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Residential Mobility and Resource Use in the Chiribaya Polity of Southern Peru: Strontium Isotope Analysis of Archaeological Tooth Enamel and Bone

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ABSTRACT The Chiribaya were a complex polity during the Andean Late Intermediate Period (c. AD 1000–1300) in the Ilo and Moquegua Valleys of southern Peru. Recent research has demonstrated that the Chiribaya polity was a *señorío*, a confederacy of economically specialised *parcialidades*. Here we test hypotheses regarding the movement of individuals and resources among the Chiribaya-affiliated sites of Chiribaya Alta, Chiribaya Baja, San Gerónimo and El Yaral, as well as from outside of the Ilo and Moquegua Valleys. Although archaeological human enamel and bone strontium isotope ratios from Chiribaya Baja and San Gerónimo cluster closely, there is a wider variety of strontium isotope ratios observed at Chiribaya Alta and El Yaral. This indicates that individuals buried in cemeteries at these sites had access to a wider variety of resources, and probably moved between different geological zones throughout their lifetimes. Copyright © 2007 John Wiley & Sons, Ltd.

Key words: Andes; bone chemistry; migration; palaeodiet

Introduction

Although recent research on the Chiribaya polity (c. AD 1000–1300) of southern Peru has demonstrated the complex economic relationships among various Chiribaya-affiliated communities, the movement of individuals and resources between them is not well understood. This research project complements earlier palaeodietary analyses of archaeological human bone from Chiribaya-affiliated sites by incorporating strontium isotope analyses of archaeological human tooth enamel and bone from a subset of the same individuals to elucidate residential mobility. In this paper we begin with a brief discussion of residential mobility studies using isotopic data, followed by a presentation of the Chiribaya-affiliated sites included in this project, our strontium isotope results, and our interpretations of these data.

Residential mobility through strontium isotope analysis

Archaeologists are increasingly turning to analyses of both heavy and light stable isotopes to identify archaeological residential mobility. Although strontium concentrations vary according to trophic level, strontium isotope ratios vary

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according to the age and composition of the bedrock in a given geological region (Faure & Powell, 1972; Faure, 1986). The strontium isotope ratios in an individual's bone and teeth directly reflect the isotope ratios found in the plants, animals and water that she or he consumed, which in turn reflect the isotope ratios found in the soil and bedrock of that geological region. Since tooth enamel, unlike bone, does not regenerate, differences in strontium isotope ratios in human tooth enamel and bone can be used to identify migration and the geological origins of immigrants (Ericson, 1985, 1989; Krueger, 1985; Sillen *et al.*, 1989; Sealy *et al.*, 1991; Price *et al.*, 1994). This has been successfully applied in a number of different geological regions and time periods (e.g. Knudson *et al.*, 2004; Price *et al.*, 2004; Montgomery *et al.*, 2005; Wright, 2005).

Strontium isotope analysis is well-suited to test hypotheses on Chiribaya residential mobility. We use these techniques to test the hypothesis that the inhabitants of Chiribaya-affiliated sites in the Ilo Valley are migrants from the mid-altitude Moquegua Valley and/or Lake Titicaca Basin. In addition, we use heavy and light stable isotope analyses to examine variability in migration patterns and/or access to resources at the Chiribaya-affiliated sites of Chiribaya Alta, Chiribaya Baja, San Gerónimo and El Yaral in the Ilo and Moquegua Valleys (Figure 1).

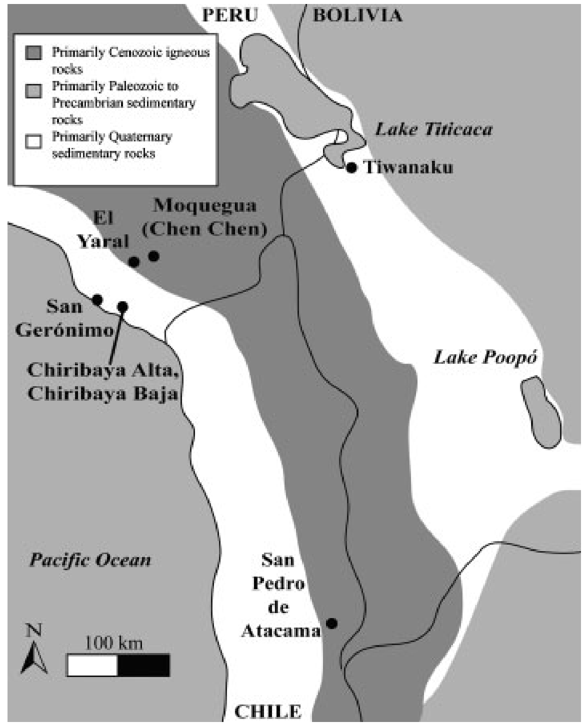

Figure 1. Geological sketch map of the South Central Andes with the Chiribaya-affiliated sites of El Yaral, San Gerónimo, Chiribaya Alta and Chiribaya Baja, as well as the Tiwanaku-affiliated sites of Tiwanaku, Chen Chen and San Pedro de Atacama mentioned in the text (Bellido *et al.*, 1956; Hawkesworth *et al.*, 1982; James, 1982; Rogers & Hawkesworth, 1989; Argollo *et al.*, 1996; Hartley & Chong, 2002).

The Chiribaya polity of the South Central Andes

During the Late Intermediate Period (c. 1000–1300), the Chiribaya were a powerful and populous polity in the Ilo and Moquegua Valleys of southern Peru, which are also referred to as the Osmore Drainage (Bawden, 1989; Jessup, 1990; Mujica Barreda, 1990; Williams & Buikstra, 1990; Williams *et al.*, 1990; Rice, 1993; Satterlee, 1993; Buikstra, 1995; Wallert & Boytner, 1996; Owen, 1998; Burgess, 1999; Cartmell *et al.*, 1999; Reycraft, 2000, 2005; Umire Alvarez & Miranda, 2001; Lozada Cerna & Buikstra, 2002, 2005; Martinson *et al.*, 2002; Reinhard & Buikstra, 2002; Zaro & Umire Alvarez, 2005). The Ilo Valley sites of Chiribaya Alta, Chiribaya Baja and San Gerónimo, as well as the Moquegua Valley site of El Yaral, all contain material culture in Chiribaya styles and extensive residential and mortuary sectors (Figure 1) (Jessup, 1990; Buikstra, 1995; Lozada Cerna & Buikstra, 2005). Previous cranial modification and palaeodiet studies of carbon and nitrogen isotopes in archaeological human bone from Chiribaya-affiliated sites have elucidated complex socioeconomic patterns which support the hypothesis that the Chiribaya polity was a *señorío*, a confederacy of economically specialised *parcialidades*, or factions (Lozada Cerna & Buikstra, 2002, 2005; Tomczak, 2003; Buikstra *et al.*, 2005). Scholars have also focused on its origins on the coast or in the highlands (Sutter, 1997, 2000; Boytner, 1998; Lozada Cerna, 1998; Tomczak, 2001; Lozada Cerna & Buikstra, 2002; Buikstra *et al.*, 2005).

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The Ilo Valley site of Chiribaya Alta

The largest and most complex of the Chiribaya sites, Chiribaya Alta is widely considered to be the regional centre of the Chiribaya polity (Rice, 1993). Located 7 km from the Pacific Ocean on the Pampa del Descanso, Chiribaya Alta overlooks the Ilo Valley and consists of nine discrete cemeteries, numerous domestic units, plazas and terraces, and a defensive wall (Buikstra, 1995). Because of its large mortuary component, Chiribaya Alta may have been a centre of political power and ceremonial activity to which local lords and priests were taken for burial, much like the Peruvian ceremonial centres of Pachacamac and Pacatnamu (Lozada Cerna, 1998; Lozada Cerna & Buikstra, 2002).

The Ilo Valley site of Chiribaya Baja

Chiribaya Baja is located approximately 8 km from the Pacific Ocean. Systematic excavations uncovered formally bounded cemeteries adjacent to residential terraces and agricultural systems. Chiribaya Baja tombs generally contained a limited number of grave goods including utilitarian ceramics, wooden spoons, and gourds. Because of the location of the site as well as grave goods, it is likely that Chiribaya Baja was predominately an agricultural site (Tomczak, 2001).

The Ilo Valley site of San Gerónimo

San Gerónimo is the largest Chiribaya site on the coast, and is located 200 m from the Pacific Ocean. Salvage excavations revealed domestic and mortuary components that spanned the Formative through the Colonial periods, including 92 rectangular, stone-lined Chiribaya graves (Jessup, 1990). Individuals were buried in flexed positions and the burial offerings reflect gender-based occupational specialisations (Buikstra, 1990, 1995; Jessup, 1990). For example, females were often accompanied by looms and a large number of ceramic vessels, while males were buried with harpoons, fishhooks, weights and string (Buikstra, 1990, 1995; Jessup, 1990). Some males were buried with non-utilitarian axes in addition to fishing gear, and both females and males were buried with miniature wood boats (Buikstra, 1995). Based on burial offerings as well as carbon and nitrogen isotope data, various researchers have argued that the inhabitants of San Gerónimo were *pescadores*, or fisherfolk, who subsisted primarily through fishing (Sandness, 1992; Buikstra, 1995; Lozada Cerna, 1998; Tomczak, 2001).

The Moquegua Valley site of El Yaral

Unlike the coastal Chiribaya sites, the site of El Yaral is located in the Moquegua Valley approximately 50 km from the Pacific Ocean at an altitude of 1000 m.a.s.l., where it is surrounded by Tiwanaku-affiliated sites like Chen Chen. In fact, El Yaral, along with La Victoria and Porobaya Baja, is one of the few Chiribaya-affiliated sites in the mid-valley zone. El Yaral consists of more than 330 residential terraces which contained evidence of wood and cane structures that were used for a variety of activities, including the ritual sacrifice of 26 llamas and alpacas, *cuyes* (guinea pigs), fish, maize and other objects, and a large mortuary component (Lozada Cerna & Torres Pino, 1991; Rice, 1993; Wheeler *et al.*, 1995; Rofes, 2000).

Mortuary excavations uncovered the remains of 99 individuals buried in circular or oval cist tombs in a flexed position facing east (Buikstra, 1995). Interestingly, this is in contrast to the Ilo Valley Chiribaya sites, where tombs are typically rectangular, although individuals are usually also buried in a flexed position facing east or south (Buikstra, 1995). The number and types of grave goods at El Yaral are limited, although gender-based occupational specialisation is apparent in the mortuary assembly (Buikstra, 1995). The mortuary data do show a close relationship between El Yaral inhabitants and *serranos*, or highland dwellers; for example, collar tombs are found only at El Yaral and are more similar to tombs at the Tiwanaku-affiliated site of Chen Chen than the rectangular tombs found at other Chiribaya sites (Buikstra, 1995; Lozada Cerna, 1998). Ceramic evidence from both residential and mortuary components of El Yaral shows the

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presence of both Chiribaya and Ilo-Tumilaca/Cabuza traditions, and Rice (1993) argued that El Yaral was in fact a multiethnic settlement.

Laboratory methodology for isotope analyses

Sampling strategy for Chiribaya-affiliated sites

At each study site, samples for strontium isotope analysis were chosen from the individuals who had been included in previous biodistance and cranial modification studies (Table 1) (Lozada Cerna, 1998; Burgess, 1999; Tomczak, 2001, 2003; Lozada Cerna & Buikstra, 2002). Samples for palaeodiet and residential mobility studies were chosen to reflect the age and sex composition of the adult mortuary population at each cemetery; whenever possible, the same individuals were included in all chemical analyses, including nitrogen and carbon isotope analyses of archaeological human bone collagen, oxygen and carbon isotope analyses of archaeological human bone and enamel carbonate, and strontium isotope analysis of archaeological human enamel and bone (Tomczak, 2001; Knudson, 2004).

Laboratory methodology for strontium isotope analyses

Samples for heavy stable isotope and elemental concentration analyses were initially prepared in the Laboratory for Archaeological Chemistry at the University of Wisconsin at Madison. Tooth and bone samples were mechanically cleaned by abrasion. Approximately 5–10 mg of tooth enamel or 1–2 g of bone were removed with a Patterson NC-350 dental drill equipped with a carbide burr or a diamond saw. Archaeological bone samples were chemically cleaned with 5% acetic acid in an ultrasonic bath in order to remove diagenetic contaminants and then ashed (Sillen, 1989; Price *et al.*, 1992, 1994; Nielsen-Marsh and Hedges, 2000b).

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. Sample preparation has been discussed elsewhere and was based on established methodologies using EiChrom SrSpec resin to separate the strontium from the sample matrix (Horwitz *et al.*, 1992; Knudson, 2004; Knudson *et al.*, 2004, 2005; Charlier *et al.*, 2006). Isotopic ratios were measured on a VG Sector 54 thermal ionisation mass spectrometer in quintuple-collector dynamic mode, using the internal ratio $^{86}Sr/^{88}Sr = 0.1194$ to correct for mass fractionation. Recent analyses of Sr carbonate standard SRM 987 yield a value of $^{87}Sr/^{86}Sr = 0.710245 \pm 0.000018$ (2σ). Long-term analyses over approximately 24 months of SRM 987 yielded an average $^{87}Sr/^{86}Sr = 0.710242$. Internal precision for Sr carbonate runs is typically 0.0006–0.0009% standard error, based on 100 dynamic cycles of data collection.

A smaller number of bone samples from Chiribaya Alta and El Yaral were analysed at Geochron Laboratories at the Massachusetts Institute of Technology, on a VG Sector 54 thermal ionisation mass spectrometer in dynamic multi-collector mode, using the internal ratio $^{86}Sr/^{88}Sr = 0.1194$ to correct for mass fractionation. Long-term reproducibility of Sr carbonate standard SRM 987 is $^{87}Sr/^{86}Sr = 0.710247 \pm 0.000014$ (2σ), and internal precision for Sr carbonate is greater than $^{87}Sr/^{86}Sr = 0.000018$ (2σ).

Table 1. Archaeological human samples from Chiribaya-affiliated sites

	Chiribaya Alta	Chiribaya Baja	San Gerónimo	El Yaral
Site MNI for Chiribaya-affiliated mortuary population	372	78	99	74
Individuals in biodistance and cranial modification studies	147	22	39	47
Bone $^{87}Sr/^{86}Sr$ samples	12	2	0	9
Enamel $^{87}Sr/^{86}Sr$ samples	12	2	4	4

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Laboratory methodology for trace element concentration analyses

Trace element concentration analysis was performed at the Laboratory for Archaeological Chemistry in order to attempt to identify diagenetically contaminated samples using uranium concentrations and Ca/P values. For uranium concentration analysis using a Finnegan Element inductively coupled plasma–mass spectrometer (ICP–MS), approximately 4 mg of tooth enamel or powdered bone ash was dissolved in 0.5 ml ultrapure concentrated HNO_3, heated to 100°C for one hour, and diluted with 19.5 mL deionised water. Total procedural blanks for uranium were below the levels of ICP–MS detection, and analyses of strontium carbonate standard NIST 1400 yielded $U = 0.006 \pm 0.0004$ ppb (1σ, $n = 11$).

Archaeological human bone Ca/P values were obtained using an Applied Research Labs Model 3520 inductively coupled plasma–atomic emission spectrometer (ICP–AES). Approximately 50 mg of powdered bone ash was dissolved in 1.0 ml ultrapure concentrated HNO_3, heated to 100°C for one hour, and then diluted with 17 ml deionised water. Analyses of Laboratory for Archaeological Chemistry standard reference 9511 yielded $Ca = 3.12 \times 10^4 \pm 1.42 \times 10^3$ ppm (2σ, $n = 7$) and $P = 5.39 \times 10^3 \pm 2.24 \times 10^2$ ppm (2σ, $n = 7$). Long-term analyses of laboratory standards and international bone standard reference material have demonstrated accuracy of ±5% and precision of ±2% (Burton *et al.*, 2003).

Strontium isotope signatures in the Moquegua and Ilo valleys

The geological variability in the Andes means that individuals whose calcium, and hence strontium, comes from different geological zones can be identified through strontium isotope analysis (Bellido *et al.*, 1956; Hawkesworth *et al.*, 1982; James, 1982; Rogers & Hawkesworth, 1989; Argollo *et al.*, 1996; Grove *et al.*, 2003). As shown in Figure 1, the Andes themselves are predominately composed of late Cenozoic volcanic rocks, particularly andesites; this geological zone includes the Moquegua Valley, where El Yaral and Chen Chen are located, as well as part of the Ilo Valley, where Chiribaya Alta, Chiribaya Baja and San Gerónimo are located. Analyses of exposed bedrock from this geological zone show that $^{87}Sr/^{86}Sr = 0.7055–0.7068$ in southern Peru and $^{87}Sr/^{86}Sr = 0.7062–0.7068$ in northern Chile, near the San Pedro de Atacama oasis (Hawkesworth *et al.*, 1982; James, 1982; Rogers & Hawkesworth, 1989).

In contrast, the strontium isotope signatures of the Cenozoic volcanic rocks are lower than those found in the Lake Titicaca Basin where Tiwanaku is located. There, 10–20 m of Quaternary fluvial and lacustrine sediments overlie igneous basalts and andesites (Argollo *et al.*, 1996). While strontium isotope analysis of exposed bedrock in the southeastern Lake Titicaca Basin has not been performed, Lake Titicaca surface water has $^{87}Sr/^{86}Sr = 0.7082–0.7085$ and four Lake Titicaca sediment cores had $^{87}Sr/^{86}Sr = 0.7083–0.7087$ ($n = 20$) (Grove *et al.*, 2003). Higher strontium isotope signatures are found in the northern Lake Titicaca Basin; for example, $^{87}Sr/^{86}Sr = 0.7103–0.7135$ in rivers that drain into Lake Titicaca in the northern Basin (Grove *et al.*, 2003).

These data are supported by strontium isotope ratios in modern and archaeological fauna from the same regions (Table 2). Small mammals, predominately *cuyes* (guinea pigs), were collected from various regions in the South Central Andes; while far-ranging camelids were also analysed, they were not included in our definition of the local range. By defining the local range as the mean of modern and archaeological small mammals plus and minus two standard deviations, the local ranges are as follows: $^{87}Sr/^{86}Sr = 0.7059–0.7066$ for the Moquegua Valley, $^{87}Sr/^{86}Sr = 0.7058–0.7082$ for the Ilo Valley, $^{87}Sr/^{86}Sr = 0.7074–0.7079$ for the San Pedro de Atacama region and $^{87}Sr/^{86}Sr = 0.7087–0.7105$ for the southeastern Lake Titicaca Basin.

Therefore, there are broad trends in the Andes that allow us to distinguish movement from the *altiplano* to the Moquegua and Ilo Valleys. However, the Ilo Valley range as determined by modern fauna encompasses the Moquegua Valley range, complicating the detection of movement between the two valleys using

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Table 2. Strontium isotope data for archaeological and modern fauna samples

Region (site)	Lab no.	Specimen no.	Material	Corrected $^{87}Sr/^{86}Sr$
Ilo Valley (Chiribaya Alta)	F1631	CHA-1144	Camelid bone (archaeological)	0.708826
Ilo Valley (Chiribaya Alta)	F1633	CHA-1432	Camelid bone (archaeological)	0.706860
Ilo Valley (Chiribaya Alta)	F1634	CHA-1664	Camelid bone (archaeological)	0.707658
Ilo Valley (Chiribaya Alta)	F1632	CHA-1808	Camelid bone (archaeological)	0.707531
Ilo Valley (Chiribaya Baja)	F0757	CHB-11804	*Cuy* bone (archeological)	0.707891
Ilo Valley (Chiribaya Baja)	F0758	CHB-13176	*Cuy* bone (archeological)	0.706719
Ilo Valley (Ilo)	F1239	I3B	*Cuy* bone (modern)	0.706682
Ilo Valley (Ilo)	F1248	I11A	*Cuy* bone (modern)	0.706709
Moquegua Valley (Moquegua)	F1027	M5A	*Cuy* bone (modern)	0.706184
Moquegua Valley (Moquegua)	F1028	M9A	*Cuy* bone (modern)	0.706452
Moquegua Valley (Moquegua)	F1029	M14A	*Cuy* bone (modern)	0.706121
San Pedro de Atacama (Quitor-6)	F1635	QT6-18	Mouse bone (archaeological)	0.707659
San Pedro de Atacama (Quitor-6)	F1636	QT6-33	Dog bone (archaeological)	0.707762
San Pedro de Atacama (San Pedro)	F1714	SPA1	*Cuy* bone (modern)	0.707511
Titicaca Basin (Achuta)	F1912	T5A	*Cuy* bone (modern)	0.709877
Titicaca Basin (Achuta)	F1717	T6A	*Cuy* bone (modern)	0.709304
Titicaca Basin (Chiripa)	F1024	Ch1A	*Cuy* bone (modern)	0.709291
Titicaca Basin (Lukurmata)	F1025	L2A	*Cuy* bone (modern)	0.710561
Titicaca Basin (Tiwanaku)	F1026	T1A	*Cuy* bone (modern)	0.709368
Titicaca Basin (Tiwanaku)	F1718	T7	*Cuy* bone (modern)	0.709545
Titicaca Basin (Yanarico)	F1715	T3A	*Cuy* bone (modern)	0.709562

strontium isotope analysis. However, we hypothesised that the large quantities of marine products consumed by inhabitants of Chiribaya-affiliated sites on the coast would raise their strontium isotope signatures. Tomczak's (2001, 2003) nitrogen isotope analysis clearly demonstrated marine food consumption at Chiribaya-affiliated sites. Since $^{87}Sr/^{86}Sr = 0.7092$ in seawater, individuals who consume large amounts of marine products should have strontium isotope signatures in their tooth enamel and bone that are close to $^{87}Sr/^{86}Sr = 0.7092$, which should allow us to distinguish the Moquegua and Ilo Valleys (Veizer, 1989).

Strontium isotope data from Chiribaya-affiliated sites

The Ilo Valley site of Chiribaya Alta

As discussed above, the local strontium isotope ratio for the Ilo Valley as determined by modern and archaeological *cuyes* is $^{87}Sr/^{86}Sr = 0.7058$–0.7082. However, even with a large range of signatures defined as local, there are still non-local strontium isotope ratios at Ilo Valley sites. At Chiribaya Alta, there are four individuals with a non-local strontium isotope signature in their first molar tooth enamel (CHA-3907, $^{87}Sr/^{86}Sr = 0.708617$; CHA-3763, $^{87}Sr/^{86}Sr = 0.708861$; CHA-1144, $^{87}Sr/^{86}Sr = 0.708847$; CHA-1475, $^{87}Sr/^{86}Sr = 0.717065$) (Figure 2, Table 3).

The individual with the highest, and most clearly non-local, enamel strontium isotope ratio is CHA-1475 ($^{87}Sr/^{86}Sr = 0.717065$). This value is clearly outside of the local Ilo Valley signature, and implies that she did not live in the Ilo Valley during the first 3–4 years of her life. This adult female is one of the two individuals buried at Chiribaya Alta with non-local enamel and bone signatures (Figure 3). The strontium isotope signature in one rib (CHA-1475, $^{87}Sr/^{86}Sr = 0.710031$) is outside of the local Ilo Valley signature and thus retains at least some biogenic strontium (Figure 3). There is one other person (CHA-3763) buried at Chiribaya Alta with non-local strontium isotope ratios in both tooth enamel and bone. The enamel strontium isotope ratio from CHA-3763 is $^{87}Sr/^{86}Sr = 0.708861$ and the femoral signature is $^{87}Sr/^{86}Sr = 0.708675$. This individual was buried in the oldest cemetery 3 at Chiribaya Alta, which dates to approximately AD 750–850 (Lozada Cerna & Buikstra, 2002; see also Owen, 2005). The other two non-locals buried at Chiribaya Alta have non-local enamel strontium isotope ratios but local bone strontium

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Table 3. Strontium isotope data for human samples

Site (sector)	Lab no.[a]	Specimen no.	Burial no.	Age[b]	Sex[b]	Material	Corrected $^{87}Sr/^{86}Sr$
Chiribaya Alta (3)	F0683	CHA-1173	317	55–60	M	UM1	0.707335
Chiribaya Alta (4)	F0700	CHA-3907	427	30–40	M	LM1	0.708617
Chiribaya Alta (7)	F0723	CHA-2375	726	35–45	F	LM1	0.707162
Chiribaya Alta (3)	F0679	CHA-3763	325	32–35	F	UM1	0.708861
Chiribaya Alta (3)	F0687	CHA-1144	310	40–45	M	UM1	0.708847
Chiribaya Alta (4)	F0702	CHA-3704	419	45+	M	LM1	0.707693
Chiribaya Alta (7)	F0714	CHA-1475	703	30–40	F	LM1	0.717065
Chiribaya Alta (3)	F0691	CHA-3494	321	30–40	F	UM1	0.708053
Chiribaya Alta (4)	F0694	CHA-1219	402	25–35	F	UM1	0.707707
Chiribaya Alta (4)	F0705	CHA-3610	419	25–32	F	UM1	0.707830
Chiribaya Alta (7)	F0711	CHA-2574	726	25–35	M	LM1	0.707874
Chiribaya Alta (7)	F0719	CHA-3218	754	45–50	M	LM1	0.707448
Chiribaya Alta (3)	F0685	CHA-1173	317	55–60	M	Femur	0.707475
Chiribaya Alta (4)	F0697	CHA-3907	427	30–40	M	Rib	0.707424
Chiribaya Alta (7)	F0724	CHA-2375	726	35–45	F	Femur	0.707347
Chiribaya Alta (3)	F0681	CHA-3763	325	32–35	F	Femur	0.708675
Chiribaya Alta (3)	F0688	CHA-1144	310	40–45	M	Femur	0.707430
Chiribaya Alta (4)	F0704	CHA-3704	419	45+/−	M	Femur	0.707469
Chiribaya Alta (7)	F0716	CHA-1475	703	30–40	F	Rib	0.710031
Chiribaya Alta (3)	SS-3083	CHA-1000	301	25–35	F	Bone	0.707634
Chiribaya Alta (3)	SS-3084	CHA-3854	331	45+/−	M	Bone	0.707666
Chiribaya Alta (6)	SS-3085	CHA-2291	610	45+/−	F	Bone	0.707787
Chiribaya Alta (9)	SS-3086	CHA-2059	901	55–60	F	Bone	0.708127
Chiribaya Alta (7)	SS-3087	CHA-2728	728	25–28	M	Bone	0.707490
Chiribaya Baja (1)	F0753	CHB-10035	103	MA	PF	UI1	0.706560
Chiribaya Baja (1)	F0755	CHB-10488	176	MA	PM	UI1	0.707513
Chiribaya Baja (1)	F0751	CHB-10035	103	MA	PF	Femur	0.707096
Chiribaya Baja (1)	F0754	CHB-10488	176	MA	PM	Rib	0.708027
San Gerónimo	F0726	SG-5785	126	25–38	F	UM1	0.707338
San Gerónimo	F0730	SG-3796	66	30–40	M	LM1	0.707038
San Gerónimo	F0734	SG-3804	63	35–45	M	LM1	0.707320
San Gerónimo	F0740	SG-1458	48	35–45	F	UM1	0.707433
Yaral (1)	F0677	M8-10166	131	30–45	F	UM1	0.707202
Yaral (1)	F0665	M8-10187	135	32–35	F	UM1	0.706886
Yaral (1)	F0669	M8-10212	140	50+/−	M	UM1	0.707472
Yaral (1)	F0671	M8-10427	229	32–40	M	UM1	0.717364
Yaral (1)	F0674	M8-10166	131	30–45	F	Femur	0.707291
Yaral (1)	F0662	M8-10187	135	32–35	F	Rib	0.706985
Yaral (1)	F0666	M8-10212	140	50+/−	M	Rib	0.707428
Yaral (1)	F0670	M8-10427	229	32–40	M	Rib	0.706858
Yaral (2)	SS-3091	M8-10427	229	32–40	M	Bone	0.706916
Yaral (1)	SS-3088	M8-10024	101F	18–21	F	Bone	0.707549
Yaral (1)	SS-3089	M8-10200	137	20–22	F	Bone	0.707119
Yaral (2)	SS-3090	M8-10593	246	30–35	M	Bone	0.707325
Yaral (2)	SS-3092	M8-10360	216	6.5	U	Bone	0.706841

[a] Laboratory numbers that begin with F were analysed at the University of North Carolina at Chapel Hill, while laboratory numbers that begin with SS designate samples analysed at Geochron Laboratories.
[b] The age and sex of the individuals included in this study were determined by María Cecilia Lozada Cerna and Paula Tomczak (Lozada Cerna, 1998; Tomczak, 2001).

isotope ratios (Figure 3). One individual, CHA-3907, has an enamel signature of $^{87}Sr/^{86}Sr = 0.708617$ and a rib signature of $^{87}Sr/^{86}Sr = 0.707424$. The other, CHA-1144, has an enamel signature of $^{87}Sr/^{86}Sr = 0.708847$ and a femoral signature of $^{87}Sr/^{86}Sr = 0.707430$.

The Ilo Valley site of Chiribaya Baja

Both individuals sampled from Chiribaya Baja exhibit local strontium isotope signatures in their upper incisor enamel (CHB-10035, $^{87}Sr/^{86}Sr = 0.70656$; CHB-10488, $^{87}Sr/^{86}Sr = 0.707513$),

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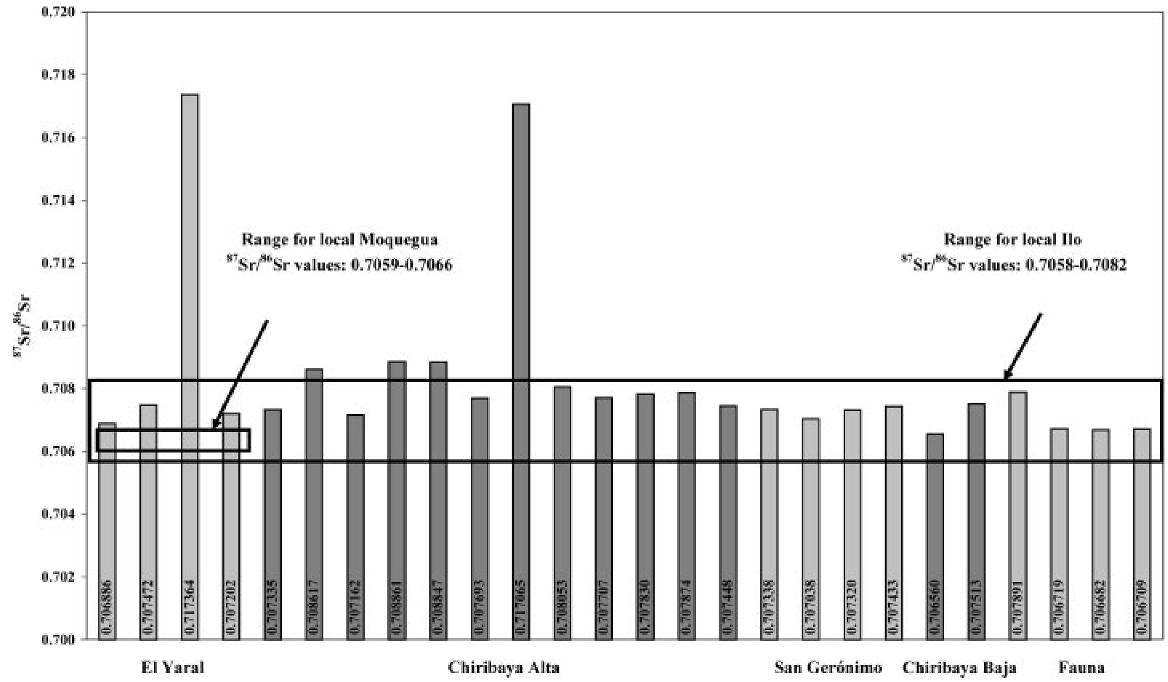

Figure 2. Strontium isotope ratios from human tooth enamel from the Moquegua Valley cemeteries of El Yaral, the Ilo Valley cemeteries of Chiribaya Alta, San Gerónimo and Chiribaya Baja, as well as archaeological *cuy* bone from the site of Chiribaya Baja and modern *cuy* bone from Ilo, Peru.

which implies that they lived in the Ilo Valley for the first 4–5 years of their lives (Figure 3, Table 3). In addition, femoral bone (CHB-10035, $^{87}Sr/^{86}Sr = 0.707096$) and rib bone values (CHB-10488, $^{87}Sr/^{86}Sr = 0.708027$) are also within the local range for the Ilo Valley ($^{87}Sr/^{86}Sr = 0.7058$–0.7082). Both individuals have very similar enamel and bone strontium isotope signatures, which imply that they obtained the strontium in their diets from the same geological zone for the first and last years of their lives. Alternatively, if the bone samples contained a mixture of diagenetic and biogenic strontium, they obtained the strontium in their diets from a geological zone or zones with higher or lower strontium isotope signatures than the Ilo Valley.

The Ilo Valley site of San Gerónimo

Of the four individuals who were analysed from San Gerónimo, none were identified as non-local to the Ilo Valley based on their first molar tooth enamel (Figure 2, Table 3). In fact, the mean of these four enamel samples is $^{87}Sr/^{86}Sr = 0.707282 \pm 0.000170$ (1σ, $n = 4$). These values cluster closely, and imply that these individuals also obtained strontium from the same Ilo Valley geological zone or zones during the first years of their lives.

The Moquegua Valley site of El Yaral

The tooth enamel values of four individuals from El Yaral were compared with the local range for the Moquegua Valley ($^{87}Sr/^{86}Sr = 0.7059$–0.7066). Three of the El Yaral individuals sampled have very similar strontium isotope values (M8-10187, $^{87}Sr/^{86}Sr = 0.706886$; M8-10212, $^{87}Sr/^{86}Sr = 0.707472$; M8-10166; $^{87}Sr/^{86}Sr = 0.707202$). In fact, the mean of these three enamel samples is $^{87}Sr/^{86}Sr = 0.707216 \pm 0.000100$ (1σ, $n = 3$). There is only one individual buried at El Yaral who has a clearly anomalous or non-local enamel signature (M8-10427, $^{87}Sr/^{86}Sr = 0.717364$) (Figure 2). Although this non-local adult male (M8-10427) clearly did not live near El Yaral for the first 3–4 years of his life, the bone strontium

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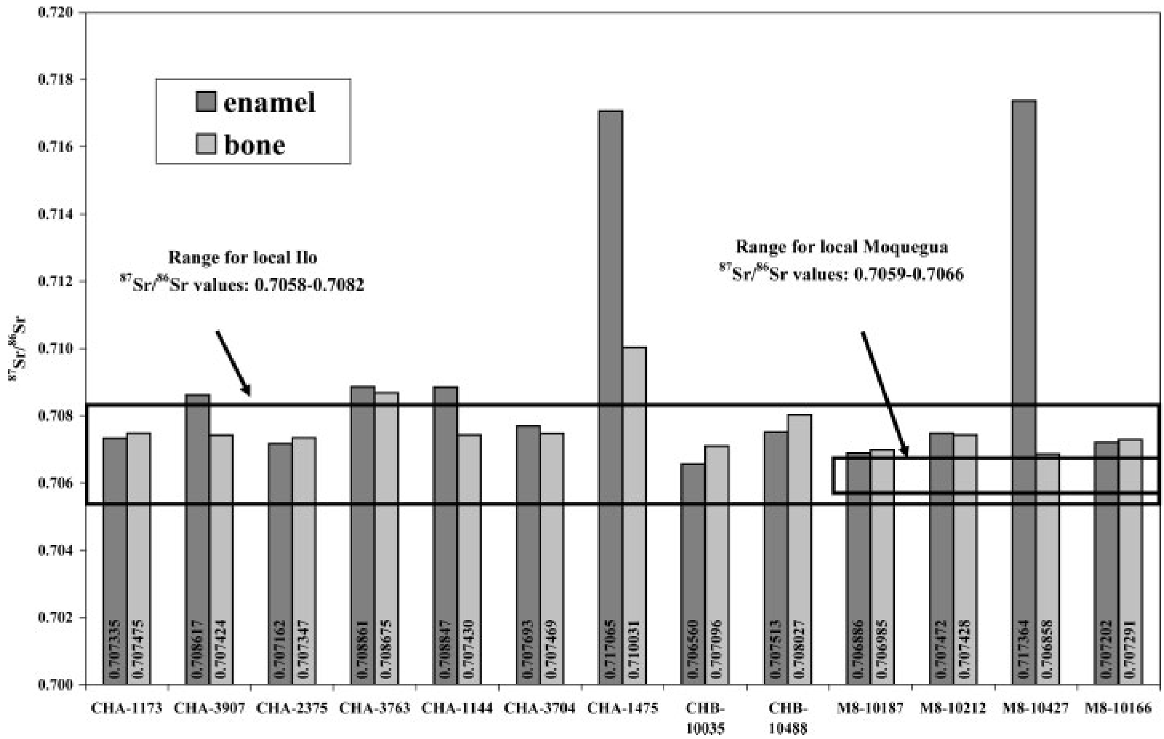

Figure 3. Strontium isotope ratios from human tooth enamel and bone pairs from the Ilo Valley cemeteries of Chiribaya Alta (CHA) and Chiribaya Baja (CHB), and the Moquegua Valley cemetery of El Yaral (M8).

isotope value reflects a local value (M8-10427, $^{87}Sr/^{86}Sr = 0.706858$) (Figure 3). The mean of the bone samples is 0.707146 ± 0.000262 (1σ, $n = 9$). Therefore, there are no individuals sampled from El Yaral that had clearly anomalous bone strontium isotope signatures. If these data represent biogenic bone strontium, these individuals did not live in another geological zone during the last years of their lives.

Interpretations of strontium isotope data from Chiribaya-affiliated sites

Diagenetic contamination at Chiribaya-affiliated sites

Chiribaya-affiliated sites, particularly in the Ilo Valley, are exceptionally well-preserved, and many individuals are naturally mummified. However, while numerous studies have shown that tooth enamel is remarkably resistant to diagenetic contmination, bone is more likely to be contaminated (Nelson *et al*., 1986; Sillen, 1989; Sillen *et al*., 1989; Tuross *et al*., 1989a,b; Ezzo, 1992; Price *et al*., 1992; Edward & Benfer, 1993; Sillen & Sealy, 1995; Budd *et al*., 1998, 2000; Montgomery *et al*., 1999; Burton & Price, 2000; Nielsen-Marsh and Hedges, 2000; Knipper, 2002; Chiaradia *et al*., 2003; Hoppe *et al*., 2003; Lee-Thorp & Sponheimer, 2003) and researchers are still searching for a way to remove diagenetic strontium from bone, particularly once it has recrystallised (Radosevich, 1989; Sealy *et al*., 1991; Sillen & LeGros, 1991; Price *et al*., 1992, 1994; Horn *et al*., 1994; Nielsen-Marsh and Hedges, 2000; Hedges, 2002; Trickett *et al*., 2003). As discussed above, we attempted to identify diagenetically contaminated samples by monitoring the uranium concentrations and Ca/P ratios in the samples included in this study (Price *et al*., 1994).

Previous trace element analysis of bone from 53 individuals buried at Chiribaya Alta shows that mean $Ca/P = 2.14 \pm 0.03$ (1σ, $n = 53$), which is within the range for uncontaminated bone (Tomczak, 1995). Bone samples included in this study exhibited mean $Ca/P = 2.23 \pm 0.04$ (1σ, $n = 13$). However, one bone sample from El Yaral, which is less arid than the Ilo Valley sites, exhibited a Ca/P value much higher than Ca/P found in uncontaminated bone (M8-10212, Ca/P = 2.42); therefore it is likely that this bone sample contains at least some diagenetic strontium, and that the biogenic strontium isotope signature in this individual's bone was higher or lower than the measured value (M8-10212, $^{87}Sr/^{86}Sr = 0.707428$). In addition, the uranium concentrations in archaeological tooth enamel from the Moquegua Valley and the Lake Titicaca Basin were below the detection limits of the ICP–MS, which implies that tooth enamel was not diagenetically contaminated. Because of the limitations of available sample sizes, bone samples were not analysed using ICP–MS.

Therefore, monitoring uranium concentrations and Ca/P cannot conclusively distinguish between diagenetic and biogenic strontium isotope ratios, although they can identify samples with anomalies that may indicate the presence of diagenetic strontium. However, the presence of at least some bone samples from Chiribaya-affiliated sites that exhibit strontium isotope ratios that are higher than the local Ilo Valley strontium isotope signatures, as determined by modern fauna, indicates that at least some biogenic strontium isotope signatures were retained (Figure 3) (Bentley, 2006). This will be discussed in more detail below.

Food sources and strontium isotopes in the Ilo and Moquegua Valleys

In addition, it is possible that the consumption of food sources imported from distant geological zones contributed to the strontium isotope patterns seen in this study. Therefore, a detailed examination of Chiribaya palaeodiet and its relationship to the strontium isotope results is necessary. Light stable isotope analysis has shown that palaeodiet at each site reflects local ecology, although each site also had access to goods from other parts of the Chiribaya polity (Tomczak, 2001, 2003). Although there is evidence for food moving between different Chiribaya sites, there is no evidence that substantial amounts of food from outside the Moquegua and Ilo valleys are present at Chiribaya sites.

The site of Chiribaya Alta exhibits the greatest variability in palaeodiet, as well as mortuary practices and cranial modification (Buikstra, 1995; Tomczak, 1995, 2001, 2003; Sutter, 2001; Lozada Cerna & Buikstra, 2002). Tomczak (2001) noted that the light stable isotope values at Chiribaya Alta span the range of values from other Chiribaya sites, and preclude any classification of economic specialisation. However, some of this variability corresponds to intra-site variation within Chiribaya Alta. For example, cemeteries 4, 5, 7 and 8 have light isotopic values that are most similar to those at San Gerónimo, suggesting that individuals in these cemeteries consumed large amounts of marine foods (Tomczak, 2001). Ceramic analysis, cranial modification types and tomb form in cemeteries 4, 7 and 8 are also most similar to those found at San Gerónimo (Lozada Cerna, 1998). Two of the non-locals identified at Chiribaya Alta were buried in cemeteries 4 and 7 (CHA-3907, $^{87}Sr/^{86}Sr = 0.708617$, CHA-1475, $^{87}Sr/^{86}Sr = 0.717065$). Nitrogen isotope values of bone from these individuals are $\delta^{15}N = 20.44‰$ (CHA-3907) and $\delta^{15}N = 16.90‰$ (CHA-1475), which are both indicative of consumption of marine protein (Tomczak, 2001). It is possible that the enamel strontium isotope ratios of CHA-3907 (CHA-3907, $^{87}Sr/^{86}Sr = 0.708617$, $\delta^{15}N = 20.44‰$) are higher than the Ilo Valley local range because of consumption of marine foods. Consumption of marine foods would make an individual's strontium isotope signature more similar to that of seawater, which is $^{87}Sr/^{86}Sr = 0.7092$ (Veizer, 1989), if that individual was receiving large amounts of strontium, possibly through consuming fish bones from whole small fish or fish meal. In addition, a marine strontium isotope signature could result from consuming terrestrial plants from areas that receive seaspray or seaweed fertilisers (Whipkey *et al.*, 2000; Montgomery *et al.*, 2003; Bentley, 2006). However, the other non-local from a cemetery associated with *pescadores* (CHA-1475, $^{87}Sr/^{86}Sr = 0.717065$) has a strontium isotope ratio much higher than the seawater signature. If marine food consumption is affecting her strontium isotope ratio, then she regularly consumed food from a geological zone where $^{87}Sr/^{86}Sr \geq 0.717$. In other words, even if CHA-1475 consumed strontium

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from marine foods or terrestrial foods with marine strontium, her strontium isotope signature is clearly outside of the Ilo Valley signature and is non-local. Moreover, her bone strontium isotope signature (CHA-1475, $^{87}Sr/^{86}Sr = 0.710031$) is intermediate between her enamel strontium isotope signature and the Ilo Valley signature. It is possible that this person moved into the Ilo Valley during adulthood yet towards the end of her life, and that her bone strontium isotope values reflect both of these regions.

The other two individuals with high enamel strontium isotope ratios (CHA-3763, $^{87}Sr/^{86}Sr = 0.708861$; CHA-1144, $^{87}Sr/^{86}Sr = 0.708847$) were both buried in cemetery 3 at Chiribaya Alta. Cemetery 3 is one of the earliest cemeteries at Chiribaya Alta, and mean carbon and nitrogen isotope values correspond to a diet of marine foods supplemented by terrestrial C_3 and C_4 plants (Tomczak, 2001). One individual has non-local strontium isotope ratios in both her tooth enamel (CHA-3763, $^{87}Sr/^{86}Sr = 0.708847$) and femoral bone (CHA-3763, $^{87}Sr/^{86}Sr = 0.708675$). Light stable isotope analysis on bone from this individual shows a reliance on terrestrial plants and animals, with some consumption of freshwater fish or marine plants (CHA-3763, $\delta^{13}C_{collagen} = -17.38‰$, $\delta^{15}N = 11.00‰$, and $\delta^{13}C_{carbonate} = -13.83‰$) (Tomczak, 2001). The nitrogen isotope ratios are not positive enough to imply seafood consumption, so it is unlikely that high seafood consumption altered the strontium isotope ratio in this person's teeth and bones. The fourth non-local individual identified at Chiribaya Alta (CHA-1144, $^{87}Sr/^{86}Sr = 0.708847$) was also buried in cemetery 3. Light stable isotope analysis of bone from CHA-1144 shows a reliance on marine animals and C_4 plants (CHA-1144, $\delta^{13}C_{collagen} = -12.16‰$ and $\delta^{15}N = 18.52‰$) (Tomczak, 2001).

In contrast to Chiribaya Alta, Chiribaya Baja was hypothesised to be a site of Chiribaya-affiliated agriculturalists who had lived in the Ilo Valley all of their lives. Palaeodiet analysis showed that individuals at Chiribaya Baja consumed more terrestrial resources than individuals buried at other Chiribaya sites, although small amounts of marine foods were also consumed (Tomczak, 2001, 2003). Enamel and bone strontium isotope ratios at Chiribaya Baja are within the local range for the Ilo Valley. Light stable isotope analysis of bone from CHB-10035 shows that $\delta^{13}C_{collagen} = -18.33‰$, $\delta^{15}N = 11.81‰$, and $\delta^{13}C_{carbonate} = -14.25‰$ (Tomczak, 2001). This implies a reliance on terrestrial plants with less marine food than other individuals at the site. In fact, Tomczak (2001) identified this individual as one of five outliers at the site of Chiribaya Baja; these outliers ate less marine produce than other individuals buried at the site, and have $\delta\delta^{18}O$ values that are within the *altiplano* range (Tomczak, 2001). Interestingly, this individual (CHB-10035) was buried in an extended, instead of flexed, position, making her anomalous in comparison with other burials at Chiribaya Baja. Both her burial position and bone oxygen isotope value identify her as non-local to the site, although the strontium isotope ratios in her tooth enamel and bone are local. It is possible that the bone samples were contaminated by local groundwater and that her bone strontium isotope ratio is actually non-local and indicates earlier residence in the Lake Titicaca Basin. Trace element analysis of femoral bone from CHB-10035 shows that Ca/P = 2.19; in modern bone, Ca/P = 2.1, so it is possible that the bone from CHB-10035 was contaminated with local groundwater which changed the bone strontium isotope ratio from a non-local to a local signature. Finally, light stable isotope analysis of bone from CHB-10488 shows that $\delta^{13}C_{collagen} = -14.57‰$, $\delta^{15}N = 17.97‰$, $\delta^{13}C_{carbonate} = -10.03‰$ and $\delta^{18}O = -7.60‰$, which implies a reliance on terrestrial plants with higher amounts of marine foods (Tomczak, 2001). However, this individual is not identified as an *altiplano* immigrant based on oxygen or strontium isotope analysis.

In contrast to Chiribaya Baja, individuals buried at San Gerónimo consumed primarily marine products (Tomczak, 2001, 2003). Strontium isotope analysis of tooth enamel from San Gerónimo did not identify anyone who lived outside of the Ilo Valley during the first few years of life. In fact, the range of strontium isotope values measured at San Gerónimo is very low, and the mean enamel strontium isotope ratio was $^{87}Sr/^{86}Sr = 0.707282 \pm 0.000170$ (1σ, $n = 4$). It is interesting to note that, although nitrogen isotope analysis showed that the individuals

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buried at San Gerónimo consumed more marine products than individuals buried at other Chiribaya sites (Tomczak, 2001, 2003), the strontium isotope ratios do not reflect a marine signature. Although protein from marine products was obtained at San Gerónimo, the calcium, and hence strontium, source clearly was terrestrial and not predominately marine.

At El Yaral, the most common botanical remains are maize and *molle* (*Schinus molle*), which are consumed as *chicha*, although highland products such as *chuño*, or freeze-dried potatoes, are also present (Lozada Cerna & Buikstra, 2002). In addition, 26 llamas and alpacas were sacrificed in the residential sector of the site (Wheeler *et al.*, 1995). However, the palaeodiet reconstruction at El Yaral shows that individuals buried there consumed a predominately terrestrial diet. Carbon isotope analysis of bone collagen in 21 individuals buried in El Yaral showed a mean collagen carbon value of $\delta^{13}C = -14.00 \pm 1.61‰$ (Tomczak, 2001, 2003). Three of the four individuals included in the strontium isotope analysis were included in Tomczak's study (M8-10166, M8-10187, M8-10427) and had carbon isotope values that ranged from $-14.03 - -12.28‰$ (Tomczak, 2001). The $\delta^{13}C_{collagen}$ = mean apatite carbon value for four individuals buried at El Yaral was $\delta^{13}C = -8.35 \pm 1.10‰$ or $\delta^{13}C = -17.75‰$ after adjusting for the bioapatite correction (Tomczak, 2001). From these data, Tomczak (2001) concluded that individuals buried at El Yaral consumed a diet of C_4 carbohydrate sources, such as maize, and C_3 protein sources. Therefore, it is unlikely that the majority of terrestrial food consumed at El Yaral was non-local.

However, it appears that the individuals buried at El Yaral did have access to marine foods. Carbon isotope analysis of bone collagen in 21 individuals buried at El Yaral showed a mean collagen nitrogen value of $\delta^{15}N = 11.85 \pm 1.99‰$, which suggests a predominately terrestrial diet with access to marine foods (Tomczak, 2001, 2003). Three of the four individuals included in the strontium isotope analysis were included in Tomczak's study (M8-10166, M8-10187, M8-10427) and had nitrogen isotope values that ranged from $\delta^{15}N = 9.34–15.68‰$ (Tomczak, 2001). Although marine foods, particularly small fish such as anchovies which were probably consumed whole, could have skewed the El Yaral results and caused some individuals to be identified as non-local, the one non-local individual identified at El Yaral (M8-10427, $^{87}Sr/^{86}Sr = 0.717364$, $\delta^{15}N = 11.20‰$, $\delta^{13}C = -13.80‰$) does not have a marine strontium isotope signature in his tooth enamel, and was therefore not identified as non-local because of the consumption of marine foods.

Although the El Yaral values are outside of the Moquegua Valley range, which is $^{87}Sr/^{86}Sr = 0.7059–0.7066$ based on modern faunal bone values, it is likely that at least three individuals are all local to El Yaral. The diet of El Yaral inhabitants is probably inaccurately reflected by the diet of the modern *cuy*, who were fed alfalfa from agricultural fields outside the modern town of Moquegua to the north. As previously discussed, the mean of these three enamel samples is $^{87}Sr/^{86}Sr = 0.707216 \pm 0.000100$ (1σ, $n = 3$). It is possible that all of these individuals are from the same microregion in the Ilo Valley, and that they migrated to El Yaral together to found a Chiribaya agricultural site in the Moquegua Valley. However, the most parsimonious explanation is that these three individuals lived at El Yaral during childhood and before death, and that they consumed food from the same agricultural fields near El Yaral, most likely just below the site on the banks of the Río Moquegua.

Strontium isotope results and mortuary assemblages

At Chiribaya Alta, the highest strontium isotope ratio is from a female who was 30–40 years old at death and who does not exhibit any signs of cranial modification (CHA-1475, $^{87}Sr/^{86}Sr = 0.717065$). This individual was buried with one *jarra* (pitcher) and two *cuencos* (bowls) in the Chiribaya Algarrobal ceramic style (M.C. Lozada Cerna, personal communication), as well as two baskets, a model raft, one gourd, one wooden spoon, three camelid crania, and coca leaves, maize, *pacae* (*Inga vera*) and *guayaba* (*Psidium guajava*). Although this is a relatively rich

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collection of grave goods, it is typical of Chiribaya Alta tombs and does not contain any clearly foreign goods. The only grave goods that may be non-local are the camelid crania. However, there is a growing amount of evidence that camelids were raised on the coast during this time, and three out of the four camelids buried at Chiribaya Alta and included in this study have strontium isotope signatures that are within the Ilo Valley signature (Table 2). This adult female was buried in cemetery 7 at Chiribaya Alta, which dates to approximately AD 750–850 (Lozada Cerna & Buikstra, 2002; see also Owen, 2005). Interestingly, cemetery 7 had the highest percentage of burials with camelid offerings (Lozada Cerna & Buikstra, 2002). This connection between non-locals and camelid offerings is intriguing.

Like CHA-1475, another non-local individual (CHA-3763, enamel $^{87}Sr/^{86}Sr = 0.708861$) is an adult female with an unmodified cranium who was 32–35 years old at death. However, unlike CHA-1475, this individual was buried with only a basket and the textiles used for her *fardo*, or mummy bundle. Despite the lack of grave goods or characteristics that distinguish this tomb from others at Chiribaya Alta, this individual has both enamel and femoral strontium isotope ratios that are outside of the Ilo Valley signature.

The other two non-local individuals buried at Chiribaya Alta have non-local enamel strontium isotope ratios but local bone strontium isotope ratios (Figure 3). One adult male, CHA-3907, had an unmodified cranium. His grave goods included one *jarra* and *cuenco* in the San Gerónimo ceramic style (M.C. Lozada Cerna, personal communication), one basket, one *cuy*, maize and one gourd. Again, there are no clearly foreign objects in this burial, which was located in cemetery 4 in Chiribaya Alta. The other individual at Chiribaya Alta with a non-local enamel strontium isotope ratio and local bone strontium isotope ratio is CHA-1144 (Figure 3). This male was 40–45 years old at death and exhibited fronto-occipital cranial modification. He was buried in cemetery 3 with one *cuenco* (bowl) in the Chiribaya Algarrobal ceramic style (M.C. Lozada Cerna, personal communication), a llama skin that covered the *cuenco*, three textile bags containing coca leaves, two projectile points, one gourd, one wooden spoon, three camelid crania and one *cuy*. None of these artefacts appears to be non-local, and the coca leaves are a coastal variety (Buikstra, 1995). However, it is possible that the camelids were raised outside of the Ilo Valley, or regularly travelled outside of the Ilo Valley on caravans. Strontium isotope analysis was performed on one of these camelids (CHA-1144, $^{87}Sr/^{86}Sr = 0.708826$), and shows that the camelid bone value is outside of the Ilo Valley signature. Therefore, this adult male and at least one of the camelids he was buried with lived outside of the Ilo Valley during part of their lives.

No clearly anomalous strontium isotope signatures were identified at Chiribaya Baja or San Gerónimo. However, it is interesting to note that, while the San Gerónimo mortuary assemblage and nitrogen isotope signatures demonstrate a reliance on marine products, the strontium isotope signatures showed a reliance on a terrestrial calcium source.

Finally, one individual at El Yaral did not live near the site during the first 3–4 years of his life. This individual, a 32–40 year old male, was buried in a rectangular tomb with various grave goods, including a basket, wooden spoon, gourd and remains of maize and yuca (*Manihot esculenta*). The ceramics, a *kero* (beaker) and a *cuenco*, were in the Chiribaya El Yaral style (M.C. Lozada Cerna, personal communication). Moreover, this individual was associated with the burial of a dog (Feature 202), which may have been a mortuary offering. In addition, this individual was buried in one of only eight rectangular tombs, which are similar to the rectangular Chiribaya tombs on the coast, instead of the more common circular tombs at El Yaral (Buikstra, 1995). Both the ceramics included with this burial and the tomb type show clear ties to the Chiribaya archaeological culture (M.C. Lozada Cerna, personal communication). Despite the evidence that this individual had strong ties to the coastal Chiribaya, the strontium isotope values are not within the Ilo Valley signature ($^{87}Sr/^{86}Sr = 0.7058\text{-}0.7082$), and do not reflect high amounts of marine food consumption.

In general, there are no clearly non-local grave goods that can be used to identify non-local individuals at Chiribaya sites. For example, individuals with non-local enamel strontium

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isotope values are buried with both San Gerónimo and Chiribaya Algarrobal ceramics (M.C. Lozada Cerna, personal communication). Two of the non-locals identified at Chiribaya Alta were buried with camelid remains (CHA-1475, CHA-1144). As discussed previously, at least one of the camelids buried with CHA-1144 was raised outside of the Ilo Valley. This raises the intriguing possibility that individuals buried with camelids had ties to *altiplano* groups, or that individuals who regularly participated in llama caravans were buried with camelid remains.

Conclusions

In general, individuals whose tooth enamel strontium isotope signatures appear non-local to the region were buried at El Yaral and Chiribaya Alta. In contrast, smaller Ilo Valley sites such as San Gerónimo and Chiribaya Baja show less variability in enamel strontium isotope ratios, although this can continue to be examined with additional samples from San Gerónimo and Chiribaya Baja. Strontium isotope ratios were most variable at the site of Chiribaya Alta, where mortuary assemblages, cranial modification styles and palaeodiet were also highly variable (Lozada Cerna, 1998; Tomczak, 2001, 2003; Lozada Cerna and Buikstra et al., 2002; Lozada Cerna & Buikstra, 2002). The number of non-locals identified at Chiribaya Alta may result from increased access to resources from a variety of different ecological zones, including increased marine consumption as discussed previously. However, it could also support the hypothesis that Chiribaya elites from a variety of sites were buried at Chiribaya Alta, which would have had a function similar to the great ritual and pilgrimage centre of Pachacamac on the central Peruvian coast (Lozada Cerna, 1998). The fact that two out of four non-locals buried at Chiribaya Alta also had non-local bone strontium isotope ratios also supports this hypothesis, and future analysis of additional bone–tooth pairs from Chiribaya Alta will continue to test these hypotheses.

However, at Chiribaya Alta, identifying the locals is as informative as identifying the non-locals. For example, one of the richest tombs excavated at Chiribaya Alta was tomb number 419 in cemetery 4 (Buikstra, 1995). One of the few Chiribaya tombs that contained more than one person, it consisted of one male and two females (Buikstra, 1995). The rectangular tomb had been closed by large rocks and mortar laying over three cane litters, and was oriented northeast to southwest with the three burials facing the northeast. Each body had been individually wrapped in textiles and the male wore a four-pointed hat while the two females each wore metal bands across their foreheads. Grave goods, which were placed near the feet of the three individuals, included 32 ceramic vessels, 20 baskets, 25 textiles and six metal items. Four camelid crania, camelid feet and a large ceramic sherd were placed near the capstone of the burial (Buikstra, 1995). According to cranial modification styles and the presence of San Gerónimo ceramics, the adult females were more likely to be *pescadores*, while the adult male was more closely linked to the *labradores* (Lozada Cerna & Buikstra, 2002). The adult male had a local Ilo Valley signature in his first molar tooth enamel (CHA-3704, $^{87}Sr/^{86}Sr = 0.707693$) (Figure 2) and femur (CHA-3704, $^{87}Sr/^{86}Sr = 0.707469$) (Figure 3). In addition, one of the adult females buried in the same tomb also had a local signature (CHA-3610, $^{87}Sr/^{86}Sr = 0.70783$) in her first molar tooth enamel (Figure 2). The adult male in tomb 419 has been identified as a paramount lord of the Chiribaya polity (Lozada Cerna, 1998; Lozada Cerna & Buikstra, 2002), yet both this individual and one of the individuals buried with him clearly lived in the Ilo Valley during the first few years and the last decade of their lives. This lends support to the hypothesis that the Chiribaya polity was predominately a coastal society with coastal, not *altiplano*, origins.

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