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A NEW RADIOCARBON SEQUENCE FROM LAMANAI, BELIZE: TWO BAYESIAN MODELS FROM ONE OF MESOAMERICA'S MOST ENDURING SITES

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ABSTRACT. The ancient Maya community of Lamanai, Belize, is well known for its span of occupation from the Early Preclassic (before 1630 BC) to the present. Although most centers in the central and southern Maya Lowlands were abandoned during the Terminal Classic period (AD 750–1000), ceramic and stratigraphic evidence at Lamanai has shown continuous occupation from the start of the Early Preclassic to the Spanish Conquest. In this paper, we present the first complete set of radiocarbon dates from this important site, including 19 new accelerator mass spectrometry (AMS) ^{14}C dates. We use these dates to build Bayesian models for a Terminal Classic structure and an Early Postclassic structure in the site center. This method assists in the refinement of older, conventional dates and provides key chronological information about the site during this volatile time. Adjustments to the standard, uniform distribution model are made using exponential, long-tail, and trapezoidal distributions to incorporate outlier samples and more accurately portray ceramic phases. Because of changes in construction behavior in the Terminal Classic, it is difficult to acquire primary samples from this period, but there remains enough overlap between dates and ceramic phases to deduce persistent occupation at Lamanai during the transition from Late Classic to Postclassic times.

KEYWORDS: Terminal Classic, Postclassic, trapezoid, outlier, old wood.

INTRODUCTION

The ancient city of Lamanai boasts one of the longer chronologies known for any Maya site. Ceramic and architectural evidence support occupation extending from the Early Preclassic (1600–900 BC) (Metcalfe et al. 2009; Rushton et al. 2013) through the Spanish and British colonial periods and into the 21st century (Pendergast 1981, 1982a, 1988; Graham 1987, 2004, 2011; Powis 2002). Like other ancient cities in the Maya Lowlands, Lamanai experienced profound changes during the Terminal Classic period (AD 750–960),[1] including diminution in monumental construction, increased use of wood as a construction medium for civic buildings, and changes in portable material culture. By the time of the Spanish Conquest, the community's center was positioned far south of the former Classic-period core, and the monumental structures built during the Classic (AD 250–1000) were no longer in use (Pendergast 1981, 1998), although some plaza groups were reoccupied during the Colonial period (Graham 2011). Pendergast (1986) attributes Lamanai's perseverance in part to its location along the New River Lagoon—a rich, freshwater resource that provided a means of subsistence, transportation, communication, and trade with other regions of Mesoamerica. Recent paleolimnological studies (Metcalfe et al. 2009; Rushton et al. 2013) confirm the lagoon's reliability and resilience to the prehistoric climatic fluctuations that affected other parts of the Maya Lowlands (Haug et al. 2001; Hodell et al. 2005; Mueller et al. 2010; Aimers and Hodell 2011; Kennett et al. 2012; Douglas et al. 2016).

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[1] Unless otherwise noted, all dates from Lamanai refer to ^{14}C dates calibrated in OxCal v 4.2.4 (Bronk Ramsey 2014a), as described in the Methods section.

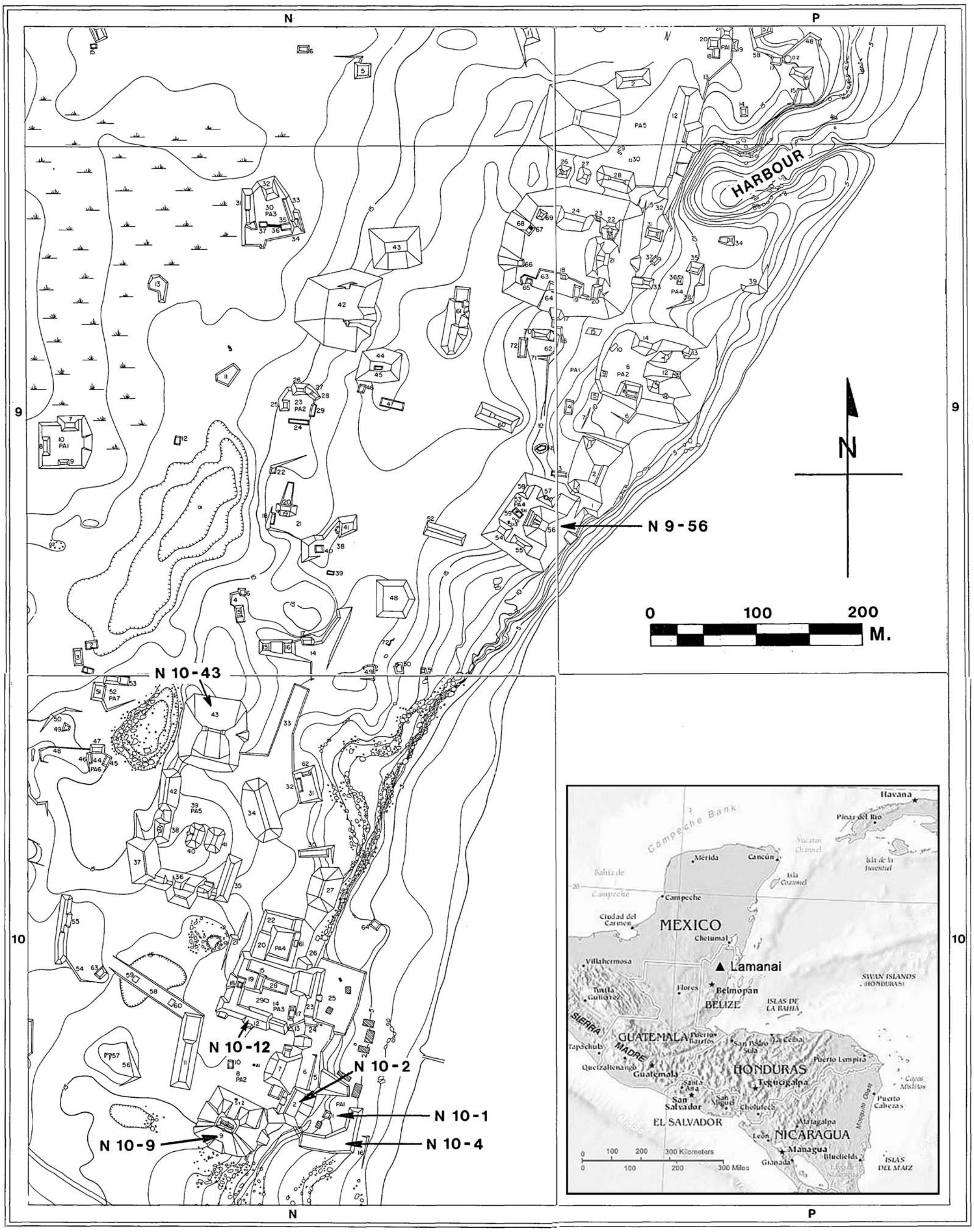

Figure 1 Central Precinct of Lamanai (modified from Pendergast 1981)

Lamanai consists of 718 structures positioned along a 4.5-km^2 section of the New River Lagoon in northern Belize (Figure 1) (Pendergast 1981: 32). Preclassic settlement was largely concentrated in the north with the location of the community's core expanding southward over time. Preclassic activity appears to have been extensive—in fact, the Spanish churches far to the south of the site core were constructed in a zone of Preclassic occupation. Recent pollen analysis has confirmed Early Preclassic activity with the presence of *Zea mays* and *Cucurbita* sp. beginning by 1630 BC (Metcalfe et al. 2009; Rushton et al. 2013), and a maize offertory deposit in the northern "harbor" area has been dated to 1500 BC (Pendergast 1998: 56; Powis et al. 2009). Although many of the northernmost structures had fallen into disuse by the beginning of the Classic period, occasional venerations continued, as represented by deposits of ceramics from later periods at the base of some temples (Pendergast 1981). Additionally, nearly 100 ceramic censers were ritually smashed atop the degraded surface of the Mask Temple (Structure N9-56) during the Late Postclassic (AD 1350–1544), accompanied by a re-siting of Stelae 1 and 3 (Pendergast 1981: 51, 1986: 240). Such ceremonies were typical of the Late Postclassic Lowlands, yet the venerations at Lamanai were more substantial than the portable offerings found at abandoned centers elsewhere (Pendergast 1985: 99; Hammond and Bobo 1994; Sullivan and Sagebiel 2003).

The first systematic archaeological investigations at Lamanai were carried out from 1974 to 1986 and consisted of mapping, excavation, and consolidation (Pendergast 1981, 1982a,b, 1985, 1986, 1988, 1990, 1998, 2006). Since 1998, excavations have concentrated on periods of cultural transition, focusing particularly on the Terminal Classic, the Spanish Colonial period, and more recently, British colonial activities (Graham 2004, 2008, 2011; Mayfield 2015).

The Sampling Contexts: Structures N10-2, N10-7, and N10-9

The southern end of Lamanai's Central Precinct consists of a series of interconnected plazas, the largest of which, Plaza N10[2], is dominated by the Jaguar Temple (Str. N10-9 on Figure 1). Most of the investigated structures in the site core were constructed during the Late Preclassic (400–100 BC) and underwent numerous modifications later in their history (Pendergast 1981; Loten 2006). The Jaguar Temple is one of the few large structures to have been erected during the Early Classic (AD 250–450) (Pendergast 1981: 35).

In the shadow of the Jaguar Temple, bordering the lagoon to the east, a small plaza-like complex appears to have been the focus of activity from Terminal Classic through Late Postclassic times. Structure N10-2, which featured a distinctive columned portico with a masonry altar along the center of the back wall, is believed to have been built during the Terminal Classic and repeatedly renovated until the early 15th century (Pendergast 1986: 241). Fifty burials were found in Str. N10-2, of which 25 were associated with diagnostic Buk-phase ceramics (Early Postclassic pottery characterized by Zakpah Group vessels) (Walker 1990; Wrobel and Graham 2015).[2] Buk-phase ceramics were also found in 20 of the 47 burials from Str. N10-4 of the same plaza, and in both burials from the small platform, N10-1, that lay between N10-2 and N10-4. Many of these burials contained prestige goods indicating high status, including copper ornaments, rings, and bells (Pendergast 1981, 1985; Simmons et al. 2009).

The wealth of the Buk burial assemblages in Structures N10-1, N10-2, and N10-4 demonstrates that Lamanai remained an active and influential community during the Early Postclassic (AD 900/960–1200) (Pendergast 1981: 41). The site's importance during this period is also indicated by the presence of Zakpah ceramic types at Altun Ha, Mayflower, Tipu, and Marco Gonzalez (Graham 1987), as well as at neighboring sites in northern Belize (Andres and Pyburn 2004; Wrobel and Graham 2015). Marco Gonzalez, on Ambergris Caye, appears to have been a

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[2] Lamanai's ceramic phases are based on stratigraphic relationships rather than a type-variety system—see Aimers and Graham (2013) for a general discussion. For specific phases, see Pendergast (1982a) for Buk; Graham (1987) and Howie (2005, 2012) for Buk and Terclerp; and Powis (2002) for Preclassic. Other phases are not as well described, but see Pendergast (1981).

thriving coastal trade port in the Early Postclassic (Graham et al. 1989; Pendergast 1990; Guderjan and Garber 1995), and the large quantity of Zakpah ceramics recovered there points to connections with Lamanai and other sites in northern Belize (Ting 2013).

Masses of Postclassic ceramic imports recovered on the lagoon shoreline east and south of Structure N10-4 may reflect greater involvement in commerce during the Postclassic period (Pendergast 1985: 98; Graham 2004: 228; Powis et al. 2009: 259). Some of the structures from this time appear to face the lagoon, and farther south, several residential buildings (N11-5, N11-7, and N11-9) were constructed along the waterside during the Terminal Classic and Postclassic periods (Howie 2012: 24), further supporting the strong connection of Lamanai's residents to coastal trade routes during the period (e.g. Chapman 1957; Sabloff and Rathje 1975; McKillop 1996; Masson 2002; Masson and Freidel 2012, 2013; King 2015).

In 1976, 15 samples (13 wood charcoal fragments, one charred bean sample, and one charred maize sample) from Structures N10-2, N10-7, and N10-9 produced a series of uncorrected dates[3] that spanned the Classic and Postclassic periods.[4] The samples from primary contexts within Str. N10-2 (GX-4660, 4661, 4663, 4670) suggested that Postclassic ceramic trends (represented by Buk/Zakpah Group ceramics) were well developed by AD 1140 (Pendergast 1981: 49–50). Reanalysis of these dates below indicates an even earlier appearance for this phase.

The Sampling Contexts: Plaza N10[3], the Ottawa Group

To the west of N10-4, two structures (Strs. N10-12 and N10-77) from Plaza N10[3] (Figure 2) provide a second set of ^{14}C dates from ongoing excavations since 1998 (Graham 2004, 2007). Nicknamed the "Ottawa Group" by Canadian students working with H Stanley Loten in 1975, Plaza N10[3] lies just north of the Jaguar Temple (N10-9). The range structures that were exposed through excavation in 1981 and 1982 (Pendergast 1982b, 1985, 2006: 66)—Strs. N10-15, N10-28, N10-17, N10-18 on the north, east, and west sides of the plaza, respectively—showed Late Classic (AD 625–750) and Terminal Classic (AD 750–960) activity, with a large number of cached ceramics recovered from excavations in those structures. Burials that cut through the collapse of these buildings contained Buk-phase vessels, originally dated by Pendergast to the Middle Postclassic (AD 1200–1350). The plaza area itself was cleared only far enough to expose the stairs of the excavated structures; its full extent was not uncovered until work in 2002 and 2003.

Beginning in 1998, new excavations at the Ottawa Group have revealed that the last standing masonry architecture around Plaza N10[3] dates to the transition from the Late Classic to Terminal Classic periods. Towards the end of the 8th century, the masonry buildings were razed (except for Strs. N10-15 and N10-18) and the entire courtyard filled with 2.5 m (21,000 metric tons) of large, quarried blocks, sascab (eroded limestone bedrock), and Terminal Classic midden (dubbed the "Boulders" phase), and then capped with plaster. Excavations in 2002–2003 identified that the southern structure of the courtyard, Str. N10-77, was covered by a low masonry platform that supported a wooden superstructure (Str. N10-12) dating to the Terminal Classic and Early Postclassic periods. Buk-phase burials within the Boulder core were thus found to be associated with this perishable building (Graham 2004: 235). Wooden buildings

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[3] "Corrected" here is defined as the correction derived from measured δ^{13}C (^{13}C/^{12}C or converted from ^{14}C/^{12}C), normalized to –25‰ VPBD. See Table S3 (online Supplemental Material) for corrections made to these dates.

[4] As a result of this imprecision, only the lab numbers and a summary of the data were published at the time (Pendergast 1981: 49).

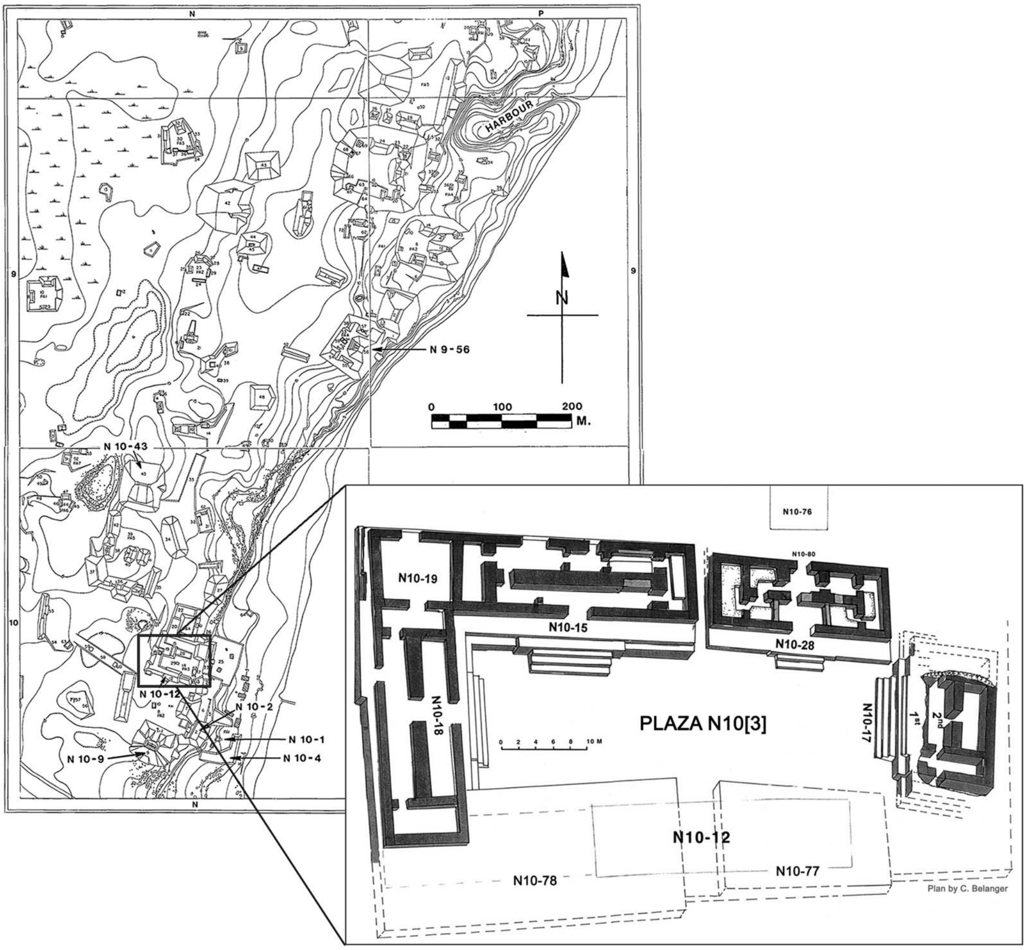

Figure 2 Plaza N10[3] (Ottawa Group) (from Graham 2004)

were also built atop N10-17 and N10-28. Masonry additions and alterations continued to be made to N10-15 and N10-18, but ultimately these, too, were razed, and wooden structures on low stone platforms were built atop what remained. As a result of these investigations, the timing of the Buk phase was subsequently realigned from the Middle Postclassic period (AD 1200–1350) (Graham 1987; Pendergast 1981) to the Early Postclassic period (AD 900/960–1200) (Graham 2004).

METHODS

During the 2002–2003 field seasons, excavations in 15 contexts from N10-77 and N10-12 yielded 17 wood charcoal samples: 12 from secure primary deposits (11 caches and one burnt stratum), and three from less secure, secondary contexts (one from a midden used in a bench extension, one from the core of a bench, and one sample from a concentration of Zakpah sherds in the Boulder core). Identification of botanical materials was conducted at the Paleoethnobotanical Laboratory at the University of Cincinnati, after which the samples were sent to the Oxford Radiocarbon Accelerator Unit (ORAU) for accelerator mass spectrometry (AMS) ^{14}C analysis in 2007.

Table 1 All ^{14}C dates from Lamanai (see the Appendix for complete information).

					Unmodeled cal AD	
Lab # (Sample #)	Lot #	Structure	δ^{13}C	Corrected ^{14}C	Range	*P*
GX-4659	LA 30/1C	N10-2	−24^	1786 ± 139*	90 BC–AD 565	95.40%
GX-4660	LA 34/1C	N10-2	−17.4*	915 ± 115	710–1225	95.40%
GX-4661	LA 34/2C	N10-2	−25.6*	830 ± 120	975–1395	95.40%
GX-4662	LA 110/1C	N10-2	−25.3*	1235 ± 130	550–1035	95.40%
GX-4663	LA 115/1C	N10-2	−27.7*	715 ± 130	1035–1435	95.40%
GX-4664	LA 115/2C	N10-2	−24^	1251 ± 129*	545–1025	95.40%
GX-4665	LA 136/1C	N10-2	−26.2*	1690 ± 125	55–600	95.40%
GX-4666	LA 139/1C	N10-2	−24^	826 ± 134*	905–1410	95.40%
GX-4667	LA 166	N10-7	−24^	1526 ± 134*	215–770	95.40%
GX-4668	LA 167/1C	N10-2	−24^	926 ± 129*	775–1385	95.40%
GX-4669	LA 171/1C	N10-2	−24^	1191 ± 129*	605–1150	95.40%
GX-4670	LA 177/1C	N10-2	−24^	1061 ± 124*	685–1215	95.40%
GX-4671	LA 207	N10-9	−24^	1611 ± 134*	125–660	95.40%
GX-4672	LA 208	N10-9	−24^	1511 ± 134*	215–775	95.40%
GX-4673	LA 209	N10-9	−24^	1401 ± 188*	240–1020	95.40%
OxA-17968 (1)	LA 1742	N10-12	−25.9	1050 ± 24	900–925	5.00%
					960–1025	90.40%
OxA-17969 (2)	LA 1764	N10-77	−26.8	1312 ± 25	655–725	70.40%
					740–770	25.00%
OxA-17970 (3)	LA 1777	N10-77	−25.7	1409 ± 25	600–665	95.40%
OxA-17971 (4)	LA 1778	N10-77	−25.3	1423 ± 25	585–660	95.40%
OxA-17972 (5)	LA 1779	N10-77	−26.3	1367 ± 26	615–685	95.40%
OxA-17973 (6)	LA 1783	N10-77	−26.1	1280 ± 24	670–770	95.40%
OxA-17974 (7)	LA 1784	N10-77	−26.1	1304 ± 25	660–725	65.90%
					735–770	29.50%
OxA-17975 (8)	LA 1785/1	N10-77	−26.7	1297 ± 25	660–730	63.10%
					735–770	32.30%
OxA-17976 (9)	LA 1798	N10-77	−26.1	1284 ± 25	665–770	95.40%
OxA-17985 (3)	LA 1777	N10-77	−26.6	1402 ± 25	600–665	95.40%
OxA-18014 (10)	LA 1894/6	N10-12	−26.3	1282 ± 26	665–770	95.40%
OxA-18015 (11)	LA 1894/8	N10-12	−26	1206 ± 26	715–745	6.10%
					765–890	89.30%
OxA-18016 (12)	LA 2522	N10-77	−26.2	1260 ± 26	665–780	90.50%
					790–805	1.70%
					810–825	0.90%
					840–865	2.30%
OxA-18017 (13)	LA 2524	N10-77	−26.1	1275 ± 26	670–775	95.40%
OxA-18018 (14)	LA 2525	N10-77	−26.1	1331 ± 27	645–715	81.40%
					740–765	14.00%
OxA-18019 (14)	LA 2525	N10-77	−26.1	1282 ± 26	665–770	95.40%
OxA-18020 (15)	LA 2532	N10-77	−28.3	1240 ± 26	685–780	64.50%
					785–875	30.90%
OxA-18021 (16)	LA 34/1C	N10-2	−9.62	856 ± 25	1055–1255	95.40%
OxA-18022 (18)	LA 115/1C	N10-2	−26.2	950 ± 25	1020–1155	95.40%

Calibrated with OxCal v4.2.4 (Bronk Ramsey 2013).
IntCal13 northern atmospheric curve (Reimer et al. 2013); all calibrations rounded to 5.
*Estimated, based on Stuiver and Reimer 2015, see text and Table S3.
^Based on Stuiver and Polach (1977).

At ORAU, the samples first underwent standard ABA pretreatment to remove intrusive sediments and contaminants (Brock et al. 2010; Staff et al. 2014). The wood was shaved (20–100 mg) with a scalpel, and then soaked in 1M HCl for 20 min. The sample was then rinsed in ultrapure water before undergoing repeated 20-min soakings in 0.2M NaOH until the solution was colorless. The samples were again washed in ultrapure water and subjected to the final ABA stage of soaking for 60 min in 1M HCl. Wood samples are then typically soaked in a 5% bleach solution for no more than 30 min, to break down resins, waxes, and lignin. Samples are then freeze-dried so as to provide optimal conditions for combustion and graphitization. Dried samples were loaded into tin capsules, combusted, and converted into N_2 and CO_2. The CO_2 was graphitized using methods laid out in Dee and Bronk Ramsey (2000). Finally, the samples were measured in ORAU's HVEE tandem AMS system, online since 2002.

In addition to the 17 AMS ^{14}C dates from the Ottawa complex, three contexts from N10-2, originally dated in 1976, were reanalyzed at ORAU (contexts LA 115/1C, LA 34/1C, and 34/2C). One of these new samples (34/2C) did not produce a carbon yield and was subsequently rejected for AMS ^{14}C redating.[5]

For the present paper, all samples were recalibrated using OxCal version v 4.2.4 (Bronk Ramsey 2009b, 2014a) and 100% of the IntCal13 Northern Hemisphere curve (Reimer et al. 2013). Of the 15 contexts from N10-77 and N10-12 that produced samples, two (LA 1777 and LA 1894) contained two samples each (hence 17 total samples from these structures). These 17 samples, plus the two successfully reanalyzed from 1977, are presented in Table 1 and detailed in the Appendix (online Supplemental Material), along with the other 15 ^{14}C dates mentioned above, run by Geochron Laboratories in 1977. The Appendix also includes the remaining set of available dates from Lamanai that were not used in a modeled sequence below, including those from N10-9 (the Jaguar Temple), N10-27 (the only structure associated with a hieroglyphic date), and N10-77. A total of 34 dates are presented in these tables, comprising the complete list of ^{14}C samples available from Lamanai to date, excluding the core samples taken in the New River Lagoon by Metcalfe et al. (2009) and the original 1500 BC date from the Harbor area (Pendergast 1998).

Evaluation of the 1976–1977 Geochron Dates

The first set of samples from Lamanai was analyzed by Geochron Laboratories (Cambridge, MA) in December 1976 through February 1977. By 1976, most ^{14}C labs in the USA had adhered to the conventions laid out in the roughly 10 major ^{14}C conferences since 1954 (see list in Taylor and Bar-Yosef 2014: 305). Still, it was not until Stuiver and Polach's (1977) publication that all labs began following the same standard practices. Even though these standards were presented at the July 1976 international conference in San Diego and Los Angeles, it is possible that some were not yet in place when the Lamanai samples were run at Geochron. Thus, before incorporating these dates in our analysis, we needed to assess the exact procedures used by Geochron at the time the samples were run in 1976 [see the supplemental data in Kennett et al. (2013) for another example of evaluating conventional radiometric dates; also Kennett et al. 2014].

According to laboratory announcements made in the journal *Radiocarbon* (Krueger and Weeks 1965, 1966), Geochron began ^{14}C analysis in 1964, using the gas proportional counter technique (CO_2 method). At this time, pretreatment of wood samples included hot dilute HCl to remove

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[5] At ORAU, as at many labs, if a sample cannot be measured during stable isotope analysis, it will be rejected on the basis that any date attached would be improperly corrected and likely misleading (ORAU website 2015).

carbonates, hot 2N NaOH to remove humic acids, and "thorough rinsing" (Krueger and Weeks 1965: 47). Libby's revised half-life (5568 ± 30) was used, as is still the convention today (Godwin 1962). Oxalic acid was used as the standard for modern activity (Olsson 1970), though the oxalic acid reference was likely the original 1957 NBS mixture rather than the "new" batch produced in 1977 (Taylor and Bar-Yosef 2014: 122). Because the "new" batch contained slightly more activity than the original, using the original standard would actually have improved the quality of the measurement (though the error ranges were so wide at this time as to make the improvement negligible). The reference year used was 1950, as was required for all dates published in *Radiocarbon* after 1962 (Flint and Deevey 1962). However, it was not until Stuiver and Polach (1977) that $\delta^{13}C$ corrections were required in reporting, though many researchers continued to report "uncorrected" dates thereafter (meaning the $\delta^{13}C$ fractionation effects were not normalized). No reports of dates from Geochron during this decade contain $^{14}C/^{12}C$ ratios or $\delta^{13}C$ corrections (e.g. Honea 1975; Phillipson 1977; Nelson 1980).

For the Lamanai samples, Geochron initially reported only the "uncorrected" dates, but corrections for five samples were eventually sent in a later report. Unfortunately, while Geochron is still in business (now with an AMS service), they no longer possess records going back to 1976, so we cannot obtain the original report to see if any other $\delta^{13}C$ values were taken. Instead, we used Stuiver and Polach's table (1977: 358) to estimate the $\delta^{13}C$ values for the remaining samples and then input those into a fractionation spreadsheet provided on the CALIB website (Stuiver and Reimer 2015) (see Table S3 of the Supplemental Material). As described above, the corrected dates were then calibrated using the IntCal13 Northern Hemisphere curve (Table 1 and Appendix).

Modeling

The quality and quantity of the available ^{14}C samples allowed two Bayesian models to be constructed for structures N10-2 and N10-77/N10-12 using the OxCal v 4.2.4 software package (Bronk Ramsey 2014a). OxCal uses a Markov chain Monte Carlo (MCMC) sampler to approximate all possible solutions and probability outcomes (Bronk Ramsey 2008, 2009b).[6] Bayesian statistics allow archaeologists to incorporate "prior" information about the samples into the statistical model, including relative stratigraphic and architectural sequences, monument dates, textual dates, ceramic chronologies, and unknown gaps between samples (Bronk Ramsey 2009b; Kennett et al. 2011, 2014; Culleton et al. 2012; Inomata et al. 2013, 2014; Hoggarth et al. 2014; Overholtzer 2014; Huster and Smith 2015; Ebert et al. 2016). The relative ordering of samples within the stratigraphy of an excavation can therefore verify and constrain the calibrated date ranges. Given such influence, the prior knowledge must be robust, ideally from uncompromised, primary contexts with known associations to ceramic, architectural, or other chronologies (Pendergast 2000; Bronk Ramsey 2009b).

In some cases, the statistical model is able to identify incongruent (outlier) date ranges, allowing the researcher to investigate why certain samples may be problematic. In OxCal, this is indicated by the agreement index, which has a scale of roughly 0–100% and a cutoff at 60%, correlated to the 5% confidence interval of a chi-square test (Bronk Ramsey 1995, 2009b). This indicates the agreement between a sample's prior value and its posterior value from the

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[6] A full explanation of Bayesian techniques is beyond the scope of this paper, but interested readers should consult seminal works by Buck et al. (1991, 1996), Steier and Rom (2000), Bayliss (2009), and Bronk Ramsey (2009b).

model. Despite their usefulness, high agreement indices only show that the probability ranges are compatible—it is up to the researcher to decide, based on all available evidence, whether the agreement is actually significant. Graphically, the effects of model constraints can be seen in the generated histograms (Figures 3 and 5), where the original, unmodeled ranges are grayed in the background and the newly constrained (posterior) ranges are darkened in the foreground.

Even within pristine deposits, samples taken from the same context often cannot be placed in sequential order (e.g. multiple vessels in the same cache). Because the group as a whole precedes or succeeds other groupings, a *phase* designation in OxCal can be used as a container for an unordered group of dates within an otherwise ordered sequence. Similarly, the use of a *boundary* provides margins for an unknown span of time between two samples or phases (Bronk Ramsey 2000).

Because Bayesian models are the products of multiple lines of evidence, it can be difficult to use modeled data in subsequent ^{14}C sequences without including all of the prior information. For example, in the case of N10-77, two rooms with separate sequences were situated below structure N10-12, with the thick Boulder layer between them (Figure 3). This means that the N10-12 dates must be *later* than both N10-77 rooms, while the rooms themselves are independent sequences. In order to include all three sequences within the same OxCal plot, an *After* command (or *terminus post quem*) (Bronk Ramsey 2014b) was used, along with an *xref* parameter to cross-reference the end dates in each sequence. Likewise, provenience LA 1764 was from a burnt stratum in Room B2 but represented the final termination event of Str. N10-77, which thus had to come *after* the last cache of the adjacent room (Floor 1, Room C). Since there is an unknown span of time between the Floor 1 cache and termination event, the *boundary* for the end of Floor 1 was cross-referenced instead of the latest sample from Floor 1. Similarly, a *terminus ante quem* of AD 1544 was used at the end of each model as a final constraint for the year Spanish encomiendas were established at Tipu and Lamanai (Graham 2011: 49). These parameters can be seen in Figure 3 and in the OxCal codes listed in Table S2 of the Supplemental Material.

Sum and Trapezoidal Probabilities

In addition to Bayesian modeling, all available dates were also evaluated using the OxCal *sum* and trapezoidal boundary models (Figure 4). Summed probability distributions essentially function the same as *phase* designations except that one histogram is generated for all samples within the sequence (Bronk Ramsey 2014b). A sum plot was generated for all dates studied in this project and is shown grayed in the background of Figure 4.

Figure 4 also includes a bar graph of 25-yr binned intervals, which depict a tally of the number of samples falling within a given 25-yr period (using individual 2σ ranges). For example, the modeled, 2σ range for sample OxA-18016(12) is AD 680–750, which means it was tallied for the four periods AD 675–699, AD 700–724, AD 725–749, and AD 750–774. Unlike sum probabilities, the 25-yr bins are not informed by the ^{14}C calibration curve, giving each sample's entire probability equal weight. Because it is still influenced by the measurement's precision, however, this can become particularly deceptive. For example, the Buk-phase sample from LA 177/1C (dated via conventional means in 1977 to AD 685–1215) would have counted in 22 bins—over 500 yr—had it not been first constrained by the Bayesian model to AD 965–1215 prior to its incorporation in the tally. Both the sum and 25-yr graphs are also biased by the archaeologist's choice of samples (Culleton 2008; Williams 2012; Contreras and Meadows 2014). For Lamanai's dates, both distributions suggest either a potential bias in sampling or a decrease in activity between the Terminal Classic and Postclassic periods, which will be

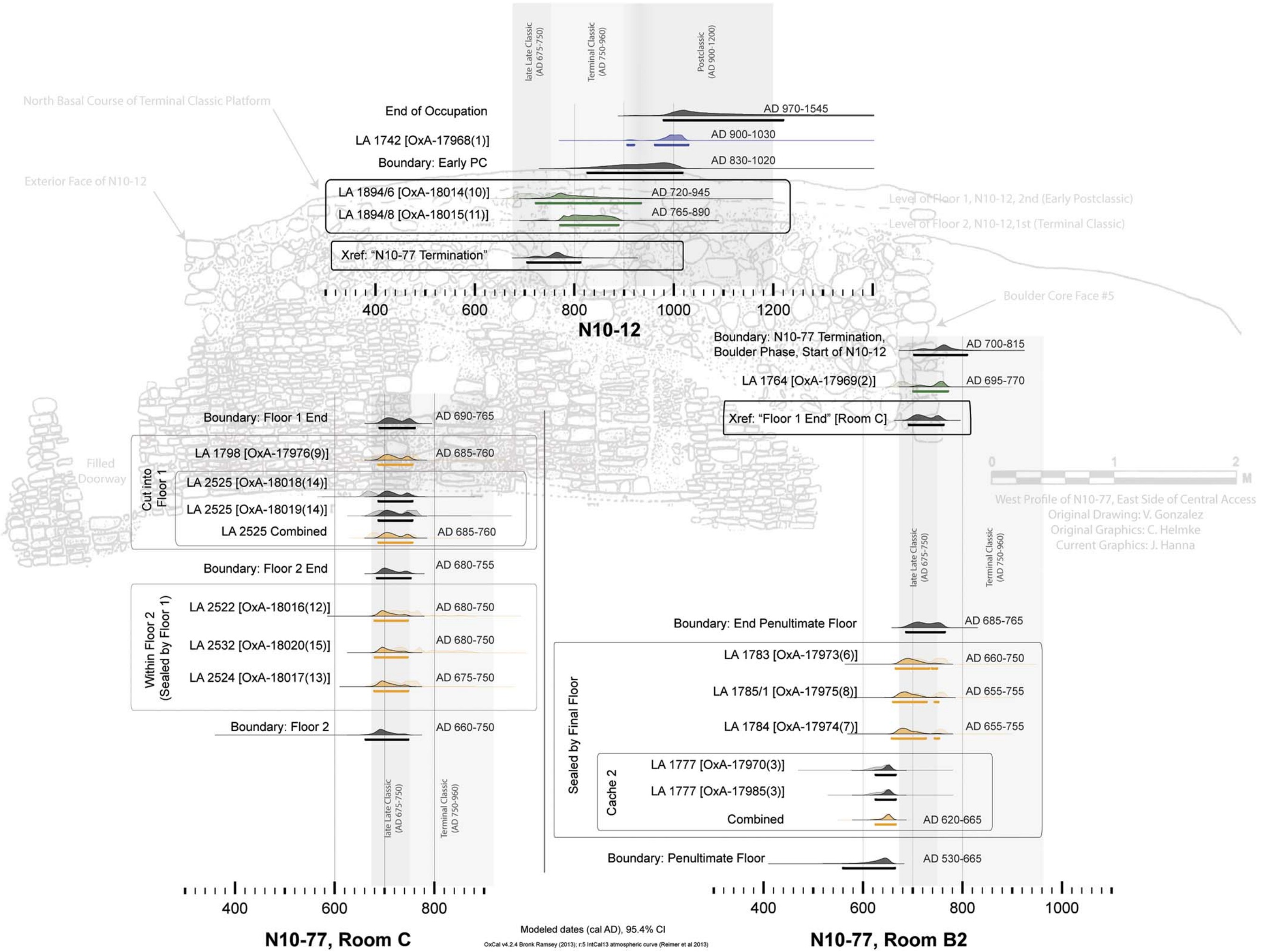
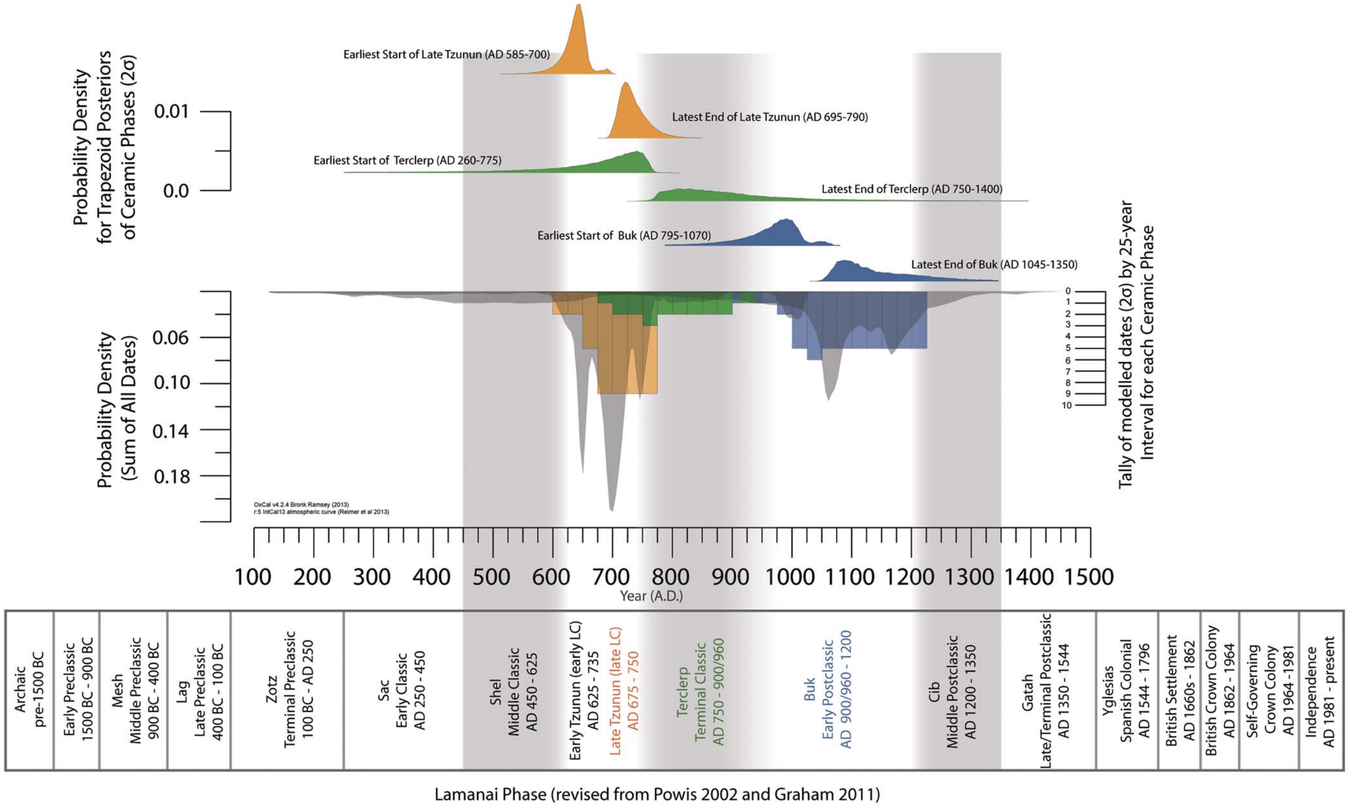


Figure 3 Modeled Sequence for Structures N10-77/N10-12, Ottawa Group, Lamanai (colors in the online version correspond to samples used in Figure 4 ceramic sums)



Samples Included in Ceramic Phases:

Late Tzunun: LA 1783 [OxA-17973], LA 1785/1 [OxA-17975], LA 1784 [OxA-17974], LA 1777 (combined OxA-17970 & OxA-17985), LA 1798 [OxA-17976], LA 2525 [combined OxA-18019 & OxA-18018], LA 2522 [OxA-18016], LA 2532 [OxA-18020], LA 2524 [OxA-18017]
Terclerp: LA 1894/6 [OxA-18014], LA 1894/8 [OxA-18015], LA 1764 [OxA-17969]
Buk: LA 34/1C [combiined GX-4660 & OxA-18021], LA 34/2C [GX-4661], LA 115/1C [combined GX-4663 & OxA-18022], LA 177/1C (GX-4670), LA 1742 [OxA-17968]

Figure 4 Samples associated with diagnostic ceramics (colored in online version), with trapezoidal probability distributions and sum of all samples in background discussed more below. Viewed appropriately, however, one could say the *sum* function and 25-yr tally depict the “strength” of our knowledge about each phase and offer a simple method for identifying tipping points in cultural activity (for other successful examples, see Hoggarth et al. 2016; Bettinger 2016; Zahid et al. 2016).

Samples associated with the same ceramic phase were also evaluated using a trapezoidal distribution. For the construction sequences (Figures 3 and 5), the default uniform distribution is appropriate because they represent abrupt events like floors and renovations. For ceramic phases, however, modeling with a trapezoidal distribution simulates the more gradual changes seen in typological seriations (Brainerd 1951; Robinson 1951; Lee and Bronk Ramsey 2012). The trapezoidal model in OxCal uses a Student’s *t* distribution to estimate the absolute beginning and absolute end parameters of the typology, giving it a wider range and less precision than the uniform model (though it approximates a uniform distribution as the transition lengths approach zero). However, because the duration is never completely 0, it avoids the abrupt transitions of uniform models and provides a more nuanced understanding of the gradations between phases. The trapezoidal distribution was applied in the manner described by Lee and Bronk Ramsey (2012; see also Lee et al. 2013), where three boundaries (start, middle, end) are anchored at the beginning and end of each phase. For these data, 17 posteriors from the earlier models associated with diagnostic ceramics (listed at the bottom of Figure 4) were saved as *.prior* files in OxCal and cross-referenced in a trapezoidal plot for each Lamanai phase. The three plots (Tzunun, Terclerp, and Buk) were then combined into one graph in Grapher 11 by Golden Software, Inc. Samples without definitive ceramic associations were not incorporated, including some posteriors from the earlier models (e.g. LA 139/1C, LA 115/2C, and LA 110/1C).

RESULTS

Outliers in Structures N10-77 and N10-12 (Ottawa Group)

Of the 17 AMS ^{14}C dates from the Ottawa Group, two were not refined in our Bayesian analysis, and another two were identified as outliers by the models. As mentioned above, LA 1778 and LA 1779 were transposed secondary contexts inside bench features and therefore did not contain sufficient prior information to be included in a model. OxA-18018(14) from LA 2525 and OxA-18014(10) from LA 1894/6, on the other hand, were outlier dates that could not be reconciled in the standard (uniform) model because of low agreement with other samples in the same cache (see the Appendix for the probability values). Given their unexpectedly early ranges, these may have been cases of “old” (e.g., heirloom) wood, where the ^{14}C is much older than the associated event (Schiffer 1986; Kennett et al. 2002; Taylor and Bar-Yosef 2014: 67–70). Because the samples were from caches of burnt materials, often following architectural renovations, there is a risk that the charcoal selected for AMS ^{14}C dating was derived from old building materials or other household items that predate the caching event.

There are several ways to handle outliers. The easiest way is to simply drop the sample altogether. If going that route, it is best to still include a *boundary* in the outlier’s place (which is also a way to check the accuracy of the “Charcoal” models described below). Another common and intuitive technique is to use the outlier as a *terminus post quem* (TPQ, using the *After* command). Unfortunately, however, the TPQ method is a coarse start/stop function that could push subsequent distributions out of agreement with their prior information (see Dee and Bronk Ramsey 2014: 90).

A far better method for handling and evaluating outliers, described by Bronk Ramsey (2009a), is to run all the dates in OxCal by calling a normal distribution *OutlierModel(N(0,2),0,“t”)* instead of the standard, uniform model— where *t* means the timing of the event may have been wrong (rather than the ^{14}C measurement), and *N* calls a normal distribution with a mean of 0 and a standard deviation of 2. This will provide a rough probability on whether a given date is an outlier, as long as all samples are subsequently tagged with *Outlier(0.05)* to designate how often divergent iterations should be down-weighted (0.05 is used because 1 in 20 charcoal dates are older than the associated event) (Bronk Ramsey 2009a). This method identified LA 2525 [OxA-18018(14)] and LA 1894/6 [OxA-18014(10)] as likely outliers, confirming a similar output from the agreement index when using the standard model.

The latter method can be taken even further by using an exponential distribution ("Charcoal") or a long-tail Student's *t* distribution ("General") outlier model in OxCal (Bronk Ramsey 2009a; Dee and Bronk Ramsey 2014). The Charcoal model hinges on the idea that "old" dates could be better integrated into the sequence by using an *exponential* curve, where the density of dates from the same context would rise precipitously over the true date and then diminish exponentially. Rather than a rough TPQ, then, the "old" date creates a curving influence on the others, pushing them towards the ends of their distributions but still within the parameters of the model.

In using the outlier models with Lamanai's dates, it was decided to keep all wood samples tagged with *Outlier(0.05)*, as all are expected to be at least 1 yr older than the deposition event. The General and Charcoal models were then used in tandem, where the "good" dates were fitted to the General model shown below, and the potential "old wood" dates were fitted to the Charcoal model at 1.0 (or 100% probability) (see Supplementary Materials for further descriptions of these models).

For the combined dates from LA 1777, LA 2525, and LA 1894, the syntax is slightly different. A "t-type" outlier model cannot be used on individual samples within the *R_Combine* container because the assumptions of t-type models and R_Combine are in conflict (i.e. either all of the samples should have the same measurement or they should not). This therefore requires the inclusion of a normal distribution within the R_Combine operation ("SSimple" model), followed by a General outlier applied overall:

```
R_Combine("Cache 2")
  {
    {Outlier("General", 0.05);};
    R_Date("LA 1777 [OxA-17985(3)]", 1402, 25) {Outlier("SSimple", 0.05);};
    R_Date("LA 1777 [OxA-17970(3)]", 1409, 25) {Outlier("SSimple", 0.05);};
  };
```

The combined dates from LA 1777 were always in high agreement, so the 0.05 outlier probability here is simply a safety check. For the other two combines in the other sequences, however, there was less agreement between samples. Excavators described 1894/6 and 1894/8 as having been likely placed in the cache at the same time. The initial (standard) model, however, indicated OxA-18018(14) from LA 2525 and OxA-18014(10) from LA 1894/6 as too old for their contexts, potentially due to old wood.

For LA 1894, Lentz identified 1894/6 as having a mixture of plant parts, including stems and tubers (similar to LA 1785), but all identifiable genera were trees (pine, logwood, and sapote), whereas its accompanying vessel, 1894/8, contained solely pine wood charcoal. However, the sample size of *Pinus caribaea* (57.25 g) in 1894/6 was nearly six times larger than that of 1894/8 (9.38 g), which may have left 1894/6 more susceptible to old wood, possibly explaining the ~80-yr disparity between the two vessels. Because of the low agreement introduced into the model by combining these dates, the R_Combine parameter was removed and they were instead *phased* using a 1.0 Charcoal outlier for 1894/6 and a 0.05 General model for 1894/8. This allowed both samples to (cautiously) continue informing the model and obtain a more robust posterior probability for how much 1894/6 is at odds with the sequence. As a result, LA 1894/6 now effectively functions as a *boundary*, reducing the impact of its measurement but still loosely influencing 1894/8.

For cache LA 2525, there were no comparable clues regarding why the two sample dates were so vastly different. In this case, they were from the same vessel, likely burnt *in situ*, and both identified as entirely *Pinus caribaea* charcoal by Lentz. Throughout extended experimentation with different models and parameters, sample OxA-18018(14) was repeatedly identified as an outlier, likely due to old wood (perhaps outer bark vs. inner heartwood). Because the overall agreement of the N10-12 model was 85.9%, the low agreement between the combined LA 2525 samples (26.5%) could be safely ignored, with OxA-18018(14) simply assigned a 1.0 probability in the SSimple model. This was considered more favorable than dropping OxA-18018(14) or phasing them separately, since they were from the same vessel. The final result of this analysis was the high-resolution model of N10-77 and N10-12 presented in Figure 3 and detailed in the Appendix.

Structure N10-2

Excavation of Structure N10-2 (Pendergast 1981) showed that it was a focal point of Postclassic activity in the southern section of the site. Unfortunately, the samples analyzed in 1977 exemplify the low precision of conventional techniques, with distributions that are spread several centuries wide and virtually meaningless for the timescales relevant to Maya archaeology. What the N10-2 sequence needed, therefore, were new, high-precision AMS ^{14}C dates that could be used to constrain (or replace) the originals. Along with the Ottawa Group samples in 2007, Graham submitted three previously dated (Geochron) samples from N10-2 as a test. Two of these provided a critical foundation for modeling the N10-2 sequence (Figure 5), but problems measuring the $\delta^{13}C$ values of the third sample (from LA 34/2C) led to its rejection for redating. By linking the associated construction events to the redated samples using Bayesian techniques, the once expansive ranges in N10-2 have now been heavily constrained. The sequence is less robust than the Ottawa model because the only primary sampling contexts known are the two redated in 2007 (LA 34/1C and LA 115/1C). Nonetheless, it is clear that the N10-2 ^{14}C sequence lends a strong line of support to the existing ceramic and architectural evidence for Postclassic continuity at Lamanai. Future sampling from other structures in this area and to the south would buttress this chronology further.

The N10-2 Bayesian model was simpler than Ottawa's, with boundaries laid between each construction phase as a check, and only one phase containing multiple dates (the "Gom" construction phase, which is associated with diagnostic Buk ceramics; Graham 1987: 85, Figure 5–h). Eleven Geochron ^{14}C dates and two ORAU AMS ^{14}C were available from Structure N10-2, of which 11 total were included in a Bayesian uniform model—the locations within the construction sequence for LA 167/1C and LA 136/1C were not known (see Figure 5 for list of N10-2 construction phases). The samples from LA 171/1C and LA 30/1C were identified early on as outliers hundreds of years too early for their associated contexts (and roughly 1% chance of agreement with other samples around them; see Appendix). As with the N10-77/N10-12 sequence, however, the use of outlier models allowed them to still contribute some information to the sequence.

Some problems arose from vessels LA 34/1C and LA 34/2C in Cache 2 (samples GX-4660, GX-4661, and OxA-18021) and vessel LA 115/1C (GX-4663 and OxA-18022). LA 34/2C was from the same context as LA 34/1C, but when combined with the other samples, it strongly offset the overall model agreement. Because they are two separate vessels, this may be an indication that they were placed at separate times, but the sealed context had led excavators to believe they were concurrent (34/2C was instead phased with the combined 34/1C dates in the model).

Caching with Old, New, and Ancient Wood in N10-2

As mentioned in the Ottawa modeling section, charcoal caches present the risk for old wood. Because conventional radiometric techniques required much larger sample sizes, the measurement taken by Geochron's gas counting should have had a much higher risk of old-wood effects than a newer AMS date from the same cache. For LA 115/1C, then, it was unusual that GX-4663 (AD 1035–1435) turned out to be *younger* than its new equivalent, OxA-18022 (AD 1020–1155). LA 115/1C was from wall construction that dates to the beginning of the 4th phase of N10-2 during the Early Postclassic. Pendergast's notes from 1976 described the contents of LA 115/1C as "probably wattle," and Lentz identified it as "young wood," with mostly *Pinus caribaea* (pine) and a small amount of *Acromia aculeata* (palm). Because this material was likely assembled just prior to the construction event, some of it (probably the pine wood) may have been recycled from a previous structure. This would explain how it could be "young" when initially harvested but still older than the event being dated. The smaller size of the AMS ^{14}C sample (OxA-18022) means that it had a higher chance of containing *purely* old wood, while the larger, conventional sample (GX-4663) averaged both old and new wood. Thus, both samples are older than the construction event, but the old Geochron sample is

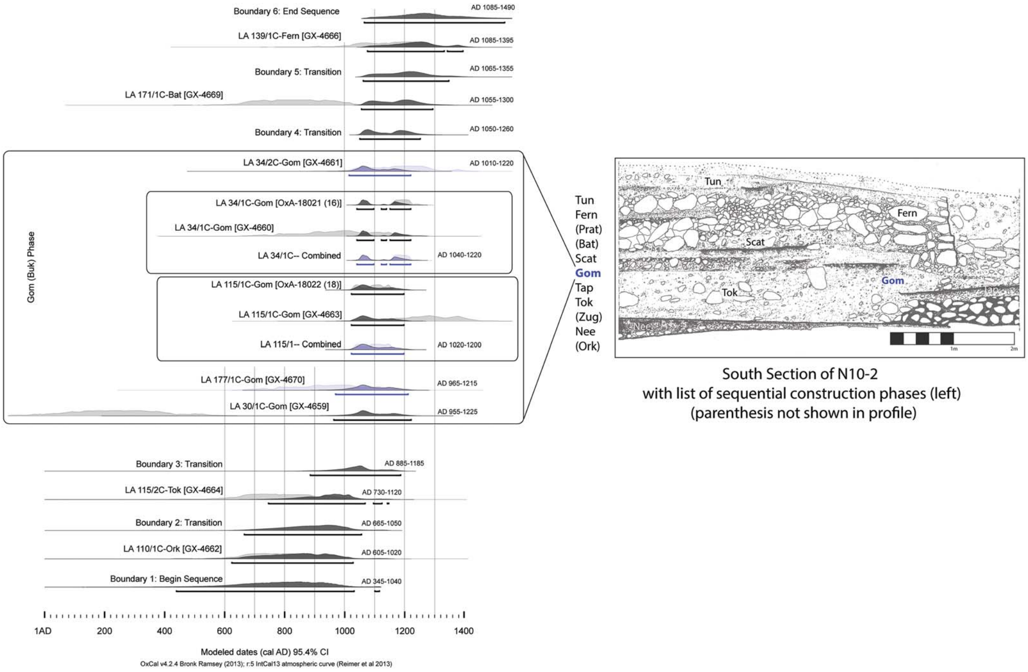


Figure 5 Modeled sequence and stratigraphy for Structure N10-2, Lamanai (colors in online version correspond to samples used in Figure 4 ceramic sums).

probably closer to the "true" date. Additionally, because GX-4663 was a combination of old and new wood, its 2σ range still overlapped with OxA-18022, satisfying a chi-square test for compatibility (Ward and Wilson 1978) and allowing the samples to remain combined in the Bayesian model. Sample OxA-18022 was subsequently given a 1.0 outlier value and GX-4663 given a 0.5 value, granting GX-4663 more influence, but the actual construction event for LA 115/1C still likely occurred towards the later end of the modeled 2σ range of AD 1020–1200.

For the LA 34/1C samples (GX-4660 and OxA-18021), the older, conventional date does appear to have an old-wood effect, given that it is significantly older than its AMS equivalent. LA 34/1C was a cache containing stick-like figurines overlying maize and beans, burnt as an offering at the abandonment of the 4th phase of N10-2. Both Pendergast in 1976 and Lentz in 2007 noted that the samples consisted primarily of charred maize. GX-4660 was also one of the samples for which Geochron had provided the corrected date, though not the actual $\delta^{13}C$ value. Thus, we were able to input the corrected and uncorrected dates into CALIB's fractionation spreadsheet, as described above (Stuiver and Reimer 2015), and backwards-calculate the original $\delta^{13}C$ readings for that particular sample. Geochron appears to have measured –17.4‰ $\delta^{13}C$ for GX-4660, which is exactly where you would expect a mix of maize (–10‰) and wood (–24‰) (Stuiver and Polach 1977: 358). The $\delta^{13}C$ reading for the smaller AMS sample (OxA-18021) was –9.62‰ $\delta^{13}C$, pure maize. Thus, the small amount of wood that was included in GX-4660 (e.g. pieces of the stick figurines) likely contained "old wood," causing the ^{14}C determination to be older than OxA-18021. As in the 115/1C case, both 34/1C samples passed a chi-square test for compatibility (again, the larger sample size of the conventional date lessened the old-wood effect), but their influence on each other caused high enough disagreement within the overall model that sample GX-4660 had to be assigned a 1.0 outlier value. Because OxA-18021 was purely maize, its date is likely very close to the original caching event, with a modeled date of AD 1040–1220. Since, as described above, LA 115/1C dates to the beginning of this construction phase and likely occurred within the 12th century, the latter portion of the 34/1C modeled date (AD 1150–1220, CI: 44.3%) appears more plausible than is granted by the final model. In fact, the unmodeled date for OxA-18021 was AD 1150–1255 (CI: 91.9%), indicating that the sample's placement within the Bayesian model may actually have had a deleterious effect on its accuracy, in part because of interactions with the ^{14}C curve (see Appendix and Supplementary Materials for more).

One last note should be made regarding GX-4659, the extreme outlier from a Buk-phase lot (LA 30/1C) in N10-2. This sample appears to date roughly 1000 yr earlier than its associated deposit, making its measurement wholly ignored in any model. Though problematic for our purposes, it should be emphasized that such aberrant outliers are not "bad" dates. Indeed, the accuracy of the measurement is not in doubt. Rather, the antiquity of the date causes us to wonder: what kind of wood was being burned in this cache that was so incredibly ancient? It is unlikely that ancient wood would be readily accessible as firewood from common house materials or midden— particularly in a tropical climate. It seems more plausible that this cache contained pieces of discarded heirlooms or older construction materials (e.g. lintels) from recently dismantled or ritually terminated structures. Further analysis of the species of wood present in this cache, its contextual information, and continued high-precision dating may provide additional clues to the human behavior underlying this peculiar sample.

DISCUSSION

The results of the chronometric work presented above have implications for the Late Classic/ Terminal Classic ceramic chronologies at Lamanai, as well as for the timing of the Boulders construction effort in the Ottawa Group. The original scenario for Plaza N10[3] held that sometime between AD 950–1050, the courtyard was filled and the masonry structures of the Ottawa Group were razed and covered—the Boulders phase (Pendergast 1986: 232). Later excavations redated the Boulders construction to the Terminal Classic (~AD 800) based on the stratigraphy of courtyard infill and primary ceramics associated with N10-77 (Graham 2004). The refined chronology presented here confirms that the infilling of the courtyard dates to sometime around the end of the 8th century. The ^{14}C dates for the final occupation of N10-77 (Floor 1) date to AD 680–755, with a final termination (razing) event shortly after, between AD 700–815; the Boulders phase likely began just after that termination. Two diagnostic vessels associated with Floor 1 provided ideal markers for a true Late Classic to Terminal Classic transition: an upturned, glossy-black, Late Classic (Tzunun) vase filled with burnt wood fragments (LA 1785/1) and sealed by the final floor, followed by a diagnostic Terminal Classic (Terclerp) basal-break bowl stamped into the burnt floor during the structure's termination (LA 1764) (Graham 2004: 236–7). Their associated samples date to AD 655–730 (CI: 93.2%) and AD 695–770 (CI: 95.4%), respectively (Figure 6). While significant overlap exists between these dates, there are clear ceramic and stratigraphic differences between the Late Classic and Terminal Classic, including the shift from masonry to wood construction mentioned above (Graham 2004).

Above the Boulders phase, additional carbonized caches were found in the core of the masonry platform supporting N10-12/1st. The platform, as noted above, was built as the courtyard was

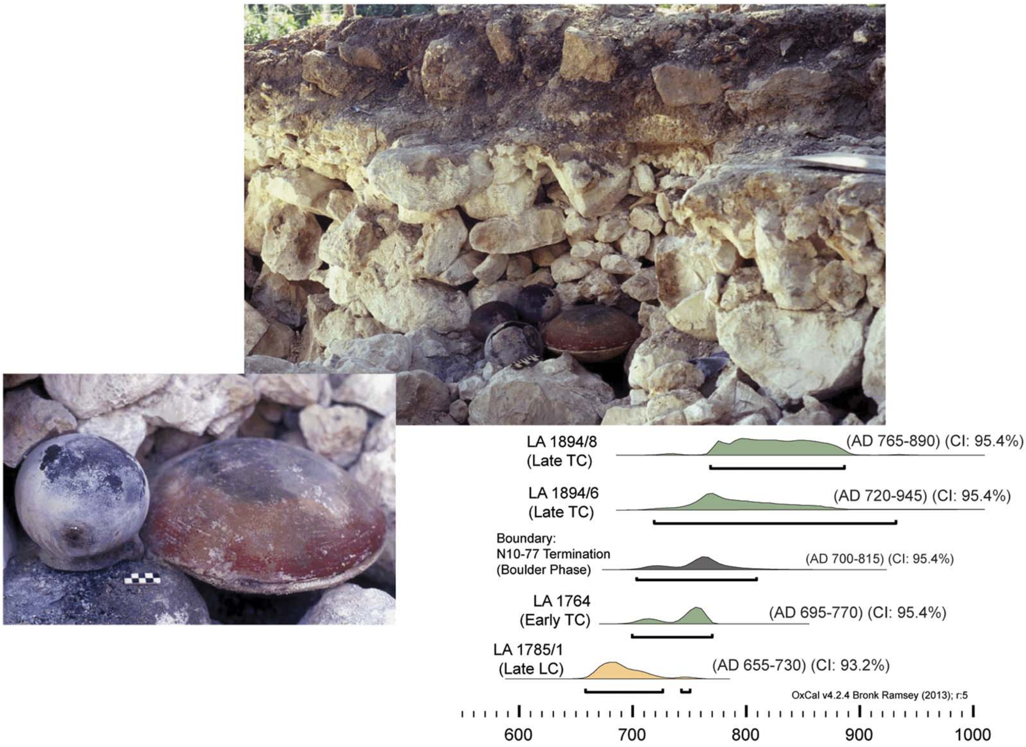


Figure 6 Diagnostic ceramic markers for transition from the late Late Classic to early Terminal Classic to late Terminal Classic at Lamanai; photos of cache LA 1785.

filled, so samples within it provide a potential end date for the Boulders construction effort. The caches associated with N10-12/1st comprise either monochrome red-slipped or polychrome lip-to-lip shallow ceramic bowls (LA 1894/8 and 1894/6)—characteristic of Lamanai during the Terminal Classic. The samples from LA 1764 (the burned basal-break vessel) and LA 1894/8 therefore serve as early and late markers for the Terminal Classic period. The boundary calculation estimates the first occupation of N10-12 occurred between AD 700 and 815, and the date for LA 1894/8 is AD 765–890. Figure 6 highlights these important chronological markers.

When combined with the other dates associated with Late Tzunun (Late Classic) pottery in N10-77, these new (modeled) dates now push the Late Tzunun phase back 60 yr earlier, from a previous start time around AD 735 to 675. Likewise, the start of the subsequent Terclerp (Terminal Classic) ceramic phase may be pushed back roughly 25 yr, from a start of AD 775 to 750 (ending sometime between AD 900–960). These changes are reinforced by the probability density graphs (Figure 4), which provide the combined probabilities for all samples associated with diagnostic Tzunun ($n = 9$), Terclerp ($n = 3$), and Buk ($n = 5$) ceramics.

For the N10-77/N10-12 sequence, the only Early Postclassic date is from LA 1742. This sample derives from a concentration of Zakpah sherds and charcoal that were determined to be intrusive into the Boulder core and probably part of a burial in the N10-12 platform just above (Pendergast 1982a; Graham 1987, 2004; Wrobel and Graham 2015). Given the tendency of material to shift among the stones of the core, however, we cannot be as certain of this association as we can with other samples. Ceramic evidence indicates that the structure was occupied into the Late Postclassic, but no charcoal was recovered from any later contexts.

The sample from the LA 1742 burial cache also contained pine as the main material. *Pinus caribaea* is a prevalent wood type in Terminal Classic caches at the site but has only been found in two other Early Postclassic contexts, both of which likely contained old wood: LA 115/1C and LA 34/1C (discussed above). Although caching continued through the Colonial period (Graham et al. 1989), the practice appears to have decreased following the Terminal Classic, when the main structural interments became human burials instead of ceramic caches (Pendergast 1998). It is interesting that Rushton et al. (2013: 491) observed declining pollen signals for pine during times of major construction, particularly AD 600–975, but saw a resurgence after AD 1000. It appears that the prevalence of *Pinus* caching exhibits an inverse relationship to the pollen record, suggesting that the decline of its use in caches may be correlated to its heavy exploitation as timber and firewood (Thompson 1930; Vogt 1981; Rushton et al. 2013) as well as for ritual use (Lentz et al. 2005; Morehart et al. 2005; Prufer and Dunham 2009; Robinson and McKillop 2013). Perhaps confirming its use for construction, wall materials sampled in LA 115/1C contained old *P. caribaea* wood, and the burnt stratum sampled from N10-77 (LA 1764) contained only pine. Caches LA 1894/8, 2525, and 34/1C also contained old pine wood. Thus, if *P. caribaea* was a preferred source of timber at Lamanai, it is unsurprising that old wood (e.g. from house renovations or terminations) was so strongly represented in caches.

Finally, the broadest impact of the chronometric work presented here is perhaps the continuity demonstrated between the Terminal Classic and Postclassic periods at Lamanai. Though the dates available suggest decreased activity in the site core during the 10th century AD, there is clearly overlap between the Terclerp and Buk phases, as shown in the N10-12 sequence (Figure 3). The "lull" may be, in part, an artifact of the number of samples measured from the Terclerp phase. A larger sample of ^{14}C AMS dates from this transition would resolve the ambiguity. Likewise, the latest ^{14}C date available (GX-4666 from LA 139/1C in N10-2) provides only tentative evidence for occupation after ~AD 1300, but the ceramic chronology at the site continues with the Gatah (AD 1350–1544) and Yglesias (AD 1544–1700) phases, for which no ^{14}C dates yet exist (Graham 2011). The problem—one faced at many Postclassic sites (Masson and Mock 2004: 378)—is the paucity of well-sealed primary contexts that can yield organic samples like those from the lower levels of the Ottawa Group. Additionally, the Terminal Classic is characterized at many sites by a transition in construction techniques—notably a reduction in masonry architecture. As a result, several centuries of occupation following the Late Classic are often represented by only thin scatters of debris that are difficult or impossible to discern. These issues continue to present obstacles for the selection of high-quality samples from Postclassic contexts and highlight the potential for alternative dating programs, such as those that directly date human burials from primary contexts (Hoggarth et al. 2014; Kennett et al. 2015).

CONCLUSION

This paper presented 19 new ^{14}C dates for the site of Lamanai and demonstrated the power of Bayesian analytical techniques for chronological refinement of old and new dates. The new cluster of ^{14}C samples from the Ottawa Group corroborate existing stratigraphic and ceramic records that the years spanning the Late Classic to Postclassic periods at Lamanai were characterized by continuous activity, albeit with changing sociocultural mores. The massive Boulder construction effort and subsequent shift to wood construction indicate that the priorities of Lamanai's elites began to change as early as the end of the 8th century AD (Graham 2004). This was a time of frenetic activity across the Maya lowlands when many cities experienced peak population levels (Sabloff and Henderson 1993; Adams et al. 2004; Hammond and Tourtellot 2004; Rice and Forsyth 2004; Robichaux and Houk 2005; Sullivan et al. 2007; Ebert et al. 2014) tempered by drought, increased warfare, and political fragmentation (Hodell et al. 2005; Kennett et al. 2012) and the rise of the northern Lowlands (Hoggarth et al. 2016). Lamanai's endurance was never believed a complete anomaly (Pendergast 1986: 226), and we now know that many communities survived, adapted, and endured into the Postclassic period (Webster 2002; Demarest et al. 2004; Aimers 2007). The evidence presented here refines the chronology for perhaps the most tenacious of such communities, and may have implications for other sites in the region whose ceramic traditions and political affiliations were tied to those of Lamanai.

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SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit http://dx.doi.org/10.1017/RDC.2016.44

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