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A CENTENNIAL AMBIGUITY: THE CHALLENGE OF RESOLVING THE DATE OF THE JEAN-BAPTISTE LAINÉ (MANTLE), ONTARIO, SITE—AROUND AD 1500 OR AD 1600?—AND THE CASE FOR WOOD-CHARCOAL AS A *TERMINUS POST QUEM*

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ABSTRACT. Considered in isolation, the radiocarbon (^{14}C) dates on short-lived plant remains from the Jean-Baptiste Lainé (formerly Mantle) site, Ontario, yield an ambiguous result: more or less similar probability around AD 1500 or alternatively around AD 1600. This village site, likely of no more than ca. 20–30 years total duration, illustrates the challenges of high-resolution dating across periods with a reversal/plateau in the ^{14}C calibration curve. Another problem we identify is the tendency for dating probability for short-duration sites to sometimes be overly compressed as dating intensity increases under analysis with OxCal, and for probability to shift away from the real age range especially during reversal/plateau episodes. To address both issues additional constraints are necessary. While a tree-ring sequenced ^{14}C "wiggle-match" is the best option where available, we investigate how, in the absence of such an option, use of the in-built age in wood-charcoal samples can be used to distinguish the likely correct date range. This approach can resolve ambiguities in dating, e.g., for shorter-duration Late Woodland village sites in northeastern North America, but also other short-duration cases corresponding with reversal/plateau episodes on the ^{14}C calibration curve. We place the Jean-Baptiste Lainé site most likely in a range between ca. AD 1595–1626 (95.4% probability).

KEYWORDS: Bayesian modeling, Huron-Wendat, Jean-Baptiste Lainé (Mantle), Late Woodland, North America.

INTRODUCTION

Jean-Baptiste Lainé (formerly "Mantle") is among the largest and most extensively excavated Northern Iroquoian sites currently known from Ontario, Canada (Birch and Williamson 2013): *hereafter J-BL*. Based on the material culture and the absence of all but minimal European trade goods (two pieces of European copper, one piece of iron), a date for the site was originally proposed as ca. AD 1500–1530 (also Williamson et al. 2016: 238; Williamson 2014: 6) (note: all calendar dates in this paper are AD). Further, it was argued that the site was the last village occupation of a contiguous sequence of three village sites in the West Duffins drainage belonging to the very same community and comprising (in sequential order) the Draper, then Spang and then J-BL sites. The initial pair of radiocarbon (^{14}C) dates from J-BL lay on the reversal/plateau in the ^{14}C calibration curve 1480–1630. They could support calendar ages around 1500 or around 1600. In keeping with understandings of the local ceramic seriation and the presence of only a very small quantity of European metal at the site, Birch and Williamson (2013) therefore proposed a date of ca. 1500–1530. This was entirely reasonable given the knowledge then available.

Subsequent analysis of additional ^{14}C dates from these three sites suggested a major chronological revision (Manning et al. 2018a). Those from Draper clearly indicated a date range in the earlier to mid-16th century, and not the mid-15th century or ca. 1450–1475 as

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previously supposed (e.g., Williamson et al. 2016: 242; Birch and Williamson 2013: 30): Figure 1 (note: for a description of each model in each Figure in this paper, see Methods below and in particular the Supplementary Material). It was generally assumed and stated that the Draper site was "undoubtedly occupied prior to Mantle" (Williamson et al. 2016: 242). Given ethnohistoric understandings and archaeological evidence regarding the frequent relocations of Iroquoian villages in the sixteenth century, on the order of once every 20–40 years or less (Warrick 1988; Fitzgerald 1990: 123–133; Fitzgerald et al. 1995:120; Birch and Williamson 2015; Birch et al. 2021: 66–67), the ^{14}C dates from all three sites were consistent with favoring the archaeologically inferred settlement relocation sequence as probable: Draper then Spang then J-BL. The result, if this ordering of the sites is accepted, given the clear (non-ambiguous) placement of the Draper ^{14}C data, was that both Spang and then J-BL must be after the earlier to mid-16th century. This analysis appeared to resolve what was otherwise a dating ambiguity looking at the Spang or J-BL ^{14}C evidence in isolation. It suggested a date for the J-BL site ca. 1587–1623 at 95.4% probability, nearly a century more recent than previously assumed. This result was of course an initial surprise, since it ran contrary to the conventional expectations.

If the inferred settlement relocation sequence is correct, then the ^{14}C picture was, and is, clear. In the past, several such "readily recognizable site relocation sequences of contact period Iroquoian groups in southern Ontario and New York" (Fitzgerald et al. 1995:118) formed more or less standard assumptions within the field. However, do we continue to regard the accepted inferred Draper-Spang-Mantle (J-BL) settlement sequence (Birch and Williamson 2013) as secure? Times and thinking continue to change and (hopefully) improve: the ^{14}C-led rethink of this period in northeastern North America, in particular, has led to critical re-assessment of a number of past assumptions and theoretical constructs (e.g., Birch 2020; Birch et al. 2021; Manning et al. 2019, 2021). In particular, recent work based on both social network analysis and ^{14}C has now strongly questioned several past assumptions concerning inferred linear site sequences/order relationships, and in turn the nature and extent of population circulation and movement between villages in different sequences (e.g., Manning and Hart 2019; Birch and Lesage 2020; Hart 2020; Birch and Hart 2021; Manning et al. 2021).

Today, greater skepticism might therefore be addressed towards the hypothesis of an inferred linear site relocation sequence for the Draper, Spang, and J-BL sites. It remains possible from the available ^{14}C evidence, but it should not be considered *a priori* to form the only potential historical trajectory. Indeed, recent geophysical prospection and renewed excavations at Spang revealed neither the site layout nor the dense quantities of material expected, based on comparisons with Draper and J-BL (Curtis and Birch 2020). Although additional excavation is required for resolution, this recent work has raised further questions about the nature and intensity of occupation of Spang and whether it is isomorphic with either the Draper or J-BL community. Thus, although consideration of the ^{14}C evidence from each site would indicate that some degree of order relationship is most likely, this need not necessarily be linear. It could instead include possible overlaps or alternatively be non-contiguous. In general, assessed today, it is clearly a desideratum to try to evaluate, and date, each such village site independent of any past assumptions regarding inter-village chronological relationships derived merely from archaeological "inference" (and so avoid a circular logic chain). Indeed, it has become clear that material culture cannot be used arbitrarily as a comprehensive guide to past community/ethnic identification and thus does not provide a refined temporal measure for settlement ordering in northeastern North

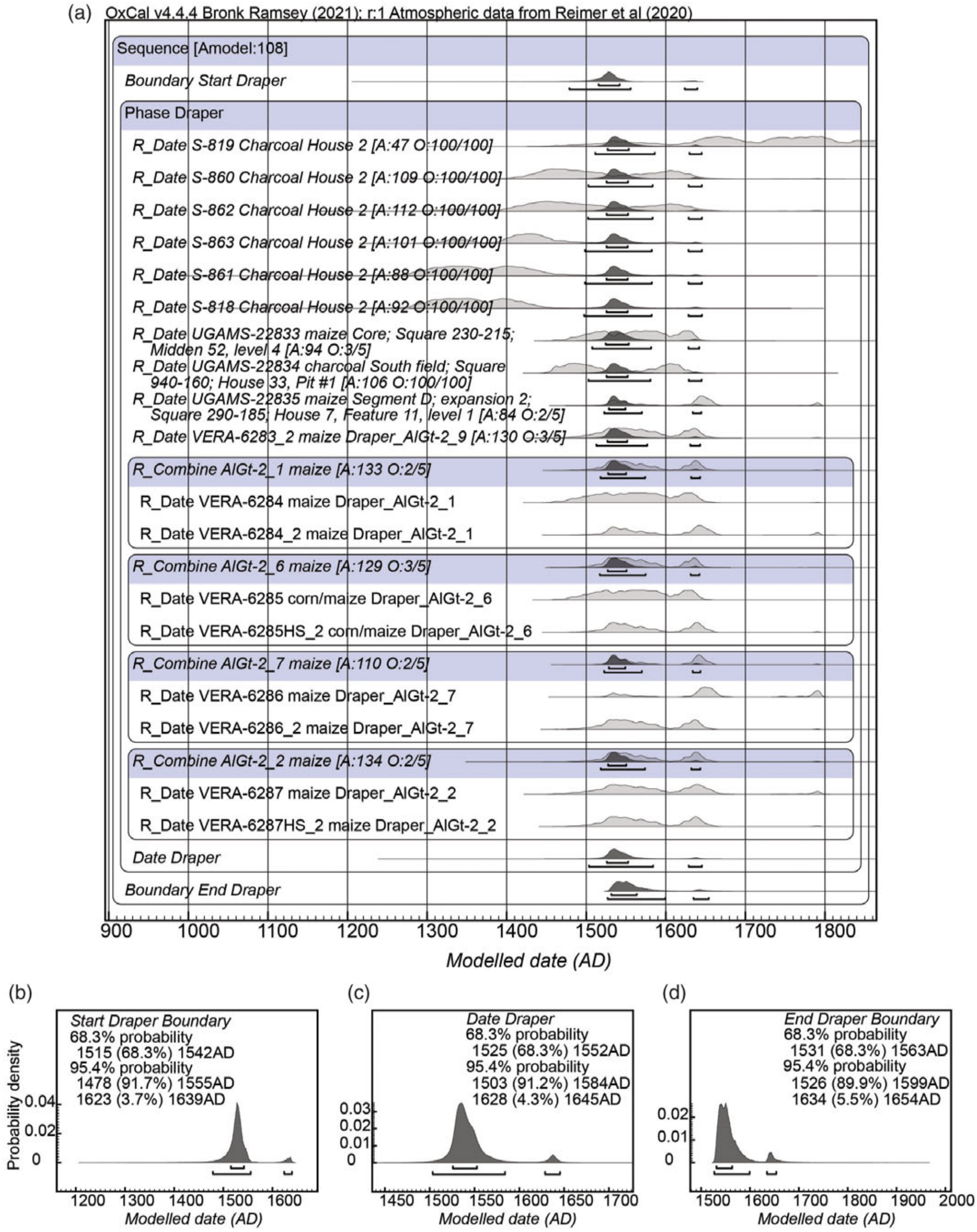

Figure 1 [14]C data from the Draper, Ontario, site from Manning et al. (2018a) modeled in isolation. See Methods. (a) Overall site model. (b) Modeled start `Boundary`. (c) Modeled `Date` query applied to the site `Phase`. (d) Modeled end `Boundary`. Data from OxCal (Bronk Ramsey 2009a, 2009b) version 4.4.4 and IntCal20 (Reimer et al. 2020) with curve resolution set at 1 year.

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America (e.g., Gaudreau and Lesage 2016; Birch and Lesage 2020). A caveat should therefore apply to previous work relying solely on such inference-based assumptions pending independent confirmation (e.g., Manning et al. 2021).

We therefore re-examine the dating of J-BL in isolation. We use only evidence available directly from the site itself. This is a challenge, as the ^{14}C data from the site inherently offer two possible dating solutions. But, in reality, it is possible for only one of these to be correct. We identify the likely plausible solution for the site, but also note the possible problems. We find that the ^{14}C dates available on selected wood-charcoal from early in the site's history, and the in-built age represented within these, are central to resolving what is otherwise an ambiguous situation, along with use of the archaeologically inferred *intra*-site sequence. Such an intra-site sequence here refers to where distinct ordered phases can be archaeologically observed and so provide the elements where C > B > A, etc., in an OxCal `Sequence` analysis (Bronk Ramsey 1995, 2009a). Note: OxCal Chronological Query Language (CQL2) terms, like `Sequence`, `Phase`, `Boundary`, when used in the context of OxCal employment, are shown in `Courier` font. While our paper addresses the J-BL case, the issues and approaches discussed apply to other similar cases affected by dating ambiguities created by calibration curve taphonomy.

J-BL Site Data, Materials Available, and Issues to be Addressed

Jean-Baptiste Lainé (Mantle), J-BL: Site Data

There is a substantial set of ^{14}C dates on samples from J-BL (Manning et al. 2018a). The majority are on short-lived plant remains (n=34), a smaller set are on wood-charcoal (n=8) (see Supplementary Material). The focus on short-lived materials is typical of archaeological dating using ^{14}C in recent decades where priority is placed on short-lived materials securely associated with a context of interest (the target event). The logic is that the dated material (the relevant short-lived organic material) offers a ^{14}C age that is the same as the contemporary atmospheric ^{14}C value. Thus, the dated event (the sample) is deemed equivalent to the target event (the context of interest) in ^{14}C terms (Waterbolk 1971; Dean 1978). However, a problem comes when the relevant ^{14}C age is not unique, and instead the same ^{14}C age can describe two or more quite discrete calendar periods as occurs when the dated event falls on a wiggle/reversal/plateau in the ^{14}C calibration curve. If there is a (securely) known time series, for example from stratigraphy, then such ambiguities can be resolved. This has been a mainstay of work applying Bayesian chronological modeling where the constraints of known order (sequence), and potentially other prior information, allows for resolution of what was otherwise ambiguous (Buck et al. 1991, 1996; Bronk Ramsey 1995, 2001, 2009a; Bayliss 2009). However, when dealing with a single, discrete, and relatively short overall episode, the situation is more problematic.

J-BL is one such problematic example. Modeled in isolation, the dates on short-lived samples, even just those placed into the archaeologically inferred intra-site sequence (only those 22 of the 34 dates on short-lived plant samples that can be so associated with a specific `Phase` within the intra-site `Sequence`), yield an ambiguous result: Figure 2a. Substantial probability lies either around 1500 or alternatively around 1600. The sequence over a short calendar period—and again these Late Woodland village sites are understood to have had lifetimes of no more than ca. 40 years and typically around 20 or 25 years (Warrick 1988; Birch et al. 2021: 66–67)—cannot discriminate between the two possible calendar locations. If we remove the inferred intra-site sequence, and add in the other 12 dates on short-lived plant samples

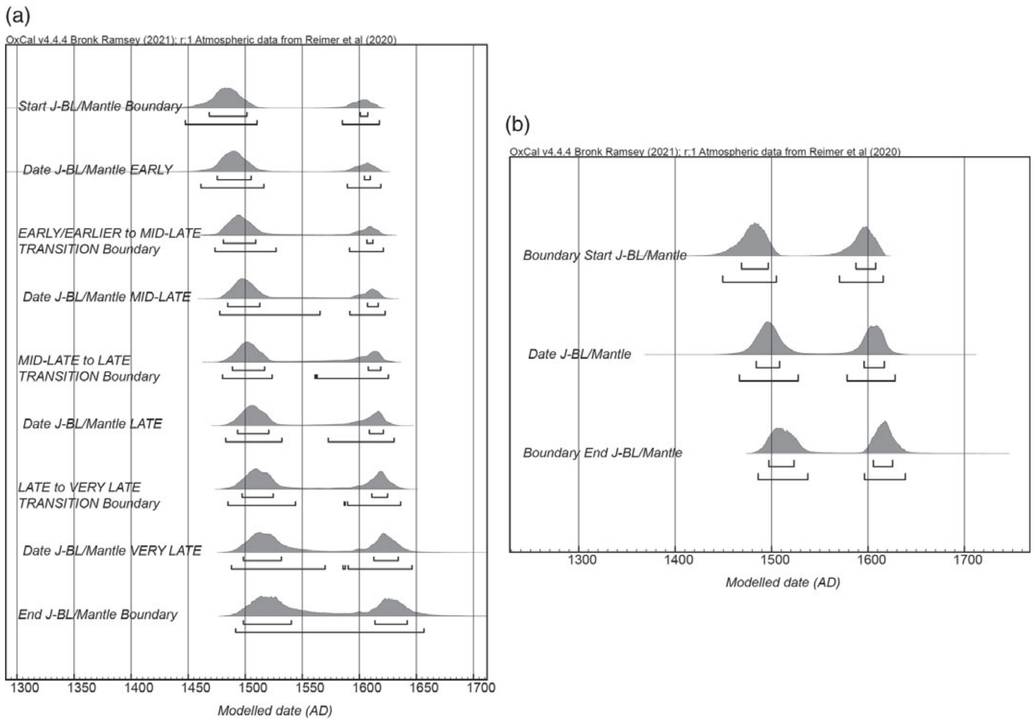

Figure 2 Modeled results from the ^{14}C dates on short-lived plant remains from the J-BL site. (a) Only samples securely associated with each `Phase` from the intra-site `Sequence`, analyzed using this `Sequence`. (b) Modeled results from the set of 34 ^{14}C dates on short-lived plant remains from the J-BL site treated as one `Phase` (no intra-site `Sequence`). Data from Manning et al. (2018a). See Methods and Supplementary Material. The `Boundaries` from start through end of the `Sequence` are shown along with `Date` queries applied to each of the successive `Phases` from the intra-site `Sequence`. Data from OxCal (Bronk Ramsey 2009a, 2009b) version 4.4.4 and IntCal20 (Reimer et al. 2020) with curve resolution set at 1 year.

lacking a specific association within the intra-site sequence, a similar ambiguity results. Considering the most likely 68.3% range from a `Date` query addressed to the site `Phase` yields ca. 1484–1508 (37.4%) or 1596–1617 (30.9%): Figure 2b. These two date placements, seemingly almost equally likely, are around 100 years apart and yield very different historical narratives.

Possible Constraints on Site Dating

If we only had the ^{14}C dates on the short-lived samples, there appears an inherent ambiguity we cannot resolve. Additional data and constraints are required in such cases (as discussed by Meadows et al. 2020; Manning et al. 2020). An ideal solution is where a wood-charcoal sample securely associated with a site context provides a tree-ring sequence covering several decades or more and hence potentially a specific (non-ambiguous) ^{14}C-wiggle-match (Pearson 1986; Bronk Ramsey et al. 2001; Galimberti et al. 2004; Hogg et al. 2017). Analogous examples from the earlier Hallstatt ^{14}C plateau period include Quarta et al. (2010); Jacobsson et al. (2018); and Manning et al. (2018b). Where available, this can provide not only a *terminus post quem* (TPQ) or date for the last extant tree-ring or waney edge (and cutting and use date) but, if it is sufficiently long enough to define a unique (or at least overwhelmingly likely) solution, it can resolve the previous ambiguity. Typically,

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this means a wiggle-match ca. 50+ years in length given the properties of the calibration curve in the last millennium, although even shorter tree-ring sequences linked to specific contexts within a site history can nonetheless be informative (Manning et al. 2020; Manning et al. 2021). An example in the time period of interest is the Warminster, Ontario, site (Manning et al. 2018a, 2019). Here what would have been an ambiguous result considering just the ^{14}C dates on short-lived samples from the site is resolved because of a wiggle-match on the 57 years (tree-rings) preserved of a *Larix laricina* post from a longhouse at the site. Since the external part of this sample is poorly preserved and there is no evidence of original outermost tree-rings or waney edge or bark, we may assume that this post sample is missing a number (unknown) of original outermost tree-rings. The wiggle-match placement of the last extant tree-ring from this structural element therefore reasonably sets a TPQ for the occupation of the site: Figure 3.

There is no such wiggle-match tree-ring sample available from J-BL. We must instead consider other available constraints. Late Woodland village sites usually lack clear vertical stratigraphic sequences. Nonetheless, careful excavation and recording can often determine some aspects of progressive site history: an intra-site sequence (the Draper site provides a notable case where such intra-site sequencing for Late Woodland sites was first archaeologically recognized in detail: Finlayson 1985). For example, there can be evidence of certain structures being extended from their initial built form, or for a subsequent structure as built over (superimposed) on a previous (and hence earlier) structure or feature, or there is other evidence of settlement reorganization or expansion or contraction to which an earlier versus later time characterization may be applied. Such an intra-site sequential history is argued in detail for J-BL with an internal site (village) history running from early to later contexts (Birch and Williamson 2013: 65–77; ASI 2012)—in particular, it is observed that “there is a distinct difference in settlement pattern between the early and late phases” (ASI 2012: 20). Such direct site sequence inference from careful observation and excavation is the basis to practical well-conducted archaeology, and can be regarded as “known” prior information that may usefully and justifiably inform modeling.

However, even where present, such sequences *within* a village lifetime of less than 40 years in total, and on average maybe 20–25 years, typically fail to provide sufficiently distinctive constraints to offer unique placements on the ^{14}C calibration curve if they occur at periods where there is a reversal or plateau (e.g., ca. 1480–1630). Indeed, this is the basic problem. Whether a `Phase` or a `Sequence`, if the total period represented via data and constraints, from start to end, is less than around ca. 50 years or more, then there is often no unique solution in the case of a reversal/plateau that creates two or more possible periods—allowing for measurement errors—with similar ^{14}C dates.

We arrive at the remaining potential source of resolution—commonly lacking because of the focus on dating short-lived plant remains in recent archaeological work using ^{14}C. Even if there is no wiggle-match wood-charcoal sample available, dates on wood-charcoal from the site occupation `Phase` add a TPQ constraint. The very in-built age incorporated into a wood-charcoal sample, and previously deemed to render wood-charcoal a non-ideal dating material (e.g., Schiffer 1986), in fact can offer a key temporal constraint in such circumstances: a TPQ. Further, where available, deliberate selection of some of these samples on the basis of (i) including those from earlier contexts at a site (where an intra-site sequence is recognized), and (ii) including older or inner-most available tree-rings from the available set of samples, can serve to clarify and add to the period of time that a set of

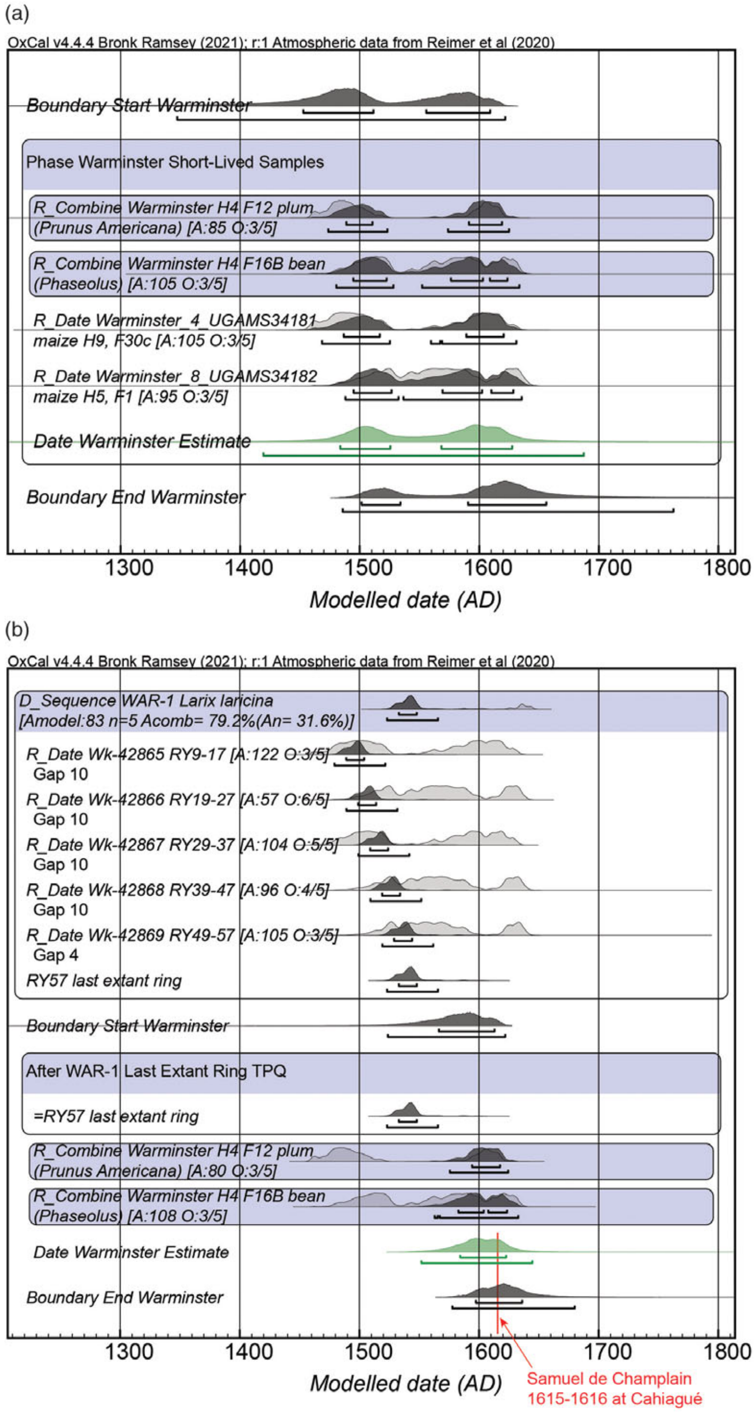

Figure 3 Dating model for the Warminster site, Ontario in isolation. Data from Manning et al. (2018a, 2019). See Methods. (a) Summary of modeled results for the Warminster dates from the site `Phase` on short-lived plant materials only. Ambiguous result. (b) Modeled results incorporating the TPQ information available from a wiggle-match of a post from a structure at the site—this resolves the dating ambiguity. Compare `Date` query for (b) versus `Date` query for (a) Data from OxCal (Bronk Ramsey 2009a, 2009b) version 4.4.4 and IntCal20 (Reimer et al. 2020) with curve resolution set at 1 year.

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such data will represent in terms of the "post" in the TPQ. This expansion of time incorporated is important, since the time occupied by the wood-charcoal TPQ can help identify a unique placement for the site data overall by ruling out what was otherwise an alternative.

Wood-Charcoal TPQ Evidence

In the case of J-BL, there are eight ^{14}C dates on wood-charcoal samples—and each of these samples is from an early context at the site in terms of the intra-site sequence (the Early `Phase` in Manning et al. 2018a): Feature 427—a refuse-filled depression that predates the later House 46; Feature 648—a pit feature associated with the early phase Houses 60 and 61; Feature 718—a pit feature associated with a support post belonging to the early phase House 1 (ASI 2012). An additional point must also be emphasized. None of these wood-charcoal samples represented exterior tree-rings (bark, waney edge, sapwood) or likely shorter-lived samples (twigs, smaller round wood), and several were instead selected deliberately as representing likely heartwood samples. The original aim in selection was to identify and include material with a reasonable amount of "post" in the TPQ for the reasons outlined above. The samples are thus a selection from a possible population of charcoal samples with some bias towards older ages maximizing the "post" in the relevant TPQ. The TPQ provided thus applies to the Early `Phase` of the site and, given the dated tree rings are all at least some (unknown) number of rings = years, from several years to decades to even centuries, *before* the respective cutting and use dates, it is very likely that this TPQ applies to all the dates on short-lived plant material from the site. Hence the eight dates likely form a TPQ for the entire period of the J-BL site. Figure 4a shows the calibration of the eight dates on the wood-charcoal with no modeling. Given that there are several years to a few decades to some centuries of "post" in all the relevant TPQs, this implies that the date for the occupation of J-BL is *after* the earliest likely calibrated date ranges for all these samples (and so the most recent group of the dates on wood-charcoal). If we were to take the very earliest year from the most likely 68.3% calibrated ranges as indicative of about the earliest even plausible, versus most likely, TPQ (to which then some years to decades to centuries should be added, NB) this is 1178, 1431, 1456, 1491, 1501, 1509, 1510, and 1521. The later grouping, suggesting similar ages that likely reflect the beginning of 68.3% ranges indicating the real TPQ for the site, suggests that this must, at the absolute minimum, be *after*, and after by some years to some decades, these starting points of 1501–1521. This minimum scenario suggests that the relevant TPQ likely rules out much of, or even all of, the earlier of the two possible date regions for the site identified in Figures 2a and 2b. Such a conclusion is even more evident if we consider the median values for the non-modeled calibrated probabilities. These are 1199, 1437, 1476, 1563, 1567, 1568, 1571 and 1572, very much ruling out the earlier of the two possible date regions for the site identified in Figures 2a and 2b.

The idea that dates on wood-charcoal samples provide TPQ information is well known. The type of information they describe has also been investigated and suitable quantifications offered. Assuming that there is at least a group of (that is several) ^{14}C dates on a population of wood-charcoal from a context, then, if the sample is a random selection from the possible population, we may assume that these dates will likely offer a specific form of TPQ distribution. A minority of samples may exhibit substantial in-built age (i.e., inner, older tree-rings from longer-lived trees) but most are likely to come from outer wood (simple principles of allometry indicate that ca. 70% of wood volume comes from the radial outer 30% of tree-rings) or from relatively juvenile samples (smaller young trees or branches used for many purposes including fuel, where felling and processing large trees is

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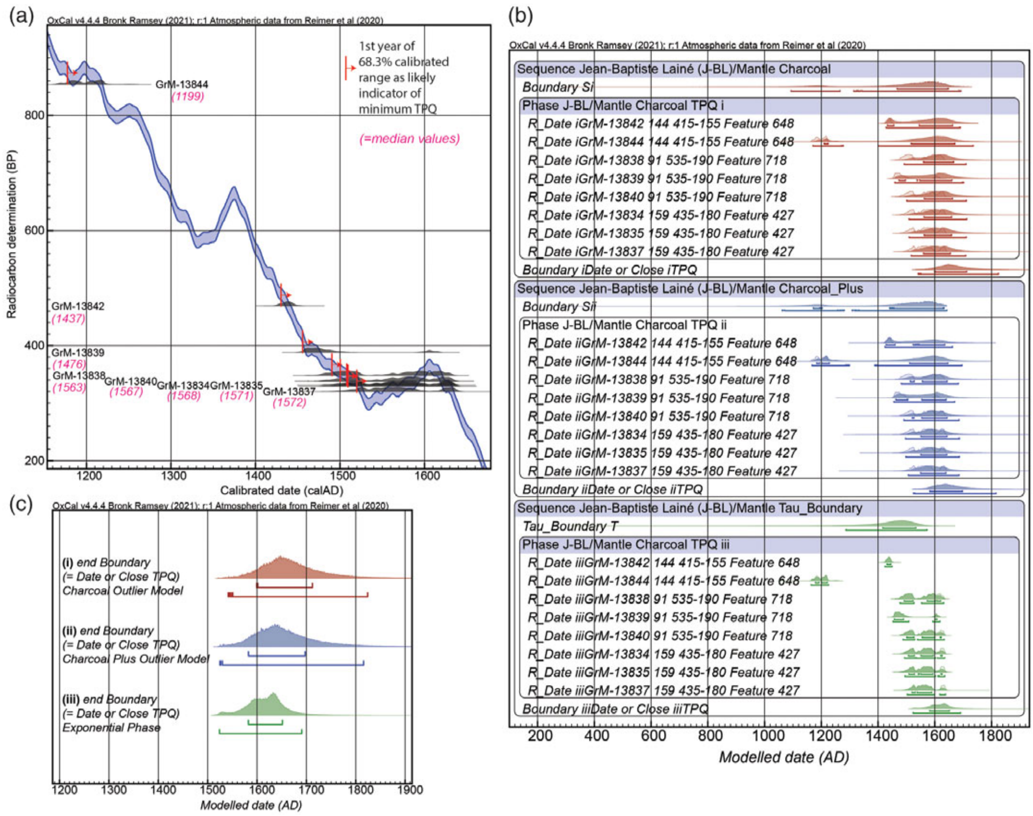

Figure 4 (a) The eight ^{14}C dates on wood-charcoal from J-BL shown, non-modeled, as calibrated calendar age probability distributions against the IntCal20 ^{14}C calibration curve. The earliest date of the most likely 68.3% ranges is indicated in each case. (b) The eight ^{14}C dates on wood-charcoal from J-BL modeled in a `Phase` with the closing `Boundary` defining the date or most closely defined TPQ. (i) with the Charcoal `Outlier_Model`, (ii) with the Charcoal Plus `Outlier_Model`, and (iii) using an exponential `Phase` with a `Tau_Boundary` paired with a `Boundary`. (c) Details of the end of `Phase Boundaries` in (b) defining the date or most closely defined TPQ in each case.

not desirable nor efficient). Thus, a broadly exponential distribution can be anticipated with most dates offering only modest to relatively short to negligible TPQs, and only a few dates offering large to very substantial TPQs (where potentially long-lived tree species are involved). This expected form of wood-charcoal age distribution can be modeled in several ways (Dee and Bronk Ramsey 2014), with reasonable and generally similar results from, in OxCal (Bronk Ramsey 2009a, 2009b; Dee and Bronk Ramsey 2014), use of the Charcoal `Outlier_Model`, the Charcoal Plus `Outlier_Model`, or an exponential `Phase` model using a `Tau_Boundary` paired with a `Boundary`. In each case, the in-built age modeled from the wood-charcoal samples offers a constraint, a TPQ, for the dates from the site on short-lived samples. Figure 4b shows the models and Figure 4c shows the detail of the `Boundary` immediately following a `Phase` with the eight J-BL wood-charcoal dates under the above three approaches. However, as explained above, the eight J-BL wood-charcoal samples were not an entirely random sample of all the available wood-charcoal samples. They were deliberately selected to include some samples maximizing the "post" in the TPQ. Hence the results shown in Figures 4b and 4c are if anything *minimum* requirements and the real relevant age is likely more recent. Therefore, whereas Dee and Bronk Ramsey

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(2014) argued that an `After` TPQ model was the least successful or appropriate approach for a random population of dates on wood-charcoal, in this particular case, where the wood-charcoal samples were deliberately selected to include some older material and were not an entirely random selection, we might argue the opposite. All the dates on the wood-charcoal are likely *before* any of the dates on short-lived plant material at J-BL. Thus, although the logic of an exponential distribution within the wood-charcoal dates likely applies, the end TPQ may be regarded in this case as a TPQ `Boundary` for all the dates on short-lived samples and hence the site `Phases` that these represent. They should not, in this case, be seen as potential temporal elements within the site occupation `Phases`.

Site Duration

A further element of known information applies to Late Woodland sites. As noted above, ethnohistoric and archaeological information attests that the lifetimes of Late Woodland villages were relatively short. In cases where the calendar age range available from a set of ^{14}C dates describes possible long ranges of likely substantially more than ca. 40 years, we may assume that not all this large age range is in fact equally likely. As discussed in previous work, we may consider the effect of applying an assumption reflecting this prior information (Manning et al. 2020; Birch et al. 2021). Incorporating this site duration limit assumption can take the form of a constraint applied to an `Interval` query applied to the overall site `Phase`. Or alternatively, we may use a `Difference` query applied to the time period between the start `Boundary` and end `Boundary` describing the overall site duration. An appropriate solution appears to be a constraint that is to a degree flexible and so able to respect the available data. Thus, the data should be able to overwhelm the prior assumption if they contradict this expectation—and, if so, indicate a problem with this assumption. A Normal distribution offers one satisfactory solution. Given statements in the literature of site duration of no more than ca. 40 years and average lifetimes of around 20 or 25 years, we might choose an anticipated Normal distribution of e.g., `N(20,10)`. Thus a query along the lines of `Interval ("Site Duration",N(20,10))`. Perhaps even better is use of a Log Normal distribution. While the population of all settlements will exhibit a median or average value, it is unlikely the overall distribution of site durations is symmetrical. It is likely that most probability should focus around durations from e.g., 10–25 years with then relatively little probability from 30+ and very especially 40+ years, but with a long tail to allow for the occasional exception. Thus an expected site duration of the form `LnN(ln(20),ln(2))` or similar seems useful. Thus a query along the lines of `Interval ("Site Duration", LnN(ln(20),ln(2)))`.

Over-Compression of Site Durations

A group of dated events from a village site are inherently related, even if unordered. In Bayesian chronological modeling this group of unordered events should be considered as a portion of a population of events that should be treated as a whole. The default assumption is a random population of events sampled from a uniform distribution (a `Phase`) between a start and an end `Boundary` (Buck et al. 1992) as implemented in OxCal (Bronk Ramsey 1995). Without this step, the events are considered as entirely independent of each other. This leads to a wider chronological spread than is realistic (Steier and Rom 2000; Bronk Ramsey 2000; 2001). However, in reverse, as a consequence of using a `Phase` circumscribed by `Boundaries`, there is also a danger in trying to constrain a site occupation to be too short, and especially in a single, isolated, case, where there is considerable dating intensity applied. Indeed, once there are a reasonable number of samples from the dated context, then, unless the target date lies on a plateau in the

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calibration curve that spreads probability, the OxCal Phase command if anything tends to slightly overly compress dating probability as the number of dated elements within the Phase increases. Usually this is not a real concern, but, when the overall Phase duration is relatively short and if there are a number of ^{14}C dates with good precision, this can indeed become a problem. For example, the correct date can in fact fail to be within the 68.3% highest posterior density (hpd) range in some instances. We outline and discuss five hypothetical cases in the Supplementary Material to illustrate this issue. The key relevance of this topic here is that it may serve to increase/decrease the likelihood of an incorrect placement of site dating probability in a case where there is an ambiguity available due to ^{14}C calibration curve taphonomy. In such cases, constraining TPQ data from wood-charcoal (and best a wiggle-match) can therefore help prevent such complications.

METHODS

Our paper reviews and investigates a number of different dating models. The primary ^{14}C data for the sites that are modeled are from a published study (Manning et al. 2018a: Table S1) (see Supplementary Material). Labels for the samples in the Figures are sometimes abbreviated for reasons of display space: for example, F = Feature. The modeling employs OxCal (Bronk Ramsey 2009a, 2009b) version 4.4.4 and the IntCal20 ^{14}C calibration curve (Reimer et al. 2020) with curve resolution set at 1 year. Where shown, the lines under probability distributions indicate the modeled 68.3% and 95.4% ranges. Successful models should yield overall model diagnostic OxCal A_{model} and $A_{overall}$ values that are above the approximate satisfactory threshold value of 60. They should also minimize the numbers of apparent outliers identified. In addition, we should only accept as plausible those models where individual convergence (C) values are $\geq$95. In order to increase the likelihood of model runs returning acceptable Convergence values, we increased the kIterations value from the default value by factors of $\times$10 and $\times$100 in some cases (this lengthens the computer time for a model to complete). Models were run to completion and/or >15M iterations.

The specifics of each dating model are defined in the Figures via the OxCal keywords cited and the groupings indicated. The Supplemental Material provides further description of the models shown in each Figure. Where there are multiple ^{14}C dates on the same sample these were combined into a weighted average (Ward and Wilson 1978) using the OxCal R_Combine function. Within the R_Combine, the OxCal SSimple Outlier_Model is applied to each date. The OxCal General Outlier_Model is applied to the R_Combine result as a whole. The OxCal General Outlier_Model is also applied to each date on a short-lived sample. These outlier models identify the probability that a date or weighted average is an outlier and accordingly down-weight these outliers in the analysis. As indicated in each Figure, the ^{14}C dates on wood-charcoal are variously modeled using (i) the OxCal Charcoal Outlier_Model (Bronk Ramsey 2009b), (ii) the Charcoal Plus Outlier_Model (Dee and Bronk Ramsey 2014), and (iii) an exponential Phase model (using a Tau_Boundary paired with a Boundary), to allow approximately for the in-built age present and to quantify a dating estimate for an end Boundary for a Phase comprising these wood-charcoal dates and which is then a TPQ for the site Phase(s).

RESULTS

The results from the preliminary discussion and data and analysis reviewed in that discussion and illustrating the "topics to address," are shown in Figures 1–4 and Supplementary Material Figures S1–S3.

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Here, we discuss the analysis of J-BL. The key preliminary observation is that the ^{14}C dates on wood-charcoal from the Early Phase (of the intra-site Sequence) at J-BL not only set a very definite TPQ for any later Phases within the intra-site Sequence, but, since none are outermost tree-rings and several were selected as heartwood to try to maximize the "post" in the TPQ, they in fact very likely set a TPQ for the entire J-BL village occupation (see with Figure 4). We therefore consider three possible models.

Figure 5 shows a simplified (two-Phase: Early, Later) intra-site Sequence with those samples linked with one or other (only) of these groupings following the discussion of Birch and Williamson (2013: 65–77; see also ASI 2012). We simplify as the more detailed intra-site Sequence in the Manning et al. (2018a) paper involves a degree of subjective assessment, whereas the Early to Later differentiation within the site history is clear. The aim here is to be as objective as possible. The eight dates on wood-charcoal samples from Early contexts are included within the Early Phase and the Charcoal Outlier_Model is applied to these wood-charcoal dates. Selected results are listed in Table 1 (see note to Table 1). The 68.3% hpd dates resolved for the start Boundary (1591–1611) and the end Boundary (1612–1634) for the site Sequence indicate a likely date range for the site around 1600.

Figure 6 shows the same model but with the Charcoal Plus Outlier_Model applied. The results are very similar: selected elements are listed in Table 1 (see note to Table 1). The 68.3% hpd dates resolved for the start Boundary (1590–1612) and the end Boundary (1612–1635) for the site Sequence again indicate a likely date range for the site around 1600.

Figure 7 uses the same intra-site Sequence but places this after a TPQ from the wood-charcoal samples modeled as an exponential Phase. This better reflects the known information that the wood-charcoal samples dated were deliberately selected to try to maximize the length of the "post" in the TPQ (see above). Selected results are listed in Table 1. The 68.3% hpd dates resolved for the start Boundary (1592–1610) and the end Boundary (1613–1635) for the site Sequence are, again, very similar to those in the Figures 5 and 6 models, and indicate a likely date range for the site around 1600.

There are in addition another 12 ^{14}C dates on short-lived plant remains from contexts that could not be associated with a single Phase within the intra-site Sequence but instead belonged to multiple Phases (e.g., both Early and Later). We include these in the models shown in Figures 8, 9 and 10. Figure 8 considers an overall J-BL Phase with two independent Phases within this, one with the dates from the multiple contexts and one with the intra-site Sequence in Figures 5–7. The eight dates on wood-charcoal are applied to each of these two independent Phases via the Charcoal Outlier_Model. The date ranges for selected elements of this model are listed in Table 2. The Date query for the overall J-BL Phase including both separate Phases yields a most likely 68.3% hpd range of 1597–1618. This indicates a likely date for the site around 1600. A re-run version of this model with the Charcoal Plus Outlier_Model offers very similar results: Table 2. Figure 9 considers a site model (overall site Phase and two independent Phases) as in Figure 8 but places all the site occupation Phases as after a TPQ set by an exponential Phase with the eight wood-charcoal dates. The date ranges for selected elements of this model are listed in Table 2. The Date query for the overall J-BL Phase including both separate Phases yields a most likely 68.3% hpd range of 1596–1620. Again, this indicates a likely date for the site around 1600. Finally, in Figure 10 we consider a dating model for the J-BL site that ignores the intra-site Sequence and simply places all the data (on short-lived samples and wood-charcoal) within a single site

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Table 1 Selected results from the models shown/used in Figures 5-7. *This is the Boundary "Date or Close TPQ Charcoal" in Figure 7.

	Figure 5. A_{model} 94		Figure 6. A_{model} 89		Figure 7. A_{model} 94	
	68.3% hpd	*95.4% hpd*	*68.3% hpd*	*95.4% hpd*	*68.3% hpd*	*95.4% hpd*
Boundary Start J-BL (Mantle)*	1591–1611	1563–1564 (0.2) 1567–1619 (95.2)	1590–1612	1480–1508 (2.9) 1557–1620 (92.6)	1592–1610	1578–1618
Date J-BL (Mantle) Early	1597–1615	1580–1621	1596–1615	1500–1517 (2.0) 1570–1623 (93.4)	1598–1615	1587–1620
Interval J-BL (Mantle) Early	*0–14*	*0–46*	*0–16*	*0–63*	*0–13*	*0–32*
Boundary Earlier to Later Transition	1604–1619	1592–1624	1603–1619	1582–1629	1604–1619	1593–1623
Date J-BL (Mantle) Later	1608–1625	1594–1635	1607–1626	1589–1640	1608–1625	1595–1635
Interval J-BL (Mantle) Later	*0–17*	*0–36*	*0–18*	*0–40*	*0–18*	*0–36*
Boundary End J-BL (Mantle)	1612–1634	1596–1644	1612–1635	1593–1648	1613–1635	1597–1644

Different runs of such models can produce slightly differing results (especially at the less likely extremes of ranges). Use of higher kIterations values can reduce instances of minor, low probability, possible ranges. We illustrate such small differences here through comparison/contrast between the results listed/shown. Figure 5 shows a kIterations = 3000 model run, Table 1 gives results from a default kIterations run; Figure 6 shows a default kIterations model run, Table 1 lists a kIterations = 3000 model run. Figure 7 and Table 1 both show/list the kIterations = 3000 model run. The text cites the kIterations = 3000 model run in each case.

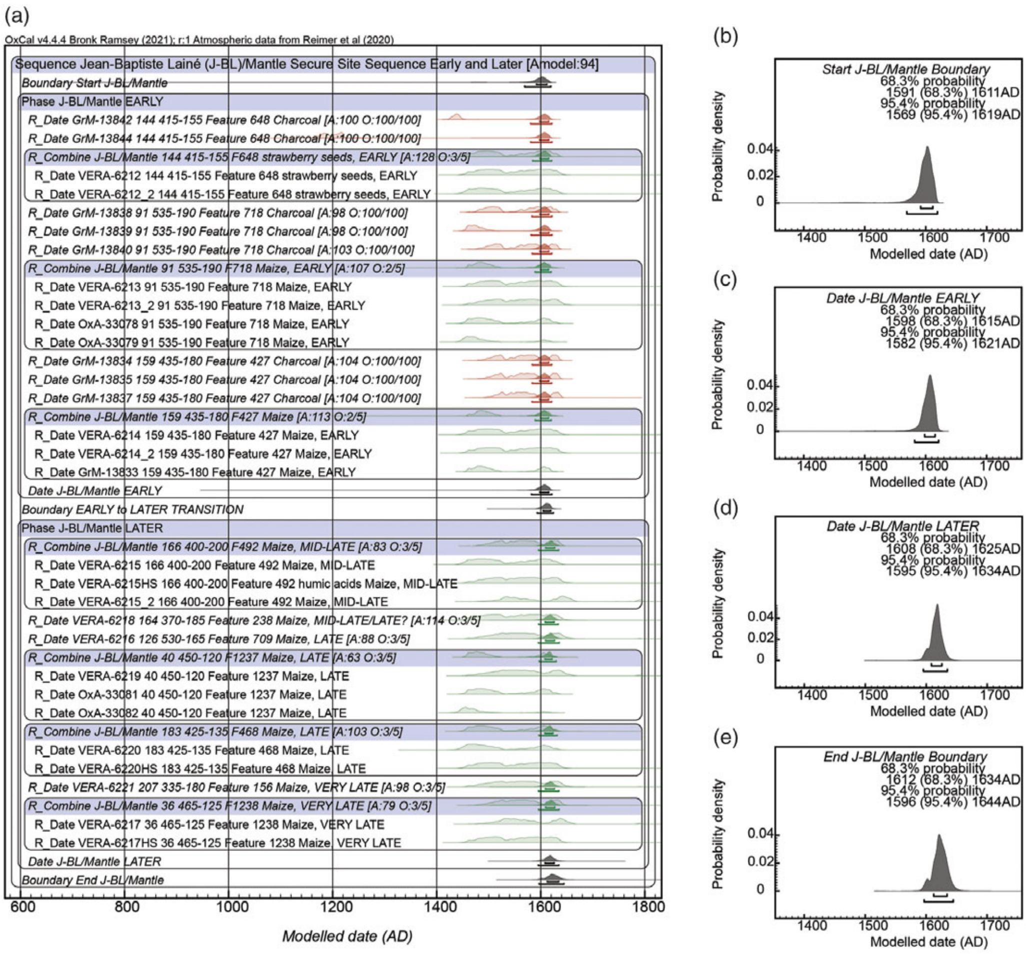

Figure 5 J-BL dating model using the 22 dates on short-lived plant material from specific contexts within the intra-site `Sequence` (see Figure 2a) and with the wood-charcoal dates placed in the Early `Phase` with the Charcoal `Outlier_Model` applied. (a) model, (b)–(e), details of the model.

`Phase`: see Table 3. This approach, while simple and efficient, clearly risks potentially exacerbating the `Phase` compression issue (see above). We apply the Charcoal `Outlier_Model` to the dates on wood-charcoal in order to address (approximately) the in-built TPQ element incorporated into these samples. The `Date` query for the site `Phase` yields a most likely 68.3% hpd range of 1596–1616, a time range very similar to those found above. In the J-BL case we prefer the Charcoal `Outlier_Model` since the additional assumption involved in the Charcoal Plus `Outlier_Model`, allowing for a "minute level of probability for the presence of intrusive material" (Dee and Bronk Ramsey 2014: 92), is less likely since we know that we selected wood-charcoal from early in the site `Phase` and only dated samples that did not include outermost tree-rings and so deliberately increased the available amount of in-built age. In practice, there is only a very small difference, but use of the Charcoal Plus `Outlier_Model` creates a very small (ca. 2%) probability for the earlier date range for the site (Table 3).

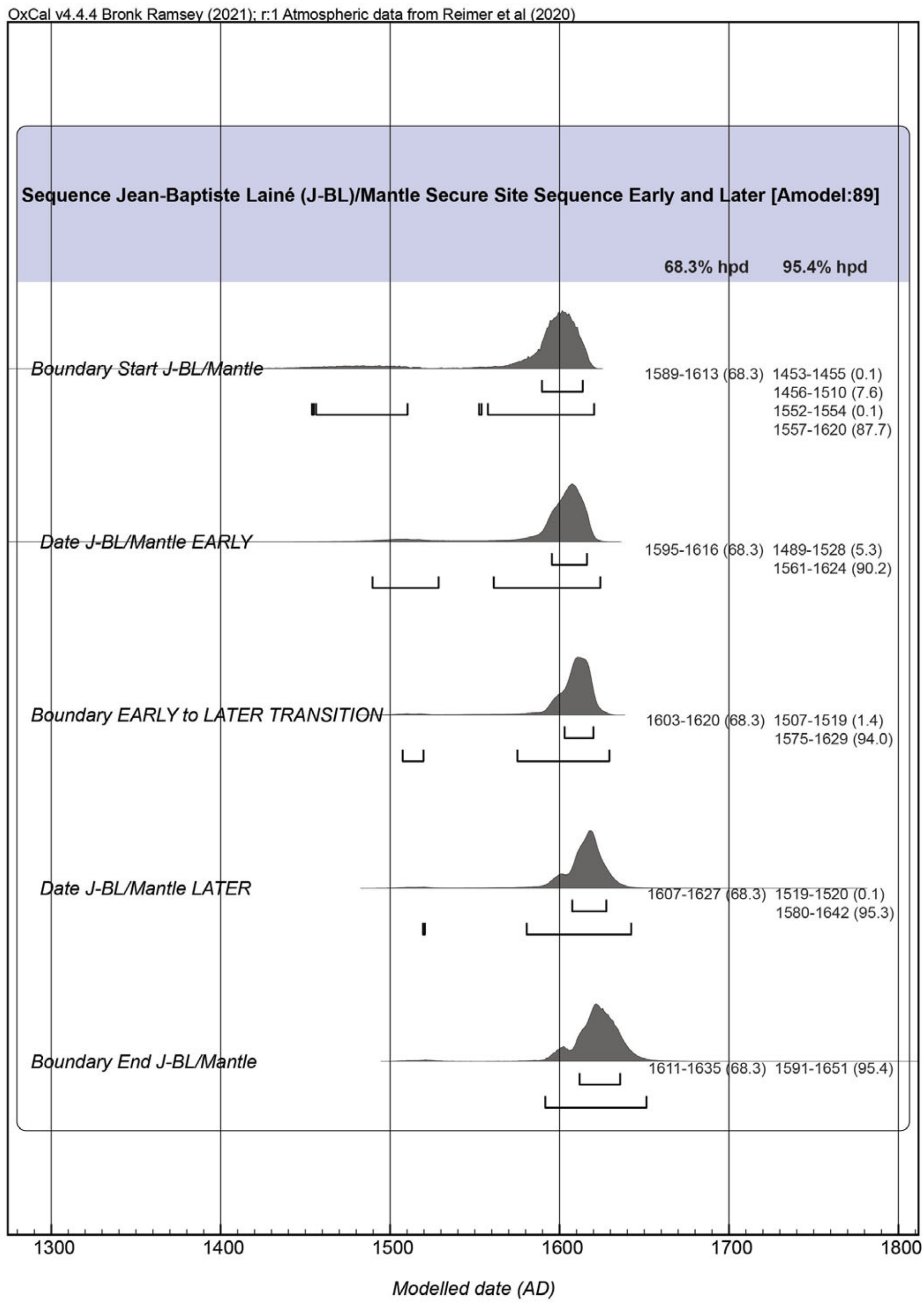

Figure 6 Results of details of the model in Figure 5 when re-run using the Charcoal Plus `Outlier_Model`.

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Table 2 Selected results from the models shown/used in Figures 8 and 9. *In Figure 9 this is the `Boundary` "TPQ" from the initial Exponential `Phase` with the dates on charcoal samples.

	Figure 8. A_{model} 64		Figure 8 re-run with Charcoal Plus `Outlier_Model` A_{model} >60		Figure 9. A_{model} 61		Figure 9 re-run with `LnN(ln(20),ln(2))` `Interval` constraint for overall site duration A_{model} 58 but $A_{overall}$ >60	
	68.3% hpd	*95.4% hpd*	*68.3% hpd*	*95.4% hpd*	*68.3% hpd*	*95.4% hpd*	*68.3% hpd*	*95.4% hpd*
`Boundary` Start J-BL (Mantle) Overall*	1588–1611	1557–1617	1587–1611	1554–1617	1586–1608	1566–1616	1591–1608	1582–1614
`Boundary` Start J-BL (Mantle) Multiple	1597–1613	1587–1618	1596–1613	1586–1618	1596–1612	1586–1618	1598–1613	1591–1617
`Boundary` End J-BL (Mantle) Multiple	1603–1618	1595–1625	1603–1619	1594–1626	1604–1620	1595–1629	1604–1619	1596–1624
`Boundary` Start J-BL (Mantle) Early	1598–1613	1591–1618	1597–1613	1590–1618	1598–1613	1590–1618	1599–1613	1592–1617
`Date` J-BL (Mantle) Early	1601–1615	1593–1618	1600–1615	1592–1618	1601–1616	1593–1618	1601–1616	1593–1618
`Interval` J-BL (Mantle) Early	*0–5*	*0–17*	*0–5*	*0–18*	*0–6*	*0–20*	*0–4*	*0–13*
`Boundary` Earlier to Later Transition	1601–1602 (2.4) 1604–1618 (65.8)	1594–1620	1600–1602 (6.8) 1604–1618 (61.5)	1594–1620	1604–1618	1594–1620	1604–1618	1594–1620

Table 2 (*Continued*)

	Figure 8. A_{model} 64		Figure 8 re-run with Charcoal Plus `Outlier_Model` A_{model} >60		Figure 9. A_{model} 61		Figure 9 re-run with `LnN(ln(20),ln(2))` `Interval` constraint for overall site duration A_{model} 58 but $A_{overall}$ >60	
	68.3% hpd	*95.4% hpd*	*68.3% hpd*	*95.4% hpd*	*68.3% hpd*	*95.4% hpd*	*68.3% hpd*	*95.4% hpd*
`Date` J-BL (Mantle) Later	1600–1602 (6.1) 1606–1620 (62.1)	1594–1624	1599–1603 (10.4) 1606–1620 (57.8)	1594–1624	1606–1621	1594–1627	1606–1620	1595–1623
`Interval` J-BL (Mantle) Later	*0–5*	*0–19*	*0–5*	*0–20*	*0–7*	*0–23*	*0–5*	*0–14*
`Boundary` End J-BL (Mantle) Later	1600–1603 (8.2) 1607–1621 (60.1)	1594–1630	1599–1604 (11.6) 1607–1622 (56.6)	1594–1630	1601–1603 (3.4) 1607–1624 (64.9)	1595–1633	1601–1603 (3.4) 1607–1621 (64.8)	1595–1627
`Date` J-BL (Mantle) Overall	1597–1618	1575–1642	1596–1618	1573–1643	1596–1620	1577–1649	1599–1617	1589–1628
`Interval` J-BL (Mantle) Overall	*0–32*	*0–96*	*0–33*	*0–99*	*0–40*	*0–98*	*5–24*	*3–45*
`Boundary` End J-BL (Mantle) Overall	1603–1629	1595–1660	1602–1629	1594–1662	1606–1637	1595–1675	1609–1627	1599–1638

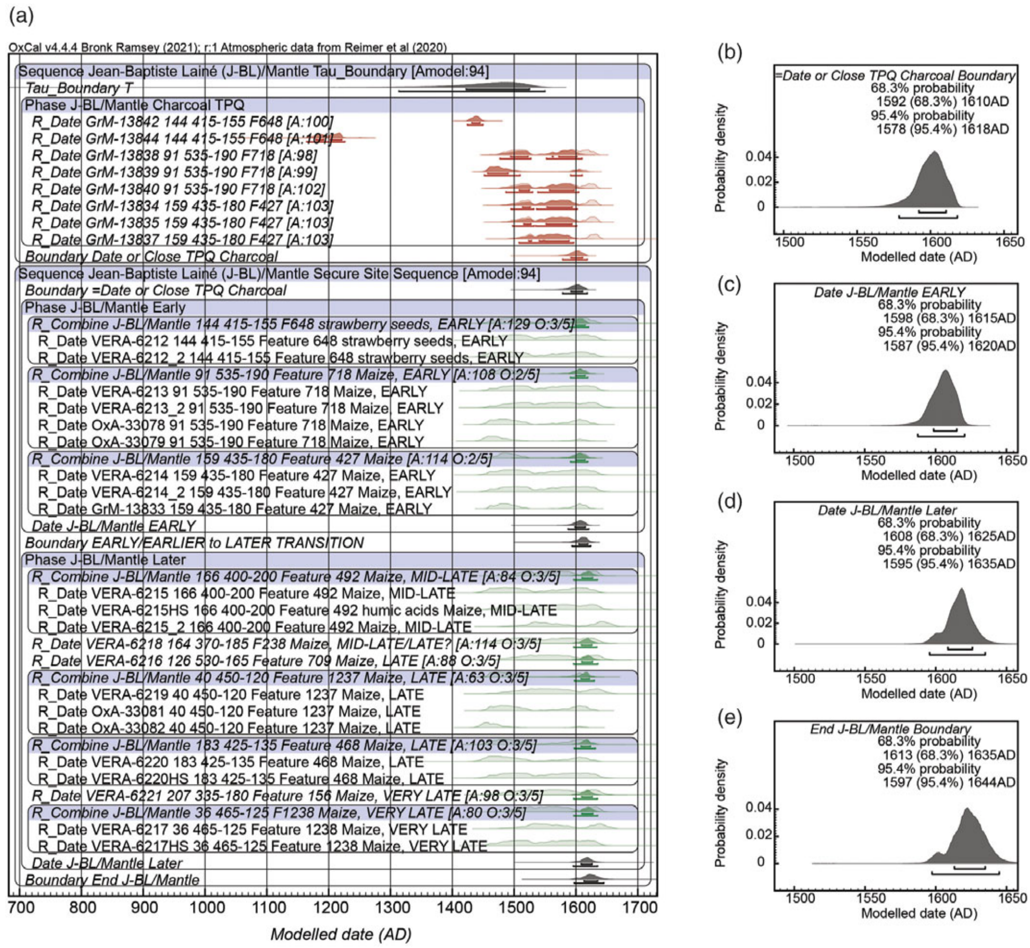

Figure 7 The wood-charcoal dates are placed in an exponential `Phase` (`Tau_Boundary` paired with `Boundary`) with the closing `Boundary` (the TPQ) employed then as the start `Boundary` for the J-BL dating model using the 22 dates on short-lived plant material from specific contexts within the intra-site `Sequence` (see Figure 2a) as in Figures 5 and 6. (a) the model, (b)–(e) details of the model.

Therefore, across a range of analyses, the most likely date range for the J-BL site appears clear. However, an alternative much earlier date placement in the first couple of decades of the 16th century seems perfectly possible. We already know that this alternative range is entirely possible from the dates on the short-lived samples (Figure 2). The question is whether it is plausible to achieve this dating range *including* the information incorporated in the dates on wood-charcoal. Often the answer is no: models do not achieve satisfactory A_{model} and $A_{overall}$ values—these are less than the satisfactory threshold of 60, and/or Convergence values are not satisfactory (<95) for the individual elements. For example, if we run all the dates in one single `Phase` (ignoring the intra-site `Sequence` as in Figure 10) with the Charcoal `Outlier_Model` and then apply in addition a `N(20,10)` constraint on an `Interval` query for the site `Phase` then this usually, when there is satisfactory Convergence, leads to a model result that finds the early age range (see Table 3). But from several model runs the best A_{model} value is ca. 42 and the $A_{overall}$ value is ca. 34, both well

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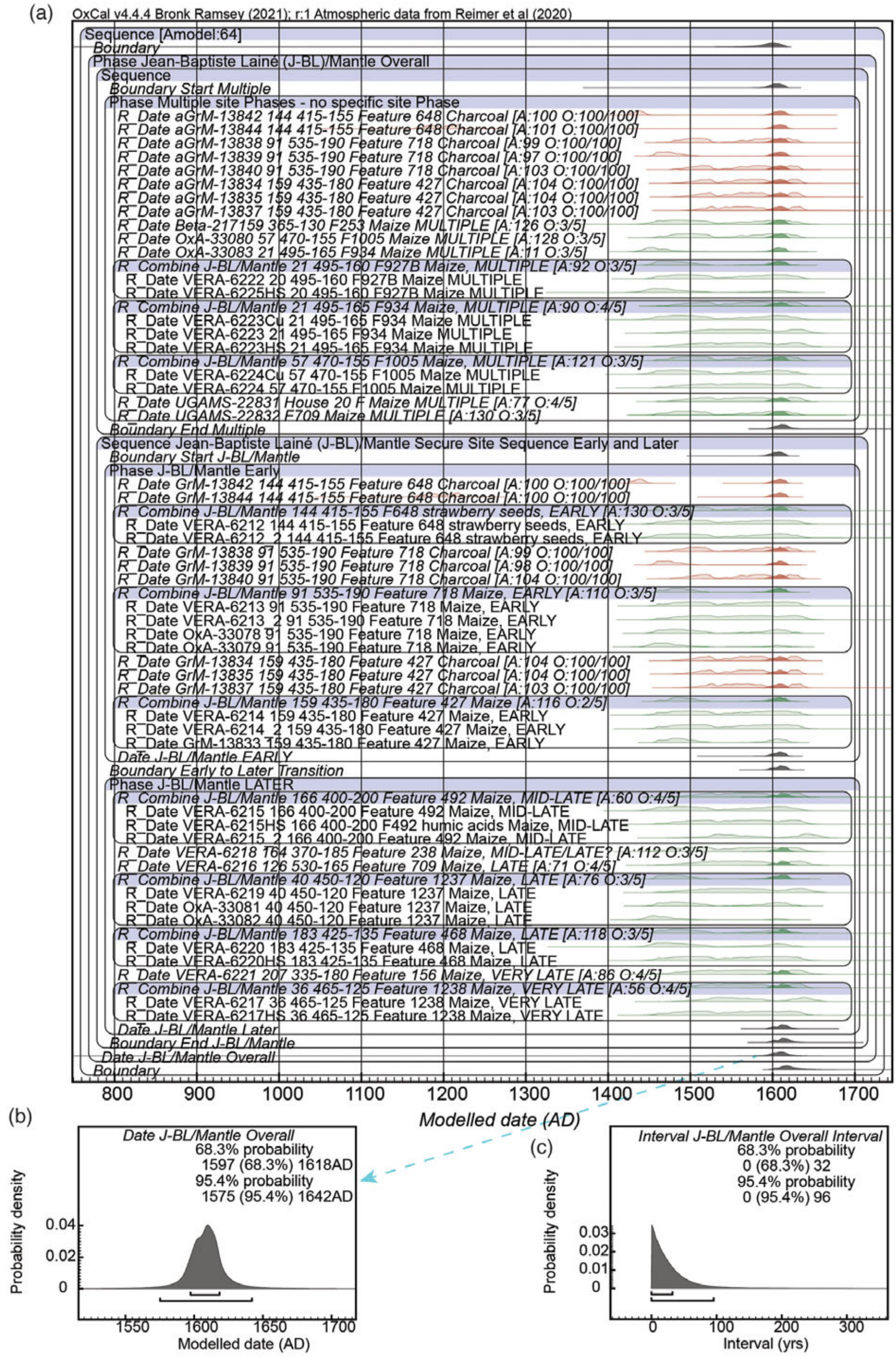

Figure 8 The J-BL dating model using all 34 dates from the site on short-lived plant remains. An overall site `Phase` incorporates one `Phase` with the intra-site `Sequence` in Figure 5 and another `Phase` with the 12 dates from contexts with multiple associations within the site `Sequence`. Each `Phase` is independent within the overall site `Phase`. The wood-charcoal dates are used twice, applied to each `Phase` using the Charcoal `Oulier_Model`. (a) overall model. (b) `Date` query and (c) an `Interval` query applied to the overall site `Phase`.

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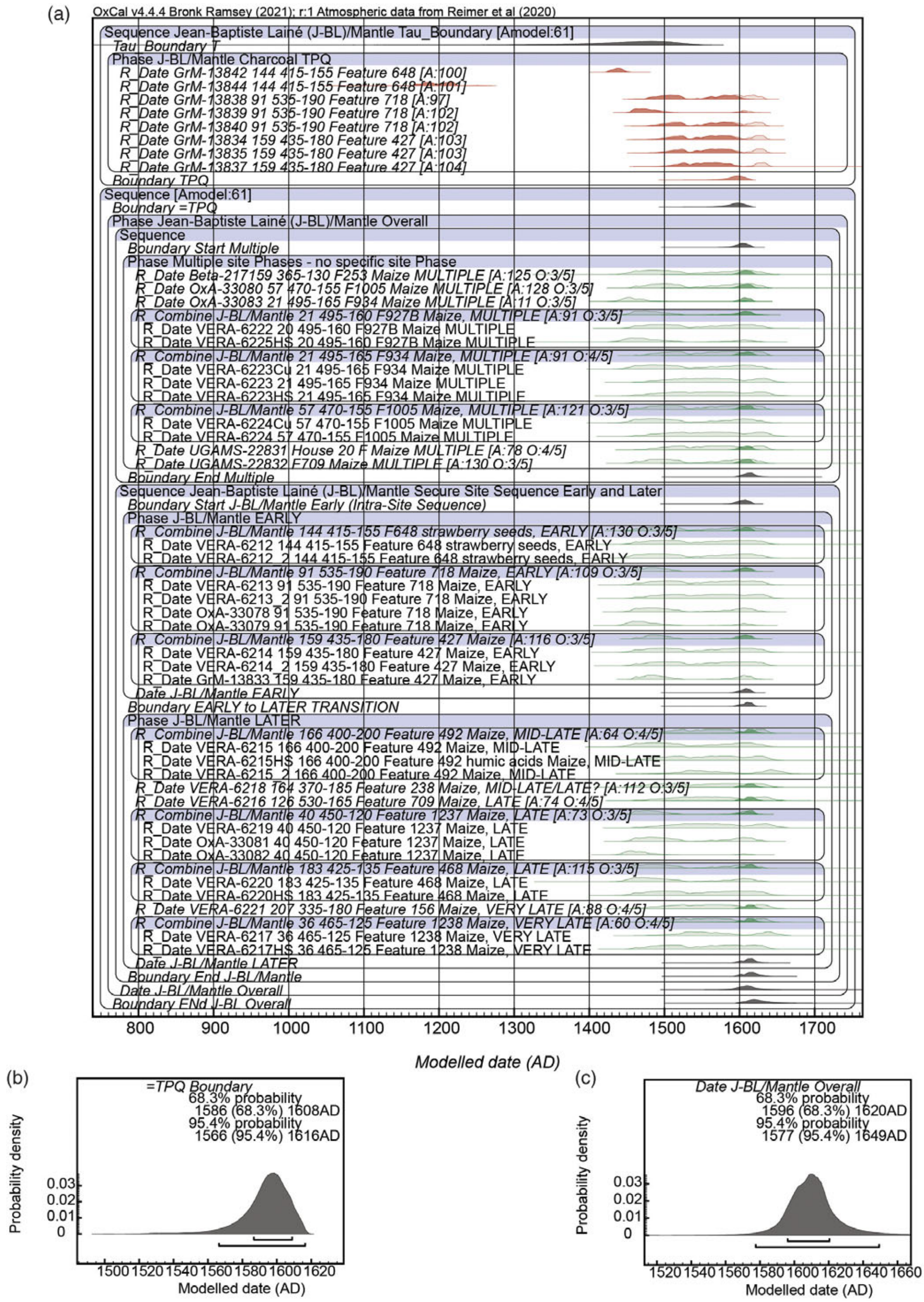

Figure 9 The J-BL dating model using all 34 dates from the site on short-lived plant remains with an exponential `Phase` containing the dates on wood-charcoal forming a TPQ for the site occupation contexts in an expanded version of the Figure 7 model. (a) overall model. (b) the TPQ from the exponential `Phase` with the wood-charcoal. (c) the `Date` query on the overall site `Phase`.

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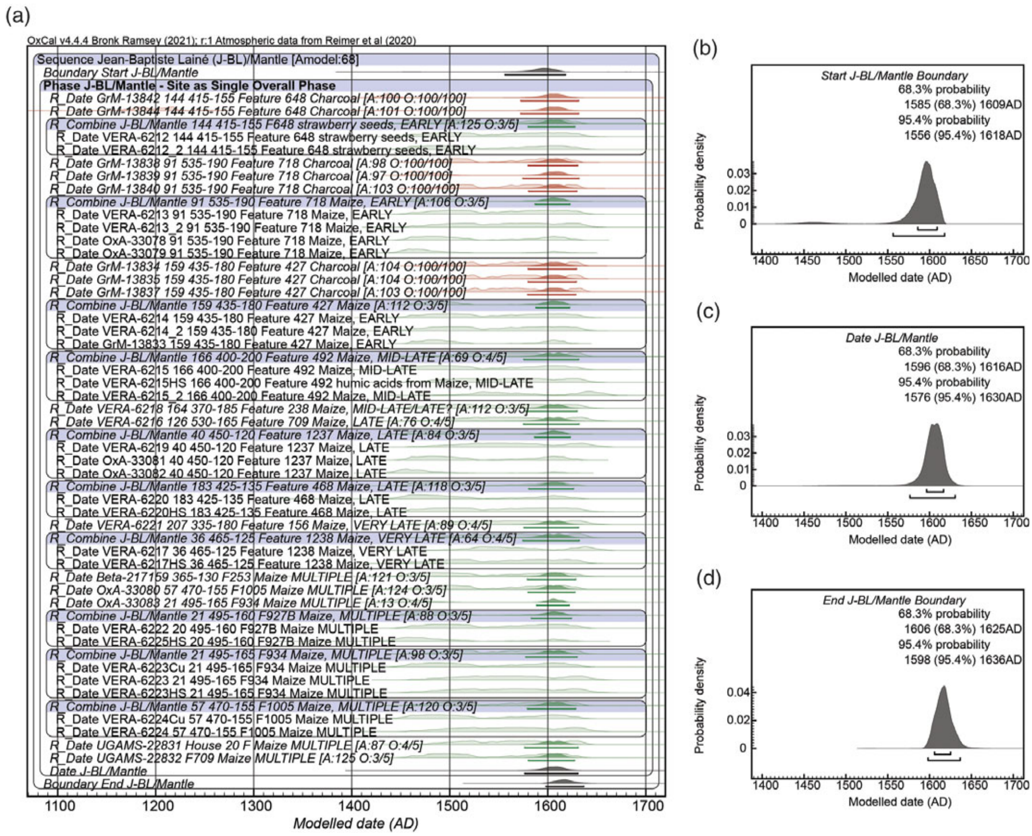

Figure 10 Dating model for the J-BL site placing all data within a single site `Phase` (thus ignoring the intra-site `Sequence`) with the dates on wood-charcoal included in this `Phase` with the TPQ element applied via the Charcoal `Outlier_Model`. 95.4% hpd modeled calendar ranges, only, indicated by the line under each probability distribution.

below the satisfactory threshold value of 60. Many other runs offering similar dating placements achieved lower A_{model} and $A_{overall}$ values in the ca. 32/31 range. Four elements (one weighted average comprising three dates, and three separate dates including two of the wood-charcoal dates) exhibit unsatisfactory individual Agreement values. In other cases, those with poor Convergence values and/or poor A_{model} and $A_{overall}$ values, the probability is split. For example, a run of this same model yielding A_{model} ca. 60 and $A_{overall}$ ca. 48 placed the `Date` query 1487–1527 (34.3), 1584–1627 (60.1) and 1943–1951 (1.1) at 95.4% hpd—*but* the Convergence values for the individual elements dated in the model were all <30 and thus entirely unsatisfactory. Hence such a model is not used. Successful models do not exhibit these diagnostic failings.

Therefore, we only regard as potentially acceptable those model results with satisfactory A_{model} and $A_{overall}$ values and satisfactory Convergence values. An example is the re-run version of the Figure 10 model with the addition of a `LnN(ln(20),ln(2))` constraint on an `Interval` query for the site `Phase` listed in Table 3. This has all satisfactory Convergence values and A_{model} and $A_{overall}$ values of ca. 65. In other examples, a re-run of the Figure 10 model but

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Table 3 Selected results from the model shown in Figure 10 and for re-runs of versions of this model with the Charcoal Plus `Outlier_Model` and with `N(20,10)` and `LnN(ln(20),ln(2))` constraints on an `Interval` query applied to the site `Phase` (using the Figure 10 model with Charcoal `Outlier_Model`). In the case of the `N(20,10)` model we report also on 2 additional models runs (all with `kIterations` set at 3000) to illustrate the approximate range in possible early placement outcomes, with all reporting unsatisfactory A_{model} and $A_{overall}$ values. These two runs with even lower A_{model} and $A_{overall}$ values (ca. 31/32) found no later range probability within the 95.4% hpd ranges. The maximum alternative age range values from the other two runs are listed in the parentheses under each element in the table in red. (Please see electronic version for color table.)

	Figure 10. A_{model} 68		Figure 10 re-run with the Charcoal Plus `Outlier_Model` A_{model} 69		Figure 10 re-run with `N(20,10)` `Interval` constraint A_{model} 42, $A_{overall}$ 34 (both <60) Other runs A_m/A_o: 31/32, 32/31		Figure 10 re-run with `LnN(ln(20),ln(2))` `Interval` constraint A_{model} 65	
	68.3% hpd	*95.4% hpd*	*68.3% hpd*	*95.4% hpd*	*68.3% hpd*	*95.4% hpd*	*68.3% hpd*	*95.4% hpd*
`Boundary` Start J-BL (Mantle)	1585–1609	1556–1618	1583–1609	1451–1481 (4.3) 1555–1617 (91.2)	1488–1505 (1489–1505)	1478–1516 (91.6) 1590–1602 (3.9) (1479–1513)	1589–1606	1578–1614
`Date` J-BL (Mantle)	1596–1616	1576–1630	1595–1617	1494–1516 (2.0) 1565–1634 (93.5)	1499–1519 (1499–1518)	1486–1528 (91.2) 1599–1614 (4.2) (1488–1526)	1597–1615	1587–1624
`Interval` J-BL (Mantle)	*0–29*	*0–70*	*0–32*	*0–76 (93.7)* *152–174 (1.7)*	*12–33* *(12–33)*	*2–41* *(2–42)*	*6–23*	*3–39*
`Boundary` End J-BL (Mantle)	1606–1625	1598–1636	1605–1625	1595–1641	1512–1527 (1513–1526)	1503–1534 (91.6) 1610–1621 (3.9) (1505–1532)	1606–1622	1599–1631

incorporating an `Interval` constraint of either `N(20,10)` or `LnN(ln(20),ln(2))` achieves very similar results. The `Date` query for the overall J-BL `Phase` including both separate `Phases` yields a most likely 68.3% hpd ranges in each case of 1599–1617. The difference is that the added constraint and very slight additional compression leads to the A_{model} values dipping just below 60 (58 in each case) and the $A_{overall}$ value for the `N(20,10)` model doing the same (at 59). The `LnN(ln(20),ln(2))` model achieves an $A_{overall}$ value just over 60. We show selected results from this model in Table 2.

It should be noted that other combinations can lead to models that complete with satisfactory Convergence values and the earlier date solution. But in such cases the A_{model}/$A_{overall}$ values are well below the satisfactory level and a number of individual samples exhibit poor Agreement values (see Supplementary Material and Figures S4, S5). We can thus reject all such model run outcomes as unsatisfactory based on the criteria of failing either or both satisfactory Convergence values and A_{model}/$A_{overall}$ values. In reverse, only models that resolve the more recent date range ca. 1600 offered satisfactory diagnostic values. Hence, we regard this as the robust date range for the J-BL site. (One question that may arise: can we rule out the possibility of two periods of occupation at the site: one around 1500 and one around 1600? Yes: see Supplementary Material.)

DISCUSSION

^{14}C dating the J-BL site is a challenge. The properties of the calibration curve in the relevant period, a reversal/plateau ca. 1480–1630, render dating a short-duration village site primarily from ^{14}C dates on short-lived plant remains ambiguous. The additional information provided by an intra-site `Sequence` alone, over such a short total duration, does not help to resolve since the period is not long enough to describe a unique or clearly more likely solution versus the calibration curve. Thus, if we only had the dates on short-lived samples, no matter how many and how precise, we would have ambiguity. Indeed, having too many such dates might inhibit finding the correct solution in a case of such a reversal/plateau ambiguity due to a tendency to overly compress (narrow) dating ranges for a `Phase` (Supplementary Material Figures S1–S3).

Obtaining resolution therefore depends on additional constraints being available. If the aim is to avoid the circularity in assumptions about local site sequences, these constraints need to come from independent, site-specific, ^{14}C data. In the absence of a distinctive ^{14}C wiggle-match, we have shown that this can be achieved using the in-built age (TPQ) incorporated into the eight ^{14}C dates on wood-charcoal available from the site, especially if it is known that such samples are selected to maximize the length of the in-built time element. Hence dates on wood-charcoal selected from the initial `Phase` of a site `Sequence` and dates on tree-rings from some such samples that are *not* just from outer/outermost tree-rings or shorter-lived round wood/twigs, etc. This means reversing the usual logic of sample selection solely aimed at trying to get as close to the target event as possible, and instead including some samples that define the range of a TPQ.

We found across several plausible scenarios that incorporation of these eight dates on wood-charcoal (versus either 22 or 34 dates on short-lived plant remains) permitted satisfactory resolution of the dating ambiguity (Figures 5–10). These models all pointed to dates for the J-BL site around or just after 1600. In contrast, those model runs that achieved satisfactory Convergence values and yet found an earlier date solution (early 16th century) could

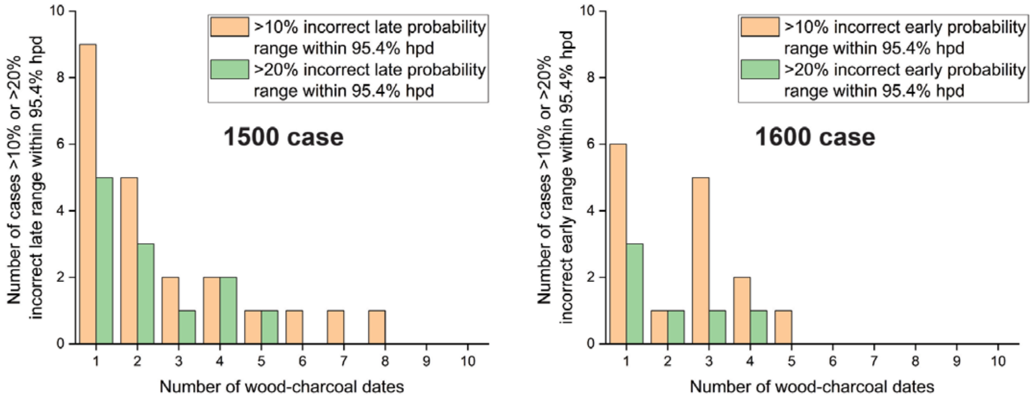

Figure 11 Summary of runs of simulation models for sites dated 1500 and 1600 with 10 randomly simulated ^{14}C dates on short-lived samples and variously 1 to 10 dates randomly simulated on wood-charcoal samples with the Charcoal `Outlier_Model` applied. The figure shows how many runs produced results with satisfactory Convergence values (≥95) with 10+% and 20+% probability assigned to an incorrect respectively more recent (1500 case) or older (1600 case) date range within the 95.4% hpd ranges. These models used the default curve resolution of 5 years and the default kIterations value.

clearly be distinguished as not satisfactory with poor A_{model} and $A_{overall}$ values and with a number of individual elements with poor Agreement values (Supplementary Material Figures S4, S5 or the `N(20,10)` model reported in Table 3).

We can consider the characteristics of such modeling. For example, we can investigate an approximate simulation, where we have sites dated ca. 1500 and ca. 1600, each represented by 10 randomly simulated ^{14}C dates (`R_Simulate`) on short-lived samples, and then instances of 1 to 10 dates on wood-charcoal samples randomly simulated from an exponential distribution over ca. 0–500 years, for the 1500 case, as `R_Simulate("",1500+(100*rand())*ln(rand()),15)` and treated with the Charcoal `Outlier_Model`. In each case the set of dates are modeled in a `Phase` with start and end `Boundary` within a `Sequence` with curve resolution here left at the default of 5 years and a measurement on each date assumed as ±15 ^{14}C years (see Supplementary Material). Across 10 runs of each of the models we show where there was a >10% and >20% incorrect late or early range within the 95.4% hpd range for the start or end `Boundary` or a `Date` query on the `Phase` in cases with satisfactory Convergence values (Figure 11). In each case, while there is some potential ambiguity at the 10%+ to 20%+ level in several cases with ≤4 wood-charcoal dates, there is no >20% erroneous early or late probability region within the 95.4% hpd ranges once >5 wood-charcoal samples are available. The one instance of a major, >80%, incorrect probability result (shown in Supplementary Materials Figure S7) was for a 1500 case with just three wood charcoal TPQ dates. It is evident that there is a greater possibility of an incorrect placement of the 1500 site versus the 1600 site, but, again, there is no incorrect placement with >20% probability once 6 or more charcoal TPQ dates are employed.

The J-BL case has rather more dates on short-lived samples than the example summarized in Figure 11. We thus re-ran the simulation for the 1500 case with 30 simulated dates on short-lived samples in each case (see Supplementary Material and Figure S10). While in all cases a few runs identified incorrect probability in the 10+% and 20+% ranges, in only 3 of 94 cases

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with satisfactory Convergence was there a strong probability (here arbitrarily defined as >70% probability within the 95.4% hpd range) for the incorrect date range—versus merely degrees of ambiguity. None of these occurred in cases with ≥6 wood-charcoal samples (and indeed only one where there were ≥4 wood charcoal dates). Thus, in the J-BL case, with eight wood-charcoal TPQ dates representing a good range of TPQ values (see Figure 4a), with satisfactory OxCal model agreement and Convergence, and no ambiguity, we may assume with good confidence that the calendar placement determined is correct (Figures 5–10).

We may also assess the J-BL dataset itself. For example: (a) how many of the wood-charcoal dates from most recent (mR) or very oldest (vO) are necessary to avoid substantial ambiguity using the Charcoal (CHAR) Charcoal Plus (CHAR+) or `Tau_Boundary` approaches expressed in terms of the start and end `Boundary` for the J-BL site `Phase`; and (b) what approximate range of TPQ dates are required to remove ambiguity. Figure 12a shows (left) the probability of an earlier (pre-1541) range within the 95.4% hpd range for the start and end `Boundary` for the secure intra-site `Sequence` at J-BL depending progressively on 1 to 8 wood-charcoal dates in order from either most recent or very oldest with the three model approaches. Figure 12b does the same with all the dates treated in one site `Phase`. In each case, if we can make a firm TPQ assumption and apply the `Tau_Boundary` approach, there is no earlier ambiguity. With the Charcoal `Outlier_Model`, regardless of whether we start with the most recent or very oldest wood-charcoal age, by the time there are 6 such dates the probability of an ambiguous result is <25% and with all eight dates it is 0–5%. It is (self-)evident that it is important to have a sample that does not include solely the oldest TPQ dates to avoid a possible early-shift ambiguity since such data cannot exclude this. On the right side of Figure 12a and b the ambiguity percent for dating various combinations of a middle (M), old (O) or most recent (mR) or very oldest (vO) TPQ dates are shown (with M arbitrarily selected as GrM-13838 and O as GrM-13842). To better remove ambiguity it is clear that (a) creating the criteria for the assumption that all samples establish a TPQ for the subsequent `Phase` (the assumption in the `Tau_Boundary` model as used above) is strongest, and (b) otherwise it is best to have as wide a range of TPQs represented as possible (the mR, M vO models).

Overall, relatively fine margins are at stake in a dating case like this. Even a few less dates on wood-charcoal, and, in particular, without the 2 or 3 dates on wood-charcoal which, allowing for their in-built age as a TPQ, specifically run strongly against the early date possibility for J-BL, could lead to a different result, or a return to ambiguity. In retrospect, in a case like this, running additional dates on selected wood-charcoal would likely make the situation even clearer and certainly more robust. For example, whereas the versions of the Figure 9 model with the addition of the `N(20,10)` or `LnN(ln(20),ln(2))` constraint on the `Interval` query with the current J-BL dataset led to A_{model} and $A_{overall}$ values just under the satisfactory threshold value of 60 (see above), if we simply had twice as much wood-charcoal data (so a repeat of the eight dates available) these values become respectively satisfactory at 63 & 63 and 63 & 65. We highlight this issue, since it runs contrary to most recent advice in archaeological ^{14}C dating to focus, even exclusively, on dates from short-lived samples. Instead, in cases of short-duration site occupations on reversals/plateaus in the ^{14}C calibration curve, use of a balanced portfolio of dates, with some selected to add a range of in-built age TPQs from wood-charcoal, and some direct dates from short-lived samples, will maximize prospects of successful dating (as shown here for Draper, Figure 1, and J-BL, Figures 5–10). This point applies to other cases and periods where plateaus and reversals in the calibration curve create potential dating ambiguities.

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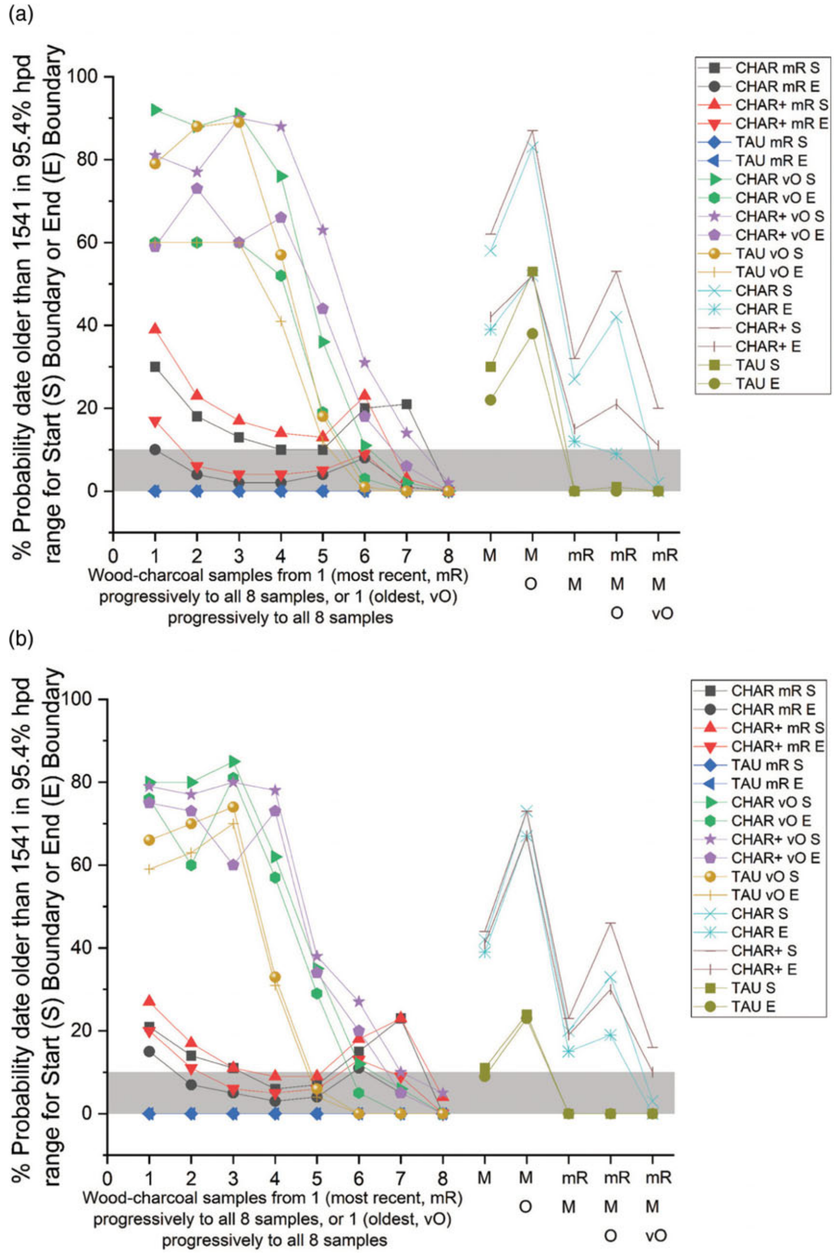

Figure 12 Probabilities of an (incorrect—see this paper) too old (pre-1541) date within either the Start (S) Boundary or End (E) Boundary for J-BL under a range of scenarios with variously 1–8 wood-charcoal dates included progressively either from most recent (mR = GrM-13837) or oldest (vO = GrM-13844) or via a mixture from mR, "middle" = M = GrM-13838, "old" = O = GrM-13842 or vO using the Charcoal (CHAR) or Charcoal Plus (CHAR+) Outlier models or via the Tau_Boundary paired with a Boundary model with this End Boundary cross-referenced as the Start Boundary for the Site Sequence/Phase. Only data where the Convergence was ≥95 included. (a) J-BL site data from secure contexts within the intra-site Sequence with the End Boundary treated as a TPQ and cross-referenced as the Start Boundary for the Site Sequence or Site Phase. (b) J-BL site data treated as one single Phase and including all available ^{14}C dates. The grey bar in each case indicates probabilities of ≤10% for the "early" date range within the 95.4% hpd ranges. Data from OxCal and IntCal20 with calibration curve resolution set at 1 year.

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Our investigation finds that the only coherent and satisfactory overall dating solution for J-BL is a date range around 1600 (as reported previously: Manning et al. 2018a). This date is much more recent than the previous age estimate of 1500–1530. It complicates conventional sweeping generalizations based on specific ethnohistorical inferences that have been extrapolated to infer the timing of ancestral Huron-Wendat population resettlements. These include a statement by Champlain (the account dating to 1615–16) that the Trent Valley was abandoned by the Arendahronon for fear of enemies (Biggar 1922-1936: 3:59) and that of Lalement who, in 1639, reported (i) that the Arendahronon had relocated to Wendake some "fifty" years ago, and (ii) that the Tahontaerat, whose assumed origins are on the north shore of Lake Ontario, had done the same some "thirty" years previously (Thwaites 1896–1901, 16:227). The result has been the entrenchment of 1590 and 1610 as representing the termination of permanent settlement in each area (Trigger 1985: 157; Williamson 2014: 35), regardless of the very large regions and uncertainty of actual years. We appreciate for those scholars attached to these seemingly firm historical waypoints that the ^{14}C-based date range presented herein for J-BL may be unacceptable. However, when one considers the likely short duration of site occupation and the uncertainties involved in estimation of Lalement's informant of what constituted 30 or 50 years in the past, we find the totality of the data and historical accounts reconcilable. Further, we have shown that this ^{14}C-based date range is robust with appropriate incorporation of the wood-charcoal TPQ and also the archaeologically inferred intra-site `Sequence`. Any alternative (earlier) solution fails to offer a satisfactory model result in terms of OxCal Convergence values for several elements, or OxCal A_{model} or $A_{overall}$ values. We also identify a tendency with large numbers of dates from a `Phase` for over-compression on the calendar time-scale. In a case like J-BL, this can in fact tend to raise the probability for the incorrect (early) date solution. Hence again the key role of the in-built age TPQ from the wood-charcoal to prevent such over-compression from potentially leading to an incorrect date placement.

A most likely date for J-BL in a range between 1595 to 1626 (extremes of the 68.3% ranges in Tables 1 and 2 for Early and Late `Phases`, or for the Overall `Phase`, Table 2, or for those one-`Phase` site models with satisfactory A_{model} and $A_{overall}$ values in Table 3) supports the re-assessments of the dates for this site as discussed in recent publications (Manning et al. 2018a; also Birch et al. 2021). The specific date applies solely to the J-BL site. Other sites should only be dated and assessed on the basis of dates directly on appropriate samples from each such site. Thus, despite the field's reliance on site sequence models in past work, we should not build wider chronologies based on either previously inferred site relocation sequences nor previously inferred site groupings and relationships.

^{14}C dates and Bayesian chronological modeling have prompted a substantive methods and theory critique of previously assumed models of chronology and, as importantly, socio-economic practices in northeastern North America (Manning et al. 2018a; 2021; Manning and Hart 2019; Birch et al. 2021). The evidence indicates that the dates for some sites need radical revision (e.g., Draper, J-BL), whereas long assumed dates for other sites are confirmed (e.g., Warminster). Overall, the underlying assumptions behind the conventional chronology have to be re-examined from first principles—regarding especially the use and the interpretation of the presence or absence of trade goods at different sites (for an example of the same from the southeastern United States, see Holland-Lulewicz et al. 2019). Going forward, each site should be dated independently on its own evidence, avoiding the incorporation of unjustified inferences. In order to overcome the challenges created by a reversal and plateau in the calibration curve, this especially requires use of

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wood-charcoal samples securely associated with a site occupation `Phase` in order to achieve non-ambiguous date estimates. Ideally this should be via a tree-ring defined ^{14}C "wiggle-match."

However, when this is not possible, use of the in-built age TPQ accessible through dating wood-charcoal samples can suffice, especially when these samples are deliberately selected to include a *range* of time (*range* of TPQs) within the set of such samples. As evident in the analyses in this paper, selecting samples that (i) accentuate the "post" in the TPQ so that this forms a likely start `Boundary` for a site occupation, and/or (ii) selecting and dating a reasonable range of wood-charcoal samples—including some from heartwood and likely substantially older than the relevant felling/use date—in order that these describe a substantive period of time from closer to the use context to many decades to a century-plus older allow us to rule out ambiguity. As evident in this paper, a set of several such samples is usually required to capture the temporal range necessary to exclude ambiguity.

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SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit https://doi.org/10.1017/RDC.2022.23

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