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MERGING THE MATRIX: STRATIGRAPHY, RADIOCARBON DATES, AND FIRE REGIMENS IN THE AMBATO VALLEY (CATAMARCA, NW ARGENTINA)

M Bernarda Marconetto[1] • Marcos R Gastaldi • Henrik B Lindskoug • Andrés G Laguens

IDACOR-CONICET, Museo de Antropología, Facultad de Filosofía y Humanidades, Universidad Nacional de Córdoba, Av. Hipólito Yrigoyen 174, Córdoba, CP 5000, Argentina.

ABSTRACT. This article compares radiocarbon dates and the stratigraphic matrix obtained from excavations at the Piedras Blancas archaeological site, Ambato Valley, NW Argentina. Analysis revealed inconsistencies between ^{14}C dates and certain events that can be clearly identified in the stratigraphy of the site. This fact led first to recognize the importance of a detailed stratigraphic record to allow a point of control and comparison. Secondly, this article discusses for the present case, (a) the consistency shown by the dating performed on bone materials in relation to the stratigraphic matrix and (b) the inconsistencies identified in relation to the dating performed on charred plant material, although this type of material was chosen for collection and dating using all appropriate caution to prevent dating bias. Finally, the possibility is considered that the dated plant materials could be affected by the high microcharcoal concentrations observed in the valley's sediments as the result of fire regimes with a high frequency, which seem to have existed since at least about 4000 BP.

INTRODUCTION

The southern Andean cultural complex known as Aguada developed a presence in the Ambato Valley between the 4th and 10th centuries AD (González 1961–1964, 1998; Pérez Gollán 1991). This society was defined by González (1961–1964, 1998) and in his view formed part of the Middle period in northwestern Argentina, a period of time now referred to in the archaeological literature as the Regional Integration period (Pérez Gollán 1991). This period can be characterized, among other traits, by the circulation of goods with high symbolic values (hallucinogenic substances, textiles, and metallic plates) between different societies in NW Argentina, with integration occurring on a broad regional scale among the autonomous social groups that had predominated in earlier times. During this period, changes within these groups can also be observed at the political, economic, and ideological levels, with the changes marking the appearance of a society with a higher degree of social heterogeneity (Laguens 2004; Pazzarelli 2006; Assandri 2007; Fabra 2007; Marconetto 2008).

The Aguada culture inhabited an extensive region in the northwestern part of what is today the country of Argentina (González 1998), and certain regional differences can be found in the archaeological record (e.g. decorative styles, architecture, use of space) and also with respect to chronology. Determination of the degree, range, and duration of the societal changes observed has been an intensely researched theme with respect to the Aguada culture, and development of a detailed chronology for this society's evolution became very important (Bonnin and Laguens 1996; Gordillo 2009). This interest in chronological studies developed not only in order to identify the starting point for these political and social changes, but also to focus on determining the duration of societies of this type. Around the 10th century, the Aguada culture underwent a process of social disintegration, which led in the case of the Ambato Valley to a total abandonment of the area. In this context, it is notable that at multiple sites, occupation ended with burning of the site, and also that paleoenvironmental studies have indicated that conditions drier than those of the present affected the region at the time of the end of the Aguada occupation (Marconetto 2009; Marconetto and Laguens 2014). A strong chronological framework is thus required to address these questions, whether for understanding the temporal ranges involved in the processes of change, establishing a closer approximation of the end of the occupation, or for dating the environmental changes that could have been partly responsible for abandonment of the settlements with greater precision.

Considering these issues, this study concentrates on analyzing and discussing the inconsistencies observed between the radiocarbon dates obtained in the Piedras Blancas site in the Ambato Valley

1. Corresponding author. Email: bermarconetto@yahoo.com.ar.

and the site stratigraphy. This analysis and comparison with the remaining dates obtained in the valley allow us to modify and improve the chronology of the Aguada occupation in this region. Also, on a more general methodological level, this study considers the classic discussion inside the discipline about the importance of possessing a well-defined association between sample and event (Boaretto 2009). Finally, the article demonstrates how the integration of data from various lines of evidence, such as stratigraphic analysis, precise identification of the types of material dated, and paleoclimatic studies, have allowed a more profound evaluation of the chronology of a region while avoiding erroneous inferences.

Piedras Blancas (PB) is one of the sites in northwestern Argentina with the largest number of dates available in relation to its size and excavated surface, with 16 ^{14}C dates existing for the settlement (Figure 1). There are 23 further dates from other sites excavated in the Ambato Valley (13 from Iglesia de los Indios [IDI], 3 from Martínez 2 [M2], 2 from Martínez 3 [M3], 1 from Martínez 1 [M1], 3 from El Altillo, and 1 from Terrazas de los Varela [TLV]) (see Table 1).

The material dated from the Piedras Blancas site was selected using all possible precautions, and following appropriate procedures given our modern knowledge of ^{14}C dating. Material with a short biological life was selected for dating, recovered from contexts where excavations were performed using a controlled stratigraphic matrix based upon the Harris (1991) method[2], which gave us the closest sample-event associations possible.[3] However, the dating results have raised a few problems in terms of interpretation, as will be discussed here.

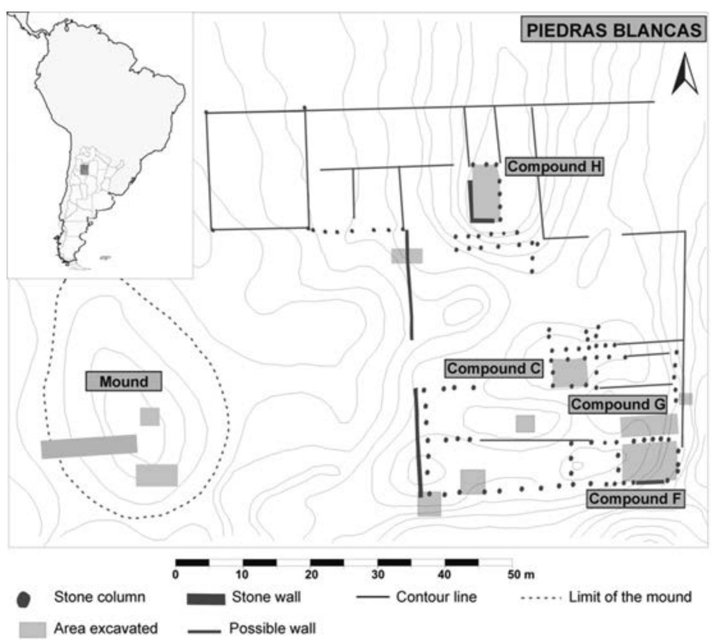

Figure 1 Map of the Piedras Blancas site

2. Application of the principles of archaeological stratigraphy proposed by E C Harris was performed by following and adapting the systematization described in the *Archaeological Site Manual* of the Museum of London (Spence 1994).

3. The relationship between stratigraphic units using the Harris method and ^{14}C dating is only available for the Piedras Blancas site. The other dates correspond to sites that were excavated using different methods, and were published without complete contextual information.

Table 1 Radiocarbon dates from archaeological sites in the Ambato Valley. Calibration was conducted using OxCal v 4.1.7 (Bronk Ramsey 2010); r:5. Atmospheric data from Reimer et al. (2009), “ShCal04.14c”; LP (LATyR, UNLP, conventional date); AA (Arizona, AMS); H (Heidelberg); GIF (Centre des Faibles Radioactivites del CNRS); Beta (Beta Analytic Inc.).

				Calibrated age							
				1σ			2σ				
Structure	Material	Lab code	^{14}C age BP	Low	High	% prob.	Low	High	% prob.	$\Delta^{13}C$ (‰)	Fraction modern C
Piedras Blancas, Compound F	Wattle 1	LP-1241	1000 ± 70	1024 AD	1155 AD	68.2	975 AD	1224 AD	95.4		
Piedras Blancas, Compound F	Wattle 2	LP-1257	920 ± 70	1046 AD	1085 AD	17.5	1030 AD	1270 AD	95.4		
				1110 AD	1118 AD	2.6					
				1131 AD	1225 AD	48.1					
Piedras Blancas, Compound F	Pot organic residue	AA82323	1281 ± 33	722 AD	740 AD	10.2	688 AD	753 AD	26.3	–12.2	0.8526 ± 0.0036
				770 AD	868 AD	58	759 AD	886 AD	69.1		
Piedras Blancas, Compound F	Hearth branch	AA82324	1273 ± 49	720 AD	742 AD	9.2	674 AD	898 AD	92	–21.6	0.8534 ± 0.0052
				770 AD	883 AD	59	920 AD	944 AD	3.4		
Piedras Blancas, Compound F	Camelid bone	AA93888	1320 ± 44	674 AD	779 AD	66.6	665 AD	871 AD	95.4	–11.5	0.8485 ± 0.0047
				794 AD	798 AD	1.6					
Piedras Blancas, Patio G	Chañar fruit 1	LP-2175	1200 ± 50	784 AD	787 AD	1.4	724 AD	739 AD	1.2		
				825 AD	841 AD	6.4	770 AD	994 AD	94.2		
				862 AD	978 AD	60.4					
Piedras Blancas, Patio G	Chañar fruit 2	AA93886	1269 ± 35	773 AD	880 AD	68.2	687 AD	894 AD	95.4	–25.5	0.8539 ± 0.0037
Piedras Blancas, Patio G	Chañar fruit 3	AA93885	1330 ± 35	684 AD	772 AD	68.2	660 AD	826 AD	92.3	–24.4	0.874 ± 0.0037
							849 AD	862 AD	3.1		
Piedras Blancas, Patio G	Camelid bone	AA93887	1316 ± 44	676 AD	780 AD	62.9	666 AD	875 AD	95.4	–12.7	0.8489 ± 0.0047
				792 AD	805 AD	5.3					
Piedras Blancas, Compound C	Hearth	LP-1223	1370 ± 70	650 AD	775 AD	68.2	606 AD	883 AD	95.4		
Piedras Blancas, Compound H	Charcoal from	LP-1269	1230 ± 80	773 AD	904 AD	49.7	674 AD	994 AD	95.4		
	Burial (intrusive)			914 AD	970 AD	18.5					
Piedras Blancas, Compound H, structure 1	Camelid bone	AA82322	1309 ± 43	680 AD	782 AD	59.3	670 AD	878 AD	95.4	–11.2	0.8496 ± 0.0046
				790 AD	810 AD	8.9					

Table 1 (*Continued*)

				Calibrated age							
				1σ			2σ				
Structure	Material	Lab code	^{14}C age BP	Low	High	% prob.	Low	High	% prob.	$\Delta^{13}C$ (‰)	Fraction modern C
Piedras Blancas, Compound H	burial tooth	AA82326	1509 ± 43	574 AD	644 AD	68.2	469 AD	480 AD	0.8	–10.3	0.8287 ± 0.0045
							534 AD	664 AD	94.6		
Piedras Blancas, mound 1	Dispersed charcoal	LP-1105	1040 ± 50	994 AD	1047 AD	35	975 AD	1163 AD	94.9		
				1084 AD	1136 AD	33.2	1169 AD	1175 AD	0.5		
Piedras Blancas, mound 2	Dispersed charcoal	LP-1090	1340 ± 40	675 AD	726 AD	41.2	656 AD	826 AD	92.5		
				738 AD	770 AD	27	840 AD	862 AD	2.9		
Iglesia de los Indios	Chañar fruit 1	LP-932	840 ± 55	1202 AD	1278 AD	68.2	1050 AD	1078 AD	2.5		
							1146 AD	1300 AD	92.9		
Iglesia de los Indios	Chañar fruit 2	LP-1206	930 ± 40	1050 AD	1078 AD	17.5	1040 AD	1224 AD	95.4		
				1146 AD	1212 AD	50.7					
Iglesia de los Indios	Trunk undeterminated 1	H 7004	1260 ± 40	774 AD	885 AD	68.2	687 AD	898 AD	91.6		
							920 AD	944 AD	3.8		
Iglesia de los Indios	Trunk undeterminated 2	GIF 9413	1420 ± 50	613 AD	690 AD	63.7	585 AD	773 AD	95.4		
				752 AD	761 AD	4.5					
Iglesia de los Indios	Trunk, *Alnus*	GIF 9412	1180 ± 45	884 AD	984 AD	68.2	778 AD	994 AD	95.4		
Iglesia de los Indios	Trunk, *Phoebe*	LP-464	1650 ± 75	391 AD	556 AD	68.2	258 AD	299 AD	4.2		
							318 AD	614 AD	91.2		
Iglesia de los Indios	Trunk, *Phoebe*	Beta 79180	1250 ± 60	723 AD	740 AD	5.4	686 AD	974 AD	95.4		
				770 AD	896 AD	58.9					
				924 AD	937 AD	3.9					
Iglesia de los Indios	Trunk, *Acacia* 5 cm	LP-1199	1230 ± 40	779 AD	895 AD	64.1	722 AD	740 AD	2.6		
				926 AD	935 AD	4.1	770 AD	979 AD	92.8		
Iglesia de los Indios	Full carbonized post	LP-495	1710 ± 45	264 AD	275 AD	3.8	257 AD	300AD	10.1		
				332 AD	434 AD	60.5	317 AD	535 AD	85.3		
				494 AD	506 AD	3.9					

Table 1 (*Continued*)

				Calibrated age							
				1σ			2σ				
Structure	Material	Lab code	^{14}C age BP	Low	High	% prob.	Low	High	% prob.	$\Delta^{13}C$ (‰)	Fraction modern C
Iglesia de los Indios	Dispersed charcoal 1	H 7005	1380 ± 40	655 AD	708 AD	52.5	640 AD	778 AD	95.5		
				747 AD	766 AD	15.7					
Iglesia de los Indios	Dispersed charcoal 2	LP-481	1800 ± 80	179 AD	189 AD	2.4	79 AD	529 AD	95.4		
				213 AD	404 AD	65.8					
Iglesia de los Indios	Bone	LP-1225	1220 ± 80	777 AD	904 AD	47.5	682 AD	996 AD	94.4		
				912 AD	971 AD	20.7	1006 AD	1015 AD	1		
Iglesia de los Indios	External rings *Prosopis*	LP-1754	1200 ± 60	783 AD	979 AD	68.2	716 AD	1017 AD	95.4		
Martínez 2	Post	LP-444	1690 ± 80	340 AD	536 AD	68.2	235 AD	600 AD	95.4		
Martínez 2	Wattle	LP-1317	990 ± 70	1025 AD	1160 AD	68.2	982 AD	1225 AD	95.4		
Martínez 2	Charcoal	LP-558	1510 ± 70	544 AD	655 AD	68.2	428 AD	679 AD	95.4		
Martínez 3	Charcoal	LP-553	1700 ± 60	336 AD	442 AD	47.9	251 AD	547 AD	95.4		
				452 AD	461 AD	2.9					
				484 AD	532 AD	17.4					
Martínez 3	Camelid bone	AA93889	1458 ± 44	606 AD	663 AD	68.2	553 AD	688 AD	95.4	–13.4	0.8340 ± 0.0046
Martínez 1	Trunk	LP-461	1770 ± 90	214 AD	429 AD	68.2	90 AD	100 AD	0.6		
							124 AD	540 AD	94.8		
El Altillo	Branch	LP-474	1900 ± 70	79 AD	245 AD	68.2	17 AD	348 AD	94.4		
El Altillo	Dispersed charcoal, *Prosopis* sp.	LP-1329	1390 ± 80	624 AD	776 AD	68.2	566 AD	885 AD	95.4		
El Altillo	Charcoal, *Prosopis* sp.	LP-1331	Modern								
Terrazas Los Varela	Camelid bone	AA93890	1312 ± 43	680 AD	780 AD	61.6	669 AD	874 AD	95.4	–12.2	0.8493 ± 0.0046
				792 AD	806 AD	6.6					

SECURE ARCHAEOLOGICAL CONTEXTS AND MATERIAL SUITED FOR ^{14}C DATING

There are several problems related to dating material by the ^{14}C method, as discussed by various authors (van Klinken 1999; Alon et al. 2002; Boaretto 2007, 2009), for both the materials dated and the need for "secure archaeological contexts." Boaretto (2007, 2009) has discussed the problem of secure contexts in relation to both macro- and microcontexts and has argued that "charred material and bones are often not preserved in the location where they were originally deposited, as they are susceptible to being moved by bioturbation" (2009:275). Further, she argues that plaster/mortar, phytoliths, and organic residues preserved inside ceramic vessels are often preserved in excellent contexts but can be troublesome to date. When selecting material to date during recent field excavations, one must always select material from secure contexts and materials with a short biological lifespan in order to get as close as possible to a specific event one wants to date, and avoid using troublesome materials as suggested by Boaretto (2007, 2009). This study uses carefully chosen materials from secure contexts that have not been affected by later human intervention or bioturbation. The seeds chosen for ^{14}C dating have come from groups of seeds associated with complete ceramic vessels, rather than single seeds that can easily be displaced by burrowing animals or other types of animal activity or bioturbation. Seeds are also short lived, which should make the selection as secure as possible, and the same is also true for dating small branches used in roof construction, which should not be affected by the "old wood effect." Although these branches may have been part of the roof for several years, they would not survive for as long as the posts, which may frequently have been reused in the construction as well. The same considerations are valid for the bones dated herein, which were all selected because they came from secure contexts, rather than small single bones that may have been transported between different stratigraphic layers or affected by bioturbation. As described later in this article, this study benefits from the site's special archaeological context of abandonment related to a fire event, including collapsed roofs and walls and many *in situ* objects, which enabled selecting material for dating that should be almost contemporaneous. This study has strictly avoided using materials from wall constructions for dating, based upon on several factors observed in the study area, including reuse or reoccupation of sites and the reuse of local sediments to produce rammed earth walls, which often contains inclusions of ceramic materials and charred plant materials (this has been observed both in archaeological sites and in modern houses in the area built with similar techniques). However, in spite of the fact that selected both secure contexts and secure materials for dating were selected, the dated material shows interesting variations in age that cannot be related to insecure contexts but rather to the nature of the dated material.

RADIOCARBON DATES FROM THE PIEDRAS BLANCAS SITE

The dates from the Piedras Blancas site are grouped into three sets. The first set includes the earliest dates from the site, with one date performed on an infant's tooth recovered from a burial and a second on a carbonized maize cob associated with the burial of a juvenile camelid. These two dates have a clear stratigraphic relationship with an area that could correspond to an occupation prior to construction of the area of the site known as Compound H. Since they maintain a clear coherence with the site stratigraphy, these two dates [1509 ± 43 BP, cal AD 469 (95.4%) 664 and 1488 ± 33 BP, cal AD 562 (95.4%) 660] could be reasonably interpreted as representing the initial occupation phase for Piedras Blancas.

A second group of dates, which includes 11 samples from bone, charcoal, organic residues, and *Geoffroea decorticans* (*chañar*) fruits recovered from compounds C, H, F, and G, are all grouped in a calibrated range between AD 660 and 894 (95.4%) (see Table 1). Although this group of dates indicates that practically all of the areas excavated up until now have been occupied during this timespan, they have also raised an issue in terms of the degree of resolution possible for dating specific events.

The third group includes three dates, two performed on wattle (small diameter, twiggy branches) used in construction of the burned roof in Compound F, and a third date performed on dispersed charcoal recovered from the lowest level of a test excavation on a small mount located to the west of the site. These are the latest dates obtained from the site [mound: 1040 ± 50 BP, cal AD 975 (94.9%) 1163; wattle 1: 1000 ± 70 BP, cal AD 975 (95.4%) 1224; and wattle 2: 920 ± 70 BP, cal AD 1030 (95.4%) 1270]. This final group of late dates could be interpreted as being linked to the burning of the site. However, although at one point these dates were interpreted as being associated with this episode (Marconetto 2007), in the light of the new interpretation of the results, it is not definitive whether these dates correspond to that final moment with certainty.

A FEW PROBLEMS

This section discusses a few cases that have raised problems at the time of forming interpretations linked to the initial questions (see Figure 2).

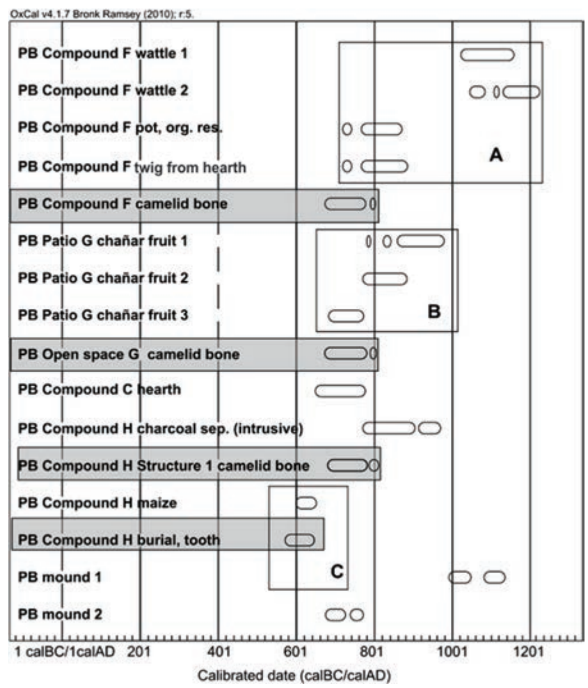

Figure 2 Plot with ^{14}C dates from the Piedras Blancas site. Marked in gray are the dates performed on bone material, which show coherence among them. In the boxes are the dates realized on botanical materials with a short biological lifespan and with a clear stratigraphic association, which, however, show inconsistencies among them.

Case of Patio G: Dates from *Chañar* (*Geoffroea decorticans*) Fruits

Compound G is adjacent to Compound F and consists of an open space (Patio G) with a gallery (Figure 3). Both of these areas show evidence of having been affected by the fire that ended occupation of the site. From the excavations performed in this area, 41 stratigraphic units were identified[4]: horizontal strata such as collapsed walls (GUE4, GUE5, GUE6, GUE13, GUE14, GUE16, GUE17, GUE18, GUE19, and GUE20), a collapsed roof (GUE22), spilled contents of vessels (GUE23), and compacted mud floors (GUE21). Vertical strata were also identified, such as rammed earth walls with stone columns and multiple successive construction phases (GUE3a, GUE3b, GUE7, GUE8, GUE9, GUE10, GUE11, GUE12, GUE15, GUE26a, GUE26b, GUB27a, GUB27b, GUB28a, and GUB28b), as well as structural support posts for a gallery roof (GUE29, GEU30). From the excavations, it can be determined that this was an open space (patio), which had a gallery-type roof about

4. The name of the stratigraphic unit (abbreviated as UE in Spanish) consists of the enclosure letter followed by the stratum number. For example, stratigraphic unit 22 of Compound G = GUE22.

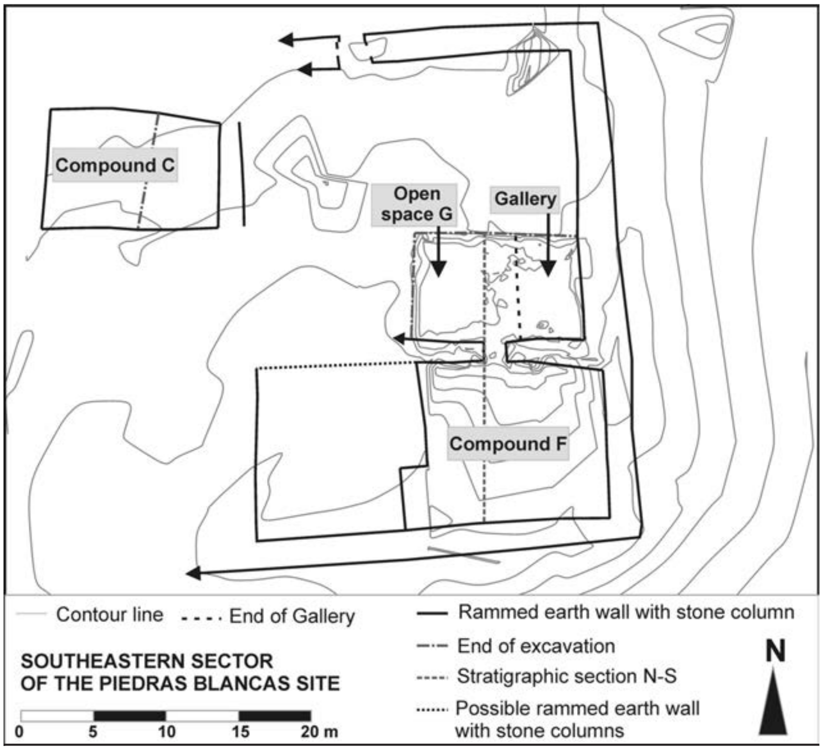

Figure 3 Map of the southeastern sector of the Piedras Blancas site

2 m wide and at least 7.5 m long, built against the main perimeter wall that surrounded the site. Since excavations have not yet been completed to the north, this space could in fact be even longer (Figure 4).

Below the gallery roof, at least 14 large ceramic vessels were found stored, supported both on a low earthen bench and on the patio floor against the wall that separates Patio G from Compound F. These vessels were decorated with painting and modeled faces (Pazzarelli 2012) (Figure 5), and were broken in place on the floor (GUE21) and covered by materials from the collapsed gallery roof (GUE22) and walls (GUE16, GUE19, GUE20) (Figure 6). One of these vessels[5] crushed by GUE22 contained more than 1000 carbonized *Geoffroea decorticans* (*chañar*) fruits (GUE23) (Marconetto et al. 2009). Samples of this material were selected for dating for two reasons:

a. First, the ^{14}C dating performed at various sites on carbonized tree trunks used as construction elements had raised problems based upon the old-wood effect (Marconetto 2007). Since *chañar* fruits grow on an annual cycle, it was thought that their short biological lifespan would make it possible to closely associate the resulting date with the fire that impacted Piedras Blancas.

b. Secondly, there was a very precise contextual association (sample-event). The stratigraphic matrix provided practically a single event, where the fire, collapse of the gallery roof, breakage of

5. This vessel was defined as a separate UE since it was possible to reconstruct it completely. In addition, it still contained contents at the time of being crushed, which could be associated with it.

the vessel, spilling of the contents, and burning of the *chañar* fruits took place simultaneously.[6]

Two dates have been reported for other *G. decorticans* fruits recovered from a similar context at the Iglesia de los Indios site, located about 400 m south of Piedras Blancas. These samples returned dates of 840 ± 55 BP, cal AD 1050 (95.4%) 1300; and 930 ± 40 BP, cal AD 1040 (95.4%) 1224 (Gordillo 2007b), which were at the time interpreted as being consistent with the roof wattle dates from Compound F at Piedras Blancas, mentioned in the previous section, as well as with burned wattle from the Martínez 2 site [990 ± 70 BP, cal AD 982 (95.4%) 1225].

By sending the fruits recovered at Piedras Blancas for dating, it was hoped to confirm the interpretation of these late dates as representing the end of the occupation. However, the results from the three dating samples submitted were outside the expected dates [1200 ± 50 BP, cal AD 770 (94.2%) 994; 1269 ± 35 BP, cal AD 687 (95.4%) 894; and 1330 ± 35 BP, cal AD 660 (92.3%) 826]. These dates do, however, approximate other dates on samples recovered from beneath the burned roof materials in Compound F: bone, organic residues from a vessel, and a small branch recovered from a hearth.

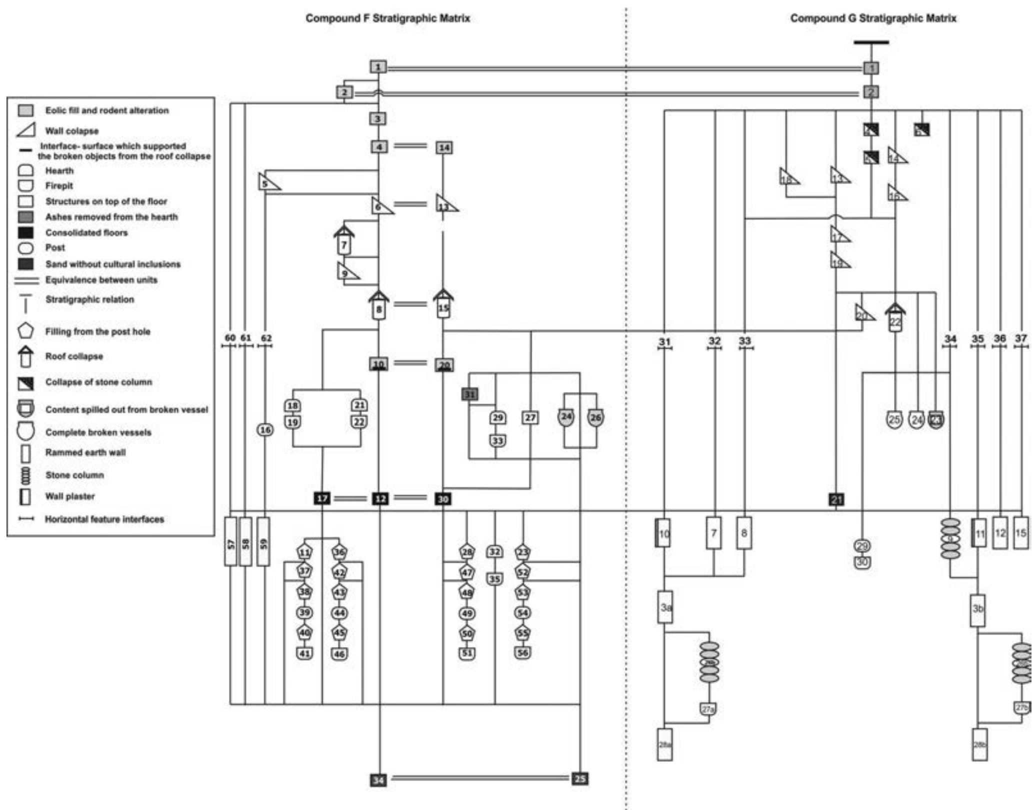

Figure 4 Stratigraphic matrix for compounds F and G

6. Geological and taphonomic processes were considered that might have interfered with the stratigraphy of the site. However, this is not geological stratigraphy but rather with "cultural" archaeological stratigraphy, which differs in several ways. See Harris (1991) for further explanation of these differences. However, this study identified several biological and other physical mechanisms that could lead to stratigraphic mixing. These actions should be considered as postdepositional processes that can modify spatial relationships (contraction, cracks, moisture, etc.). Processes linked to bioturbation may also be involved in the migration of the inclusions contained in the deposit. While certain alterations were identified (mainly rodent burrows, which were mapped), these were mainly in the layers of collapsed walls, rarely passing through them. In turn, the boundaries between stratigraphic units identified were defined as "sharp" or "clear" *sensu* Spence (1994). Gastaldi (2010) presents a deeper analysis of the postdepositional processes that may have influenced the formation of deposits excavated in this compound.

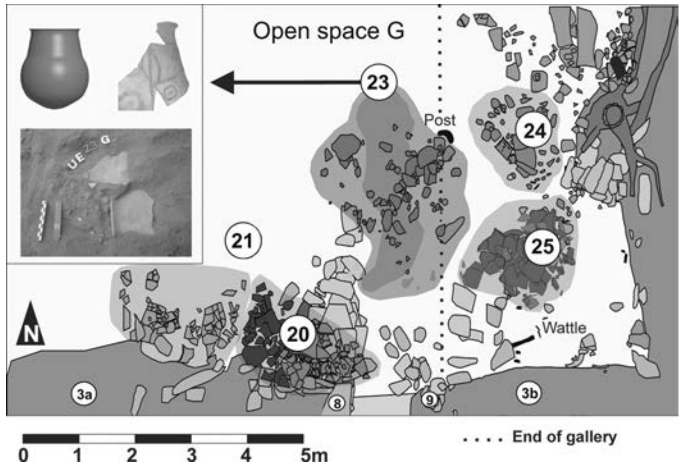

Figure 5 Plan of Open area G and Gallery with objects broken by the fire and collapse of the structure.

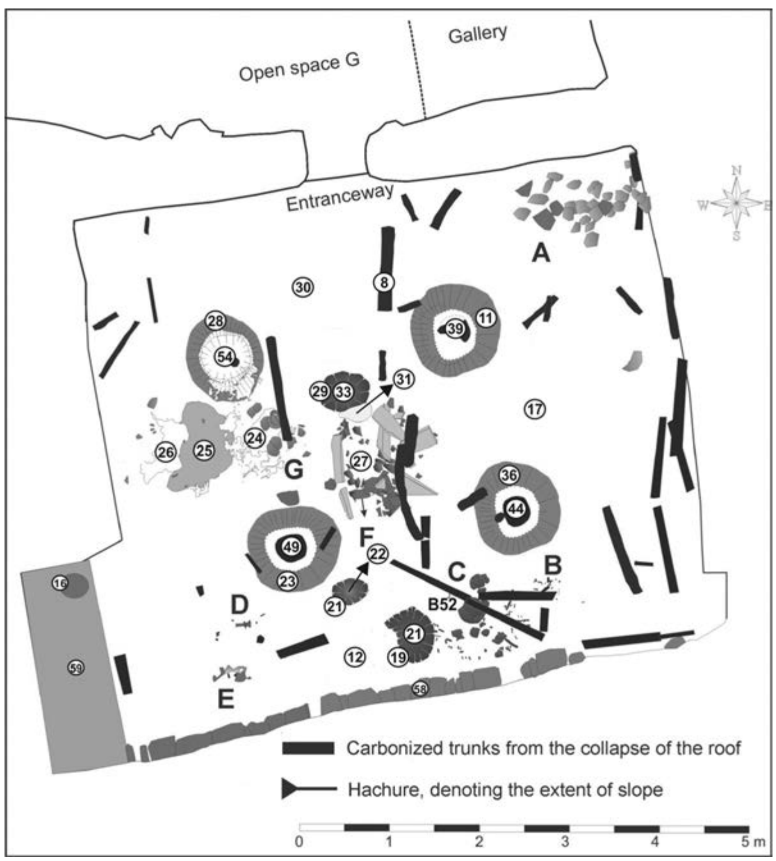

Figure 6 Plan of Compound F with objects broken by the fire and collapse of the structure: (A) ceramic vessel; (B) broken red ceramic dish; (C) ceramic vessel (B52); (D) pipe; (E) camelid pelvis; (F) globular vessel with soot similar to B52; (G) ceramic vessel with spilled contents of liquid white paint.

In addition to these dates being outside of the expected range, another problem is the difference in the date ranges. Although the contextual association and contemporaneity of the three samples is unequivocal, since the samples are three fruits from the same vessel recovered together, the variation in the dates is notable, since at 1σ, the earliest and latest calibrated date ranges do not overlap.

The Case of Compound F: Small Branches, Bones, and Organic Residues

This enclosure is located in the southeast corner of the site. It is rectangular in shape, ~7.5 m long in the east-west direction and ~6.5 m in the north-south direction (Figure 3). The south and west walls of the enclosure coincide with the site's perimeter wall. In the middle section of the north wall, there is an access doorway that connects to the Patio G and Gallery area, the area discussed in the previous section. The total surface area excavated in this compound was ~46 m^2, with 62 stratigraphic units identified (Figure 4). These units were defined as collapsed stone and rammed earth walls with stone columns (FUE5, FUE6, FUE9, FUE13), accumulative strata showing signs of mixing by eolian action and rodent activity (FUE1, FUE2, FUE3, FUE4, FUE14) and roof-fall events in the compound (FUE7, FUE8, FUE15), as well as a compacted floor (FUE12=FUE17=FUE30), hearths (FUE18, FUE21, FUE29, FUE32), and fire pits (FUE19, FUE22, FUE33, FUE35). There were also some vertical stratigraphic units, such as a continuous stone wall, a rammed earth wall, and a rammed earth wall with stone columns (south wall, east wall, and west wall). Four post support structures were also found, with carbonized trunks in their interiors (FUE39, FUE44, FUE49, FUE54). From analysis of the stratigraphic matrix, it can be determined that, as with Patio G, the end of the site's occupation is marked by the burning of the roof and its collapse onto the objects that were being stored on the compacted floor beneath it, or that were being used there at the time (FUE12=FUE17=FUE30) (Figure 6). As examples of some of these destroyed objects, stratigraphic units FUE24 and FUE26 are two whole vessels, which spilled their contents of white liquid paint into the surrounding area (Gastaldi 2010). Another vessel (B52 in Figure 6), which has signs of carbonization on its exterior, was recovered broken at the side of a hearth (FUE18 and FUE19). An organic residue sample was obtained from the interior walls of this vessel and was dated (discussed below). The floor also contained a stone structure with two vessels stored in its interior. These were completely destroyed by the fall of one of the roof's main beams (Figure 6: FUE27).

The floor in Compound F is linked with floor GUE21 of Patio G via an entranceway and a 0.20-m step, where the vessel containing the *chañar* fruits was recovered (Figure 7). In terms of E C Harris' stratigraphic principles, this would be referred to as a period interface, a surface with contemporaneous uses.[7] In spite of this stratigraphic clarity, where the end of occupation is marked by the collapse of the roof and the destruction of objects and structures that were in use at the time, the results received when dating some of these contexts have been dissimilar and contradictory.

1. Dating Wattle Samples from the Roofing.

The samples labeled Wattle 1 and 2 correspond to part of the roofing structure that covered Compound F. This material is made up of thin branches that, along with an applied mud surfacing (FUE7), formed the roof of the enclosure. In order to avoid dating problems caused by the in-built age of old wood, it was decided not to date other elements of the built structure in this area, such as the carbonized posts or beams recovered during excavation. Instead, this roofing material with a short biological lifespan was chosen for dating, since it was expected that it would give a result reflecting the time at which this part of the roof was constructed. The dates obtained were 1000 ± 70 and 920 ± 70 BP.

7. For an expanded discussion of the stratigraphy and the period interfaces in Compound F, see Gastaldi (2012).

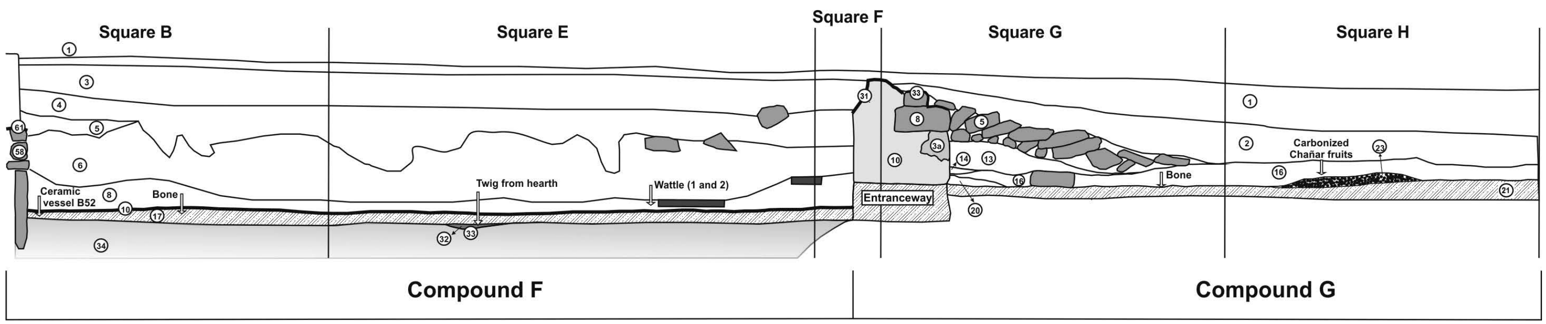

Figure 7 (above) N-S section drawing of compounds F and G with ^{14}C-dated objects

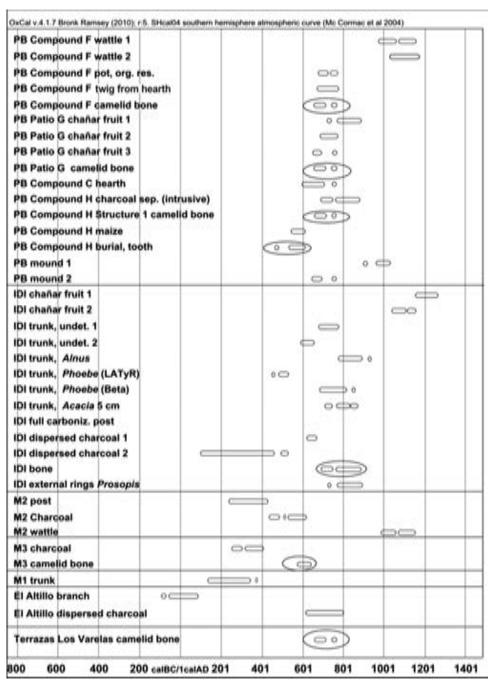

Figure 9 (left) Plot with all ^{14}C dates from the Ambato Valley. The dates made on bone, which show coherence between them, are marked with ovals.

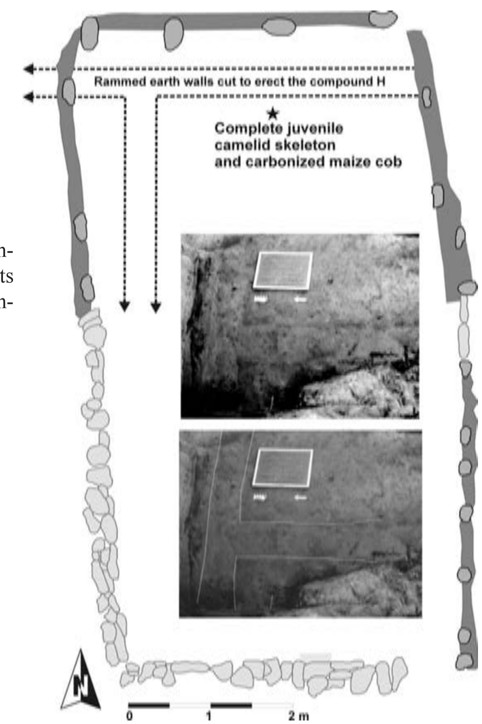

Figure 8 (right) Plan of Compound H with ^{14}C-dated objects and the cut made during construction of the compound.

The burned structure and collapsed roof have a distinct stratigraphic relationship with the materials that were located beneath them at the time of the fire (see Figure 6). The falling roof broke ceramic pots and vessels. The dating of organic residues from one of these vessels (B52 in Figure 6) has yielded a result of 1281 ± 33 BP, cal AD 688 (95.4%) 886. Taken on its own, this date would indicate that the broken materials in Compound F were crushed by a roof that would not be built until centuries into the future. Although this is obviously rather implausible, it can serve as a hypothesis. However, such a hypothesis would have to support some contrasting implications, such as the absence of evidence for sediment accumulation taking place during the centuries separating the existence of the pot and construction of the roof. Another process that could have affected these dating results is that of recycling of this vessel, with the vessel therefore being older than the enclosure, or contemporaneous with one of the first events recorded linked to its construction. However, the context where this pot was recovered (next to a hearth), and the fact that its exterior also possesses signs of carbonization and oxidation processes, which even allow the positions occupied by the vessel during cooking activities to be determined (Gastaldi 2010; Pazzarelli 2012), suggest that the dated material extracted from the vessel's interior would have been produced during the same time period when the hearth was in use.

2. Dates on Bone

There have been four dates performed on bone collagen from the Piedras Blancas site (three camelid bones and a human tooth), corresponding to compounds H, F, and G. These dates are consistent among themselves and coherent with the stratigraphic matrix established for the site (Gastaldi 2010). Two of the camelid bones dated correspond to the floors of compounds F and G, returning dates of 1320 ± 44 BP, cal AD 665 (95.4%) 871, and 1316 ± 44 BP, cal AD 666 (95.4%) 875 (Figure 7). Another dated bone corresponds to the burial of a juvenile camelid beneath a combustion feature in structure 1 (an oven surrounded by a low mud wall). This sample produced a result of 1309 ± 43 BP, cal AD 670 (95.4%) 878. These three dates seem to indicate contemporaneous occupation of the three enclosures at this time.

The remaining date was performed on bone collagen from the tooth of an infant found buried in Compound H with a set of goods including small vessels, pigments, and a small camelid figurine. The date returned from this sample is earlier than the others [1509 ± 43 BP, cal AD 534 (94.6%) 664], although this date does coincide with the date from a maize cob recovered along with another juvenile camelid burial [1488 ± 33 BP, cal AD 562 (95.4%) 660]. This assemblage was found below the level where the Compound H wall begins, and in an area where there is a section of wall undoubtedly corresponding to a structure built at a time earlier than Compound H (Gastaldi 2010) (Figure 8). The coherence of the dates performed on bone collagen is notable in comparison with those performed on carbonized botanical materials. This will be discussed further below.

DATES FROM THE REST OF THE AMBATO VALLEY

If Piedras Blancas is excluded for now and the situation at neighboring sites is evaluated, some other issues arise that must be analyzed. Figure 9 presents the dates for seven sites excavated in the Ambato Valley. At 1σ, these dates cover a range between 40 BC and AD 1279, or between 111 BC and AD 1300 at 2σ.[8] At 1σ, 60% of the dates are located between AD 600 and 800, with 16% of the others distributed between AD 1000 and 1200 and 24% before AD 600.

One point worth emphasizing is the difference between the date ranges from Piedras Blancas and Iglesia de los Indios, the two sites with the largest number of dates available. Although this differ-

8. We use 1σ here to emphasize what we want to show in a more visual way. If 2σ visual depictions were used, the range is too broad and the problem we want to show "disappears."

ence could be due to actual differences in the periods of occupation, it must also be remembered that many of the dates from the Iglesia site were performed on tree trunks used to construct the site, and as discussed above, may be affected by the "old wood effect" (Marconetto 2007; Gordillo 2009). On the other hand, dating of this type of material was avoided at Piedras Blancas, which could to a large degree explain why those dates are concentrated within a tighter period of time.

The Iglesia de los Indios site has the same types of contexts associated with the burning and collapse of the built structures, with the earliest dating sample coming from dispersed charcoal fragments [1800 ± 80 BP, cal AD 79 (95.4%) 529] and the latest sample being a *chañar* fruit [840 ± 55 BP, cal AD 1050 (95.4%) 1300].

Another date for this site comes from an area corresponding to the final outer rings and bark of a trunk, which was expected to reinforce the late occupation dates for the site as obtained from the *chañar* fruits. The date returned was 1200 ± 60 BP, cal AD 716 (95.4%) 1017 (Gordillo 2007a). Although this date is consistent with those from the *chañar* fruits at Piedras Blancas, it differs from the *chañar* fruit dates from the Iglesia site.

As Marconetto (2007) discussed, there are sample-event problems at the Martínez 2 site, where two very disparate dates exist separated by almost 1000 yr. One of these dating samples was from a post and one from wattle associated with it, while a third date from this site came from unidentified charcoal material reported as 1510 ± 70 BP, cal AD 428 (95.4%) 679.

The Martínez 1 and 3 sites were excavated in the 1970s. Each site received one ^{14}C date, from a trunk in the case of M1 and using unidentified charcoal material for M3. These two dates are M1: 1770 ± 90 BP, cal AD 124 (94.8%) 540, and M3: 1700 ± 60 BP, cal AD 251 (95.4%) 547. Dating recently performed on collagen from a camelid bone from the Martínez 3 site gave results of 1458 ± 44 BP, cal AD 553 (95.4%) 688.

The Terrazas de los Varela (Varela Terraces) site is an agricultural system located in the northern Ambato Valley (Figueroa 2010). A corral excavated within this system was recently dated, using camelid bone collagen, to 1312 ± 43 BP, cal AD 669 (95.4%) 874. This date would make the site contemporaneous with most of the dated Aguada contexts at Piedras Blancas and Iglesia de los Indios.

The dated sites and contexts discussed above have components that have been defined as Aguada (Assandri 1991; Juez 1991; Pérez Gollán 1991; Laguens 2004, 2006; Assandri 2007). On the other hand, the El Altillo site dates to a time period prior to the Aguada occupation within the valley. This site includes a mound structure with a circular perimeter wall, with high densities of archaeological materials present that show significant contrasts with materials from later contexts (Fabra 2007). There is one date obtained in 1992, which corresponds to the deepest level (17) of a test excavation [1900 ± 70 BP, cal AD 17 (94.4%) 348]. Excavations performed in 2000 and 2001 recovered two samples submitted for dating. The first, which consisted of an assemblage of charcoal fragments from multiple species, returned a date of 1390 ± 80 BP, cal AD 566 (95.4%) 885, while the other sample, a carbonized fragment of *Prosopis* sp. wood, returned a modern date.

DISCUSSION

Based upon the results obtained so far, the following can be confirmed with a good degree of confidence:

1. Occupation of the Piedras Blancas site took place during a range of time between AD 574 and

1225 (1σ) or AD 469 and 1270 (2σ);
2. There are two periods of occupation at Piedras Blancas, at least in the area of Compound H;
3. The end of the occupation of the burned sites in the valley (PB, IDI, and M2) may have occurred between AD 674 and 1278 (1σ) or AD 660 and 1300 AD (2σ), based only on dates performed on materials with short biological life and excluding dates from tree trunks (which would extend this range by centuries); and
4. The earliest agroceramic occupation of the valley is represented by the El Altillo site.

Undoubtedly, the width of the temporal ranges presented above is disappointing given the objective of temporally confining a social process, and of defining the time and the circumstances of the end of the Aguada occupation in the Ambato Valley. These temporal ranges are also too broad to think of them in terms of the classic sequences proposed by archaeologists for the agroceramic populations of northwestern Argentina.

This broad time range is to a large degree due to the problems discussed above. These problems can be addressed on one hand by discussing methodological issues, and on the other by reflection upon the study questions. Laguens (2007) asked whether, in the search for an ethnographic solution, we have denied the historical component of archaeology. Perhaps the chance to work with "Pompeian" contexts in the Ambato Valley, as they might be called, made us think that we could gain access to high chronological resolution. However, it seems as though the more dates available, the more resolution is lost.

Possibly one point linked to this is the fact that ^{14}C dating does not provide the degree of fine-grained resolution hoped for, and problems with the resolution of the method can affect the interpretations. This point has emphasized the importance of combining both detailed stratigraphy and ^{14}C dating in the interpretations produced. However, it must also be emphasized that a variety of regional chronological reviews have been published for northwestern Argentina (see Nielsen 2007; Scattolin 2007; Greco 2010), which when discussing dates from similar contexts, do not present the kind of marked variability observed among dating results seen in the study area. This has raised questions regarding the existence of some peculiarity in this area compared to others in northwestern Argentina where such problems do not occur. Although it is still just a hypothesis, there is one particular factor that could be participating in the generation of these problems. The dates performed on collagen material extracted from bone were consistent with the stratigraphy and did not show marked variation among them. This led us to think that something was affecting the dates on carbonized botanical materials.

As demonstrated by Longin (1971), collagen can be extracted in a soluble form, which allows a higher degree of decontamination for the sample. Most laboratories have adopted the soluble collagen extraction method, since dates on this material are less sensitive to external contamination caused by carbon in soils. Assuming then that in the Ambato Valley the bone samples could have been less susceptible to carbon contamination from the soils than the carbonized botanical materials, then what could be affecting these botanical materials? Why are the results so variable when compared to other regions where both bone and carbonized botanical materials have been dated? What is unusual about Ambato? We believe that some recent research in progress regarding past forest fires in the valley (Lindskoug 2010, 2013, 2014; Lindskoug and Marconetto 2013) could now contribute to this issue.

In relation to the problem of the end of occupation, we propose a hypothetical situation of environmental decline for the time period at the end of the Aguada settlement. The results of an ecological analysis using the tree-ring anatomy of *Geoffroea decorticans* branches recovered from contexts associated with the fire at the Piedras Blancas site indicate that aridity greater than in the present existed in the region until around the end of the 1st millennium (Marconetto 2009, 2010). The nature of the fires that affected the region therefore becomes a relevant issue in relation to this point. Differences in the origins of these fires—either natural or human caused—would have significant implications for understanding the process of population abandonment. Conditions of aridity are an important factor, since fires are more likely and more frequent when a large amount of combustible material is available along with low levels of environmental humidity (Carcaillet 1998; Whitlock et al. 2003). With the type of vegetation characteristic of the region, both currently (De la Orden and Quiroga 1997) and in the past (Marconetto 2008), with a predominance of forest in the valley's base and lower slopes and grasslands at higher altitudes, the natural vegetation coverage would have become a highly available fuel source. Given that, as mentioned above, the existence of arid conditions has been detected for this area during the time under study, one of the hypotheses to consider is that conditions for the occurrence of natural fires may have been established.

Along these lines, research has been initiated focusing on analysis of microcharcoal in sediments outside of the site boundaries, in order to monitor forest fire "signals" from the past. Microscopic and chemical analysis of these materials is beginning to reveal some interesting results regarding fire ecology in the region. The analysis of sediment sequences up to 2.35 m deep, taken at 17 sampling stations, shows evidence for recurring forest fires along sequences dating back to 4000 BP (see Lindskoug and Marconetto 2013).

This data allow us to infer that forest fires have been a part of the ecosystem for thousands of years. Given that (1) human presence generally increases risk of fires; (2) since the middle of the 1st millennium AD, population increases have been recorded for the valley; and (3) conditions of aridity existed that would have produced highly susceptible biomass, it is likely that the frequency of fires has increased during the last 2 millennia. For this reason, the soils of the Ambato Valley are rich in microcharcoal that has accumulated over the centuries from the burning of vegetative biomass more highly sensitive than that found in other areas of NW Argentina, where problems of this nature do not exist in the chronologies. To the extent that this problem is affecting the dating results, it is no minor issue. As a hypothesis, it could be possible that the carbonized botanical materials dated are contaminated because of this particular characteristic of the Ambato Valley, while the collagen extracted from bones and teeth is not, or at least is contaminated to a lesser degree.[9]

Based on the possibility that the collagen samples may be providing a more reliable set of dates, we can return to our initial questions: to understand the processes involved in the change towards a growing degree of heterogeneity (Laguens 2006), and to establish as securely as possible the time of the end of occupation and the environmental changes that may have been partly involved in the abandonment of the burned settlements (Marconetto 2009). These questions require a tighter temporal framework than the one offered by the fairly broad range of dates we have available.

Figure 9 presents the results of the 38 dates obtained so far from the Ambato Valley, at 1σ. Of the episodes dated, 55% have high probabilities of having occurred between AD 600 and 800, while four dates occur between AD 400 and 600. The rest of the dates fall into either earlier (AD 200–400) or later (AD 1000–1300) ranges. The early dates may reflect potential problems with the old-wood effect, since these dates were performed on posts and may be yielding artificially early results, while in the case of the later dates, there are the problems with stratigraphic relations discussed above. The dates on collagen give results between AD 200 and 400 for the early occupation of Piedras Blancas

9. The relation between the fire regimens (i.e. the high levels of microcharcoals detected in the soil in the area) and the possible contamination of the botanical plant material is a topic that needs more research, which we plan to investigate.

and for the Martínez 3 site. Events dated from Iglesia de los Indios, Piedras Blancas, and the TLV cultivated terrace system fall into the range AD 600–800. None of the dates performed on collagen up until now have given results outside of these ranges.

Within this context, the idea of local change, although abrupt and occurring over a brief timespan (Laguens 2006), could be considered for this particular period of time. In terms of the fires associated with the end of the site occupations, it does not seem likely that these occurred later than AD 900. It would therefore be important to focus paleoenvironmental studies on this time period.

CONCLUSION

This work has attempted to address two issues, one linked to local chronological problems, and the other more general in nature, linked to contextualization of the dated material both at the scale of site, with more detailed control of the stratigraphic relationships, and at the interpretive level, by trying to think of conditions that may have affected the dating results. At the same time, there are three other points that this study can address

a. The relevancy of having a high-resolution stratigraphic matrix available, which allows the dates obtained to be contextualized and discussed. Having such information has allowed to some degree to address problems inherent in the ^{14}C method, such as the range of possible dates returned. A detailed stratigraphic matrix has also allowed a level of resolution at the "biographical" scale for the relationships among units.

b. Another issue that appears significant for the cases discussed is related to the differences seen in the dates derived from either bone or botanical materials. This is an important matter, and we are now more aware of this issue in terms of selection of future dating material, as least in the contexts where we are currently working.

c. Finally, the peculiarity that we think is affecting the dates from the Ambato Valley is the recurrence of forest fires in the region. This is a subject where we have not found other precedents, although it does represent a plausible explanation for the dating problems observed, and therefore should be a point worthy of further research. The possibilities for merging information from the stratigraphic analyses and paleoenvironmental studies with the ^{14}C dates have allowed us to expand discussion of the study region's chronology, and to open up new lines of research for continuing exploration.

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