Quaternary International xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

The interior frontier: Exchange and interculturation in the Formative period (1000 B.C.-A.D. 400) of Quillagua, Antofagasta region, northern Chile

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ABSTRACT

While the village of Quillagua, a riparian oasis in the hyperarid Atacama Desert of northern Chile, is of limited modern importance, there is strong evidence to support the contention that during different prehistoric periods the village was a frontier between the populations of the Pampa, the Pacific Coast, the Loa River, and the Salar of Atacama. Indeed, it can be argued that it served as a node for systems of inter-regional exchange. Archaeological evidence indicates that this frontier function may have its origins as early as the Formative Period (1000 B.C.-A.D. 400), a crucial era of regional cultural change. Scholarship from across the social sciences suggests that frontier/border spaces can be dynamic zones of cultural innovation and that prolonged inter-group contact at such spaces can change perception and behavior, notions that we test through isotopic analysis and multi-source mixture modeling of individuals from two distinct precincts of Formative Period Quillagua. Ultimately, based on our paleodietary reconstructions, we find that some individuals from Quillagua were not simply engaged in systems of inter-regional economic exchange, but that their involvement likely fomented the creation of novel cultural forms.

1. Introduction

Frontiers and borders often are conceived of as limits; places that inhibit movement, and that divide and separate people and places. Even in fractious political circumstances, however, borders and their surrounding regions can be places of union, interaction, negotiation, and exchange, with their permeability changing in response to the political and economic demands of societies on either side. Ultimately, borders are what we want them, or make them, to be.

A wealth of literature views borders, frontiers, and the regions that surround them as zones of cultural transition between the societies that lie on either side. It is possible that, "(w)ithin the transition zone, cultural, linguistic and social hybridity can emerge," (Newman, 2006:151), and that these spaces can engender creolization and even *bona fide* ethnogenesis (Barth, 1976[1969], 1998, 2000; van Dommelen, 1997, 1998; White, 1991). Indeed, borders can be, "landscapes in between, where negotiations take place, identities reshaped, and personhoods invented," (Naum, 2010:107). This leads us to speculate that in prehistory, as in the contemporary moment, we might expect new cultural forms or practices to spring forth in those portions of ancient societies most closely involved in frontier interactions.

It is clear that economic needs are a prime driver of the movement across frontiers and borders. People are motivated to cross boundaries in search of material goods that they desire or need. Indeed, archaeologists often track such these cross-border economic relationships through the identification of exotic goods. Of equal or greater importance, however, are the inter-personal linkages, or *vínculos*, that can form at the frontier as a consequence of economically motivated cross-border actions. These *vínculos* are similar to the "cross-cutting social networks" discussed by Lightfoot and Martinez (1995). Negotiation of these border-crossing linkages can materially affect the cultural traditions of all actors engaged in their construction and performance, as parties interacting with one-another with frequency are exposed to, and may be expected to begin to experiment with, one-another's cultural practices.

Real social and cultural change becomes far more likely, however, when parties' interactions extend beyond the strictly transactional. In this regard, we see a parallel to the "contact hypothesis," a proposition first advanced by Allport (1954), which predicts that in circumstances of prolonged equal-status co-existence and interaction, common

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https://doi.org/10.1016/j.quaint.2019.03.014
Received 24 April 2018; Received in revised form 5 January 2019; Accepted 15 March 2019
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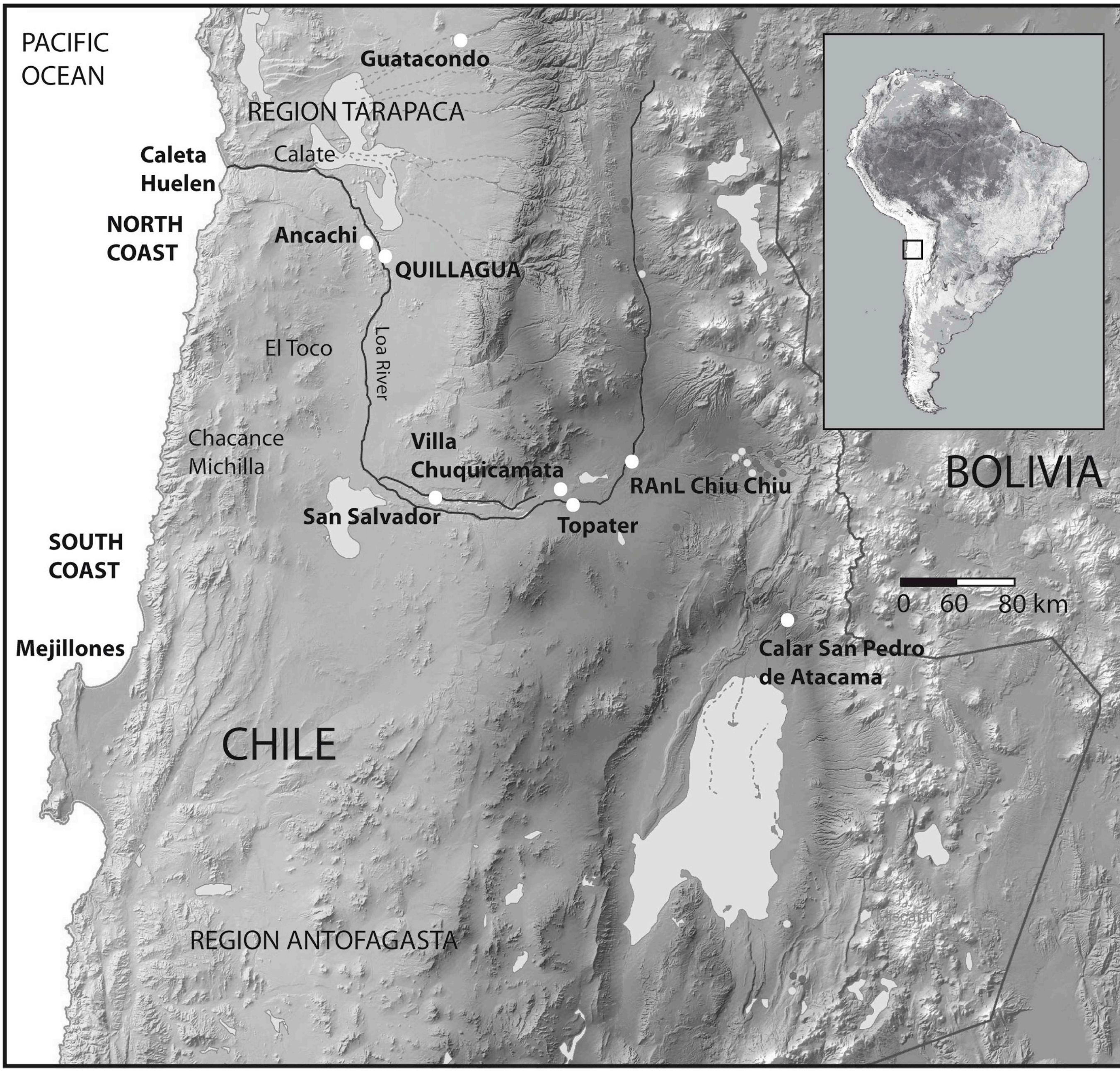

Fig. 1. Map of study region with sites mentioned in text noted.

experience will shape and sway the opinions and worldview of even the most entrenched actors (Kende et al., 2017; Pettigrew and Tropp, 2006; Mirwaldt, 2010; Pettigrew et al., 2011). We posit that this could, over long enough time spans, promote the development of new cultural forms. As such, one of the lasting and pervasive effects of frontier spaces may be the appearance of novel cultural forms, which we take to be a natural corollary of the linkages that form in these liminal zones.

It is this notion of social and cultural linkages created by movement and exchange, and the new cultural forms that can result, which we explore in this work. In particular, we focus on Quillagua, a small town in northern Chile's Atacama Desert, which is, today, of limited regional economic importance (Fig. 1). There is, however, strong evidence to support the contention that in various periods of the historic and prehistoric past, the village was a key node of ancient routes linking the populations of the Pampa, Pacific Coast, Loa River, and Salar of Atacama (e.g., Agüero et al., 1999, 2001; 2006; Adán et al., 2013; Pimentel, 2013; Pimentel et al., 2011; Agüero y Cases, 2004; Uribe y Ayala, 2004; Santana-Sagredo et al., 2012, 2015a; Agüero y Uribe, 2015). Most recently, 18th century (A.D.) documents suggest that Quillagua was an "internal frontier" between populations residing to the north and south of the oasis (Paz Soldán, 1878). Several centuries earlier, in the Late Intermediate Period (A.D. 1000–1400), Quillagua is judged to have served as an important frontier zone between populations of Arica, Pica-Tarapacá, and the Loa region, up to and including San Pedro de Atacama (Agüero et al., 1999). And, as concerns the present work, emerging evidence supports the notion that Quillagua's nodality, and its role as a frontier, can be traced earlier still, to the Formative Period (Agüero et al., 2001, 2006). Our research, and the research of others in and around Quillagua, judged alongside our longer-term efforts at understanding movement and exchange in the Atacama, suggests that, during the Formative, Quillagua was a center for regional movement, economic exchange, and the creation and maintenance of *vínculos.*

In this work, we present tangible evidence of the lived cultural consequence of these linkages by elucidating their effects at the scale of the individual, as manifested in diet, a key cultural indicator. We employ stable isotope analysis of preserved skeletal tissues and Bayesian multi-source mixture modeling of dietary contributions to characterize the diets of a small number of people buried in Formative Period Quillagua. These Quillagua dietary data are then compared with the results of our analysis of a large corpus of individuals from other sites throughout the region, spanning the coast to the far interior. This process allows us to stipulate varied points/groups of origin for individuals buried in Quillagua and, more interestingly, to identify certain people who would appear to have been eating (and living) in ways not seen elsewhere in the desert. We argue that those individuals are an embodied manifestation of the frontier that was Quillagua. They may have been involved in the creation of new cultural forms in a border space, the creation of which flowed from prolonged interaction with actors from other regions.

Quillagua in the Formative Period appears to have been the site of cultural pluralism and cultural innovation. Ultimately, we argue that new lifeways, indeed new cultural forms, may have been forged in Quillagua during the Formative precisely because the town and region served as a frontier at which people from multiple regions interacted, in a manner that went beyond the simply transactional.

2. Temporal and regional setting

The Formative Period in the Americas is generally understood as a time of profound economic and social change. Indeed, many of the ways of life that had sustained the societies of the Americas for nearly 10,000 years prior were left behind during this period, and wholly new modes of existence appeared in their place. In the southern Andes, the Formative Period is characterized by rapid population growth, the emergence of sedentary residential centers, increasing importance of camelid pastoralism, intensification of gathering and hunting, a growing (although likely variable) reliance on agriculture, the production and storage of food surpluses, and persistent and far-reaching systems of exchange (Gallardo, 2009; Labarca and Gallardo, 2015; Lumbreras, 2006; Núñez and Santoro, 2011; Núñez et al., 2006; Pimentel, 2013; Castro et al., 2016; Santana-Sagredo et al., 2015b). These changes and processes are clearly inter-related (e.g., surplus agricultural products were moved between residential centers in a system of exchange facilitated by camelid transportation) and combined to radically alter ways of life in the prehistoric Atacama.

The Atacama Desert dominates much of northern Chile, stretching from 30° to 18° South (Fig. 1, inset). The vast desert is bounded on the west by the Pacific Ocean and to the east by the towering cordillera of the Andes. The intense aridity of this desert— "an extreme habitat for life on Earth and… An analog for life in dry conditions on Mars" (McKay et al., 2003:393)—has characterized the regional climate throughout much of its human occupation (Moreno et al., 2008). This pervasive aridity made, and makes, life in the region dependent on successful strategies of risk management and mitigation. One such strategy was the logistical situation of settlements in the desert's few hospitable areas, particularly in oases or along river canyons, as well as on the comparatively resource-rich coast (Ballester and Gallardo, 2011; Pimentel, 2013).

The modern town of Quillagua, located in the heart of the Atacama at S 21.66° W 69.54°, is one of these logistically positioned settlements (Fig. 1). It is generally recognized as being the driest inhabited place on the planet, with an average annual rainfall of just 0.15 mm (Houston, 2006). Life, human or otherwise, would be impossible in such a setting were it not for the presence of the Loa River, the region's only perennial river. Indeed, Quillagua is located in a riparian oasis astride the Loa, in a canyon some 70 km upriver from where the river meets the Pacific. Throughout documented history, Quillagua has been the site of intensive agriculture and arboriculture thanks to the waters of the Loa, the latter focusing in particular on the leguminous tree known locally as *algarrobo* (*Prosopis* spp.), the seeds of which were ground into flour for human consumption (McRostie et al., 2017).

Multiple lines of evidence indicate the centrality of Quillagua to the regional systems of movement and exchange from the earliest portion of the Formative (Castro et al., 2016). Indeed, Quillagua would appear to be a place of meeting and exchange of a number of Formative Period groups, from the Upper and Middle Loa to southern Tarapacá to the Coast. Supporting this contention, Pimentel and colleagues (Pimentel, 2009, 2013; Pimentel et al., 2011, 2017; Gallardo et al., 2017a) have documented a number of Formative Period trails, and associated sites (shelters, habitations, and funerary contexts) that converge on Quillagua. Uribe and Ayala (2004), in analyzing Formative Period ceramics from a number of sites from San Pedro de Atacama to Arica, found that sites in/around Quillagua showed the greatest diversity of ceramic types present anywhere in the region, a material manifestation of its wide-ranging reach. Finally, Agüero and colleagues (Agüero and Cases, 2004; Agüero et al., 2001, 2006) have found similar evidence in the ceramic and textiles of Quillagua, which show the influence and/or presence of materials, and presumably peoples, from the coast and interior portions of both the Antofagasta and Tarapacá regions.

If one considers Quillagua as a node in a system of movement and exchange involving, at a minimum, populations from the Pacific Coast to the west, Guatacondo and greater Tarapacá to the north, and San Salvador and the Calama oases to the southeast, a provisional economic schema of the sort seen in Fig. 2 can be envisioned. The tracking of exotic goods is the classic archaeological means of tracing *vínculos*, but such methods fail to distinguish transactional relationships from the sort of deeper contacts that might engender cultural change. Besides the purely economic, the presence of non-local materials in Quillagua is testament to the existence of social relations crossing the desert. Given the persistent set of linkages Quillagua seems to have, it suggests that these social relations were equally long-lived and robust, and that the potential for interculturation at such a site would have been great.

To test whether, and to what degree, the nodality of Quillagua and the presence of the *vínculos* that characterized it, are manifest in local cultural innovation, we turned to a biogeochemical technique, stable isotope analysis, that is capable of providing individual-level insights into diet, which itself is a highly sensitive indicator of culture and identity creation (Mintz, 1985; Smith, 2006). The use of isotope analysis can help to differentiate the movement of goods, an economic phenomenon, from the movement and residence of people, which seems a better proxy for understanding how new cultural forms may have been created through the persistent interaction of people from different places and cultures. In terms of the aforementioned contact hypothesis, it may help us to separate the strictly transactional (economic) from more meaningful social relations that are likely to engender the creation of new cultural forms.[1] Put simply, we take the evidence of differences or changes in diet to be a strong testament to changes in the culture of the people doing the consuming, especially as isotopic analysis provides evidence of years or even decades of consumptive practices, thus attesting to long term behavioral patterns (Ambrose, 1993).

3. Materials and methods

Stable isotope analysis has been used in archaeology since the 1970s (Vogel and Van Der Merwe 1977), and it now possesses a robust track record of providing otherwise unobtainable insights into past diet. We present only a brief review of the method here, and encourage interested readers to consult more detailed reviews elsewhere if they desire (e.g. Ambrose and Krigbaum, 2003; Lee-Thorp, 2008).

The central premise of stable isotope analysis is that differences in

[1] Acknowledging that in economies not characterized by market exchange, such a dichotomy may not be fully applicable.

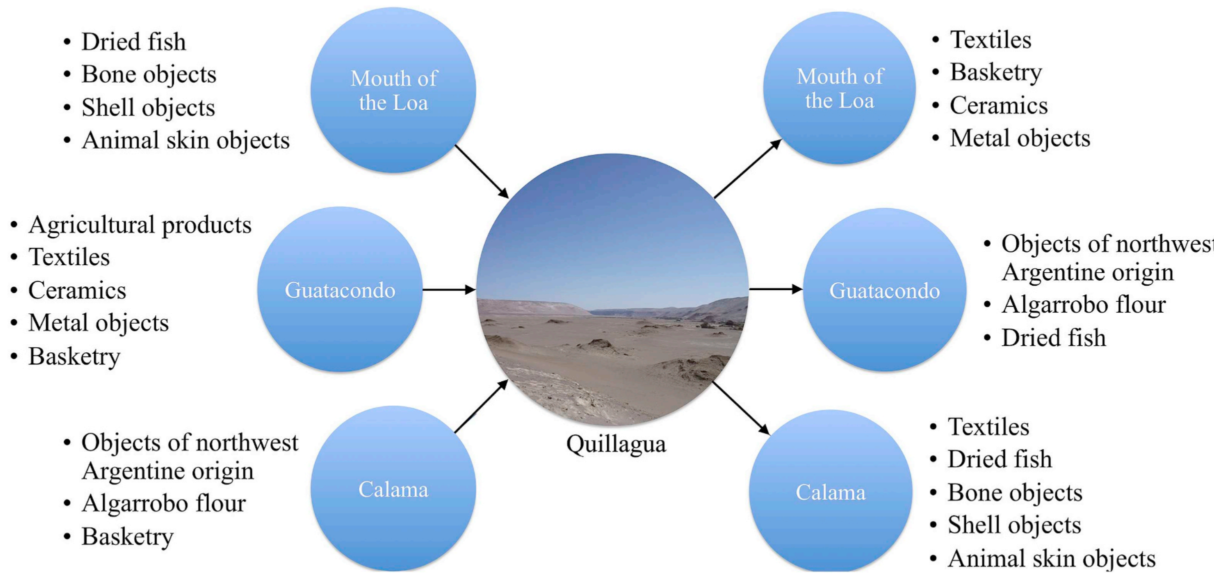

Fig. 2. Schematic of economic flows into, and out of, Quillagua.

the isotopic makeup of different foods (over the course of ten to thirty years) will present in consumer tissues in proportion to that consumer's consumption thereof. Unlike most other archaeological techniques, this method, when properly applied, can provide reliable information on the broad dietary makeup of the various individuals that made up a past society. In contrast, macrobotanical, faunal, and artifact residue analysis provide information about the range of foods available or consumed at a given site, saying little about the relative contribution of specific food groups to individual diet or about differences in diet between portions of any given past society. Stable isotope analysis provides such complementary data and is thus ideally suited for identifying individual-level cultural innovation and identity creation.

The target biomolecules in archaeological applications of stable isotope analysis are, most typically, collagen, the protein that makes up 20–22% of fresh bone, and hydroxyapatite, a calcium phosphate mineral that makes up approximately 70% of fresh bone by weight. The carbon and nitrogen isotope composition of bone collagen ($\delta^{13}C_{co}$ and $\delta^{15}N_{co}$, respectively) predominantly reflects the protein portion of an individual's diet, while the carbon isotope composition of hydroxyapatite ($\delta^{13}C_{ap}$) reflects both dietary energy (fats and carbohydrates) and protein, also known as "whole diet" (Ambrose and Norr, 1993; Jim et al., 2006; Fernandes et al., 2012). Given sufficient preservation of osseous tissues, both of these biomolecules are regularly extracted from archaeological bone using well-established laboratory methods and analytical procedures.

Here we present data derived from twelve recently analyzed individuals representing Formative Period Quillagua (Table 1). While we acknowledge that the present sample is not as large as might be desired for such analysis, given the degree to which the tombs of Quillagua have been impacted by more recent human activities, particularly looting, any such study in the region would be similarly constrained. Future work in the region may allow us to augment this sample. Moreover, even a small sample such as this should allow for the formation of preliminary statements about past behavior, statements that can be evaluated later in light of more robust data sets.

The present study sample is made up of individuals from two distinct precincts/portions of the area. It includes seven individuals recovered from *in situ* sampling in the heavily looted cemetery of Ancachi (02QUI75) (Latcham, 1933), a site located close to the Loa River, several kilometers to the northwest of the village of Quillagua (Fig. 3). Mortuary treatments at 02QUI75 include both pit/shaft burials (typical of the Formative Period populations of the oases) and burials in *tumuli* (typical of the coastal populations of this era in the region between the mouth of the Loa River and the city of Taltal [e.g., Núñez, 1971; Moragas, 1982; Castro et al., 2016, Gallardo et al., 2017b]). These *tumuli*, which are characterized by low elevation, rounded form, and individual burials, are substantively different from those observed in the Azapa valley, where one finds large tumuli with collective burials, and those from ceremonial mounds without burials produced by successive acts of material offering (as those described by Agüero et al., 2006 and Pimentel, 2009).

The Ancachi (02QUI75) individuals included in this study come from heavily looted coastal-style tumuli. While the majority of the offerings at the site come from the artisanal repertoire of the oases, in contrast, the adjacent open-air camp site (02QUI76) that appears to have served as the habitation site for the people responsible for the burials at 02QUI75, features abundant evidence of bifacial lithic production, a hallmark of coastal fisher-gatherer populations of the region (Gallardo et al., 1993; Agüero and Uribe, 2015). It is likely that this settlement had been logistically positioned to facilitate exchange with the village populations of Tarapacá and the Atacama.

A further five individuals were recovered during rescue excavations from two sites (02QUI37 and 02QUI81, both cemeteries with pit/shaft tombs) in the center of the valley (Fig. 3), in the area of the modern village of Quillagua (Agüero et al., 1999; Agüero and Uribe 2105; Gallardo et al., 1993). The remains from which these samples were collected are curated in the Museo de Quillagua. These cemeteries are associated with a population that resided in villages with aggregated precincts (02Qui100 and 02Qui89, two sites recently documented by this research team). The structure of these precincts recalls residential sites from Guatacondo in the Tarapacá region. Archaeological evidence allows us to characterize this settlement pattern as belonging to farmers and sedentary shepherds (e.g.Agüero et al., 2006) who are clearly distinct from those who lived in Ancachi and buried their dead at 02Qui75 (Fig. 3).

Unfortunately, extensive looting of the Ancachi cemetery resulted in only these few individuals available for analysis, and similarly sparse contextual data. The Quillagua individuals, in contrast, possess greater contextual information. Importantly, radiocarbon dates (available for nine of the twelve individuals considered here) all fall in the Late Formative, between 80 and 360 cal AD, with largely overlapping 2-sigma ranges. All available information for the individuals in this study is provided in Table 1.

Results for these Quillagua individuals were judged against our

Table 1
Contextual data for the twelve individuals analyzed in course of the present work.

Sample number	Site	Tomb/Grave #	Age	Sex	Element sampled	Offerings	Date	Reference
I-99	Ancachi (02QUI75)	UR-3			Rib	Surface collection, no data	80–240 cal AD (Beta-360551)	Clarot personal communciation 2018
I-100	Ancachi (02QUI75)	UR-3			Metacarpal	Surface collection, no data		Clarot personal communication 2018
I-101	Ancachi (02QUI75)	UR-1	Adult	?	Metacarpal	Surface collection, no data		Clarot personal communciation 2018
I-102	Ancachi (02QUI75)	UR-6	Adult	?	Metacarpal	Surface collection, no data		Clarot personal communciation 2018
I-103	Ancachi (02QUI75)	UR-2	Adult	Female	Rib	Surface collection, no data		Clarot personal communciation 2018
I-104	Ancachi (02QUI75)	UR-7			5th metatarsal	Surface collection, no data		Clarot personal communciation 2018
I-105	Ancachi (02QUI75)	UR-4	18–20	Male?	Rib	Surface collection, no data		Clarot personal communciation 2018
J-84	Quillagua (02QUI81)	Museo, caja 3-3	20–35	Male	Rib	No data	No date	Agüero et al., 1999, Clarot personal communciation 2018
J-85	Quillagua (02QUI81)	Museo, caja 2	20–35	Male	Humerus	1 piece woven cotton (brown and green), leather fragment with feathers, animal and vegetable fiber cordage, one bunch cotton (possible turban)		Agüero et al., 1999, Clarot personal communciation 2018
J-86	Quillagua Torre 203 (02QUI37)	Quillagua 1 FC-1	20–35	Female?	Rib	3 baskets (2 decorated), 1 necklace with snails pearls (Strophocheilus), 1 ceramic bottle type Quillagua Tarapacá (QTC), 1 vegetable mat, 1 woven blanket	125–256 cal AD (Beta-464541)	Agüero y Uribe (2015), Sinclaire and Clarot personal communciation 2018
J-92	Quillagua Torre 203 (02QUI37)	Quillagua 02 FC-2	≈4		Rib	4 baskets (3 decorated), 1 ceramic bottle type Quillagua Tarapacá (QTC), 1 ceramic vessel type Quillagua Rojo Pulido (QRP), 1 woven blanket, 1 bone artifact, 1 beam of vegetable fibers, remains of leather with feathers (marine bird)	202–362 cal AD (Beta-464544)	Agüero y Uribe (2015), Sinclaire and Clarot personal communciation 2018
J-93	Quillagua (02QUI81)	Quillagua rescate 2013-1	35–50	Male	Rib	1 retouched silica flake, 3 ceramic fragments (black, unregistred type)	No date	Agüero et al., 1999, Clarot personal communciation 2018

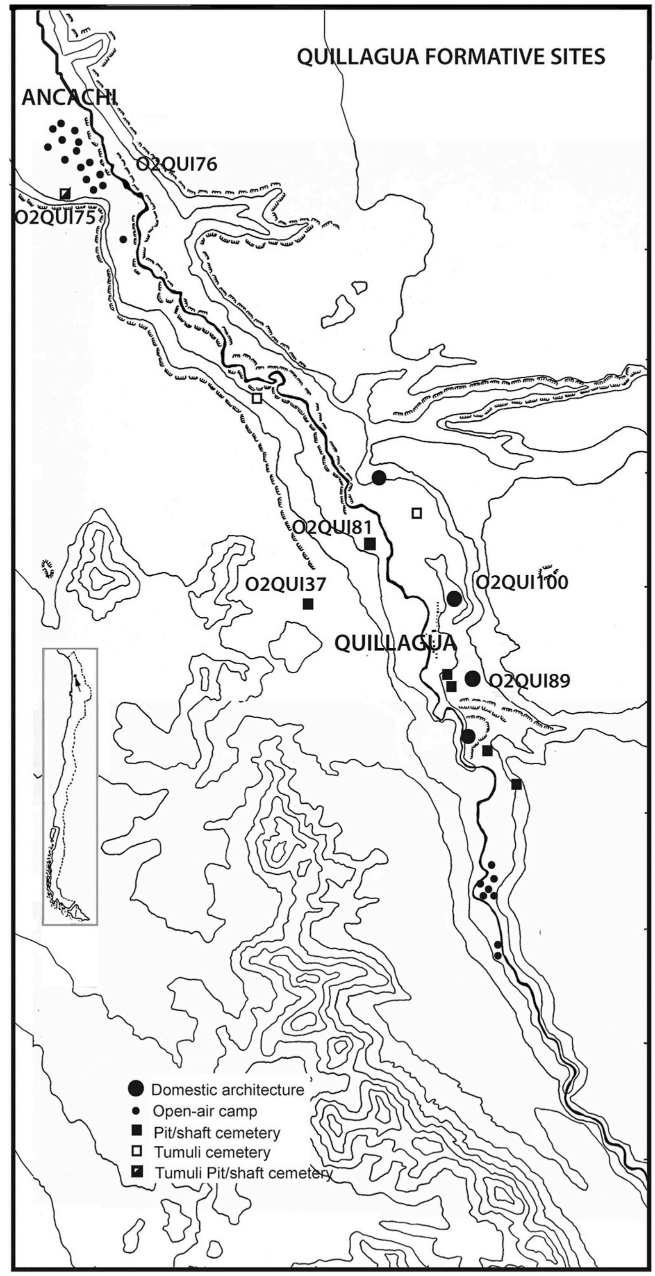

Fig. 3. Map of Quillagua and environs, locations of sites represented in present sample study indicated.

comparative regional sample of isotopically analyzed Formative Period human remains that now numbers 164 individuals (Table 2). Crucially, this comparative sample includes individuals from throughout the broad region of Quillagua's exchange networks. Among those included are coastal individuals from near the mouth of the Loa River (principally the Caleta Huelen sites of CH7, CH10, CH10A, CH20, and CH51) and sites farther south (Gualaguala 1 and 4, Michilla Norte 2 and 5, among others), individuals buried at a series of inland Loa oases (San Salvador, Villa Chuquicamata, and Topater), others from the extreme interior (Chiu Chiu and Calar), and a series of seven travelers, individuals who died and were buried alongside the aforementioned travel/trade routes (Torres-Rouff et al., 2012; Pimentel et al., 2017). Finally, the comparative sample includes twelve individuals from the Tarapacá 40 cemetery, facilitating comparison with populations residing several hundred kilometers north of the Quillagua oasis (Santana-Sagredo et al., 2015b).

Table 2
Regional comparative dataset, n = 164.

Region	Site	n
Coastal-Loa	Urcu-1	1
	CH51	2
	CH7	14
	CH10	1
	CH10A	5
	CH20	6
Coastal-South	Michilla Norte 02	15
	Gualaguala 01	10
	Gualaguala 04	10
	Al Norte de Tocopilla	1
	Costa Tocopilla	1
	Los Canastos	1
	Punta Tames	1
	Aguada Gualaguala 04	1
	Hornitos 1	3
	Michilla 4	1
	Michilla 5	17
	Punta Guaque	1
	Punta Guaque 2	2
	Punta Yayes 109	2
Loa oases	San Salvador	12
	Villa Chuquicamata	15
	Topater	12
Interior	RAnL	6
	Calar	5
Tarapacá	Tarapacá 40	12
Travelers	El Toco	1
	Chancance-Michilla	1
	Calate	4
	Choluto-Taltal	1

Extraction of collagen and hydroxyapatite from human bone samples was performed at the Archaeological Stable Isotope Lab at the University of Miami. Samples were ground by hand in a ceramic mortar and pestle and then separated into size fractions using geological screens. Collagen extraction followed a protocol established by Longin (1971) and modified by Pestle (2010). For each sample, 0.5 g of the 0.5–1.0 mm fraction were weighed, placed in 50 ml centrifuge tubes, and demineralized in 30 mL of 0.2 M HCl on a spinning rotator for 24 h. Samples were then rinsed to neutral by a process of centrifugation, decanting, and the addition of distilled water, repeated a total of four times. Humic removal was achieved by adding 30 mL of 0.0625 M NaOH to each sample for 20 h, after which time, the samples were again rinsed to neutral. The remaining collagen was then gelatinized in 10^{-3} M HCl at 90 °C, filtered using single-use 40 μm Millipore Steriflip® vacuum filters, condensed, frozen, and freeze-dried. Start and end weights were used to calculate collagen yield.

Hydroxyapatite extraction followed a protocol laid out in Lee-Thorp (1989) and Krueger (1991), and modified by Pestle (2010). 0.1 g of the 0.125–0.25 mm fraction of each sample, after being placed in 50 ml centrifuge tubes, underwent 24 h oxidation of organics in 30 mL of 50% bleach. This process was repeated one more time for a total of 48 h of treatment. The apatite samples were rinsed to neutral in the same manner as the collagen samples before undergoing acid treatment for removal of labile carbonates in 30 mL of 0.1 M acetic acid for 4 h, with a 5 min vacuum treatment at the 2-h mark. After acid treatment, the samples were rinsed again in the same manner as described previously, before being frozen and freeze-dried. Again, before and after weights were used to calculate the wt% hydroxyapatite yield.

Isotopic analysis of both biomolecules was performed in the Marine Geology and Geophysics Stable Isotope Laboratory at the Rosenstiel School of Marine and Atmospheric Science at the University of Miami. Collagen samples were packed into tin capsules and analyzed using a PDZ Europa ANCA-GSL elemental analyzer interfaced to a PDZ Europa 20–20 isotope ratio mass spectrometer (IRMS). This process yields data on elemental (C and N) composition as well as $\delta^{13}C_{co}$ and $\delta^{15}N_{co}$, the stable isotope ratios of carbon and nitrogen, respectively. Analysis of hydroxyapatite samples was conducted using a Kiel-IV Carbonate Device coupled to a Thermo-Finnigan DeltaPlus IRMS, providing the $\delta^{13}C_{ap}$ values. Precision for replicates of bone collagen and hydroxyapatite was better than 0.1‰ for all analyzed isotope systems. All isotope results were calibrated using acetanilide and glycine for collagen and an in-house carbonate standard calibrated to NBS-19 for hydroxyapatite. Standards were run in every sample run bracketing analyzed samples.

Traditionally, measured isotopic values were visually compared with the range of possible source values, permitting only statements of the relative importance of various foodstuff contributions to individual diet. Over the last fifteen years, however, multi-source mixture modeling techniques have been applied with increasing frequency to the analysis of isotopic paleodiet data, in the hopes of better bounding estimates of food source contribution (Lubetkin and Simenstad, 2004; Moore and Semmens, 2008; Parnell et al., 2010, 2013; Phillips, 2001; Phillips and Gregg, 2003; Fernandes et al., 2014). The early forms of such analysis were generally Euclidian distance and linear mixing models, the first of which were inaccurate when all possible sources did not contribute to the mixture, and the second of which could not accommodate data coming from more than $n+1$ sources, with n being the number of measured dietary proxies (Phillips, 2001).

Recent southern Andean attempts (e.g. Andrade et al., 2015; Pestle et al., 2016a, 2016b) at modeling have used a Bayesian approach, which accommodates underdetermined systems (those with more than $n+1$ sources), and also allows for the incorporation of prior knowledge (Parnell et al., 2010; Moore and Semmens, 2008; Fernandes et al., 2014). These approaches "offer a powerful means to interpret data because they can incorporate prior information, integrate across sources of uncertainty and explicitly compare the strength of support for competing models or parameter values," (Moore and Semmens, 2008, p. 471). Crucially, these approaches are model-bound and therefore infer the probability of possible alternatives fitting the observed data following Bayesian principles.

For the purposes of the present work, we employed the FRUITS (Food Reconstruction Using Isotopic Transferred Signals) model of Fernandes' and colleagues (2014). This software allows the user to incorporate uncertainty, routing/fractionation (consumer-foodstuff offsets), foodstuff macronutrient concentration and digestibility, protein consumption limits, and various other information specific to the sample, in a model that can probabilistically quantify dietary inputs on an individual-by-individual basis. As the authors note, "FRUITS is a novel Bayesian mixing model that efficiently handles knowledge on dietary routing mechanisms and provides a platform for the simple introduction of expert prior information to arrive at an accurate diet reconstruction, complete with uncertainty estimates, based on chemical and isotopic dietary proxies," (Fernandes et al., 2014:8). In the present case, the input parameters include fractionation-corrected consumer (human) isotope values, food web macronutrient and isotope composition, stipulated routing of dietary macronutrients to consumer tissues, and physiological boundaries for protein intake. 10,000 simulation runs were performed for each individual included in the present study.

In the case of the Quillagua individuals, the fractionation value for $\delta^{13}C_{co}$ was determined using the regression method of Pestle et al. (2015a). The offset employed for $\delta^{13}C_{ap}$ was 10.1 ± 0.4‰ (Fernandes et al., 2012), and for $\delta^{15}N_{co}$ fractionation value was stipulated as 3.6 ± 1.2‰ (Ambrose, 2000; DeNiro and Epstein, 1981; Hare et al., 1991; Howland et al., 2003; Sponheimer et al., 2003; Warinner and Tuross, 2009). With respect to elemental routing, $\delta^{15}N_{co}$ was stipulated as reflecting nitrogen in dietary protein alone, $\delta^{13}C_{ap}$ was taken to reflect whole diet, and $\delta^{13}C_{co}$ was designated as reflecting a ratio of roughly 3:1 dietary protein to energy (74 ± 4%:26%) following the example of Fernandes et al. (2012). Consumption of protein was limited to between 10% and 60% of protein as energy (using the FRUITS prior data option), reflecting the lower and upper limit of possible human

Table 3
Macronutrient, elemental, and isotopic data for foodweb groupings used in multi-source mixture model.

Food grouping	Group n	Macronutrient concentration (%)				%C				Tissue δ13C (‰)					Tissue δ15N (‰)	
		Protein	Fat	Carbohydrates	Energy	Protein	Fat	Carbohydrates	Energy	Bulk	Protein	Fat	Carbohydrates	Energy	Bulk	Protein
Terrestrial animals	30	83 ± 12	16 ± 12	1 ± 3	17 ± 12	43 ± 12.7	12 ± 12.1	0 ± 4.2	13 ± 12.7	−19.7 ± 3.4	−21.7 ± 3.4	−26.7 ± 3.4	−20.2 ± 3.4	−26.5 ± 3.4	8.1 ± 1.9	8.1 ± 1.9
Marine animals	90	74 ± 11	18 ± 11	8 ± 3	26 ± 11	39 ± 11.3	14 ± 10.9	4 ± 3.9	17 ± 11.3	−14 ± 2.7	−16.5 ± 2.7	−20 ± 2.7	−14.5 ± 2.7	−18.8 ± 2.7	19.1 ± 3	19.1 ± 3
C3 plants	63	11 ± 5	5 ± 4	84 ± 7	89 ± 5	5 ± 6.9*	4 ± 6.7	37 ± 8.5	41 ± 6.9	−23.9 ± 1.5	−25.9 ± 1.5	−29.9 ± 1.5	−24.4 ± 1.5	−24.9 ± 1.5	6.7 ± 4.9	6.7 ± 4.9
C4/CAM plants	19	11 ± 5	5 ± 4	84 ± 7	89 ± 5	5 ± 6.9*	4 ± 6.7	37 ± 8.5	41 ± 6.9	−10.5 ± 1.1	−12.5 ± 1.1	−16.5 ± 1.1	−11 ± 1.1	−11.5 ± 1.1	7.6 ± 4.4	7.6 ± 4.4
Legumes	21	28 ± 2	2 ± 1	71 ± 3	72 ± 2	13 ± 5.6*	1 ± 5.3	31 ± 5.8	33 ± 5.6	−23.4 ± 1.4	−25.4 ± 1.4	−29.4 ± 1.4	−23.9 ± 1.4	−24.1 ± 1.4	1.6 ± 1.8	1.6 ± 1.8

* assumes 87.4% digestibility of plant protein as compared to animal protein.

protein intake World Health Organization (2007).

Foodweb isotope values were based on a corpus of some 233 representative southern Andean animal and plant samples (DeNiro and Hastorf, 1985; Pestle et al., 2015b; Schoeninger and DeNiro, 1984; Tieszen and Chapman, 1992), which were grouped for the purposes of the present analysis into the five categories (C_3 plants, C_4/CAM plants, legumes, land animals, marine animals). As seen in Table 3, Macronutrient and/or isotopic differences among these five food groupings are stark. Any modern data included in this reference sample had $\delta^{13}C$ values corrected by +1.5‰ to account for the fossil fuel burning effect (Keeling et al., 1979). Macronutrient composition of each food group was determined by reference to a range of comparable foodstuffs in the USDA National Nutrient Database for Standard Reference (United States Department of Agriculture, 2017). Elemental composition (particularly %C) of each foodstuff/macronutrient group was based on formulae provided in Morrison et al. (2000). Isotopic offsets between measured bulk food isotope values and the isotopic values of specific dietary macronutrients were derived from Tieszen (1981), and digestibility differences were determined following Hopkins (1981).

4. Results

Quality of sample preservation was assessed using chemical (collagen yield) and elemental (carbon and nitrogen yield, atomic C/N ratio) measures, all of which are routinely generated in the course of sample extraction and elemental analysis. Only those samples meeting widely accepted standards (collagen yield > 0.5 wt%, carbon and nitrogen yields of greater than 4.5 and 0.9 wt%, respectively, and atomic C/N ratios between 2.9 and 3.6) were included in subsequent analysis/discussion (Ambrose, 1990; Pestle and Colvard, 2012). Samples with sufficient collagen preservation were assumed to also have well-preserved hydroxyapatite (a safe assumption given the almost complete absence of ground water in soils of the study region).

Details of the state of sample preservation are presented in Table 4. Overall, 83.3% (10 of 12) of the analyzed samples possessed sufficient unaltered collagen for isotope study (note that the elemental analyzer did not produce any data for sample I-102, however based on the high collagen yield and midrange isotope values, the sample was included for later analysis). The average collagen yield for the ten well-preserved samples was 15.9 ± 6.7 wt%, whereas elemental carbon yield averaged 41.2 ± 2.5 wt%, nitrogen 14.1 ± 1.3 wt%, and atomic C:N 3.4 ± 0.2. Given the small overall sample size, we did not attempt inter-site statistical comparisons of these sample quality data, nor of the isotopic data presented below.

Turning to the isotopic results (Table 4), $\delta^{13}C_{co}$ for individuals from the two sites averaged −15.3 ± 1.0‰, $\delta^{15}N_{co}$ 17.3 ± 4.2‰ (a large standard deviation, a point to which we return below), $\delta^{13}C_{ap}$ −11.3 ± 0.6‰, and $\Delta^{13}C_{ap\text{-}co}$ averaged 4.0 ± 0.7‰. Comparing the isotopic characteristics of individuals from Ancachi and Quillagua proper found relatively similar average $\delta^{13}C_{co}$, $\delta^{13}C_{ap}$, and $\Delta^{13}C_{ap\text{-}co}$ values, but the Quillagua individuals were more variable for all three of the carbon isotope systems. In the case of $\delta^{15}N_{co}$, the four Quillagua individuals were far more variable than their counterparts from Ancachi (a range of 14.8‰ compared to 3.7‰). The results of FRUITS modeling provide insights into the causes of these isotopic differences.

As seen in Table 5, based on the results of the FRUITS modeling, C_3 plants were the largest contributor to diet for individuals at both sites, providing 37–49% of total calories to those people buried at Ancachi and 34–42% for those from Quillagua. C_4/CAM plants (including maize) were a much less important part of the diet at both sites, accounting for 5–8% of diet at Ancachi and a slightly higher 7–11% at Quillagua. Turning to more protein-rich foods, some inter-site differences are evident, although small sample size makes assessments of the significance of these differences impossible. While land animals made up 6–11% of diet at Ancachi, there was greater variability in its dietary contribution (from 4 to 15%) at Quillagua. This trend of greater

Table 4
Chemical, elemental, and isotopic data for twelve analyzed Quillagua/Ancachi individuals.

Sample number	Site	Tomb/Grave #	Collagen yield (wt%)	Apatite yield (wt%)	wt% C	wt% N	Atomic C:N	δ13Cco (‰)	δ15Nco (‰)	δ13Cap (‰)	Δ13Cap-co (‰)
I-99	Ancachi	UR-3	18.4	42.8	39.6	13.6	3.4	−14.8	20.4	−11.6	3.2
I-100	Ancachi	UR-3	23.9	40.1	43.5	14.9	3.4	−15.1	17.9	−11.4	3.7
I-101	Ancachi	UR-1	14.6	33.2	38.6	12.0	3.7	−15.4	18.5	−10.5	4.9
I-102	Ancachi	UR-6	24.5	23.8	–	–	–	−15.3	16.9	−11.5	3.8
I-103	Ancachi	UR-2	14.6	41.2	39.6	13.4	3.4	−15.4	16.7	−11.8	3.6
I-104	Ancachi	UR-7	*10.9*	*33.1*	*36.1*	*9.7*	*4.3*	*−16.2*	*19.5*	*−11.2*	*5.0*
I-105	Ancachi	UR-4	20.2	44.0	39.8	14.0	3.3	−14.6	16.9	−11.2	3.4
J-84	Quillagua (02QUI81)	Museo, caja 3-3	16.0	43.3	44.4	15.6	3.3	−15.1	17.7	−11.6	3.5
J-85	Quillagua (02QUI81)	Museo, caja 2	*19.0*	*20.3*	*43.1*	*12.5*	*4.0*	*−19.4*	*13.1*	*−14.6*	*4.8*
J-86	Quillagua Torre 203 (02QUI37)	Quillagua 1 FC-1	7.0	34.0	41.9	13.6	3.6	−13.4	25.8	−10.0	3.4
J-92	Quillagua Torre 203 (02QUI37)	Quillagua 02 FC-2	16.6	34.5	44.9	16.3	3.2	−16.5	10.9	−11.5	5.0
J-93	Quillagua (02QUI81)	Quillagua rescate 2013-1	3.2	43.5	38.9	13.4	3.4	−17.1	11.2	−12.1	5.0

variability at Quillagua continues when considering legumes, which made up 16–21% of diet at Ancachi and 9–25% of dietary intake at Quillagua. Finally, when considering marine animal consumption, the same pattern is expressed, as such animals make up between 21 and 29% of the diet at Ancachi, and a more varied 10–43% of dietary intake at Quillagua. In all of these instances, however, the magnitude of error in dietary contribution estimates is quite large (averaging between 7% and 14% for the various dietary components), making determination of the meaning of these differences in variability more contingent.

All told, the diets of the four individuals buried at the center of the Quillagua valley showed far greater variability than those from Ancachi, particularly insofar as proteinaceous foods were concerned. Viewed in light of previous research in the region, these differences may well be attributable to different points of origin/cultural affiliations of the individuals buried in these different precincts. It is only when the results from these two sites are considered in the context of the modeling results of the host of other individuals from throughout the Atacama that the notion of interculturation, with which we began this paper, becomes evident.

5. Discussion

In Figs. 4 and 5, we present a biplot of collagen isotope values for all samples under consideration here and one possible visualization of the results of the isotope analysis and dietary modeling of the ten newly analyzed individuals from Quillagua and the 164 previously analyzed Formative Period individuals from the Norte Grande of Chile, who together represent the region's complex dietary landscape (foodscape). Against this backdrop, the divergent tendencies of the ten Ancachi/Quillagua individuals seem particularly intriguing.

From these data, it is quite obvious, first of all, that the diet of the coastal peoples included here was very distinct, with a very heavy focus on marine animal consumption. This finding comes as no real surprise given the wealth of the available marine resources and previous archaeological and isotopic work. Intriguingly, the modeled data suggest that we can now differentiate between those individuals recovered from sites near the mouth of the Loa River (the Caleta Huelén sites) and coastal residents from farther south (near Punta Mejillones) based on differences in carbon isotope composition that modeling ascribes to differences in C_4/CAM plant intake.

At the other dietary extreme from the coastal populations are those individuals buried at Chiu Chiu and Topater, whose diets featured almost exclusive land animal and C_3 plant consumption. Those individuals recovered from San Salvador and Villa Chuquicamata would appear to have more varied diets (among individuals buried at each site), especially as far as plant consumption is concerned, and Villa Chuquicamata shows a particularly notable degree of dietary diversity in this regard. The Tarapaqueño individuals analyzed bySantana-Sagredo et al. (2015b) are also quite variable and fall into the iso-space that also describes individuals from sites as varied as Villa Chuquicamata, San Salvador, and Calar. Finally, the modeling data would appear to indicate that most of the travelers (those who died *en route* crossing the Atacama) were coastal in origin, likely from near the mouth of the Loa River, and one possibly from farther south. Judged against this backdrop, the two groups of individuals from the Quillagua valley presented here show starkly different patterns of consumption.

Table 5
Results of multi-source mixture modeling for twelve analyzed Quillagua/Ancachi individuals.

Sample number	Site	Tomb/Grave #	Modeled dietary contribution (%), mean ± sd				
			Terrestrial animals	Marine animals	C3 plants	C4/CAM plants	Legumes
I-99	Ancachi	UR-3	6 ± 4	28 ± 9	42 ± 17	8 ± 7	16 ± 14
I-100	Ancachi	UR-3	10 ± 9	21 ± 7	43 ± 18	6 ± 5	19 ± 17
I-101	Ancachi	UR-1	9 ± 8	28 ± 9	38 ± 16	7 ± 5	19 ± 14
I-102	Ancachi	UR-6	11 ± 8	25 ± 9	40 ± 14	6 ± 4	17 ± 14
I-103	Ancachi	UR-2	8 ± 7	21 ± 12	49 ± 23	5 ± 4	17 ± 16
I-104	Ancachi	UR-7	-	-	-	-	-
I-105	Ancachi	UR-4	8 ± 6	29 ± 7	37 ± 14	6 ± 4	21 ± 15
J-84	Quillagua (02QUI81)	Museo, caja 3-3	4 ± 4	43 ± 8	34 ± 13	9 ± 5	10 ± 9
J-85	Quillagua (02QUI81)	Museo, caja 2	-	-	-	-	-
J-86	Quillagua Torre 203 (02QUI37)	Quillagua 1 FC-1	4 ± 3	41 ± 9	35 ± 13	11 ± 8	9 ± 9
J-92	Quillagua Torre 203 (02QUI37)	Quillagua 02 FC-2	15 ± 10	10 ± 6	42 ± 18	7 ± 6	25 ± 17
J-93	Quillagua (02QUI81)	Quillagua rescate 2013-1	13 ± 11	20 ± 9	40 ± 16	8 ± 6	20 ± 15

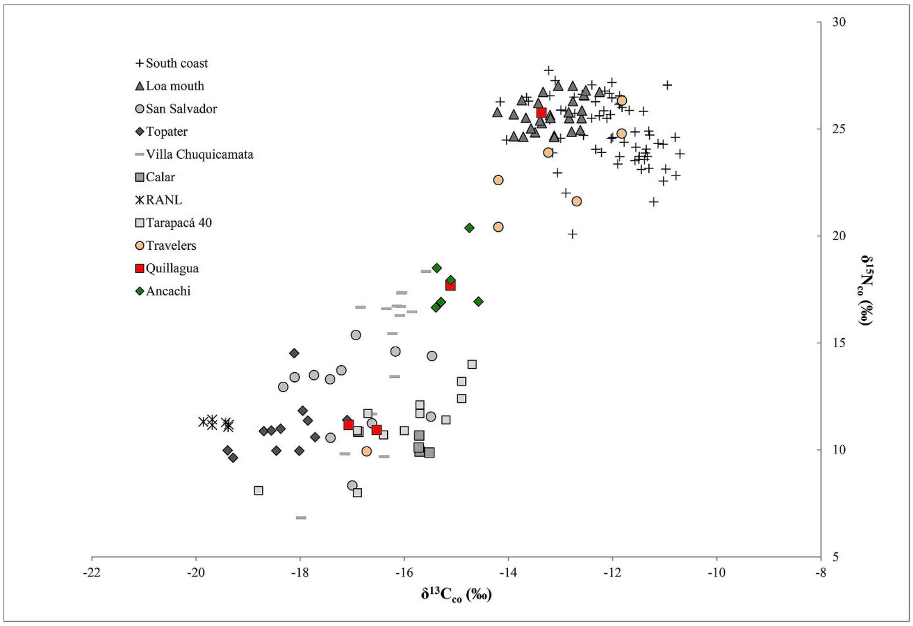

Fig. 4. Collagen isotope biplot of all individuals discussed in present study. Data for previously analyzed 164 individuals and ten individuals from present study juxtaposed.

On the one hand, at Quillagua proper we see a pattern of significant dietary diversity, particularly in terms of protein consumption. On an individual basis, there is clear evidence of individuals (J-84 and J-86), buried inland at Quillagua, who possessed dietary patterns (40% plus marine animal consumption) entirely consistent with coastal origin (specifically from the mouth of the Loa River). Put differently, these two individuals would appear to be coastal peoples buried at an inland site (as opposed to isolated burials alongside a travel route), a first in our studies in the region. Alongside these individuals, however, another individual (J-92) showed a pattern of consumption (high legume and animal protein consumption) congruent with diets from far inland and oasis sites like San Salvador, Topater, and Calar. It is intriguing to note that both J-86 (an individual with a diet typical of the coast) and J-92 (with a typically inland diet) were from the same site (02QUI37), were contemporaries, and shared most aspects of their mortuary provisioning (decorated baskets, Quillagua Tarapacá ceramics). In fact, of the two, it was individual J-92, who had a diet typical of inland residents, who was interred with objects hinting at coastal affiliation (a fishing tool and marine bird feathers). This finding attests to the complexity of identity formation in this interconnected space.

An additional Quillagua individual (J-93) presented an intriguing intermediate diet that combined features of both inland and coastal patterns of consumption, a combination that patterns closely with the consumption habits seen for all six of the individuals recovered from Ancachi. Unlike the dietary diversity seen at Quillagua proper, at Ancachi we find a pattern of consistently mixed diets, particularly as dietary protein is concerned. Diets at Ancachi were highly standardized, with heavy reliance on C_3 plants, very low consumption of C_4/CAM

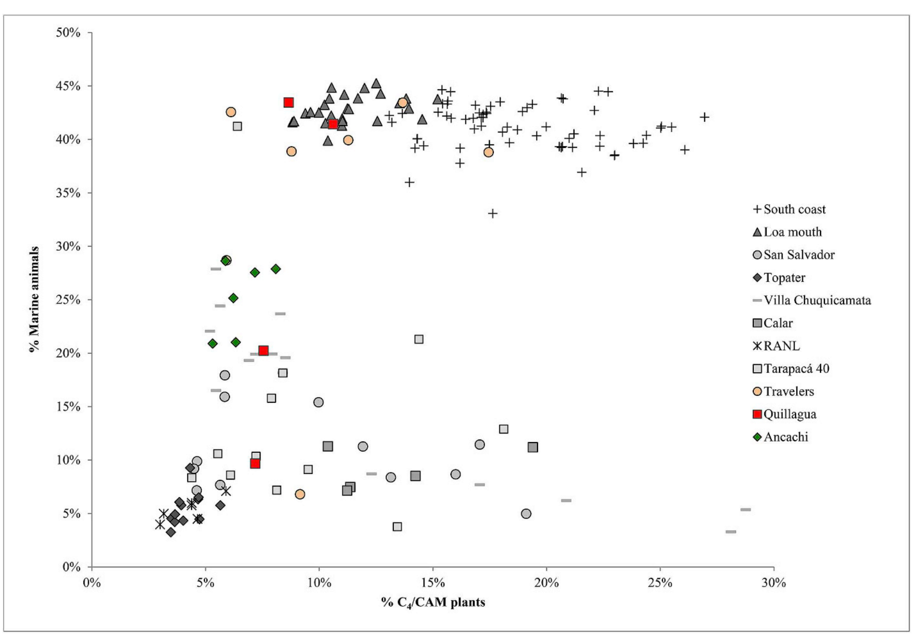

Fig. 5. Scatterplot of modeled consumption of C_4/CAM plants and marine animals. Data for previously analyzed 164 individuals and ten individuals from present study juxtaposed.

plants, and a dietary protein regime that consisted of a mixture of marine, terrestrial, and leguminous protein (with an average ratio of approximately 3:1:2). Both the consistency of inter-individual diet at Ancachi and its "middle position" between the coastal and interior dietary extremes sets the individuals of this site apart from almost every other individual in our regional sample (some Villa Chuquicamata individuals excepted). We argue that this ability to examine diet at the micro-scale, while limited in individuals, offers a unique perspective with which to understand this cultural phenomenon.

The cultural implications of the dietary patterns seen in Quillagua and Ancachi are noteworthy. On the one hand, these data confirm that Quillagua was neither a simple economic node in a broader network, nor merely a barrier between two groups. The presence, in this small sample, of individuals representing nearly the full extent of dietary extremes of the region, suggests instead that the site may have been a locale of cultural (or at least dietary) pluralism. Indeed, in this space we can clearly see the existence of coastal peoples in the interior, and interior people moving nearer the coast, a model of mobility that is more complex than archipelagic or gyratory models would suggest, and akin to findings from studies of later periods in the region (e.g. Santana-Sagredo et al., In Press). As such, we argue that these data support notions advanced by others working on the Formative Period in the region (e.g. Agüero et al., 2001, 2006), that Quillagua was a true frontier, a borderland, in which people of diverse origin were congregating at great time depth.

More importantly, however, in this spatially restricted and logistically situated site, we posit that we also find a space where people appear to have been forging a new way of life and making a new culture from components derived from previously existing coastal and interior lifeways. We argue that the mixed diet of the six individuals from Ancachi and the one additional individual from Quillagua (J-93) are a manifestation of the interculturation that can exemplify frontier spaces. Taking cultural (dietary) practices from two ends of the Atacama region and hybridizing them over decades of life, these Formative Period individuals stand as testament to the ways in which the ancient border or frontier of Quillagua once functioned. The formation of new dietary traditions in a frontier space stands in marked contrast to the maintenance of homeland cultural traditions suggested by previous models for the behaviors of colonists (e.g. Núñez, 1984; Núñez and Dillehay, 1995). These individuals were living and embodying the border space in a powerful example of the sort of cultural innovation that often occurs at such liminal zones. As interdisciplinary work on borderlands suggests, new forms of culture—new lifeways—often spring forth from those actors and societies involved in frontier/border interactions. And, as the contact hypothesis suggests, such cultural change and innovation is far more likely to have resulted from long-term meaningful social contact rather than simply being a consequence of transactional/economic relations.

6. Conclusions

Few phenomena are as fundamental to cultural and ethnic identity as diet and, as a consequence, paleodietary characterization can serve as a powerful tool for the reconstruction of past ethnic differences and processes of identity formation. In the present work, stable isotope analysis and Bayesian multi-source mixture modeling permitted the identification and characterization of individuals with markedly different consumption practices among a group of twelve Formative Period individuals buried in/near the modern village of Quillagua. Given that this village has been identified as both a frontier between Formative Period groups and as a node of inter-regional exchange networks of the Formative and later periods, we posit that the different dietary regimens are a consequence of different economic and cultural behaviors and roles.

In addition to both coastal and interior-derived individuals, who may have been transient actors in the aforementioned systems of regional movement and exchange, our analysis also identified a subset of seven individuals whose patterns of consumption were distinct from both such regional extremes. We associate the diet of this final group of individuals, who, most notably, consumed a previously unobserved combination of coastal and interior protein sources, with the propensity of frontier zones to produce cultural hybridity and creolization (Barth, 1976[1969], 1998, 2000; Naum, 2010; Newman, 2006:151; van Dommelen, 1997, 1998; White, 1991). The creole diet of these individuals is a powerful testament to the generative power of border spaces. Furthermore, we suggest that the production of novel beliefs and behaviors, in this case new patterns of lifelong diet, are most likely to result from circumstances of long-term equal status contact and interaction, the kinds of interactions that literature on the contact hypothesis suggests are more likely to sway the habits and beliefs of peoples of different cultural backgrounds (Kende et al., 2017; Pettigrew and Tropp, 2006; Mirwaldt, 2010; Pettigrew et al., 2011).

Based on the data presented here, we suggest that these seven Formative Period individuals likely were engaged, or were the descendants of people engaged, in profound social relations between coastal and interior groups, groups that passed through, and interacted at, Quillagua. Regardless, their creation/adoption of new cultural practices provides strong evidence of the intensity and depth of social relations that existed in Formative Period Quillagua. That groups of individuals began eating and living in entirely new ways, which drew from both coastal and interior cultural repertoires, provides stark, if preliminary, testament of *vínculos*, strong and pronounced social linkages between individuals and groups operating in border/frontier spaces. The economic dimensions of Quillagua's Formative Period importance are well-established, and its role as a frontier and node have previously been suggested; this analysis reveals a social and cultural consequences of the site's role as a border and nodal space. While this preliminary conclusion is based on analysis of what is, at present, a limited number of individuals, the putative identification of this distinct social and cultural phenomenon is a point to which future studies can, and should, return and examine.

Acknowledgements

The authors would like to acknowledge the financial support of CONICYT, FONDAP 15110006 and FONDECYT 1160045. Furthermore, we would like to thank Dr. Peter Swart and the staff of the Marine Geology and Geophysics' Stable Isotope Laboratory at the University of Miami's Rosenstiel School of Marine and Atmospheric Science.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.quaint.2019.03.014.

References

Adán, L., Urbina, S., Pellegrino, C., Agüero, C., 2013. Aldeas en los bosques de *Prosopis*: arquitectura residencial y congregacional en el período Formativo tarapaqueño (900 ac-900 DC). Estud. Atacameños 45, 75–94.

Agüero, C., Ayala, P., Uribe, M., Carrasco, C., Dases, B., 2006. El periodo formativo desde Quillagua. In: Lechman, H. (Ed.), Esferas de interacción prehistóricas y fronteras nacionales modernas. IEP, Lima, pp. 73–118.

Agüero, C., Dases, B., 2004. Quillagua y los textiles formativos del Norte Grande de Chile. Chungara, pp. 585–597 Especial.

Agüero, C., Uribe, M., 2015. Tombs and tumuli on the coast and Pampa of tarapaca: explaining the Formative Period in northern Chile (South-Central Andes). In: Eeckhout, P., Owens, L.S. (Eds.), Funerary Practices and Models in the Ancient Andes. The Return of the Living Dead. Cambridge University Press, Cambridge, UK, pp. 152–183.

Agüero, C., Uribe, M., Ayala, P., Dases, B., 1999. Una aproximación arqueológica a la etnicidad: el rol de los textiles en la construcción de la identidad cultural en los cementerios de Quillagua (Norte de Chile). Gaceta Arqueológica Andina 25, 167–198.

Agüero, C., Uribe, M., Ayala, P., Dases, B., Carrasco, C., 2001. Ceremonialismo del período Formativo en Quillagua, Norte Grande de Chile. Boletín de la Sociedad

Chilena de Arqueología 32, 24–34.
Allport, G.W., 1954. The Nature of Prejudice. Addison-Wesley, Cambridge MA.
Ambrose, S.H., 1990. Preparation and characterization of bone and tooth collagen for isotopic analysis. J. Archaeol. Sci. 17 (4), 431–451.
Ambrose, S.H., 1993. Isotopic analysis of paleodiets: methodological and interpretive considerations. In: Sanford, M.K. (Ed.), Investigation of Ancient Human Tissue Chemical Analyses in Anthropology. Gordon and Breach, Langhorne, PA, pp. 59–130.
Ambrose, S.H., 2000. Controlled diet and climate experiments on nitrogen isotope ratios of rats. In: Ambrose, S.H., Katzenberg, M.A. (Eds.), Biogeochemical Approaches to Paleodietary Analysis. Kluwer Academic/Plenum Publishers, New York, pp. 243–259.
Ambrose, S.H., Krigbaum, J., 2003. Bone chemistry and bioarchaeology. J. Anthropol. Archaeol. 22 (3), 193–199.
Ambrose, S.H., Norr, L., 1993. Experimental evidence for the relationship of the carbon isotope ratios of whole diet and dietary protein to those of bone collagen and carbonate. In: Lambert, J.B., Grupe, G. (Eds.), Prehistoric Human Bone: Archaeology at the Molecular Level. Springer-Verlag, New York, pp. 1–37.
Andrade, P., Fernandes, F., Codjambassis, K., Urrea, J., Olguín, L., Rebolledo, S., Lira, F., Aravena, C., Berríos, M., 2015. Subsistence continuity linked to consumption of marine protein in the Formative Period in the interfluvic coast of northern Chile: Re-assessing contacts with agropastoral groups from the highlands. Radiocarbon 57 (4), 1–10.
Ballester, B., Gallardo, F., 2011. Prehistoric and historic networks on the Atacama Desert coast (northern Chile). Antiquity 85, 875–889.
Barth, F., 1976. Los Grupos Étnicos Y Sus Fronteras. Fondo de Cultura Económica, Mexico D.F.
Barth, F., 1998. Ethnic Groups and Boundaries: the Social Organization of Culture Difference. Waveland press, Prospect Heights, Illinois.
Barth, F., 2000. Boundaries and connections. In: Cohen, A.P. (Ed.), Signifying Identities. Routledge, London, pp. 17–36.
Castro, V., Berenguer, J., Gallardo, F., Llagostera, A., Salazar, D., 2016. Vertiente Occidental Circumpuñena. Desde las sociedades posarcaicas hasta las preincas (ca. 1.500 años a.C. a 1.470 años d.C.). In: Falabella, F., Uribe, M., Sanhueza, L., Aldunate, C., Hidalgo, J. (Eds.), Prehistoria en Chile: Desde sus Primeros Habitantes Hasta Los Incas. Editorial Universitaria, Santiago de Chile, pp. 239–283.
DeNiro, M.J., Epstein, S., 1981. Influence of diet on the distribution of nitrogen isotopes in animals. Geochimica et Chosmochimica Acta 45, 341–351.
DeNiro, M.J., Hastorf, C., 1985. Alteration of 15N/14N and 13C/12C ratios of plant matter during the initial stages of diagenesis: studies using archaeological specimens from Peru. Geochimica et Chosmochimica Acta 49, 97–115.
Fernandes, R., Nadeau, M.-J., Grootes, P.M., 2012. Macronutrient-based model for dietary carbon routing in bone collagen and bioapatite. Archaeol. Anthropol. Sci. 4, 291–301.
Fernandes, R., Millard, A.R., Brabec, M., Nadeau, M.-J., Grootes, R., 2014. Food reconstruction using isotopic transferred Signals (FRUITS): a bayesian model for diet reconstruction. PLoS One 9 (2) e87436.
Gallardo, F., 2009. Social interaction and rock art styles in the Atacama. Antiquity 83, 619–633.
Gallardo, F., Cornejo, L., Sánchez, R., Casses, B., Román, A., Deza, A., 1993. Una aproximación a la cronología y el asentamiento en el oasis de Quillagua (río Loa, II región). Actas del XII Congreso Nacional de Arqueología. vol. 4. Boletín del Museo Regional de la Araucanía, Temuco, pp. 41–60.
Gallardo, F., Correa, I., Pimentel, G., Blanco, J.F., 2017a. Consumption consumes: circulation, exchange, and value of San Pedro de Atacama black polished ceramics. Lat. Am. Antiq. 28 (2), 252–268.
Monumentos funerarios en la costa del desierto de Atacama. In: In: Gallardo, F., Ballester, B., Fuenzalida, y N. (Eds.), Serie Monográfica de la Sociedad Chilena de Arqueología 7 Santiago de Chile.
Hare, P.E., Fogel, M.L., Stafford, T.W., Mitchell, A.D., Hoering, T.C., 1991. The isotopic composition of carbon and nitrogen in individual amino acids isolated from modern and fossil proteins. J. Archaeol. Sci. 18, 277–292.
Hopkins, D.T., 1981. Effects of variations in protein digestibility. In: Bodwell, C.E., Adkins, J.S., Hopkins, D.T. (Eds.), Protein Quality in Humans: Assessment and in Vitro Estimation. AVI Publishing, Westport, CT, pp. 178–181.
Houston, J., 2006. Variability of precipitation in the Atacama Desert: its causes and hydrological impact. Int. J. Climatol. 26, 2181–2198.
Howland, M.R., Corr, L.T., Young, S.M.M., Jones, V., Jim, S., van der Merwe, N.J., Mitchell, A.D., Evershed, R.P., 2003. Expression of the dietary isotope signal in the compound-specific δ^{13}C values of pig bone lipids and amino acids. Int. J. Osteoarchaeol. 13, 54–65.
Jim, S., Jones, V., Ambrose, S.H., Evershed, R.P., 2006. Quantifying dietary macronutrient sources of carbon for bone collagen biosynthesis using natural abundance stable carbon isotope analysis. Br. J. Nutr. 95 (6), 1055–1062.
Keeling, C.D., Mook, W.G., Tans, P.P., 1979. Recent trends in the 13C/12C ratio of atmospheric carbon dioxide. Nature 277, 121–123.
Kende, J., Phalet, K., den Noortgate, W.V., Kara, A., Fischer, R., 2017. Equality revisited: a cultural meta-analysis of intergroup contact and prejudice. Social Psychological andPersonality Science 1–9 ##.
Krueger, H.W., 1991. Exchange of carbon with biological apatite. J. Archaeol. Sci. 18, 355–361.
Labarca, R., Gallardo, F., 2015. The domestic camelids (Cetartiodactyla: Camelidae) from the Middle Formative Cemetery of Topater 1 (Atacama Desert, northern Chile): osteometric and palaeopathological evidence of cargo animals. Int. J. Osteoarchaeol. 25 (1), 61–73.
Latcham, R., 1933. Notas preliminares de un viaje arqueológico a Quillagua. vol. XXXVII. Revista Chilena de Historia Natural, pp. 130–138.
Lee-Thorp, J.A., 1989. Stable Carbon Isotopes in Deep Time: the Diets of Fossil Fauna and Hominids. dissertation, Department of Archaeology, University of Cape, Town Unpublished Ph.D.
Lee-Thorp, J.A., 2008. On isotopes and old bones. Archaeometry 50 (6), 925–950.
Lightfoot, K.G., Martinez, A., 1995. Frontiers and boundaries in archaeological perspective. Annu. Rev. Anthropol. 24, 471–492.
Longin, R., 1971. New method of collagen extraction for radiocarbon dating. Nature 230, 241–242.
Lubetkin, S.C., Simenstad, C.A., 2004. Multi-source mixing models to quantify food web sources and pathways. J. Appl. Ecol. 41, 996–1008.
Lumbreras, L.G., 2006. Un Formativo sin cerámica y cerámica preformativa. Estud. Atacameños 32, 11–34.
McKay, C.P., Friedmann, E.I., Gómez-Silva, B., Cáceres-Villanueva, L., Andersen, D.T., Landheim, R., 2003. Temperature and moisture conditions for life in the extreme arid region of the Atacama Desert: four years of observations including the el niño of 1997-1998. Astrobiology 3 (2), 393–406.
McRostie, V.B., Gayo, E.M., Santoro, C.M., De Pol-Holz, R., Latorre, C., 2017. The pre-Columbian introduction and dispersal of algarrobo (*prosopis*, section Algarobia) in the Atacama Desert of northern Chile. PLoS One 12 (7), e0181759.
Mirwaldt, K., 2010. Contact, conflict and geography: what factors shape cross-border citizen relations? Polit. Geogr. 29 (8), 434–443.
Mintz, S.W., 1985. Sweetness and Power: the Place of Sugar in Modern History. Viking Penguin, New York.
Moore, J.W., Semmens, B.X., 2008. Incorporating uncertainty and prior information into stable isotope mixing models. Ecol. Lett. 11, 470–480.
Moragas, C., 1982. Túmulos funerarios de la costa sur de Tocopilla (Cobija), II Región. Chungara. Rev. Chil. Antropol. 9, 152–173.
Moreno, A., Santoro, C.M., Latorre, C., 2008. Climate change and human occupation in the northernmost Chilean Altiplano over the last ca. 11,500 cal a BP. J. Quat. Sci. 24, 373–382.
Morrison, D.J., Dodson, B., Slater, C., Preston, T., 2000. ^{13}C natural abundance in the British diet: implications for 13C breathe tests. Rapid Commun. Mass Spectrom. 14, 1312–1324.
Naum, M., 2010. Re-emerging frontiers: postcolonial theory and historical archaeology of the borderlands. J. Archaeol. Method Theory 17, 101–131.
Newman, D., 2006. The lines that continue to separate us: borders in our 'borderless' world. Prog. Hum. Geogr. 30 (2), 143–161.
Núñez, L., 1971. Secuencia y cambio en los asentamientos humanos de la desembocadura del Río Loa, en el Norte de Chile. vol. 112. Boletín de la Universidad de Chile, pp. 2–25.
Núñez, L., 1984. Tráfico de complementariedad de recursos entre las tierras altas y el Pacífico en el área Centro-Sur Andina. PhD Dissertation. University of Tokyo, Tokyo.
Núñez, L., Santoro, C., 2011. El transito arcaico-formativo en la circumpuna y valles occidentales del centrosudandino: hacia los cambios "neolíticos". vol. 43. Chungara, pp. 487–530.
Núñez, L., Cartajena, I., Carrasco, C., de Souza, P., Grosjean, M., 2006. Emergencia de comunidades pastoralistas formativas en la Puna de Atacama. Estud. Atacameños 32, 93–117.
Núñez, L., Dillehay, T., 1995. Movilidad giratoria, armonía social y desarrollo en los Andes Meridionales: patrones de tráfico e interacción económica. Universidad del Norte, Antofagasta.
Parnell, A.C., Inger, R., Bearhop, S., Jackson, A.L., 2010. Source partitioning using stable isotopes: coping with too much variation. PLoS One 5 (3), e9672.
Parnell, A.C., Phillips, D.L., Bearhop, S., Semmens, B.X., Ward, E.J., Moore, J.W., Jackson, A.L., Grey, J., Kelly, D.J., Inger, R., 2013. Bayesian stable isotope mixing models. Environmetrics 24, 387–399.
Paz Soldán, M., 1878. Verdaderos límites entre el Perú y Bolivia. Imprenta Liberal, Lima, Peru.
Pestle, W.J., 2010. Diet and Society in Prehistoric Puerto Rico, an Isotopic Approach. Unpublished Ph.D. Dissertation, Department of Anthropology, University of Illinois at Chicago.
Pestle, W.J., Colvard, M., 2012. Bone collagen preservation in the tropics: a case study from ancient Puerto Rico. J. Archaeol. Sci. 39 (7), 2079–2090.
Pestle, W.J., Hubbe, M., Smith, E.K., Stevenson, J.M., 2015a. Technical note: a linear model for predicting $\delta^{13}C_{protein}$. Am. J. Phys. Anthropol. 157, 694–703.
Pestle, W.J., Torres-Rouff, C., Gallardo, F., Ballester, B., Clarot, A., 2015b. Mobility and exchange among marine hunter-gatherer and Agropastoralist communities in the Formative Period Atacama Desert. Curr. Anthropol. 56 (1), 121–133.
Pestle, W.J., Torres-Rouff, C., Hubbe, M., 2016a. Modeling diet in times of change: the case of quitor, san Pedro de Atacama, Chile. J. Archaeol. Sci.: Report 7, 82–93.
Pestle, W.J., Torres-Rouff, C., Hubbe, M., Smith, E.K., 2016b. Eating in or dining out: modeling diverse dietary strategies in middle period san Pedro de Atacama, Chile. Archaeol. Anthropol. Sci. https://doi.org/10.1007/s12520-016-0398-9.
Pettigrew, T.F., Tropp, L.R., 2006. A meta-analytic test of intergroup contact theory. J. Personal. Soc. Psychol. 90 (5), 751–783.
Pettigrew, T.F., Tropp, L.R., Wagner, U., Christ, O., 2011. Recent advances in intergroup contact theory. Int. J. Intercult. Relat. 35, 271–280.
Phillips, D., 2001. Mixing models in analyses of diet using multiple stable isotopes: a critique. Oecologia 127 (2), 166–170.
Phillips, D.L., Gregg, J.W., 2003. Source partitioning using stable isotopes: coping with too many sources. Oecologia 136, 261–269.
Pimentel, G., 2009. Las huacas del tráfico: arquitectura ceremonial en rutas prehispánicas del Desierto de Atacama. Boletín del Museo Chileno de Arte Precolombino. 14 (2), 9–38.
Pimentel, G., 2013. Redes viales prehispánicas en el Desierto de Atacama: Movilidad, viajeros e intercambio. Unpublished Ph.D. dissertation, Universidad Católica del Norte, Instituto de Investigaciones arqueológicas y Museo Gustavo Le Paige S.J. y Universidad de Tarapacá, San Pedro de Atacama, Chile.

Pimentel, G., Rees, C., de Souza, P., Arancibia, L., 2011. Viajeros costeros y caravaneros: dos estrategias de movilidad en el Período Formativo del Desierto de Atacama, Chile. In: Núñez, L., Nielsen, A. (Eds.), En ruta: Arqueología, historia y etnografía del tráfico Sur Andino. Encuentro Grupo Editor, Córdoba, Argentina, pp. 43–81.

Pimentel, G., Ugarte, M., Blanco, J.F., Torres-Rouff, C., Pestle, W.J., 2017. Calate. De Lugar Desnudo a Laboratorio Arqueológico de la Movilidad y el Tráfico Intercultural Prehispánico en el Desierto de Atacama (*Ca.* 7000 AP-550 AP). Estud. Atacameños 56, 21–56.

Santana-Sagredo, F., Herrera, M.J., Uribe, M., 2012. Acercamiento a la paleodieta en la costa y quebradas tarapaqueñas durante el período Formativo: análisis de isótopos estables a partir de tres casos de estudio. Boletín de la Sociedad Chilena de Arqueología 41–42, 109–126.

Santana-Sagredo, F., Hubbe, M., Uribe, M., 2015a. Isotopic evidence for marine consumption and mobility in the Atacama Desert (Quillagua, northern Chile). Int. J. Osteoarchaeol. https://doi.org/10.1002/OA.2437.

Santana-Sagredo F., Lee-Thorp, J., Schulting, R., Uribe, M. In Press. Mobility in the Atacama Desert, northern Chile, in the Late Intermediate Period (AD 900–1450): A re-evaluation using stable isotope analysis. Quaternary International. https://doi.org/10.1016/j.quaint.2018.05.013.

Santana-Sagredo, F., Uribe, M., Herrera, M.J., Retamal, R., Flores, S., 2015b. Dietary practices in ancient populations from northern Chile during the transition to agriculture (Tarapacá region, 1000 BC–AD 900). Am. J. Phys. Anthropol. 158 (4), 751–758.

Schoeninger, M.J., DeNiro, M.J., 1984. Nitrogen and carbon isotopic composition of bone collagen from marine and terrestrial animals. Geochem. Cosmochim. Acta 48 (4), 625–639.

Smith, M.L., 2006. The archaeology of food preference. Am. Anthropol. 108, 480–493.

Sponheimer, M., Robinson, T., Ayliffe, L., Roeder, B., Hammer, J., Passey, B., West, A., Cerling, T., Dearing, D., Ehleringer, J., 2003. Nitrogen isotopes in mammalian herbivores: hair $\delta^{15}N$ values from a controlled feeding study. Int. J. Osteoarchaeol. 13, 80–87.

Tieszen, L.L., 1981. Natural variation in the carbon isotope values of plants: implications for archaeology, ecology, and paleoecology. J. Archaeol. Sci. 18, 227–248.

Tieszen, L.L., Chapman, M., 1992. Carbon and nitrogen isotopic status of the major marine and terrestrial resources in the Atacama Desert of Northern Chile. In: Proceedings of the First World Congress on Mummy Studies. Museo Arqueológico y Etnográfico de Tenerife, Tenerife.

Torres-Rouff, C., Pimentel, G., Ugarte, M., 2012. ¿Quiénes viajaban? Investigando la muerte de viajeros prehispánicos en el desierto de atacama (ca. 800 ac–1536 dc). Estud. Atacameños 43, 167–186.

Uribe, M., Ayala, P., 2004. La alfarería de Quillagua en el contexto formativo del Norte Grande de Chile (1000 AC-500 DC). Chungará 36, 585–598.

United States Department of Agriculture, 2017. National Nutrient Database for Standard Reference.

van Dommelen, P., 1997. Colonial constructs: colonialism and archaeology in the mediterranean. World Archaeol. 28 (3), 305–323.

van Dommelen, P., 1998. On Colonial Grounds: A Comparative Study of Colonialism and Rural Settlements in First Millennium BC West Central Sardinia. Doctoral Thesis. Faculty of Archaeology, Leiden University, Leiden.

Vogel, J.C., can der Merwe, N.J., 1977. Isotopic evidence for early maize cultivation in New York state. Am. Antiq. 42 (2), 238–242.

Warinner, C., Tuross, N., 2009. Alkaline cooking and stable isotope tissue-diet spacing in swine: archaeological implications. J. Archaeol. Sci. 36, 1690–1697.

White, R., 1991. The Middle Ground: Indians, Empires and Republics in the Great Lakes Region. Cambridge University Press, Cambridge, pp. 1650–1815.

World Health Organization, 2007. Protein and Amino Acid Requirements in Human Nutrition, vol. 935 WHO Press, Geneva.