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THE CHRONOLOGY OF SETTLEMENTS WITH PRE-INCA AND INCA OCCUPATIONS SUPERIMPOSED: THE CASE OF PUCARÁ DE TILCARA (HUMAHUACA GORGE, ARGENTINA)*

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The region of the Central and South Andes was, in about the ninth and 15th centuries AD, the stage for the development of political systems tending towards demographic centralization in villages with defensive structures, known as Pucará. The chronological accuracy for these phenomena still remains uncertain, mainly because it involves intervals of long and superimposed occupations, masked by the Inca domination. Thus, this paper analyses the history of the occupation at Pucará de Tilcara, one of the biggest populated centres of the Humahuaca Gorge (Quebrada de Humahuaca, Argentina). Twenty-five radiocarbon dates are critically evaluated to judge its reliability. The Bayesian statistics show that all the dated spaces were used on a long-term basis. The most ancient signs are in the middens and relate at least to the 10th century AD, and the occupation of the housing areas could be calculated to the 13th and 16th centuries. A phase of higher intensity of occupation is observed during the Inca period. This redefinition of this site occupation shows the need to statistically analyse the dates in order to differentiate the phases of occupation.

KEYWORDS: ANDEAN AREA, NORTHWESTERN ARGENTINA, RADIOCARBON, BAYESIAN STATISTICS, PALIMPSEST, LATE INTERMEDIATE OR REGIONAL DEVELOPMENT PERIOD, INCA PERIOD

INTRODUCTION

Pucará de Tilcara is one of the most emblematic archaeological sites in the north of Argentina, which has been included on the list of UNESCO's World Heritage Sites since 2003. From the first interventions in 1908, this place has yielded a wide range of archaeological materials, and they have not only allowed us to characterize the agropastoral societies that inhabited the Humahuaca Gorge (*Quebrada de Humahuaca*), but they have also provided information about the chronology of the region. As with other *pukaras*, from its traditional framework, it was temporally located in the interval that starts at the end of the first millennium AD up to the moment of Hispanic–aboriginal contact. Nonetheless, our research allowed us to re-evalute its positioning and to reflect on the reliability of the radiocarbon results, according to the methodology of the applied analysis. This work is oriented to show the set of datings available for the Pucará, in order to make progress in the history of its occupation, and at the same time to yield new elements that enable a re-interpretation of the regional chronological framework.

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The topographic features of the Humahuaca Gorge, a semi-arid valley stretching between 1800 and 2800 m asl, had facilitated its functioning as a natural corridor linking nearby desert-like high-altitude regions (the Puna) to lower-altitude humid valleys (the Yungas) located to the east, in what is today the province of Jujuy (Albeck 1992). This easy access to the adjacent regions and the availability of the necessary resources for survival had allowed the settlement of human groups on a permanent basis since early times, around 10 000 BC. Although the archaeological records account for the whole sequence of occupation, they reflect to a greater extent the first centuries of the second millennium AD, up to the arrival of the Spanish. During this time interval, complex productive societies with an important technological development were located in the hills (Nielsen 2007). Due to the archaeological appreciation, these settlements were defined as *pukara*. Although they present defensive features, such as the location in an elevated landform, from which a wide field of view of the surrounding landscape could be achieved, this location at altitude could be due to religious or supernatural rituals, because hills were considered the home of ancestors (Arkush and Stanish 2005; Tarragó 2011).

Many of these villages were occupied by the Incas when, in the 15th century AD, they annexed the region to *Tawantinsuyu*. This domination marked a milestone in the regional history, because it implied large sociopolitical and economic transformations. It also produced the reconfiguration of the local landscape due to the construction of the *tampus*,[1] the remodelling and foundation of settlements, the expansion of productive spaces, the construction of road networks and the formation of sacred and ceremonial spaces. In Pucará de Tilcara, the installation of an administrative control centre over a pre-existing population was carried out. From the ethno-historical sources and archaeological research, it can be deduced that this location worked as the capital of the Inca province, or *wamani*, of Humahuaca (González 1982; Williams 2004; Otero 2013). The strategic location of the site in the centre of a natural corridor must have been very important for the Inca State to control the region.

With an area of 17.5 ha, this site is one of the largest in the region. It consists of a conglomerate village located 80 m over the river (Fig. S1). Its higher part reaches 2500 m asl. The configuration of the space in Pucará shows evidence of planning in the building trace (Fig. 1). The burial areas together with the farmyards are linked to the main access roads and they are segregated from the dwellings and from handicraft workplaces. Between these spaces, which are composed of a minimum of 580 stone structures of different shapes and sizes, several squares and an Inca *kancha* used as a ceremonial building were identified (Hyslop 1992). The village was one of the main productive points in the region, with more than 50 handicraft workshops installed for the manufacturing of ornamental goods in shell, metal and rocks such as onyx, limestone, silica and alabaster (Krapovickas 1958–9; Otero 2013, 2015).

In Pucará de Tilcara, we can recognize long-term occupation with at least one pre-Inca stage and one Inca stage (Fig. S2). Nonetheless, the Inca occupation was so important that it altered the configuration of the archaeological record, hindering the differentiation of local and Inca components. Thus, the objective of this work is to contribute to this differentiation, through the interrelation of the stratigraphic data, the association of artefacts and the radiocarbon dates.

THE RADIOCARBON DATINGS OF PUCARÁ DE TILCARA

The 25 samples (Table 1) were collected from different sectors of Pucará (Tarragó 1992; Tarragó and Albeck 1997; Otero 2013), with the intention of determining if there were different stages of

[1] *Tampus* functioned like shelters and storage centres, and were distributed along the Inca Trail every 20 or 30 km, roughly one day's journey on foot (Hyslop 1992).

Figure 1 *A plan of Pucará de Tilcara (after Zaburlín 2006; the mapping of the north and south slopes was carried out by Lanzelotti* et al. *2012).*

occupation at this site and, at the same time, the sequence of its extension. Ten belong to Dwelling 1 (Fig. 2), which is placed on two levels, and consists of four rooms around a yard, with an excavated surface of 127 m^2. The analysis of the material allowed us to identify some activities related mainly to the production of pottery and metallurgy (Otero and Cremonte 2014). These activities developed simultaneously as a multi-craft type of production (*sensu* Shimada 2007), together with other daily activities and rituals related to mortuary practices and religious beliefs. This defines the dwelling as a house–workshop. After that occupation, Dwelling 1 was used as a burial area for 25 adults and sub-adults (Tarragó 1992; Otero 2013). Seven datings were made on samples from room and yard floors, and three datings on burials, to determine the phase of occupation and to corroborate the series of burial events.

The two samples of Structure 2.1 (#18 – LP 247 and #5 – LP 2191) correspond to small charcoal pieces collected from two cooking fires related to faunal remains, local late and Inca ceramic and elements for pottery elaboration. In Structure 2.2, camelid bones were processed (#4 – LP 2231 and #3 – LP 2240), which were stuck into the thick floor of the yard for the purpose of food processing, and grinding of copper mineral, clay pigments and pottery. Also from camelid bones, the north quadrant floor of the central yard, also called Structure 3.1 (#16 – AA89445), was dated, as was the floor of Structure N4 (#6 – LP 2467). Dating #21 – LP 536 was made on

Table 1 *The list of datings from Pucará de Tilcara, using the ShCal 13 calibration curve (Hogg* et al. *2013) and the OxCal v4.2 software (Bronk Ramsey 2009)*

Number (#)	*Laboratory ID*	*Dating technique*	*Year of measurement*	*Sector*	*Context*	*Material*	$\delta^{13}C$	^{14}C *age* (*BP*)	*Calibrated dates* AD (*68.2% probability*)	*Calibrated dates* AD (*95.4% probability*)
1	LP 2433	Radiometric	2010	B	E 2 C 1	Charcoal		380 ± 50	1482 (19.3%) 1516 1540 (48.9%) 1626	1456 (95.4%) 1641
2	LP 2448	Radiometric	2011	V	E 3	Charred sediment		440 ± 40	1446 (56.5%) 1501 1596 (11.7%) 1612	1431 (65.8%) 1515 1540 (29.6%) 1625
3	LP 2240	Radiometric	2009	Dwelling 1	R 2.2 C NO Upper layer	Camelid bone		450 ± 40	1441 (60.7%) 1499 1598 (7.5%) 1610	1424 (72.3%) 1512 1547 (23.1%) 1624
4	LP 2231	Radiometric	2009	Dwelling 1	R 2.2 C NO Lower layer	Camelid bone		450 ± 50	1436 (54.7%) 1504 1591 (13.5%) 1615	1419 (65.3%) 1520 1537 (30.1%) 1626
5	LP 2191	Radiometric	2009	Dwelling 1	R 2.1 C SE	Charcoal		450 ± 60	1430 (51.1%) 1508 1585 (17.1%) 1619	1417 (95.4%) 1628
6	LP 2467	Radiometric	2011	Dwelling 1	C N4	Camelid bone		470 ± 50	1425 (65.1%) 1498 1600 (3.1%) 1606	1405 (76.2%) 1513 1545 (19.2%) 1624
7	AA88342	AMS	2010	Dwelling 1	Burial 5	Human bone	–15.6	510 ± 46	1414 (68.2%) 1455	1395 (94.3%) 1499 1599 (1.1%) 1609
8	AA88340	AMS	2010	Dwelling 1	Burial 1	Charcoal	–22.6	512 ± 41	1418 (68.2%) 1452	1397 (95.4%) 1484
9	LP 2967	Radiometric	2014	Midden 2	Unit 2/3, level 13, #257	Camelid bone		520 ± 40	1415 (68.2%) 1450	1396 (95.4%) 1477
10	AA88339	AMS	2010	Z	E 4	Human bone	–11.1	523 ± 47	1411 (68.2%) 1451	1327 (1.3%) 1340 1390 (94.1%) 1495
11	AA88338	AMS	2010	B	E 2 C 2	Camelid bone	–19.3	527 ± 47	1409 (68.2%) 1449	1325 (1.9%) 1342 1390 (93.5%) 1485
12	AA88341	AMS	2010	Dwelling 1	Burial 1	Charcoal	–23.7	561 ± 42	1400 (68.2%) 1438	1323 (7.6%) 1346 1388 (87.8%) 1452
13	AA89444	AMS	2010	A	E 1	Camelid bone	–19.7	566 ± 52	1392 (68.2%) 1445	1312 (17.9%) 1359 1380 (77.5%) 1458
14	LP 2965	Radiometric	2014	Midden 2	Unit 2/5, level 18, #258	Camelid bone		570 ± 50	1391 (68.2%) 1444	1314 (18.6%) 1358 1380 (76.8%) 1455
15	LP 546	Radiometric	1994	Midden 1		Charcoal		610 ± 60	1317 (30.7%) 1354 1383 (37.5%) 1426	1297 (95.4%) 1442

(*Continues*)

Table 1 *(Continued)*

Number (#)	*Laboratory ID*	*Dating technique*	*Year of measurement*	*Sector*	*Context*	*Material*	$\delta^{13}C$	^{14}C *age* (*BP*)	*Calibrated dates* AD (*68.2% probability*)	*Calibrated dates* AD (*95.4% probability*)
16	AA89445	AMS	2010	Dwelling 1	R 3.1 C N1	Camelid bone	–18.4	635 ± 52	1311 (43.2%) 1359 1380 (25.0%) 1409	1293 (95.4%) 1425
17	LP 544	Radiometric	1994	Midden 1		Charcoal		770 ± 70	1225 (57.6%) 1310 1360 (10.6%) 1379	1180 (95.4%) 1395
18	LP 247	Radiometric	1991	Dwelling 1	R 2.1 C NE	Charcoal		800 ± 50	1224 (68.2%) 1286	1182 (90.6%) 1314 1358 (4.8%) 1380
19	LP 2960	Radiometric	2014	Midden 2	Unit 1/0, C2, level 100–110, #145	Camelid bone		800 ± 50	1224 (68.2%) 1286	1182 (90.6%) 1314 1358 (4.8%) 1380
20	LP 485	Radiometric	1994	Midden 1		Charcoal		860 ± 90	1070 (2.0%) 1076 1148 (66.2%) 1286	1027 (92.8%) 1313 1358 (2.5%) 1380
21	LP 536	Radiometric	1994	Dwelling 1	R 3.3	Charcoal		910 ± 70	1048 (15.1%) 1083 1139 (49.0%) 1230 1250 (4.0%) 1261	1033 (95.4%) 1273
22	LP 532	Radiometric	1994	Midden 2	Unit 1/0, C2, level 100–110, #145	Charcoal		930 ± 70	1046 (18.8%) 1086 1108 (4.4%) 1120 1129 (44.9%) 1220	1026 (95.4%) 1268
23	LP 486	Radiometric	1994	Midden 1		Charcoal		950 ± 80	1044 (68.2%) 1201	995 (1.5%) 1007 1015 (93.9%) 1269
24	LP 531	Radiometric	1994	Midden 1		Charcoal		1020 ± 80	995 (4.4%) 1007 1015 (63.8%) 1153	894 (4.7%) 936 954 (90.7%) 1220
25	LP 466	Radiometric	1993	Midden 1		Charcoal		1160 ± 80	790 (3.7%) 805 857 (64.5%) 1020	685 (3.9%) 738 762 (89.5%) 1046 1089 (1.3%) 1110 1119 (0.7%) 1130

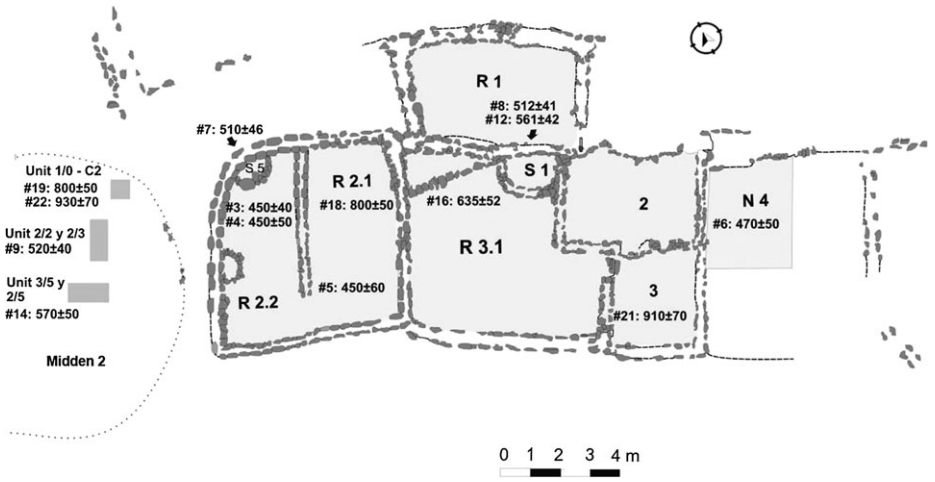

Figure 2 *A plan of Dwelling 1, with the locations of the datings.*

charcoal collected from a hearth located within Structure 3.3, mainly used for melting and shaping metal pieces and many instruments and blocks of clay, possibly for the purpose of elaborating pottery.

The three remaining datings of this house are linked to the burials. Fragments of an adult woman's heel were analysed, left unburied in Structure 2.2 (#7 – AA88342). To bury this woman, a small stone chamber had been constructed, breaking the room floor. The other two datings of graves (#8 – AA883403 and #12 – AA88341) were made on carbon samples collected on ash lenses that used to cover human remains kept in a burial chamber that was built in the central yard (Fig. 2). This chamber, which was also built on the yard floor, served as an ossuary, keeping not only a unique primary burial but also the remains of 20 people who were secondarily buried, in different events (Adaro 2002).

Further excavations were made in two village middens. Midden 1, measuring 5×7 m, located on the upper edge of the south slope (Fig. 1), had been excavated up to 4 m deep by earlier researchers (Casanova *et al*. 1976). In 1992, the exposed profiles were re-studied and charcoal samples with stratigraphic control were taken. Six radiocarbon determinations were conducted (#15 – LP 546, #17 – LP 544, #20 – LP 485, #23 – LP 486, #24 – LP 531 and #25 – LP 466). The dates obtained from the profile correlate with the stratigraphic levels of the neighbouring grids, where local ceramic assemblages decorated in black on red were found.

Midden 2, next to Dwelling 1, has a surface of 96 m^2, and 5 m^2 of the midden was excavated. For a similar stratigraphic level, two datings were made, #22 – LP 532 from charcoal and #19 – LP 2960 from camelid bones. At deeper levels, many pottery and faunal remains were found. From these two levels, two animal bone samples were dated (#14 – LP 2965 and #9 – LP 2967). The pottery material associated with Midden 2 corresponds to local Inca styles, assigned to more recent phases than the radiocarbon results.

Other sectors of the Pucará have fewer datings, because they are part of a recently started research project (Otero 2013). In sector A, a portion of the yard called Structure 1, to which three facilities are attached, was excavated. Among them, a fragment was selected for dating (#13 – AA89444).

In sector B, located on the south-west slope of the site, Structure 2 was excavated. It was characterized as a handicraft workshop, because travertine carvings and tools for the elaboration of

lithic handicrafts were found. Likewise, close to a hearth, grinding tools and pottery belonging to the late local style and Humahuaca Inca N/R used for the processing and serving of food were found. Two datings were made: #1 – LP 2433 from charcoal recovered from a discard well, and #11 – AA88338) from a camelid bone sample on the room floor.

In sector V, we took samples from an exposed profile of a road built in 1955. In this case, carbonaceous sediment was dated (#2 – LP 2448). Among the related materials, pottery in both the late style and the local Inca style, and many faunal remains, were recovered. Finally in sector Z, close to the summit. a secondary burial of three individuals was excavated (Rivolta and Ceruti 1996). From the bones of one of them, dating #10 – AA88339 was obtained.

THE BAYESIAN APPROACH

Bayesian statistic modelling was used for the analysis of the radiocarbon data from Pucará de Tilcara. Although radiocarbon dating has been common in the Humahuaca region for many decades, statistical analysis of the chronological information had been applied only once (Nielsen 2007). To evaluate the duration and order of events a uniform-phase model (Buck *et al*. 1996) was used, assuming that the whole set of phenomena in a phase has the same probability of occurrence at every point in time. Also, the sum of probabilities of the calibrated datings and the Span and Boundaries parameters were calculated. The analysis has been performed using the OxCal v4.2 software (Bronk Ramsey 2009) and the SHCal13 Southern Hemisphere calibration curve (Hogg *et al*. 2013) (see Fig. 3). Every generated model consists of *phases*—or groups of dates without a specific internal order—defined by their starting and final *boundaries*, ordered into *sequences*. The agreement between the model and the data is evaluated using the A_{model} index, with a minimum acceptable value of 60% (Bronk Ramsey 2009).

The sum of probabilities was calculated in two ways: first, with the SUM function directly for the data set, resulting in an addition of the probabilities of all datings into the same distribution; and, second, with the SUM function defined in a uniform-phase model, for which the resulting distribution was modelled by Bayesian statistics. This second option is more significant according to Bayliss *et al*. (2009), although from our perspective the observation of the two sums together is more useful. The first one conveys the maximum range of possible years for the duration of the phenomena, even though it is distorted due to the inaccuracy of the datings, while the second sum represents a highly probable range of years for that duration, which is derived from a simulation (Greco 2014).

To discuss the calibrated dates and the statistical parameters, ranges of 95% confidence intervals were used, although to simplify we sometimes refer to point estimates. Research has shown that there is no way to correctly estimate the true age of a radiocarbon date with a point estimate (Michczynski 2007), although several authors agree that the mode—observed as the area of maximum probability in the density function—would be acceptable (Needham *et al*. 1997; Zeidler *et al*. 1998; Michczynski 2007; Alberti 2013).

In Pucará de Tilcara as a whole, there is not enough *a priori* information to distinguish more than one phase; therefore, one of the assumptions is that all dates belong to the same phase. Although we assume that this study is about a long-term occupation, where there was at least one moment prior to the arrival of the Incas and one other one after that point in time, in practice it is not possible to distinguish more than one component in the excavations. On the other hand, in Dwelling 1, from stratigraphic overlapping, two phases of occupation could be differentiated: one corresponding to the occupation floor and handicraft activities and a subsequent other phase corresponding to the burials.

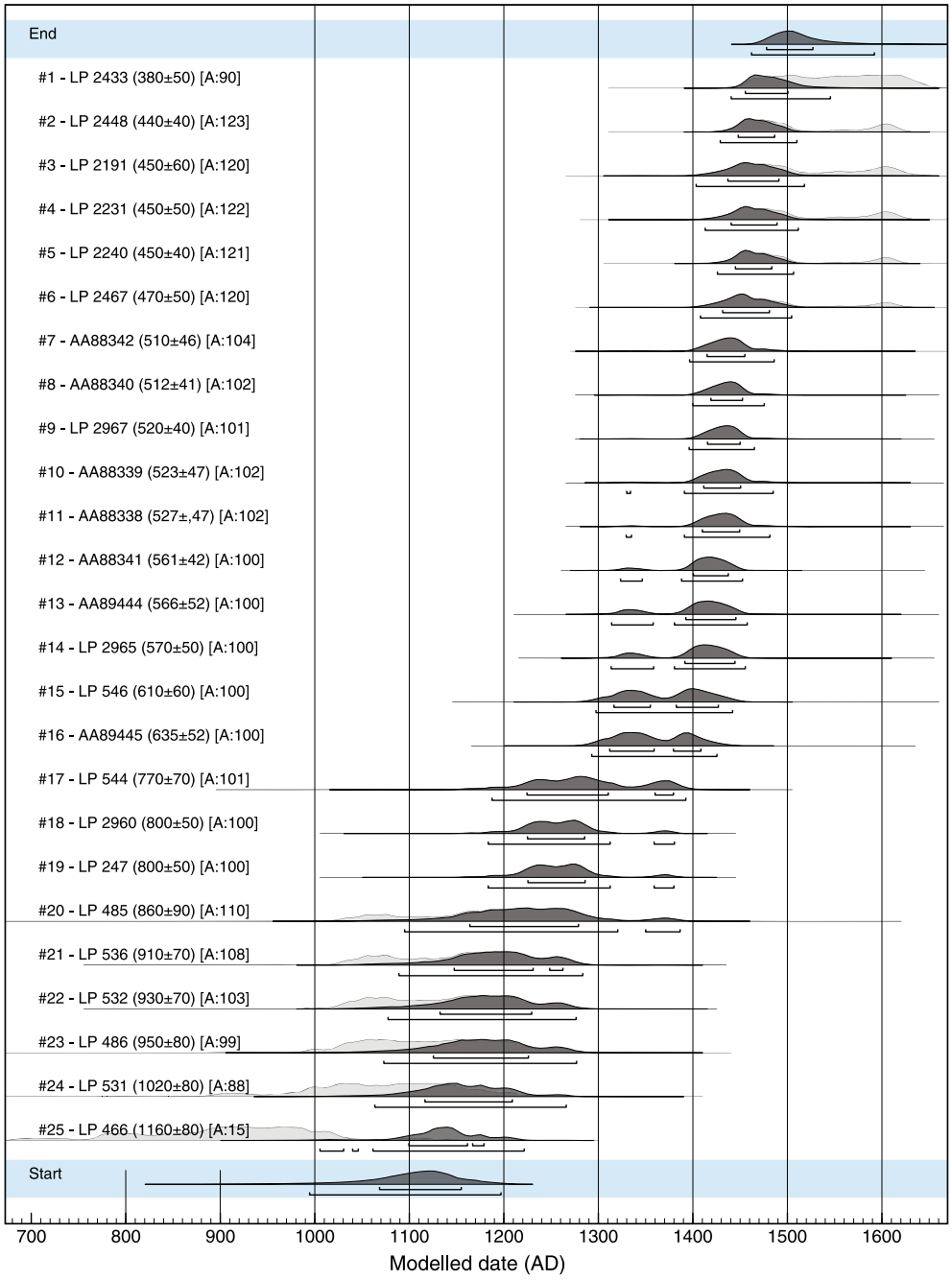

Figure 3 *The datings of Pucará de Tilcara, employing a single-phase model (A_{model} = 83.9%, $A_{overall}$ = 83.4%) with the ShCal13 calibration curve (Hogg* et al. *2013) and using the OxCal v4.2 software (Bronk Ramsey 2009).*

RESULTS

As this study is about a complex village, we started by evaluating all the dating series, using the sum of probabilities with and without Bayesian modelling, according to the provenance (Fig. 4). It can be noted that in every curve—except for the one for Midden 1, which will be discussed later—the maximum densities are at around AD 1400–1500, which means that all the village sectors were functioning at that point in time. However, the redundancy in the occupation and in the cleaning practices in the houses would leave traces of the latest occupation or of the averaged remnants of a long period of occupation, which means a *true palimpsest* (*sensu* Bailey 2007). For this reason, the beginnings of the settlement are difficult to establish from radiocarbon datings of domestic or handicraft cooking fires, but the datings will show the last points in time.

With regard to the final picture, it can be observed that the longer apparent persistence was in sectors B and V. Those spaces still have very few datings for consideration of a significant tendency, but they are close to the high terrace of Pucará, where Hispanic–aboriginal and early colonial artefacts were recovered (Otero 2013). In all the series, the high probability densities do not in general exceed the year AD 1500. It is feasible that this is showing a period for those years when the site was unoccupied; however, we cannot conclusively sustain this affirmation, because there is enough material evidence of continuity in certain spaces in early colonial times. The historical chronicles show that the current town of Tilcara, 1000 m north of Pucará, was established at the end of the 16th century AD (Sánchez 1996).

Another pattern detected in the data set is a separation into two groups based on ages, which correlates with the year of measurement (Pearson correlation coefficient, $r = -0.87$). Except for datings #16 and #19, those undertaken lately are more modern than those of the period from 1991 to 1994. Although we cannot effectively know if this is related to any change in the measurement techniques or to inter-laboratory variation (Figini 2007), this is a topic that deserves

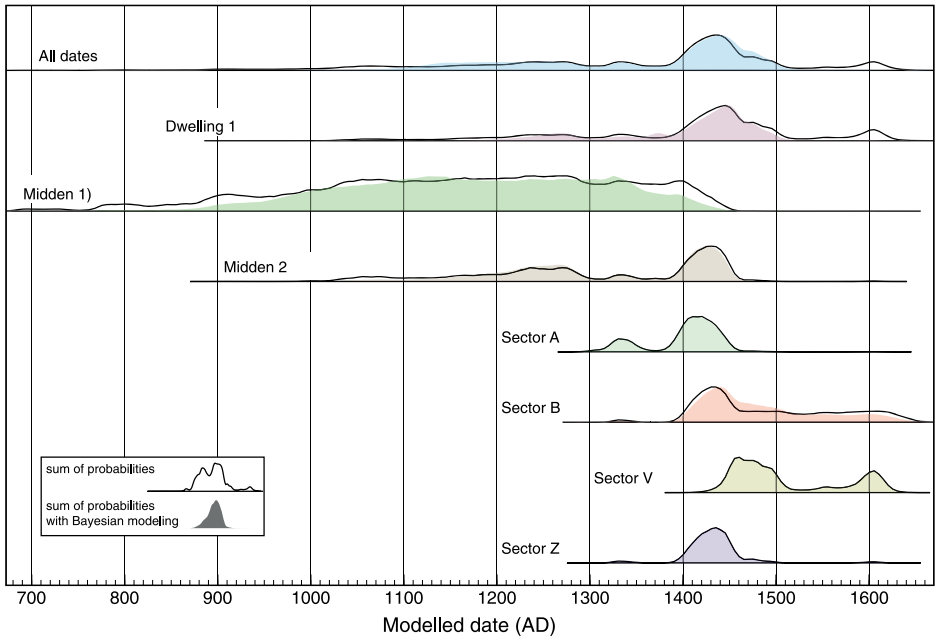

Figure 4 *The sum of probabilities by village sectors.*

further research. Current techniques might provide more accurate results in relation to those of a few decades ago, which could determine the temporal shift to the present.

On the other hand, most of the ancient dates are represented in the middens. The oldest dating of the series (#25) is comparable to those obtained at sites of the previous formative period (Rivolta and Albeck 1992; Rivolta 1996; Tarragó and Albeck 1997; Nielsen 2007; Otero and Rivolta 2015). Also, this dating is an outlier with regard to the set in the Bayesian model, and it should be revised with new samples from this context. These midden piles can reveal previous events that have remained buried by the more recent ones, in contrast with what is distinguished from the houses and workshops. This is a *cumulative palimpsest* (*sensu* Bailey 2007), where the mixture makes it difficult to separate the original components and it is only possible to observe averaged tendencies.

There is also evidence of this antiquity in Midden 2, although it might have started to be used some centuries later than Midden 1 and the biggest density of probabilities is found close to the 15th century, in agreement with the material evidence of a large quantity of Inca material, which is found mixed equally with the local material.

To these general understandings about the distribution of the calibrated probabilities, we can give details of more accurate models to estimate the events of interest, in the cases where we have enough information. Starting with the middens, the two cases are complex slope deposits, whose formation processes have not yet been studied. Due to the type of excavation and its objectives, which combined the study of profiles and the correlation of adjacent grids, and because we do not participate in the fieldwork, we cannot find any evidence to separate the events. In both cases an apparent reversal could be considered, because the deeper levels gave later results than the upper levels. This situation is related to the type of formation of the middens, which is difficult to recognize in the fieldwork. Thus, the chronological model that better represents Middens 1 and 2 would be a single uniform phase.

For Midden 1 (Fig. S3), the Bayesian analysis allows us to estimate that the starting boundary falls somewhere in the 95% confidence range AD 593–1150, but a mode in AD 950 makes us think that the beginning was from the 10th century onwards. The timespan of use of the midden can be calculated to between 169 and 550 years (95.4% probability), with a mode of 360 years of use before the end boundary in AD 1286–1706, with the mode at around AD 1400. Because in this midden there is plenty of typologically Inca debris, this must be related to an early stage in the imperial presence. The wide range calculated in the area, of 95.4%, is influenced by the error of those datings (*c*. ±60–90 years), all of which were performed using the conventional technique; for this reason, a better option is to take into account the areas of maximum probability summarized by the modal date.

In Midden 2 (Fig. S4), the model allows us to estimate the beginning of the accumulation in the 95% confidence range AD 615–1277, with the mode at AD 1170. The end also has a wide distribution of probabilities, between AD 1399 and AD 1966, with the mode at AD 1450. Taking those values and the presence of Inca-related pottery fragments into account, the end of the use of this midden would also be at an early time in the Inca period.

To formally assess the temporal relationship between the middens, we used the DIFFERENCE query of OxCal, which allows us to estimate the difference in years between the Start and End boundaries calculated in the preceding two models (Fig. S5). If we consider the modal values, Midden 1 is likely to have been started about 200 years before Midden 2, and is likely to have fallen into disuse about 100 years before Midden 2.

In the case of Dwelling 1, the 10 radiocarbon datings apparently determine a temporal range with a probability of occurrence between the 12th and 16th centuries, which makes us think that

the house–workshop involved many socially linked generations, and we suppose that there was at least a pre-Inca and a post-Inca point in time. However, the stratigraphic analysis of the recovered objects did not allow us to distinguish more than one component, so it would be hard to select some dates and to assign them to one point in time or another.

The only recorded case of stratigraphic overlapping is with the burials that are subsequent to the floor, as they are dug or deposited above it. This allowed us to design a model with two sequential phases (Fig. S6); the first one related to the floor, and the second one to the burials, also supposing that there is a gap between the one phase and the other. With an A_{model} index of 26%, the model is not acceptable, because the burials gave an even earlier value than for the floor, which is contrary to the stratigraphic evidence. This suggests a number of alternative interpretations. On the one hand, the datings are still too imprecise to distinguish events that were relatively close in time, but on the other hand the possibility also exists that the people buried there were the ancestors of the final inhabitants of the house–workshop, who were re-buried when it was abandoned. This is also justified by the fact that one of the burials corresponds to an ossuary.

Thus, to calculate the duration of that occupation in more accurate terms, a single uniform-phase model was built, leaving aside the dates from the burials (Fig. S7). The model enables us to calculate the probabilities of the start and the end of the occupation of the house–workshop. The start could be referred into two probability ranges, AD 944–1286 (94.8%) and AD 1353–1370 (0.6%), with the mode at around AD 1200. For the same reasons as for Midden 1, the mode is reasonable for the estimation of the beginning of the occupation of Dwelling 1 at a time prior to the arrival of the Incas.

This dated occupation—the final phase of the house—lasted between 176 and 468 years, according to the Span calculation, with a mode of 250 years. It would have been abandoned between AD 1452 and 1759 (95.4% probability) with the mode at around AD 1500, dates that correlate well with the historical chronicles for the final interval in the Inca conquest of the region.

Finally, referring to the duration of the revealed processes in Pucará (Fig. S8), it was calculated that each series has a duration of two to four centuries. In the case of sectors A, B, V and Z, which have one or two datings each, we were still unable to make a calculation using the Span command. Longer durations are recorded in the middens than in the housing area. Midden 1 has a duration as long as the village as a whole. Midden 2, on the other hand, is very similar to Dwelling 1, which is understandable because of its proximity to the housing area, with the possibility that it was the midden for Dwelling 1 and other neighbouring dwellings.

The total duration of the process dated in Pucará is in the 95% confidence range of 277–507 years, with the mode at around 370 years. We consider this to be a minimum date for the duration, because as we have already said, there is a superposition of occupations with the loss of previous information, and also there are some very late recorded events, from Hispanic–aboriginal times, which were not dated using radiocarbon.

DISCUSSION AND CONCLUSIONS

In this work, we have presented 25 datings made in Pucará de Tilcara over the past 25 years, considering their contexts and associated materials. Given the relation of the stratigraphic information and the typology of the objects, we could state differing chronological hypotheses, which were evaluated using Bayesian statistics.

From this analysis, we can state that the occupations in Pucará de Tilcara were continuous during the later time periods, going through two situations of impact with the Inca and Hispanic

conquests. The results show that all the dated spaces were used on a long-term basis. The most ancient signs are in the middens and relate to at least the 10th century AD, and the occupation of the housing areas could be calculated to the 13th and 16th centuries. A phase of higher intensity of occupation is observed during the Inca period, where the highest densities of the calibrated probabilities are concentrated.

Signs of early occupations were only detected on the lower south slope, as in the cases of Dwelling 1 and Midden 2, located in the south-west part, and Midden 1, located in the upper south part. In sector A, Structure 1, located on the south slope, could be also considered. The range of dates obtained there (#13) begins at the end of the 13th century AD. Up to now, the other sectors have been dated to points in time closer to the Inca period. One possible scenario is that before reaching its shape as a conglomerate, the Pucará de Tilcara started as a small set of houses on the lower slopes, coinciding with the model of 'domestic terraces' (Rivolta 2005). We still need to discuss, on the basis of more information, when the enlargement of the site took place, until it attained its shape as a conglomerate. It is difficult to deduce the organization of the spaces in those centuries, because the imperial occupations can be observed in all the sectors, rebuilding and altering the previous configuration. Most of the available datings are located in the Inca period during the 15th and 16th centuries, when the occupations might have been more intense. Considering recent excavations and collections in museums (Otero 2013), a high percentage of the studied contexts are attributable to those times. In the archaeological record of Pucará de Tilcara, the housing areas were identified as true palimpsests (*sensu* Bailey 2007), in which the previous stage is blurred because the last occupation manifests with better visibility. For the distribution of the datings, we suggest that the maximum extent of the village was attained during the 15th century, when it reached 17.5 ha.

These new results contribute to the discussion of the population dynamics of the region during the *Tawantinsuyu*, because until now it has been supposed that no other conglomerate had exceeded the extent of Los Amarillos or La Huerta (Palma 1998; Nielsen 2007). In the case of Pucará de Tilcara, a vast population was grouped to develop handicraft activities, and became an important centre in the region, as the capital of the Inca political–administrative division, or *wamani*.

At about the time in the culmination of the occupation of the site, the results of this study are consistent with interpretations of the historical sources. In 1536, Diego de Almagro made the first Spanish entry into the Argentine North-West and began the conquest. The political reorganization must have started a few years earlier, with the news of the collapse of Cusco, the Inca imperial capital. Then, the effective colonial occupation of the Humahuaca Gorge occurred in 1595, when the Jesuits succeeded in pacifying its inhabitants (Salas 1945). During those six decades, the people of Humahuaca were able to maintain certain traditions and authorities, together with a strong resistance to European penetration (González 1982; Tarragó 1984; Madrazo 1988), which for the area of Tilcara is expressed in the findings at the cemetery of La Falda (Rivolta and Nielsen 1996–8; Mendonça *et al*. 1997, 2003; Bordach 2006). Our results show that the depopulation of Pucará de Tilcara could have begun early in the 16th century. This is understandable since it could have been the capital of the *wamani*, and it may have suffered the demise of the Inca imperial power faster than elsewhere. The abandonment would have taken place gradually, with a restrained use of burials in the Hispanic–aboriginal era, and then complete abandonment with the effective establishment of the colony. However, there is enough material evidence of continuity in certain locations in early colonial times, not yet dated by radiocarbon.

Moreover, these results provide new data on the expansion of the *Tawantinsuyu*. The most widely accepted date for that is AD 1480 (Rowe 1945); however, in recent decades, the radiocarbon datings

have pointed to an earlier chronology (Barcena 2007; D'Altroy *et al*. 2007; Nielsen 2007). Our results also showed starting ages of the 15th century and earlier for contexts with Inca-type materials.

Finally, this work shows that, despite the limitations of the palimpsest of occupations and the inaccuracy of most of the available datings, it is possible to determine, using modern statistic techniques, the dates of events and the duration of processes, which could be useful as a new framework in which to discuss the chronological problems at a regional level.

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SUPPORTING INFORMATION

Additional Supplementary material may be found in the online version of this paper on the publisher's website:

Figure S1. General view of Pucará de Tilcara from the East.
Figure S2. Examples of pots recovered in Pucará de Tilcara. Above: local styles and local provincial Inca (Humahuaca / Inca). Down: Inca styles and pre-Inca of non-local origin.
Figure S3. Single uniform phase model for Midden 1.
Figure S4. Single uniform phase model for Midden 2.
Figure S5. Difference between Start and End boundaries of Midden 1 and 2.
Figure S6. Two sequential phase model for Dwelling 1.
Figure S7. Single uniform phase model for Dwelling 1.
Figure S8. Duration in year quantities of the considered series.