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EXAMINING LOCAL SOCIAL IDENTITIES THROUGH PATTERNS OF BIOLOGICAL AND CULTURAL VARIATION IN THE SOLCOR *AYLLU*, SAN PEDRO DE ATACAMA, CHILE

EXAMINANDO LAS IDENTIDADES SOCIALES LOCALES A TRAVÉS DE LOS PATRONES DE VARIACIÓN BIOLÓGICA Y CULTURAL EN EL AYLLU *DE SOLCOR, SAN PEDRO DE ATACAMA, CHILE*

Kristin L. Nado[1], Sara J. Marsteller[1], Laura M. King[2], Blair M. Daverman[3], Christina Torres-Rouff[2, 4], and Kelly J. Knudson[1]

Studies of local forms of social organization in peripheral areas can enrich our understanding of the sociopolitical factors structuring core-periphery interactions. This research explores how local group identities impacted the ways in which individuals and communities at San Pedro de Atacama, Chile, expressed their relationship to the Tiwanaku polity during the Middle Horizon. Combining information from body modification practices, burial contexts, and isotopic indicators of diet and geographic origin, we demonstrate that differential incorporation of Tiwanaku goods and practices may have served alongside other local customs to mark social group distinctions between individuals interred in the Solcor 3 and Solcor Plaza cemeteries.

Key words: Bioarchaeology, carbon, oxygen and strontium isotopes, cranial vault modification, mortuary practices, social differentiation**,** Middle Horizon, Tiwanaku.

Estudios de las formas locales de organización social en zonas periféricas pueden enriquecer nuestra comprensión de los factores sociopolíticos que estructuran las interacciones entre centro y periferia. Esta investigación explora cómo las identidades de grupos locales de San Pedro de Atacama, Chile, influyeron en la manera como los individuos y las comunidades expresaron su relación con el Estado de Tiwanaku durante el Horizonte Medio. Combinando múltiples líneas de evidencia, como prácticas de modificación corporal, contextos funerarios e índices isotópicos ligados a dieta y origen geográfico, demostramos que la incorporación diferencial de objetos y prácticas Tiwanaku junto a otras constumbres locales pudieron servir para marcar diferencias sociales entre los individuos inhumados en los cementerios Solcor 3 y Solcor Plaza.

Palabras claves: *bioarqueología, isótopos de carbono, estroncio y oxígeno, modificación craneana artificial, prácticas mortuorias, diferenciación social, Horizonte Medio, Tiwanaku.*

Traditional models of empire (e.g., D'Altroy 1992; Doyle 1986) view state expansion as a top-down process that reorganizes peripheral areas for the benefit of an imperial core. Due to the complexity and internal diversity of the Tiwanaku polity, however, it is difficult to fit Tiwanaku expansion during the Andean Middle Horizon (ca. AD 500-1,000) within an exclusively top-down conceptual framework. Studies documenting the maintenance of smaller-scale group identities alongside that of state affiliation (e.g., Albarracin-Jordan 1996; Bermann 1994; Janusek 2004) have revealed the plural nature of social identities within Tiwanaku and have highlighted the importance of local traditions and power structures in the functioning of the Tiwanaku polity. Given the persistence of these small-scale social distinctions, investigations of social dynamics throughout the polity are relevant to understanding the processes behind Tiwanaku's expansion and internal functioning.

Here, we investigate local systems of social differentiation within prehispanic San Pedro de

1 Center for Bioarchaeological Research, School of Human Evolution and Social Change, Arizona State University, PO Box 872402, Tempe, AZ, 85287, U.S.A. knado@asu.edu
2 Department of Anthropology, The Colorado College, 14 East Cache La Poudre Street, Colorado Springs, CO, 80903, U.S.A. ctorresrouff@coloradocollege.edu
3 Department of Anthropology, Purdue University, 700 W. State St., West Lafayette, IN 47907, U.S.A. bdaverma@purdue.edu
4 Instituto de Investigaciones Arqueológicas y Museo, Universidad Católica del Norte, San Pedro de Atacama, 141-0000, Chile. ctorres@ucn.cl

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Atacama, Chile, using information derived from archaeology, skeletal morphology, and biogeochemistry. This study complements and extends upon other recent research combining information from bioarchaeology and archaeological chemistry at San Pedro de Atacama (Knudson and Torres-Rouff 2009; Torres-Rouff and Knudson 2007) by focusing on mechanisms of social demarcation between the Solcor 3 and Solcor Plaza cemeteries. Taken together, these lines of evidence allow us to argue that subgroup identities reflected in multiple aspects of life and mortuary treatment existed within the larger Solcor community and that these identities impacted how Tiwanaku material culture was used in mortuary ritual within San Pedro de Atacama.

San Pedro de Atacama during the Middle Horizon

The site of San Pedro de Atacama consists of thirteen small agricultural oases located in the Atacama Desert of northern Chile, approximately 800 km from the site of Tiwanaku in the Bolivian *altiplano* (Figure 1). Resident within these oases were a number of distinct *ayllu* groupings, ascriptive descent groups that form the fundamental unit of Andean social organization (Abercrombie 1998; Bastien 1978; Rasnake 1988). Though the oases experienced a long and continuous history of occupation, the Middle Horizon is distinguished by increased complexity, prosperity, and foreign trade, as evidenced through interactions with the Tiwanaku polity (Bravo and Llagostera 1986; Llagostera 2004; Torres and Conklin 1995).

Archaeological evidence suggests that Tiwanaku influence in San Pedro de Atacama was based on economic and ideological links with the Tiwanaku core rather than on direct colonization through the large-scale presence of individuals from the *altiplano*. Interaction between San Pedro de Atacama and Tiwanaku appears archaeologically in the form of Tiwanaku stylistic elements incorporated into local traditions, small numbers of imported goods found primarily in mortuary contexts, and limited changes in cultural uses of the body (Le Paige 1971; Llagostera et al. 1988; Torres-Rouff 2008, 2009). Local settlement patterns and utilitarian ceramic wares used during the Middle Horizon remain largely unchanged from earlier periods (Mujica 1996).

The incorporation of Tiwanaku objects into funerary practices –a cultural realm rich with symbolic and ideological significance (cf. Carr 1995)– indicates that Tiwanaku symbols held important meanings for the residents of San Pedro de Atacama, though not necessarily ones identical to those held within the Tiwanaku core (Torres-Rouff 2008). When Tiwanaku-style artifacts, including snuff implements and textiles, are present in Atacameño burial assemblages, they are found in association with local grave offerings rather than as distinct Tiwanaku mortuary assemblages (Llagostera et al. 1988). This combination of local and nonlocal or foreign style objects argues against the notion that state representatives from the Tiwanaku core inhabited San Pedro de Atacama (Stovel 2001:388; Torres and Conklin 1995:91) and instead suggests the appropriation and use of Tiwanaku material symbols by local peoples for their own purposes. While textile evidence has been used to argue for an ethnic enclave of Tiwanaku colonists within the Coyo Oriental cemetery (Kolata 1993:277; Oakland Rodman 1992), radiogenic strontium isotope analyses of human remains from Coyo Oriental suggests that first generation immigrants to the oases were rare (Knudson 2008), and it is possible that stylistically different textile groups may instead represent local lineages with differential access to Tiwanaku-style trade goods (Goldstein 2005:94).

The Solcor *ayllu* appears to have occupied an advantageous position within Atacameño society, as it contains a number of tombs with Tiwanaku-style artifacts and local high status goods (Bravo and Llagostera 1986; Llagostera et al. 1988) (Figure 2). Here, we explore subgroup differentiation within the Solcor *ayllu* via the contemporary cemeteries of Solcor Plaza and Solcor 3 (Figure 1). These two cemeteries span the length of Atacameño interaction with Tiwanaku (Table 1) and provide us with the opportunity to explore how links with the Tiwanaku polity may have been differently expressed within single *ayllus* at San Pedro de Atacama.

Archaeological and Bioarchaeological Indicators of Social Difference

We hypothesize that interactions between the expanding Tiwanaku polity and San Pedro de Atacama encompassed both biological and cultural spheres. However, we expect that the ways in which indicators of interaction were expressed within the local population were varied and mediated by local group identities. To understand how ties to

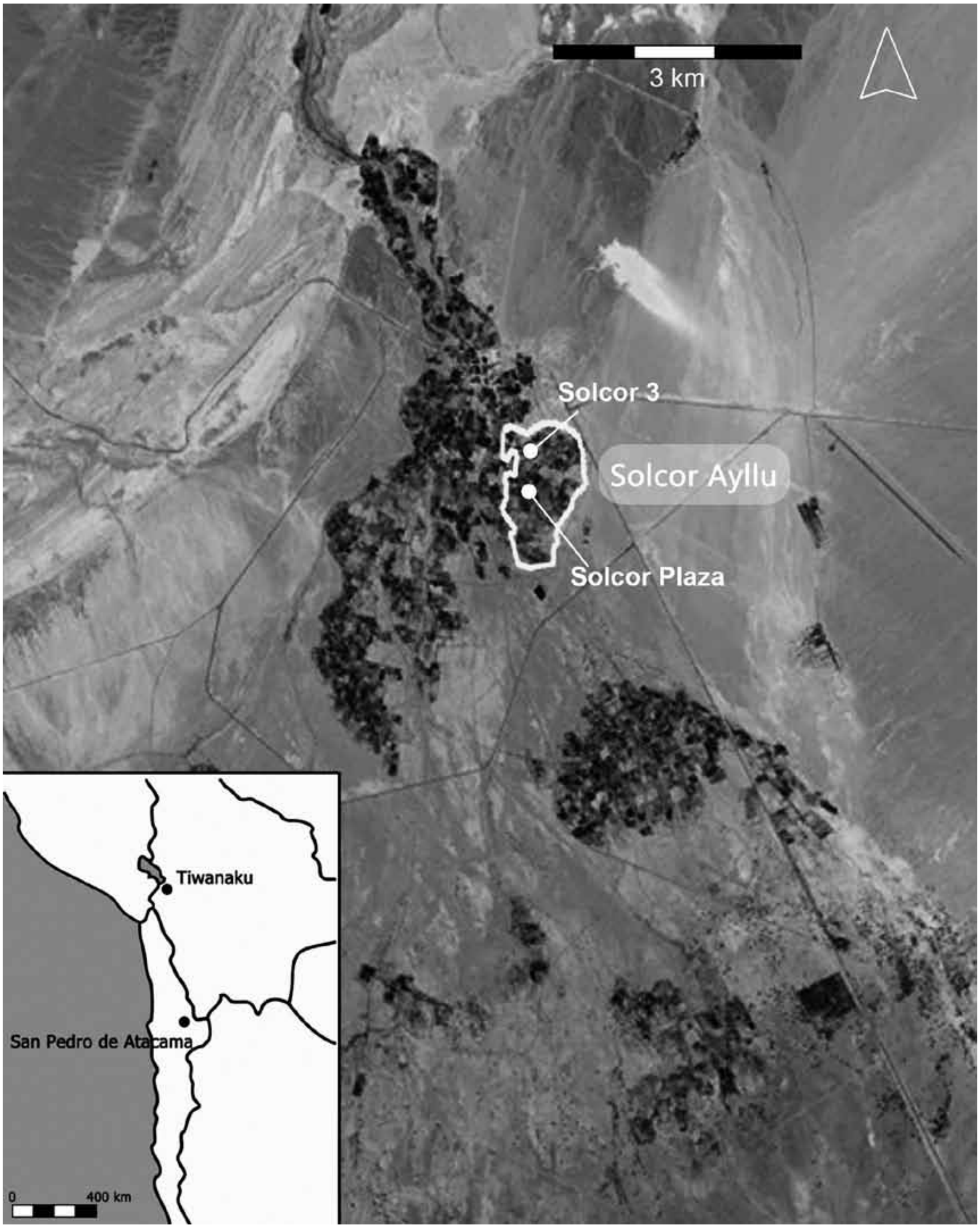

Figure 1. Location of the Solcor *ayllu* within San Pedro de Atacama. Inset map demonstrates the location of San Pedro de Atacama within the South Central Andes.
Ubicación del ayllu *de Solcor en San Pedro de Atacama. El encarte muestra la ubicación de San Pedro de Atacama en los Andes Centro Sur.*

Tiwanaku were expressed within the local canon of social identities in the Solcor *ayllu*, we incorporate information from body modification, patterns of mortuary treatment, and biogeochemical indicators of dietary practices and geographic origins. Here, we introduce each of these approaches.

Figure 2. Snuff tube with Tiwanaku iconography recovered from the Solcor 3 cemetery (Museo Arqueológico R.P. Le Paige, Catalog Number 2768).
Tubo para insuflar con iconografía Tiwanaku, recuperado del cementerio Solcor 3 (Museo Arqueológico R.P. Le Paige, número de catálogo 2768).

Mortuary assemblages

Grave assemblages accompanying individuals into the afterlife have been variously interpreted as reflecting the social identities of the deceased (Binford 1971; Saxe 1970), abstract religious or cosmological notions (Carr 1995), or the active manipulation of social reality by the living (Hodder 1982; Parker Pearson 1993). While grave goods may not perfectly reflect the social persona of the individual decedent, mortuary patterns can nevertheless inform our understanding of broad cultural norms concerning social identities such as kin group, status, and geographic origins. At San Pedro de Atacama, the specific manner in which Tiwanaku-style goods were incorporated into the mortuary assemblages of a socially diverse local population may shed light on the cultural uses of symbolic links with the Tiwanaku polity within local social organization.

Cranial vault modification

Recent theoretical perspectives within archaeology emphasize that the human body is not exclusively the product of biology but is also shaped by cultural practices (e.g., Hamilakis et al. 2002; Joyce 2005; Sofaer 2006). Cranial modification practices often represent the conscious manipulation of the infant body to provide a visual, permanent, and conspicuous marker of group identity (e.g., Blom 2005a, 2005b; Torres-Rouff 2002, 2009). Ethnohistoric documents from the Andes substantiate the use of cranial modification style as a means of overt, visual differentiation between groups (see Blom 2005a), and previous archaeological studies of cranial modification in the region (e.g., Allison et al. 1981; Gerszten 1993; Hoshower et al. 1995; Torres-Rouff 2002, 2009) have been able to link specific cranial modification forms and practices to group identity at a variety of sociospatial scales. At San Pedro de Atacama, changing cultural influences associated with the Middle Horizon seem to have resulted in the diversification of cranial vault modification styles among the local population (Torres-Rouff 2009). However, tabular forms of modification remain the most common local variant in the San Pedro oases over the course of their occupation (Munizaga 1969; Torres-Rouff 2009).

Table 1. Radiocarbon dating of Solcor 3 and Solcor Plaza cemeteries.
Dataciones radiocarbónicas de los cementerios de Solcor 3 y Solcor Plaza.

Site	Radiocarbon Dates[a]	Reference
Solcor 3	533-720 Cal AD	(Llagostera et al. 1988:64)
	504-774 Cal AD	(Llagostera et al. 1988:65)
	607-829 Cal AD	(Llagostera et al. 1988:65)
	659-986 Cal AD	(Llagostera et al. 1988:65)
	975-1164 Cal AD	(Llagostera et al. 1988:65)
Solcor Plaza	436-654 Cal AD	(Hubbe et al. 2010)
	1,019-1,189 Cal AD	(Hubbe et al. 2010)

[a]2 sigma calibration produced using the CALIB Radiocarbon Calibration Program (Stuiver and Reimer 1993) and SHCal04 calibration dataset (McCormac et al. 2004).

Biogeochemical indicators of diet and geographic origins

Biogeochemistry can be used to make inferences about diet and residential mobility in past populations, lines of evidence which can potentially enable us to deduce some of the mechanisms through which social difference was created at San Pedro de Atacama. Intra-community patterning in food consumption can be one way by which meaningful social distinctions between subgroups are maintained (Hastorf 1990; Ubelaker 1995; White 2005). Among other paleodietary isotopes, carbon isotope values ($\delta^{13}C$)[1] from the mineral portion of bones and teeth shed light on consistent differences in the types of plants that individuals consumed during their lifetimes. Though altitude and climatic factors have an impact on the carbon isotope values in a variety of food sources, $\delta^{13}C$ values in the Atacama Desert range from –12.4‰ to –19.0‰ for plants using the C_4-photosynthetic pathway (such as maize, amaranth, and tropical grasses), from –10.7‰ to –28.4‰ for plants using the CAM-photosynthetic pathway (such as cacti and succulents), and from –21.8‰ to –28.0‰ for plants using the C_3-photosynthetic pathway (all other plants) (Tieszen and Chapman 1992). Since the carbon isotope ratios of foods in the diet are incorporated into human bone carbonate with a constant shift in isotope ratios of 9.4‰ (Krueger and Sullivan 1984), these ranges allow us to infer differences in the proportion of C_3 versus C_4 plants consumed by individuals living at San Pedro de Atacama during their lifetimes. The carbon isotope values derived from bone carbonate produced in this project reflect the isotopic composition of total dietary intake, in contrast to the $\delta^{13}C$ values derived from the analysis of bone collagen, not produced or reported here, which more selectively reflect the isotopic signatures in the protein portion of the diet (Ambrose and Norr 1993; Kellner and Schoeninger 2007; Tieszen and Fagre 1993).

The integration of nonlocal individuals into local social groups can impact how particular social identities are expressed, both among the immigrants themselves as well as among local communities (Cusick 1998). Together, the use of radiogenic strontium isotope ratios ($^{87}Sr/^{86}Sr$) and stable oxygen isotopic values ($\delta^{18}O$) allows the identification of individuals who spent their childhood in a region geologically or meteorologically different from San Pedro de Atacama (see Bentley 2006 and Gat 1996 for reviews). While tooth enamel forms early in life and can be used to assess an individual's place of origin, somatic bone constantly remodels throughout life and provides information on place of residence during an individual's later life. The combination of oxygen and strontium isotope data may allow us to recognize the presence of nonlocal individuals from the highland Tiwanaku core or from other areas of the Tiwanaku polity within the Solcor cemeteries at San Pedro de Atacama and to assess the degree to which cultural indicators of interaction with the Tiwanaku polity correspond with the actual presence of Tiwanaku immigrants within the Solcor community.

Materials and Methods

Sampling strategy

All human skeletal material and associated mortuary assemblages from excavations at the

Solcor Plaza and Solcor 3 cemeteries are housed at the Museo Arqueológico R.P. Gustavo Le Paige in San Pedro de Atacama, Chile. A total of 190 individuals were evaluated for bioarchaeological and mortuary parameters (Table 2). The age and sex of each individual were estimated using standard osteological techniques described in Buikstra and Ubelaker (1994). Sex determinations were based on the sexually dimorphic features of the pelvis and skull, while age estimates were based on the appearance of the pubic symphysis, dental development, and cranial suture closure.

A representative sample of approximately 20% of adult individuals excavated from each cemetery was sampled for isotope analysis (Solcor Plaza: n = 16/72; Solcor 3: n = 23/118). First molars were preferentially chosen when possible, so that residence and diet during the same developmental period of life could be compared across a number of different individuals. When necessary due to preservation or to minimize destruction to the crania, other early forming teeth were substituted. In order to assess changes in mobility and diet over the lifetime, paired tooth and bone samples were collected from 11 Solcor 3 individuals, and a series of three teeth forming at different ages were collected from three individuals (Table 3).

Mortuary analysis

Information about mortuary assemblages was taken from detailed field notes and cemetery descriptions (Bravo and Llagostera 1986; Le Paige 1961; Llagostera and Costa Junqueira 1990; Llagostera et al. 1988). The type, number, and component materials of mortuary objects in each grave were recorded. Objects were designated as local or nonlocal based on stylistic indicators, while nonlocal objects were further designated as stylistically Tiwanaku or stylistically linked to peoples outside of the Tiwanaku sphere, including cultures from the nearby Loa River area as well as areas further away such as Northwest Argentina. Materials designated as "Tiwanaku goods" include objects such as Tiwanaku-style ceramics, textiles, and snuff paraphernalia featuring Tiwanaku iconography, while materials designated as "other foreign goods" include ceramics featuring other nonlocal forms and decorative techniques, as well as conch and oyster shells that must have been traded into the San Pedro de Atacama area from elsewhere. "Local high value goods", including ritual objects, ceremonial weapons, and objects crafted from gold and copper metals, were also inventoried to help explore potential status differences among members of the Solcor *ayllu*.

Cranial vault modification

Intentional modification of cranial shape was assessed through visual examination of each skull. The presence or absence of artificial modification as well as the resulting cranial shape were recorded using the classification system described in Dembo and Imbelloni (1938), which recognizes erect and oblique variants of both annular and tabular modification forms. A similar classification system has been applied to crania from San Pedro de Atacama by a number of previous researchers (e.g., Cocilovo and Zavattieri 1994; Knudson and Torres-Rouff 2009; Munizaga 1969; Torres-Rouff 2002). Individuals displaying only slight alteration to natural head shape were scored as unmodified to account for normal variation.

Biogeochemical analysis

Sample preparation

Samples were prepared at the Archaeological Chemistry Laboratory at Arizona State University and at the Laboratory for Archaeological Chemistry at

Table 2. Demographic characteristics of individuals interred in the Solcor 3 and Solcor Plaza cemeteries.
Características demográficas de los individuos enterrados en los cementerios de Solcor 3 y Solcor Plaza.

Site	Males	Females	Indeterminate		Total
			Adults	Juveniles	
Solcor 3	52	52	5	9	118
Solcor Plaza	22	30	9	11	72

Table 3. Stable isotope samples included in the current study and biogeochemical data.
Muestras de isótopos estables incluidos en el estudio actual y datos biogeoquímicos.

Cemetery	Laboratory Number	Specimen Number	Sex	Sample	$^{87}Sr/^{86}Sr$ [a, b]	$\delta^{13}C_{c\ (VPDB)}$	$\delta^{18}O_{c\ (VPDB)}$
Solcor Plaza	ACL-1828	SCP-1029	I	ULM1	0.70772	–6.1	–6.2
Solcor Plaza	ACL-1829	SCP-2938	F	URM1	0.71061	–5.3	–9.0
Solcor Plaza	ACL-1830	SCP-0627	I	ULP4	0.70766	NA	NA
Solcor Plaza	ACL-1831	SCP-1377	M	ULM1	0.70776	–6.0	–4.0
Solcor Plaza	ACL-1832	SCP-0625	M	URP3	0.71097	–10.8	–10.6
Solcor Plaza	ACL-1833	SCP-2940	F	ULM1	0.71088	–10.7	–7.5
Solcor Plaza	ACL-1834	SCP-0611	F	ULM2	0.70779	–3.2	3.0
Solcor Plaza	ACL-1835	SCP-0629	F	URM2	0.70773	–6.5	–6.5
Solcor Plaza	ACL-1836	SCP-0A95	M	URM2	0.70775	–5.4	–0.3
Solcor Plaza	ACL-1837	SCP-1378	M	URM1	0.70780	–7.1	0.1
Solcor Plaza	ACL-1838	SCP-1245	F	ULM2	0.70771	–8.0	–3.8
Solcor Plaza	ACL-1839	SCP-0621	M	URC	0.70826	–5.1	–4.8
Solcor Plaza	ACL-1840	SCP-0613	M	URM1	0.70784	–6.7	–7.0
Solcor Plaza	ACL-1841	SCP-0628	F	ULM2	0.70783	–6.0	2.6
Solcor Plaza	ACL-1842	SCP-1394	F	URM1	0.70786	NA	NA
Solcor Plaza	ACL-1843	SCP-1379	M	URM2	0.70774	NA	NA
Solcor 3	ACL-1814	SC3-0113	F	URM3	0.70808	–8.9	–0.1
Solcor 3	ACL-1815	SC3-0113	F	ULM2	0.70805	NA	NA
Solcor 3	ACL-1816	SC3-0113	F	LLI1	0.70805	–7.6	–3.8
Solcor 3	ACL-1817	SC3-0107	M	LRM3	0.70839	–6.4	–2.7
Solcor 3	ACL-1818	SC3-0107	M	LRM2	0.70812	–6.1	–4.9
Solcor 3	ACL-1819	SC3-0107	M	ULI1	0.70809	–5.0	–4.9
Solcor 3	ACL-1820	SC3-0115	F	LLM2	0.70815	–7.7	–5.1
Solcor 3	ACL-1821	SC3-0038	F	LRP4	0.70815	–9.5	–5.5
Solcor 3	ACL-1822	SC3-0071	F	LRP4	0.70812	–6.1	–0.1
Solcor 3	ACL-1823	SC3-0071	F	rib	0.70780	–8.9	–7.5
Solcor 3	ACL-1824	SC3-0111	M	ULM1	0.70829	NA	NA
Solcor 3	ACL-1825	SC3-0111	M	rib	0.70781	–8.3	–5.6
Solcor 3	ACL-1826	SC3-0097	F	LLM1	0.70909	–7.4	–10.4
Solcor 3	ACL-1827	SC3-0097	F	rib	0.70884	–7.1	–9.8
Solcor 3	F1670	SC3-0005	M	LRM1	0.708206[a,b]	–5.3	–5.0
Solcor 3	F1671	SC3-006(1078)	M	LLM1	0.707892[a,b]	NA	NA
Solcor 3	F1672	SC3-006(1078)	M	rib	0.70848	–8.9	–12.3
Solcor 3	F1673	SC3-006(1080)	F	ULM1	0.707663[a,b]	NA	NA
Solcor 3	F1674	SC3-006(1080)	F	rib	0.70886	–11.1	–8.0
Solcor 3	F1675	SC3-0008	I	LRM2	0.707725[a,b]	NA	NA
Solcor 3	F1676	SC3-0008	I	rib	0.70776	–10.5	–9.9
Solcor 3	F1677	SC3-0012	M	LLM1	0.708015[a,b]	NA	NA
Solcor 3	F1678	SC3-0016	M	LLM1	0.707823[a,b]	–9.6	–10.0
Solcor 3	F1679	SC3-0020	M	LRM1	0.707975[a,b]	NA	NA
Solcor 3	F1680	SC3-027(1628)	F	LLM1	0.707580[a,b]	NA	NA
Solcor 3	F1681	SC3-0050	M	URM1	0.712522[a,b]	–2.2	–5.3
Solcor 3	F1682	SC3-0050	M	LRM2	0.70781	–10.3	–11.1
Solcor 3	F1683	SC3-0050	M	rib	0.70795	NA	NA
Solcor 3	ACL-1533	SC3-0050	M	LLM2	0.70929	–8.5	–9.5
Solcor 3	F1684	SC3-0052	I	LLM1	0.708204[a,b]	–8.9	–11.0
Solcor 3	F1685	SC3-0052	I	rib	0.70837	NA	NA
Solcor 3	F1686	SC3-0055	M	ULM1	0.708118[a,b]	NA	NA
Solcor 3	F1687	SC3-0055	M	rib	0.70822	–10.4	–8.0
Solcor 3	F1688	SC3-0067	M	URM1	0.707699[a,b]	–8.2	–11.0
Solcor 3	F1689	SC3-0067	M	rib	0.70790	NA	NA
Solcor 3	F1690	SC3-0069	M	LRM2	0.708072[a,b]	–6.7	–6.1
Solcor 3	F1691	SC3-0069	M	rib	0.70805	–8.5	–9.0
Solcor 3	F1692	SC3-0078	F	LLM1	0.707837[a,b]	–5.4	–3.4
Solcor 3	F1693	SC3-0078	F	rib	0.70804	NA	NA
Solcor 3	F1694	SC3-0106	M	LLM1	0.708093[a,b]	NA	NA
Solcor 3	F1695	SC3-0117	M	LRM1	0.708052[a,b]	NA	NA

[a] Radiogenic strontium isotope data marked with an "a" were produced via thermal ionization mass spectrometry (TIMS) carried out in the Isotope Geochemistry Laboratory at the University of North Carolina at Chapel Hill. All other strontium isotope data were produced in the W.M. Keck Foundation Laboratory for Environmental Biogeochemistry at Arizona State University using multi-collector inductively-coupled plasma mass spectrometry (MC-ICP-MS). Due to differences in the precision of these analytical techniques, strontium isotope ratios produced at UNC-Chapel Hill are reported to the sixth decimal place, while ratios produced at ASU are reported to the fifth decimal place.
[b] These data have been previously published elsewhere (Knudson and Price 2007; Knudson 2008; see also Torres-Rouff and Knudson 2007).

the University of Wisconsin at Madison. All samples were mechanically cleaned using a Dremel MultiPro dental drill with a carbide burr to remove all traces of adhering dirt and contamination prior to analysis. Enamel powder was then removed from each tooth sample using a clean carbide burr. Approximately 1 g of each rib was cut from the remainder of the bone using a circular diamond saw.

Trace element concentration analysis

All bone samples and a subset of tooth samples were analyzed for trace element concentrations to screen for diagenetic contamination. Because tooth enamel is much less susceptible to diagenetic alteration than is bone (Budd et al. 2000; Kohn et al. 1999; Lee-Thorp and Sponheimer 2003) and because previous assessments of tooth samples from the San Pedro area have not identified diagenetic alteration to tooth enamel (Knudson 2007; Knudson and Price 2007), trace element concentration analysis was not undertaken for the majority of tooth enamel samples.

Bone samples for trace element concentration analysis were chemically cleaned using a weak acetic acid solution, ashed to remove organic content, and finely ground with an agate mortar and pestle. Approximately 6 mg of ground tooth enamel or bone ash from each sample were dissolved in 5M nitric acid and diluted to a final concentration of 0.32 M nitric acid with Millipore water. Trace element samples were analyzed on a Thermo X Series quadrupole inductively coupled plasma mass spectrometer (Q-ICP-MS) at the W.M. Keck Foundation Laboratory for Environmental Biogeochemistry at Arizona State University.

Stable carbon and oxygen isotope analysis

Enamel and bone powder samples for carbon and oxygen analysis were treated with 2% bleach and 0.1 M acetic acid using procedures described in Koch et al. (1997). Isotopic analysis of these samples was performed on a Thermo Delta Plus Advantage isotope ratio mass spectrometer (IRMS) at the W.M. Keck Foundation Laboratory for Environmental Biogeochemistry at Arizona State University. Replicate analyses of international standard NBS-19 on the Thermo Delta Plus spectrometer indicate a reproducibility of +/- 0.2‰ for values of $\delta^{18}O$ and +/- 0.3‰ for values of $\delta^{13}C$ produced in this laboratory.

Radiogenic strontium isotope analysis

The strontium content of tooth enamel and ashed bone samples for strontium isotope analysis was isolated using EiChrom SrSpec resin following established procedures described in Torres-Rouff and Knudson (2007). As indicated in Table 3, a subset of samples for radiogenic strontium isotope analysis were analyzed on a Thermo Neptune multicollector inductively coupled plasma mass spectrometer (MC-ICP-MS) at the W.M. Keck Foundation Laboratory for Environmental Biogeochemistry at Arizona State University, while the remainder were analyzed via thermal ionization mass spectrometry (TIMS) at the Isotope Geochemistry Laboratory at the University of North Carolina at Chapel Hill. At Arizona State University, MC-ICP-MS analysis of international standard SRM-987 produced $^{87}Sr/^{86}Sr$ = 0.710265 +/- 0.000010 (2σ, n=25), comparable to published values of $^{87}Sr/^{86}Sr$ = 0.710263 +/- 0.000016 (2σ) (Stein et al. 1997). Accuracy and precision of TIMS at Chapel Hill are demonstrated by analyses of SRM-987, where $^{87}Sr/^{86}Sr$ = 0.710260 +/- 0.000010 (2σ, n=20).

All isotopic results were interpreted with reference to published baseline data on the carbon isotopic signature of various food sources in the Atacama Desert (Tieszen and Chapman 1992) and on the radiogenic strontium and stable oxygen isotopic signatures for the San Pedro de Atacama area and surrounding regions of the Tiwanaku polity (Knudson 2008, 2009).

Results

The results of this study demonstrate significant variability between the Solcor cemeteries in each of the bioarchaeological variables investigated here. Combined, these lines of evidence are consistent with the hypothesis that local group identities within San Pedro de Atacama structured the ways in which real or fictive ties to the Tiwanaku polity were expressed.

Mortuary assemblages and cranial vault modification

Comparisons between the Solcor 3 and Solcor Plaza cemeteries reveal that subgroups within the Solcor *ayllu* both had differential access to wealth and differentially incorporated

Figure 3. Tabular oblique cranial vault modification of an individual buried in the Solcor 3 cemetery (Museo Arqueológico R.P. Le Paige, Catalog Number 1516).
Deformación craneana tabular de un individuo enterrado en el cementerio Solcor 3 (Museo Arqueológico R.P. Le Paige, número de catálogo 1516).

Tiwanaku-style material culture into their mortuary repertoire. Table 5 presents the distribution of local high value and stylistically nonlocal goods throughout the Solcor *ayllu*. Individuals interred in the Solcor 3 cemetery demonstrate significantly greater burial wealth than those in the Solcor Plaza cemetery, both in terms of the mean number of total goods (Student's t-test, $t=13.78$, $df=135.13$, $p<0.001$) and in terms of the mean number of local high value goods such as metal objects and snuff tablets (Student's t-test, $t=5.55$, $df=157.02$, $p<0.001$) within individual burials. In addition, the Solcor 3 cemetery demonstrates a greater incorporation of Tiwanaku-style material culture into the burial assemblage, as measured by a significantly larger proportion of individuals buried with Tiwanaku goods ($\chi^2=10.277$, $df=1$, $p=0.001$). Correlation between the presence of local high status goods and Tiwanaku goods in individual burial assemblages within the Solcor 3 cemetery is very weak (Pearson's $r = 0.059$), however, indicating that burial with Tiwanaku goods was largely independent from overall burial wealth. The slight difference between the Solcor 3 and Solcor Plaza cemeteries in the proportion of individuals buried with stylistically nonlocal goods linked to areas other than Tiwanaku does not reach statistical significance ($\chi^2=3.133$, $df=1$, $p=0.078$).

Individuals interred within each cemetery employed multiple cranial modification styles (Table 4) but differed in the proportion of individuals featuring traditionally foreign or local forms. While the overall proportion of modified and unmodified crania is not significantly different between the cemetery samples ($\chi^2=2.648$, $df=1$, $p=0.104$), there was a highly significant distinction in the forms of cranial modification present at the two sites ($\chi^2=7.457$, $df=1$, $p=0.006$), with annular forms characteristic of the *altiplano* much more common at Solcor Plaza than at Solcor 3.

Table 4. Distribution of cranial vault modification styles among individuals interred in the Solcor 3 and Solcor Plaza cemeteries.
Distribución de los tipos de deformación craneana entre los individuos enterrados en los cementerios de Solcor 3 y Solcor Plaza.

Cemetery	Unmodified		Tabular Forms						Annular Forms					
			Tabular Erect		Tabular Oblique		Total		Annular Erect		Annular Oblique		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Solcor 3	55	49	25	22	11	10	36	32	6	5	16	14	22	19
Solcor Plaza	45	61	4	5	5	7	9	12	7	9	13	18	20	27

Table 5. Distribution of grave good categories within the Solcor *ayllu*.
Distribución de las categorías de objetos mortuorios en el ayllu *Solcor.*

Cemetery	Tiwanaku		Other Foreign		Local High Status	
	Individuals	Per-individual frequency	Individuals	Per-individual frequency	Individuals	Per-individual frequency
Solcor 3	19/118 (16%)	0.24	5/118 (4%)	0.11	74/118 (63%)	1.95
Solcor Plaza	1/72 (1%)	0.01	0/72 (0%)	0.00	20/72 (28%)	0.47

Biogeochemical data

Diagenetic contamination

Before meaningful interpretations of isotopic data can be made, the possibility of diagenetic alteration to the chemical composition of the samples must be assessed. Elements such as uranium and neodymium, which are absent or present in extremely low levels in normal, unaltered bone can be used to detect the uptake of contaminants during diagenesis (Kohn et al. 1999). Uranium and neodymium concentrations are uniformly low among our samples, which is expected in enamel and bone that has not been diagenetically altered. The highest ratio of U/Ca present among our samples is 1.9 x 10^{-10} (ACL-1825 SC3-0111), a value several orders of magnitude lower than values considered acceptable by other authors (e.g., Price et al. 2002).

Stable carbon isotope analysis

Carbon isotope data from bone carbonate suggest that individuals at San Pedro de Atacama relied on a diet relatively abundant in maize or other C_4 food resources, which could have been consumed either directly or indirectly through the consumption of animals that themselves regularly ate C_4 resources (Figure 4). Patterned differences do exist between the cemeteries, however, with individuals from the Solcor Plaza cemetery featuring significantly higher average $\delta^{13}C$ values than those interred in the Solcor 3 cemetery (Student's t-test, t=-4.10, df=26.08, p<0.001). These differences indicate that members of the social group interred in the Solcor Plaza cemetery consumed greater relative quantities of maize or other C_4 resources during childhood than those interred in Solcor 3.

Three individuals identified as nonlocal through their strontium isotope signatures had a childhood diet different from the majority of individuals interred in the Solcor cemeteries. One nonlocal adult male interred in the Solcor 3 cemetery (F-1681 SC3-0050) had a childhood diet enriched in maize or other C_4 plants relative to all other individuals, while two nonlocal individuals with likely *altiplano* origins interred in the Solcor Plaza cemetery (ACL-1833 SCP-2940 and ACL-1832 SCP-0625) featured a childhood diet more heavily based on C_3 plant resources than the majority of individuals interred in the Solcor cemeteries. Two other individuals with nonlocal strontium isotope signatures (discussed below) do not show substantial differences in diet from the rest of the individuals in this sample.

Because many marine foods have a carbon isotope signature similar to that of C_4 plants such as maize (Chisholm et al. 1982), additional nitrogen isotope data is necessary in order to determine whether or not the $\delta^{13}C_{carbonate}$ values reported here reflect marine food consumption among some or all of the individuals interred in the Solcor cemeteries. Carbon isotope data from the collagen portion of bone could also help to determine whether the dietary source of isotopically heavy carbon was consumed directly through plant resources or indirectly through animal-derived foods.

Radiogenic strontium and stable oxygen isotope analysis

The distribution of radiogenic strontium and stable oxygen isotope values found in the tooth enamel of individuals from the Solcor *ayllu* is presented in Figure 5. Five individuals display $^{87}Sr/^{86}Sr$ values far outside the local range (Knudson 2008) and appear to have originated from two or more separate geographical areas. Two adult females (ACL-1829 SCP-2938 and ACL-1833 SCP-2940) and one adult male (ACL-1832 SCP-0625) buried in the Solcor Plaza cemetery show radiogenic strontium isotope values consistent with an origin in the southeastern Lake Titicaca Basin. A fourth adult female (ACL-1826 SC3-0097) buried in the Solcor 3 cemetery additionally displays an enamel strontium isotope ratio indicating an origin in the *altiplano*. The fifth individual, an adult male interred within the Solcor 3 cemetery, is represented by two nonlocal enamel values derived from the first and second molars (samples F1681 SC3-0050 and ACL-1533 SC3-0050). This individual appears to have been born outside of either the San Pedro de Atacama or the Lake Titicaca areas, and to have subsequently moved elsewhere prior to or during the mineralization of the second molar crown.

In addition to these five individuals, a number of individuals from Solcor 3 were found to have enamel strontium isotope values only slightly outside the published local baseline values for San Pedro de Atacama ($^{87}Sr/^{86}Sr$ = 0.7074-0.7079; Knudson 2007, 2008; Knudson and Price 2007). It is possible that the current baseline characterization of

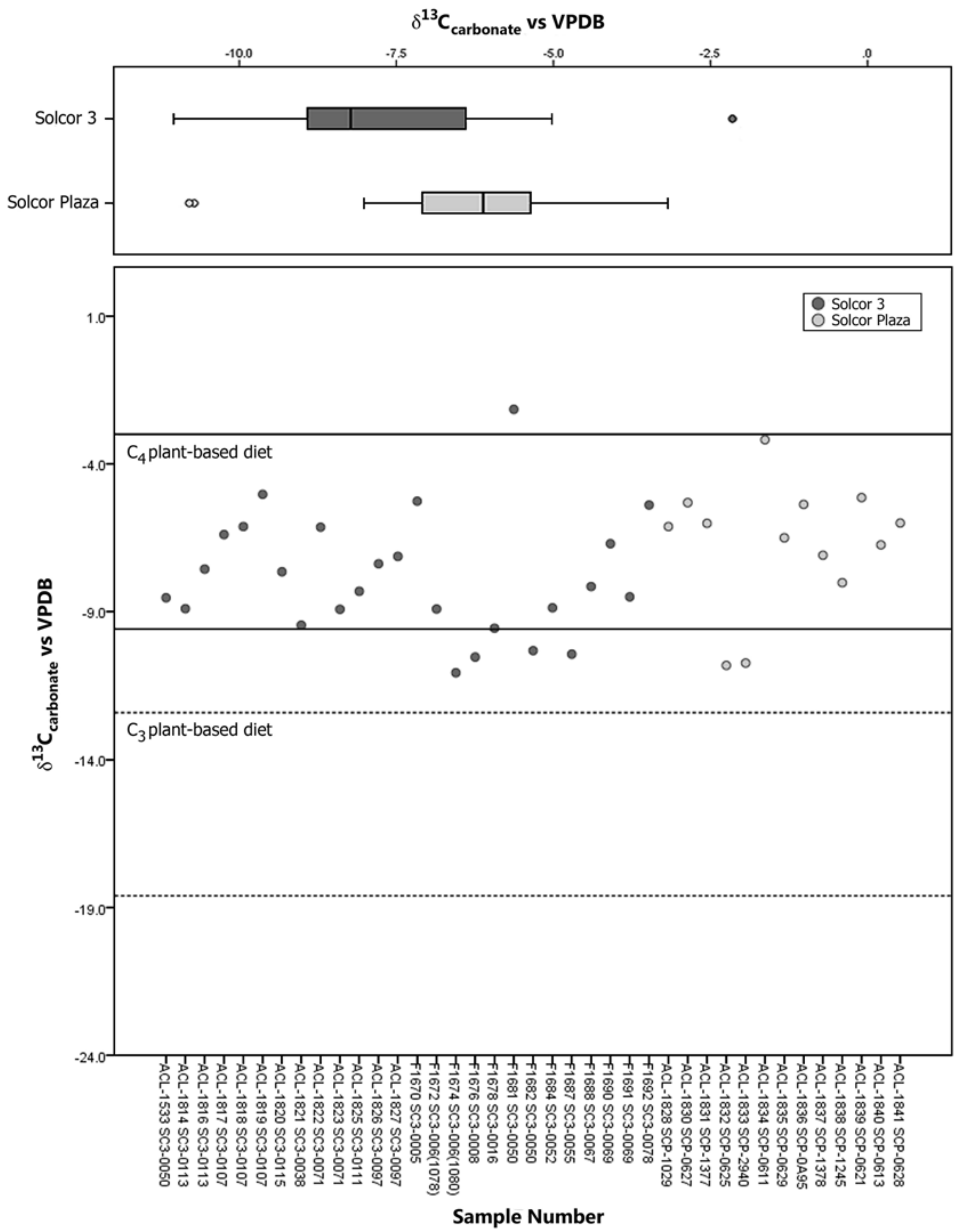

Figure 4. Carbon isotope signatures in bone and tooth enamel carbonate of individuals interred in the Solcor 3 and Solcor Plaza cemeteries.
Índices de isótopos de carbono en el carbonato de huesos y dientes de individuos enterrados en los cementerios de Solcor 3 y Solcor Plaza.

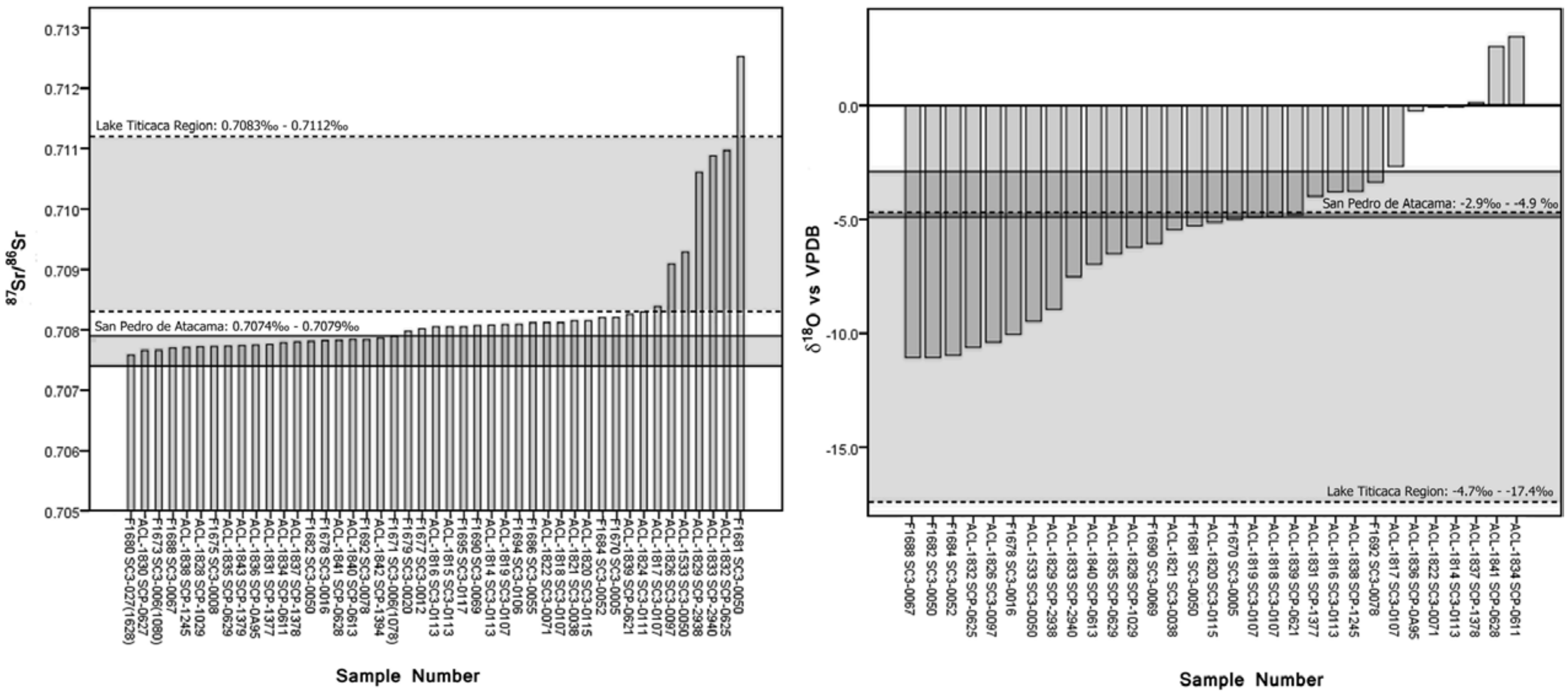

Figure 5. Strontium and oxygen isotope signatures from the tooth enamel of individuals from the Solcor cemeteries. The solid lines delineate the local range of isotope values for the San Pedro de Atacama area, while the dashed lines demonstrate baseline values for the southeastern Lake Titicaca Basin.
Índices de isótopos de estroncio y oxígeno del esmalte de los dientes de los individuos enterrados en los cementerios de Solcor. Las líneas continuas delimitan el rango local de los valores de isótopo de San Pedro de Atacama, mientras que las líneas discontinuas muestran los valores para el sureste de la cuenca del Lago Titicaca.

Table 6. Cranial modification style and funerary materials associated with strontium isotope outliers.
Estilo de modificación craneal y materiales funerarios relacionados con individuos con valores extremos de isótopos de estroncio.

Cemetery	Specimen number	Sex	Cranial Vault Modification	Foreign Goods	Tiwanaku Goods	Local High Status Goods
Solcor 3	SC3-0050	Male	Tabular	Absent	Absent	Present
Solcor 3	SC3-0097	Female	Tabular	Absent	Absent	Present
Solcor Plaza	SCP-2938	Female	Tabular	Absent	Absent	Absent
Solcor Plaza	SCP-2940	Female	Tabular	Absent	Absent	Present
Solcor Plaza	SCP-0625	Male	Unmodified	Absent	Absent	Absent

the area does not adequately represent the range of local variation at San Pedro or alternatively, that the catchment area for the Solcor 3 cemetery may have extended beyond the immediately local area. Similarly, relatively few individuals within the Solcor cemeteries have $\delta^{18}O_{carbonate\ (VPDB)}$ values falling within the currently established local range for San Pedro de Atacama (Knudson 2009), potentially indicating that the San Pedro de Atacama area is characterized by greater oxygen isotope variation than currently recognized. The broad range of oxygen isotope signatures found among individuals buried in the Solcor cemeteries is not entirely unexpected, as the mixing of water sources can often lead to high within-site variability in $\delta^{18}O$ signatures (Knudson 2009).

Differences in radiogenic strontium isotope signatures within the San Pedro population do appear to pattern with cemetery membership. In all but one case, individuals with enamel strontium isotope signatures slightly above published local baseline values were interred within the Solcor 3 cemetery. Indeed, the majority of enamel values produced for individuals sampled from the Solcor 3 cemetery (n=18/25; 72%) fall into this "slightly nonlocal" strontium isotope range, while all but one individual sampled from the Solcor Plaza cemetery (n=13/14; 93%) fall well within published local baseline values. This difference between the cemeteries in the proportion of individuals displaying local and slightly nonlocal strontium isotope signatures is statistically significant (χ^2=15.11, df=1, p=0.0001) and suggests corresponding differences in strontium sources for individuals interred in these two cemeteries, perhaps in the form of subgroup-specific dietary patterns involving the consumption of foods grown or caught in slightly differing geological areas.

Despite the presence of nonlocal goods and highly varied cranial modification styles within the Solcor *ayllu*, these cultural symbols were associated primarily with local individuals. Cranial modification data show the exclusive use of tabular forms -the local variant- among individuals with nonlocal isotope signatures despite the high incidence of annular forms within both cemeteries. Additionally, none of the non-local individuals were buried with Tiwanaku objects, despite their presence elsewhere in these cemeteries (see Table 6).

Discussion and Conclusions

Our data present a complex picture of the local negotiation of foreign influence within the Solcor *ayllu*. Though individuals buried at both Solcor 3 and Solcor Plaza appear to have had a strong overarching Atacameño identity reflected in their primarily local-style mortuary treatment, the patterned differences that we have demonstrated in diet, cultural body modifications, and mortuary treatment between individuals interred in the Solcor 3 and Solcor Plaza cemeteries suggest that social identities were also formulated and negotiated at the scale of subgroups within the broader Solcor *ayllu*. The data also suggest that social identities within the Solcor *ayllu* were not straightforward or static. While cultural differences were maintained between local residents of the site in part using foreign symbols of identity, nonlocal individuals were incorporated into the local population and displayed distinctly Atacameño identities in burial.

The varied patterns of cranial vault modification and differential distribution of foreign goods between the two cemeteries investigated here suggest local variability in the adoption of Tiwanaku culture in a way that strongly patterns with cemetery membership. Particularly, the statistically significant difference in the use of annular forms among individuals interred in the two cemeteries suggests differing use of the body, potentially as a symbol of real or fictive interactions with groups from different areas of the Tiwanaku polity. Annular forms of cranial modification remain uncommon at San Pedro de Atacama through time (Torres-Rouff 2002, 2009) and are much more characteristic of prehispanic groups living in the Bolivian highlands and on the Chilean coast (Arriaza 1988; Cocilovo 1994; Marroquin 1944). It is possible that individuals interred in the Solcor Plaza cemetery used annular cranial modification forms to a greater extent than those interred in Solcor 3 to emphasize ties with foreign regions.

In contrast, the population interred within the Solcor 3 cemetery expressed their relationship with the Tiwanaku polity by incorporating Tiwanaku-style material goods into the funerary ritual. Though the generally higher socioeconomic standing of this social group, as indicated by their greater burial wealth, may suggest that members of the Solcor 3 subgroup were better able to acquire Tiwanaku-style material goods through trade or elite influence, the weak correlation between local high value goods and Tiwanaku-style material culture within individual burials in the Solcor 3 cemetery suggests that incorporation of Tiwanaku goods into the burial ritual served as a mechanism of group differentiation largely independent from individual economic standing. The lack of association between annular cranial vault modification and Tiwanaku grave goods (χ^2=1.350, df=2, p=0.509) suggests that these foreign symbols formed distinct and separate strategies for asserting group identity with reference to foreign powers.

Given the ritual and political importance of maize throughout time in the Andes (Cavero Carrasco 1986; Hastorf and Johannessen 1993), as well as evidence for the large-scale production of maize beer during the Middle Horizon (e.g., Cook and Glowacki 2003; Goldstein 2003; Janusek 2004), our carbon isotope results indicate that differential consumption of maize or of maize beer may have played a role in shaping and maintaining social distinctions between individuals or groups at San Pedro. If the slightly divergent radiogenic strontium isotope discrepancies between individuals interred in the Solcor 3 and Solcor Plaza cemeteries represent differences in the geographic origin of food sources, they may indicate that dietary distinctions between the social groups were maintained based not only on the types of foods consumed but also on the origins of food sources exploited.

Our results suggest more extensive immigration into San Pedro than previously identified and are consistent with the hypothesis that the expansion of a common Tiwanaku-style material culture tradition during the Middle Horizon period would have facilitated migration between San Pedro and other areas in the southern Andes. Previous radiogenic strontium isotope analyses conducted on skeletal material from San Pedro de Atacama have suggested that few first-generation migrants from other regions of the Tiwanaku polity were buried within the cemeteries of Solcor 3, Coyo 3, and Coyo Oriental (Knudson 2008; Knudson and Price 2007). The oxygen and strontium isotope analyses presented here do, however, indicate that both local individuals and first-generation migrants potentially from the Tiwanaku core were present within the Solcor cemeteries. The results presented here are also consistent with skeletal analyses documenting an increase in genetic diversity in the Atacama during this time period (Varela and Cocilovo 2002).

The burial assemblages of radiogenic strontium and stable oxygen isotope outliers suggest a degree of flexibility in *ayllu* group identity in terms of the assimilation of nonlocals into local traditions. The complete lack of Tiwanaku and other foreign goods in the burials of both adult male and adult female outliers indicates that though these individuals were born outside of the oases, they were not treated as outsiders in death. This pattern corroborates earlier observations by Torres-Rouff and Knudson (2007) concerning the ability of nonlocal individuals to acculturate into local Atacameño society. Taken together, these data do not support a direct colonization model, but rather migration into San Pedro by a diverse group of foreigners. Rather than maintaining a distinct foreign identity in the grave vis-à-vis objects from their homeland, these individuals instead appear to have adopted local material culture and group identities.

The data presented here indicate that local social group membership mediated the ways in which Tiwanaku cultural symbols were accepted and employed by residents of San Pedro de Atacama. While the use of Tiwanaku goods in the mortuary record of the Solcor cemeteries is not straightforwardly linked with the presence or identity of immigrants from the *altiplano*, local group identity as manifested through burial in separate cemeteries appears to remain socially salient during the

Middle Horizon and is emphasized in part through differential adoption and incorporation of certain facets of Tiwanaku culture into mortuary contexts and cranial modification forms. Rather than simply receiving forms of social organization transmitted uniformly from core to periphery, individuals in San Pedro de Atacama manipulated the material indicators of contact with Tiwanaku within their peripheral setting in order to negotiate their local community identities.

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Note

1 Carbon isotope ratios are expressed as a δ value, defined as: $\delta^{13}C=((^{13}C/^{12}C_{sample} - {}^{13}C/^{12}C_{standard})/(^{13}C/^{12}C_{standard})) \times 1{,}000$ (Coplen 1994). Oxygen isotope signatures ($\delta^{18}O$) are defined similarly to $\delta^{13}C$, though the ratio of $^{18}O/^{16}O$ is substituted for $^{13}C/^{12}C$.