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BOUNDING MIDDLE PERIOD CEMETERY USE IN SAN PEDRO DE ATACAMA, CHILE

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ABSTRACT. The San Pedro de Atacama oases, located in northern Chile's hyperarid Atacama Desert, have been occupied for at least 3000 years. Here, we examine cemetery use in the oases, with emphasis on the Middle Period (ca. AD 400–1000). By modeling of a large corpus (n=243) of radiocarbon dates, over 90% of which are direct AMS assays of human bone collagen, we attempt to establish a temporal framework by which to explore the establishment of formalized social inequality in this period. Modeling of these dates at three locally defined scales (all *ayllus*, inter-*ayllu*, and intra-*ayllu*) permit heretofore unavailable insights into the chronological and spatial dimensions of life and mortuary activity in the oases and allow us to better contextualize patterns of social inequality during the dynamic Middle Period. The results of this modeling indicate two distinct peaks of occupation during the Middle Period in San Pedro and document significant temporal variability in cemetery use patterns on both inter- and intra-*ayllu* scales. These results stress the importance of local social and environmental factors to the occupation of the oases and provide crucial chronological structure for future archaeological and bioarchaeological research in the region.

KEYWORDS: Andes, cemeteries, Chile, chronology, Middle Period.

INTRODUCTION AND BACKGROUND

At the northern end of the Atacama salt flat, the San Pedro and Vilama Rivers feed a series of small oases in the otherwise hyperarid Atacama Desert of northern Chile (Figure 1). These oases have been host to some of the longest human occupations in the region, with the earliest evidence of habitation dating to the Formative Period (ca. 1200 BC), if not earlier (Núñez 1991; Costa Junqueira and Llagostera 1994; Llagostera 2004). The initial occupation of the oases was associated with the progressive expansion and adoption of horticultural practices by human groups from the nearby *puna* (Núñez et al. 2005), and the adoption of practices of arboriculture and silvopastoralism in the oases (McRostie 2014). This human presence slowly came to occupy most, if not all, of the arable land of the different San Pedro de Atacama oases and, by the beginning of the Spanish colonial period, the pattern of occupation was largely similar to that seen at present (Llagostera and Costa Junqueira 1999; Torres-Rouff and Hubbe 2013).

Permanent human presence in the region is evidenced by both habitation sites and large cemeteries. The cemeteries, in particular, have been at the center of discussions about human presence and demography, as they are thought to reflect conscious decisions about land occupancy, and are, in general, less disturbed by more recent human activity than the habitation sites. As such, there has long been a strong emphasis on the study of prehistoric Atacameño life through the study of burials and mortuary offerings from the many cemeteries in the region (e.g. Le Paige 1964; Llagostera 2004).

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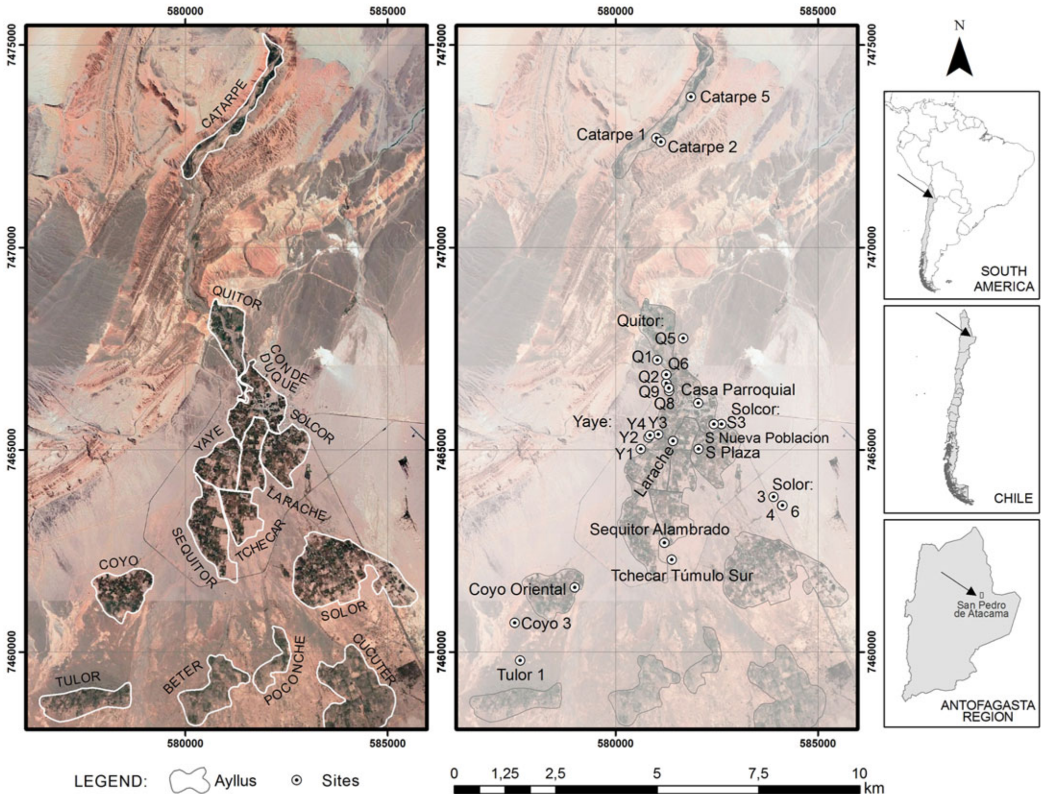

Figure 1 Map of San Pedro de Atacama, Chile, with locations of *ayllus* and sites discussed in text noted.

Human occupation of the oases has traditionally been divided into cultural phases based on changes in local material culture, particularly ceramic typologies and the presence of foreign or exotic objects. The deep and well-preserved archaeological evidence of human presence has led to a long history of the exploration of the chronology of the San Pedro de Atacama oases. The 1960s saw the development of work by pioneers in modern Chilean archaeology, most notably Mario Orellana (1962, 1963, 1964) and Lautaro Núñez (1963, 1965, 1966) as well as by Father Gustavo Le Paige (1963, 1972/1973), an amateur archaeologist and the village priest. In 1963, a number of Andean archaeologists came together for the "Congreso Internacional de Arqueología de San Pedro de Atacama" (Niemeyer 1963), now embraced as the second meeting of the Chilean Archaeological Society (*Congreso Nacional de Arqueología Chilena*; Campbell 2015), at which they presented research covering the entire occupation of the oases. Following this, a consensus was reached that established a local framework of phases for San Pedro de Atacama that was synchronized with both neighboring areas and the larger patterns of south-central Andean prehistory (Niemeyer 1963; Orellana 1963, 1964). These initial proposed phases were refined by Tarragó (1968, 1989) through ceramic seriation, and subsequently given an absolute chronological framework using a small number of radiocarbon dates (Núñez 1966, 1976; Le Paige 1976) and the thermoluminescence dating of a large sample of ceramic types (Berenguer et al. 1986, 1988).

More recently, efforts have been made to expand the absolute chronology of San Pedro de Atacama through analysis of a suite of radiocarbon dates of human skeletal material (Hubbe et al. 2011; Torres-Rouff and Hubbe 2013), which have indicated that the limits of the local cultural phases are harder to define than previously suggested. Analysis of these radiocarbon dates for the oases' cemeteries have demonstrated that (1) multiple cemeteries have use-lives that span cultural phases, and (2) some cemeteries traditionally associated with different phases in fact exhibit concurrent occupation, calling attention to the fact that there is significant cultural diversity among, and within, individual oases in each supposed cultural phase (Torres-Rouff and Hubbe 2013).

The significance of the periodization of San Pedro's prehistory is tied not only to local developments but also to the role the oases played in the larger context of social developments in the region. Throughout its prehistory, the oases were an important node on the trade network that connected the region, through which passed goods and influence of the large polities that shaped the region's development, and from which flowed locally manufactured goods of regional importance (e.g., Núñez and Dillehay 1995; Llagostera 1996; Gallardo et al. 2017). In this context, San Pedro de Atacama's Middle Period (AD 400–1000) has been of particular scholarly interest due to the wide distribution of characteristic goods from this period of the oases throughout the region. Much like the broader Andean Middle Horizon (AD 600–1000), the Middle Period has been characterized as a time of prosperity, peace, the growth of social complexity and inequality, and burgeoning intra- and inter-regional interaction (e.g., Llagostera 2004; Núñez 2007; Isbell 2008; Castro et al. 2016). It should be noted, however, that the timing and manifestation of the Middle Period in San Pedro is not entirely consonant with the Middle Horizon of the Andes writ large.

Of late, a consensus has emerged among researchers regarding the relationship that might have existed between the Tiwanaku polity and the peoples of San Pedro de Atacama. Early research explored the notion that San Pedro operated as a colony of the large altiplano polity and significant emphasis was placed on the importance of this relationship in the oases' rise to prominence at this time (e.g., Browman 1980; Serracino 1980; Orellana 1985; Oakland 1992; Kolata 1993: 275–280; Núñez and Dillehay 1995: 98–106; Torres and Conklin 1995). However, it is now considered likely that the relationship was mediated by other individuals and via other areas, for example Cochabamba, which would have served as an indirect connection between the altiplano state and the oases (Browman 1997; Stovel 2001; Uribe et al. 2016). Importantly, this new framework shifts the emphasis away from a single power dynamic to the role of broader networks of circulation and exchange in the larger region at this time. This then, creates a system in which the peoples of San Pedro de Atacama interacted and prospered while also serving as an engine propelling the ideology and iconography of the Tiwanaku polity across the southern Andes. Moreover, the Middle Period in San Pedro shows marked differences with the Middle Period of other regions, for example, in Arica, in Chile's northernmost region, attesting to a great deal of dynamism and local and regional heterogeneity in a period broadly characterized by the same (e.g., Berenguer 1998; Uribe and Agüero 2001, 2004; Agüero 2004; Agüero and Uribe 2014; Muñoz et al. 2016; Salazar et al. 2014; Uribe et al. 2016). Ultimately, we agree with this dynamic vision of the Middle Period, a time that is not necessarily bounded by the direct presence of a Tiwanaku outpost or an abundance of Tiwanaku goods in any given locality, but is rather understood as being correlated with, and/or the consequence of, a complex meshing of ideological flows and economic exchange.

STATEMENT OF PROBLEM

The simplified chronology established for the local cultural phases, which can serve to equate specific sites or specific material objects to periods, has been essential in defining the broad strokes of local prehistory. However, we also suspect that it may have obscured nuances internal to the periods. As such, to be able to contribute to a larger discussion about the ways in which inequality shaped life experiences in the San Pedro de Atacama oases (e.g., Llagostera et al. 1988; Neves and Costa 1998; Torres-Rouff 2011; Hubbe et al. 2012; Figueroa et al. 2013; Salazar et al. 2014; Torres-Rouff et al. 2018), and to connect phenomena occurring in the oases with happenings in the broader Andean region, a more nuanced mapping of the chronological dimensions of San Pedro de Atacama's prehistory is required. Indeed, a better understanding of the temporal patterns of the San Pedro cemeteries, and the individuals within them, forms a foundational aspect of the study of social inequalities in the ancient southern Andes by allowing us to explore the ways in which inequality manifests in the body and the mortuary context over time and space.

Here, we aim to contribute to the discussion and identification of inequalities in the San Pedro de Atacama oases over time through the establishment of a detailed chronological framework for the main oases and principal cemeteries that represent the local archaeological record (Figure 1). Through our intensive radiocarbon dating program we aim to add nuance to the discussion and contextualize cemetery use in the different *ayllus*.[1] This will allow us to explore the potential contemporaneity of cemeteries in each *ayllu* and, ideally, the potential motivations behind distinct burial grounds in shared geographic and cultural spaces. Specifically, we argue that these more detailed data allow us to explore the Middle Period as a discrete phenomenon in the oases and, further, provide a basis for archaeologists to better classify and establish the temporal dimensions of the Middle Period and subsequent phases in San Pedro de Atacama as they relate to larger patterns in the south-central Andes.

MATERIALS AND METHODS

We began our assessment of temporal patterns of Middle Period human activity in San Pedro de Atacama with a database of 243 radiocarbon dates, almost all of which were obtained from bone collagen of securely contextualized human burials, representing eleven *ayllus* and 27 cemeteries. Of these, 121, which are thought to be of Middle Period cultural affiliation, are reported here for the first time, and a further 96, which represent the broader sweep of occupation of the oases, were generated in the past decade by Torres-Rouff and Hubbe (2013). In both the present study and Torres-Rouff and Hubbe (2013), selection and collection of samples for dating were performed concurrently with osteological assessment of remains and the collection of samples for stable isotope analyses. Target samples of dense cortical bone were removed using sterilized diamond cutoff wheels, with samples stored in aluminum foil and sterile sample bags.

[1]*Ayllu* refers to the traditional form of Andean kin-based community structure. The *ayllu* reflects a political grouping and one built on lineage (ascriptive descent groups; Cock 1981; Abercrombie, 1998), but also refers to a territory, as it is always tied to a place, and importantly, these boundaries are typically associated to a *huaca* or sacred space tied to the ancestors of a group (Goldstein 2000: 185). In the case of San Pedro de Atacama this frequently corresponds to a naturally differentiated oasis, as is the case of the *ayllus* of Solor, Tulor, or Coyo in addition to internal distinctions marked by territorial features.

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Dating of those samples reported here for the first time, as well as the majority (67/96) of those from Torres-Rouff and Hubbe (2013), was performed at the National Science Foundation-Accelerator Mass Spectrometry Laboratory at the University of Arizona. The remaining 29 samples presented in Torres-Rouff and Hubbe (2013) were dated by Beta Analytic. Finally, for the purposes of modeling, we included 26 published radiocarbon dates (20 from cemeteries and six from habitation sites) derived from other studies in the oases conducted over the past decades (Núñez 1976; Llagostera et al. 1984, 1988; Baron 1986; Costa Junqueira 1988; Torres et al. 1991; Oakland 1992; Llagostera 1995). The material/nature of the samples and the methods of sample selection and collection for these different studies varied, as did the laboratories performing the analysis; indeed, in some cases, there is very limited information available pertaining to said samples. While acknowledging these shortcomings, the inclusion of these dates allows us to obtain an understanding of the broad sweep of occupation of the *ayllus,* given that these include the putatively earliest and latest occupation of the region. Regardless of source, we calibrated all available dates following the procedures outlined below. Sample details are provided in Table 1. In nine instances, we possessed multiple dates for a given tomb, burial, or individual, all of which are noted as such (with an *) in the tables.

Our initial model (all *ayllus*) considered all available dates in an attempt to bound the Middle Period phenomenon (phase) in the oases in the broadest possible sense, but was not performed in any attempt to establish limits of settlement of the oases *per se*, as our sampling strategy was designed with an emphasis on presumed Middle Period sites. The sites included in this study that are considered as representative of the Middle Period were defined as such based on the archaeological presence of artifacts associated with this period (Berenguer et al. 1986; Llagostera et al. 1988; Oakland 1992; Torres-Rouff and Hubbe 2013). However, not all the individuals from the sites are directly associated with diagnostic objects from this period, and therefore it is possible that, if cemeteries spanned beyond the boundaries of the Middle Period, our study will not be able to accurately detect the length of the period in the Atacama oases. While this can be seen as a potential limitation in our study, we argue that the continuity of use of cemeteries over time is a stronger indicators of local social cohesion than the individual associations with diagnostic artifacts, especially in the context of the recent debates about the nature of the Middle Period in the oases (e.g., Berenguer 1998; Uribe and Agüero 2001, 2004; Agüero 2004; Agüero and Uribe 2014; Salazar et al. 2014; Uribe et al. 2016). As such, they represent local occupations that visibly interacted with the Middle Period phenomenon in the oases and serve as the ideal evidence of human spread during the period. Thus, the goal of the first model was to establish the temporal distribution of the occupation of the oases during what is classically seen as the Middle Period, with realization that the inclusion of some known non-Middle Period dates would tend to overestimate the boundaries of the period/phase. Prior to initiating this model, outliers (defined here as those samples with uncalibrated radiocarbon age Z-scores outside 2 standard deviations) were removed, reducing the sample size to 229 individual dates, with removed outliers noted as such in Table 1. Calibration and modeling were performed using OxCal v 4.3.2 (Bronk Ramsey 2009) and the SHCal13 curve (Hogg et al. 2013). Given the lack of evidence for marine foodstuff consumption in the oases (Pestle et al. 2016, 2017), no marine reservoir was employed in calibration. Two sigma (95.4%) ranges are presented for both individual samples and phase boundaries in all resulting tables and figures. Model and individual sample agreement indices for this iteration are presented in Table S1. Samples with agreement indices falling below the recommended cutoff value of 60% (Bronk Ramsey 1995, 2009) were subsequently removed, and models re-run.

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Table 1 List of individuals included in present analysis, with provenience information, radiocarbon dates, and outlier designations.

									Outlier?		
Ayllu	Site	Sample ID (site & burial number)	Source	Lab #	Material	Radiocarbon age	(sd)	^{13}C	All *ayllus*	Inter-*ayllu*	Within *ayllu*
Catarpe	Catarpe 1	294	Torres-Rouff & Hubbe 2013	X14963A	Bone collagen	752	43	–12.6	Yes	No	
Catarpe	Catarpe 1	2397	Torres-Rouff & Hubbe 2013	X14964A	Bone collagen	689	43	–13.8	Yes	No	
Catarpe	Catarpe 1	764	Torres-Rouff & Hubbe 2013	Beta-293923	Bone collagen	620	30	–12.7	Yes	No	
Catarpe	Catarpe 2	1753	Torres-Rouff & Hubbe 2013	Beta-251747	Bone collagen	1220	40	–13.8	No	No	
Catarpe	Catarpe 2	1801	Torres-Rouff & Hubbe 2013	Beta-251748	Bone collagen	1030	40	–12.3	No	No	
Catarpe	Catarpe 2	1850	Torres-Rouff & Hubbe 2013	Beta-251749	Bone collagen	770	40	–12.5	Yes	No	
Catarpe	Catarpe 2	1786	Torres-Rouff & Hubbe 2013	Beta-251750	Bone collagen	750	40	–9.2	Yes	No	
Catarpe	Catarpe 5	2392	Torres-Rouff & Hubbe 2013	X14966A	Bone collagen	1123	44	–13.3	No	No	
Catarpe	Catarpe 5	2385	Torres-Rouff & Hubbe 2013	X14965A	Bone collagen	1083	47	–13.2	No	No	
Conde Duque	Casa Parroquial	CP18	Torres-Rouff & Hubbe 2013	X14962A	Bone collagen	1113	44	–11.0	No	No	
Conde Duque	Casa Parroquial	CP5	Torres-Rouff & Hubbe 2013	X27412	Bone collagen	1091	46	–12.9	No	No	
Conde Duque	Casa Parroquial	CP10	Torres-Rouff & Hubbe 2013	X27413	Bone collagen	1091	46	–12.0	No	No	
Conde Duque	Casa Parroquial	CP6*	Torres-Rouff & Hubbe 2013	X14961A	Bone collagen	1067	44	–12.8	No	No	
Conde Duque	Casa Parroquial	CP6*	Torres-Rouff & Hubbe 2013	X27414	Bone collagen	1063	55	–13.9	No	No	
Conde Duque	Casa Parroquial	CP8	This study	AA111794	Bone collagen	1027	26	–13.0	No	No	
Conde Duque	Casa Parroquial	CP9	Torres-Rouff & Hubbe 2013	X27411	Bone collagen	1018	55	–13.1	No	No	

(Continued)

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Table 1 (*Continued*)

Ayllu	Site	Sample ID (site & burial number)	Source	Lab #	Material	Radiocarbon age	(sd)	^{13}C	Outlier?		
									All *ayllus*	Inter-*ayllu*	Within *ayllu*
Coyo	Coyo 3	T57	Torres-Rouff & Hubbe 2013	X30228	Bone collagen	1361	26	–15.9	No	No	No
Coyo	Coyo 3	T46	Torres-Rouff & Hubbe 2013	X30227	Bone collagen	1329	25	–13.6	No	No	No
Coyo	Coyo 3	T51	This study	AA111822	Bone collagen	1314	26	–15.1	No	No	No
Coyo	Coyo 3	T32	This study	AA111824	Bone collagen	1303	41	–14.7	No	No	No
Coyo	Coyo 3	T35	Torres-Rouff & Hubbe 2013	X30224	Bone collagen	1302	28	–13.2	No	No	No
Coyo	Coyo 3	T13*	Torres-Rouff & Hubbe 2013	X30220	Bone collagen	1291	26	–14.6	No	No	No
Coyo	Coyo 3	T13*	This study	AA111823	Bone collagen	1290	27	–13.4	No	No	No
Coyo	Coyo 3	T36	Torres-Rouff & Hubbe 2013	X30225	Bone collagen	1273	35	–14.9	No	No	No
Coyo	Coyo 3	T1*	This study	AA107696	Bone collagen	1263	25	–11.2	No	No	No
Coyo	Coyo 3	T1*	Torres-Rouff & Hubbe 2013	X30219	Bone collagen	1263	25	–11.2	No	No	No
Coyo	Coyo 3	T18	This study	AA111820	Bone collagen	1258	26	–12.4	No	No	No
Coyo	Coyo 3	T23	Torres-Rouff & Hubbe 2013	X30223	Bone collagen	1244	25	–12.8	No	No	No
Coyo	Coyo 3	T21	Torres-Rouff & Hubbe 2013	X30222	Bone collagen	1232	26	–12.1	No	No	No
Coyo	Coyo 3	T28	This study	AA111821	Bone collagen	1231	26	–12.9	No	No	No
Coyo	Coyo 3	T16	Torres-Rouff & Hubbe 2013	X30221	Bone collagen	1185	28	–12.0	No	No	Yes
Coyo	Coyo 3	T10	This study	AA111819	Bone collagen	1181	27	–14.6	No	No	Yes
Coyo	Coyo Oriental	4164	This study	AA107733	Bone collagen	1449	26	–14.4	No	No	No
Coyo	Coyo Oriental	5317	This study	AA107737	Bone collagen	1433	25	–14.4	No	No	No
Coyo	Coyo Oriental	5383	Oakland 1992	Beta-33858	Textile	1430	60	nr	No	No	No
Coyo	Coyo Oriental	3973	This study	AA107712	Bone collagen	1393	25	–13.8	No	No	No
Coyo	Coyo Oriental	4053	This study	AA107718	Bone collagen	1388	25	–16.2	No	No	No

(*Continued*)

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Table 1 (*Continued*)

Ayllu	Site	Sample ID (site & burial number)	Source	Lab #	Material	Radiocarbon age	(sd)	^{13}C	Outlier? All *ayllus*	Outlier? Inter-*ayllu*	Outlier? Within *ayllu*
Coyo	Coyo Oriental	3904	This study	AA107706	Bone collagen	1378	26	−15.1	No	No	No
Coyo	Coyo Oriental	4052	This study	AA107717	Bone collagen	1375	25	−15.8	No	No	No
Coyo	Coyo Oriental	4055	This study	AA99873	Bone collagen	1375	46	−15.0	No	No	No
Coyo	Coyo Oriental	5334	This study	AA107738	Bone collagen	1367	25	−13.9	No	No	No
Coyo	Coyo Oriental	4049	This study	AA107716	Bone collagen	1362	25	−14.6	No	No	No
Coyo	Coyo Oriental	5300	This study	AA107736	Bone collagen	1362	39	−14.6	No	No	No
Coyo	Coyo Oriental	4067	This study	AA107722	Bone collagen	1361	25	−15.4	No	No	No
Coyo	Coyo Oriental	4109	This study	AA107728	Bone collagen	1361	25	−12.2	No	No	No
Coyo	Coyo Oriental	3959	This study	AA107711	Bone collagen	1360	25	−15.0	No	No	No
Coyo	Coyo Oriental	3956	This study	AA107709	Bone collagen	1360	25	−14.8	No	No	No
Coyo	Coyo Oriental	4102	This study	AA107727	Bone collagen	1355	25	−14.9	No	No	No
Coyo	Coyo Oriental	4003	This study	AA99870	Bone collagen	1333	45	−11.9	No	No	No
Coyo	Coyo Oriental	4093	This study	AA107725	Bone collagen	1330	25	−13.3	No	No	No
Coyo	Coyo Oriental	4077	This study	AA107724	Bone collagen	1326	25	−15.5	No	No	No
Coyo	Coyo Oriental	5341	Oakland 1992	Beta-33856	Textile	1320	60	nr	No	No	No
Coyo	Coyo Oriental	4020	This study	AA107714	Bone collagen	1320	25	−14.1	No	No	No
Coyo	Coyo Oriental	3957	This study	AA107710	Bone collagen	1315	25	−15.7	No	No	No
Coyo	Coyo Oriental	4069	This study	AA107723	Bone collagen	1312	25	−13.9	No	No	No
Coyo	Coyo Oriental	5335	This study	AA107739	Bone collagen	1311	25	−15.5	No	No	No
Coyo	Coyo Oriental	4012	Oakland 1992	Beta-33853	Bone	1310	70	nr	No	No	No
Coyo	Coyo Oriental	4064*	Oakland 1992	Beta-33855	Bone/muscle	1310	80	nr	No	No	No
Coyo	Coyo Oriental	4190	This study	AA99868	Bone collagen	1305	45	−14.6	No	No	No
Coyo	Coyo Oriental	3948	This study	AA107708	Bone collagen	1303	25	−16.2	No	No	No
Coyo	Coyo Oriental	4163	This study	AA107732	Bone collagen	1301	26	−15.9	No	No	No
Coyo	Coyo Oriental	4193	This study	AA107735	Bone collagen	1295	26	−14.0	No	No	No
Coyo	Coyo Oriental	4054	This study	AA99869	Bone collagen	1293	45	−13.7	No	No	No
Coyo	Coyo Oriental	4080	This study	AA99872	Bone collagen	1292	47	−12.6	No	No	No
Coyo	Coyo Oriental	4132	This study	AA107729	Bone collagen	1280	25	−14.5	No	No	No
Coyo	Coyo Oriental	4098	This study	AA107726	Bone collagen	1276	25	−14.8	No	No	No
Coyo	Coyo Oriental	5316	This study	AA99866	Bone collagen	1265	46	−12.8	No	No	No

(*Continued*)

Table 1 (*Continued*)

									Outlier?		
Ayllu	Site	Sample ID (site & burial number)	Source	Lab #	Material	Radiocarbon age	(sd)	^{13}C	All *ayllus*	Inter-*ayllu*	Within *ayllu*
Coyo	Coyo Oriental	4151	This study	AA107731	Bone collagen	1264	25	–13.3	No	No	No
Coyo	Coyo Oriental	5308	This study	AA99875	Bone collagen	1248	46	–10.8	No	No	No
Coyo	Coyo Oriental	4046	This study	AA99867	Bone collagen	1247	45	–13.4	No	No	No
Coyo	Coyo Oriental	4147	This study	AA107730	Bone collagen	1237	25	–14.2	No	No	No
Coyo	Coyo Oriental	4060	This study	AA107720	Bone collagen	1218	25	–13.4	No	No	No
Coyo	Coyo Oriental	4059	This study	AA107719	Bone collagen	1215	25	–14.6	No	No	No
Coyo	Coyo Oriental	3913	This study	AA107707	Bone collagen	1213	25	–13.9	No	No	No
Coyo	Coyo Oriental	5343	This study	AA107740	Bone collagen	1196	25	–14.2	No	No	No
Coyo	Coyo Oriental	3984	This study	AA107713	Bone collagen	1172	25	–13.7	No	No	No
Coyo	Coyo Oriental	4031	This study	AA107715	Bone collagen	1157	25	–12.8	No	No	No
Coyo	Coyo Oriental	5347	Oakland 1992	Beta-33857	Textile	1155	80	nr	No	No	No
Coyo	Coyo Oriental	4178	This study	AA107734	Bone collagen	1137	25	–12.7	No	No	Yes
Coyo	Coyo Oriental	4064*	This study	AA107721	Bone collagen	1126	25	–11.8	No	No	Yes
Coyo	Coyo Oriental	4158	This study	AA99874	Bone collagen	1102	52	–14.7	No	Yes	Yes
Coyo	Coyo Oriental	4026	Oakland 1992	Beta-33854	Muscle/skin	1100	70	nr	No	Yes	Yes
Coyo	Coyo Oriental	5345	This study	AA107741	Bone collagen	1082	26	–14.2	No	Yes	Yes
Coyo	Coyo Oriental	4175	This study	AA99871	Bone collagen	1020	44	–14.4	No	Yes	Yes
Larache	Larache	3803	This study	AA111747	Bone collagen	1829	22	–16.2	Yes	No	
Larache	Larache	3797	This study	AA111746	Bone collagen	1759	21	–15.9	Yes	No	
Larache	Larache	3802	This study	AA111743	Bone collagen	1723	38	–17.4	No	No	
Larache	Larache	5056	Torres-Rouff & Hubbe 2013	X14967A	Bone collagen	1667	45	–17.1	No	No	
Larache	Larache	1583	This study	AA111744	Bone collagen	1363	21	–15.3	No	No	
Larache	Larache	357	This study	AA111753	Bone collagen	1270	31	–15.2	No	No	
Larache	Larache	115	This study	AA111757	Bone collagen	1230	26	–13.6	No	No	
Larache	Larache	356	This study	AA111745	Bone collagen	1221	21	–12.9	No	No	
Larache	Larache	366	This study	AA111755	Bone collagen	1202	21	–14.3	No	No	
Larache	Larache	124	This study	AA111756	Bone collagen	1185	26	–11.7	No	No	
Larache	Larache	390	This study	AA111748	Bone collagen	1120	20	–11.0	No	No	
Larache	Larache	358	This study	AA111750	Bone collagen	1086	21	–10.7	No	No	

(*Continued*)

Table 1 (*Continued*)

									Outlier?		
Ayllu	Site	Sample ID (site & burial number)	Source	Lab #	Material	Radiocarbon age	(sd)	^{13}C	All *ayllus*	Inter-*ayllu*	Within *ayllu*
Larache	Larache	125	Torres-Rouff & Hubbe 2013	X33243	Bone collagen	1076	25	–14.8	No	No	
Larache	Larache	3480	This study	AA111754	Bone collagen	681	20	–15.1	Yes	Yes	
Quitor	Quitor 1	3487	Torres-Rouff & Hubbe 2013	X14968A	Bone collagen	956	44	–15.6	No	No	No
Quitor	Quitor 2	3770	Torres-Rouff & Hubbe 2013	X14970A	Bone collagen	1696	46	–17.9	No	No	No
Quitor	Quitor 2	3716	Torres-Rouff & Hubbe 2013	Beta-251751	Bone collagen	1520	40	–15.3	No	No	No
Quitor	Quitor 2	3684	Torres-Rouff & Hubbe 2013	X14969A	Bone collagen	1491	46	–17.3	No	No	No
Quitor	Quitor 2	3783	Torres-Rouff & Hubbe 2013	Beta-251752	Bone collagen	1310	40	–13.6	No	No	No
Quitor	Quitor 2	1983:15	Llagostera 1995	Beta-53566	unknown	1190	50	nr	No	No	No
Quitor	Quitor 5	3397*	Núñez 1976	I-1205	unknown	1750	80	nr	No	No	No
Quitor	Quitor 5	3347	Torres-Rouff & Hubbe 2013	X27403	Bone collagen	1742	40	–15.9	No	No	No
Quitor	Quitor 5	3380	This study	AA111791	Bone collagen	1735	26	–17.1	No	No	No
Quitor	Quitor 5	2020	This study	AA111792	Bone collagen	1720	26	–16.7	No	No	No
Quitor	Quitor 5	3397*	This study	AA111789	Bone collagen	1693	29	–17.2	No	No	No
Quitor	Quitor 5	1942	This study	AA111786	Bone collagen	1690	26	–17.2	No	No	No
Quitor	Quitor 5	2021	Torres-Rouff & Hubbe 2013	X27402	Bone collagen	1673	40	–16.7	No	No	No
Quitor	Quitor 5	1957	Torres-Rouff & Hubbe 2013	X27401	Bone collagen	1631	34	–16.8	No	No	No
Quitor	Quitor 5	3066	This study	AA111781	Bone collagen	1627	29	–17.2	No	No	No
Quitor	Quitor 5	3394	Torres-Rouff & Hubbe 2013	X14974A	Bone collagen	1623	46	–17.1	No	No	No
Quitor	Quitor 5	2026	This study	AA111785	Bone collagen	1575	26	–15.8	No	No	No

(*Continued*)

Table 1 (*Continued*)

									Outlier?		
Ayllu	Site	Sample ID (site & burial number)	Source	Lab #	Material	Radiocarbon age	(sd)	^{13}C	All *ayllus*	Inter-*ayllu*	Within *ayllu*
Quitor	Quitor 5	1964	Torres-Rouff & Hubbe 2013	X27404	Bone collagen	1543	34	–17.7	No	No	No
Quitor	Quitor 5	2009	Torres-Rouff & Hubbe 2013	X14972A	Bone collagen	1511	46	–17.4	No	No	No
Quitor	Quitor 5	2109	This study	AA111782	Bone collagen	1469	29	–15.1	No	No	No
Quitor	Quitor 5	2055	This study	AA111784	Bone collagen	1436	28	–17.5	No	No	No
Quitor	Quitor 5	2100	This study	AA111783	Bone collagen	1371	29	–12.9	No	No	No
Quitor	Quitor 5	2179	Torres-Rouff & Hubbe 2013	X14973A	Bone collagen	1338	45	–11.1	No	No	No
Quitor	Quitor 5	1916	This study	AA111779	Bone collagen	1326	28	–15.3	No	No	No
Quitor	Quitor 5	2212	This study	AA111787	Bone collagen	1243	26	–12.8	No	No	No
Quitor	Quitor 5	2245	This study	AA111780	Bone collagen	1191	28	–11.5	No	No	No
Quitor	Quitor 5	2169	Torres-Rouff & Hubbe 2013	X27405	Bone collagen	1185	34	–10.8	No	No	No
Quitor	Quitor 5	1921	Torres-Rouff & Hubbe 2013	X14971A	Bone collagen	1164	44	–13.5	No	No	No
Quitor	Quitor 6	2532	Núñez 1976	Sa-226	Wood	1700	50	nr	No	No	Yes
Quitor	Quitor 6	3633	Torres-Rouff & Hubbe 2013	Beta-263470	Bone collagen	1490	40	–16.9	No	No	No
Quitor	Quitor 6	2588	Torres-Rouff & Hubbe 2013	Beta-263468	Bone collagen	1290	40	–15.6	No	No	No
Quitor	Quitor 6	2928	Torres-Rouff & Hubbe 2013	Beta-263469	Bone collagen	1180	40	–12.5	No	No	No
Quitor	Quitor 6	2529	Torres-Rouff & Hubbe 2013	Beta-263467	Bone collagen	1050	40	–13.8	No	No	No
Quitor	Quitor 6 Tardío	T27 C871	This study	AA111764	Bone collagen	1508	26	–17.3	No	No	No
Quitor	Quitor 6 Tardío	T28 C876	This study	AA111768	Bone collagen	1490	27	–16.6	No	No	No
Quitor	Quitor 6 Tardío	T17 C222/223	This study	AA111770	Bone collagen	1415	27	–13.7	No	No	No
Quitor	Quitor 6 Tardío	T28 C877	This study	AA111769	Bone collagen	1403	26	–14.9	No	No	No
Quitor	Quitor 6 Tardío	T14 C469/470	This study	AA111763	Bone collagen	1259	27	–14.1	No	No	No

(*Continued*)

Table 1 (*Continued*)

Ayllu	Site	Sample ID (site & burial number)	Source	Lab #	Material	Radiocarbon age	(sd)	^{13}C	Outlier? All *ayllus*	Inter-*ayllu*	Within *ayllu*
Quitor	Quitor 6 Tardío	T54 C685	This study	AA111774	Bone collagen	1147	26	−11.6	No	No	No
Quitor	Quitor 6 Tardío	T55 C694	This study	AA111767	Bone collagen	1146	26	−14.3	No	No	No
Quitor	Quitor 6 Tardío	T8 C80/81	This study	AA111772	Bone collagen	1072	26	−14.9	No	No	No
Quitor	Quitor 6 Tardío	T9 C88/89	This study	AA111765	Bone collagen	1062	26	−14.0	No	No	No
Quitor	Quitor 6 Tardío	T10 C104	This study	AA111771	Bone collagen	1054	27	−13.8	No	No	No
Quitor	Quitor 6 Tardío	T36	Costa 1988	Beta-11208	Textile	1030	70	nr	No	No	No
Quitor	Quitor 6 Tardío	T38 C943	This study	AA111766	Bone collagen	974	26	−14.1	No	No	No
Quitor	Quitor 6 Tardío	T50	Costa 1988	Beta-9349	Wood	810	80	nr	Yes	Yes	Yes
Quitor	Quitor 6 Tardío	T35	Costa 1988	Beta-11207	Wood	710	70	nr	Yes	Yes	Yes
Quitor	Quitor 8	3227	This study	AA111776	Bone collagen	1657	27	−16.1	No	No	No
Quitor	Quitor 8	3202	This study	AA111777	Bone collagen	1651	31	−16.9	No	No	No
Quitor	Quitor 8	3146	This study	AA111775	Bone collagen	1597	31	−16.5	No	No	No
Quitor	Quitor 8	3145	Torres-Rouff & Hubbe 2013	Beta-251753	Bone collagen	1510	40	−17.3	No	No	No
Quitor	Quitor 8	3226	Torres-Rouff & Hubbe 2013	Beta-251754	Bone collagen	1450	40	−16.4	No	No	No
Quitor	Quitor 9	3236*	This study	AA111761	Bone collagen	1148	26	−12.2	No	No	No
Quitor	Quitor 9	3237	This study	AA111760	Bone collagen	1090	25	−12.8	No	No	No
Quitor	Quitor 9	3249	This study	AA111762	Bone collagen	1077	26	−2.2	No	No	No
Quitor	Quitor 9	3251	Torres-Rouff & Hubbe 2013	X14976A	Bone collagen	1068	44	−13.7	No	No	No
Quitor	Quitor 9	3236*	Núñez 1976	I-1205	unknown	900	80	nr	No	No	No
Sequitor	Sequitor Alambrado	1068	Torres-Rouff & Hubbe 2013	Beta-251746	Bone collagen	1680	40	−17.5	No	No	
Sequitor	Sequitor Alambrado	1043	Torres-Rouff & Hubbe 2013	Beta-263472	Bone collagen	1680	40	−15.9	No	No	
Sequitor	Sequitor Alambrado	1062	Torres-Rouff & Hubbe 2013	Beta-251745	Bone collagen	1600	40	−15.9	No	No	
Solcor	Solcor 3	T54 C2071	Torres-Rouff & Hubbe 2013	X30273	Bone collagen	1649	26	−16.6	No	Yes	Yes

(*Continued*)

Table 1 (*Continued*)

									Outlier?		
Ayllu	Site	Sample ID (site & burial number)	Source	Lab #	Material	Radiocarbon age	(sd)	^{13}C	All *ayllus*	Inter-*ayllu*	Within *ayllu*
Solcor	Solcor 3	T60 C2342	Torres-Rouff & Hubbe 2013	X30274	Bone collagen	1641	26	−16.8	No	Yes	Yes
Solcor	Solcor 3	T56 C3070	This study	AA111809	Bone collagen	1521	27	−15.4	No	No	Yes
Solcor	Solcor 3	T117 C13156*	Llagostera et al. 1988	Beta-27192	unknown	1470	80	nr	No	No	No
Solcor	Solcor 3	T23 C1536	Llagostera et al. 1988	Beta-27572	unknown	1470	60	nr	No	No	No
Solcor	Solcor 3	T75 C2607	This study	AA111805	Bone collagen	1461	27	−15.6	No	No	No
Solcor	Solcor 3	T29 C1666	This study	AA111808	Bone collagen	1430	27	−16.3	No	No	No
Solcor	Solcor 3	T27 C1628	This study	AA111800	Bone collagen	1392	27	−15.6	No	No	No
Solcor	Solcor 3	T139	This study	AA111796	Bone collagen	1391	26	−16.3	No	No	No
Solcor	Solcor 3	T107 C13118*	Llagostera et al. 1988	Beta-22461	unknown	1380	60	nr	No	No	No
Solcor	Solcor 3	T6 C1080	This study	AA111815	Bone collagen	1373	28	−15.4	No	No	No
Solcor	Solcor 3	T70 C2514	Torres-Rouff & Hubbe 2013	X30277	Bone collagen	1366	25	−15.0	No	No	No
Solcor	Solcor 3	T60 C2341	Torres-Rouff & Hubbe 2013	X30275	Bone collagen	1364	25	−15.0	No	No	No
Solcor	Solcor 3	T116 C13126	This study	AA111814	Bone collagen	1359	27	−16.9	No	No	No
Solcor	Solcor 3	T27 C1629	Torres-Rouff & Hubbe 2013	X30292	Bone collagen	1357	25	−16.0	No	No	No
Solcor	Solcor 3	T30 C1683	This study	AA111799	Bone collagen	1355	27	−15.8	No	No	No
Solcor	Solcor 3	T79 C2762	This study	AA111817	Bone collagen	1350	27	−15.4	No	No	No
Solcor	Solcor 3	T70 C2513	Torres-Rouff & Hubbe 2013	X30276	Bone collagen	1347	25	−14.7	No	No	No
Solcor	Solcor 3	106 C13177	This study	AA111804	Bone collagen	1322	26	−15.2	No	No	No
Solcor	Solcor 3	T16 C3061	Torres-Rouff & Hubbe 2013	X30270	Bone collagen	1322	25	−16.1	No	No	No
Solcor	Solcor 3	T103 C3599	This study	AA111795	Bone collagen	1316	27	−12.6	No	No	No

(*Continued*)

Table 1 (*Continued*)

									Outlier?		
Ayllu	Site	Sample ID (site & burial number)	Source	Lab #	Material	Radiocarbon age	(sd)	^{13}C	All *ayllus*	Inter-*ayllu*	Within *ayllu*
Solcor	Solcor 3	T112 C13111*	Torres-Rouff & Hubbe 2013	X30267	Bone collagen	1312	26	–14.8	No	No	No
Solcor	Solcor 3	T107 C13118*	Torres-Rouff & Hubbe 2013	X30266	Bone collagen	1302	25	–14.7	No	No	No
Solcor	Solcor 3	T126	This study	AA111818	Bone collagen	1298	27	–13.9	No	No	No
Solcor	Solcor 3	T115 C3610	This study	AA111802	Bone collagen	1292	27	–13.9	No	No	No
Solcor	Solcor 3	T78 C2699	This study	AA111813	Bone collagen	1289	27	–14.8	No	No	No
Solcor	Solcor 3	T115 C3609	This study	AA111807	Bone collagen	1271	27	–15.1	No	No	No
Solcor	Solcor 3	T2	Llagostera et al. 1988	Beta-27191	unknown	1270	90	nr	No	No	No
Solcor	Solcor 3	T117 C13156*	Torres-Rouff & Hubbe 2013	X30268	Bone collagen	1270	25	–14.0	No	No	No
Solcor	Solcor 3	T113 C13120	This study	AA111797	Bone collagen	1266	26	–14.3	No	No	No
Solcor	Solcor 3	T115 C3611	This study	AA111798	Bone collagen	1242	26	–14.3	No	No	No
Solcor	Solcor 3	T111 C3604	This study	AA111812	Bone collagen	1224	30	–13.0	No	No	No
Solcor	Solcor 3	T101 C3597	Torres-Rouff & Hubbe 2013	X30265R	Bone collagen	1223	25	–12.0	No	No	No
Solcor	Solcor 3	T111 C3605	This study	AA111803	Bone collagen	1215	26	–13.2	No	No	No
Solcor	Solcor 3	T30 C1871	Torres-Rouff & Hubbe 2013	X30272	Bone collagen	1214	25	–12.2	No	No	No
Solcor	Solcor 3	T111 C3606	This study	AA111806	Bone collagen	1205	27	–13.7	No	No	No
Solcor	Solcor 3	T98 C3593a	This study	AA111816	Bone collagen	1202	27	–13.0	No	No	No
Solcor	Solcor 3	T132	Torres-Rouff & Hubbe 2013	X30269	Bone collagen	1202	28	–12.4	No	No	No
Solcor	Solcor 3	T112 C13111*	Torres et al. 1991	Beta-32447	Skin/muscle	1170	60	nr	No	No	No
Solcor	Solcor 3	T24 C1558	Torres-Rouff & Hubbe 2013	Beta-305870	Bone collagen	1160	30	–15.9	No	No	No
Solcor	Solcor 3	T32 C1737	This study	AA111801	Bone collagen	1156	26	–13.1	No	No	No

(*Continued*)

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Table 1 (*Continued*)

Ayllu	Site	Sample ID (site & burial number)	Source	Lab #	Material	Radiocarbon age	(sd)	^{13}C	Outlier? All *ayllus*	Inter-*ayllu*	Within *ayllu*
Solcor	Solcor 3	T8 C11161A	Torres-Rouff & Hubbe 2013	Beta-305869	Bone collagen	1080	30	–17.6	No	No	Yes
Solcor	Solcor 3	N/A	Llagostera et al. 1988	Beta-27573	unknown	1040	50	nr	No	No	Yes
Solcor	Solcor Nueva Población	4791	This study	AA111826	Bone collagen	1051	27	–13.6	No	No	No
Solcor	Solcor Nueva Población	4789	This study	AA111827	Bone collagen	1041	27	–15.7	No	No	No
Solcor	Solcor Nueva Población	4778	This study	AA111825	Bone collagen	1003	28	–14.5	No	No	No
Solcor	Solcor Plaza	5093	Torres-Rouff & Hubbe 2013	X30290	Bone collagen	1071	25	–14.7	No	No	No
Solcor	Solcor Plaza	1377	Torres-Rouff & Hubbe 2013	X30284	Bone collagen	1057	27	–13.0	No	No	No
Solcor	Solcor Plaza	1286	Torres-Rouff & Hubbe 2013	X30293	Bone collagen	1041	25	–15.2	No	No	No
Solcor	Solcor Plaza	1246	This study	AA107759	Bone collagen	1036	29	–13.2	No	No	No
Solcor	Solcor Plaza	1244	Torres-Rouff & Hubbe 2013	X30281	Bone collagen	1031	28	–14.2	No	No	No
Solcor	Solcor Plaza	1243	Torres-Rouff & Hubbe 2013	X30280	Bone collagen	1028	25	–14.6	No	No	No
Solcor	Solcor Plaza	1391	Torres-Rouff & Hubbe 2013	X30288	Bone collagen	1001	25	–13.9	No	No	No
Solcor	Solcor Plaza	629	Torres-Rouff & Hubbe 2013	X30291	Bone collagen	997	25	–14.9	No	No	No
Solcor	Solcor Plaza	1394	Torres-Rouff & Hubbe 2013	X30289	Bone collagen	990	25	–14.8	No	No	No
Solcor	Solcor Plaza	1241	Torres-Rouff & Hubbe 2013	X14978A	Bone collagen	987	44	–14.8	No	No	No

(*Continued*)

Table 1 (*Continued*)

Ayllu	Site	Sample ID (site & burial number)	Source	Lab #	Material	Radiocarbon age	(sd)	^{13}C	Outlier? All *ayllus*	Outlier? Inter-*ayllu*	Outlier? Within *ayllu*
Solcor	Solcor Plaza	1381	Torres-Rouff & Hubbe 2013	X30286	Bone collagen	951	25	–13.9	No	No	No
Solcor	Solcor Plaza	1379	Torres-Rouff & Hubbe 2013	X30285	Bone collagen	894	26	–12.3	Yes	Yes	Yes
Solor	Solor 3	991	Torres-Rouff & Hubbe 2013	X14981A	Bone collagen	1859	47	–17.8	Yes	No	
Solor	Solor 3	983	Torres-Rouff & Hubbe 2013	X14980A	Bone collagen	1616	46	–15.8	No	No	
Solor	Solor 4	cementerio N/A (1)	Núñez 1976	Gr-N-4124	Wood	970	75	nr	No	No	
Solor	Solor 4	cementerio N/A (2)	Núñez 1976	Gr-N-4125	Wood	770	65	nr	Yes	No	
Solor	Solor 6	between tombs N/A	Núñez 1976	Sa-109	Wood	1650	50	nr	No	No	
Solor	Solor Vilama 3	300	Torres-Rouff & Hubbe 2013	Beta-293924	Bone collagen	1280	30	–10.7	No	No	
Solor	Solor Vilama 3	308	Torres-Rouff & Hubbe 2013	X14983A	Bone collagen	1125	45	–14.6	No	No	
Solor	Solor Vilama 3	265	Torres-Rouff & Hubbe 2013	X14982A	Bone collagen	1076	45	–13.7	No	No	
Tchecar	Tchecar Túmulo Sur	686	Torres-Rouff & Hubbe 2013	X27407	Bone collagen	1429	38	–14.3	No	No	
Tchecar	Tchecar Túmulo Sur	815	Torres-Rouff & Hubbe 2013	X27406	Bone collagen	1296	33	–13.6	No	No	
Tchecar	Tchecar Túmulo Sur	824	Torres-Rouff & Hubbe 2013	Beta-263475	Bone collagen	1240	40	–13.7	No	No	
Tchecar	Tchecar Túmulo Sur	838	Torres-Rouff & Hubbe 2013	Beta-293928	Bone collagen	1190	30	–13.2	No	No	
Tchecar	Tchecar Túmulo Sur	807	Torres-Rouff & Hubbe 2013	X27409	Bone collagen	1137	46	–13.0	No	No	
Tchecar	Tchecar Túmulo Sur	680	Torres-Rouff & Hubbe 2013	X27408	Bone collagen	1091	46	–13.7	No	No	

(*Continued*)

Table 1 (*Continued*)

									Outlier?		
Ayllu	Site	Sample ID (site & burial number)	Source	Lab #	Material	Radiocarbon age	(sd)	^{13}C	All *ayllus*	Inter-*ayllu*	Within *ayllu*
Tchecar	Tchecar Túmulo Sur	650	Torres-Rouff & Hubbe 2013	Beta-263473	Bone collagen	1090	40	–12.3	No	No	
Tchecar	Tchecar Túmulo Sur	1158	Torres-Rouff & Hubbe 2013	X27410	Bone collagen	1018	46	–13.5	No	No	
Tchecar	Tchecar Túmulo Sur	806	Torres-Rouff & Hubbe 2013	Beta-263474	Bone collagen	960	40	–13.4	No	No	
Tulor	Tulor 1	Circle 2	Baron 1986	?	Charcoal?	1885	95	nr	Yes	No	
Tulor	Tulor 1	Recinto 3C	Llagostera et al. 1984	P-3351	Charcoal	1850	60	nr	Yes	No	
Tulor	Tulor 1	Sector 7 nivel 9	Baron 1986	?	Charcoal?	1775	250	nr	Yes	No	
Tulor	Tulor 1	Sector 7 nivel 2	Baron 1986	?	Charcoal?	1690	170	nr	No	No	
Yaye	Yaye 1	5498	Torres-Rouff & Hubbe 2013	Beta-251756	Bone collagen	1100	40	–13.9	No	No	
Yaye	Yaye 1	5494	Torres-Rouff & Hubbe 2013	Beta-251755	Bone collagen	920	40	–11.7	Yes	No	
Yaye	Yaye 2	3309	Torres-Rouff & Hubbe 2013	Beta-251757	Bone collagen	1300	40	–12.6	No	No	
Yaye	Yaye 2	3417	Torres-Rouff & Hubbe 2013	Beta-251758	Bone collagen	1040	40	–13.2	No	No	
Yaye	Yaye 3	1573	Torres-Rouff & Hubbe 2013	Beta-251759	Bone collagen	1180	40	–15.0	No	No	
Yaye	Yaye 4	1545	Torres-Rouff & Hubbe 2013	Beta-251760	Bone collagen	1170	40	–11.0	No	No	

The next model iteration (inter-*ayllu*) was performed on an *ayllu*-by-*ayllu* basis to establish phases of use/occupation of each *ayllu*. Prior to phase modeling, outliers (defined as above) were removed on an *ayllu*-by-*ayllu* basis, reducing the overall sample size for this analysis to 234 (removed outliers noted in Table 1). Calibration and phase modeling was performed as above using OxCal v 4.3.2 and the SHCal13 curve. In the case of the *ayllu*-level modeling, we employed the "Overlapping" phase option of OxCal, as there are no reliable independent priors relating to the succession of *ayllu* occupation. As before, no marine reservoir was employed in calibration and two sigma (95.4%) ranges are presented for both individual samples and phase boundaries in all resulting tables and figures. Model and individual sample agreement indices for this iteration are presented in Table S2. Samples with agreement indices falling below the recommended cutoff value of 60% (Bronk Ramsey 1995, 2009) were removed and the model subsequently re-run.

Finally, we further investigated the use-life of cemeteries internal to the three *ayllus* for which we have the largest and most representative samples: Coyo, Quitor, and Solcor (Figure 1). This iteration of modeling (intra-*ayllu*) was intended to assess the degree of contemporaneity of cemetery use internal to each of these geographical/social units. We chose to focus on these three *ayllus* (comprising 10 cemeteries) as they present the largest and best explored putatively Middle Period cemeteries in our sample. Importantly, analyzing multiple cemeteries from the same *ayllu* also allows us the ability to explore internal social differentiation while controlling for temporal distinctions. Varied excavation strategies over the decades have resulted in diverse records, however, together these 10 cemeteries have large sample sizes, high quality preservation, well-documented mortuary contexts, and include metals, elaborate textiles, ritual paraphernalia, and objects from varied foreign groups (Llagostera et al. 1988; Oakland 1992; Llagostera 1995; Torres-Rouff 2008; Figueroa et al. 2013). As such, these cemeteries provide a thorough view into the Middle Period in the San Pedro de Atacama oases.

The dates included for each cemetery were again trimmed for outliers following the procedure employed above, resulting in a total of 62 dates from two cemeteries in Coyo, 54 from five cemeteries in Quitor, and 52 from three cemeteries in Solcor (Table 1). Each *ayllu* was modeled independently following the same procedures identified above (OxCal v 4.3.2 and SHCal13 curve, "Overlapping" phase option, no priors, no marine reservoir, two sigma ranges, and reporting of any/all models/samples with agreement indices falling below the recommended cutoff value of 60%, with subsequent removal and re-running of model without those samples as noted below). Model and individual sample agreement indices for this iteration are presented in Tables S3–S5.

RESULTS

We present here the results of our analyses at each of the three scales discussed above. Initially we consider the pattern revealed by integrating all the dates for the oases to explore broader patterns of occupation. Subsequently, we move into a presentation and discussion of the results between *ayllus*. Finally, we conclude with a deeper exploration of the three *ayllus* for which we have the most dates, allowing us to consider broader questions of internal variation and cemetery use across the oases. In all cases, we refer to the Boundary Start and End ages from the various iterations of the OxCal models as the *de facto* beginnings and ends, respectively, of the use-life of the respective *ayllus* and cemeteries.

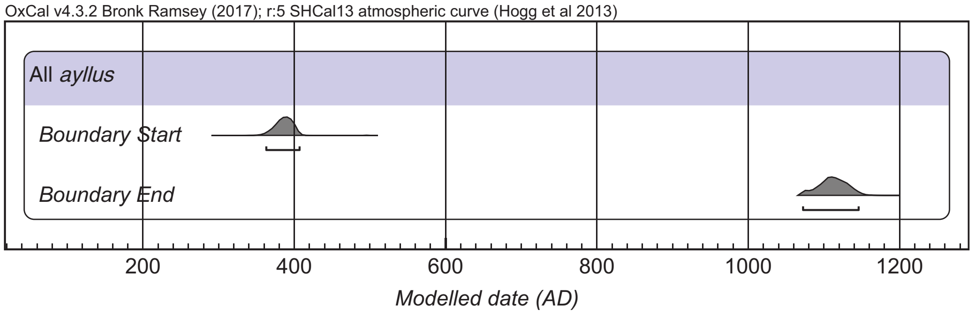

Figure 2 Structure of all *ayllu* model.

All *Ayllus*

The structure of the model that includes all the available dates for the San Pedro oases is presented in Figure 2, with details of phase boundaries and individual dates presented in Table S1. Agreement indices for the initial iteration of this model were A_{model}=60.9 and $A_{overall}$=70.2. In that iteration, three individual dates (Beta-9349, X30285, and Beta-251755), had unacceptable individual agreement index values (A=5.2–56.5) and were removed. The resulting sample size of 226 samples produced final model agreement indices of A_{model}=83.7 and $A_{overall}$=100.8.

The Boundary Start age of the amalgamated sample was 363–407 cal AD and the Boundary End was 1072–1146 cal AD The modeled individual date ranges align almost perfectly with these phase boundaries, extending from 365 to 1135 cal AD at the limits of their respective 95.4% ranges. As mentioned previously, this estimate of the temporal dimensions of the Middle Period in San Pedro de Atacama should, if anything, serve to overestimate the boundaries of the period, as the sample is known to include some dated events which lie beyond the Middle Period (culturally). If one considers the distribution of individual modeled start and end dates binned by century as in Figure 3, it is clear that the peak intensity of the Middle Period as a "phase" in the San Pedro oases extends from the 7th–11th centuries AD (calibrated), with over 75% of the individual modeled (start and end) dates falling within that 500–year period.

The most obvious implication of the model at this scale is that the Middle Period in San Pedro appears to have a later onset of peak activity than previously understood. Unsurprisingly, the Middle Period in the oases is specific to the region and only loosely aligned to the larger Andean patterns dubbed the Middle Horizon (e.g., Isbell 2008; Castro et al. 2016). The most recent summation of the region's prehistory (Castro et al. 2016) describes the Middle Period of the oases as having consisted of two phases, Quitor (400–700 AD) and Coyo (700–1000 AD), as based on the earlier stylistic and thermoluminescence works of Tarragó (1968, 1989) and Berenguer et al. (1986). While the overall boundaries of our model are generally in line with this proposition (i.e., our data support the existence of an early Middle Period in San Pedro), the overwhelming majority (more than 75%) of the individual modeled dates fall in the latter two-thirds of the proposed 600-year span, with some overlap into the early 11th century AD (calibrated). This concords with data from elsewhere in the Andes that pushes the start of events tied to the subsequent Late Intermediate Period (such as the collapse and partial abandonment of the centers of

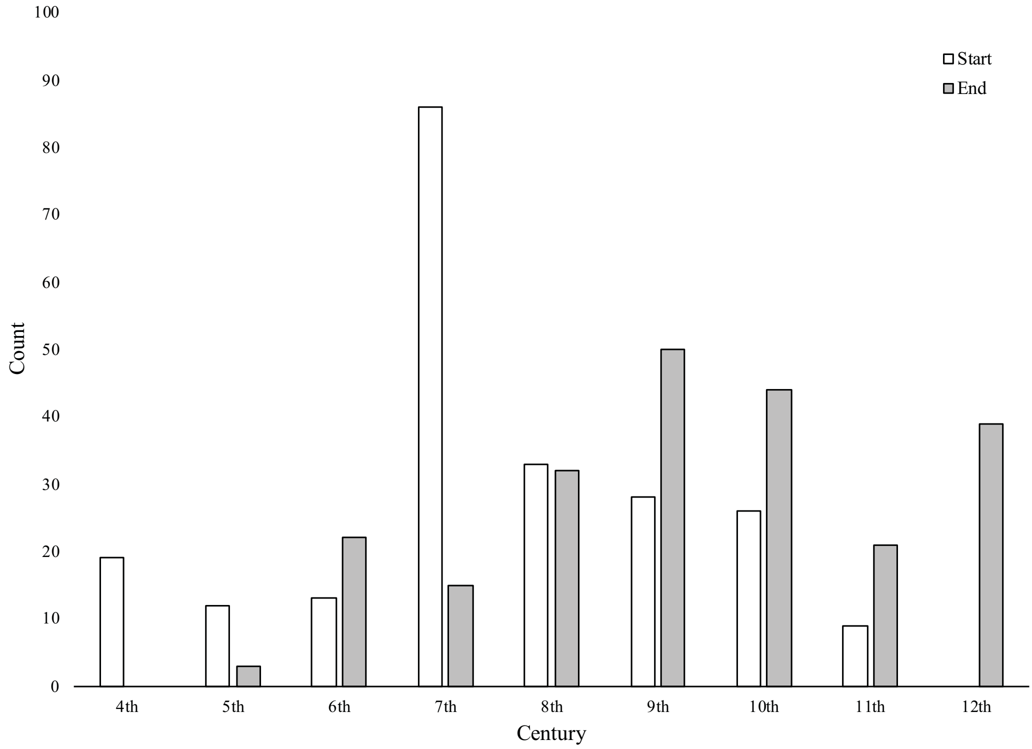

Figure 3 Individual modeled start and end dates binned by century. Note dramatic increase in dates post-600 calAD.

Tiwanaku and Wari) into the 11th century AD (calibrated) (e.g., Janusek 2004; Arkush 2008; Isbell 2008; Jennings et al. 2015). Given our sampling strategy, our findings would appear to support the notion of a florescence of Middle Period culture/society in the later period 600–1000 cal AD. Whether this represents a demographic expansion, or simply greater use of the sampled cemeteries, is irresolvable based on these temporal data alone.

On the basis of this, we support the idea that the chronology of the oases in the Middle Period be refined by employing the evident dichotomy of early (400–600 cal AD) vs. late (600–1000 cal AD), dividing the incipient and established phases of the period without reference to geography. This allows us to step away from the association of specific *ayllus* with particular phases of occupation. If nothing else, this phasing can be used to structure hypotheses to be tested using other classes of (bio)archaeological evidence.

Inter-*Ayllu*

The structure of the *ayllu*-level modeling is presented in Figure 4, with details of phase boundaries and all individual dates in Table S2. Agreement indices for this iteration were A_{model}=73.6 and $A_{overall}$=98.2. For the sake of comparison, the same model run without outlier trimming produced far lower agreement indices (A_{model}=50.1 and $A_{overall}$=57.4), thus validating the initial step taken to mitigate the effects of a small number (n=9 or 3.7%) of outlying dated events. Only one individual date (Solcor X30285) had an individual

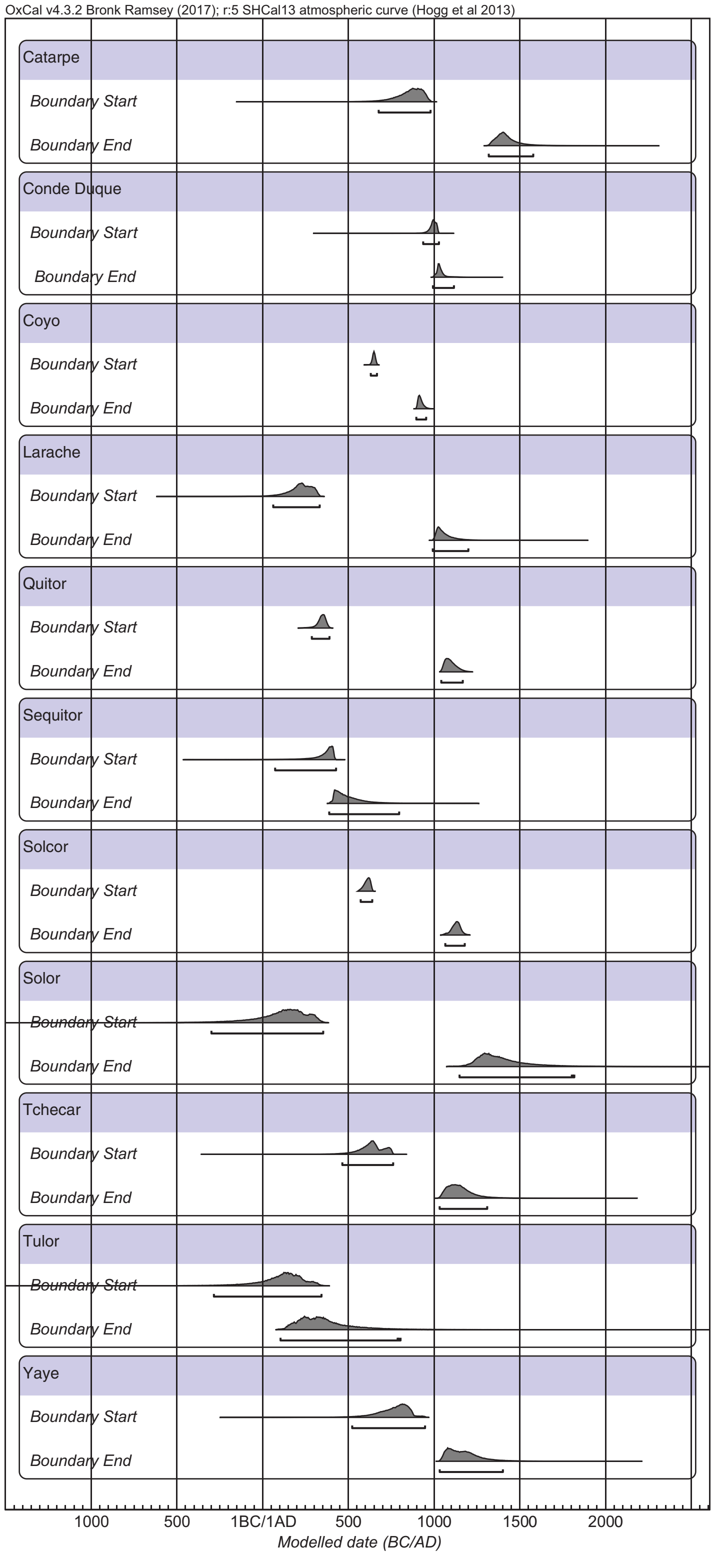

Figure 4 Structure of inter-*ayllu* model.

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modeled age range with an unacceptable individual agreement index value (A=22.9). With the date removed, the final model agreement indices were A_{model}=110.8 and $A_{overall}$=108.4.

In terms of inception of use (based on the beginning of the modeled "Boundary Start" ages), the earliest-occupied *ayllus* are the southern Solor and Tulor oases, both of which have Boundary Start ages that begin in the 3rd century BC (calibrated), but with uncertainties that stretch well into the 4th century AD (calibrated). In terms of modeled dates, the range of all four dates from the settlement at Tulor begin in the 1st century BC/AD (calibrated), whereas the earliest Solor individual has a calibrated range beginning in the 2nd century AD (calibrated) and the next earliest date range for that *ayllu* does not commence until the 4th century AD (calibrated). Tulor thus remains as the *ayllu* with the earliest evidence of sustained occupation and activity in the San Pedro oases as is supported by archaeological evidence concerning habitation structure and ceramic assemblages (Llagostera et al. 1984; Barón 1986; Llagostera and Costa Junqueira 1999).

Moreover, Tulor and Solor seem to be well-established by the time the next earliest *ayllus* begin to show evidence of use, as Sequitor and Larache both have Boundary Start date ranges that commence in the 1st century AD (calibrated). In the case of Larache, examination of individual modeled date ranges reveals several samples (4 of 13) with calibrated ranges that begin in the third century AD (calibrated), whereas the limited number (three) of individual determinations from Sequitor all begin in the fourth century AD (calibrated).

Quitor has the next earliest Boundary Start age (288–391 cal AD), which is noteworthy if for no other reason than its span is so much more tightly constrained than any of the other putatively earlier *ayllus* as a consequence of the much larger number of individual determinations (55) that make up that phase. Both the individual modeled date ranges (13/55, 23.6%) and the Boundary Start age would indicate an earliest occupation of the Quitor *ayllu* in the fourth century AD (calibrated). Tchecar comes next, with a Boundary Start age that begins in the fifth century AD (calibrated), and with individual modeled ages (three of nine) starting in the 7th century AD (calibrated).

Both Yaye and Solcor have Boundary Start ages that begin in the 6th century AD (calibrated), but while Solcor has a small number of individual date ranges (3/56, 5.4%) that begin in the 6th century and 25 (44.6%) that start in the 7th century, the earliest individual age range from Yaye does not begin until the late 7th century AD (calibrated). On this basis, while Solcor has a somewhat later Boundary Start age than Yaye, we contend that, in the main, the occupation of Solcor predates that of Yaye. This is also corroborated in the material culture of the cemeteries (Torres-Rouff and Costa Junqueira 2006; Castro et al. 2016).

Coyo and Catarpe both present Boundary Start ages in the 7th century AD (calibrated), with the modeled beginning range of Coyo (thirty-six years) being the most constrained of any *ayllu* presented here. In terms of relative ordering, while 76.6% (49/64) of the individual modeled age ranges from Coyo begin in the 7th century AD (calibrated), none of the Catarpe modeled individual ranges begin any earlier than the last decade of the 8th century AD (calibrated). On balance, the occupation of Coyo seems likely to have preceded that of Catarpe. The *ayllu* with the latest evidence of an onset of activity is Conde Duque, which presents a Boundary Start age and all modeled individual age ranges that begin in the 10th century AD (calibrated). It should be noted that the sample for Conde Duque is small and all derived from one cemetery. Moreover, the center of the modern town of San Pedro sits atop much of this *ayllu*, thus obscuring more detailed insights into its past.

Turning to the cessation of activity by *ayllu* (as judged by the end of the various Boundary End ranges), Sequitor and Tulor are the two localities with the earliest termination of activity. Occupation of Sequitor has the earliest end to its Boundary End age (389–797 cal AD), but with individual modeled age ranges that end in the 5th to 6th centuries AD (calibrated). Tulor possesses only a slightly later end to its Boundary End age (105–805 cal AD) but has individual modeled age ranges that are far more restricted, with ranges that end between the 4th and 6th centuries AD (calibrated). With the limited number of available dates from these *ayllus*, it is difficult to determine the relative sequence of activity cessation, although occupation of Tulor may have ended slightly earlier.

The Boundary End age (897–955 cal AD) of Coyo comes next, suggesting a limited (250–300 year) overall duration of occupation and use of that *ayllu*, when one considers that the onset of activity there falls in the mid-7th century AD (calibrated). It is noteworthy that the entirety of the Boundary End range for Coyo is exclusive of any other *ayllu's* Boundary End, suggesting that the cessation of activity at Coyo was wholly temporally distinct from the end of the activity at any other *ayllu*. Moreover, none of the individual modeled age ranges extend until even the middle of the 10^{th} century AD (calibrated). This finding is in line with earlier observations that the Coyo *ayllu*, for example, shows distinct patterns of trauma (Torres-Rouff et al. 2018) and the presence of exotic tropical diseases (Costa Junqueira et al. 2009; Marsteller et al. 2011; Costa Junqueira and Llagostera 2014), as compared with many of its neighbors.

Activity at Conde Duque would appear to have ended next, sometime in the late 10th–early 12th century AD (calibrated). The modeled ranges for all seven of the samples from Conde Duque fall entirely within the 10th/11th centuries AD (calibrated), indicating a short and intense period of activity, as was the case with Coyo. Quitor emerges as the *ayllu* with the next Boundary End age range termination, falling between 1043–1168 cal AD. There is a substantial number of samples (12/55, 21.8%) with modeled ranges that terminate in the 11th or 12th century AD (calibrated), suggesting that its use life/occupation persisted until, or beyond, that of Conde Duque.

Both Solcor and Larache have Boundary End date ranges that terminate in the late 12th/early 13th century AD (calibrated). The range of Larache's Boundary End (993–1201 cal AD) begins earlier and ends later than that of Solcor (1066–1180 cal AD). Comparing individual dates, only three samples from Larache have modeled age ranges that extend into the first half of the 11th century AD (calibrated), while there are 16 samples (29.1%) from Solcor with modeled age ranges extending into the 12th century AD (calibrated). On this basis, the cessation of activity at Larache would appear to predate that seen at Solcor.

The beginnings of the Boundary End dates ranges for the next two *ayllus*, Tchecar (1033–1311 cal AD) and Yaye (1034–1402 cal AD), are essentially contemporary, although the end of the Yaye range is nearly a full century later than that of Tchecar. There are, however, fairly small sample sizes representing each *ayllu*, making detailed inferences about their relative ordering rather speculative.

Finally, the *ayllus* of Catarpe and Solor present the two latest-concluding Boundary End ranges, 1320–1579 cal AD and 1149–1819 cal AD, respectively. The latest individual modeled age for Catarpe extends only to the early 15th century AD (calibrated), while at Solor the latest individual age range ends in the late 14th century AD (calibrated). It is the small sample size and wide variance of the individual dates from Solor that pushes the Boundary End range into the 19th century AD (calibrated), much later than that seen for

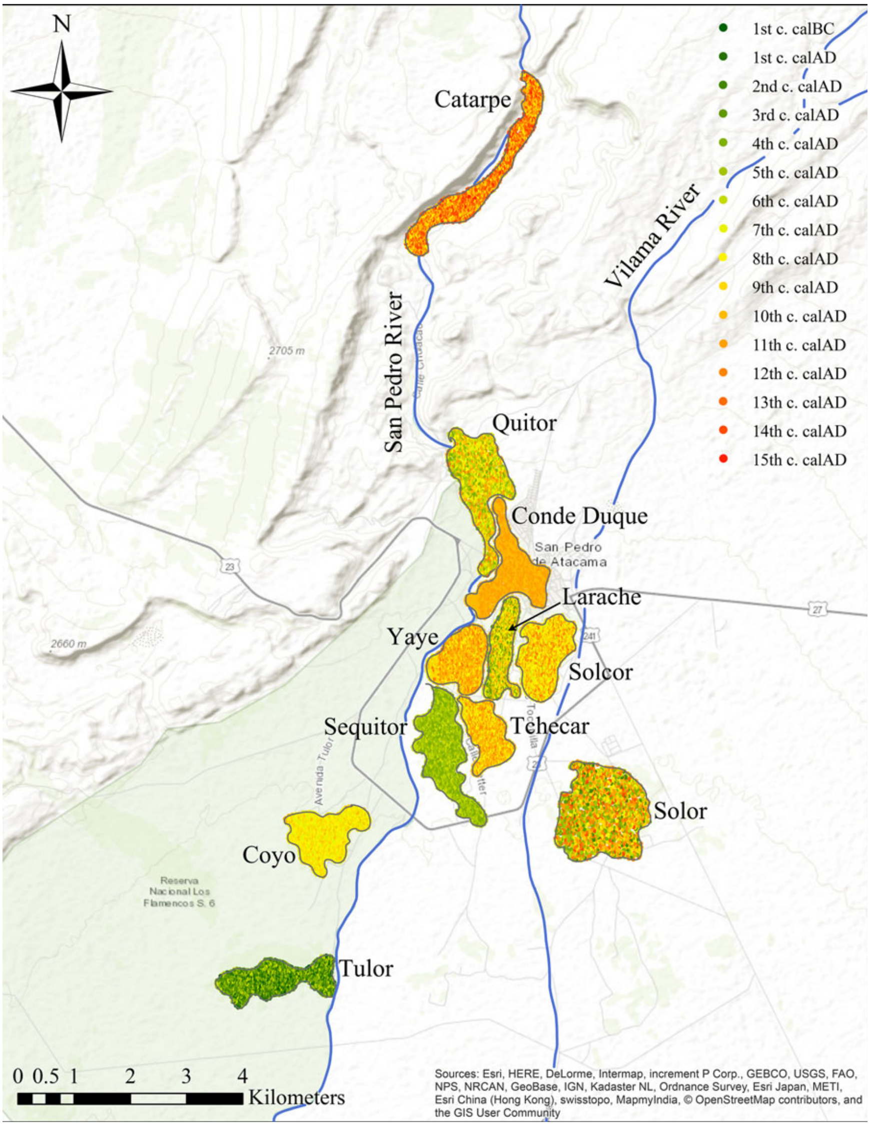

Figure 5 Heat map of inter-*ayllu* dates by century.

Catarpe. One imagines that a larger sample size for Solor might bring its modeled conclusion into greater alignment with that seen for Catarpe.

In summary, our results indicate that the sequence of initial use of the various tested *ayllus* is as follows: Tulor, Solor, Larache, Sequitor, Quitor, Tchecar, Solcor, Yaye, Coyo, Catarpe, and Conde Duque. The sequence of the cessation of use of the various tested *ayllus* is as follows: Tulor or Sequitor, Coyo, Conde Duque, Quitor, Larache, Solcor, Tchecar or Yaye, and finally Catarpe or Solor. These results are visualized, in a summary form in Figure 5.

Taken together, the chronological modeling of cemetery use across the different *ayllus* reveals a complex pattern of human occupation. The chronological pattern of occupation of the oases has been of particular interest to archaeologists (Orellana 1964; Llagostera and Costa Junqueira 1999; Uribe 2002; Núñez et al. 2010; Agüero and Uribe 2011; Torres-Rouff and Hubbe 2013; Uribe et al. 2016), due to their geographic and ecological circumscription, and to the role that said circumscription may have played in shaping the human presence therein. Indeed, the perceived challenge of occupying the limited fertile land in the oases has driven much of the discussion about the human occupation in the area. Previous studies have suggested a general south-to-north succession of human settlements over the oases, with access to, and control over, water playing an important role in population displacement across the oases over time (Llagostera and Costa Junqueira 1999; Torres-Rouff and Hubbe 2013). Our results speak directly to this discussion and depict a pattern of occupation that is considerably more nuanced than previously considered.

The refined results obtained with the chronological modelling of *ayllu*/cemetery use reveal considerable variation in the pattern and length of occupation of the oases. While the earliest *ayllus* to be occupied are in the southern portion of oases (Tulor and Solor) and the last to show human presence is the northernmost *ayllu* of Catarpe, the rest of the *ayllus* do not show any directional pattern of occupation. For instance, the northern *ayllu* of Quitor has earlier Boundary Start dates than most of the central and south located *ayllus*. As such, the reasoning that led to the human expansion across the oases during the Middle Period cannot be easily ascribed to a solely geographic logic.

On the other hand, our results support previous suggestions that access to water sources played a role in the length of occupation of individual *ayllus*. Tulor shows a short modeled period of occupation when compared to Solor, which shows the longest range of any *ayllu* in the oases. This pattern has been noted before (Torres-Rouff and Hubbe 2013) and has been suggested to be the result of past changes in river courses. Tulor and the other western *ayllus* (Coyo and Yaye) are located close the San Pedro river, which shifted course significantly in the past (Llagostera et al. 1984; Niemeyer 1989). These three *ayllus* show relatively short periods of occupation, which supports the hypothesis of a changing path of the San Pedro River. Solor, on the other hand, is directly associated with the Vilama River, which has a narrower riverbed near this *ayllu* and only shows evidence of having shifted farther south of the *ayllu*. As such, it would have sustained the longer period of occupation in the latter *ayllu*.

Finally, it is noteworthy that the pattern of occupation of the oases during the period studied is not tied to region-wide events, since the times of occupation and abandonment of the studied cemeteries show no common chronological dimensions. As such, these results demonstrate that human expansion in the oases largely responded to factors intrinsic to each of the *ayllus*, reflecting micro-environmental differences between them, local socio-cultural dynamics, or other local factors. As such, the chronological diversity of cemetery use across *ayllus* suggests local independence in defining the period and duration of cemetery use, complementing the archaeological and bioarchaeological literature that demonstrates significant differences and inequalities between *ayllus* during the Middle Period (e.g., Torres-Rouff 2011).

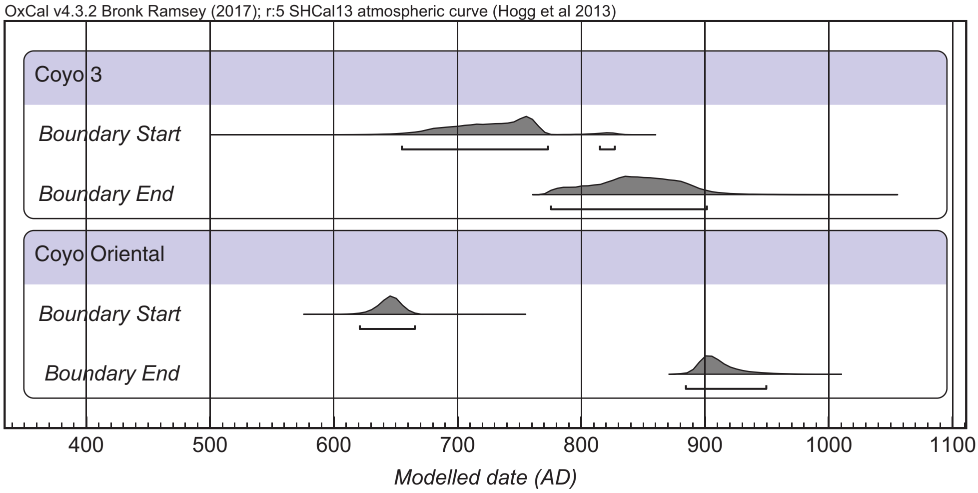

Figure 6 Structure of intra-*ayllu* model for Coyo.

Intra-*Ayllu*

As noted previously, the more in-depth sampling approach taken to sites in the Coyo, Quitor, and Solcor *ayllus* has resulted in an abundance of dates for some of the ten cemeteries in those three *ayllus*: Coyo Oriental and Coyo 3, Quitor 1, 2, 5, 6, and 8/9, and Solcor 3, Solcor Plaza, and Solcor Nueva Población. Below we explore these in more detail, assessing both sequencing and duration of use for each *ayllu* and cemetery.

Coyo

The structure of the model for the two Coyo cemeteries is presented in Figure 6, with details of phase boundaries and all individual dates in Table S3. Agreement indices for this model were A_{model}=84.8 and $A_{overall}$=78.4. Two dates from Coyo 3 (X30221 and AA111819) had agreement index values below the suggested index cutoff value of 60.0 (A=50.4 and 48.8, respectively). Removal of these two dates increased the model's agreement indices to A_{model}=97.1 and $A_{overall}$=94.7.

The model for Coyo indicates complete overlap, and even contemporaneity, of the two cemeteries considered here. The Boundary Start age for Coyo Oriental (621–665 cal AD) slightly predates that of Coyo 3 (655–827 cal AD), while the Boundary End date of Coyo Oriental (884–949 cal AD) is slightly later but largely overlapping with that of Coyo 3 (775–901 cal AD). If any difference can be detected on the basis of the ranges of individual modeled dates, it would appear that use of Coyo Oriental both commences slightly earlier and ends slightly later than that of Coyo 3, with differences at both extremes of forty to sixty years.

In terms of the duration of use of the Coyo cemeteries, the use of Boundary Start and End ages indicates that Coyo 3 was in use for approximately 250 years, while Coyo Oriental had some 220–330 years of use. The several century use-life of these cemeteries is quite different to that observed in Quitor but is in line with what was observed for Solcor.

Regardless of these differences, the Coyo cemeteries would appear to have been used largely contemporaneously for some two to three centuries despite their shared location in the Coyo *ayllu*. The cemeteries themselves are geographically distinct (Figure 1), occupying the southwest and northeast corners of the small area of Coyo. Given that time does not distinguish the cemeteries, the concurrent use of these two separate cemetery precincts may represent social distinctions internal to that *ayllu.* The established distinctions in mortuary goods, for example in so-called luxury items such as metals and foreign objects, between these cemeteries may in fact reflect some form of intra-*ayllu* differentiation tied to social status (Oakland 1992; Costa Junqueira and Llagostera 1994; Cocilovo et al. 2011; Torres-Rouff et al. 2018).

Quitor

The structure of the model of the five Quitor cemeteries is presented in Figure 7, with details of phase boundaries and all individual dates offered in Table S4. Due to complete temporal overlap, all dates from Quitor 6 (both the putatively earlier section and that denoted by excavators as Quitor 6 Tardío [late]) were combined and treated as one cemetery, as were samples from cemeteries Quitor 8 and 9, which were combined on the basis of their geographic proximity (being separated only by a modern road). The resulting five groupings used in the model were Quitor 1, 2, 5, 6, and 8/9. Agreement indices for this model were A_{model}=98.4 and $A_{overall}$=96.3. No individual dates had agreement index values below the stipulated cutoff of 60.0. It should be noted that there are large differences in sample size among these different cemeteries, with Quitor 1 and 2 being represented by only one and five dates, respectively, while the other three cemeteries have sample sizes of 10 to 22 dates each. Direct comparisons of use-lives of these cemeteries must thus be viewed as being somewhat contingent.

As at Coyo, the modeled use-life of the cemeteries of Quitor reveals a large degree of simultaneous cemetery use. On the basis of both Boundary Start ages and individual modeled age ranges, Quitor 2 and 5 were in-use from the mid-3rd century AD (calibrated), with the use of Quitor 8/9 commencing at the same time or soon thereafter (depending on whether one considers the Boundary Start or individual modeled age range). By the late 5th century AD (calibrated), Quitor 6 begins to be used as well, such that by the 5th/6th century AD (calibrated), there are at least four cemeteries in simultaneous use within the Quitor *ayllu*. This number rises to five cemeteries if we take the one available date from Quitor 1 (X14968A, 1030–1210 cal AD) to be representative of sustained activity there. Unlike the case of Coyo, several of the Quitor cemeteries are in close geographic proximity, and therefore it is unlikely that they represent clear spatial distinctions in use.

The collective activity in these cemeteries begins to wane in or after the 8th century AD (calibrated), as Quitor 5 (Boundary End age 812–1048 cal AD), Quitor 6 (Boundary End age 1026–1145 cal AD), Quitor 8/9 (Boundary End age 1013–1378 cal AD), and Quitor 2 (Boundary End age 700–1381 cal AD) all cease evidence of use between the 8th and 14th centuries AD (calibrated).

The modeled duration of the three Quitor cemeteries for which we possess sufficient sample size to speak with confidence reveals a pattern very distinct from that observed for Coyo. As based on Boundary Start and End ranges, Quitor 5 was used for some 430–840 years, Quitor 6 for 400–730 years, and Quitor 8/9 for 500–1190 years. Even at their lower limits, these use-life

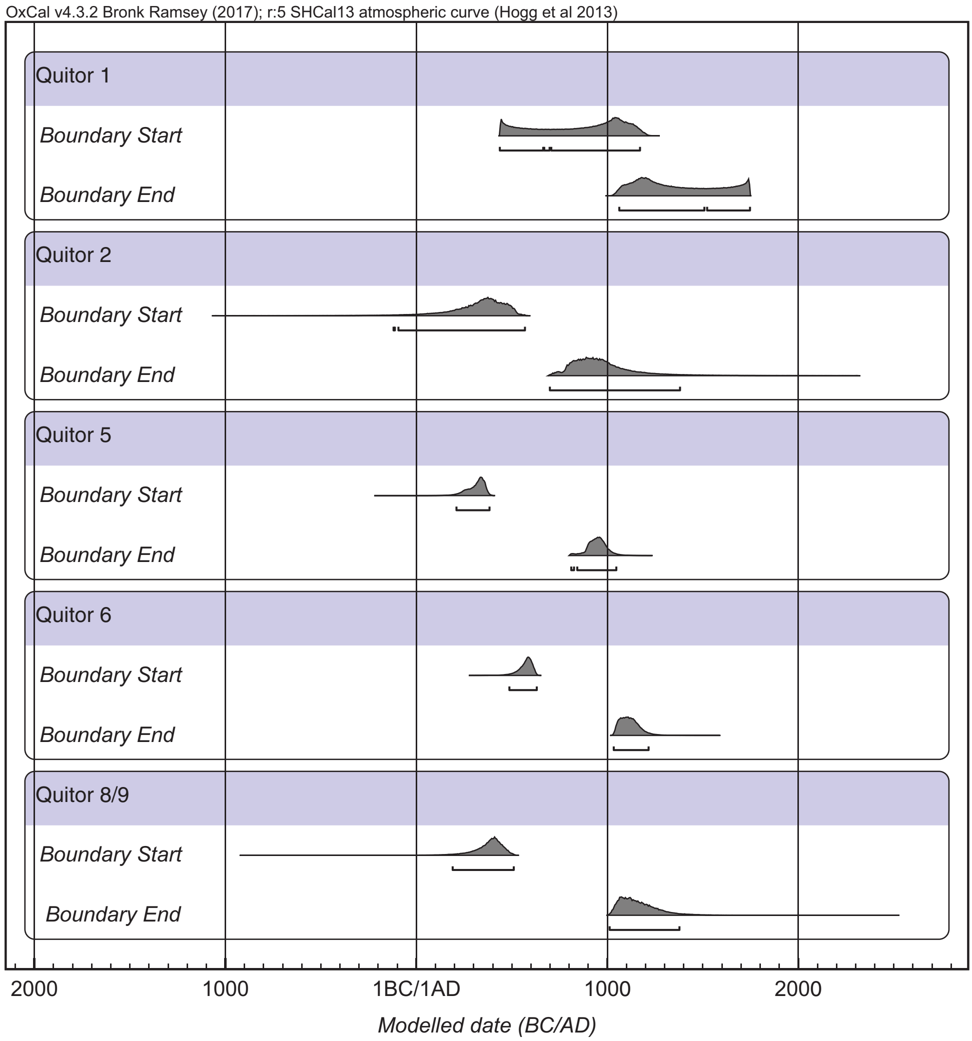

Figure 7 Structure of intra-*ayllu* model for Quitor.

periods are appreciably longer than those of the Coyo or Solcor cemeteries. That said, the data also suggest the clear contemporaneity of multiple cemeteries like seen at Coyo, which may reflect their use by lineage groups or other forms of social groupings that had salience over a long period of time.

Solcor

The structure of the model of the three Solcor cemeteries is presented in Figure 8, with details of phase boundaries and all individual dates offered in Table S5. Agreement indices for this model were A_{model}=97.1 and $A_{overall}$=93.4. No individual dates had agreement index values below the stipulated cutoff of 60.0.

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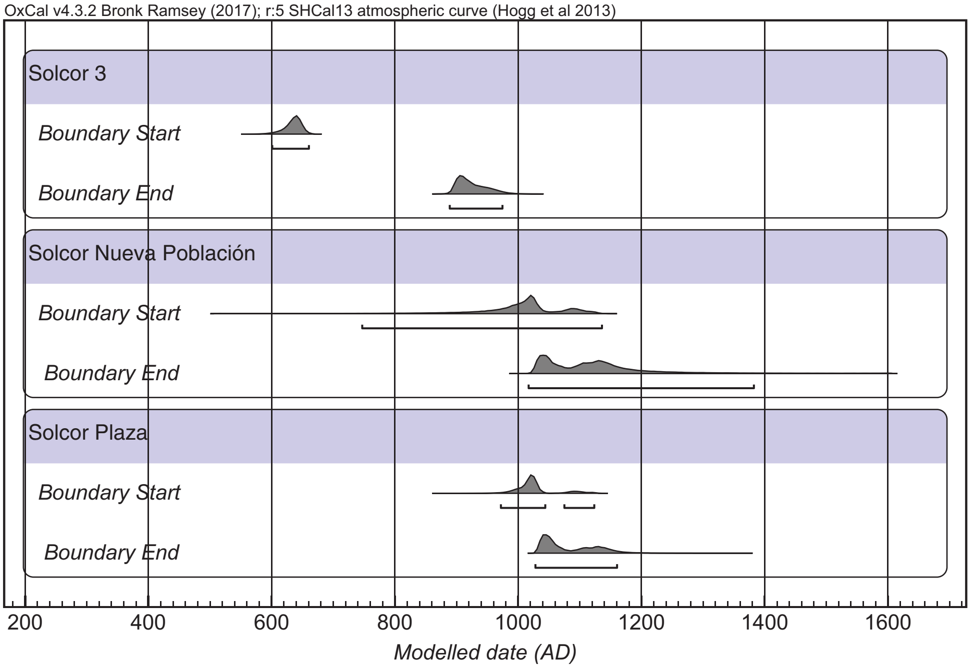

Figure 8 Structure of intra-*ayllu* model for Solcor.

Unlike Coyo or Quitor, at Solcor, the intra-*ayllu* model revealed a clear sequence, and even succession, of cemetery use. Solcor 3 has the earliest onset of use, with a Boundary Start age range of 601–660 cal AD, and with the earliest individual modeled age ranges commencing in the first two decades of the 7th century AD (calibrated). It is not until nearly the conclusion of Solcor 3's Boundary End range (889–974 cal AD) that activity begins at Solcor Plaza (Boundary Start age 972–1123 cal AD) or, as based on individual modeled age ranges, at Solcor Nueva Población, where the earliest samples' ranges do not commence until the last decade of the 10th century AD (calibrated). While the small sample size for Solcor Nueva Población (n=3) precludes any categorical statement about use-life, there is clear evidence at Solcor 3 and Solcor Plaza of a succession of cemetery use, with activity at Solcor Plaza commencing at, or within a generation of, the cessation of activity at Solcor 3. Ultimately, activity at both of the later cemeteries ceases by, most likely, the 12th century AD (calibrated) (based on the Boundary End age at Solcor Plaza and the end of the individual modeled age ranges at Solcor Nueva Población).

The duration of use of the larger Solcor cemeteries shows greater similarity to the pattern observed at Coyo rather than that documented for Quitor. The results of the modeled Boundary Start and End ranges indicate that Solcor 3 was in use for 230–370 years, while Solcor Plaza was utilized for up to 190 years. In contrast to the two other *ayllus* we have studied more closely, the temporal data provides no clear evidence to support the idea that existing social structures limited access to cemetery use at Solcor, as this *ayllu's* cemeteries show limited concurrent use.

DISCUSSION AND CONCLUSION

The three-tiered modeling of these 243 dates from the cemeteries of San Pedro de Atacama has yielded a series of novel insights into the chronological structure of Middle Period life and cemetery use in the oases. Furthermore, the results generated allow us to formulate a series of questions, and even explicit hypotheses, that will be examined and tested in our future analysis of a suite of archaeological, bioarchaeological, and isotopic data from the individuals and cemeteries considered here. As this work is currently in progress, we cannot yet speak to the impact of these results on our broader bioarchaeological endeavor. Instead, we consider below only a few of these new insights and focus more extensively on directions for future testing on the all *ayllus*, inter-*ayllu*, and intra-*ayllu* scales. Finally, we conclude by offering more general thoughts about the implications of these results for our understanding of lifeways in San Pedro de Atacama's Middle Period and for future archaeological and bioarchaeological work conducted therein.

At the coarsest spatial scale (all *ayllus*), we call attention to the evident dichotomy of early/incipient (400–600 cal AD) vs. late/established (600–1000 cal AD) phases of the Middle Period in the San Pedro de Atacama oases. While this dichotomy is clear in the assembled radiometric corpus, we present this phasing not as novel dogma, but rather as a crucial aspect of the oases' occupation that should be examined in—and tested by—other archaeological work in the region moving forward. Crucially, this proposed division can be used to generate a series of structuring questions by which future work could be guided, for instance by examining whether various embodied social phenomena (inequality, body use, diet), or indeed the stylistic dimensions of a myriad of material culture, change between these proposed phases. Indeed, previous studies already have identified shifts in the production of certain ceramic styles (Stovel 2013, the disappearance of the *Rojo Pulido* style) or the diminution of San Pedro as a ceramic production center (Gallardo et al. 2017) in the century between 600–700 cal AD. The robustness of this possible moment of transition deserves examination across a broader range of artifacts and archaeological data. Moreover, in light of the discussions surrounding the mediated form that Tiwanaku influence took in the oases, it is possible that this moment of disjuncture around 600 cal AD represents an inflection point in the intensity, level, or mechanism of that highland polity's presence in San Pedro, a phenomenon that could, conceivably, be visible in some classes of (bio)archaeological data.

Moving to the inter-*ayllu* scale, the results presented here shed new light on long-running debates about purported similarities and differences between and among *ayllus* and the drivers of suggested diachronic shifts in their use and occupation. In broad terms, our data show that some of these previous *ad hoc* models have been overly simplistic, while these new formulations reveal (or support) far greater complexity. As seen in Figure 5, notions of an overall south-to-north succession of occupation in the oases find little support, whereas closer proximity to water engendered long term occupation as compared to those communities where water became scarce over time due to movement of river channels (for example, at Tulor, Coyo, or Yaye) and occupation/cemetery-use were short-lived (a finding that supports previous suggestions in Torres-Rouff and Hubbe 2013).

Most crucially, this model iteration stresses the independence of the trajectories of different *ayllus*, with local conditions being the best predictor of chronological patterns of cemetery use. Patterns of occupation of the oases during the Middle Period are not simply echoes of region-wide events as the dynamics of human activity in each *ayllu* responded to local environmental or socio-cultural dynamics. This finding buttresses the archaeological and bioarchaeological literature showing significant differences and inequalities between *ayllus* during the Middle Period. For example, our previous research has documented radical differences in the presence of violent injury between individuals interred at different cemeteries in this period (Torres-Rouff 2011; Torres-Rouff et al. 2018), while, simultaneously, other aspects of mortuary treatment (e.g., the provisioning of *Negro Pulido* ceramics) are standardized to the point of ubiquity across time and *ayllus* (Stovel 2005).

Clearly, with the temporal framework we provide here in hand, much more work on the nuances of inter-*ayllu* differences is merited, further exploring the processes described by Salazar and colleagues who noted that, "during the [Middle Horizon] the local community of [San Pedro de Atacama] created and reproduced social boundaries and affiliations at different levels simultaneously" (Salazar et al. 2014: 148). Indeed, Salazar and colleagues identified inter-*ayllu* variation in cranial modification, the presence and ubiquity of paraphernalia associated with the use of hallucinogenic snuffs, and metallurgical practices, among other practical and material differences, which deserve re-examination with the added context of the temporal modeling presented here.

Finally, just as these results reveal diversity between/among *ayllus*, at the finest scale, they also indicate differences in intra-*ayllu* patterns of cemetery use. In sum, what these analyses expose is that intra-*ayllu* patterns of cemetery use in San Pedro de Atacama's Middle Period were not homogenous and, consequently, are likely to reflect a society in which there existed multiple distinct mortuary practices (in terms of the designation and maintenance of cemetery precincts/ burial space). The three *ayllus* we examine in greater detail here reveal three distinct patterns of use, suggestive of a lack of standardization of the use of mortuary spaces across the *ayllus*. While some burial spaces were used for centuries, others had more discrete and constrained use-lives. Similarly, some small communities had several cemeteries in use at a given time (which may reflect their use by lineage groups or other forms of social groupings that had salience over a long period of time), while others had a sole burial location. Thus, while the identity of *ayllus* is, at least in part, chronological, the multiplicity of patterns ultimately suggests a complex picture of cemetery use in the Middle Period that cannot be parsed with temporal data alone and calls for the integration of bioarchaeological and archaeological data.

The full meaning or motivation behind these distinct patterns awaits consideration of other classes of (bio)archaeological data, and the social differences reflected in cemetery use are a crucial future distinction for analyses. However, based on these observed differences, we might expect differences in artifact style, mortuary treatment, and lived experience (as evidenced by bioarcheology) to vary in distinct ways among the cemeteries of the different *ayllus* considered here. Crucially, these data allow us to disaggregate the effects of diachronic change from synchronic variation, permitting far more nuanced comparisons of difference observed among the mortuary goods of Coyo or Quitor, where multiple cemeteries were in use at the same time, and Solcor, where there is a chronological distinction between periods of use of different mortuary spaces. Specialists in material culture will be able to explore these possibilities in varied materialities. Regardless of the outcomes of these future studies, what is happening among and within the San Pedro *ayllus* is notably distinct, and, even after nearly a century of study, merits more detailed consideration.

At its broadest, this study permits the formulation of new questions, which can be examined in future studies and provoke the re-analysis of decades of accumulated archaeological work in the San Pedro oases. While we cannot say with certainty what the impact of the incorporation of this understanding of these results will be for our understanding of life in San Pedro in the Middle Period, they could well provide ample ground for radical transformations thereof. At the very least, these findings lay bare the fact that, just as there was no one Middle Period, let alone Middle Horizon, experienced across the southern Andes for a 600-year period, there likely was not a homogenous experience of the Middle Period in San Pedro de Atacama over time, across, or within *ayllus*. We then raise a series of possibilities. Does 600 cal AD represent a meaningful moment of disjuncture across different classes of evidence? What might detailed archaeological study of textiles, ceramics, snuff paraphernalia and other material culture reflect when tied to the distinctions between cemeteries and time? Do the divergent trajectories of cemetery use and occupation seen among and within *ayllus* represent not just distinct responses to local environmental conditions, but also different strategies/levels/intensities of interaction with the Tiwanaku polity? Indeed, these results, rooted in the modeling of such a large corpus of radiocarbon assays, may form the basis for a re-thinking of long-accepted social development models in the region.

Ultimately, it is clear that these results can help to reduce the equifinality of different proposed explanations of social change, if for no other reasons than they eliminate the confounding effect of an inability to differentiate between synchronic variation and diachronic change. Indeed, we hope the structure this analysis provides will serve as a useful scaffolding for a host of future detailed examinations of stylistic variation, settlement patterning, mortuary analysis, and bioarchaeology in the San Pedro oases in the coming decades.

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SUPPLEMENTARY MATERIAL

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