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THE SEQUENCE OF HUMAN OCCUPATION IN THE ATACAMA OASES, CHILE: A RADIOCARBON CHRONOLOGY BASED ON HUMAN SKELETAL REMAINS

Christina Torres-Rouff and Mark Hubbe

The San Pedro de Atacama oases have been permanently occupied since ca. 2500 B.P. and over this time developed a rich culture that was intertwined with social developments in the south-central Andes. However, despite decades of archaeological research, the region still lacks a strong chronological framework based on absolute dates. Here we present 53 new AMS ^{14}C dates from osteological remains from San Pedro de Atacama, in order to contribute to an understanding of the Atacameño cultural sequence. These dates suggest that some cemeteries were occupied for long periods, frequently transcending cultural phases, and that in fact a number of cemeteries within the same ayllu *were in use concurrently. We also show that, not surprisingly, population displacement through time primarily follows oscillations in the sources of water. The new information presented here suggests that future work in the region should emphasize detailed analyses that consider intra-*ayllu *variability, given that diversity within periods is masked by the uniform use of cultural phases to describe human development.*

Los oasis de San Pedro de Atacama han sido ocupados permanentemente por casi 2,500 años, periodo durante el cual se desarrolló una elaborada cultura que se entrelazó directamente con los acontecimientos sociales ocurridos en los Andes surcentrales. Sin embargo, a pesar de décadas de investigaciones arqueológicas, la región aún carece de un marco cronológico sólido basado en fechas absolutas. Presentamos aquí 53 nuevas fechas de C^{14} AMS obtenidas a partir de restos osteológicos provenientes de diferentes cementerios precolombinos de San Pedro de Atacama, con el fin de contribuir a la comprensión de la secuencia cultural atacameña. Estas fechas sugieren que algunos cementerios fueron ocupados por largos períodos que a menudo trascendieron las fases culturales y que, de hecho, múltiples cementerios estuvieron en uso simultáneamente al interior de cada ayllu*, mostrándonos que posiblemente existieron ciertas diferencias sociales que dictaron el uso de los diferentes espacios sagrados. También concluimos que, como es lógico en un desierto tan árido, los desplazamientos poblacionales a través del tiempo estuvieron condicionados principalmente por las oscilaciones en las fuentes de agua. Los nuevos datos que aquí presentamos plantean la necesidad de que futuras investigaciones en la región enfaticen la variabilidad dentro de los* ayllus*, dado que la diversidad existente dentro de los períodos tiende a quedar enmascarada bajo el uso uniforme de las fases culturales como marco para describir el desarrollo humano.*

The San Pedro de Atacama oases have been occupied for over 2,500 years and during this time developed a rich culture intertwined with south-central Andean social developments (Llagostera 2004; Llagostera and Costa 1999; Núñez 2007). Located at nearly 2,500 m asl between the Andes and the Cordillera de Domeyko at the northern tip of the Salar de Atacama (Figure 1), this human occupation occurs in one of the driest climates on the planet (Errázuriz et al. 1987; Niemeyer 1989). These conditions account for excellently preserved archaeological remains, have facilitated substantial research, and ultimately resulted in one of the more representative archaeological collections of any region in South America (Hubbe et al. 2011; Le Paige 1964, 1972/1973; Llagostera 2004; Núñez 1992, 2007). The archaeological collections housed at the *Instituto de Inves-*

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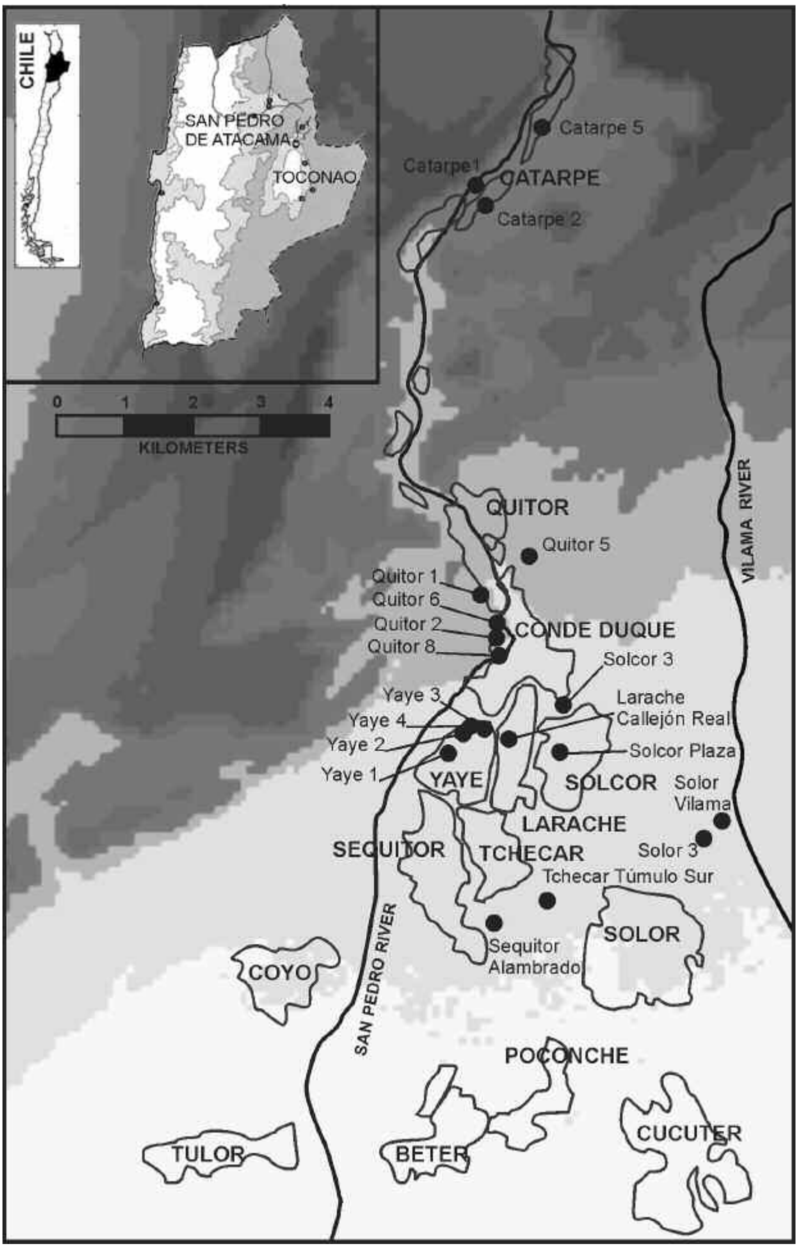

Figure 1. Map of the region indicating *ayllu* boundaries and the cemeteries included in this study.

tigaciones Arqueológicas y Museo Le Paige encompass the various phases of occupation in the oases and river valleys of the region, particularly in the cluster of oases known today as San Pedro de Atacama.

Given the abundance of well-preserved archaeological remains and longstanding research, several scholars have attempted to define and understand the local chronology, initially through ceramic typology (e.g., Le Paige 1972/1973) and seriation (e.g., Tarragó 1968, 1989), and subsequently with thermoluminescence dating (e.g., Berenguer et al. 1988). In the late 1980s, only six radiocarbon dates were available for the area. However, new dates have appeared at a slow but steady pace over recent decades (Costa 1988; Costa and

Llagostera 1994; Llagostera et al. 1984, 1988; Núñez 1976; Oakland Rodman 1992).

Despite the fact that the south-central Andes' sweeping chronology fits the general occupational pattern of the Atacama oases, only a few researchers have focused on local developments or considered the variable pattern of human occupations of the local *ayllus,* the traditional form of Andean community organization (Cock 1981). The *ayllu* has both broad (community) and narrow (family) meanings (e.g., Isbell 1977). In most cases, it is a socially constructed grouping that speaks to kinship and reciprocity. As such, burial practices are frequently tied to *ayllu* membership and can serve as a structuring principle for analyses of prehistoric occupations. In San Pedro de Atacama, the *ayllus* are historically conceived of as the separate oases (including some that are geographically contiguous), each of which is a political grouping with kin affiliations (Figure 1).

Studies focused on chronology and settlement patterns have tended to center on technological advances and symbolic traditions in ceramics. Not surprisingly, archaeologists have relied on changes in technique and iconography to define cultural phases, beginning with some of the earliest research in the area (Le Paige 1964, 1972/1973; Orellana 1963). In some cases, ceramic seriation has been verified by absolute dating (Berenguer et al. 1988; Uribe 2002), allowing for the refinement of phase boundaries. Nevertheless, archaeologists have defined local periods without great sensitivity to the different *ayllus*. Finally, there are very few direct dates for the individuals buried in local cemeteries, which make up the bulk of the archaeological record for the area. Consequently, much of the chronological context results from the correlation of funerary offerings across cemeteries. Together, these methods may have failed to accurately reflect the details of the precolumbian human occupation in the San Pedro oases. A reconsideration of the chronology should help to situate the cemeteries within the larger context of human occupation of the oases.

Here we attempt to generate a micro-scale chronological context for the occupation of the oases through the direct radiocarbon dating of human skeletal remains. We present 53 new radiocarbon dates from 22 cemeteries, allowing us to determine an absolute context for many of San Pedro de Atacama's precolumbian cemeteries. Our approach relies on the assumption that the use of cemeteries serves as a good proxy for the occupation of each of these districts, and, as such, permits discussion of the local human occupation. Given that cemeteries are ritual spaces, the patterns revealed by these new dates may not exactly parallel the usage given to habitation sites. It is possible that certain cemeteries were favored by individual *ayllus* and that their use reflects an extended relationship between a particular sacred space and a particular social group. Archaeological evidence from the region supports this scenario by demonstrating that habitation sites have been found in close proximity to the cemeteries included here; similarly, the few dates available from habitation sites also support these contentions (Llagostera and Costa 1999; Núñez 1976, 2005).

Development of the Atacama Oases: The Cultural Phases

Since the earliest human presence in the area, around 10,000 B.P., group survival was linked to the exploitation of different ecological niches through the seasonal migration of hunter-gatherer groups following large mammals (Lynch 1975; Núñez 1995; Núñez and Santoro 2011). With the emergence of semi-permanent and permanent settlements in the Formative period (beginning ca. 1200 B.C.), the oases, like the neighboring river valleys, provided good conditions for maize and other cultigens. These favorable conditions also allowed for the development of stable settlements that served as stopping-off points for llama caravans traveling through northern Chile, southern Bolivia, and northwestern Argentina (Núñez and Santoro 2011).

The cultural development of precolumbian Atacameño culture, in part, reflects the relationship between the oases and their neighboring areas (Figure 2; Berenguer et al. 1988; Llagostera and Costa 1999; Núñez et al. 2010; Tarragó 1968). Locally, the Late Formative period (Toconao phase, 300 B.C.–A.D. 100, and Sequitor phase, A.D. 100–400) is associated with the first stable occupation of the oases. During this time, groups ceased to be highly mobile and began to rely on the regular exchange of material goods with neighboring and more distant regions, relationships that eventually charac-

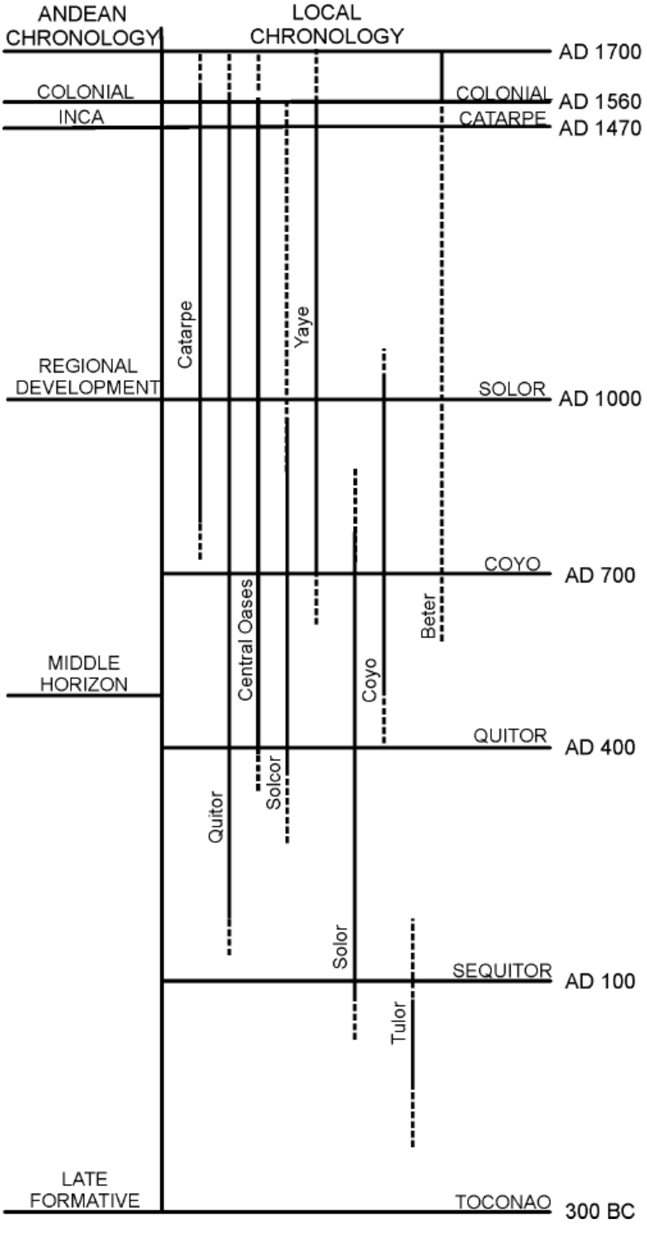

Figure 2. General Andean and local chronologies. Approximate occupation of each *ayllus* based on archaeological data and radiocarbon dates. Solid lines indicate known periods of occupation; dashed lines present unconfirmed, but expected durations.

terized interactions in the Atacama oases (Llagostera 1996, 2004; Núñez 1992). The Formative period is followed by a time that includes strong cultural influences from the Tiwanaku polity (Middle period, A.D. 400–1000, encompassing the Quitor, A.D. 400–750, and Coyo phases, A.D. 750–1000). Concurrently, interregional exchange reached a peak as the oases were incorporated into major traffic networks linking the south-central Andes (Berenguer and Dauelsberg 1989; Llagostera 2004; Stovel 2008). This period is considered one of great affluence and expansion for the people of the oases.

Tiwanaku's collapse, possibly resulting from internal strife and further complicated by increasing dryness (Janusek 2004; Schiappacasse et al.

1989), is associated with the rise of local leadership and an amplification of social conflict (Torres-Rouff and Costa 2006). The Regional Developments period (Yaye phase, A.D. 1000–1250, and Solor phase, A.D. 1250–1470) is characterized by population movement to outlying oases (Berenguer et al. 1988; Llagostera and Costa 1999). Overall, these later phases witnessed increased violence, the construction of fortified sites, and interments with less abundant mortuary assemblages (Mostny 1949; Torres-Rouff and Costa 2006; Uribe 2002). The Inca Empire incorporated the region in the late 1400s, as suggested by the sporadic presence of Inca objects and the construction of Inca roads and a *tambo* (an administrative structure usually found along Inca roads [Lynch 1993]). This last, brief, precolumbian period ended with the Spanish conquest (Catarpe phase, A.D. 1470–1560).

Consequently, the permanent settlement of the Atacama oases was always marked by the influence of neighboring groups, which, in some cases, were integrated into local culture. The presence of these societies has been used to demarcate the different periods in local prehistory, internal cultural change in San Pedro, and the large changes in sociopolitical organization in adjacent regions. The influence of social groups far from the Atacama and the presence of foreign materials in these areas demonstrate the complex trade networks in which the precolumbian inhabitants of the Atacama oases actively participated (Berenguer and Dauelsberg 1989; Llagostera 1996, 2004; Núñez 1992).

A Chronological Framework Based on AMS ^{14}C Dates

Table 1 presents the 53 AMS radiocarbon dates obtained from the osteological collections of the Museo Le Paige. Figure 3 shows the calibrated range of these dates in addition to 24 radiocarbon dates found in the published literature. Two laboratories ran these dates: Beta Analytic and the University of Arizona Accelerator Mass Spectrometry Laboratory. Dating was performed on the organic fraction (collagen) of dense cortical bone tissue samples, primarily from crania. In all cases, these samples were subject to standard pretreatment protocols.[1] Despite the different pretreatment procedures employed by the two labs, the collagen yield information provided by the Arizona lab (BETA was unable to provide us yield values) and the $\delta^{13}C$ values suggest good preservation and reliable dates (Table 1). Despite the wide range of dates for particular cemeteries, all of the dates demonstrated a general internal consistency within cemeteries in terms of what has been predicated by the associated material culture (e.g., Berenguer et al. 1988; Tarragó 1968). That is, the dates in large part affirmed our expectations. The absence of a reservoir effect in these populations is suggested by the lack of evidence for the regular consumption of marine foods, depleted $\delta^{15}N$ values from archaeological human remains in the area, distance from the ocean and the lakes of the high puna, and, finally, the drying trend of the first two millennia A.D. (Núñez et al. 2006, 2010; Pestle et al. 2014). It should be noted that we also present a series of dates obtained over the past 50 years for sites in the San Pedro area that may not be as reliable as the new dates obtained in our study (Figures 2 and 3). However, we felt it was important to present these dates here as reference material for other scholars and for our discussions and conclusions.

Excavations in the San Pedro area have produced over 4,000 individuals with carefully recorded mortuary contexts (Hubbe et al. 2011). For this analysis, cemeteries were chosen based on a number of factors. We prioritized those with a large population that were most likely to be used in future studies and those excavated in the 1960s and 1970s because they had not been systematically dated. As a result of earlier collection strategies, most of these sites are only represented by isolated crania and, as such, our samples are almost exclusively from cranial bones. In some cases, in order to corroborate earlier thermoluminescence dates, individuals from sites discussed by Berenguer and colleagues (1988) were also analyzed.

Sampling within cemeteries was opportunistic. In order to minimize damage to individual remains, we favored those skeletal remains that showed some evidence of breakage, after verifying that these individuals had no identification or contextualization problems in the museum records. For the few samples taken from cemeteries with more thorough excavations (Casa Parroquial, Solcor 3, and Toconao Oriente) we were able to sample ribs. All samples taken were from adult skeletons. Attempts were made to sample individuals from

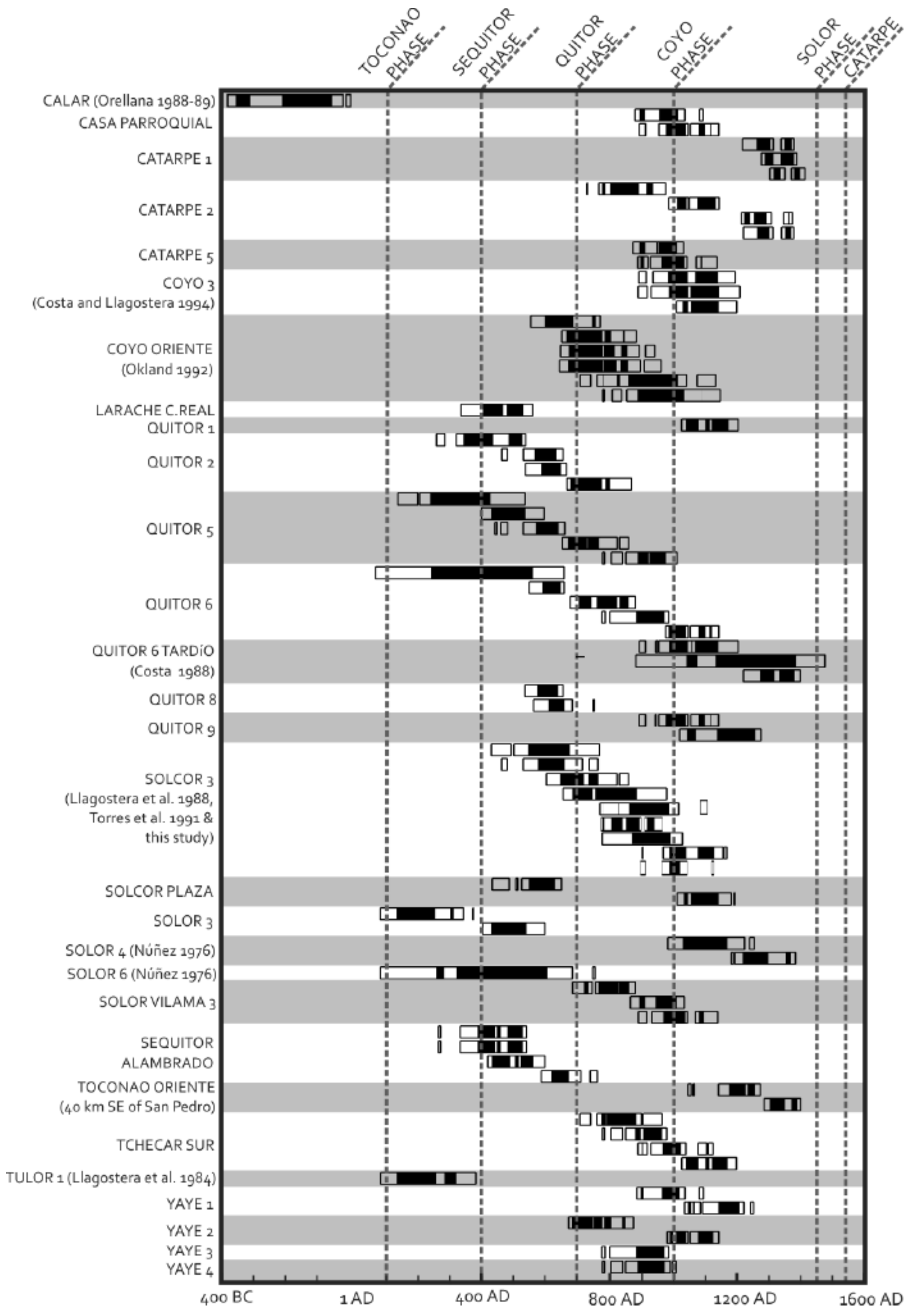

Figure 3. Calibration of all known radiocarbon dates (SHCAL04). Black boxes indicate 68 percent probability, while white boxes indicate 95 percent probability.

different parts of each cemetery to obtain a closer estimation of cemetery lifespan. It was our aim to provide a broad perspective on cemetery use in the oases. Following selection of appropriate individuals and data recording, a sample with a target weight of 1–2 g was removed using a diamond cut-off wheel (Dremel #545) on a high speed Dremel Rotary Tool. In total, we sampled individuals from 22 different cemeteries (Table 1). All radiocarbon ages, including those obtained previously, were

Table 1. Radiocarbon Dates Obtained from Human Skeletal Remains as Part of This Study.

Site[a]	Sample ID[b]	Lab #[c]	Radiocarbon Age	δ13C	Collagen Yield[d]	Calibrated Radiocarbon Age[e]
Casa Parroquial (n = 22)	CP-6	X14961A	1067 ± 44	-12.8	7.6%	899–919 [p = .04] 961–1054 [p = .67] 1060–1150 [p = .29]
	CP-18	X14962A	1113 ± 44	-11.0	13.5%	885–1043 [p = .99] 1090–1101 [p = .01]
Catarpe 1 (n = 27)	CT1-294	X14963A	752 ± 43	-12.6	5.5%	1225–1322 [p = .73] 1347–1388 [p = .27]
	CT1-764	Beta-293923	620 ± 30	-12.7	N/A	1311–1359 [p = .52] 1379–1422 [p = .48]
	CT1-2397	X14964A	689 ± 43	-13.8	6.6%	1284–1396
Catarpe 2 (n = 203)	CT2-1753	Beta-251747	1220 ± 40	-13.8	N/A	734–735 [p = .001] 772–983 [p = .999]
	CT2-1786	Beta-251750	750 ± 40	-9.2	N/A	1228–1321 [p = .72] 1348–1387 [p = .28]
	CT2-1801	Beta-251748	1030 ± 40	-12.3	N/A	992–1055 [p = .41] 1056–A.D. 1151 [p = .59]
	CT2-1850	Beta-251749	770 ± 40	-12.5	N/A	1221–1316 [p = .87] 1355–1382 [p = .13]
Catarpe 5 (n = 38)	CT5-2385	X14965A	1083 ± 47	-13.2	10.9%	895–927 [p = .09] 934–1050 [p = .74] 1079–1145 [p = .17]
	CT5-2392	X14966A	1123 ± 44	-13.3	11.9%	879–1039
Larache Callejón Real (n = 26)	LCR-5056	X14967A	1667 ± 45	-17.1	5.8%	337–562
Quitor 1 (n = 50)	QT1-3487	X14968A	956 ± 44	-15.6	3.5%	1032–1211
Quitor 2 (n = 77)	QT2-3684	X14969A	1491 ± 46	-17.3	7.5%	539–669
	QT2-3716	Beta-251751	1520 ± 40	-15.3	N/A	465–482 [p = .02] 533–659 [p = .98]
	QT2-3770	X14970A	1696 ± 46	-17.9	10.1%	259–285 [p = .05] 321–540 [p = .95]
	QT2-3783	Beta-251752	1310 ± 40	-13.6	N/A	671–874
Quitor 5 (n = 214)	QT5-1921	X14971A	1164 ± 44	-13.5	4.3%	782–789 [p = .01] 811–847 [p = .05] 856–1019 [p = .94]
	QT5-2009	X14972A	1511 ± 46	-17.4	18.6%	443–450 [p = .01] 462–483 [p = .02] 533–664 [p = .97]
	QT5-2179	X14973A	1338 ± 45	-11.1	1.0%	656–829 [p = .95] 837–865 [p = .05]
	QT5-3394	X14974A	1623 ± 46	-17.1	2.4%	401–599
Quitor 6 (n = 393)	QT6-2529	Beta-263467	1050 ± 40	-13.8	N/A	982–1054 [p = .57] 1060–1150 [p = .43]
	QT6-2588	Beta-263468	1290 ± 40	-15.6	N/A	681–886
	QT6-2928	Beta-263469	1180 ± 40	-12.5	N/A	780–791 [p = .02] 806–992 [p = .98]
	QT6-3633	Beta-263470	1490 ± 40	-16.9	N/A	551–662
Quitor 8 (n = 55)	QT8-3145	Beta-251753	1510 ± 40	-17.3	N/A	538–659
	QT8-3226	Beta-251754	1450 ± 40	-16.4	N/A	566–689 [p = .99] 754–757 [p = .01]
Quitor 9 (n = 18)	QT9-3251	X14976A	1068 ± 44	-13.7	1.5%	899–919 [p = .038] 950–951 [p = .002] 961–1053 [p = .679] 1062–1149 [p = .281]
Solcor 3 (n = 154)	SLC3-8/11161A	Beta-305869	1080 ± 30	-17.6	N/A	901–917 [p = .02] 967–1045 [p = .94] 1086–1107 [p = .03] 1120–1128 [p = .01]

Table 1 (continued). Radiocarbon Dates Obtained from Human Skeletal Remains as Part of This Study.

Site[a]	Sample ID[b]	Lab #[c]	Radiocarbon Age	δ^{13}C	Collagen Yield[d]	Calibrated Radiocarbon Age[e]
	SLC3-24/1558	Beta-305870	1160 ± 30	-15.9	N/A	778–903 [p = .73] 914–969 [p = .27]
Solcor Plaza (n = 55)	SLCP-759	X14977A	1535 ± 45	-17.2	4.3%	436–489 [p = .10] 510–516 [p = .01] 529–654 [p = .89]
	SLCP-1241	X14978A	987 ± 44	-14.8	21.0%	1019–1189 [p = .99] 1197–1201 [p = .01]
Solor 3 (n = 78)	SO3-983	X14980A	1616 ± 46	-15.8	15.4%	406–602
	SO3-991	X14981A	1859 ± 47	-17.8	7.1%	83–345 [p = .999] 374–375 [p = .001]
Solor Vilama 3 (n = 120)	SOV3-265	X14982A	1076 ± 45	-13.7	7.1%	986–923 [p = .06] 940–1052 [p = .73] 1077–1147 [p = .21]
	SOV3-300	Beta-293924	1280 ± 30	-10.7	N/A	690–886
	SOV3-308	X14983A	1125 ± 45	-14.6	4.0%	871–1041
Sequitor Alambrado (n = 323)	SQAL-533	Beta-263471	1430 ± 40	-15.2	N/A	591–715 [p = .95] 745–768 [p = .05]
	SQAL-1043	Beta-263472	1680 ± 40	-15.9	N/A	265–273 [p = .01] 335–544 [p = .99]
	SQAL-1062	Beta-251745	1600 ± 40	-15.9	N/A	422–602
	SQAL-1068	Beta-251746	1680 ± 40	-17.5	N/A	265–273 [p = .01] 335–544 [p = .99]
Toconao Oriente (n = 18)	TO-2	X14984A	867 ± 44	-14.6	1.4%	1053–1063 [p = .013] 1069–1073 [p = .004] 1149–1281 [p = .983]
	TO-18	X14985A	653 ± 43	-14.5	2.4%	1293–1408
Tchecar Túmulo Sur (n = 190)	TS-650	Beta-263473	1090 ± 40	-12.3	N/A	895–925 [p = .10] 936–1046 [p = .83] 1085–1112 [p = .05] 1116–1132 [p = .02]
	TS-806	Beta-263474	960 ± 40	-13.4	N/A	1033–1206
	TS-824	Beta-263475	1240 ± 40	-13.7	N/A	711–746 [p = .06] 766–907 [p = .80] 911–971 [p = .14]
	TS-838	Beta-293928	1190 ± 30	-13.2	N/A	782–789 [p = .01] 810–847 [p = .08] 856–986 [p = .91]
Yaye 1 (n = 52)	Y1-5494	Beta-251755	920 ± 40	-11.7	N/A	1042–1093 [p = .21] 1099–1230 [p = .77] 1251–1260 [p = .02]
	Y1-5498	Beta-251756	1100 ± 40	-13.9	N/A	892–1043 [p = .98] 1089–1102 [p = .02]
Yaye 2 (n = 64)	Y2-3309	Beta-251757	1300 ± 40	-12.6	N/A	667–881
	Y2-3417	Beta-251758	1040 ± 40	-13.2	N/A	988–1054 [p = .49] 1059–1150 [p = .51]
Yaye 3 (n = 26)	Y3-1573	Beta-251759	1180 ± 40	-15.0	N/A	780–791 [p = .02] 806–992 [p = .98]
Yaye 4 (n = 20)	Y4-1545	Beta-251760	1170 ± 40	-11.0	N/A	782–789 [p = .01] 810–848 [p = .06] 856–998 [p = .92] 1004–1016 [p = .01]

[a]n = individuals in good condition with clear context.
[b]Site & burial number.
[c]For lab number, ‘Beta’ designates dates generated by Beta Analytic; ‘X’ designates dates generated by the University of Arizona Accelerator Mass Spectrometry Laboratory.
[d]Beta Analytic does not provide collagen yields.
[e]cal A.D.; 95% probability.

calibrated with the SHCAL04 curve using Calib 6.0 (McCormac et al. 2004; Stuiver and Reimer 1993). With the exception of the one site we dated that was excavated during the 1980s (Solcor 3), there are no reliable archaeological or stratigraphic contexts for the burials included in this study. Consequently, we were unable to attempt a radiocarbon likelihood correction (Bayesian method) on the dates generated by our study.

Figure 3 shows that many cemeteries were used for long periods of time, in some cases several centuries. This confirms the idea that human settlement in the oases was stable, and that ritual sites (in this case, cemeteries) were occupied by consecutive generations (Berenguer et al. 1988; Llagostera and Costa 1999). Therefore, we suggest that the established cultural phases do not fully represent the occupation of the oases as seen through cemetery use. Below, we present a chronological assessment of the occupation of the San Pedro de Atacama oases, stressing areas where the new dates reveal interesting shifts in our conception of Atacameño prehistory.

Contributions to an Understanding of the Atacameño Chronological Sequence

The new dates presented here mainly cover the period of intense occupation of the *ayllus*, and, as such, they contribute little to an understanding of the earliest occupations of the oases (Tilocalar phase, 1500–300 B.C.; Toconao phase, 300 B.C.–A.D. 100). Nevertheless, it should be noted that this is a time of increasing interest to archaeologists working in the area. Recent research has documented the existence of numerous sites from the Formative on the periphery of the oases. However, many of these remain unstudied (e.g., Agüero 2005). Most evidence suggests that the territory was sparsely populated during the Early and Middle Formative, expanding into village settlements only during the Late Formative, something supported by the few dates available for the period (Agüero and Uribe 2011; Núñez et al. 2010). Considering the documented sites, research has shown that the earliest settlements in the area of the oases, beyond small occupations in Poconche and Tchaputchayna (please see Agüero and Uribe 2011 for discussion of these sites, as well as a series of radiocarbon dates), are the village of Calar (Núñez 2005:168), some 15 km northeast of the core of the oases along the Vilama River, and a series of habitation sites in the Tulor *ayllu*, located in the far south near the mouth of the San Pedro River (Figure 1; Llagostera et al. 1984).

The dates available for Calar situate it in the Late Formative (2070 ± 70 B.P., cal A.D. 132–406, 95 percent probability [Orellana 1988–89:77]; cal A.D. 76–346, Agüero and Uribe 2011:71).[2] However, given its location outside the oases proper we do not discuss it further here. There are two dates available for Tulor 1, a large village settlement located in open areas on the west of the oases: a thermoluminescence date of 1920 ± 200 B.P. (Berenguer et al. 1988) and a ^{14}C date of 1850 ± 60 B.P. (cal A.D. 84–384, 95 percent probability; Llagostera et al. 1984). Both place the occupation during the Late Formative period or, locally, in the Sequitor phase (A.D. 100–400). The first occupation of the *ayllu* appears to be associated with the spread of corn and a sedentism based on horticulture along the Andean foothills. Some authors (e.g., Llagostera et al. 1984; Serracino 1976) argue for an earlier occupation that would predate the ceramic period. However, consolidation into settled village life comes with the growth of Tulor 1, which centralized habitation and may have helped organize the growing interregional interactions of the oases. Habitation at the *ayllu* was subsequently abandoned, likely due to an eastward shift in the course of the San Pedro River and the spread of the desert's sand dunes (Llagostera et al. 1984:114).

Our data indicate that Tulor is not the only early occupation of the oases. We obtained relatively early dates for Quitor and Solor *ayllu* cemeteries, favoring the idea that human expansion into the main *ayllus* began during the Late Formative (Table 1; Figure 3; Sequitor phase, A.D. 100–400). The dates from cemeteries and habitation sites in the Solor *ayllu* (Figure 3) proved to be among the most surprising results of this study. The general consensus holds that the *ayllu* was only occupied in the period of Regional Developments (after A.D. 1000), to the extent that the local phase is called the Solor phase (Berenguer et al. 1988). Our radiocarbon dates from the Solor 3 and Solor Vilama 3 cemeteries suggest a very different story, with an occupation beginning in the Late Formative and extending through the Middle period. Although we cannot be sure of its reliability, a radiocarbon date obtained decades ago from the habitation site of Solor 6 (Núñez 1976:70) coincides with our findings (1650 ± 150 B.P.; cal A.D. 83–689, 95 percent probability).

In contrast to what we see at Tulor, Solor and Quitor were not abandoned after their initial occupations and, instead, show long-term occupation. It is possible that the continuous occupation of Solor is a result of its ties to the Vilama River, which, unlike the San Pedro River, did not alter its course during the first millennium A.D. Similarly, Quitor is located inside the constricted river canyon, where shifts in the San Pedro River's course were minimal. Therefore, the more consistent source of water accessible from these *ayllus* may have allowed for successful long-term occupations of what continue to be some of the most fertile areas of the San Pedro oases, ideas espoused by numerous archaeologists working in the area (e.g., Llagostera and Costa 1999; Núñez 1995:35). It is not surprising that habitation would follow the changes in watercourses in this hyper-arid environment. Our new dates suggest that Solor, like Quitor, may be home to one of the more successful occupations of these oases.

While previous work (Llagostera and Costa 1999) suggested a sparse human occupation for the early Quitor phase (A.D. 400–750), our data show the occupation of a number of *ayllus* by this period. We support Llagostera and Costa's argument (1999) that occupation was strongest in the northern and central *ayllus*. Quitor is one of the only *ayllus* reflecting a continuous occupation from the Late Formative period through the period of Regional Developments. New radiocarbon dates range from cal A.D. 259 to cal A.D. 1485. The location of the sites near the entrance of the San Pedro River into the oases supports the consensus that these sites were strategically placed for better control of water (Llagostera and Costa 1999; Núñez 1995, 2007). This *ayllu's* long-term occupation is reflected in the use of cemeteries over extended periods of time, as well as the use of multiple cemeteries simultaneously. During the Middle period (A.D. 400–1000), the Quitor cemeteries included the graves of people who enjoyed considerable affluence, with objects from Tiwanaku as well as from the Aguada culture in northwest Argentina (Llagostera 2004). As in the rest of the oases, however, this affluence tapers off considerably at the end of the Middle period, which also witnesses the construction of the large Pukara de Quitor, a fortified settlement (Mostny 1949). The *pukara* rises up on a ridge on the southeast edge of the *ayllu* and consists of a series of stone-walled rooms and passageways that provided shelter and defense during local conflicts and foreign invasion. In sum, the Quitor *ayllu* reflects a successful long-term occupation of the northern oases.

The *ayllus* that comprise the central oases (Conde Duque, Larache, Sequitor, Solcor, Tchecar, and Yaye) seem to have shared a similar history of occupation. The earliest occupation indicated by our results for this area is in the Late Formative and early Middle periods (or Quitor phase), with dates from both the Sequitor and Larache *ayllus* falling in this period (Table 1; Figure 3). There may have been a consolidation and increase in population in this area during the Middle period, as a number of cemeteries in the central *ayllus* date to this time and continued in use into the subsequent period of Regional Developments (after A.D. 1000). Llagostera and Costa's (1999) study of settlement patterns also documented an increase in population during this time. Exemplary of this is the large cemetery of Tchecar Túmulo Sur, which includes evidence of some interaction with Tiwanaku and encompasses the subsequent period as well (cal A.D. 711–1206, 95 percent probability). Interestingly, these Middle period occupations also reflect intra-*ayllu* differences in their relationship with the altiplano polity. For example, two Solcor cemeteries vary significantly in the presence of traumatic injury, prestige goods, and objects with Tiwanaku iconography (Nado et al. 2012; Torres-Rouff 2011). We have argued elsewhere that this suggests the possibility that different cemeteries within an *ayllu* could have been used by different segments of the population, be they kinship groups or social classes (Torres-Rouff 2011). Similarly, the presence of Tiwanaku goods varies considerably between the cemeteries in different *ayllus*, with the sites of Larache Callejón and Solcor 3, for example, demonstrating a higher presence of foreign goods than seen at Tchecar Túmulo Sur.

In our consideration of the central oases, it is again worth highlighting the Solcor *ayllu,* which was occupied from the Middle period through the Regional Developments period, as it demonstrates one of the key results of our study: the oases were home to long-term occupations that stretched across a number of cultural phases. Considering the Middle period, bioarchaeological research on skeletal remains has suggested that the prosperity associated with this time resulted in an increase in quality of life for the individuals buried at the Solcor 3 cemetery (cal A.D. 433–1164, 95 percent probability [Costa et al. 2004; Neves and Costa 1998]). However, a recent study that incorporated some of the dates presented here for the Solcor *ayllu* suggested that the differences observed in quality of life might be due to social inequality during the Middle period, instead of differences between cultural phases (Hubbe et al. 2012). Similarly, other recent studies demonstrate that the Middle period was not a time of equally shared prosperity; the contemporary Solcor Plaza cemetery (cal A.D. 436–1201, 95 percent probability) showed much less grave wealth and significantly higher rates of trauma than Solcor 3 (Torres-Rouff 2011). Studies of cranial vault modification also reflect differences between the *ayllus* that suggest their role as discrete social units (Torres-Rouff 2007, 2008). These intra-*ayllu* differences indicate the existence of multiple levels of social organization in the oases, particularly in the Middle period.

South of the main oasis cluster, a series of ^{14}C dates also provide evidence of a long-standing occupation of Coyo (cal A.D. 557–1216). The two excavated cemeteries at Coyo seem to have been used simultaneously for a period of time (Figure 3). A radiocarbon date from a habitation site in this area, Coyo Aldea, also falls within this range (A.D. 650–995; Núñez 2005:170[3]). Despite the lack of substantive temporal differences between the two cemeteries, there are notable differences in the objects found in the mortuary context. Coyo Oriente presents an interesting case in the clear interaction with the Tiwanaku polity that is evident in the form of textiles as well as numerous snuff trays bearing Tiwanaku iconography (Oakland Rodman 1992; Torres 2004). Similarly, the individuals buried at the site had a preponderance of goods, including foreign objects and metals, while those laid to rest at the slightly later cemetery of Coyo 3 possessed few grave goods and bore no overt indications of wealth (Costa and Llagostera 1994). These materials suggest that the individuals interred in the Coyo Oriente cemetery had a closer tie with the highland polity than was the case for the individuals interred at Coyo 3. This stands as another example of the intra-*ayllu* variation that we also see in the Solcor cemeteries.

Also noteworthy in our sample is an evident expansion into what seem to have been previously unoccupied *ayllus* during the Coyo phase (A.D. 750–1000). The Yaye, Tchecar, and Catarpe *ayllus* demonstrate this trend most clearly (Figure 3). The occupation of these new *ayllus* is well established by the period of Regional Developments (Yaye phase, A.D. 1000–1250 and Solor phase, A.D. 1250–1470). This is of interest given that earlier work associated this population movement with the restructuring of local life after the collapse of Tiwanaku (Schiappacasse et al. 1989). However, it is possible that Tiwanaku's role in these large-scale changes within the *ayllus* has been given too much prominence by archaeologists. Our data would suggest that this movement began earlier than previously proposed (e.g., Llagostera and Costa 1999). Therefore, the occupation of these *ayllus* appears to have been a consequence of population increase during the Middle period and perhaps of better usage of available resources, instead of being solely a response to the river's shifts and the restructuring of hierarchies, as would be expected for the later period (Schiappacasse et al. 1989). These dates may also suggest that the loss of prosperity visible in some cemeteries may have its origins in social inequality in the preceding period.

None of our dates fall during the Inca period (Catarpe phase, A.D. 1470–1560). This may be due, in part, to archaeologists' focus on the Late Formative and Middle periods, a preference that resulted in fewer excavations of later settlements and burial places. Additionally, the brevity of the period of Inca influence in the region likely affects the availability of samples from this time. Nevertheless, despite earlier dates for the Catarpe cemeteries, several Inca artifacts were documented in the graves at Catarpe 1. Together, the discrepancy between these dates and the Inca arrival in the Atacama in the sixteenth century might suggest that objects from the Inca Empire, and consequently connections with the Inca polity, predate imperial expansion. This is consistent with arguments espoused for the Inca in the region, where foreign influence starts in the Solor phase and is administrative in nature (Núñez 1992). Upon arrival in the area, the Inca reused extant structures and built their administrative site (Catarpe Tambo) adjacent to a local settlement, benefiting from the existing constructions and networks (Alden et al. 2006; Lynch 1993); this use of preexisting social structures and infrastructure was characteristic of Inca imperial expansion.

Finally, it is worth mentioning the small Toconao oases, 38 km southeast along the edge of the Salar de Atacama (Figure 1). While considerably smaller in size as well as in their involvement in interregional exchange, Toconao formed part of the Atacameño network in prehistory with the material culture from Le Paige's excavations, reflecting its use during the Late Formative period (Le Paige 1972/1973; Orellana 1991). Coinciding with this, Toconao Oriente has a series of thermoluminescence dates that argue for early sedentism in these oases (Berenguer et al. 1988). However, our recent dates from a new excavation at Toconao Oriente (cal A.D. 1053–1408) suggest a later period of use. These few individuals were part of a salvage excavation conducted in the early 2000s by the staff of the *Museo Le Paige* and involved a previously unexcavated portion of the same expansive cemetery. Nevertheless, at this point there is insufficient information to determine whether the cemetery was used continuously for a millennium or simply employed in the Formative period and again in the Regional Developments period.

These patterns serve as an interesting parallel to the developments in San Pedro de Atacama by demonstrating that the mobility of populations within the San Pedro oases is not a hallmark of Atacameño culture, but rather a localized response. This can be seen not only in the San Pedro/Toconao distinctions, but also within the San Pedro oases in the Formative period contrasts between Tulor, which was occupied and then abandoned, and Solor and Quitor, both with long and continuous occupation.

Conclusion

The 53 AMS radiocarbon dates presented here show important population displacements across the San Pedro de Atacama oases since the time of their original occupation. In this conclusion, we highlight several themes—the crucial role of water in occupation, the use of multiple cemeteries concurrently, and the importance of a nuanced interpretation of absolute chronologies—that may revise our understanding of the local chronology and stress the significance of these new data for archaeological and bioarchaeological research.

Given that the Atacama is one of the driest deserts in the world, it should come as no surprise that the San Pedro River's volatility was a strong influence on the occupation of the oases. Previous research has documented the early occupation and subsequent abandonment of the Tulor villages, located near the southern extreme of the San Pedro River, and likely as a result of shifts in the volume of water reaching the area (Llagostera et al. 1984). In contrast, our data show the persistence of occupation in the Solor *ayllu*, which receives its water from the more reliable Vilama River, after the abandonment of Tulor. Also tied to water flow, oasis populations generally moved northward throughout the precolumbian period. Specifically, our data show that movement out of the central cluster of oases began earlier than previously thought, as habitation sites moved closer to the river itself before the Regional Developments period. The occupation timeline established by our data from the Yaye cemeteries and their geographic location offer the clearest example of this phenomenon (Table 1). Also during the Regional Developments period (and even before), we see the construction of habitation sites and cemeteries in the far northern Catarpe oasis. The Catarpe *ayllu* seems to have witnessed a surge in population in the Regional Developments period, and its strategic location near the San Pedro River's entrance to the oases likely influenced the Inca's decision to settle there. The Inca practice of employing local elites and settlements is documented in archaeological work both here and elsewhere in the empire.

A second significant point gleaned from this analysis arises when we note the number of contemporary cemeteries in use within any given *ayllu* and in concert with this, the long use life of many cemeteries. It is possible that the resolution necessary to explore intra-*ayllu* and intra-cemetery nuances cannot be obtained from the archaeological data that resulted from the more casual excavations of Le Paige and could be studied more successfully by focusing on the five scientific cemetery excavations conducted in later decades (Casa Parroquial, Coyo 3, Solcor 3, Quitor 6 Tardío, and Toconao Oriente). As Stovel (2008) has argued, different communities may be co-occupying areas, and social ties may be maintained over long periods. While it is possible that different ethnic groups or migratory populations could employ these different burial grounds, the data collected thus far via bioarchaeological and biogeochemical analyses do not support this idea and, rather, suggest that some kind of internal differentiation is responsible for these distinctions (Knudson 2007; Torres-Rouff 2008, 2011). Given the documented rates of violence at many of these sites, distinct cemetery use related to internal conflicts stands as another possible influence on internal dynamics (Lessa and Mendonça de Souza 2004, 2006, 2007; Torres-Rouff 2011; Torres-Rouff and Costa 2006). Beyond simple geography, the concurrent occupation of multiple *ayllus* suggests that more sophisticated analyses need to be engaged when studying human remains and artifacts from these areas.

Exploring the details of social organization in the oases is a way to get at this potential diversity in inter- and intra-ayllu relationships. For example, factors such as status may play a role in determining the composition of a cemetery community. The two contemporary cemeteries in use during the Middle period at Solcor seem to reflect social distinctions with, for example, differential access to prestige goods (Nado et al. 2012; Torres-Rouff 2011). This is only one approach to what is likely to be a complex mesh of intersecting identities that are represented in the grave. Interestingly, it would be worth considering the possibility that spatial distribution within a cemetery also reflects social or temporal distinctions. As such, studies that explore this segregation of the dead merit further exploration.

Finally, stepping away from the use of a ceramic typology has allowed for a more refined intra-ayllu perspective. This situation is perhaps compounded by the fact that the ceramic traditions in San Pedro de Atacama are conservative and similar styles persist, particularly in the mortuary context, for centuries (Stovel 2001). This consistency is something that lessens their value for establishing fine distinctions over time. Clearly, the sequence presented by others presents a picture that is accurate in its broad strokes, yet misses some interesting nuances of the oases' occupational history. Framing chronological studies solely around ceramics and other forms of cultural seriation does not offer the precision available with analyses of individuals themselves. Moreover, the extant local cultural phases are clearly tied to more general trends in Andean prehistory and do not necessarily reflect diversity within periods. In fact, these cultural phases, particularly with the association of time periods with certain *ayllus* (Berenguer et al. 1988:345), serve to mask intra-*ayllu* diversity in issues such as interregional interaction and social standing that are only visible with a closer perspective (Knudson and Torres-Rouff 2009; Torres-Rouff 2008, 2011; Varela and Cocilovo 2009). A standardized vision has oversimplified the complex human processes employed in occupying marginal spaces over millennia, processes that can be made visible through careful archaeological examinations. An archaeological analysis that unites these dates with mortuary assemblages may allow for the creation of cultural phases that are of more use in archaeological and bioarchaeological interpretations.

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Data Availability Statement. A complete digital copy of the data presented in this article (raw and calibrated C14 dates) is available upon request to the authors: ctorres-rouff@umerced.edu or hubbe.1@osu.edu

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Notes

1. Bone collagen extraction procedures at Beta Analytic followed their standard pretreatment (acid-alkali-acid) protocols (Beta Analytic 2012). Samples were tested for friability, washed with deionized water, cleaned and crushed, followed by an acid/base treatment. Dilute, cold HCl was repeatedly applied until all bone apatite was removed and the collagen was then cleaned. Samples in good condition, including all the ones discussed here, were subsequently treated with sodium hydroxide (NaOH) to ensure the absence of secondary organic acids.

Bone collagen extraction procedures at the NSF Arizona AMS facility made use of a semi-automated acid-base-acid system. This system, which is a modified version of the Law and Hedges-designed apparatus, treats samples with a predetermined sequence of acid (HCl), base (NaOH), and water washes in order to remove bone mineral and post-depositional contaminants (University of Arizona AMS Laboratory 2013).

In all cases the extracted collagen product was subsequently gelatinized and freeze-dried prior to combustion, graphitization, and radiocarbon measurements that followed individual laboratory procedures. (Beta Analytic 2012; University of Arizona AMS Laboratory 2013.)

2. Agüero and Uribe (2011) do not provide a radiocarbon age. We also note that it is likely that their date was calibrated using the northern hemisphere curve and should not be directly compared to the other dates presented here.

3. The author did not provide the radiocarbon age.

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