Chapter 5

Using Archaeological Chemistry to Investigate the Geographic Origins of Trophy Heads in the Central Andes: Strontium Isotope Analysis at the Wari Site of Conchopata

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Comparing strontium isotope results from archaeological bone-tooth pairs from individuals buried in mortuary spaces at the Wari site of Conchopata with Conchopata trophy heads shows that the trophy head strontium isotope signatures are more variable. This implies that the individuals transformed into trophy heads likely came from different geologic zones in the Andes, and were more likely to have been victims of raiding or warfare from different parts of the Andes rather than venerated ancestors from Conchopata or the surrounding region. These data also demonstrate the ability of strontium isotope analysis to elucidate individual life histories using archaeological bone-tooth pairs.

Although there is a growing body of bioarchaeological and iconographic evidence that the Wari Empire of central Peru transformed some individuals into trophy heads (*1–3*), there is still much debate about the identity of these individuals. For example, these individuals could have been victims of warfare or raiding, as has been hypothesized for Nasca trophy heads in the Andes (*4–6*). Alternatively, the trophy heads could represent revered ancestors of the local Wari community. For example, in the Andes there is archaeological, ethnohistorical, and ethnographic evidence of the importance of ancestor veneration and the incorporation of skeletal elements into religious rituals (*7–10*). Here, we test the hypothesis that the Wari trophy heads at Conchopata are victims of warfare or raiding taken from outside of the Ayacucho Basin by using strontium isotope analysis of archaeological human tooth enamel and bone from the trophy heads as well as individuals buried in mortuary spaces at Conchopata.

The Conchopata Trophy Heads

During the Andean Middle Horizon (ca. A.D. 500–1000), the Wari Empire exerted substantial influence from its capital at Huari in the Ayacucho Basin. Wari administrative centers like Pikillacta near Cuzco and Wari-style artifacts found throughout the Peruvian Andes testify to Wari political and economic power (*11–17*). Within the Wari heartland, the site of Conchopata is located 12 km south of the site of Huari (*18, 19*). New calibrated radiocarbon dates suggest that the Wari component at Conchopata began around A.D. 600–650 (*20*). In addition to its residential and ritual functions, Conchopata has Middle Horizon burials from at least 242 individuals from numerous tombs and 31 trophy heads from two ritual structures (*1*). The trophy heads were found smashed and burned on the floor of a D-shaped room (EA 72) and a circular room (EA 143) (*1, 21, 22*). Tung has shown that the trophy heads have a standardized preparation with cutmarks on the posterior edge of the mandibular ramus and perforations drilled at bregma (on the superior of the skull), suggesting that the Wari trophy heads were disarticulated and defleshed and then dangled by a cord for display, as shown in Wari iconography (*1, 23*). The combined bioarchaeological and iconographic data suggest that the trophy heads were prepared by highly skilled ritual specialists for their use in the D-shaped and circular ritual structures (*1, 21, 22*).

Strontium Isotope Analyses in Archaeology

In the twenty years since it was first proposed (*24, 25*), strontium isotope analysis of archaeological human remains to examine residential mobility has become increasingly common. Briefly, $^{87}Sr/^{86}Sr$ in a given geologic zone is determined by the age and composition of the bedrock (*26*). The isotopic composition of strontium does not fractionate as strontium moves through the ecosystem, so the strontium isotope ratios in bedrock are then reflected in the soils, plants, and animals of that geologic zone (*27–29*). This isotope signature will also be reflected in the tooth enamel and bone hydroxyapatite from humans who consumed foods grown or raised in a given geologic zone (*30, 31*).

Since tooth enamel does not regenerate after it has formed, strontium isotope ratios in tooth enamel reflect the strontium sources in the diet, and hence the geologic zone or zones in which an individual was living, during enamel formation if local foods provided the strontium in the diet. On the other hand, bone continually regenerates, with turnover rates in cortical bone dependent on the skeletal element analyzed and the age, sex, activity levels and health of the individual (*32–37*).Therefore, the strontium isotope ratios in human bone reflect the strontium source of the last years of life. Comparing the strontium isotope signatures in archaeological human tooth enamel and bone can then reveal changes in place of residence during enamel and bone formation, if local foods were consumed (*24, 25*).

Diagenesis and Strontium Isotope Analysis

When working with trace elemental analyses in archaeological samples, identifying and eliminating diagenetic contamination is clearly necessary. Strontium from the groundwater and burial environment can be incorporated into hydroxyapatite as secondary minerals. For example, calcite ($CaCO_3$) and barite ($BaSO_4$) may be deposited in the pore spaces of the calcium phosphate structure of teeth and bone (*38, 39*). Biogenic apatite could also be altered as trace elements from post-depositional contamination substitute for calcium in calcium phosphate and are converted to hydroxyapatite during recrystallization and crystal growth (*38, 39*).

Because of its mineral composition, the large size of its phosphate crystals and the small amount of pore space, mature tooth enamel is rarely affected by diagenetic contamination (*40–42*). This has been supported by experimental data that show that enamel reliably retains biogenic strontium isotope signatures (*30, 43–48*).

Unfortunately, because of its porosity and large surface area, bone is more susceptible to diagenetic contamination. As in tooth enamel, diagenetic contamination is concentrated on the outer surface of the bone (*49–52*). Therefore, mechanically cleaning the bone samples through abrasion can remove diagenetic contamination on the bone surface (*49, 53*). Although a number of techniques can be used to identify the presence of diagenetic contamination (*54–58*), removing the diagenetic contamination is more difficult. However, washing the bone sample with weak acid removes calcite that accumulated in the bone after burial (*30, 53, 55, 59*). As will be discussed below, the bone samples included in this study were mechanically and chemically cleaned in order to minimize diagenetic contamination.

Field and Laboratory Methodology

Sampling Strategy for Strontium Isotope Analysis

For this project, modern faunal samples were first collected to determine the local strontium isotope signatures in the Ayacucho region. The first author collected six guinea pigs from the Ayacucho market in 2000. Informants stated that the six animals were raised on alfalfa grown outside the city of Ayacucho, so the guinea pig strontium isotope signatures should reflect the strontium isotope signatures in the agricultural fields near Ayacucho, which are the likely food sources for the past inhabitants of Conchopata. Archaeological faunal samples were not used in order to avoid diagenetic contamination.

In addition to the modern faunal samples, the second author collected eleven samples from archaeological human skeletons at Conchopata. Six of these individuals were buried in two tombs at Conchopata. Tooth enamel and bone samples were collected from five adults interred in an undisturbed tomb in Architectural Space 105 (EA 105), and an infant from a looted tomb in Architectural Space 06 (EA 06).

Tooth enamel and bone samples from the five trophy heads came from the circular ritual structure (EA 143). Because the trophy heads and teeth were fragmented, the enamel comes from unspecified first, second or third molars and one right maxillary canine and so covers the period of enamel formation from in utero to 15 years of age (*42*). This sample of five represents approximately 20% of the 24 adult Wari trophy heads that have been discovered in the Andes (*1*). Therefore, this sample size can be used to test the hypothesis that the adult Wari trophy heads found at Conchopata were obtained from individuals taken in warfare or raiding outside of the Ayacucho Basin.

Strontium Isotope Analysis of Archaeological Enamel and Bone

All tooth and bone samples were initially prepared in the Laboratory for Archaeological Chemistry by the first author. Modern faunal samples for strontium isotope analysis were placed in a crucible and ashed at approximately 800°C for 10 hours. The bone samples were then crushed in an agate mortar and pestle. The teeth were removed from modern fauna mandibles after ashing and crushed and stored separately from the bone.

Archaeological teeth samples were mechanically cleaned by abrasion with a Patterson NC-350 dental drill equipped with an inverted-cone carbide burr (White burrs HP-59 type 2 class 2). This removed any adhering organic matter or contaminants as well as the outermost layers of tooth enamel, which are most susceptible to diagenetic contamination (*44, 48*). Approximately 5–10 mg of tooth enamel were then removed with a Patterson NC-350 dental drill equipped with a carbide burr.

Archaeological bone samples were treated for diagenesis before sample analysis. The bone samples were first mechanically cleaned with the Patterson NC-350 dental drill equipped with a carbide burr to remove any organic matter or contaminants. The mechanical cleaning also removed the layers of cortical bone most susceptible to diagenetic contamination, as well as all traces of trabecular bone. The bone samples were then chemically cleaned in an ultrasonic bath. The samples were first sonicated in water for 30 minutes, then rinsed and sonicated in 5% acetic acid for 30 minutes, and finally rinsed and sonicated with 5% acetic acid for 5 minutes (*30, 53, 55, 59*).The bone samples were dried for 1 hour at approximately 80°C. Finally, the bone samples were placed in a crucible and ashed at approximately 800°C for 10 hours.

Strontium isotope ratios were obtained at the Isotope Geochemistry Laboratory in the Department of Geological Sciences at the University of North Carolina at Chapel Hill by the first author under the direction of Paul D. Fullagar. Three to six milligrams of mechanically- and chemically-cleaned bone ash or powdered tooth enamel were dissolved in 15 mL Savillex PFA vials using 500 μL of twice distilled 5N HNO_3 in a class 100 filtered air environmental hood. The samples were then evaporated and redissolved in 250 μL of 5N HNO_3. The strontium was separated from the sample matrix using EiChrom SrSpec resin, a crown-ether Sr-selective resin (50–100 μm diameter) loaded into the tip of a 10 mL BioRad polypropylene column. Total resin volume was approximately 50 μL. The SrSpec resin was pre-soaked and flushed with H_2O to remove Sr present from the resin manufacturing process. The resin was further cleaned in the column with repeated washes of deionized H_2O and conditioned with 5N HNO_3. Resin was used once for sample elution and discarded. The dissolved sample was loaded and washed in 750 μL of 5N HNO_3, and then Sr was eluted with 1 mL of H_2O. Total procedural blanks for Sr are typically 100-to-200 picograms. The sample was then evaporated, dissolved in 2 μL of 0.1 M H_3O_4 and 2 μL of $TaCl_5$ and loaded onto degassed Re filaments. Isotopic ratios were measured by a VG Sector 54 thermal ionization mass spectrometer at the University of North Carolina-Chapel Hill in quintuple-collector dynamic mode, using the internal ratio $^{86}Sr/^{88}Sr=0.1194$ to correct for mass fractionation. Recent $^{87}Sr/^{86}Sr$ analyses of Sr carbonate standard SRM 987 yield a value of 0.710245 ± 0.000018 (2σ). Long term analyses over approximately 24 months of SRM 987 yielded and average of $^{87}Sr/^{86}Sr=0.710242$. Internal precision for Sr carbonate runs is typically 0.0006 to 0.0009% standard error, based on 100 dynamic cycles of data collection.

Strontium Isotope Results

Expected Strontium Isotope Ratios in the Andes

The Central Andean highlands, where the Wari heartland was located, are predominately composed of late Cenozoic andesites and latites, including the Quaternary Molinoyoc volcanics in the Ayacucho region (*60–62*). Strontium isotope analysis of exposed bedrock in the Ayacucho region has not yet been performed, but geologic data do exist for late Cenozoic andesites in southern Peru. For example, geologic data show that $^{87}Sr/^{86}Sr$=0.7054–0.7067 (n=7) near Moquegua, Peru, and $^{87}Sr/^{86}Sr$=0.7067–0.7079 (n=16) near Arequipa, Peru (*63*). Generally speaking, strontium isotope ratios increase as one travels from north to south in the Cenozoic volcanic zones of the Andes (*60, 63–67*). Therefore, the expected strontium isotope ratios in the Ayacucho Basin andesites should be slightly lower than the observed strontium isotope ratios of southern Peruvian andesites.

In addition to the late Cenozoic andesites and latites in the Ayacucho Basin, there are outcrops of Paleozoic and Mesozoic rocks in the Ayacucho Valley, including the Ticllas red beds as well as other Cenozoic formations such as the Huanta formation, that are composed predominately of silic tuff (*61*). Therefore, the strontium isotope signatures of the late Cenozoic volcanics could be modified as the soils and groundwater in the Ayacucho Basin incorporates strontium from different geologic formations.

However, it also is important to note from where individuals from the Wari heartland would have obtained their food, and specifically their strontium. The agricultural zones that likely provided the food for the inhabitants of Conchopata and other Wari heartland sites are located in the Ayacucho Formation, which predominately consists of Cenozoic dactites and andesites and volcaniclastic lacustrine and fluvial strata (*61*). For example, fields are still in use in the river valleys immediately west and east of Conchopata, and it is likely that Wari agriculture was generally focused on the rivers in the Cachi hydrographic unit, the Huamanga Basin of the Ayacucho Valley (*68–70*).

Strontium Isotope Analysis of Modern Fauna from the Andes

The measured strontium isotope ratios of modern guinea pigs from Ayacucho support the expected strontium isotope ratios based on the geologic literature, as shown in Table I. Small modern fauna can be used as proxies for the biologically available strontium in a given region by providing an average for one small area (*71, 72*). Bone strontium isotope ratios from six modern guinea pigs from Ayacucho are ^{87}Sr/^{86}Sr=0.707204 (F1229), ^{87}Sr/^{86}Sr=0.706306 (F1230), ^{87}Sr/^{86}Sr=0.706555 (F1231), ^{87}Sr/^{86}Sr=0.711766 (F1232), ^{87}Sr/^{86}Sr=0.705762 (F1233), and ^{87}Sr/^{86}Sr=0.705841 (F1234). Five of these samples match the expected strontium isotope signatures of the region around Conchopata, given the geology of the bedrock underneath the agricultural fields. However, one sample (^{87}Sr/^{86}Sr=0.711766, F1232) has a much higher strontium isotope signature. It is possible that imported fertilizers were used on the alfalfa fields, or that the informant misreported the source of the guinea pig's diet.

Table I. Strontium Isotope Results from Conchopata

Laboratory Number	*Individual Number*	*Type*	*Sample*	$^{87}Sr/^{86}Sr$
F1218	2095.01	Burial	R fibula	0.706096
F1219	2095.01	Burial	LM2	0.705598
F1220	2095.02	Burial	R fibula	0.705739
F1221	2095.02	Burial	RM2	0.705632
F1222	2095.03	Burial	R fibula	0.705861
F1223	2095.03	Burial	M2	0.705657
F1224	2095.04	Burial	L fibula	0.705663
F1225	2095.04	Burial	LM2	0.705646
F1226	2095.06	Burial	U rib	0.705480
F1227	2095.06	Burial	RM2	0.705739
F1228	2004	Burial	U rib	0.706734
F1784	2907.04	Trophy head	molar enamel	0.708811
F1789	2907.04	Trophy head	cranial fragment	0.707186
F1785	2907.05	Trophy head	molar enamel	0.706270
F1790	2907.05	Trophy head	cranial fragment	0.706483
F1786	2985.10	Trophy head	RC enamel	0.706404
F1787	2985.11	Trophy head	molar enamel	0.710204
F1792	2985.11	Trophy head	cranial fragment	0.709232
F1788	2985.18	Trophy head	molar enamel	0.706259
F1793	2985.18	Trophy head	cranial fragment	0.707289
F1229	A1A	Modern *cuy*	mandible, femur	0.707204
F1230	A2A	Modern *cuy*	mandible, femur	0.706306
F1231	A3A	Modern *cuy*	mandible, femur	0.706555
F1232	A4A	Modern *cuy*	mandible, femur	0.711766
F1233	A5A	Modern *cuy*	mandible, femur	0.705672
F1234	A6A	Modern *cuy*	mandible, femur	0.705841

Determining Local versus Non-Local Strontium Isotope Signatures

Another challenge in strontium isotope analyses in archaeological residential mobility studies is the determination of the local strontium isotope ratio for a particular region. One commonly used method is to define the local strontium isotope signature as the mean of the modern faunal strontium isotope from a given region plus and minus two standard deviations (*73*). Using this definition, the local range for Conchopata is $^{87}Sr/^{86}Sr$=0.7027–0.7118 as defined as the mean of the modern guinea pig samples plus and minus two standard deviations (*71, 72*). Removing the anomalous guinea pig value provides a local range of $^{87}Sr/^{86}Sr$=0.7051–0.7075, which more closely matches the expected values based on Ayacucho geology. In addition, as will be discussed below, the archaeological human bone and enamel values from the burials at Conchopata cluster closely and appear to be local based on their tomb styles, and artifacts (*74, 75*).

Strontium Isotope Results from Human Burials at Conchopata

As shown in Table I, the strontium isotope ratios from the human burials at Conchopata are all very similar ($^{87}Sr/^{86}Sr$=0.7058±0.0003 (n=11, 1σ)). Specifically, enamel samples from five adults buried in the tombs at Conchopata have $^{87}Sr/^{86}Sr$=0.705480–0.705646, while bone samples from the same adults have $^{87}Sr/^{86}Sr$=0.705663–0.706096. The infant bone from EA 06 has $^{87}Sr/^{86}Sr$=0.706734.

The small standard deviation in the enamel and bone strontium isotope signatures from individuals buried in tombs at Conchopata implies that these individuals procured their food from geologic zones with the same strontium isotope signatures during the first and last years of their lives. Since these values correspond closely with the strontium isotope signatures of geological formations near Conchopata and there is scant evidence for large quantities of food being traded into Conchopata, the most parsimonious explanation is that these individuals spent the first and last years of their lives in the Ayacucho region.

Strontium Isotope Results from Conchopata Trophy Heads

While the strontium isotope signatures in archaeological human tooth enamel and bone from tombs at Conchopata are very similar, the five trophy heads have more heterogeneous strontium isotope signatures, as shown in Table I and Figure 1. Three trophy heads exhibit enamel and bone strontium isotope

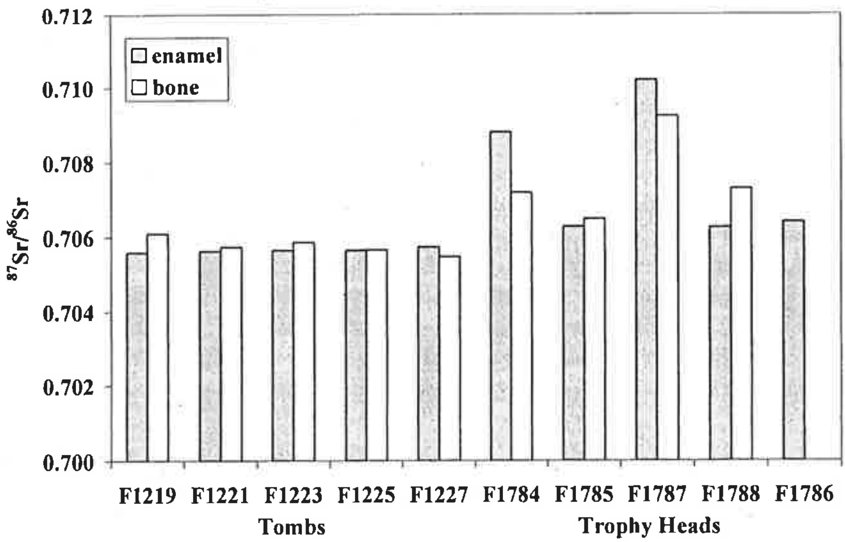

Figure 1. Strontium Isotope Results from Archaeological Human Remains from Conchopata.

signatures that are similar to the strontium isotope ratios of five of the modern guinea pigs and all of the individuals buried in Conchopata tombs.

In contrast, there are two individuals who have enamel strontium isotope ratios that are higher than the others (Individual 2907.4 (Sample F1784, $^{87}Sr/^{86}Sr$=0.708811) and Individual 2985.11 (Sample F1787, $^{87}Sr/^{86}Sr$=0.710204)). The two individuals with high enamel strontium isotope signatures also have high bone strontium isotope signatures (Individual 2907.4 (Sample F1789, $^{87}Sr/^{86}Sr$=0.707186) and Individual 2985.11 (Sample F1792, $^{87}Sr/^{86}Sr$=0.709232)). If these are biogenic strontium isotope signatures, this implies that these two individuals spent the first and last years of their lives consuming foods from different geologic regions than the other individuals analyzed here.

Finally, there is one trophy head that exhibits a low enamel strontium isotope signature (Individual 2985.18 (Sample F1788, $^{87}Sr/^{86}Sr$ =0.706259)) yet a high bone strontium isotope signature (Individual 2985.18 (Sample F1793, $^{87}Sr/^{86}Sr$ =0.707289)). This implies that this individual obtained food from different geologic zones during the first and last years of his life. Interestingly, after being transformed into a trophy head, this individual's head was found at his presumed place of childhood residence, although not his adult residence.

In conclusion, the enamel and bone strontium isotope signatures in the trophy heads exhibit more variability than the enamel and bone strontium isotope ratios in the individuals buried in the Conchopata tombs. A student's t-test demonstrates that the difference in enamel strontium isotope ratios in the two populations is statistically significant ($t = -2.38$, $p < 0.038$). In addition, the only individuals in this study who exhibited a change in strontium isotope signatures, and hence a likely change in residence, between childhood and adulthood are three trophy heads. Since three out of five trophy head samples have high strontium isotope signatures, they likely lived in a region other than near Conchopata for the last years of their lives. This supports the hypothesis that they were victims of warfare or raiding from a different population than the individuals buried in the tombs at Conchopata.

Strontium Isotope Analysis and Diagenesis: A Discussion

Diagenetic contamination of archaeological bone samples is always possible (*76, 77*). Since the trophy heads were fractured and, in some cases poorly preserved, it is possible that the samples were diagenetically contaminated with strontium from the burial environment, even though they had been mechanically and chemically cleaned. However, if the bone samples were contaminated by the burial environment, the diagenetic strontium isotope signature would be close to $^{87}Sr/^{86}Sr=0.706$. Certain trophy head bone samples still show strontium isotope signatures that are above this value. This implies that biogenic strontium isotope signatures were recovered from at least three bone samples at Conchopata. Therefore, it is likely that these individuals did in fact consume food from different geologic regions, and presumably lived in different geologic regions, during bone formation.

In addition to contact with the burial environment, the trophy head samples had been burned, presumably during ritual activities in the structures in which they were found (*1, 21, 22*). Although experimental data has shown that post-mortem burning can change the $\delta^{13}C$ values in bone collagen, this is not the case for strontium isotope ratios (*78*).

Directions for Future Research

The high strontium isotope ratios in the trophy head tooth enamel and bone samples do not match the local strontium isotope signature at Conchopata, and hence are at least partially biogenic strontium isotope signatures. However, independent lines of evidence will also be used in the future to identify contaminated bone samples. More specifically, monitoring the ratio of calcium to phosphorus (Ca/P) and the uranium concentrations in skeletal material can identify samples contaminated with diagenetic strontium (*30, 40, 59, 73*). Diagenetically contaminated skeletal elements have a much higher Ca/P ratio than the biogenic ratio of 2.1:1 if they have incorporated calcium, and likely strontium, from the burial environment. In addition, the uranium concentration in bone may also be used to identify contaminated samples because the mobile ionic form of uranium is incorporated into bone hydroxyapatite instead of remaining in secondary minerals in pore spaces of the calcium phosphate structure (*79*). Therefore, uranium is not removed through weak acid washes, and bone samples with high uranium concentrations may contain contaminated hydroxyapatite while bones with low uranium concentrations are resistant to diagenesis (*40, 73, 80*). These elemental concentration analyses will allow the further identification of diagenetically contaminated samples in this study. In addition to the use of independent lines of evidence to identify diagenetic contamination, the incorporation of more modern and archaeological faunal samples to characterize the strontium isotope signatures of the Ayacucho Basin will provide a more detailed isotopic map of the region.

Conclusion

Strontium isotope signatures in tooth enamel and bone from five adults and one infant buried in two tombs at Conchopata are very similar. This implies that these individuals consumed food from the same geologic zone, or from geologic zones with similar strontium isotope signatures. Since the strontium isotope ratios in these individuals matched the expected Ayacucho Basin strontium isotope signature, it is most likely that these individuals lived in or near Conchopata for the first and last years of life.

On the other hand, the five individuals who were transformed into trophy heads have more variable enamel and bone strontium isotope signatures. Three individuals with variable strontium isotope ratios consumed food from different geologic zones in the first and last years of their lives, and likely lived outside of the Ayacuho Basin. However, even the individuals with high bone strontium isotope signatures may have moved to or been brought to Conchopata shortly before death, since their bone may not have incorporated large amounts of local strontium isotopes. Given the high variability in the trophy head strontium isotope signatures, it is unlikely that these individuals represent venerated Wari ancestors who are local to the Ayacucho Basin. Instead, it is more likely that the Wari trophy heads were victims of warfare or raiding from a variety of different geologic zones.

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