EATING FISH IN THE DRIEST DESERT IN THE WORLD:
OSTEOLOGICAL AND BIOGEOCHEMICAL ANALYSES OF HUMAN
SKELETAL REMAINS FROM THE SAN SALVADOR CEMETERY,
NORTH CHILE

Christina Torres-Rouff, William J. Pestle, and Francisco Gallardo

The San Salvador River in northern Chile is a tributary of the Loa, the only river that traverses the Atacama Desert from the mountains to the Pacific. Recent investigations along the San Salvador River revealed the presence of a Formative period village site and associated cemetery approximately 110 km inland from the Pacific Ocean. Bioarchaeological and biogeochemical analyses conducted on human skeletal remains recovered from the San Salvador Cemetery allowed us to better understand the site’s role as an intermediary for coast/interior relations during the Middle Formative (500 B.C.–A.D. 100). Evidence from material culture and human remains at San Salvador suggests that this population was involved in exchange networks that united the oases of the Atacama Desert with the Pacific Ocean. Isotopic data support this notion, as the population demonstrates great variability in both the protein (marine and terrestrial) and carbohydrate components of their diet. During this period, communal economies produced surpluses used in a network of exchange for foods, prestige goods, and ideas. These ties were not coincidental but, rather, part of a regional economic structure that remains only partly explored.

El Río San Salvador del norte de Chile es un afluente del Río Loa, el único curso de agua dulce que atraviesa el desierto de Atacama desde las montañas hasta el Pacífico. Recientes investigaciones en San Salvador revelaron la presencia de una aldea y un cementerio del periodo Formativo emplazados a unos 110 km. de la costa del Pacífico. Análisis bioantropológicos y biogeoquímicos llevados a cabo en restos óseos humanos recuperados del cementerio permitieron comprender el funcionamiento del sitio como intermediario en las relaciones entre la costa y el interior en el Formativo Medio (500 a.C.–100 d.C.). La evidencia de la cultura material y de los restos humanos en San Salvador indica que esta población estuvo involucrada en las redes de intercambio que ligaban los oasis del desierto de Atacama y el Océano Pacífico. Los datos isotópicos apoyan esto, pues la población muestra una gran variabilidad tanto en el consumo de proteína (marina y terrestre) como en los componentes de carbohidratos en su dieta. Durante este período las economías comunales produjeron excedentes utilizados en una red de intercambio de alimentos, bienes de prestigio e ideas. Estos lazos no fueron circunstanciales, sino parte de una estructura económica regional que hasta ahora ha sido parcialmente explorada.

In the Andes, research on the social nature of prehistorical trade and interaction has yielded foundational works including Murra’s (1972, 1985) vertical archipelago, Núñez and Dillehay’s (1995) movilidad giratoria, and Martínez’s (1998) territorialidad salpicada. While these themes are of ongoing interest, much archaeological research has focused on patterns of trade in large, complex societies while neglecting small-scale exchange (Berenguer 2004; Dillehay et al. 2006; Nielsen 2004; Schortman and Urban 1992). This narrow vision has had some negative effects in the Andes, where archaeologists have placed great emphasis on the exchange networks, llama caravans, and extensive trade routes of large states and empires at the expense of smaller-scale/intensity trade interactions (e.g., Malpass 1993; Trombold 1991).

More recently, archaeologists have stepped away from binary notions of core and periphery, beginning to explore supposed empty spaces—areas

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between population centers that, while not principal nodes, may have served as loci for different forms of relationships between groups (e.g., Cases et al. 2008; Nielsen 2004; Upham 1992). Lazzari has argued that for Formative period northwest Argentina, scholars need “to think of circulation networks . . . as more flexible and complicated and as a reflection of the constitution and preproduction of different social bonds” (2005a:202). Consideration of varied mobility strategies may provide one means of approaching this flexibility. Nielsen (2004:33) stresses the value of internodal spaces for helping understand the negotiation of social relations by considering the role of individual actors and argues that this type of study requires the use of multiple lines of evidence. Here, by focusing on skeletal remains from a small cemetery associated with a settlement that likely facilitated some movements of peoples, goods, and ideas across the Atacama Desert during the Formative period (1500 B.C.–A.D. 500), we complement archaeological research in the region by providing bioarchaeological and biogeochemical perspectives on movement and exchange between northern Chile’s coast and interior. In doing so, we explore the idea that these varied movements between population groups and across the open desert included individuals in trade outposts located in otherwise unpopulated areas. The individuals and settlements found therein can help to shed light on the way that prehistoric peoples used these spaces and the dynamic created when groups interacted. Pimentel and colleagues (2010) posit that in northern Chile’s Formative period there were at least two forms of mobility, one being a small-scale pedestrian movement instigated by coastal populations in search of resources and the other encompassing the highland caravan modality. Evidence from this series of excavations
suggests that the sites along the San Salvador were logistically situated occupations resulting from increasing social complexity and increasingly complex patterns of interaction between the coast and highlands, processes that had already begun at the end of the Archaic period (Ballester and Gallardo 2011; de Souza et al. 2010; Gallardo 2009). As such, the San Salvador sites served as stable and strategic outposts for the travelers who connected the Middle Loa with the coast. This small sample provides us with an interesting view on mobility in the Formative period.

San Salvador

The San Salvador is a tributary of the Loa River (Figure 1), the only river that traverses the breadth of the hyperarid Atacama Desert of northern Chile from the mountains to the Pacific. During the Formative period in this region we see burgeoning numbers of permanent and semipermanent settlements in combination with plant and animal domestication, as well as intensified camelid pastoralism (Gallardo 2009; Lumberras 2006; Núñez, Cartajena, Carrasco, de Souza, and Grosjean 2006). Pastoralism and plant collecting form the basis of this period’s economy, despite the beginnings of small-scale agriculture and the intensification of hunting (Agüero 2005; Núñez, Cartajena, Carrasco, and de Souza 2006; Sinclaire 2004). Archaeological evidence from the Formative period has demonstrated a flow of goods through this region between more consolidated centers, or nodes, such as Tarapacá in the north and the San Pedro de Atacama oases in the interior (Agüero et al. 2004). By the Middle Formative (500 B.C.–A.D. 100), there is evidence of exchange throughout the region, from the Pacific coast to northwest Argentina. This accumulation of social and economic changes is likely tied to the rise of surplus economies, not only among settled agriculturalists but also for the marine hunter-gatherers of the coast (Gallardo 2009). Both of these patterns are evident in sites such as those discussed here, sites that occupy “empty” spaces between populations and foment interregional interaction.

During archaeological survey along the San Salvador River, the remains of a small village and cemetery were documented approximately 110 km inland along the river at 1,370 m asl (Figure 1). Other than a brief note on a looted tomb (Sphani 1964), this survey provided the first evidence of prehistoric human occupation along the San Salvador. The San Salvador sites are found 40 km west of Calama in empty desert close to a prehispanic route that linked the Calama oasis west to the coast at Cobija (110 km) and northwest to the Quillagua oasis (93 km). Their size, specialized production, and material culture suggest their logistical character in service to the population of Calama. This is particularly true if one considers that the archaeological localities mentioned above have Formative period cemeteries that have yielded hundreds of human remains. These suggest increasing population resulting from sedentism and the intensification of production during the Formative (e.g., Gallardo et al. 1993; Moragas 1982).

Excavation and surface collection were conducted at the San Salvador Village and Cemetery in 2008. Radiocarbon dates place both sites squarely in the Middle Formative period (cemetry: 2080 ± 40 B.P. [Beta-247417], 164 cal B.C.–cal A.D. 128 [p = .07] and 121 cal B.C.–cal A.D. 67 [p = .93]; village: 2370 ± 40 B.P. [Beta-247418], 511–350 cal B.C. [p = .72] and 311–209 cal B.C. [p = .28]; calibrated at 2σ with the program CALIB 6.0 using the SHCal04 curve [McCormac et al. 2004; Stuiver et al. 2005]). The village was dated using a roof tile found in one of the rooms, offering evidence for the earliest portion of the Salvador occupations. This suggests that the two dates are consistent, given that the cemetery, which is spatially and culturally associated with the village, should postdate the original construction of the habitations.

The San Salvador Village (Aldea San Salvador), located on a terrace above the river west of the cemetery, comprises approximately 15–20 circular pits with poles sustaining thatched roofs. This style of construction is consistent with the structure of other habitation sites along the Middle Loa River (Pollard 1970). Excavation of a trash midden confirmed the presence of camelids and an unusual abundance of algarrobo seeds (Prosopis flexuosa), a local fruit, as well as the remains of marine fish, likely transported to the site as a dried good. Multiple species of marine fish (Trachurus simetricus, Citus gilberti, and Graus nigra) and shells, including some carved into small beads that could have been used as adornments (Turritela cingulata, Oliva peruviana, Loxechinus albu, and
**Choromytilus choris**), were found at the site, suggesting a tie to coastal populations. Our excavations revealed no remains of freshwater fish. Finds at the village site also included vegetable and wool cordage, leather, feathers, a projectile point, carved wooden instruments, cactus spines, and gourds. It is probable that the settlement was placed at this part of the river’s course because of its proximity to grazing lands and to a small forest of algarrobo trees (de Ugarte and Gallardo 2010). The incredible preponderance of algarrobo among the botanical remains in concert with the presence of grinding stones suggests the site’s role as a production site for algarrobo flour, which could then be used as an exchange good as well as serving as a dietary staple. Foreshadowing the isotopic results discussed below, no evidence of maize (Zea mays) was recovered in the cemetery or residential excavations (de Ugarte and Gallardo 2010) despite 5-mm mesh screening and its archaeological visibility at other sites in the region, where it is frequently included as a grave offering.

The San Salvador Cemetery (Cementerio San Salvador) is located just upriver from the village site. Found on an elevated ridge above the river itself, the cemetery likely comprises some 20–25 interments in small ovoid pits demarcated by wooden posts. Some portion of the cemetery was looted during the nitrate boom of the 1930s, as determined through glass bottles found at the site. As a result, many human remains were exposed and commingled on the surface. We recovered all human remains and remaining artifacts from eight of these tombs as well as the surrounding areas. Tombs appear to have included, among other things, pottery, baskets, lithics, beads, and textiles in the form of clothing and bags. Also providing evidence for a coastal tie, *locu* (Concholepas concholepas) shells filled with pigment were among the grave goods. In line with the finds at the village site, we found a small bundle of algarrobo seedpods tied together with cord among the offerings in one tomb but no evidence of maize, a common inclusion in other regional graves. Contemporary burials from sites in Calama have produced material culture (including textiles, ceramics, and basketry) that parallels that seen in the mortuary contexts at San Salvador (González and Westfall 2006; Thomas et al. 1995). However, reflecting the Formative period’s patterns of increasing interregional interaction, goods found at the San Salvador Cemetery come from diverse areas.

Considered together, these excavations yielded evidence of interaction not just with the coast as detailed above but also with northwest Argentina. Among the trans-Andean finds were the leg of a ceramic figurine, a tubular black polished pipe fragment, and black polished ceramic fragments in shapes similar to those found in the Calchaqui Valley (e.g., Baldini 2007). In concert with the coastal material, these archaeological details support the idea that the San Salvador sites were logistical outposts that facilitated movement between the coast and the interior. Evidence from the site indicates intensive exploitation of the valley’s plant resources, maintenance of camelid herds, regular access to coastal products, and a close relationship with contemporary populations from the coastal areas of Cobija and the mouth of the Loa River as well as with other oases, such as Quillagua, Calama, and Chiu-Chiu (Agüero et al. 2004; Moragas 1982; Pollard 1970; Spahni 1964, 1967; Thomas et al. 1995). Below we present the results of skeletal analyses of the 17 fragmented human remains recovered from the San Salvador Cemetery to explore the inhabitants of this area in more detail. We follow this with a detailed analysis of paleodiet as determined through stable isotope analyses of carbon and nitrogen.

**Skeletal Analyses**

The remains of 17 individuals were recovered from eight tombs and surrounding areas at the San Salvador Cemetery (Table 1). All human skeletal remains were assessed using standard bioarchaeological protocols (Buikstra and Ubelaker 1994; Buzon et al. 2005). Minimum number of individuals was calculated for each of the tombs and surrounding areas. Sex was determined based on the sexually dimorphic features of the os coxae and the skull. Similarly, broad age assessments were made based on pelvic morphology, epiphyseal fusion, and cranial suture closure. Remains were also analyzed and scored for visible pathology and trauma. All observable pathology was documented using standard methods and terminology (Buikstra and Ubelaker 1994). Finally, each skull was examined visually for the presence and type (annular vs. tabular) of deliberate cranial shaping using adjustments
Table 1. Individuals Recovered from the San Salvador Cemetery and Results of Stable Isotope Analyses.

<table>
<thead>
<tr>
<th>Individual</th>
<th>Age</th>
<th>Sex</th>
<th>Isotope sample no.</th>
<th>Sample type</th>
<th>Element sampled</th>
<th>Collagen yield (wt%)</th>
<th>wt% C</th>
<th>wt% N</th>
<th>Atomic C:N</th>
<th>δ¹³C (‰)</th>
<th>δ¹⁵N (‰)</th>
<th>Apatite yield (wt%)</th>
<th>δ¹³C (‰)</th>
<th>Δ¹³C (‰)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Adult</td>
<td>Male?</td>
<td>A-19</td>
<td>Bone</td>
<td>Rb</td>
<td></td>
<td>4.4</td>
<td>13.5</td>
<td>40.0</td>
<td>3.5</td>
<td>11.2</td>
<td>-16.6</td>
<td>70.2</td>
<td>-10.9</td>
<td>5.8</td>
</tr>
<tr>
<td>1.2 Juvenile (8-12 yo)</td>
<td>-</td>
<td>A-20</td>
<td>Bone</td>
<td>Cervical vertebra</td>
<td></td>
<td>1.1</td>
<td>-</td>
<td>2.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F-26</td>
<td>Tooth (root)</td>
<td>Right maxillary P4</td>
<td></td>
<td>1.5</td>
<td>-</td>
<td>0.8</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>91.1</td>
<td>-20.3</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E-109</td>
<td>Bone</td>
<td>4th metatarsal</td>
<td></td>
<td>2.7</td>
<td>4.1</td>
<td>12.4</td>
<td>3.5</td>
<td>13.3</td>
<td>-17.4</td>
<td>74.1</td>
<td>-13.3</td>
<td>4.2</td>
</tr>
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<td>1.3 Adult</td>
<td>Female?</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>1.4 Juvenile (4-6 yo)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>1.5 Juvenile (2-4 yo)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
<td>n/a</td>
<td>n/a</td>
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<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>1.6 Fetal</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
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<td>n/a</td>
<td>n/a</td>
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<tr>
<td>2.1 Adult</td>
<td>Female</td>
<td>A-21</td>
<td>Bone</td>
<td>Right radius</td>
<td></td>
<td>3.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2.2 Adult</td>
<td></td>
<td>A-22</td>
<td>Bone</td>
<td>1st rib</td>
<td></td>
<td>1.6</td>
<td>-</td>
<td>3.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>85.9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A-23</td>
<td>Bone</td>
<td>Rb</td>
<td></td>
<td>0.6</td>
<td>4.4</td>
<td>14.1</td>
<td>3.7</td>
<td>12.3</td>
<td>-18.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td></td>
<td></td>
<td>A-71</td>
<td>Bone</td>
<td>Clavicle</td>
<td></td>
<td>0.7</td>
<td>-</td>
<td>8.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>77.1</td>
<td>-</td>
<td>-</td>
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<tr>
<td></td>
<td></td>
<td>F-27</td>
<td>Tooth (root)</td>
<td>M3²</td>
<td></td>
<td>12.3</td>
<td>12.8</td>
<td>36.2</td>
<td>3.3</td>
<td>15.4</td>
<td>-16.9</td>
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<td>4.9</td>
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<td>3.1 Middle Adult</td>
<td>Male</td>
<td>A-25</td>
<td>Bone</td>
<td>Humerus?</td>
<td></td>
<td>2.1</td>
<td>11.5</td>
<td>34.2</td>
<td>3.5</td>
<td>12.9</td>
<td>-18.3</td>
<td>82.0</td>
<td>-10.4</td>
<td>7.9</td>
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<td>5.1 Middle Adult</td>
<td>Male</td>
<td>A-26</td>
<td>Bone</td>
<td>Rb</td>
<td></td>
<td>19.0</td>
<td>14.5</td>
<td>42.1</td>
<td>3.4</td>
<td>14.4</td>
<td>-15.5</td>
<td>63.3</td>
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<td>4.9</td>
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<tr>
<td>5.2 Adult</td>
<td></td>
<td>A-27</td>
<td>Bone</td>
<td>Cranial fragment</td>
<td></td>
<td>5.1</td>
<td>13.0</td>
<td>37.8</td>
<td>3.4</td>
<td>14.6</td>
<td>-16.2</td>
<td>71.8</td>
<td>-11.3</td>
<td>4.9</td>
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<tr>
<td>8.1 Adolescent (16-20)</td>
<td>A-28</td>
<td>Bone</td>
<td>Rb</td>
<td></td>
<td></td>
<td>0.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
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<tr>
<td></td>
<td></td>
<td>A-70</td>
<td>Bone</td>
<td>uld long bone</td>
<td></td>
<td>4.0</td>
<td>10.8</td>
<td>29.9</td>
<td>3.2</td>
<td>8.34</td>
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<td>78.3</td>
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<td>7.1</td>
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<td></td>
<td></td>
<td>F-25</td>
<td>Tooth (enamel)</td>
<td>M3</td>
<td></td>
<td>-</td>
<td>-</td>
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<td>-</td>
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<td>96.6</td>
<td>-14.3</td>
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<tr>
<td>9.1 Young Adult</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
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<td>n/a</td>
</tr>
<tr>
<td>10.1 Adult</td>
<td></td>
<td>A-29</td>
<td>Bone</td>
<td>Humerus?</td>
<td></td>
<td>0.6</td>
<td>7.2</td>
<td>22.4</td>
<td>3.6</td>
<td>10.6</td>
<td>-17.4</td>
<td>83.4</td>
<td>-9.7</td>
<td>7.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A-72</td>
<td>Bone</td>
<td>Fibula</td>
<td></td>
<td>1.9</td>
<td>5.8</td>
<td>17.2</td>
<td>3.5</td>
<td>11.6</td>
<td>-15.5</td>
<td>79.9</td>
<td>-9.4</td>
<td>6.1</td>
</tr>
<tr>
<td>11.1 Juvenile (4-6 yo)</td>
<td>A-30</td>
<td>Bone</td>
<td>12th rib</td>
<td></td>
<td></td>
<td>1.0</td>
<td>-</td>
<td>3.2</td>
<td>-</td>
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<td></td>
<td></td>
<td>E-110</td>
<td>Bone</td>
<td>Rb</td>
<td></td>
<td>1.7</td>
<td>2.6</td>
<td>8.5</td>
<td>3.9</td>
<td>12.6</td>
<td>-16.9</td>
<td>72.1</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Individuals in bold and italics were excluded from consideration due to evidence of contamination, degradation, or instrument error.

For collagen analyses, replicate analyses of acetanilide (the laboratory secondary standard), and working standards (thiourea and hydroxyproline) resulted in reproducibility of ±0.1% for δ¹³C and ±0.2% for δ¹⁵N. For hydroxyapatite carbonate analyses, replicate analyses of BaCO₃ and CaCO₃ resulted in reproducibility of ±0.1% for δ¹³C. Carbon isotope ratios are reported relative to the V-PDB (Vienna PeeDee Belemnite) carbonate standard and are expressed in parts per mil (‰) using the following standard formula: δ¹³C = ((Csample/Cstandard) − 1) × 10⁶ (Craig 1957). Nitrogen isotope ratios are reported relative to the AIR (atmospheric nitrogen) standard and are expressed in parts per mil (‰) using the following formula: δ¹⁵N = ((Nsample/Nstandard) − 1) × 1,000 (Marotti, 1983).
to the broad classification system that originates with Dembo and Imbolloni (1938). In all cases, preservation differentially affected the sample.

The San Salvador skeletal material is primarily postcranial, likely the result of the aforementioned looting. The 17 individuals recovered from San Salvador Cemetery ranged in completeness from individual 5.1, represented by very nearly an entire skeleton, part of which was naturally mummified, to several individuals represented by minimal fragments (i.e., individuals 6.1 and 7.1). While a number of remains could not be sexed or aged (or could only be determined to be adults), analysis of the sample revealed a number of juveniles (n = 6) as well as members of both sexes (Table 1).

Pathology in the sample appears to have been limited to degenerative processes (osteoarthritis) and traumatic injury. There is no evidence of infectious disease in any of the skeletal remains. Nevertheless, the remains seem to show effects from living in a harsh environment. Qualitative appraisal of muscle insertion sites and musculoskeletal stress markers on available adult long bone fragments suggests pronounced robusticity and perhaps substantial muscle use for two of the three adult males in this population (Hawkey and Merbs 1995). Given that these results may be a reflection of long-term body use, they might be considered a product of frequent activities in difficult terrain as opposed to a sign of significant labor intensity (e.g., Niimiki 2011). Osteoarthritis is visible on most adult remains; however, vertebrae were the only affected elements. This takes the form of coalescing porosity and lipping on vertebral bodies and articular surfaces, except in the case of individual 5.1, where this is augmented with the formation of osteophytes and the fusion of the articular surfaces of the first and second cervical vertebra.

Other pathological changes noted in this sample result from traumatic injury. All three adult male individuals whose remains were more complete showed evidence of fractures. Some injuries were quite significant, including a healed mandibular fracture below individual 5.1’s left mental foramen (Figure 2). Individual 3.1 suffered a series of complete fractures to the ribs ultimately resulting in misalignment of the ends during healing, producing substantial overlap medially (Figure 3). Individual 1.1 also showed healed rib fractures as well as injuries of his left distal ulna and radius, resulting in what appears to be a nonunion fracture of the distal metaphysis of the ulna. While this could be a parry fracture, a defensive injury (Buikstra and Ubelaker 1994; Judd 2008), the involvement of the radius suggests otherwise. It has been argued that cranial injuries are more indicative of intentional injury or violence, but there is no clear evidence of interpersonal violence among these individuals. It is possible that these injuries are products of the rocky landscape at San Salvador or similar areas. Unsurprisingly, analyses of cranial vault modification were hampered by the lack of crania. No cranial fragments could be definitively assessed for alterations to head shape. However, the one complete cranium (individual 5.1) demonstrated tabular erect cranial modification with a small degree of pressure resulting in a slight flattening of the anterior and posterior aspects of the skull (Figure 4). This form of head shaping is not unusual in north Chile’s interior (Torres-Rouff 2007). Given that cranial modification results from the inscription of cultural signifiers on the bodies of infants, it reflects strong, and likely less ephemeral, associations and as such may be suggestive of long-standing familial ties to a particular place or group in the interior.

While the skeletal remains do not provide direct evidence of origin or exchange, a few salient pieces of information can be derived from them. As mentioned above, our demographic data reveal the presence of potential family groups at the cemetery, suggesting a degree of permanence and stability for this settlement. This is bolstered somewhat by patterns of osteoarthritis and traumatic injury, both of which intimate a long-standing relationship with the landscape of the San Salvador Valley. The one complete cranium showed evidence of tabular erect modification, which is also suggestive of inland ties. During the Formative period, tabular forms are the most common shape seen among populations in the interior, and they stand in sharp contrast to the annular (circumferential) forms that are typical of contemporary coastal sites (Torres-Rouff 2003, 2007).

**Stable Isotope Analyses**

Isotopic reconstruction of human paleodiet is predicated on known variation in the carbon and nitrogen isotope signatures of broad classes of plant and animal foodstuffs. Incorporation of these known-
value items into body tissues allows for the reconstruction of the relative contribution of each class of foodstuff, ultimately providing individually specific data about diet. In cases where the dominant foods vary between regions (e.g., marine foods at the coast vs. terrestrial foods in inland areas), these data can also be used as a proxy for assessing mobility.

Stable carbon isotopes in plants vary according to photosynthetic pathway. Most terrestrial plants (including many cereals, legumes, vegetables, nuts, and fruits and locally available staples like potato and algarrobo) use a C₃, or Calvin, photosynthetic pathway; tropical grasses like maize (Zea mays) and the pseudocereal quinoa (Chenopodium spp.) use the C₄,
or Hatch- Slack, photosynthetic pathway; and cacti and succulents use the crassulacean acid metabolism (CAM) pathway (Calvin and Benson 1948; Hatch and Slack 1966; Kortshak et al. 1965; Ranson and Thomas 1960). Carbon isotope signatures also differ significantly between organisms from marine and terrestrial ecosystems as a result of dramatic differences in their carbon sources (Chisholm et al. 1982; Schoeninger and DeNiro 1984).

Stable nitrogen isotopes vary in a fairly predictable manner according to trophic level and are particularly useful for identifying marine food consumption given the clear differences in marine and terrestrial organisms’ nitrogen isotope signatures (Minagawa and Wada 1984; Schoeninger and DeNiro 1984; Schoeninger et al. 1983), although there are also climatic factors, aridity being most pertinent here, that can affect nitrogen isotope values (Ambrose 1991; Ambrose and DeNiro 1987). Since both plants and animals vary from region to region in their carbon and nitrogen signatures as a result of a number of environmental factors, local isotopic signatures are a necessary part of paleodietary reconstructions.

Turning to the human consumers, different fractions of skeletal or dental tissues reflect different portions and/or different temporal dimensions of an individual’s diet. Carbon isotope signatures in bone apatite (δ¹³Cᵦ) reflect carbon sources in the whole diet (these are predominantly carbohydrate-based in humans). Carbon and nitrogen isotopes of bone collagen (δ¹³Cᵦ and δ¹⁵Nᵦ) overwhelmingly reflect dietary protein sources (Ambrose and Norr 1993; Kellner and Schoeninger 2007). While the chemical makeup of bone collagen and hydroxyapatite reflects average diet over the last 10–30 years of an individual’s lifetime, the isotopic signature of tooth root (dentine) collagen and enamel apatite reflects diet at the time of a particular tooth’s formation. Therefore, chemical analyses of different body tissues and biomolecules provide insights into diet and mobility data over different portions of an individual life.

For this study, bone collagen, tooth root (dentine) collagen, and bone, tooth root (dentine), and enamel hydroxyapatite were extracted and purified in the National Science Foundation Stable Isotope Preparation Lab at the Field Museum of Natural
History using protocols from the Environmental Isotope Paleobiogeochemistry Laboratory at the University of Illinois, Urbana-Champaign (Ambrose 2007a, 2007b). These protocols are derived from Longin (1971) and Ambrose (1990) for dentine and bone collagen and Lee-Thorp (1989) and Koch et al. (1997) for dentine, enamel, and bone hydroxyapatite. Tooth root (dentine) collagen and apatite samples and enamel apatite samples were derived from complete homogenized roots or crowns rather than being sequentially microsampled. All isotope analyses were performed in the Stable Isotope Laboratory of the Department of Earth and Environmental Science at the University of Illinois at Chicago. Collagen analysis was carried out using a Thermo-Finnigan DeltaPLUSXL stable isotope ratio mass spectrometer equipped with a Costech Analytical ECS 4010 Elemental Analyzer coupled to the mass spectrometer via a Thermo-Finnigan ConFlo III. Hydroxyapatite carbonate samples were introduced to the mass spectrometer using a Thermo-Finnigan GasBench II.

The observed variation in macroscopic preservation of the human remains from San Salvador was mirrored in substantial disparities in the four chemical and elemental indexes most commonly employed in evaluating collagen preservation: collagen yield, carbon yield (wt% C), nitrogen yield (wt% N), and atomic C:N ratio (Table 1; Ambrose 1990; van Klinken 1999). Collagen preservation must be assessed before dietary reconstruction is attempted since postmortem changes to bone can produce erroneous chemical signatures. The average collagen yield of the 16 bone samples in the study was quite low (3.1 ± 4.5 wt%), and one sample, A-28, had insufficient collagen for further consideration. A further five bone samples (A-20, A-21, A-22, A-30, A-71) had insufficient carbon (< 4.5 wt%) and/or nitrogen (< 5.5 wt%) and could not be considered chemically unaltered. Finally, we excluded two additional samples (A-23, E-110) with acceptable collagen yields and elemental concentrations because of atomic C:N ratios that were outside of the acceptable range (2.9–3.6). All told, only eight of the original 16 bone samples (50 percent) were sufficiently well preserved for consideration in dietary reconstruction. While both dental root (dentine) samples for which collagen extraction was attempted produced sufficient collagen (1.5 wt% and 12.3 wt%), the sample with the lower collagen yield (F-26) did not produce sufficient concentrations of carbon and nitrogen. As such, the isotopic value of collagen from only one dental root (dentine) sample (F-27) was considered for dietary reconstruction. Extraction of the solitary crown enamel apatite sample (F-25) produced values within expected norms. We did not perform Fourier-transform infrared spectroscopy, which has been shown to be effective in independently identifying diagenetic alteration of hydroxyapatite (Trueman et al. 2008). Instead, we employed a combination of the above-mentioned bone collagen preservation measures (Bösl et al. 2006; Schutkowski et al. 1999) and compared the isotopic values of bone and tooth apatite to evaluate the state of apatite preservation.

To permit dietary reconstruction from the remaining samples, we assembled a representative food web for northern Chile from published isotopic data for local flora and fauna (DeNiro and Hastorf 1985; Horn et al. 2009; Hückstädt et al. 2007; Minagawa and Wada 1984; Schoeninger and DeNiro 1984; Schoeninger et al. 1983; Tieszen and Chapman 1992) and from analysis of a small number of ancient and modern floral samples (including algarrobo) collected in or around the San Salvador sites. The isotopic signatures in the reconstructed ancient food web (Figure 5) can effectively be divided into three mostly exclusive subsets: (1) C3 plants and terrestrial fauna, most notably represented by algarrobo and camels, respectively, which possess generally depleted δ13C and δ15N signatures; (2) C4/CAM plants, the δ15N values of which are roughly equivalent to the first group but which possess significantly more enriched δ13C values; and (3) marine fauna, such as the fish and shell species found at the site, which possess dramatically enriched δ13C and δ15N signatures. Based on these local differences, it should be possible to differentiate both C3 vs. C4/CAM plant consumption and marine vs. terrestrial protein consumption for the San Salvador individuals.

Putting these elements together, we start by reconstructing the whole diet of the San Salvador individuals using their δ13C\textsubscript{ap} values (Table 1). On average, the δ13C\textsubscript{ap} of bone and enamel reflects the carbon isotope values of all plants and animals consumed, plus 9.4‰ (Ambrose and Norr 1993), but since carbohydrates tend to dominate in human diet
these results are viewed as a reflection of plant consumption. The observed range, from a low of 
\(-14.3\%\) (tooth enamel from individual 8.1) to a high of 
\(-9.4\%\) (bone from individual 10.1), speaks to significant differences in long-term patterns of 
(primarily) plant consumption. This 5\% variation, 
when compared against local plant end-member 
\(C_3\) vs. \(C_4/\text{CAM}\) values that differ by an average of 11\% (\(-25\%\) vs. \(-14\%\)), could equate to as much 
as a 40 percent shift from \(C_3\) to \(C_4/\text{CAM}\) plant consumption.\(^4\) Put differently, individuals with the 
most depleted \(\delta^{13}C_{\text{ap}}\) values would appear to have 
consumed predominantly \(C_3\) plants with \(C_4/\text{CAM}\) plants only providing a minor contribution to diet, 
whereas those individuals with the most enriched 
\(\delta^{13}C_{\text{ap}}\) signatures had a diet consisting of as much 
as 40 percent \(C_4/\text{CAM}\) plants. It is noteworthy, 
however, that none of the individuals analyzed in 
the course of the present study have \(\delta^{13}C_{\text{ap}}\) values 
that approach the enrichment seen in, for instance, 
Middle Horizon (A.D. 500–1000) individuals from 
Conchopata, Peru (Finucane et al. 2006), south 
coastal Peru (Nasca [Kellner and Schoeninger 
2008]), certain individuals from central Chile (Fal- 
abella et al. 2007), or other \(C_4\) carbohydrate–depend- 
et populations presented by Kellner and Schoeninger (2007). This finding is consistent with 
the lack of archaeological recovery of \(C_4\) foodstuffs 
in the San Salvador Village and Cemetery (de 
Ugarte and Gallardo 2010), and its implications are 
discussed below.

An intriguing finding from these data, however, 
is that the three samples reflecting the highest lev- 
els of \(C_3\) plant consumption were from juveniles 
(bone from individual 1.2) and/or were dental (root 
dentine and crown enamel) apatite samples reflect- 
ing a period of childhood/adolescent diet (M3 sam- 
ples from individuals 2.2 and 8.1).\(^5\) On the other 
hand, the bone samples from adults at the site 
reflect a more diversified carbohydrate diet. Given 
that the overwhelming majority of the botanical 
remains from San Salvador were from a \(C_3\) plant 
\(\text{algarrabo, } \delta^{13}C = 21.1\%\) to \(-22.8\%\), these data 
may suggest a pattern in which children, perhaps 
born to families residing at the site, consumed the 
locally available carbohydrate (\(C_3\)) throughout

Figure 5. San Salvador foodweb.
childhood/adolescence, while C4/CAM carbohydrates were only introduced into diets later in life. This may be tied to some form of greater adult mobility, if one assumes that local food remains are indicative of local diet, or it may suggest restrictions on juvenile diet. In either case, it provides an interesting view of the effect of food exchange on individual actors.

Turning from the carbohydrate to the protein portion of the diet, both the measured δ13C values and the difference between the measured apatite and collagen δ13C “spacing” values (Δ13C_{ap-co}) can be used to determine, in broad terms, the δ13C value of the predominant dietary protein (Ambrose and Norr 1993). Measured δ13C_values for the San Salvador individuals average −16.8‰ and range from −15.5‰ to −18.8‰, whereas the calculated Δ13C_{ap-co} values average 5.9‰ and range from 4.2‰ to 7.9‰. Taken together, these values suggest an average dietary protein δ13C signature between the depleted δ13C values (<−20.5‰) of local terrestrial fauna and the enriched δ13C signatures (>−14.8‰) seen for regional freshwater fish and marine taxa. That the spacing values average around 5‰ likely attests to the fact that dietary proteins, like the dietary carbohydrates discussed above, were drawn from multiple, isotopically distinct reservoirs, with some individuals, particularly those with Δ13C_{ap-co} values below 5‰, consuming slightly more marine resources and those with values greater than 5‰ eating more terrestrial protein. This final inference is lent some support by the moderate (r² = .42) negative correlation observed between Δ13C_{ap-co} and δ15N_{co}.

Coupling these results with the measured δ15N values of collagen (average 12.5‰, range 8.3‰−15.4‰) allows us to make further statements about the protein diet of the San Salvador individuals. Based on knowledge of the local food web (Figure 5) and the roughly +3‰ stepwise enrichment of δ15N values from one trophic level to the next, δ15N_{co} values greater than 12.5‰ can only be explained by the consumption of 15N-enriched marine fauna. Five of the nine San Salvador individuals have δ15N_{co} values exceeding this 12.5‰ threshold. Some portion of the observed variation in δ15N_{co} may result from a lingering elevation of trophic positioning occurring as a consequence of breast-feeding in younger individuals (e.g., Fuller et al. 2006). Given, however, that the children included in this analysis were either beginning adolescence or represented by samples that reflect adolescence (Richards et al. 2002), we argue that these data are not a consequence of a strong breast-feeding effect and instead support the presence of 15N-enriched marine fauna in the San Salvador diet.

Much like the patterns seen in the carbohydrate portion, what is evident from the collagen data, and particularly the δ15N_{co} values, is a substantial degree of intrasocietal variation in protein consumption. Interestingly, isotopic analyses of collagen from two individuals from the contemporary Middle Loa River site of Regimiento Chorillos (820–390 B.C.) suggest similar variation in dietary protein (González and Westfall 2006). If the observed variation in collagen isotope values is the result of bonfire differences in post-weaning protein consumption, then it is most likely that this results from differing amounts of marine vs. terrestrial protein in the diet of San Salvador individuals. This is also supported by the archaeological recovery of marine fauna from the site. Using local δ15N end-member values of terrestrial/freshwater (average δ15N = 6.7‰) and marine (average δ15N = 18.4‰) fauna and the formula for computing marine consumption from δ15N_{co} provided by Ambrose (1993:83), we find a 45 percent range in marine protein consumption, from as little as 6–12 percent marine consumption (in individuals 8.1 and 10.1) to as much as 45–51 percent marine consumption (individuals 5.2 and 2.2).6 The positive, but admittedly weak, correlation (r² = .16) between δ15N_{co} and δ13C_{co} values and the moderate (r² = .42) negative correlation observed between Δ13C_{ap-co} and δ15N_{co} both provide some support for this interpretation. As with the δ13C_{ap} data, this isodysynchronic variation in collagen isotope signatures may reflect intrasocietal differences in patterns of mobility (i.e., frequent movement to and from the coast by some individuals vs. greater sedentism for others) or as a result of the importation of marine foods (e.g., dried fish) over great distances to San Salvador. The lack of a uniform contribution of marine protein in all individuals’ diets may suggest the interaction of these two patterns, with certain individuals involved more heavily in trade relationships than others.

For some regional perspective on these results, we compared the collagen isotope values from San Salvador with those from individuals from other Andean sites, including six from north coastal Chile.
(Tieszen et al. 1992), nine from central Chile (Falabella et al. 2007), 16 from central western Argentina (Gil et al. 2006), and two in neighboring Peru (Finucane et al. 2006; Kellner and Schoeninger 2008). These fall into three broad groupings (Figure 6): first, the sites from central Chile and central western Argentina, which demonstrate a heavy reliance on C_4 terrestrial proteins; second, individuals from the Peruvian sites (both highland and coastal), who appear to have consumed mixed C_3/C_4 and C_4-foddered terrestrial protein sources; and third, the individuals from coastal northern Chile, who exhibit patterns of protein consumption focused on marine resources.

When assessing our collagen results vis-à-vis these regional counterparts, two phenomena are evident. First, the δ^{13}C values of the San Salvador individuals are most similar to the values observed in central Chile and west-central Argentina. In these three areas the δ^{13}C signatures of almost every individual from the comparative populations are less than −14‰, the dividing line between C_3 and C_4/marine protein established by Kellner and Schoeninger (2007) in their recent synthesis of numerous controlled diet experiments. Interestingly, the groups from Peru and north coastal Chile show values that are greater than −14‰. At San Salvador δ^{13}C values average −16.8‰, indicating a protein diet slanted toward C_4 terrestrial protein. We interpret this difference in δ^{13}C signatures to be a consequence of two differences in dietary composition: (1) the direct human consumption of far fewer C_4 plants at San Salvador than at the other sites (a conclusion buttressed by the dearth of C_4 plant material recovered from San Salvador); and (2), of more significance to collagen isotope values, the dominance of C_4-foddered terrestrial fauna in the protein portion of the average San Salvador diet, with the protein diet at the comparative sites being made up of varying combinations of marine fauna and C_4-foddered terrestrial fauna in addition to C_3-foddered fauna.

Furthermore, the δ^{15}N values of the San Salvador individuals are equal to or greater than the values seen in individuals from central western Argentina, central Chile, and the Peruvian sites, and they approach the lower end of values seen in individuals from north coastal Chile. As discussed above, based on local food web values, the intermediate trophic position of the San Salvador indi-
viduals is not a consequence of aridity-related enrichment of terrestrial δ\(^{15}\)N values. Rather, we argue that at least some of the San Salvador individuals (those with higher δ\(^{15}\)N\(_{\text{av}}\) values) were consuming more protein of a higher trophic level (i.e., marine protein) than the individuals from the Peruvian, central Chilean, and Argentina sites but less than most of the individuals from the north coastal Chilean sites, whom Tieszen and colleagues (1992) argue were consuming a minimum of 45–50 percent marine protein.

Combining these two pieces of collagen isotope evidence, we are able to arrive at a parsimonious explanation for a peculiar pattern of protein (and carbohydrate) consumption at San Salvador that would produce depleted δ\(^{13}\)C\(_{\text{av}}\) values and moderately enriched δ\(^{15}\)N\(_{\text{av}}\) values. The collagen isotope values observed in central western Argentina and central Chile reflect a diet of mixed C\(_3\)/C\(_4\) carbohydrates and predominantly C\(_3\)/terrestrial protein. Individuals from the Peruvian sites appear to have consumed primarily C\(_4\) carbohydrates plus C\(_3\)-foddered terrestrial fauna, thus producing the enriched δ\(^{13}\)C\(_{\text{av}}\) and depleted δ\(^{15}\)N\(_{\text{av}}\) signature combination. Individuals from the comparative north coastal Chilean sites likely were also consuming a large amount of C\(_4\) carbohydrates (although we do not possess apatite data for these individuals) in addition to varying combinations of C\(_4\)-foddered terrestrial fauna and marine animals, thereby producing their combination of enriched δ\(^{13}\)C\(_{\text{av}}\) values and δ\(^{15}\)N\(_{\text{av}}\) signatures that range from moderately to exceedingly enriched. In contrast, at San Salvador, we see a distinct combination of primarily C\(_3\) dietary carbohydrates (with, at most, a 40 percent minority of C\(_4\) carbohydrate consumption in some individuals) and a protein diet made up of mostly C\(_3\)-foddered terrestrial fauna plus varying amounts (5–50 percent) of marine protein. We argue that it is this combination of foodstuffs that resulted in depleted δ\(^{13}\)C\(_{\text{av}}\) and moderately enriched δ\(^{15}\)N\(_{\text{av}}\) values at San Salvador.

In summary, these isotopic results concord well with both the archaeological and the bioarchaeological data from San Salvador. Our results suggest that the inhabitants of San Salvador primarily consumed the dominant local carbohydrate, algarrobo, in particular during their childhood, and once they grew older, took part in interregional trade expeditions, thereby gaining access to and consuming varying amounts of coastal and highland food resources (meat and plant alike). As a consequence of this pattern of lifetime consumption, the inhabitants of San Salvador possessed dietary signatures that span the “isotopic space” between those most often seen in the coast and the interior, respectively.

Discussion

While the quality of this sample does not allow us to make grand statements about life during the Formative period in the Atacama Desert, we argue that there is some tantalizing evidence suggesting patterns of interaction for this population. Not only do we see a space in between population groups interacting with peoples and objects from diverse areas, but also our data are suggestive of the movement of these peoples: “This raises the question of the significance of distant worlds beyond daily interaction for the constitution of both individual and collective identities” (Lazzari 2005b:130). The inhabitants of San Salvador created a social and economic space within the spectrum of interactions they experienced. The location and material remains contribute to the argument for a strong connection to the peoples of the Middle Loa River. As mentioned earlier, there is a demonstrated presence of textiles, baskets, and ceramics akin to those from the interior in addition to material from distant cultural groups. For example, a textile fragment (Figure 7) from San Salvador bears strong resemblance to a contemporary one found at the Calama oasis site of Topater (2320 ± 40 B.P. [Beta-259695], 410–360 cal B.C.).

Archaeological evidence shows that the San Salvador population had clear relations with the interior, but in concert with our analyses it also shows that this group had a strong tie with contemporary coastal populations, despite the site’s location deep in the Atacama Desert. For example, we note the presence of numerous marine fish remains, as well as marine shells, in the site middens. Given the site’s location over 100 km from the Pacific Ocean this argues for the involvement of San Salvador’s residents in resource exchange with coastal populations, probably through the trading of algarrobo flour, some of which we found in baskets interred as grave goods at San Salvador Cemetery. Faunal remains (principally paleofeces) recovered during our excavations suggest the presence of camelids
at the site—animals that likely played an important role in these relations. As noted before the sites were located near a grove of algarrobo trees along the San Salvador River. Joehim (2006:88) has argued that the presence of sites in relationship to specific resources can serve as one piece of evidence for intensification and the presence of food exchange. Taken together these observations support de Ugarte and Gallardo’s (2010) suggestion that the site was placed in this location for production purposes.

While it is likely that this population had its origins near the modern inland city of Calama, approximately 40 km east of the sites, our evidence suggests not only that it served as a geographic intermediary but that its relationships with inland and coastal populations were complex and varied. As Lazzari and colleagues note, these “complex social networks . . . extended people’s involvement beyond their daily locations into the wider regional world” (2009:163). The peoples of San Salvador had access to seemingly exotic goods in the form of both material culture and marine foodstuffs. Their homes and graves evidence their local affiliations and their interactions with a broader world. As alluded to above, archaeological and bioarchaeological data converge on a pattern of great variety for this population. Interestingly, the isotopic data reveal a novel combination of food in the diet when compared with available data from the region. While the absence of evidence for maize among the botanical remains and cemetery offerings is not evidence of complete absence, it is suggestive of a minimal consumption of corn, a typical Andean staple that was found among the burial offerings at the contemporary cemetery of Topater in the Calama oasis (Thomas et al. 1995). Regardless of the specific foodstuffs involved, these data suggest different dietary experiences and life histories for the individual occupants of the site,
including the potential for different places of origins, varied durations of residency at San Salvador, and variation in the frequency of long-distance travel and trade. Moreover, these data suggest interesting intrasocietal patterning that may reflect differential access to resources based on age, sex, or social standing. Given the seeming stability of the settlement and the abundance of marine remains, it appears that this group had somewhat regular access to these products through exchange with coastal populations moving inland along the course of the Loa and San Salvador rivers or through caravan movements toward the coast. The logistical importance of the site suggests its economic role but also speaks to the social relations it may have been promoting and engendering.

Conclusion

Evidence from this small sample from San Salvador Cemetery supports the idea that this was a population engaged in resource intensification and trade during the Middle Formative period. People living at San Salvador, and likely at similar internodal locations, were engaged in interactions that spread across the breadth of the Atacama Desert from the coast to the Andes. The evidence from San Salvador suggests that the networks of exchange and mobility in the Atacama during the Formative period covered large expanses of desert and likely involved people living in isolated settlements in internodal spaces—spaces that are not, in fact, empty. Of particular note, the dietary variability evidenced in our stable isotope analyses supports the contention that the San Salvador population was involved in large-scale exchange networks and may have functioned as a logistical outpost. It is noteworthy that the amount of variation seen in these few individuals from San Salvador is comparable to that seen in entire regions (e.g., central western Argentina [Gil et al. 2006]). In these data, we may be seeing a facet of what Upshall has referred to as “‘economic layering,’ a feature of the panregional economic system that linked groups at widely varying levels of complexity over a vast area” (1992:143). It appears that the individuals at San Salvador engaged in these exchange networks with considerable variability, likely resulting in different dietary patterns. Moreover, these data may in fact reflect the varied modalities of human movement in the Formative.

Building on Lazzari (2005a), it seems that exchange did not occur in a simple unidirectional manner but rather that varied patterns in the movement of goods reflect the different materials being exchanged and the various social groups involved in the interactions. Archaeological evidence from the Formative period in northern Chile indicates that coastal and inland populations were producing surplus economies and a network of exchange for foods, prestige goods, and ideas at this time (Gallardo 2009). As Jochim notes, “Food exchange has been viewed as intimately involved in the development of hunter-gatherer complexity” (2006:80). Interaction between these different groups, therefore, cannot necessarily be interpreted as a simple trajectory from a center to a periphery, nor is this complex movement limited to complex polities but, rather, reflects the needs and desires of groups and individuals regardless of scale as well as the labor and varied social processes they produce. Lazzari writes, “Circulating things and people refer to places and people that are not immediately present in everyday life, thus concretizing in material form the presence of other people and places” (2005b:131). It would be worth exploring other sites from this time in order to determine if this pattern of dietary variability was unique to these outposts or part of the larger shifts seen in northern Chile at this time. These networks in the Formative period were not circumscribed but were part of a regional economic structure that remains only partly explored. Further excavation of similar small trade outposts and areas of resource intensification may help to flesh out what appear to be increasingly complex patterns of interaction. In northern Chile, the vast expanses of desert between large sites may suggest swaths of vacant land; however, they provide a prime opportunity for exploring human movement, interactions, and the use of empty or internodal spaces in prehistory.

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Notes

1. The extensive natural mumification of individual 5.1 did not allow for detailed analysis of all of the postcranial remains.

2. The delta (δ) notation represents the ratio of the heavier to the lighter isotope δ15N to δ13C in the case of carbon, 15N to 13C in the case of nitrogen) in parts per thousand (per mill or ‰) relative to an international environmental standard, Pee Dee Belemnite (Craig 1957) for carbon and AIR (Mariotti 1983) for nitrogen.

3. However, as judged against other terrestrial flora and fauna elsewhere in the world, the Δ15N signatures of these
plants and animals are somewhat, but not dramatically, elevated as a result of aridity effects (see Ambrose 1991; Schwarz et al. 1999).

4. The formula used is \%C_4 = ((–25‰ – (δ¹³C₀p – 9.4‰))/(14‰)) x 100 (Ambrose et al. 2003:221).

5. It is not absolutely clear why the δ¹³C₀p value obtained for the enamel apatite of individual 8.1 is so depleted (–4.4‰) vs. the bone apatite of the same individual, as they should, in theory, represent roughly the same adolescent time range. It seems most likely that this difference is the result of an idiosyncratic or individual difference in time averaging due to the duration of formation (i.e., the enamel apatite represents a three-year dietary average, while the bone apatite represents 10 years or more).

6. The formula used is \%Marine = ((6.7‰ – (δ¹³N₀w – 3‰))/(18.4‰ – 6.7‰)) x 100 (Ambrose 1993:83). While freshwater fish in certain ecosystems present enriched δ¹³N values that can confound such calculations, the only δ¹³N value that we possess (Orestias spp. [Tieszen et al. 1992]) is low enough (8.1‰, within the range of terrestrial fauna and C₄/CAM plants) as to be unproblematic in this regard.

7. This is directly evidenced by the δ¹³C₀p values from Conchopata (Finucane et al 2006).