



Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: <http://www.elsevier.com/locate/jas>

Identifying foreigners versus locals in a burial population from Nasca, Peru: an investigation using strontium isotope analysis

Christina A. Conlee^{a,*}, Michele R. Buzon^b, Aldo Noriega Gutierrez^c, Antonio Simonetti^d, Robert A. Creaser^e

^a Department of Anthropology, Texas State University, San Marcos, TX 78666, USA

^b Department of Anthropology, Purdue University, West Lafayette, IN 47907, USA

^c Proyecto La Tiza, Lima, Peru

^d Department of Civil Engineering and Geological Sciences, University of Notre Dame, Notre Dame, IN 46556, USA

^e Department of Earth and Atmospheric Science, University of Alberta, Edmonton, AB, T6G 2E3 Canada

ARTICLE INFO

Article history:

Received 5 February 2009

Received in revised form

20 July 2009

Accepted 31 August 2009

Keywords:

Nasca

Strontium

Andes

Mobility

Mortuary practices

ABSTRACT

During the several thousand years of human occupation in the Nasca drainage on the south coast of Peru, population movement into and out of the region impacted the formation and organization of society, as well as contributed to major cultural transformations. This study identifies foreign versus local individuals through the investigation of burial practices and strontium isotope analysis of human remains from the sites of La Tiza and Pajonal Alto dating from the Early Intermediate Period through the Late Intermediate Period (A.D. 1–1476). Of the ten samples analyzed, two individuals dating to the Middle Horizon were identified as foreigners. One of these individuals was buried in a new elite tomb type providing additional evidence that the Wari state incorporated Nasca into its realm. Two headless individuals, one dating to Middle Nasca with clear evidence of decapitation, and another dating to the Late Intermediate Period who was likely decapitated, were both locals. This suggests the practice of decapitation took place among local groups, and that the practice of decapitation and the use of heads as ritual items or trophies may have continued later in time than previously thought.

© 2009 Elsevier Ltd. All rights reserved.

1. Introduction

The Nasca region on the south coast of Peru had a dynamic history from early hunters and gatherers until conquest by the Spanish in the sixteenth century. During this period of several thousand years, irrigation agriculture developed, regional complex societies flourished, and foreign states influenced local culture and incorporated the people of the region into their realms. Throughout this trajectory there is evidence for population movement into and out of the region, which impacted the formation and organization of society as well as contributed to major cultural transformations.

This study identifies foreign versus local individuals through the investigation of burial practices and strontium isotope analysis ($^{87}\text{Sr}/^{86}\text{Sr}$) of human remains from the sites of La Tiza and Pajonal Alto in the southern Nasca drainage (Fig. 1). The sample analyzed in this study includes individuals dating from the beginning of the Early Intermediate Period through the Late Intermediate Period (A.D. 1–1476). The burials include children, adults, and two

headless males. Tracing human mobility in these burials provides an opportunity to further explore the impact of foreigners in the region and the practice of trophy head taking, as well as to define the strontium isotope signature and variability on Peru's south coast.

2. Strontium isotopic analysis and its use in tracking human mobility

Studying population movements and identifying foreign people in a region can be done through a variety of means. Material remains such as architecture, ceramic style, and burial type are all traditional ways that archaeologists distinguish immigrants from local people. Bioarchaeologists have used a range of techniques such as cranial metric and nonmetric traits, cranial modification, and DNA analysis to identify foreigners (Buzon et al., 2005). Isotopic analysis of human remains is an innovative and complimentary method of studying the origins of populations and tracking population movement. Although strontium isotope analysis is a relatively recent technique, research has already illustrated the feasibility and the potential of this kind of analysis to elucidate

* Corresponding author. Tel.: +1 512 245 6582.

E-mail address: cconlee@txstate.edu (C.A. Conlee).

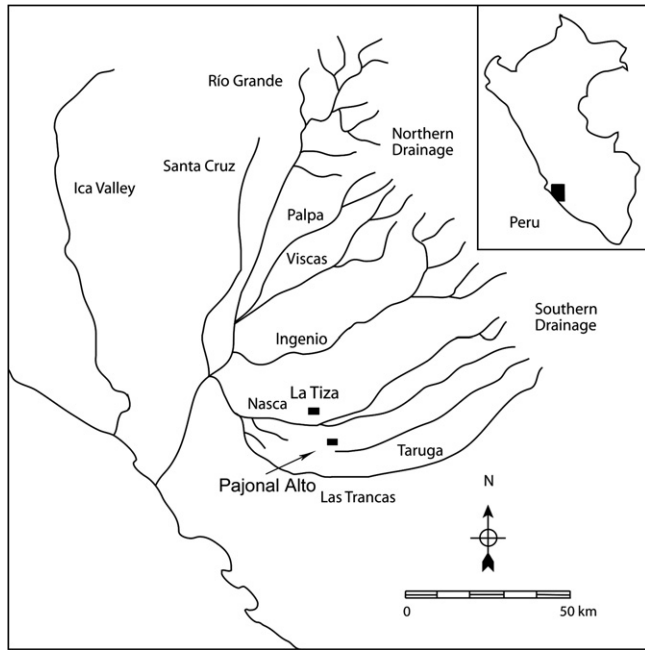


Fig. 1. Map of the Nasca drainage with the sites of La Tiza and Pajonal Alto.

residential mobility in the archaeological record (e.g., Ambrose and Krigbaum, 2003; Bentley, 2006; Burton et al., 2003; Knudson and Price, 2007; Price et al., 2008; Verano and DeNiro, 1993).

Strontium isotope analysis is able to document foreign versus local people in a burial population because strontium isotopic ratios ($^{87}\text{Sr}/^{86}\text{Sr}$) vary according to local geology, based on the age and composition of bedrock so that various regions are distinct. The strontium isotope signature in the bedrock is reflected in soil and groundwater, which are both incorporated into the plants and animals of the region. Humans incorporate the strontium isotope composition of the plants and animals that make up their diet and in turn, this is reflected in their skeletal material (Ericson, 1985; Price et al., 1994; Sealy et al., 1995). Therefore, strontium isotope values in human bone reflect the environment and foods consumed from the area where an individual spent approximately the last decade of life (Bentley, 2006). In teeth, strontium isotopes become integrated during the first 12 years of life during tooth development and do not change after formation. Thus, dental enamel strontium isotope ratios reflect childhood environment, given that they consumed local foods (Burton et al., 2003), and can establish if a person spent their childhood in the local region. In summary, this technique allows for the identification of first-generation immigrants from geologically distinct areas.

In the Andean region, two major areas of study addressed by strontium isotope analysis are the nature of state formation and expansion, and the practice of human sacrifice, both of which are explored in this paper. The development and expansion of the Wari and Tiwanaku states in the Middle Horizon (A.D. 750–1000) have been a particular focus, and researchers have used strontium isotope analysis to examine if these expansions involved colonies of migrants from the capitals and/or if state control was managed through local people (Knudson, 2008; Knudson and Price, 2007; Knudson et al., 2004; Slovak et al., 2009; Tung, 2003). The presence of Tiwanaku migrants in the Moquegua Valley on the far south coast of Peru, but not in other regions such as San Pedro de Atacama in northern Chile, has helped to document the complex relationship between the Tiwanaku core area and places on the periphery (Knudson, 2008; Knudson and Price, 2007; Knudson et al., 2004).

The Wari state covered a larger territory than Tiwanaku and strontium isotope analysis is helping to identify the various strategies and nature of control it exercised. On the central coast at Ancón at least one immigrant has been identified buried in an elaborate Wari style and has a signature similar to that of the Wari heartland (Slovak et al., 2009). At the site of Conchopata near the capital city of Wari, individuals found buried in the mortuary sector were from the local region (Tung, 2003).

Questions related to Inca origins, expansion, and political strategies have also been addressed through strontium isotope analysis. Historical accounts of the Inca tell of large numbers of people relocated by the state known as the *mitima*, as well as other labor practices such as lifelong servants, and the *mita*, the rotating labor tax that often required people to spend months away from home on state projects. Evidence for migrants from geologically diverse areas was found at the site of Choquepuquio in the Inca heartland dating to the height of Inca power (Andrushko et al., 2009). At the royal Inca estate of Machu Picchu the burial population originated from a variety of regions and most individuals moved to the settlement after childhood (Turner, 2008; Turner et al., 2009). Both of these studies confirm the Inca labor practices described in historical sources.

Human sacrifice and trophy head taking have also been examined through strontium isotope analysis (Knudson, 2008; Knudson et al., 2004, 2009; Knudson and Tung, 2007; Tung, 2003). At the Wari site of Conchopata trophy heads buried in ritual contexts exhibit greater strontium isotope variability than the regular burial population (Tung, 2003). These results suggest that the trophy heads were more likely to have been obtained in raiding or warfare than taken from respected local ancestors (Knudson and Tung, 2007; Tung and Knudson, 2008). An examination of human sacrifices found at the Tiwanaku capital reveals multiple origins of these individuals and indicates foreigners were often the focus of ritual sacrifice (Knudson, 2008). Some of the child sacrifices found at the Inca site of Choquepuquio were non-local suggesting that they were a part of the *capacocha* ritual that involved children from diverse areas of the Inca empire (Andrushko et al., 2008).

This project builds on these previous studies in the Andes and explores the impact of foreigners in the Nasca region during the Middle Horizon, and the nature of trophy heads and human sacrifice. Burials found at two sites in Nasca span a period of 1500 years and reveal changing mortuary practices that reflect shifts in sociopolitical organization. In particular, new tomb types associated with Wari imperial pottery during the Middle Horizon indicate that the Wari state had an impact in the Nasca region and that potentially foreigners connected with the state may have moved into the area. In addition, two headless individuals were recovered that have the potential to provide new information on the practice of trophy head taking and human sacrifice. The goal of this study was to test enamel and bone from all of the burials to determine which individuals were isotopically foreign or local.

3. Burial practices and cultural change in the Nasca region

The earliest well-documented sites in Nasca date to the Middle Archaic (3800–3000 B.C.) and the earliest burials come from this period at the site of Pernil Alto where individuals were placed in extended positions, covered with reed mats, and buried with shells, stones and textiles (Deutsches Archäologisches Institut, 2008; Isla, 1990) (Table 1). This site also had a significant Initial Period (1500–800 B.C.) occupation that represents the first sedentary society in the region. It was during the following Early Horizon (800 B.C.–A.D. 1) that the first intensive agriculturalists established communities in Nasca and mortuary traditions changed (Reindel

Table 1
Chronology of the Nasca region.

Horizons and Periods	Culture Name	Phases	Approximate dates
Late Horizon	Inca		A.D. 1476–1532
Late Intermediate Period	Tiza		A.D. 1000–1476
Middle Horizon	Wari Loro	8,9	A.D. 750–1000
Early Intermediate Period	Late Nasca	6,7	A.D. 550–750
	Middle Nasca	5	A.D. 450–550
	Early Nasca	2, 3, 4	A.D. 1–450
Early Horizon	Proto Nasca	1	100 B.C.–A.D. 1
	Paracas		800–100 B.C.
Initial Period			1800–800 B.C.
Archaic			9000–1800 B.C.

and Isla Cuadrado, 2004, 2006; Schreiber and Lancho Rojas, 2003; Silverman, 1994, 1996, 2002; Van Gijsegem, 2004, 2006).

During the Early Intermediate Period (A.D. 1–750) the Nasca culture developed in the region. Considered to be the first regional, complex society centered here, it is well-known for its distinctive, polychrome pottery, the ceremonial center of Cahuachi, trophy heads, and the geoglyphs (Nasca lines). During this period, burial position changed from extended to flexed with the majority of adult individuals buried in pits accompanied by at least one whole pot (Carmichael, 1988). Burials in large vessels (or with large fragments of these) were common for children six years of age and younger (Isla, 2001). The most elaborate burial type was a *barbacoa* chamber with log roofs (Carmichael, 1988). These had varying depths, with the deepest of approximately 8 m reported at the site of La Muña in the northern drainage (Isla and Reindel, 2006:385). These tombs were for the highest status individuals and generally contained one individual.

The most dramatic and well-known of Nasca burial practice involved human sacrifice, decapitation and trophy heads. Large numbers of carefully processed trophy heads have been found in the region dating to the Early Intermediate Period. They were buried alone and in caches of up to 48, and interred in both cemeteries and domestic contexts (Baraybar, 1987; Browne et al., 1993; Carmichael, 1988; Kroeber and Collier, 1998; Neira Avedaño and Pentado Coelho, 1972–73; Silverman, 1993; Verano, 1995; Williams et al., 2001). Disembodied heads are also common images in Nasca art and often associated with agriculture and fertility motifs (Carmichael, 1995; DeLeonardis, 2000; Proulx, 1989, 2001; Roark, 1965; Sawyer, 1966). A central debate regarding this practice is whether trophy heads were taken during warfare as trophies, or taken in other contexts and used in rituals such as ceremonies in honor of the dead (Carmichael, 1995; Forgey and Williams, 2005; Proulx, 1989, 2001; Silverman and Proulx, 2002; Tello, 1918; Verano, 1995). In the Nasca region this practice seems primarily confined to the Nasca culture of the Early Intermediate Period with a sharp decline in trophy head making in the Middle Horizon (Kellner, 2002, 2006), although evidence presented below may indicate this practice continued later into the subsequent Late Intermediate Period.

Changes in mortuary practices are evident by the Middle Horizon (A.D. 750–1000) and reflect broader transformations in the region. During this period the traditional Nasca culture ended and political and economic change came from the Wari state of the central highlands. The Wari presence is seen in Nasca at sites such as Pacheco and Pataraya, which may have been administrative centers (Menzel, 1964; Schreiber, 2001a, 2001b), and in Wari pottery found at many sites (Schreiber, 1992). There was also a shift in local settlement patterns with people moving to the far south away from Wari associated sites (Conlee and Schreiber, 2006; Schreiber, 2001a). During this period the traditional Nasca burials in *barbacoa* tombs, pits, and large ceramic vessels were maintained;

however, new types were also introduced. The new types included partially above ground tombs that were plastered and painted that have been documented at La Tiza (Conlee, submitted for publication), and tombs with large stone slab roofs that have been identified at the Wari site of Pataraya in the upper Nasca valley, and in the upper elevations of the Las Trancas Valley (Isla, 2001; Schreiber, 2001b). Major changes during this period include the new practice of multiple individuals buried together, and the creation and burying of mummy bundles.

In the Late Intermediate Period (A.D. 1000–1476) and Late Horizon (A.D. 1476–1532), burial practices changed once again. After the collapse of Wari the region went through a period of population decrease and movement, and few sites have been documented dating between A.D. 1000 and A.D.1200. After this two-hundred year period of disruption there was an influx of people into the region and soon after the population was at its highest in prehispanic times (Schreiber and Lancho Rojas, 2003; Silverman, 2002). Observations made primarily from looted contexts have indicated that burials of this period were commonly found in houses, which is a shift from the separate cemetery locations favored by previous peoples. At La Tiza we have confirmed this pattern with the excavation of a family group buried in a house. The adults were buried in flexed positions, and the infants with large ceramic vessels. These practices are reminiscent of the Nasca culture and indicate a partial return to local traditions. Conquest of the region by the Inca appears not to have greatly impacted many local settlements (Conlee, 2003) and this likely extends to burial practices, although few burials of this period have been scientifically documented.

The history of the Nasca region and its changing burial practices documents periods when populations may have moved into and out of the area. In particular, new burial types and evidence of Wari sites and highland goods in Nasca during the Middle Horizon indicate the possible influx of foreign populations. In addition, the dramatic loss of population in the region at the end of the Middle Horizon, and its eventual growth again during the Late Intermediate Period, were also times when population movement likely impacted sociopolitical organization. The practice of decapitation and modification of human heads during the Nasca culture has spurred debate over the nature of warfare and human sacrifice. Specifically, the question remains whether there was warfare between Nasca people and groups outside of the region during which trophy heads were obtained, or if heads were taken from local people either in warfare or in ritual contexts. These questions are addressed by a study of the burial practices in the southern Nasca drainage and the strontium isotopic analysis of the burial population.

4. Burials from La Tiza and Pajonal Alto

The samples analyzed in this study include the burials of nine individuals from the site of La Tiza and one individual from Pajonal Alto (Table 2). The human remains found at La Tiza date to Early Nasca (A.D. 1–450), Middle Nasca (A.D. 450–550), the Middle Horizon (A.D. 750–1000), and the Late Intermediate Period (A.D. 1000–1476). The one burial from Pajonal Alto dates to the Middle Horizon. Age and sex were determined using standard protocols (Buikstra and Ubelaker, 1994).

4.1. La Tiza

The site of La Tiza is located where the Aja and Tierras Blancas river valleys merge into the Nasca Valley (see Fig. 1). It is a large settlement (30 ha) built on a steep hillside near good farmland and access to water. The earliest occupation extends back to the Middle

Table 2
Burial population analyzed in this study.

Sample	Burial	Site	Cultural Affiliation	Age	Sex	Burial Location	Burial Position	Grave Goods	Additional Info
1	1	La Tiza	Middle Nasca	22–29	Male	Round stone-lined tomb	Seated cross-legged	Head jar	Headless
2	2	La Tiza	Middle Horizon	30–40	Male	Pit in domestic structure	Flexed	Bowl	Local MH Loro
3	3	La Tiza	Late Intermediate	25–35	Possible Female	Pit in domestic structure	Flexed	None	
4	4	La Tiza	Late Intermediate	12–18 months	Juvenile	In pit above Burial 6	Unknown	Shell ornaments	
5	5	La Tiza	Late Intermediate	14–15	Probable Male	Pit in domestic structure	Flexed	Textile	Headless
6	6	La Tiza	Late Intermediate	18 months	Juvenile	Inside of large olla	Unknown	None	
7	7	La Tiza	Early Nasca	45+	Female	Pit in domestic structure	Flexed	Beads, pin, miniature	
8	8	La Tiza	Early Nasca	9–10	Juvenile	Wall	Flexed	Lrg. Vessel Frag.	
9	Tomb 6	La Tiza	Middle Horizon	25–35	Female	Above ground tomb	Unknown	Multiple (see text)	Mummy bundle
10	Unit 14	Pajonal Alto	Middle Horizon	3–5	Juvenile	Pit	Flexed	Lrg. Vessel Frag.	Local MH Loro

Archaic (ca. 3500 B.C.) and it was inhabited, albeit intermittently, until the Spanish conquest in 1532. La Tiza contains several domestic areas and cemeteries with the majority dating from the late Early Horizon through the Inca period (100 B.C.–A.D. 1532).

Excavated during 2004–2006, the nine burials from the site were located in a variety of contexts (see Table 2). Burial 1 (Middle Nasca) was interred in a stone-lined tomb next to an earlier cemetery. Burial 2 (Middle Horizon) was buried in a pit inside of a domestic structure with one intact ceramic vessel. Burials 3–6 were all found in one large domestic structure (Late Intermediate Period). Burial 7 was buried in a pit in a structure with typical Nasca culture burial goods (Early Nasca), and Burial 8 was a child placed in a wall (Early Nasca) with a fragment of a large polychrome ceramic vessel. These are all local burial types that have been documented throughout the Nasca region. In contrast, the burial from Tomb 6 (Sample 9) was in a looted above ground tomb that contained multiple individuals including a partial mummy bundle, and rich grave goods. This type of elite burial is new in the Middle Horizon and a large number of these tombs have been identified at La Tiza (Conlee, submitted for publication). This new tradition involved elaborate stone tombs that were plastered and painted and grave goods such as copper objects and *Spondylus* ornaments. This new burial type is associated with the Wari presence in Nasca and Wari imperial style ceramics were often included in these tombs.

The sample of individuals from La Tiza consists of six adults and three juveniles (see Table 2). Five of the adults fall within the young to mid-adult range, 20–40 years of age; the remaining adult is aged 45+. The sample includes two males, one possible male, two females and one possible female. Of the juveniles, there is one infant aged 12–18 months, another infant aged 18 months, a child aged 9–10 years, and an adolescent aged 14–15 years.

Two burials were recovered without crania. Burial 1, a young adult male, shows clear indications of decapitation including missing first and second cervical vertebrae, and cutmarks on the third cervical vertebra (Conlee, 2006, 2007). This burial adds an important piece of information to the debate about trophy heads. The 20–25 year old male was placed in a seated cross-legged position next to a ceramic jar that dates to Middle Nasca (A.D. 450–550). On the jar an image of a head was painted with a tree sprouting out of the forehead. This discovery is one of the few decapitated bodies ever to be excavated in the region and the first dating to Middle Nasca, a time of change and potential stress in Nasca (Schreiber and Lancho Rojas, 2003; Silverman, 2002; Silverman and Proulx, 2002). The burial was located adjacent to an

earlier cemetery and to habitation dating to the Early Horizon and to Early Nasca. This burial is unique in that there is little evidence of Middle Nasca habitation at La Tiza and no other burials of this period have been found.

The second headless burial (Burial 5), an adolescent probable male, was in a flexed position among the group of individuals buried in the same Late Intermediate Period domestic structure. There were no cutmarks on the vertebrae; however, there was no evidence of disturbance indicative of later removal of the cranium. The upper two cervical vertebrae were missing along with the cranium, which is the pattern found on Burial 1 that was clearly decapitated. The absence of the upper cervical vertebrae suggests that the head was removed when the soft tissue was still intact. If the head was taken after the soft tissue had decomposed, then the cranium could have been removed leaving the upper vertebrae on the skeleton. The only burial good associated with the individual was a textile wrapped around the body. This burial is unusual in that there have been no trophy heads found in the region that date to the Late Intermediate Period.

4.2. Pajonal Alto

The site of Pajonal Alto is a small village (2–3 ha) located in the Taruga Valley, one valley south of La Tiza (see Fig. 1). It was first occupied in the early Middle Horizon, abandoned around A.D. 900, and later reoccupied in the middle of the Late Intermediate Period (A.D. 1300). The majority of the habitation dates to the later part of the Late Intermediate through the Late Horizon. The village is flanked on the east and west by cemeteries that contain burials from the Nasca culture and the Middle Horizon.

One Middle Horizon burial, a child aged 3–5 years old, was found underneath a midden in Unit 14 that dated to the Late Intermediate Period and Late Horizon. The child was in a seated position facing west and was buried with large fragments of a local Middle Horizon ceramic vessel. This was a typical local burial practice for children beginning in Early Nasca and extending through the Late Intermediate Period.

5. Strontium isotope methodology

As discussed previously, strontium isotope compositions vary by local geology and the isotopic signature of a region is incorporated into humans when they consume primarily local foods. By comparing the strontium isotope ratios in bone and dental enamel

from one individual, or multiple teeth that developed at different times from one individual, it is possible to determine if a person lived in different areas during childhood and adulthood. It should be noted that analysis of dental and bone $^{87}\text{Sr}/^{86}\text{Sr}$ values can only identify first-generation immigrants, individuals who were born and lived in an area during childhood that is different from the residence at the time of death. In addition, it may not be possible to identify migration if an individual moved to or from a region of similar geology (and thus, similar strontium isotope signature).

It is possible that $^{87}\text{Sr}/^{86}\text{Sr}$ values can fluctuate due to food importation and processing (Knudson, 2004; Wright, 2005). For example, the consumption of marine resources and sea salt can affect human strontium isotope values (Burton, 1996; Wright, 2005). Plant resources such as seeds, nuts and legumes contribute to $^{87}\text{Sr}/^{86}\text{Sr}$ values in humans (Price et al., 1994). Beans, especially, constitute an important dietary source for strontium, as legumes contain high amounts of calcium and strontium (Burton and Wright, 1995). In contrast, maize consumption does not influence human $^{87}\text{Sr}/^{86}\text{Sr}$ values, as it contains little calcium and strontium (Aufderheide and Allison, 1995). The effects of breast milk on $^{87}\text{Sr}/^{86}\text{Sr}$ values should also be considered. Human breast milk has a very low Sr/Ca ratio compared to most foods (Humphrey et al., 2007; Mays, 2003; Sillen and Smith, 1984). By examining the Sr/Ca ratios in an enamel sample, it is possible to detect the change from breast milk to weaning foods.

Because diet can influence strontium isotope values, it is necessary to consider the foods most commonly consumed by Nasca people. All of the individuals in this study lived during periods when the Nasca people were intensive agriculturalists and grew a variety of Andean crops. In the analysis of the botanical remains from Pajonal Alto, corn (*Zea mays*) was the most common cultivated plant, followed by the lima bean (*Phaseolus lunatus*) (Conlee, 2000). Two other types of beans were eaten, the common bean (*Phaseolus vulgaris*) and the jack-bean (*Canavalia plagioperma*), but they were relatively rare. Aji peppers (*Capsicum annuum*) were the fifth ranked plant and a variety of fruits were found with pacay (*Inga Feuillei*) being the most common. Another important food source may have been huarango (*Prosopis* sp.), a native tree with a fruity pod. Squash (*Cucurbita maxima* and *Cucurbita moschata*) and tubers such as achira (*Canna edulis*), yucca (*Manihot esculenta*), and less commonly sweet potato (*Ipomoea batatas*) were also eaten (Conlee, 2000).

Marine shell was common at both settlements despite the 50 km distance from the ocean, although marine resources did not make up a large portion of the diet. A few pelagic fish remains were found at Pajonal Alto (Conlee, 2000) but have not been encountered at La Tiza and were probably rare. It is unclear where the people of La Tiza and Pajonal Alto obtained salt although it may have been from the ocean since trade between the interior and coast is evident beginning with the Nasca culture and increased over time. Most meat in the diet came from domesticated camelids (*Lama glama* and *Lama pacos*) and guinea pigs (*Cavia porcellus*), and to a lesser extent wild deer and birds (Conlee, 2000).

Strontium isotope analysis was conducted on bone and enamel samples of all burials with the exceptions of Burials 1 and 5, the headless individuals who lacked teeth for analysis, and the individual from Tomb 6 for which postcranial skeletal material was not associated with the cranium and therefore not analyzed. Bone is considered to be more susceptible to diagenetic alteration than tooth enamel. In the burial environment, groundwater can dissolve and leach the bone mineral component. Due to its structure, bone mineral is a good absorbent for elements. Subsequently, elements present in the soil and groundwater can be taken up by buried bones (Nielsen-Marsh et al., 2000). In contrast, the elements that come in contact with teeth seldom penetrate deep into the enamel

(Budd et al., 2000). In order to check for diagenetic contamination, samples were subjected to trace element analysis to monitor the ratio of calcium to phosphorus (Ca/P) and uranium concentrations. Uranium concentrations were recorded for all human bone and enamel samples; Ca/P ratio was recorded for all human bone samples. In addition, uranium concentrations were recorded for two archaeological faunal samples.

In order to determine the presence of local versus non-local individuals in the burial population, the local strontium isotope range had to be first established. The local range was primarily defined using archaeological and modern faunal remains, an established and common procedure. Small animals, such as rodents, are good models for determining the local strontium isotopic signature because they have limited home ranges (Price et al., 2002). The samples used in the analysis included seven archaeological rodent bones from La Tiza, two archaeological rodent bones from Pajonal Alto, and three modern rodent (mouse) teeth from animals living in the fields near the site of La Tiza. In addition, a soil sample from La Tiza was analyzed and three modern rodent (guinea pig) bones from an area located approximately 30 km from La Tiza at 1600 m a.b.s.l. in the upper Tierras Blancas Valley were included for comparative purposes.

The sites of La Tiza and Pajonal Alto are located in similar geological regions that are dominated by the upper Jurassic Guanero Formation, which is a clastic sedimentary rock formation. The three modern rodent teeth taken from the upper Tierras Blancas Valley come from an area dominated by the younger Tiabaya grandiorite/tonalitic intrusion of upper Cretaceous age, which forms part of the Coastal Batholith unit (Montoya et al., 1994).

Laboratory methods followed standardized protocol. Enamel samples were cut from the crown and the pulp and dentine were removed leaving the intact enamel using a diamond disk saw fitted to a dental drill. All samples (enamel and bone) were then prepared for analysis in a clean room laboratory at the Radiogenic Isotope Facility in the Department of Earth and Atmospheric Sciences at the University of Alberta. Specific information regarding these methods is detailed by Buzon and colleagues (Buzon et al., 2007). The data presented here were obtained through Inductively Coupled Plasma Mass Spectrometry using a multicollector NuPlasma instrument. Accuracy and reproducibility of the analytical protocol were verified by the repeated analysis of a 100 ppb solution of the NIST SRM 987 Sr isotope standard; this yielded an average value of 0.710242 ± 0.000041 (2s standard deviation; $n = 13$ analyses) and is indistinguishable compared to the accepted standard value of 0.710245 (Faure and Mensing, 2005:78).

6. Results

Using the standard method of faunal mean ± 2 standard deviations, the local range based on nine archaeological samples and three modern samples is 0.70559–0.70727 (Fig. 2, Table 3). The soil sample from La Tiza included in this study corresponds with this local range ($^{87}\text{Sr}/^{86}\text{Sr} = 0.70670$). Additional faunal samples taken from the upper elevations of the Nasca valley produced a local range of 0.70571–0.70604, which falls within the local range of both the La Tiza and Pajonal Alto areas. Although located near the coast, it is clear that these individuals are not consuming only marine resources as their strontium isotope values vary from the signature of the ocean, $^{87}\text{Sr}/^{86}\text{Sr} = 0.7092$ (Veizer, 1989). All of the human bone and tooth samples in our sample fall within the local range except the Middle Horizon female from La Tiza who was buried in the new elite tomb type at $^{87}\text{Sr}/^{86}\text{Sr} = 0.70747$ and the Middle Horizon child from Pajonal Alto at $^{87}\text{Sr}/^{86}\text{Sr} = 0.70770$ (Fig. 3, Table 4). The bone samples for both headless burials fall inside of the determined local range.

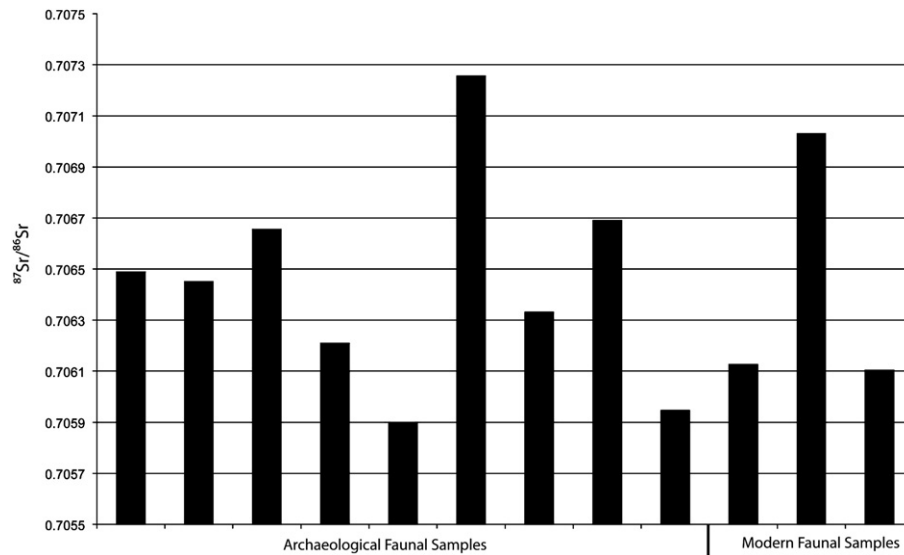


Fig. 2. $^{87}\text{Sr}/^{86}\text{Sr}$ values of the Nasca faunal samples.

The results of the trace element analysis of the bone samples (human and faunal) reveal some signs of diagenetic contamination. Most of the human bone samples have a Ca/P ratio above the normal 2.1 value for human bone and several have uranium concentrations above the detection limit that suggests possible postmortem contamination (see Table 4). However, the $^{87}\text{Sr}/^{86}\text{Sr}$ values do not covary with the Sr concentrations in each sample and the values for individuals with the highest concentrations of strontium do not show a direct relationship with the local signature (Budd et al., 2000; Horn and Müller-Sohnius, 1999). These data suggest that the bone-derived strontium values were not influenced by postmortem contamination. However, using a conservative approach, caution should be taken in the interpretation of these bone samples. This is especially important when considering the bone samples for the two headless individuals. While the strontium isotope analysis indicates that these samples are within the local range, the small amount of uranium present indicates the possibility of postburial contamination.

7. Foreigners and burial practices

The results of the strontium isotope analysis reveal that the isotopic signatures of all eight individuals from the Nasca culture

and the Late Intermediate Period at La Tiza fall into the local strontium range. The Middle Horizon individual at La Tiza who was buried in the local tradition also had a local signature. However, the $^{87}\text{Sr}/^{86}\text{Sr}$ enamel values of the other two Middle Horizon individuals, the child from Pajonal Alto and the woman from the looted tomb at La Tiza, fall outside of the local range suggesting that both spent their infancy and/or childhood outside of the local area.

The Middle Horizon was a time of great change in the Nasca region and several lines of evidence indicate that the Wari state occupied this region and that people in the Nasca Valley were closely integrated into the state. The presence of what may have been Wari administrative centers and imperial style artifacts suggests that people from the Wari heartland moved to the Nasca region during this period. The non-local adult female buried in the new elite tomb type at La Tiza suggests that this new mortuary practice may have been brought in by foreign people who were associated with the Wari state. New economic opportunities for people may have developed in Nasca during the Middle Horizon and immigrants from elsewhere may have moved to the region. Relocation may also have been accomplished through the Wari state. It is possible that Wari practiced strategies similar to the Inca in which people were resettled to areas to take advantage of certain resources or to work on specific projects as part of a labor tax.

Table 3
Strontium values of faunal and soil samples used to determine the local range.

Sample	Region/Site	Material	Sr ppm	$^{87}\text{Sr}/^{86}\text{Sr}$	2s error	U (ppm)
11	La Tiza	Rodent (archaeological)	217	0.70649	0.00002	Below detection limit
12	La Tiza	Rodent (archaeological)	359	0.70645	0.00002	Below detection limit
13	La Tiza	Rodent (archaeological)	198	0.70665	0.00002	Below detection limit
14	La Tiza	Rodent (archaeological)	385	0.70621	0.00002	Below detection limit
15	La Tiza	Rodent (archaeological)	375	0.70590	0.00001	Below detection limit
16	La Tiza	Rodent (archaeological)	390	0.70725	0.00002	Below detection limit
17	La Tiza	Rodent (archaeological)	230	0.70633	0.00003	0.04
18	Pajonal Alto	Rodent (archaeological)	219	0.70669	0.00004	Below detection limit
19	Pajonal Alto	Rodent (archaeological)	330	0.70594	0.00002	0.09
20	Middle Nasca Valley	Rodent (modern)	84	0.70612	0.00002	Below detection limit
21	Middle Nasca Valley	Rodent (modern)	114	0.70703	0.00004	Below detection limit
22	Middle Nasca Valley	Rodent (modern)	116	0.70610	0.00002	Below detection limit
23	Upper Tierras Blancas Valley	Rodent (modern)	217	0.70591	0.00003	Below detection limit
24	Upper Tierras Blancas Valley	rodent (modern)	290	0.70593	0.00003	Below detection limit
25	Upper Tierras Blancas Valley	Rodent (modern)	281	0.70578	0.00003	Below detection limit
26	La Tiza	Soil	5	0.70670	0.00003	Below detection limit

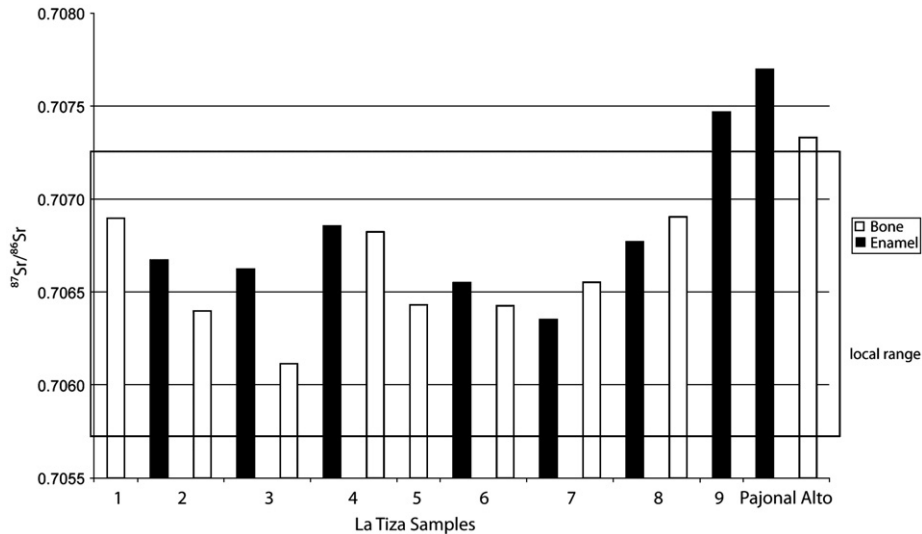


Fig. 3. $^{87}\text{Sr}/^{86}\text{Sr}$ values of human enamel and bone samples from La Tiza and Pajonal Alto.

In contrast, the child at Pajonal Alto was buried in a local style despite the fact that his/her strontium signature indicates he/she was not originally from the village. There were several indications that the child was not healthy at the time of death. The child displayed cribra orbitalia and osteoperiostitis, conditions associated with malnutrition and infection (Kellner and Conlee, 1998). The evidence that the child was under considerable stress suggests that recent immigrants into the region were not always in privileged positions or that migration itself was a physiologically stressful process.

The enamel sample used for this child is from the second deciduous molar. The crown of this tooth begins development at approximately 18 weeks in utero and is completed by 10–11 months of age (Hillson, 1996; Schwartz, 2007). The time frame of this crown development indicates that the strontium isotope signature likely reflects the diet of a breastfed infant. However, the influence of possible weaning foods, especially those that could be non-local, should be considered. The Sr/Ca ratio for this child's enamel sample from the deciduous second molar is 0.00046. In comparison with deciduous tooth samples from exclusively breastfed and weaned infants, this Sr/Ca ratio is clearly below the level observed for infants consuming nonmaternally derived foods (Humphrey et al., 2008). Thus, the non-local strontium isotope

value for this child from Pajonal Alto reflects maternal dietary sources, rather than possible non-local weaning foods.

The two headless males from La Tiza have strontium signatures that indicate they were both from the local region. Burial 1 dating to Middle Nasca, with its clear evidence of decapitation, was likely a human sacrifice and his head may have been made into a trophy head. His local strontium signature provides new insight into the debate over whether these heads were war trophies taken from individuals in battle or if they were the result of human sacrifice and involved people from the local community. Although the findings of this study do not provide a definitive answer to this question, they do suggest that in this case decapitation involved a local person. It is possible the individual was taken in battle, decapitated, and then returned to his community for burial. However, the lack of Middle Nasca habitation and burials at La Tiza indicates this was not the home of this individual or his relatives, nor was it a typical burial area during this period. This sets his burial apart from normal inhumations. It is also possible that warfare occurred between local groups and not with people from outside of the region; if so, this burial may have been the result of someone taken in battle. However, the careful burial of the body and the inclusion of a head jar do not suggest he was an enemy. Instead, the burial of this individual near an area of earlier habitation and cemetery indicates

Table 4

Analyzed bone and enamel samples from La Tiza and Pajonal Alto.

Sample	Site	Material (tooth)	Cultural Affiliation	Sr ppm	$^{87}\text{Sr}/^{86}\text{Sr}$	2s error	Ca/P	Uranium (ppm)
1	La Tiza	Bone	Middle Nasca	583	0.70690	0.00001	2.2	0.64
2	La Tiza	Bone	Middle Horizon	372	0.70667	0.00002	2.3	0.38
2	La Tiza	Enamel (P4)	Middle Horizon	149	0.70640	0.00002		Below detection limit
3	La Tiza	Bone	Late Intermediate	192	0.70662	0.00002	2.3	0.15
3	La Tiza	Enamel (P4)	Late Intermediate	104	0.70612	0.00003		Below detection limit
4	La Tiza	Bone	Late Intermediate	193	0.70686	0.00002	2.3	1.43
4	La Tiza	Enamel (I1)	Late Intermediate	80	0.70682	0.00003		0.22
5	La Tiza	Bone	Late Intermediate	272	0.70643	0.00002	2.3	0.07
6	La Tiza	Bone	Late Intermediate	255	0.70655	0.00001	2.0	1.09
6	La Tiza	Enamel (P4)	Late Intermediate	129	0.70643	0.00002		0.21
7	La Tiza	Bone	Early Nasca	310	0.70635	0.00003	2.3	Below detection limit
7	La Tiza	Enamel (C)	Early Nasca	70	0.70655	0.00003		Below detection limit
8	La Tiza	Enamel (c)	Early Nasca	284	0.70677	0.00003		Below detection limit
8	La Tiza	Bone	Early Nasca	203	0.70691	0.00002	2.3	0.69
9	La Tiza	Enamel (M1)	Middle Horizon	102	0.70747	0.00002		Below detection limit
10	Pajonal Alto	Enamel (m2)	Middle Horizon	75	0.70770	0.00003		Below detection limit
10	Pajonal Alto	Bone	Middle Horizon	137	0.70733	0.00003	2.3	Below detection limit

Table 5
Strontium values from other areas of the Andes.

Site (Region)	$^{87}\text{Sr}/^{86}\text{Sr}$	Reference
Chokepukio (Cuzco highlands)	0.7073–0.7091	Andrushko et al., 2009
Machu Picchu (Cuzco highlands)	0.7125–0.7152	Turner, 2008
Tiwanaku (Lake Titicaca highlands)	0.7087–0.7105	Knudson et al., 2004
Wari (Ayacucho highlands)	0.7054–0.7067	Tung, 2003
Conchopata (Ayacucho highlands)	0.7051–0.7065	Tung and Knudson, 2008
Ancon (Central coast)	0.7063–0.7068	Slovak et al., 2009
Chen Chen (Moquegua valley)	0.7059–0.7066	Knudson, 2008

it may have been an offering to the ancestors in order to ensure agricultural fertility, and may reflect concerns about the continuation of life and rebirth of society (Conlee, 2007). Recent isotopic research on Nasca trophy heads from a museum collection suggests that they came from the local Nasca population (Knudson et al., 2009), further indicating that trophy head taking was a local practice with a strong ritual component.

The second headless individual dates to the Late Intermediate Period, a time when there is no evidence that trophy head taking or decapitation continued. The lack of clear disturbance of the burial and absence of the upper cervical vertebrae indicate that the head was removed when there was still soft tissue and was not taken later by looters. It is certainly plausible that this individual was decapitated, despite the lack of visible cutmarks on the vertebrae, as studies have shown injury or dismemberment may not leave marks on the bone. For example, scalping can be done without leaving cutmarks (Hamperl, 1967) and some case studies have documented that less than half of projectile point wounds leave a mark on the bone (Lambert, 1997; Milner, 2005). Decapitation has also been reported without cutmarks (Boylston et al., 2000) and may be the result of individuals being incapacitated or already dead when they were decapitated. Although it is preferred to have cutmarks on the cervical vertebrae to confirm decapitation it is also possible to infer it from the deposition of the body (Roberts and Manchester, 2005:116). The evidence suggests that the Late Intermediate Period headless burial was the result of decapitation but it remains uncertain how and in what circumstances this occurred. However, it is intriguing evidence for the possibility that the practice of human sacrifice and trophy head taking continued later in time than has previously been proposed.

Strontium isotope signatures have now been defined for several areas in the Andean region (Table 5). Of these, the Nasca local range of 0.70559–0.70727 appears to overlap with the Ayacucho, Ancón and Moquegua local ranges. The establishment of local strontium ranges in several areas of the Andes, and new analyses that are underway in additional regions, will eventually allow researchers not only to determine that foreigners existed in their regions but also to explore where these people originated. It has been found that strontium values increase from north to south in the central Andes (Knudson and Tung, 2007) and that there are lower values in coastal areas than in the highlands (Turner et al., 2009). Both the Middle Horizon female from La Tiza at $^{87}\text{Sr}/^{86}\text{Sr} = 0.70747$ and the child from Pajonal Alto at $^{87}\text{Sr}/^{86}\text{Sr} = 0.70770$ fall closest in range to the local signature at Chokepukio in the Cuzco region; however, no definitive conclusions can be made about the possible origin of these individuals at this time, as geographically distinct regions may have similar strontium values, and many regions in the Andes remain undocumented.

8. Conclusions

Strontium isotopic analysis has proven to be effective in helping to document foreigners and locals in the Nasca region and

to elucidate certain aspects of prehispanic culture. Non-local individuals were only documented in the Middle Horizon during a time when the highland Wari empire may have controlled areas of Nasca. One of these non-local individuals was found buried in a new elite tomb type possibly introduced by foreigners that came to the region through their association with Wari. This mortuary practice and the presence of foreigners strengthen the argument that Wari did incorporate areas of Nasca into its realm and that highlanders moved to the area during this period. The Middle Horizon child that was buried in the local tradition at Pajonal Alto and under considerable stress at the time of his or her death may represent another kind of immigration. After the collapse of the Wari state there is evidence of upheaval and population loss in Nasca followed by a rebound of population in the middle of the Late Intermediate Period. The evidence from this study suggests that the Late Intermediate Period burials at La Tiza were individuals who were born and lived locally and were not recent immigrants. One burial group is not sufficient to evaluate migration patterns during this period but it does help to establish that people at La Tiza buried in this type of traditional burial in houses are likely locals. The analysis of additional Late Intermediate Period burials will help to address the impact of migration during this time.

The practice of decapitation and trophy head taking has also been explored through strontium isotope analysis and we have found that the two headless individuals were locals. The Middle Nasca decapitated individual was likely a human sacrifice that was buried at the settlement during a period when it was not actively being used and was possibly an offering to the ancestors. Again, while these results should be interpreted with caution due to possible diagenetic contamination, they suggest the practice of decapitation took place among local groups, possibly during warfare, and was ritual in nature. The presence of a Late Intermediate Period individual who may have been decapitated indicates the use of heads as ritual items or trophies may have continued later in time than previously thought.

As this study has shown, strontium isotope analysis has the potential to strengthen archaeological interpretations of migrations during periods of interaction and social reorganization. Coupled with archaeological data, strontium results can provide insights into the identification of non-local and local individuals in a burial population. The presence of foreigners in Nasca during the Middle Horizon suggests the Wari state did directly influence the region, and continued analysis of burials dating to this period will aid in assessing the various strategies of rule employed by the state and the impact they had on Nasca. Further strontium isotopic testing of trophy heads and decapitated individuals will help to establish if other victims were locals or foreigners, and the role this practice played in ancient ritual life and warfare in the region.

Acknowledgements

Work at La Tiza was funded by a National Science Foundation Grant BCS-0314273, the H. John Heinz III Fund Grant Program for Latin American Archaeology, and the Research Enhancement Program at Texas State University. Research at Pajonal Alto was supported by a National Science Foundation Dissertation Improvement Grant, and a Humanities and Social Science Grant from the University of California, Santa Barbara. The Radiogenic Isotope Facility at the University of Alberta is supported, in part, by an NSERC Major Resources Support Grant. We extend our gratitude to Jaime Donnelly for sample preparation and Guangcheng Chen for assistance with the MC-ICP-MS analyses. Permission to excavate at La Tiza and Pajonal Alto was granted by the Instituto Nacional de Cultura of Peru. A great deal of thanks goes to all of the participants

of Proyecto La Tiza 2002–2008 and Proyecto Pajonal Alto 1997 who aided in the excavation of these burials. Deborah Spivak deserves much appreciation for helping to capture the modern rodents used in this study and we would also like to thank Kevin Vaughn for helping to obtain the modern rodents from the upper Nasca Valley. We appreciate the insightful comments of three anonymous reviewers and of Valerie Andrushko and Kevin Vaughn who read an earlier draft of this paper.

References

- Ambrose, S.H., Krigbaum, J., 2003. Bone chemistry and bioarchaeology. *Journal of Anthropological Archaeology* 22, 193–199.
- Andrushko, V.A., Buzon, M.R., Simonetti, A., Creaser, R.A., 2008. Using strontium isotope analysis to investigate a child sacrifice from the Inca heartland. In: Paper Presented at the 73rd Annual Meeting of the Society for American Archaeology, Vancouver, B.C.
- Andrushko, V.A., Buzon, M.R., Simonetti, A., Creaser, R.A., 2009. Strontium isotope evidence for prehistoric migration at Chokepukio, Valley of Cuzco, Peru. *Latin American Antiquity*, 20 (1), 57–75.
- Aufderheide, A.C., Allison, M.J., 1995. Chemical dietary reconstruction of north Chile prehistoric populations by trace mineral analysis. In: Proceedings of the First World Congress on Mummy Studies, vol. 1. Museo Arqueológico y Etnográfico de Tenerife, Organismo Autónomo de Museos y Centros, Cabildo de Tenerife, pp. 451–461.
- Baraybar, J.P., 1987. Cabezas trofeos Nasca: nuevas evidencias. *Gaceta Arqueológica Andina* 15, 6–10.
- Bentley, R.A., 2006. Strontium isotopes from the earth to the archaeological skeleton: a review. *Journal of Archaeological Method and Theory* 13, 135–187.
- Boylston, A., Knüsel, C.J., Roberts, C.A., 2000. Investigation of a Romano-British rural ritual in Bedford, England. *Journal of Archaeological Science* 27, 241–252.
- Browne, D.M., Silverman, H., Garcia, R., 1993. A cache of Nasca trophy heads from Cerro Carapo, Peru. *Latin American Antiquity* 4, 274–294.
- Budd, P., Montgomery, J., Barreiro, B., Thomas, R.G., 2000. Differential diagenesis of strontium in archaeological human dental tissues. *Applied Geochemistry* 15, 687–694.
- Buikstra, J.E., Ubelaker, D.H., 1994. Standards for data collection from human skeletal remains. *Arkansas Archeological Survey Research Series* No. 44, Fayetteville.
- Burton, J.H., 1996. Trace-elements in bone as paleodietary indicators. In: Orna, M.V. (Ed.), *Archaeological Chemistry VI*. American Chemical Society, Washington D.C., pp. 327–333.
- Burton, J.H., Price, T.D., Cahue, L., Wright, L.E., 2003. The use of barium and strontium in human skeletal tissues to determine their geographic origin. *International Journal of Osteoarchaeology* 13, 88–95.
- Burton, J.H., Wright, L.E., 1995. Nonlinearity in the relationship between bone Sr/Ca and diet: paleodietary implications. *American Journal of Physical Anthropology* 96, 273–282.
- Buzon, M.R., Eng, J.T., Lambert, P.M., Walker, P.W., 2005. Bioarchaeological methods. In: Maschner, H.D.G., Chippindale, C. (Eds.), *Archaeological Methods*, vol. II. Altamira, Lanham, MD, pp. 871–918.
- Buzon, M.R., Simonetti, A., Creaser, R.A., 2007. Migration in the Nile Valley during the New Kingdom period: a preliminary strontium isotope study. *Journal of Archaeological Science* 34, 1391–1401.
- Carmichael, P.H., 1988. *Nasca Mortuary Customs: Death and Ancient Society on the South Coast of Peru*. Ph.D. dissertation, Department of Anthropology, University of Calgary.
- Carmichael, P.H., 1995. Nasca burial patterns: social structure and mortuary ideology. In: Dillehay, T. (Ed.), *Tombs For the Living: Andean Mortuary Practices*. Dumbarton Oaks, Washington D.C., pp. 161–188.
- Conlee, C.A., 2000. *Late Prehispanic Occupation of Pajonal Alto, Nasca, Peru: Implications for Imperial Collapse and Societal Reformation*. Ph.D. dissertation, Department of Anthropology, University of California, Santa Barbara.
- Conlee, C.A., 2003. Local elites and the reformation of Late Intermediate Period sociopolitical and economic organization in Nasca, Peru. *Latin American Antiquity* 14 (1), 47–65.
- Conlee, C.A., 2006. Nasca headless burial. In: Ono, M., Shimada, I., Baba, H., Shinoda, K. (Eds.), *Nasca, Wonder of the World: Messages Etched on the Desert Floor*. Catalog For the Museum Exhibit by the Tokyo Broadcasting System, Tokyo, Japan, pp. 36–37.
- Conlee, C.A., 2007. Decapitation and rebirth: a headless burial from Nasca, Peru. *Current Anthropology* 48, 438–445.
- Conlee, C.A. Nasca and Wari: local opportunism and colonial ties during the Middle Horizon. In: Jennings, J. (Ed.), *Beyond Wari Walls: Exploring the Nature of Middle Horizon Peru Away from Wari Centers*, University of New Mexico Press, submitted for publication.
- Conlee, C.A., Schreiber, K., 2006. The role of intermediate elites in the balkanization and reformation of post-Wari society in Nasca, Peru. In: Elson, C.E., Covey, A. (Eds.), *Intermediate Elites in Pre-Columbian States and Empires*. University of Arizona Press, Tucson, pp. 94–111.
- DeLeonardis, L., 2000. The body context: interpreting early Nasca decapitated burials. *Latin American Antiquity* 11, 363–386.
- Deutsches Archäologisches Institut, 2008. *Nasca-Palpa, Peru: recent investigations: Paracas and initial period*. Electronic document. <http://www.dainst.org/index.php?id=593&sessionLanguage=en>.
- Ericson, J.E., 1985. Strontium isotope characterization in the study of prehistoric human ecology. *Journal of Human Evolution* 14, 503–514.
- Faure, G., Mensing, T.M., 2005. *Isotopes: Principles and Applications*, third ed. John Wiley & Sons, Hoboken, New Jersey.
- Forgey, K., Williams, S., 2005. Were Nasca trophy heads war trophies or revered ancestors? Insights from the Kroeber collection. In: Rakita, G.F.M., Buikstra, J.E., Beck, L.A., Williams, S. (Eds.), *Interacting with the Dead: Perspectives on Mortuary Archaeology for the New Millennium*. University Press of Florida, Gainesville, FL, pp. 251–276.
- Hamperl, H., 1967. The osteological consequences of scalping. In: Brothwell, D.R., Sandison, A.T. (Eds.), *Diseases in Antiquity*. Charles C. Thomas, Springfield, Illinois, pp. 630–634.
- Hillson, S., 1996. *Dental Anthropology*. Cambridge University Press, Cambridge.
- Horn, P., Müller-Sohnius, D., 1999. Comment on “Mobility of Bell Beaker people revealed by strontium isotope ratios of tooth and bone: a study of southern Bavarian skeletal remains” by Grupe, G.T., Price, T.D., Schröter, P., Söllner, F., Johnson, C.M., Beard, B.L. *Applied Geochemistry* 14, 263–269.
- Humphrey, L., Dean, M.C., Jeffries, T.E., 2007. An evaluation of changes in strontium/calcium ratios across the neonatal line in human deciduous teeth. In: Bailey, S.E., Hublin, J.J. (Eds.), *Dental Perspectives on Human Evolution*. Springer, Dordrecht, the Netherlands, pp. 303–319.
- Humphrey, L., Dean, M.C., Jeffries, T.E., Penn, M., 2008. Unlocking evidence of early diet from tooth enamel. *Proceedings of the National Academy of Sciences* 105, 6834–6839.
- Isla, J., 1990. La Esmeralda: una ocupación del período arcaico en Cahuachi, Nasca. *Gaceta Arqueológica Andina* 4 (20), 67–80.
- Isla, J., 2001. Wari en Palpa y Nasca: perspectivas desde el punto de vista funerario. In: Kaulicke, P., Isbell, W.H. (Eds.), *Huari y Tiwanaku: Modelos y Evidencias. Segunda Parte*. Boletín de Arqueología PUCP, vol. 5. Fondo Editorial de la Pontificia Universidad Católica del Perú, Lima, pp. 555–584.
- Isla, J., Reindel, M., 2006. Burial patterns and sociopolitical organization in Nasca 5 society. In: Isbell, W.H., Silverman, H. (Eds.), *Andean Archaeology III: North and South*. Springer, New York, pp. 374–400.
- Kellner, C., 2002. *Coping with Environmental and Social Challenges in Prehistoric Peru: Bioarchaeological analyses of Nasca Populations*. Unpublished PhD dissertation, Anthropology, University of California, Santa Barbara.
- Kellner, C., 2006. Trophy heads in prehistoric Peru: Wari imperial influence on Nasca head-taking practices. In: Bonogofsky, M. (Ed.), *Skull Collection, Modification and Decoration*. BAR International Series, vol. 1539. Archaeopress, pp. 101–112.
- Kellner, C., Conlee, C.A., 1998. Evidence of physiological stress in a child curial at Pajonal Alto a Late Prehistoric Site on the South Coast of Peru. In: Paper presented at the Annual Meeting of the Paleopathology Association, Salt Lake City, UT.
- Knudson, K.J., 2004. *Tiwanaku Residential Mobility and Archaeological Chemistry: Strontium and Lead Isotope Analyses in the South Central Andes*. Ph.D. dissertation, Department of Anthropology, University of Wisconsin, Madison.
- Knudson, K.J., 2008. Tiwanaku influence in the south central Andes: strontium isotope analysis and Middle Horizon migration. *Latin American Antiquity* 19 (1), 3–24.
- Knudson, K.J., Price, T.D., 2007. Utility of multiple chemical techniques in archaeological residential mobility studies: case studies from Tiwanaku- and Chiribaya-affiliated sites in the Andes. *American Journal of Physical Anthropology* 132, 25–39.
- Knudson, K.J., Price, T.D., Buikstra, J.E., Blom, D.E., 2004. The use of strontium isotope analysis to investigate Tiwanaku migration and mortuary ritual in Bolivia and Peru. *Archaeometry* 46, 5–18.
- Knudson, K.J., Williams, S.R., Osborn, R., Forgey, K., Williams, P.R., 2009. The geographic origins of Nasca trophy heads using strontium, oxygen, and carbon isotope data. *Journal of Anthropological Archaeology*, 28 (2), 244–257.
- Knudson, K.J., Tung, T.A., 2007. Using archaeological chemistry to investigate the geographic origins of trophy heads in the central Andes: strontium isotope analysis at the Wari site of Conchopata. In: Glascock, M.D., Speakman, R.J., Popelka-Filcoff, R.S. (Eds.), *Archaeological Chemistry: Analytical Techniques and Archaeological Interpretation*. American Chemical Society, Washington D.C., pp. 99–113.
- Kroeber, A., Collier, D., 1998. *The Archaeology and Pottery of Nasca, Peru*. Altamira Press, Walnut Creek, California.
- Lambert, P., 1997. Patterns of violence in prehistoric hunter-gatherer societies of coastal southern California. In: Martin, D.L., Frayer, D.W. (Eds.), *Troubled Times: Violence and Warfare in the Past*. Gordon and Breach Publishing, Amsterdam, pp. 77–110.
- Mays, S., 2003. Bone strontium: calcium ratios and duration of breastfeeding in a medieval skeletal population. *Journal of Archaeological Science* 30, 731–741.
- Menzel, D., 1964. Style and time in the Middle Horizon. *Nawpa Pacha* 2, 66–105.
- Milner, G., 2005. Nineteenth-century arrow wounds and perceptions of prehistoric warfare. *American Antiquity* 70, 144–156.
- Montoya, M., García, W., Caidas, J., 1994. *Geología de los Cuadrángulos de Lomitas, Palpa, Nasca y Puquio*. INGEMET (Instituto Geológico Minero y Metalúrgico), Lima.

- Nielsen-Marsh, C., Gernaey, A., Turner-Walker, G., Hedges, R., Pike, A., Collins, M., 2000. The chemical degradation of bone. In: Cox, M., Mays, S. (Eds.), *Human Osteology in Archaeology and Forensic Science*. Greenwich Medical Media, London, pp. 439–454.
- Neira Avedaño, M., Pentado Coelho, V., 1972–73. Enterramientos de cabezas de la cultura Nasca. *Revista do Museu Paulista* 20, 109–142.
- Price, T.D., Burton, J.H., Bentley, R.A., 2002. The characterization of biologically available strontium isotope ratios for the study of prehistoric migration. *Archaeometry* 44, 117–135.
- Price, T.D., Burton, J.H., Fullagar, P.D., Wright, L.E., Buikstra, J.E., Tiesler, V., 2008. Strontium isotopes and the study of human mobility in ancient Mesoamerica. *Latin American Antiquity* 19 (2), 167–180.
- Price, T.D., Johnson, C.M., Ezzo, J.A., Ericson, J., Burton, J.H., 1994. Residential mobility in the prehistoric southwest United States: a preliminary study using strontium isotope analysis. *Journal of Archaeological Science* 21, 315–330.
- Proulx, D.A., 1989. Nasca trophy heads: victims of warfare or ritual sacrifice? In: Tkaczuk, D.C., Vivian, B.C. (Eds.), *Cultures in Conflict: Current Archaeological Perspectives*. Proceedings of the Twentieth Annual Conference of the Archaeological Association of the University of Calgary, University of Calgary, Archaeological Association, Calgary, pp. 73–85.
- Proulx, D.A., 2001. Ritual uses of trophy heads in ancient Nasca society. In: Benson, E.P., Cook, A.G. (Eds.), *Ritual Sacrifice in Ancient Peru*. University of Texas Press, Austin, pp. 119–136.
- Reindel, M., Isla Cuadrado, J., 2004. Archäologisches Projekt 'Paracas in Palpa', Peru. Bericht über die Grabungskampagne 2003. Jahresbericht der Schweizerisch-Liechtensteinischen Stiftung für Archäologische Forschungen im Ausland. SLSA, Zürich und Vaduz, pp. 137–156.
- Reindel, M., Isla Cuadrado, J., 2006. Archäologisches Projekt 'Paracas in Palpa', Peru: Ausgrabungen und Forschungen im Jahr 2005. Jahresbericht der Schweizerisch-Liechtensteinischen Stiftung für Archäologische Forschungen im Ausland. SLSA, Zürich und Vaduz, pp. 0–59.
- Roark, R.P., 1965. From monumental to proliferous in Nasca pottery. *Ñawpa Pacha* 3, 1–92.
- Roberts, C., Manchester, K., 2005. *The Archaeology of Disease*, third ed. Cornell University Press, Ithaca.
- Sawyer, A.R., 1966. *Ancient Peruvian Ceramics: the Nathan Cummings Collection*. Metropolitan Museum of Art, New York.
- Schreiber, K.J., 1992. Wari Imperialism in Middle Horizon Peru. In: *Anthropological Papers Museum of Anthropology*, vol. 87. University of Michigan, Ann Arbor.
- Schreiber, K.J., 2001a. The Wari empire of middle horizon Peru: the epistemological challenge of documenting an empire without documentary evidence. In: Alcock, S.E., D'Altory, T.E., Morrison, K.D., Sinopoli, C.M. (Eds.), *Empires*. Cambridge University Press, Cambridge, pp. 70–92.
- Schreiber, K.J., 2001b. Los Wari en su contexto local: Nasca y Sondondo. *Boletín de Arqueología* 4 (2000), 425–447. Pontificia Universidad Católica del Perú, Lima.
- Schreiber, K.J., Lancho Rojas, J., 2003. *Irrigation and Society in the Peruvian Desert: the Puquios of Nasca*. Lexington Books, Lanham.
- Schwartz, J.H., 2007. *Skeleton Keys: an Introduction to Human Skeletal Morphology, Development, and Analysis*. Oxford University Press, New York.
- Sealy, J., Armstrong, R., Schrire, C., 1995. Beyond lifetime averages: tracing life histories through isotopic analysis of different calcified tissues from archaeological human skeletons. *Antiquity* 69, 290–300.
- Sillen, A., Smith, P., 1984. Weaning patterns are reflected in strontium–calcium ratios of juvenile skeletons. *Journal of Archaeological Science* 11, 237–245.
- Silverman, H., 1993. *Cahuachi in the Ancient Nasca World*. University of Iowa Press, Iowa City.
- Silverman, H., 1994. Paracas in Nazca: new data on the early horizon occupation of the Rio Grande de Nazca drainage, Peru. *Latin American Antiquity* 5 (4), 359–382.
- Silverman, H., 1996. The formative period on the south coast of Peru: a critical review. *Journal of World Prehistory* 10, 95–147.
- Silverman, H., 2002. *Ancient Nasca Settlement and Society*. University of Iowa Press, Iowa.
- Silverman, H., Proulx, D., 2002. *The Nasca*. Blackwell Publishers, Malden, MA.
- Slovak, N.M., Paytan, A., Wiegand, B.A., 2009. Reconstructing Middle Horizon mobility patterns on the coast of Peru through strontium isotope analysis. *Journal of Archaeological Science* 36, 157–165.
- Tello, J.C., 1918. *El uso de las cabezas humanas artificialmente momificadas y su representatción en el antiguo arte Peruano*. Casa Editora de Ernesto R. Villarán, Lima.
- Tung, T., 2003. *A Bioarchaeological Perspective on Wari Imperialism in the Andes of Peru: a View from Heartland and Hinterland Skeletal Populations*. Ph.D. dissertation, Department of Anthropology, University of North Carolina, Chapel Hill.
- Tung, T., Knudson, K.J., 2008. Social identities and geographical origins of Wari trophy heads from Conchopata, Peru. *Current Anthropology* 49 (5), 915–925.
- Turner, B.L., 2008. *The Servants of Machu Picchu: Life Histories and Population Dynamics in Late Horizon Peru*. Ph.D. dissertation, Department of Anthropology, Emory University.
- Turner, B.L., Kamenov, G.D., Kington, J.D., Armelagos, G.J., 2009. Insights into immigration and social class at Machu Picchu, Peru based on oxygen, strontium, and lead isotopic analysis. *Journal of Archaeological Science* 36, 317–332.
- Van Gijseghem, H., 2004. *Migration, Agency, and Social Change on a Prehistoric Frontier: the Paracas–Nasca transition in the Southern Nasca Drainage, Peru*. Ph.D. dissertation, Department of Anthropology, UC Santa Barbara.
- Van Gijseghem, H., 2006. A frontier perspective on Paracas society and Nasca ethnogenesis. *Latin American Antiquity* 17 (4), 419–444.
- Veizer, J., 1989. Strontium isotopes in seawater through time. *Annual Review of Earth and Planetary Science* 1, 141–167.
- Verano, J.W., 1995. Where do they rest? The treatment of human offerings and trophies in ancient Peru. In: Dillehay, T. (Ed.), *Tombs for the Living: Andean Mortuary Practices*. Dumbarton Oaks, Washington D.C., pp. 189–228.
- 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 contexts. In: Sandford, M.K. (Ed.), *Investigations of Ancient Human Tissue: Chemical Analyses in Anthropology*. Gordon and Breach Science Publishers, Langhorne, pp. 361–386.
- Williams, S.R., Forgey, K., Klarich, E., 2001. An osteological study of Nasca trophy heads collected by A.L. Kroeber during the Marshall Field Expeditions to Peru. *Fieldiana* 33, 1–132.
- Wright, L.E., 2005. Identifying immigrants to Tikal, Guatemala: defining local variability in strontium isotope ratios of human tooth enamel. *Journal of Archaeological Science* 32, 555–566.