapunku complex. *Journal of Archaeological Science* **39**: 479-491.

Kuznar, L. 1991. Herd composition in an Aymara community of the Peruvian Altiplano: A linear programming problem. *Human Ecology* **19**: 369-387.

Kuznar, L.A. 1989. The domestication of South American camelids: Models and evidence, pp. 167-182 in Rice, D., Stanish, C. (eds.), *Ecology, Settlement and History in the Osmore Drainage, Peru*, Oxford: BAR International Series 545.

Lau, G.F. 2007. Animal resources and Recuay cultural transformations at Chinchawas (Ancash, Peru). *Andean Past* **8**: 449-476.

Marcus, J., Sommer, J.D., Glew, C.P. 1999. Fish and mammals in the economy of an ancient Peruvian kingdom. *Proceedings of the National Academy of Sciences of the United States of America* **96**: 6564-6570.

McCorkle, C.M. 1987. Punas, pastures and fields: Grazing strategies and the agropastoral dialectic in an indigenous Andean community, pp. 57-80 in Browman, D.L. (ed.) *Arid Land Use Strategies and Risk Management in the Andes: A Regional Anthropological Perspective*, Boulder: Westview Press.

Millaire, J.-F. 2002. *Moche Burial Patterns: An Investigation into Prehispanic Social Structure*. Oxford: BAR International Series 1066.

Millaire, J.-F. 2008. Moche textile production on the Peruvian north coast: a contextual analysis, pp. 229-245 in Bourget, S., Jones, K.L. (eds.), *The Art and Archaeology of the Moche: An Ancient Andean Society of the Peruvian North Coast*, Austin: University of Texas Press.

Millaire, J.-F. 2010. Primary State Formation in the Virú Valley, North Coast of Peru. *Proceedings of the National Academy of Sciences* **107**: 6186-6191.

Millaire, J.-F. 2015. The sacred character of ruins on the Peruvian north coast, pp. 50-75 in Shimada, I., Fitzsimmons, J.L. (eds.), *Living with the Dead in the Andes*, Tuscon: University of Arizona Press.

Miller, G.R., Burger, R.L. 1995. Our Father the Cayman, Our Dinner the Llama: Animal Utilization at Chavín de Huántar, Peru. *American Antiquity* **60**: 421-458.

Mitchell, W.P. 1991. *Peasants on the Edge: Crop, Cult, and Crisis in the Andes*. Austin: University of Texas Press.

Moore, K.M. 1988. Hunting and herding economies on the Junin puna, pp. 154-166 in Wing, E.S., Wheeler, J.C. (eds.), *Economic Prehistory of the Central Andes*, Oxford: BAR International Series 427.

Moore, K.M. 1989. *Hunting and the origins of herding in Peru*. Unpublished Ph.D. Dissertation, University of Michigan.

Moore, K.M., Steadman, D.W., deFrance, S.D. 1999. Herd, fish, and fowl in the domestic and ritual economy of formative Chiripa, pp. 105-117 in Hastorf, C.A. (ed.) *Early Settlement at Chiripa, Bolivia: Research of the Taraco Archaeological Project*, Berkeley: Contributions No. 57, University of California.

Murra, J.V. 1962. Cloth and Its Functions in the Inca State. *American Anthropologist* **64**: 710-728.

Murra, J.V. 1965. Herds and herders in the Inca state, pp. 185-215 in Leeds, A., Vayda, A.P. (eds.), *Man, Culture, and Animals: The Role of Animals in Human Ecological Adjustments*, Washington, D.C.: American Association for the Advancement of Science.

Murra, J.V. 1968. An Aymara Kingdom in 1567. *Ethnohistory* **15**: 115-151.

Murra, J.V. 1980. *The Economic Organization of the Inka State*. Greenwich: JAI Press.

Nielsen, A.M. 2001. Ethnoarchaeological Perspectives on Caravan Trade in the South-Central Andes, pp. 163-201 in Kuznar, L.A. (ed.) *Ethnoarchaeology of Andean South America: Contributions to Archaeological Method and Theory*, Ann Arbor: International Monographs in Prehistory. Ethnoarchaeological Series 4.

Ono, M. (ed.) 1986. Taxonomic and Ecological Studies on the Lomas Vegetation in the Pacific Coast of Peru. Tokyo: Makino Herbarium, Tokyo Metropolitan University.

Orlove, B.S. 1977a. Integration Through Production: The Use of Zonation in Espinar. *American Ethnologist* **4**: 84-101.

Orlove, B.S. 1977b. *Alpacas, Sheep, and Men: The Wool Export Economy and Regional Society of Southern Peru*. New York: Academic Press.

Orlove, B.S. 1982. Native Andean Pastoralists: Traditional Adaptations and Recent Changes, pp. 95-136 in Saltzman, P.C. (ed.) *Contemporary Nomadic and Pastoral Peoples: Africa and Latin America*, Williamsburg: Studies in Third World Societies Publication No. 17.

Orlove, B.S., Godoy, R.A. 1986. Sectoral fallowing systems in the Central Andes. *Journal of Ethnobiology* **6**: 169-204.

Parnell, A.C., Inger, R., Bearhop, S., Jackson, A.L. 2010. Source Partitioning Using Stable Isotopes: Coping with Too Much Variation. *PLoS One* **5**: e9672.

Pozorski, S.G. 1979a. Late prehistoric llama remains from the Moche Valley, Peru. *Annals of the Carnegie Museum* **48**: 139-170.

Pozorski, S.G. 1979b. Prehistoric Diet and Subsistence of the Moche Valley, Peru. *World Archaeology* **11**: 163-184.

Proulx, D.A. 1982. Territoriality in the Early Intermediate Period: The Case of Moche and Recuay. *Ñawpa Pacha* **20**: 83-96.

R Development Core Team. 2007. R: A Language and Environment for Statistical Computing, Series R: A Language and Environment for Statistical Computing Document Institution: City.

Rauh, W. 1985. The Peruvian-Chilean deserts, pp. 239-267 in Evenari, M., Noy-Meir, I., Goodall, D.W. (eds.), *Ecosystems of the World, Volume 12A: Hot Deserts and Arid Shrublands*, Amsterdam: Elsevier.

Reiner, R.J., Bryant, F.C. 1986. Botanical Composition and Nutritional Quality of Alpaca Diets in Two Andean Rangeland Communities. *Journal of Range Management* **39**: 424-427.

Reitz, E.J. 1979. Faunal materials from Viru 434: An Early Intermediate Period site from coastal Peru. *Florida Journal of Anthropology* **4**: 76-92.

Rick, J.W., Mesía, C., Contreras, D.A., Kembel, S.R., Rick, R.M., Sayre, M.P., Wolf, J. 2011. La cronología de Chavín de Huántar y sus implicancias para el Periodo Formativo. *Boletín de Arqueología PUCP* **13**: 87-132.

Rundel, P.W., Dillon, M.O., Palma, B., Mooney, H.A., Gulmon, S.L. 1991. The phytogeography and ecology of the coastal Atacama and Peruvian deserts. *Aliso* **13**: 1-49.

Sandweiss, D.H., Richardson, J.B., III. 2008. Central Andean environments, pp. 93-104 in Silverman, H., Isbell, W.H. (eds.), *Handbook of South American Archaeology*, New York: Springer.

Schoeninger, M.J., DeNiro, M.J. 1984. Nitrogen and carbon isotopic composition of bone collagen from marine and terrestrial animals. *Geochimica et Cosmochimica Acta* **48**: 625-639.

Shibata, K. 2010. Cerro Blanco de Nepeña dentro de la dinámica interactiva del Periodo Formativo. *Boletín de Arqueología PUCP* **12**: 287-315.

Shibata, K. 2011. Cronología, relaciones interregionales y organización social en el Formativo: esencia y perspectiva del valle bajo de Nepeña, pp. 113-134 in Giersz, M., Ghezzi, I. (eds.), *Arqueologia de la Costa de Ancash*, Warsaw/Lima: Centro de Estudios Precolombinos de la Universidad de Varsovia/Institut Français d'Études Andines.

Shimada, I. 1981. The Batan Grande-La Leche Archaeological Project: the First Two Seasons. *Journal of Field Archaeology* **8**: 405-446.

Shimada, M. 1982. Zooarchaeology of Huacaloma: Behavioral and Cultural Implications, pp. 303-336 in Terada, K., Onuki, Y. (eds.), *Excavations at Huacaloma in the Cajamarca Valley, Peru, 1979*, Tokyo: University of Tokyo Press.

Shimada, M., Shimada, I. 1985. Prehistoric llama breeding and herding on the north coast of Peru. *American Antiquity* **50**: 3-26.

Stahl, P.W. 1988. Prehistoric camelids in the lowlands of Western Ecuador. *Journal of Archaeological Science* **15**: 355-365.

Stenhouse, M.J., Baxter, M.S. 1979. The uptake of bomb ^{14}C in humans, pp. 324-341 in Berger, R., Suess, H.E. (eds.), *Radiocarbon dating*, Berkeley: University of California Press.

Stone-Miller, R. 1992. Camelids and chaos in Huari and Tiwanaku textiles, pp. 334-345 in Townsend, R.F. (ed.) *The Ancient Americas: Art from Sacred Landscapes*, Munich: Prestel Verlag and the Art Institute of Chicago.

Szpak, P. 2013. *Stable Isotope Ecology and Human-Animal Interactions in Northern Peru*. Unpublished Ph.D. Dissertation, The University of Western Ontario.

Szpak, P. 2014. Complexities of Nitrogen Isotope Biogeochemistry in Plant-Soil Systems: Implications for the Study of Ancient Agricultural and Animal Management Practices. *Frontiers in Plant Science* **5**: 288.

Szpak, P., Millaire, J.-F., White, C.D., Longstaffe, F.J. 2012a. Influence of seabird guano and camelid dung fertilization on the nitrogen isotopic composition of field-grown maize (*Zea mays*). *Journal of Archaeological Science* **39**: 3721-3740.

Szpak, P., Orchard, T.J., McKechnie, I., Gröcke, D.R. 2012b. Historical ecology of late Holocene sea otters (*Enhydra lutris*) from northern British Columbia: isotopic and zooarchaeological perspectives. *Journal of Archaeological Science* **39**: 1553-1571.

Szpak, P., Millaire, J.-F., White, C.D., Longstaffe, F.J. 2014. Small scale camelid husbandry on the north coast of Peru (Virú Valley): Insight from stable isotope analysis. *Journal of Anthropological Archaeology* **36**: 110-129.

Szpak, P., White, C.D., Longstaffe, F.J., Millaire, J.-F., Vásquez Sánchez, V.F. 2013. Carbon and Nitrogen Isotopic Survey of Northern Peruvian Plants: Baselines for Paleodietary and Paleoecological Studies. *PLoS One* **8**: e53763.

Szpak, P., Millaire, J.-F., White, C.D., Bourget, S., Longstaffe, F.J. In Press. Life Histories of Sacrificed Camelids from Huancaco (Virú Valley), pp. in Klaus, H.D., Toyne, J.M. (eds.), *Reconstructing Sacrifice on the North Coast of Peru: Archaeological Studies of Ritual Violence in the Ancient Andes*, Austin: University of Texas Press.

Szpak, P., Millaire, J.-F., White, C.D., Lau, G.F., Surette, F., Longstaffe, F.J. 2015. Origins of Prehispanic Camelid Wool Textiles from the North and Central Coasts of Peru traced by Carbon and Nitrogen Isotopic Analyses. *Current Anthropology* **In Press**.

Thornton, E.K., deFrance, S.D., Krigbaum, J., Williams, P.R. 2011. Isotopic evidence for Middle Horizon to 16th century camelid herding in the Osmore Valley, Peru. *International Journal of Osteoarchaeology* **21**: 544-567.

Troll, C. 1968. The cordilleras of the tropical Americas, pp. 15-56 in Troll, C. (ed.) *Geoecology of the Mountainous Regions of the Tropical Americas. Proceedings of the UNESCO Mexico Symposium Colloqium Geographicum Volume 9*, Bonn: Geographisches Institut der Universtat.

Vallières, C. 2012. *A Taste of Tiwanaku: Daily Life in an Ancient Andean Urban Center as Seen through Cuisine*. Unpublished Ph.D. Dissertation, McGill University.

Vásquez, V., Rosales, T. 2012. *Informe final: análisis de restos de fauna y botánicos de Caylán, valle de Nepeña*. Lima, Peru: Arqueobios centros de investigaciones arqueobiológicas y paleoecológicas andinas.

Verano, J.W., DeNiro, M.J. 1993. Locals or foreigners? Morphological, biometric and isotopic approaches to the question of group affinity in human skeletal remains recovered from unusual archaeological context, pp. 361-386 in Sandford, M.K. (ed.) *Investigations of Ancient Human Tissue: Chemical Analysis in Anthropology*, Langhorne: Gordon and Breach.

Webster, A.D. 1993. *The role of the Camelid in the Development of the Tiwanaku State*. Unpublished Ph.D. Dissertation, The University of Chicago.

Webster, A.D., Janusek, J.W. 2003. Tiwanaku camelids: Subsistence, sacrifice, and social reproduction, pp. 343-362 in Kolata, A.L. (ed.) *Tiwanaku and Its Hinterland: Archaeological* *and Paleoecological Investigations of an Andean Civilization: Volume 2, Urban and Rural Archaeology*, Washington, D.C.: Smithsonian Institution Press.

Wheeler, J.C. 1985. De la chasse a l'élevage, pp. 61-79 in Lavallé, D., Julien, M., Wheeler, J.C., Karlin, C. (eds.), *Telarmachay: Chasseurs et Pasteurs Préhistoriques des Andes I, Vol. 1*, Paris, France: Institut Français d'Études Andines, Editions Recherches sur les Civilizations.

Wheeler, J.C. 1995. Evolution and present situation of the South American Camelidae. *Biological Journal of the Linnean Society* **54**: 271-295.

Wilcox, B.P., Bryant, F.C., Fraga, V.B. 1987. An Evaluation of Range Condition on One Range Site in the Andes of Central Peru. *Journal of Range Management* **40**: 41-45.

Wild, E.M., Arlamovsky, K.A., Golser, R., Kutschera, W., Priller, A., Puchegger, S., Rom, W., Steier, P., Vycudilik, W. 2000. ^{14}C dating with the bomb peak: An application to forensic medicine. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms* **172**: 944-950.

Wilson, D.J. 1988. *Prehispanic settlement patterns in the lower Santa Valley, Peru: A regional perspective on the origins and development of complex North Coast society*. Washington, D.C.: Smithsonian Institution Press.

Winterhalder, B., Larsen, R., Thomas, R.B. 1974. Dung as an essential resource in a highland Peruvian community. *Human Ecology* **2**: 89-104.

Yakir, D. 2011. The paper trail of the ^{13}C of atmospheric CO_2 since the industrial revolution period. *Environmental Research Letters* **6**: 034007.

Zárate, A.d. 1555. Historia del desumrimiento y conquista de la Provincia del Perú. *Biblioteca de Autores Españoles* **26**: 459-574.

Zeder, M.A. 1991. *Feeding Cities: Specialized Animal Economy in the Ancient Near East*. Washington, D.C.: Smithsonian Institution Press.

Figure Captions

Figure 1. (A) Predicted average carbon and nitrogen isotopic compositions (approximating bivariate means with correlation as in the standard ellipse, see Jackson *et al.* 2011) of four camelids raised under four different foddering regimes. Note that it is not expected that *all* individuals from a given group will fall into these areas, but that a group of animals foddered under a particular set of conditions will resemble this general pattern. (B) Predicated contribution of C_4 plants for the four camelid groups (WCV=wild coastal vegetation, C_4C=cultivated C_4 crops, MXC=mixed irrigated cultigens, C_3P=C_3 pastures). Outputs approximate probability histograms generated using the Bayesian mixing model SIAR (Parnell *et al.* 2010).

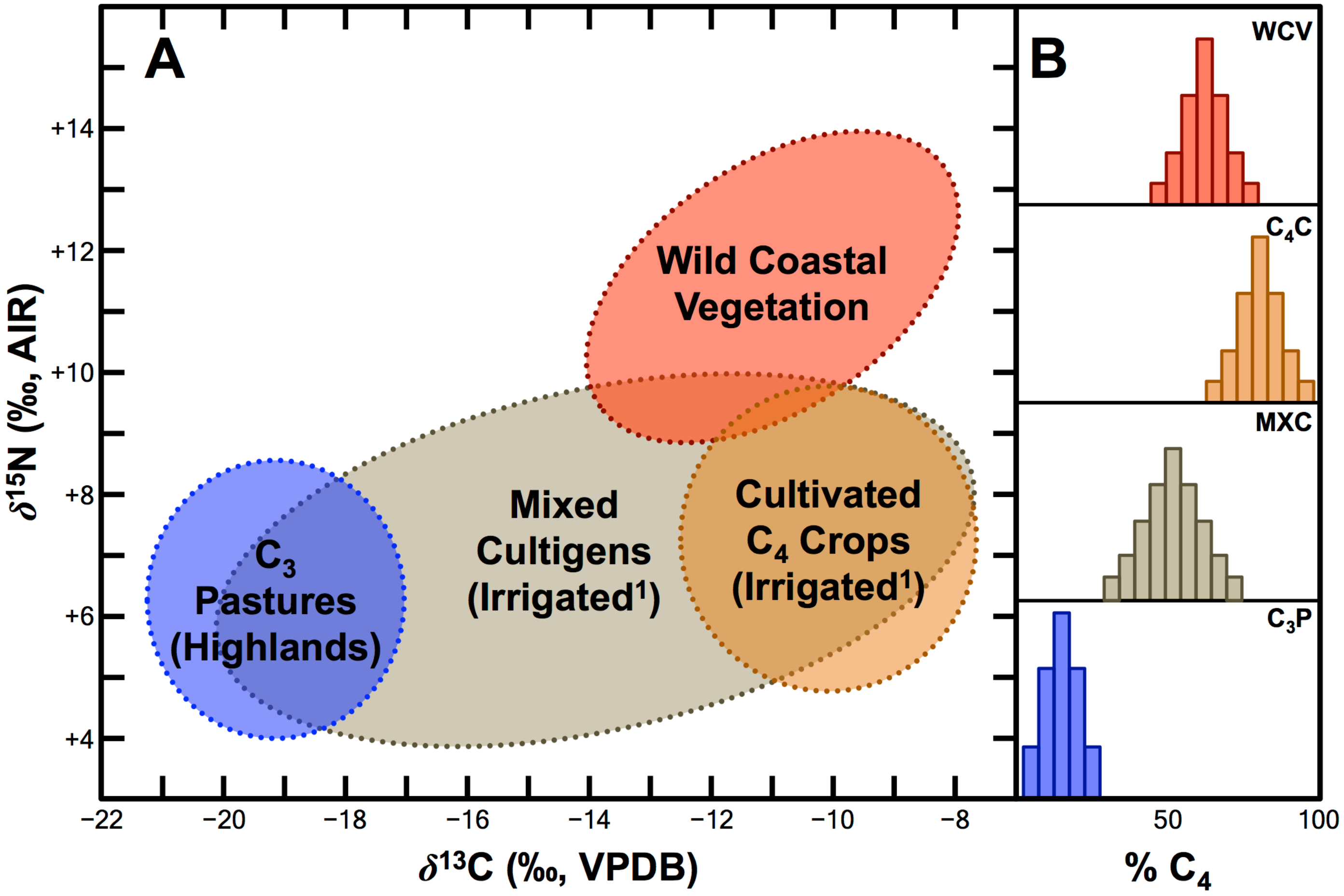
Figure 2. (A) Map of the Nepeña Valley and the location of Caylan and Huambacho in relation to other Early Horizon sites. (B) Map of Peru showing coastal river valleys and archaeological sites mentioned in the text.

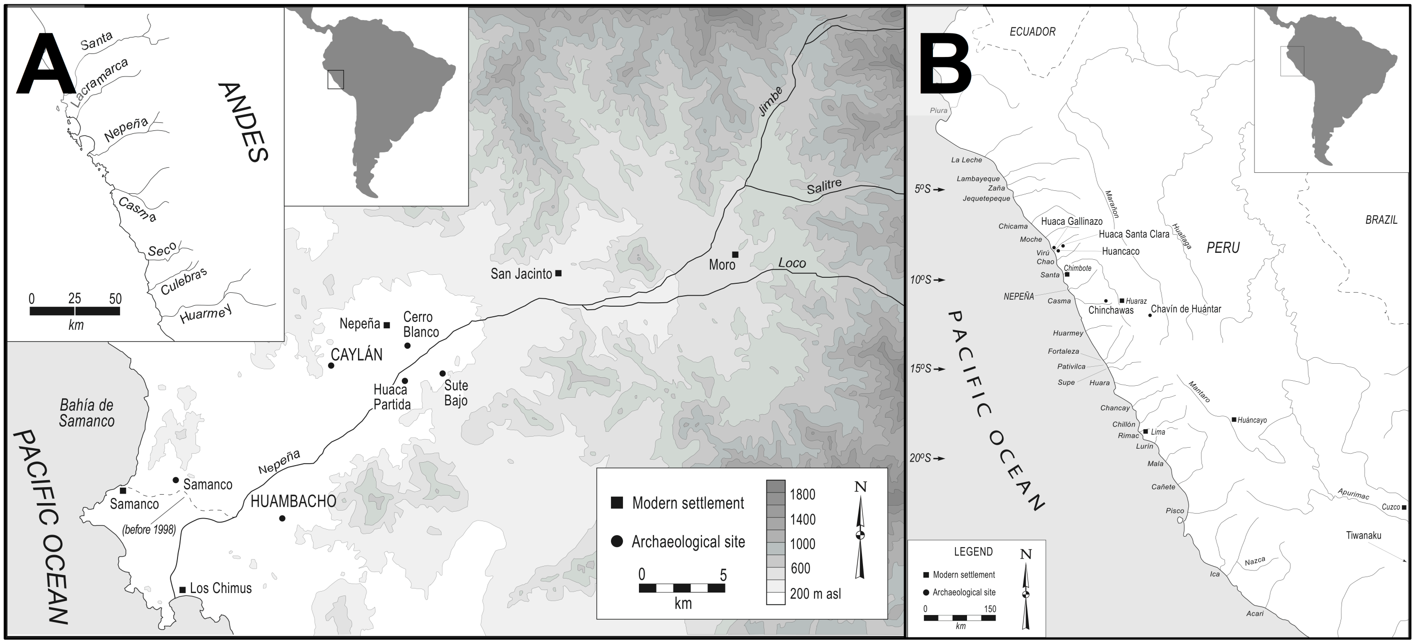
Figure 3. Chronology for the Initial Period and Early Horizon in the Nepeña Valley (Shibata 2010) presented alongside the widely utilized chronological divisions in Peruvian prehistory (EIP=Early Intermediate Period, LIP=Late Intermediate Period). Approximate temporal positions of major archaeological cultures or material culture traditions mentioned in the text are also presented.

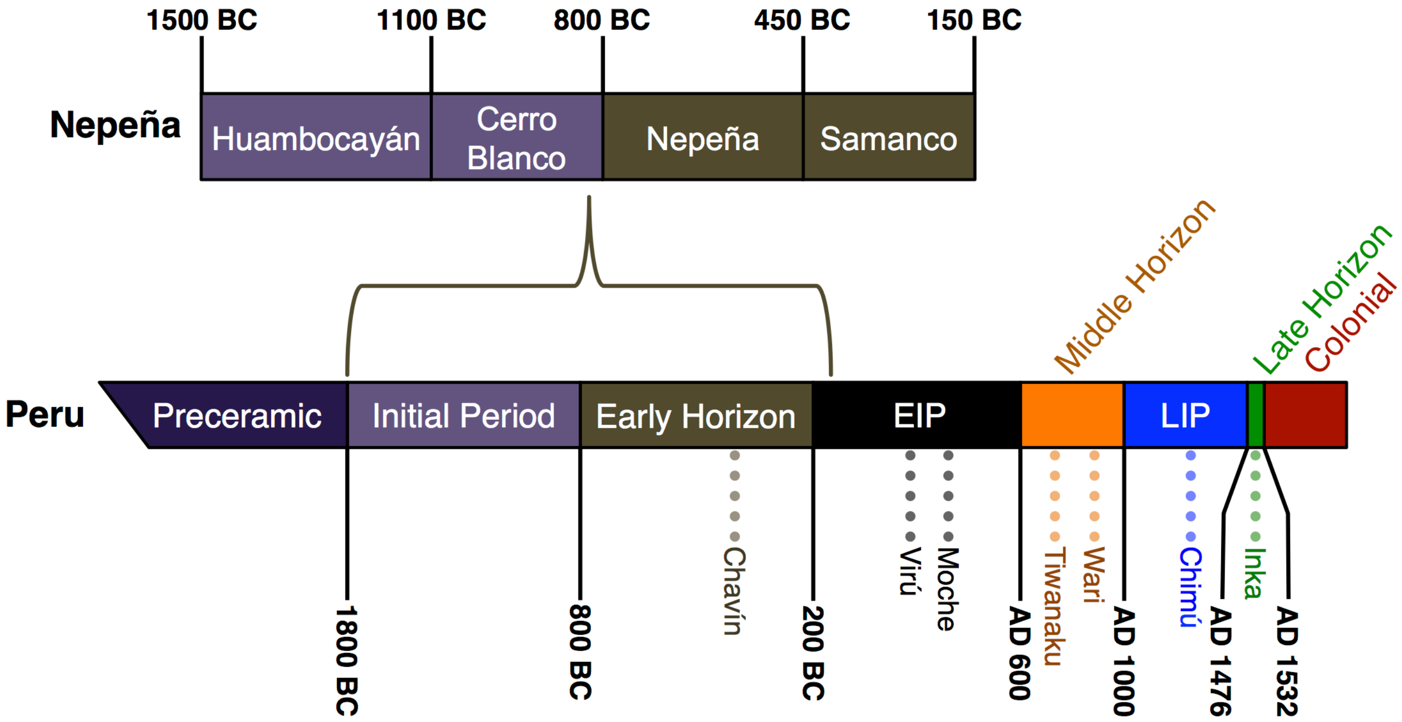
Figure 4. Site map of Caylán showing excavation units and architectural contexts excavated in 2009 and 2010. The architectural context of each sample is given in Table 1.

Figure 5. Individual carbon and nitrogen isotopic compositions for Nepeña (circles for Caylán and triangles for Huambacho) camelids plotted relative to heat maps generated on the basis of previously measured camelids from modern highland pastures and archaeological sites (A) and camelids from coastal archaeological sites (B). To generate the heat maps, data from previous studies were binned according to 1‰ × 1‰ units.

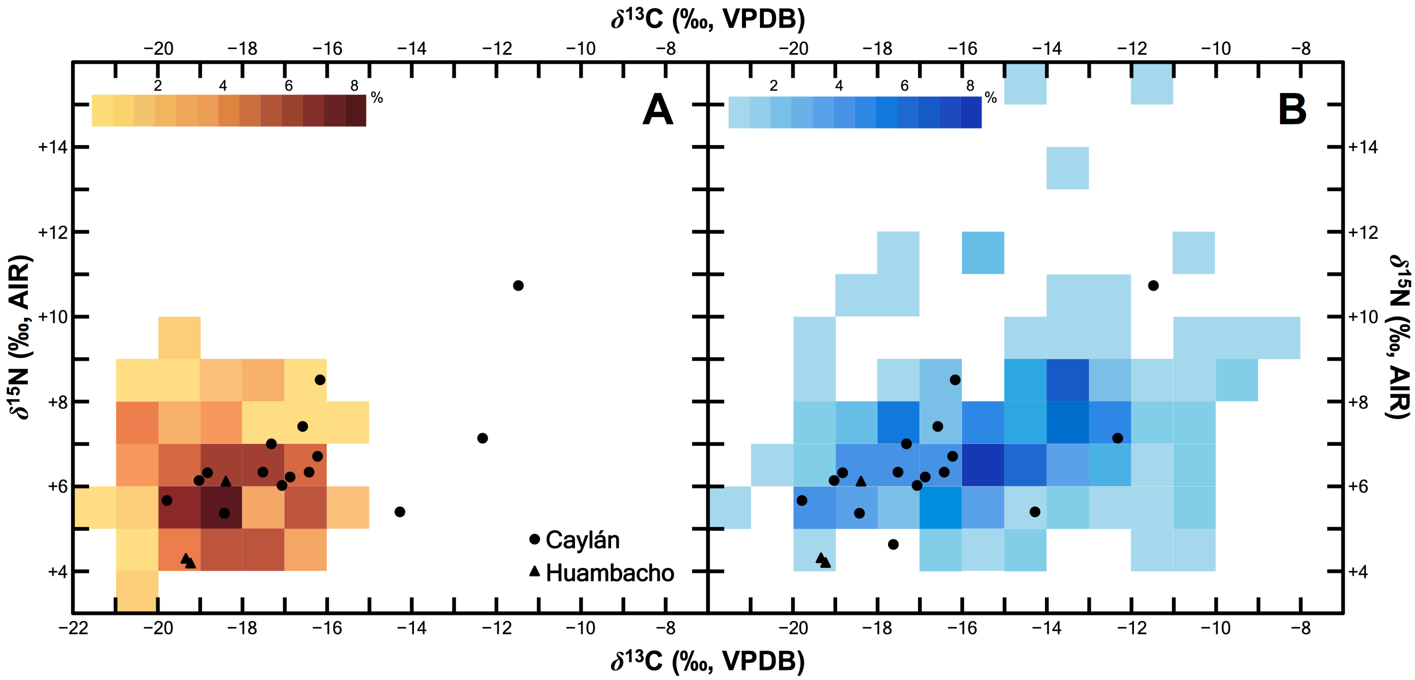
Figure 6. SIAR density histograms showing estimated contributions of C_3 and C_4 plants for Nepeña (Caylán and Huambacho) camelids (middle panels) relative to highland camelids from a Middle Horizon site in the Callejón de Huaylas region (Chinchawas, top panel) and coastal camelids from an Early Intermediate Period site in the Virú Valley (Huaca Gallinazo, lower panel). In the second panel, three camelids with $\delta^{13}C$ values > −16 ‰ are excluded.


A
B
Wild Coastal Vegetation
Mixed Cultigens (Irrigated[1])
Cultivated C_4 Crops (Irrigated[1])
C_3 Pastures (Highlands)
$\delta^{15}N$ (‰, AIR)
+14
+12
+10
+8
+6
+4
−22
−20
−18
−16
−14
−12
−10
−8
$\delta^{13}C$ (‰, VPDB)
WCV
C_4C
MXC
C_3P
50
100
% C_4


A
Santa
Lacramarca
Nepeña
Casma
Seco
Culebras
Huarmey
ANDES
0
25
50
km
Jimbe
Salitre
Loco
Moro
San Jacinto
Nepeña
Cerro Blanco
CAYLÁN
Huaca Partida
Sute Bajo
Bahía de Samanco
PACIFIC OCEAN
Samanco
Samanco
(before 1998)
Nepeña
HUAMBACHO
Los Chimus
■ Modern settlement
● Archaeological site
0
5
km
1800
1400
1000
600
200 m asl
N
B
ECUADOR
Piura
La Leche
Lambayeque
Zaña
Jequetepeque
5ºS
Chicama
Moche
Virú
Chao
Santa
Chimbote
10ºS
NEPEÑA
Casma
Huaca Gallinazo
Huaca Santa Clara
Huancaco
Chinchawas
Huaraz
Chavín de Huántar
Marañon
Huallaga
PERU
BRAZIL
Huarmey
Fortaleza
Pativilca
15ºS
Supe
Huara
Chancay
Chillón
Rimac
Lima
Lurín
20ºS
Mala
Cañete
Pisco
Mantaro
Huáncayo
Apurimac
Cuzco
Tiwanaku
Nazca
Ica
Acari
PACIFIC OCEAN
LEGEND
■ Modern settlement
● Archaeological site
0
150
km
N


1500 BC
1100 BC
800 BC
450 BC
150 BC
Nepeña
Huambocayán
Cerro Blanco
Nepeña
Samanco
Middle Horizon
Late Horizon
Colonial
Peru
Preceramic
Initial Period
Early Horizon
EIP
LIP
Chavín
Virú
Moche
Tiwanaku
Wari
Chimú
Inka
1800 BC
800 BC
200 BC
AD 600
AD 1000
AD 1476
AD 1532


E 786100
E 786200
E 786300
HP16
E 786400
E 786500
E 786600
E 786700
E 786800
E 786900
E 787000
E 787100
CERRO CAYLÁN
CULTIVATED FIELDS
HP5
HP11
N 8983100
HP3
canal
HP10
N 8983000
HP1
HP9
UE2
UE5
HP8
UE1
N 8982900
UE6
HP4
HP14
HP2
HP12
UE4
MARSHLANDS
N 8982800
UE3
HP13
HP15
HP6
N 8982700
HP7
LAGOON
N 8982600
CERRO CAYLÁN
▨ Excavation units (UEx)
● Test pits (HPx)
Defensive walls
Stone walls
0
100
m
N


δ13C (‰, VPDB)
−20
−18
−16
−14
−12
−10
−8
2
4
6
8
%
A
B
+14
+12
+10
+8
+6
+4
δ15N (‰, AIR)
Caylán
Huambacho
−22
δ13C (‰, VPDB)

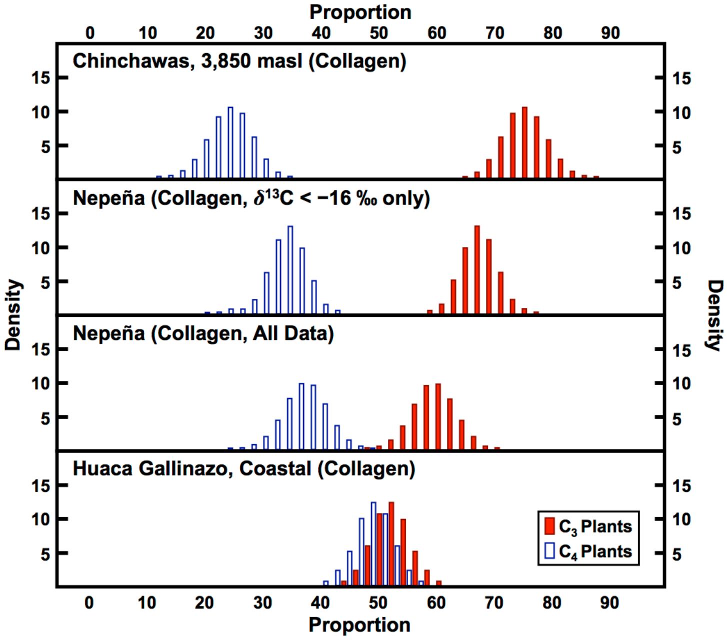

Proportion
0
10
20
30
40
50
60
70
80
90
Chinchawas, 3,850 masl (Collagen)
Nepeña (Collagen, δ^{13}C < −16 ‰ only)
Nepeña (Collagen, All Data)
Huaca Gallinazo, Coastal (Collagen)
15
10
5
Density
🟥 C_3 Plants
☐ C_4 Plants

Table 1. Isotopic and elemental compositions for Early Horizon camelids from Caylán and Humabacho. Specimens that have produced collagen deemed unreliable have been struck through.

Context	Unit	Room	Stratum	Element	Sample #	δ^{13}C (‰, VDPB)	δ^{15}N (‰, AIR)	%C	%N	C:N	% Collagen
Caylán											
Mound A	UE4	Mound A	1	1st Phalanx	AIS 1298	-16.59	7.45	46.1	16.8	3.2	13.6
Mound A	UE4	Terrace 2	1	1st Phalanx	AIS 1301	-18.46	5.39	35.8	12.7	3.3	2.8
Mound A	UE4	Top of Mound	2	1st Phalanx	AIS 1310	-12.31	7.16	40.7	14.8	3.2	16.7
Mound A	UE4	Top of Mound	4	Metatarsal (Distal)	AIS 1313	~~-15.17~~	~~13.36~~	~~22.3~~	~~5.1~~	~~5.1~~	~~0.7~~
Mound A	UE4	Ext1	1	1st Phalanx	AIS 2593	-17.65	4.65	43.0	15.3	3.3	13.0
Mound A	UE4	Top of Mound	4	1st Phalanx	AIS 1308	-16.24	6.75	47.1	17.5	3.1	12.9
Mound A	UE4	Terrace 4	3	1st Phalanx	AIS 1316	-18.85	6.33	43.9	15.9	3.2	13.0
Plaza A	UE5	Plaza A	2	Metatarsal (Distal)	AIS 1299	~~-13.93~~	~~16.33~~	~~26.5~~	~~5.10~~	~~6.1~~	~~0.4~~
Plaza A	UE5	Plaza A	2	1st Phalanx	AIS 1300	-17.32	7.02	47.5	17.6	3.1	20.8
Plaza A	HP8	Plaza A	2	1st Phalanx	AIS 1306	-17.53	6.38	46.5	17.1	3.2	16.3
Plaza A	UE2	Plaza A	5	1st Phalanx	AIS 1312	-16.20	8.55	35.8	12.3	3.4	1.1
Plaza A	UE5	Plaza A	1	1st Phalanx	AIS 2590	-14.28	5.40	35.2	12.5	3.3	6.6
Compound E	UE6	Rec5	3	1st Phalanx	AIS 1305	-19.02	6.17	42.3	15.4	3.2	10.6
Compound E	UE6	Rec6	3	1st Phalanx	AIS 1307	-16.89	6.22	46.1	17.1	3.2	13.3
Compound E	UE6	Rec6	3	1st Phalanx	AIS 1309	-17.05	6.04	39.5	14.3	3.2	6.1
Compound E	UE6	Rec1	1	Metatarsal (Distal)	AIS 1314	~~-16.15~~	~~10.56~~	~~26.6~~	~~7.0~~	~~4.5~~	~~0.3~~
Other	UE3		1	Mandible	AIS 1297	-19.81	5.69	39.8	13.9	3.3	2.9
Other	UE3		1	1st Phalanx	AIS 1315	-11.47	10.77	45.9	16.8	3.2	19.4
Other	HP16		1	1st Phalanx	AIS 1303	-16.44	6.37	42.4	15.1	3.3	7.4
Huambacho											
Huaca A	23	Huaca A	Rubble	1st Phalanx	AIS 2591	-19.30	4.23	41.9	15.1	3.3	17.0
Huaca A	23	Huaca A	Under Floor	1st Phalanx	AIS 2592	-19.32	4.30	41.7	15.1	3.2	12.7
Plaza B	25	Plaza B	Under Floor	1st Phalanx	AIS 2589	-18.40	6.12	39.9	14.2	3.3	6.8

Supplementary Material – Analytical Precision and Accuracy

Carbon and nitrogen isotopic and elemental compositions were determined using an Isoprime continuous flow mass spectrometer coupled to a Costech Elemental Analyzer at the Archaeology Isotope Laboratory (The University of British Columbia). The following standard reference materials were used for calibration of δ^{13}C relative to VPDB and δ^{15}N relative to AIR (Table S1).

Table S.1. Standard reference materials used for calibration of δ^{13}C relative to VPDB and δ^{15}N relative to AIR for the Delta V.

Standard	Material	Accepted δ^{13}C (‰, VPDB)	Accepted δ^{15}N (‰, AIR)
USGS40	Glutamic Acid	−26.389	−4.52
USGS41	Glutamic Acid	+37.626	+47.57

The following internal standards were used to monitor accuracy and precision (Table S2). The isotopic compositions reported here represent long term averages: methionine (*n*=349), NIST 1577c (*n*=195), SUBC-1 (*n*=270), SRM-1 (*n*=132), and SRM-2 (*n*=119).

Table S.2. Standard reference materials used for to monitor internal accuracy and precision.

Standard	Material	Accepted δ^{13}C (‰, VPDB)	Accepted δ^{15}N (‰, AIR)
MET	Methionine	−28.60±0.08	−5.04±0.15
NIST 1577c	Bovine liver	−17.51±0.10	+8.15±0.15
SUBC-1	Seal bone collagen	−13.67±0.11	+17.39±0.14
SRM-1	Caribou bone collagen	−19.31±0.11	+1.81±0.11
SRM-2	Walrus bone collagen	−14.70±0.12	+15.58±0.10

Table S3 summarizes the mean and standard deviation of carbon and nitrogen isotopic compositions for all check standards, as well as the standard deviation for all calibration standards – the mean of the calibration standard for an individual run is predetermined to calibrate the data.

Table S3. Accuracy and precision of calibration and check standards for all analytical sessions.

Standard	Type	Run ID	*n*	δ^{13}C (‰, VPDB)	δ^{15}N (‰, AIR)
MET	Check	G15-11	8	−28.55±0.08	−5.01±0.19
NIST 1577c	Check	G15-11	4	−17.44±0.04	+8.32±0.16
SUBC-1	Check	G15-11	6	−13.62±0.12	+17.36±0.08
USGS40	Calibration	G15-11	7	±0.14	±0.09
USGS41	Calibration	G15-11	7	±0.18	±0.17
MET	Check	G15-12	7	−28.57±0.05	−5.10±0.18
NIST 1577c	Check	G15-12	6	−17.51±0.04	+8.15±0.12
SUBC-1	Check	G15-12	6	−13.69±0.11	+17.35±0.10
USGS40	Calibration	G15-12	8	±0.07	±0.14
USGS41	Calibration	G15-12	7	±0.11	±0.31
NIST 1577c	Check	G15-13	5	−17.57±0.03	+8.08±0.08
SUBC-1	Check	G15-13	6	−13.66±0.08	+17.37±0.10
USGS40	Calibration	G15-13	9	±0.06	±0.14
USGS41	Calibration	G15-13	9	±0.22	±0.07
MET	Check	G15-14	7	−28.58±0.07	−4.94±0.08
NIST 1577c	Check	G15-14	5	−17.61±0.17	8.18±0.12
SUBC-1	Check	G15-14	4	−13.57±0.05	+17.40±0.04
USGS40	Calibration	G15-14	9	±0.13	±0.22
USGS41	Calibration	G15-14	7	±0.15	±0.03
MET	Check	G15-15	7	−28.62±0.06	−5.03±0.10
NIST 1577c	Check	G15-15	5	−17.57±0.08	+8.22±0.06
SRM-2	Check	G15-15	2	−14.96±0.01	+15.71±0.03
SUBC-1	Check	G15-15	4	−13.70±0.12	+17.28±0.15
USGS40	Calibration	G15-15	9	±0.08	±0.16
USGS41	Calibration	G15-15	9	±0.23	±0.19
MET	Check	G15-16	7	−28.64±0.06	−5.01±0.14
NIST 1577c	Check	G15-16	5	−17.52±0.06	+8.11±0.18
SUBC-1	Check	G15-16	6	−13.61±0.04	+17.38±0.08
USGS40	Calibration	G15-16	9	±0.05	±0.11
USGS41	Calibration	G15-16	9	±0.13	±0.14
MET	Check	G15-19	7	−28.63±0.03	−5.16±0.20
NIST 1577c	Check	G15-19	5	−17.53±0.02	+8.13±0.04
SUBC-1	Check	G15-19	6	−13.65±0.09	+17.35±0.06
USGS40	Calibration	G15-19	9	±0.06	±0.05
USGS41	Calibration	G15-19	9	±0.17	±0.07
MET	Check	G15-21	7	−28.62±0.06	−5.08±0.22
NIST 1577c	Check	G15-21	5	−17.52±0.07	+8.23±0.09
SUBC-1	Check	G15-21	6	−13.67±0.08	+17.41±0.10
USGS40	Calibration	G15-21	9	±0.04	±0.06

USGS41	Calibration	G15-21	9	±0.10	±0.13
MET	Check	G15-23	7	−28.64±0.05	−5.01±0.11
NIST 1577c	Check	G15-23	2	−17.52±0.05	+8.23±0.06
SRM-1	Check	G15-23	6	−19.32±0.03	+1.87±0.08
SRM-2	Check	G15-23	5	−14.69±0.06	+15.61±0.12
USGS40	Calibration	G15-23	8	±0.08	±0.10
USGS41	Calibration	G15-23	8	±0.06	±0.11
MET	Check	G15-24	7	−28.66±0.27	−5.00±0.19
SRM-1	Check	G15-24	5	−19.07±0.10	+1.93±0.04
SRM-2	Check	G15-24	4	−14.51±0.25	+15.70+-0.05
USGS40	Calibration	G15-24	8	±0.25	±0.11
USGS41	Calibration	G15-24	9	±0.14	±0.22
MET	Check	G15-25	7	−28.59±0.20	−5.02±0.07
SRM-1	Check	G15-25	6	−19.17±0.23	+1.89±0.07
SRM-2	Check	G15-25	4	−14.70±0.32	+15.66±0.11
USGS40	Calibration	G15-25	9	±0.20	±0.09
USGS41	Calibration	G15-25	9	±0.26	±0.09
MET	Check	S15-49	6	−28.88±0.13	−5.05±0.10
NIST 1577c	Check	S15-49	2	−17.70±0.05	+8.11±0.01
SRM-1	Check	S15-49	1	−19.22	+1.88
SRM-2	Check	S15-49	2	−14.73±0.04	+15.56±0.03
SUBC-1	Check	S15-49	3	−13.61±0.07	+17.39±0.03
USGS40	Calibration	S15-49	5	±0.25	±0.11
USGS41	Calibration	S15-49	6	±0.22	±0.25
MET	Check	S15-51	7	−28.64±0.06	−4.99±0.07
SRM-1	Check	S15-51	5	−19.32±0.07	+1.80±0.05
SRM-2	Check	S15-51	5	−14.72±0.02	+15.55±0.05
USGS40	Calibration	S15-51	9	±0.08	±0.14
USGS41	Calibration	S15-51	9	±0.17	±0.09
MET	Check	S15-52	7	−28.63±0.06	−5.01±0.15
SRM-1	Check	S15-52	6	−19.31±0.03	+1.83±0.04
SRM-2	Check	S15-52	4	−14.74±0.08	+15.56±0.03
USGS40	Calibration	S15-52	9	±0.06	±0.13
USGS41	Calibration	S15-52	9	±0.09	±0.12

At least ten percent of all samples were analyzed in duplicate to monitor for accuracy and precision (3 duplicates). For these replicates, the mean difference between pairs was 0.07 ‰ for δ^{13}C and 0.02 ‰ for δ^{15}N. These results are presented in full in Table S4. The boldface number in parentheses beside the first δ^{13}C or δ^{15}N value for each duplicate pair represents the difference between the two measurements for that sample.

Table S4. Carbon and nitrogen isotopic compositions for all duplicate sample pairs analyzed. Numbers in parentheses indicate differences between duplicates.

Sample ID	**δ^{13}C (‰, VPDB)**	**δ^{15}N (‰, AIR)**
AIS 1305	−11.68 **(0.04)**	+10.77 **(0.03)**
AIS 1305 DUP	−11.64	+10.80
AIS 1315	−18.87 **(0.15)**	+6.17 **(0.03)**
AIS 1315 DUP	−19.02	+6.20
AIS 2592	−19.32 **(0.02)**	+4.30 **(<0.01)**
AIS 2592 DUP	−19.30	+4.30