ANTHROPOLOGY

Radiocarbon re-dating of contact-era Iroquoian history in northeastern North America

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A time frame for late Iroquoian prehistory is firmly established on the basis of the presence/absence of European trade goods and other archeological indicators. However, independent dating evidence is lacking. We use 86 radiocarbon measurements to test and (re)define existing chronological understanding. Warminster, often associated with Cahiagué visited by S. de Champlain in 1615–1616 CE, yields a compatible radiocarbon-based age. However, a well-known late prehistoric site sequence in southern Ontario, Draper-Spang-Mantle, usually dated ~1450–1550, yields much later radiocarbon-based dates of ~1530–1615. The revised time frame dramatically rewrites 16th-century contact-era history in this region. Key processes of violent conflict, community coalescence, and the introduction of European goods all happened much later and more rapidly than previously assumed. Our results suggest the need to reconsider current understandings of contact-era dynamics across northeastern North America.

INTRODUCTION

In the earlier to mid-second millennium CE (all dates CE), Northern Iroquoian societies of the northeastern woodlands of North America underwent several major cultural transitions. These include the intensification of agriculture, the development of settled village life, endemic warfare and coalescence into towns, confederacy formation, colonialism, and, lastly, in the 16th century, contact period entry into the global political economy (*1*, *2*). The complete excavation of dozens of sites (*3*, *4*), combined with a vast ethnohistoric literature by early 17th-century explorers and missionaries (*5*–*7*), makes the Lower Great Lakes region one of the most robust archeological datasets for theorizing social processes in nonstate societies. Site durations equivalent to one to two human generations (*8*) make this record ideal for interrogating how the lived experiences of individuals and communities articulate with long-term, macroregional histories. Precise temporal control and the development of fine-grained chronologies are critical to developing and defining community and regional scales of analysis. However, despite a historically informed general narrative, direct historical associations with most sites are lacking for northeastern North America (*1*–*4*). One notable exception comes from the visit in 1615–1616 of S. de Champlain, an iconic figure of contact-era northeastern North America whose accounts are central to (re)considerations of violent colonial European interventions (*9*, *10*). He visited a village he named Cahiagué, which has often (but not always) been identified with the Warminster archeological site (Fig. 1 and Table 1) (*1*, *11*, *12*). Otherwise, an assumed refined chronology for the late prehistoric period has been based on the initial appearance and then the abundance of types of European trade goods (for example, presence/absence of types of metals and presence/absence of types of glass beads). Relative order of sites before and into the contact era has also been determined from archeological indicators, such as changing percentages of neck and incised decoration on ceramics and types of ceramic smoking pipes (*3*, *13*–*16*). Standard cultural, social, demographic, economic, and political histories of the Iroquoian peoples; our understanding of indigenous versus European contact dynamics; and associations

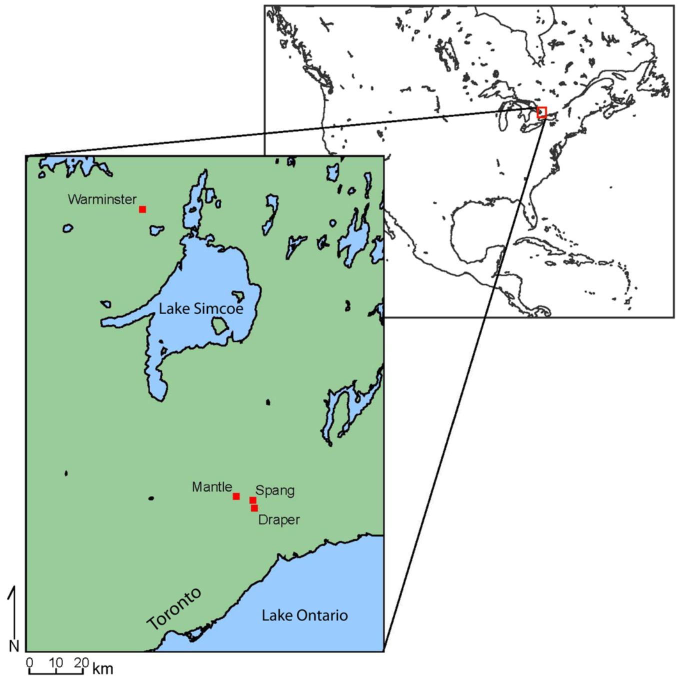

Fig. 1. Map showing the locations of the four sites investigated in this study in southern Ontario, Canada.

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Table 1. The existing traditional chronology for the Iroquoian region of south-central Ontario up to the contact era in the second millennium CE [(*1–4*, *13*, *14*, *17*, *18*); see the Supplementary Materials].

Traditional chronology	Archeological phases	Sociocultural characteristics and key events
1000–1300	Early Iroquoian	Settlement is in base camps by seasonally mobile populations; limited agriculture.
1300–1350	Middle Iroquoian	Small villages, initiation of widespread interaction networks. Migration of early farming communities to the north and east.
1350–1400		Small- to medium-sized, dispersed villages, extensive interregional interaction.
1400–1450	Late Iroquoian	Precoalescent; small villages clustered in major drainages.
1450–1500		Coalescence; formative aggregate towns, palisaded, with multiple palisade expansions. Some small villages remain. Internal conflict within the region.
1500–1550		Postcoalescent; initial nation formation. Consolidated aggregate towns. All settlements are palisaded, no evidence for expansions. Internal conflict in decline. Interregional interaction increases.
1550–1600	Protohistoric	Consolidation of nations. Consolidated aggregate towns (north shore of Lake Ontario), smaller, often unpalisaded village settlements (historic Wendake). Initiation of external conflict. First appearance of European-manufactured metals and glass beads (GBP I, ca. 1580–1600).
1600–1650	Contact era	Consolidation of Wendat confederacy. Population clusters in historic Wendake. Consolidated aggregate towns (southern Wendake), smaller village settlements (northern Wendake). Intensification of external conflict. Direct European contact, ca. 1608 (Etienne Brule); ca. 1615 (Champlain); ca. 1630s Jesuit presence increases. In 1650, the Wendat were dispersed by the Haudenosaunee (Iroquois). Extensive presence and diversification of European-manufactured metals and glass beads (GBP II, ca. 1600–1615/1620, GBP III ca. 1615/1620–1650).

of these processes with wider forces, such as climate change, are written and interpreted on the basis of this accepted chronology [(*1–4*, *13*, *14*, *17*, *18*); see the Supplementary Materials]. The general absence of a direct, independent, and verifiable time frame for this key prehistoric-historic contact era in northeastern North America is problematic, and critical attention is long overdue. Our research seeks to check and better define this contact-era timescale.

The appearances and distribution of European trade goods have conventionally formed the basis of chronology-building from the mid-16th century onward in northeastern North America, and therefore underlie archeological analyses of all aspects of social, economic, demographic, health, and political change [(*1–4*, *13*, *14*, *17*, *18*); see the Supplementary Materials]. It has been argued that European metals appeared on Iroquoian sites in the mid-16th century and were later followed by glass beads, copper kettles, and other goods that were traded to and otherwise acquired by indigenous individuals and groups [(*13*, *14*); see the Supplementary Materials]. Quantities and types of European materials on indigenous sites have been used to construct timelines such as the glass bead chronology (*19–21*) or to make assumptions about the chronological ordering of sites based on occurrences and frequencies of European goods (*12*, *14*, *22*). Although the dates of manufacture and shipment of certain goods can be identified using European documentary records, associated archeological frameworks are based on the assumption that trade goods were distributed in a distance- and time-transgressive manner. Contemporary perspectives on contact in the 16th and early 17th centuries recognize that there were different modes of participation in, and access to, trade networks (*13*). These variations resulted in unequal distributions of European-derived goods within and among Iroquoian communities (see the Supplementary Materials), including the outright rejection of European goods and influences [(*6*), vol. 15, pp. 15–22], rendering such trade good chronologies suspect as region-wide, generalized criteria and frameworks. More widely, there is now a rethinking of contact processes and indigenous consumption of foreign materials across North America. Such studies invariably identify complicated histories of differences both within (e.g., variability among lineages and by rank) and among indigenous communities (*1*, *2*, *23*). Thus, in this research, we argue that it is important to use an alternative time frame based on independent evidence—from dendrochronologically calibrated radiocarbon (^{14}C) dating—avoiding interpretative assumptions and logic transfers. Elsewhere in the world, independent absolute chronological time frames (especially ^{14}C) have repeatedly challenged the assumptions of relative chronologies built on expectations about normative chronological distribution patterns and often scarce and nonrepresentative data from trade and cultural exchange (*24–30*). We therefore test the material culture–based assumptions concerning chronology for contact-era northeastern North America and provide a start toward an independent high-resolution time frame.

We recognize that the existing chronology for contact-era northeastern North America, including both ceramic seriation and trade goods, represents the best efforts over many years by archeologists and historians with the data available to them (see the Supplementary Materials). However, two key developments now mean that an independent high-resolution time frame is possible. First, the accelerator mass spectrometry (AMS) ^{14}C method, enabling ^{14}C dates from small samples and especially on short-lived materials (such as annual-growth plant matter), allows direct dating of relevant (securely associated) archeological contexts (*31*). Second, the application of Bayesian chronological modeling provides a mathematically coherent framework for integrating ^{14}C dates with prior knowledge from the specific archeological record and securely associated history, permitting us to quantify, constrain, and refine chronological probabilities (*31–33*). Combined, these two developments create a dating revolution that has opened up a new era of much better defined chronological resolution in archeology across the world (*24–33*). We report work here using AMS ^{14}C dating incorporating Bayesian chronological modeling to test and investigate the chronology of two key cases for contact-era northeastern North America. The first case, the Warminster site (often associated with Champlain in 1615–1616), offers a case where there is a reasonable basis for an assumed historical association and calendar date association. We thus ^{14}C date this site and assess whether the resultant ages are compatible with the historical association and chronology—and thus whether a refined ^{14}C timescale provides historically useful evidence for contact-era northeastern North America. Our second case is the chronology of a key Wendat community/site relocation sequence in the Rouge River–West Duffins drainage in southern Ontario east of Toronto, Canada. This comprises the sites of Draper, Spang, and then Mantle, the largest, most complex completely excavated Iroquoian site in southern Ontario and also known as Jean-Baptiste Lainé (we retain the original site name here as per previous publications) (Fig. 1) (*14*), which is currently dated ~1450–1550 (Table 1) (*3*, *14*). In this case, there is no clear, direct, historical association. Existing dates have been applied to this sequence based on the absence of European trade goods at Draper and Spang and only three examples of such goods at Mantle. We investigate the timing of these sites via ^{14}C with Bayesian chronological modeling to test both the archeological assumptions (the relative order of the sites as per ceramic seriation) and the assumed calendar dates and offer new ^{14}C-based calendar age estimates for each site.

RESULTS

Here, we present and analyze new and extant radiocarbon (^{14}C) dates obtained on organic samples from the Warminster, Draper, Spang, and Mantle sites to test and investigate the assumed chronology and derived history (see the Supplementary Materials). We obtained samples from each site and use 86 ^{14}C dates to achieve independent dating versus the use of assumptions built around trade and cultural traits (tables S1 and S2 and figs. S1 to S3). We focus on short-lived plant remains with direct archeological associations that will provide ages contemporary with use and employ dates on wood charcoal samples to provide terminus post quem (TPQ) constraint information. The latter, despite expected inbuilt age that renders these dates as TPQ constraints, are important for the 16th century because a plateau in the ^{14}C calibration curve in this period (*34*) can otherwise create dating ambiguities and has been regarded in the past as the problem that hinders precise dating via ^{14}C for Iroquoian archeology (*14*, *20*).

To begin, we considered the analysis of each site separately. The sites are known to have had occupations typically comprising one to two generations or a few to several decades (*8*, *14*), with the communities then relocating. The Draper site, the Spang site, and then the Mantle site are interpreted as successive iterations of the same ancestral Wendat community (*3*, *14*). We thus initially considered the analysis of the data from each site as a single individual Phase in the OxCal 4.3 Bayesian Chronological Modelling software (*32*, *35*), using the current mid-latitude Northern Hemisphere appropriate IntCal13 ^{14}C calibration curve (*34*). The remains of a tamarack wood post (*Larix laricina*), WAR-1, associated with House 4 at the Warminster site with 57 preserved tree rings (fig. S4), but missing any indication of outermost tree rings, permitted "wiggle match" ^{14}C dating (*36*) of a specific sequence of tree-ring samples to define a TPQ for the short-lived material from the Warminster site. In other cases where wood charcoal dates were obtained, we used the Charcoal Outlier (*35*) or the adapted Charcoal Plus Outlier (*30*, *37*) models to account for inbuilt age in wood charcoal samples versus the other samples on short-lived plant remains from the site Phase. Where multiple dates were run on the same short-lived sample, we used the weighted average (R_Combine in OxCal) but added an additional 8 ^{14}C years error term to allow for annual-scale ^{14}C variation (*38*). We controlled for and down-weighted the influence of outliers among the samples using the General Outlier model in OxCal (*35*) for short-lived samples (individual dates or the weighted averages), and for the wiggle-match samples, we used the SSimple Outlier model in OxCal (*35*). We calculated the start and end Boundaries for each site Phase and an overall Date estimate and Span estimate for each Phase and considered any apparent issues (Figs. 2 and 3 and figs. S5 to S7). Where there is an internal sequence within the site Phase from archeological investigation, we also considered models incorporating these known archeological Sequences within the relevant site Phases (figs. S8 and S9 and table S3).

Warminster

The calendar date estimates derived for the Warminster site from the ^{14}C data (Fig. 2) offer most likely 68.2% hpd estimates—overall, these lie between 1585 and 1624—which are compatible with a possible visit to this site by Champlain in 1615–1616. The date range determined does not prove that Warminster = Cahiagué, but is consistent with this often supported, if not necessarily secure, association (*1*, *11*, *12*). In this case, where there is an at least plausible historical association, we may importantly observe that modern AMS ^{14}C dating combined with Bayesian chronological modeling offers a compatible and closely defined date range (see also fig. S5). In this case, as with other work in different areas of the world, both in this general time period (*39*) and in other time periods (*40*), AMS ^{14}C dating yields accurate dates against known calendar dates or approximately known historical dates. We may therefore regard ^{14}C dating as an accurate measure of time for the contact-era Iroquoian case.

Draper, Spang, and Mantle

In contrast, the calendar date estimates derived from the analysis of the ^{14}C dates for each of the Draper, Spang, and Mantle sites as independent Phases are completely at odds with the currently accepted chronology and account of Iroquoian late prehistory in the 16th century (Fig. 3). Rather than dating as supposed, ~1450–1500, the Draper and Spang sites most likely date to 1525–1555 and 1513–1593 (57.9%) or 1620–1640 (10.3%), respectively (68.2% hpd ranges). The Mantle site most likely dates to ~1596–1618 (Fig. 3, 68.2% hpd range) (see also figs. S6 to S9 and table S3). This is again much later than its currently accepted date of ~1500–1550.

We concentrate especially on the Mantle case, where we undertook detailed ^{14}C dating, and where the calendar age is perhaps most challenging for the existing chronology (Table 1). As observed when two initial ^{14}C dates were reported from the site, calibrated age ranges on short-lived samples (maize) from the site offered a very wide possible calendar date range from ~1446 or 1462 to 1635 or 1642 at 95.4% probability (*14*). This wide spread can be attributed to the ^{14}C ages intersecting with the 16th-century plateau in the ^{14}C calibration curve (fig. S3). For this reason, we implemented a strategy aimed at overcoming the ambiguity caused by the shape of the calibration curve to achieve a more precise estimate of the date of the Mantle site. Thus, we dated a range of wood charcoal samples specifically from what are archeologically recognized as early contexts at the Mantle site, as well as a large set of short-lived plant materials from early

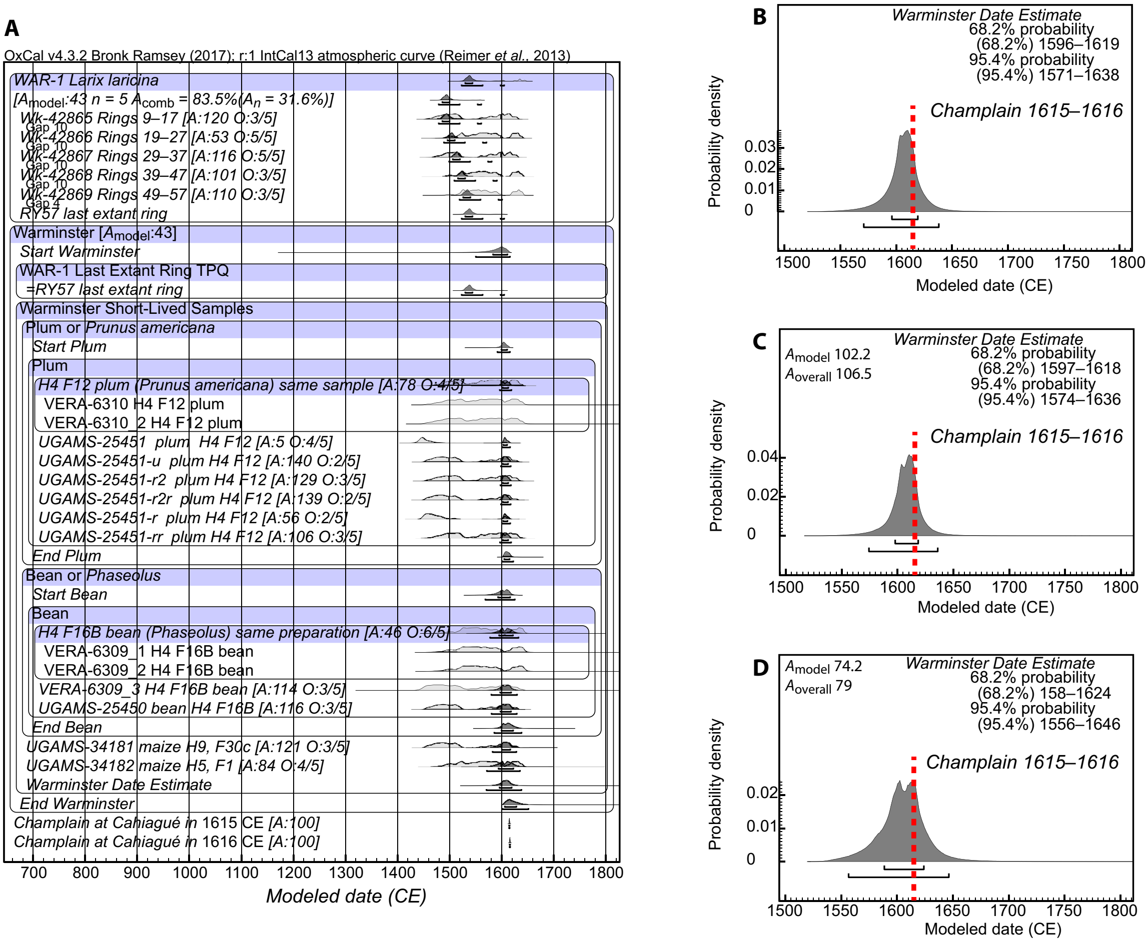

Fig. 2. ^{14}C-derived chronology for the Warminster site. (**A**) The OxCal (*32*, *35*) dating model for the Warminster site Phase with TPQ from a tree ring–sequenced ^{14}C wiggle match on a wood post (*36*) and then the ^{14}C dates on short-lived plant material, using the IntCal13 ^{14}C dataset (*34*), with the dates on the same plum and bean samples combined (table S5A). The nonmodeled calibrated dating probabilities are indicated by the gray distributions; the modeled probabilities are shown by the black distributions. The lines under the modeled distributions indicate the 68.2% highest posterior density (hpd) and 95.4% hpd ranges. OxCal agreement indices (A, A_{model}, and $A_{overall}$) >60 indicate good agreement between the ^{14}C data and the model. O values are posterior/prior probabilities that the date is an outlier. (**B**) The modeled Date estimate for the Warminster site from (A). (**C**) Date estimate from an alternative model treating each date on the plum and bean samples as independent estimates within independent "plum" and "bean" sub-Phases (table S5B). No outliers, but one low agreement date (A:5 = UGAMS-25451). (**D**) As (C) but excluding UGAMS-25451. A_{model} and $A_{overall}$ values are now >60. The dates of Champlain's visit to Cahiagué, 1615–1616, are indicated in each panel.

through very late contexts at the site (see the Supplementary Materials). The wood charcoal samples should include, unless they comprise bark or outermost tree rings, an amount of inbuilt age (since the ^{14}C age relates to when the relevant tree rings formed and not to when the tree or branch was cut down and the wood used by humans at the site). None of the wood charcoal samples dated comprise bark or bark edge, and so all involve some amount of inbuilt age. We would expect a number of such samples, from a population of such potential samples, to have relatively modest inbuilt ages (coming from outer parts of the original trees or branches—since allometry means typically >50% of the wood in a tree or branch comes from the outer 30% of the tree rings). However, there will also be some samples that have rather older ages, and a few, especially if long-lived tree species are involved, will have much older ages. The Charcoal Outlier model (*35*) and Charcoal Plus Outlier model (*30*, *37*) in OxCal seek to represent this prior knowledge. In the Mantle case, the charcoal samples are key to discerning the chronological placement. Were Mantle to date ~1500–1550 as the existing traditional chronology holds (Table 1), then the somewhat older and much older charcoal samples from early contexts at the site should extend from the earlier 16th century and back across the 15th century, and so would increasingly reflect the preplateau (much older) ^{14}C ages of the 15th century. However, most of the dates on the charcoal samples do not do this. Instead, they offer calendar ages similar to those from the short-lived plant materials, and thus in the 16th century to the later 16th century to the start of the 17th century (fig. S3B). Given the inbuilt age involved, and the fact that these samples come from early contexts at the Mantle site, these dates on the charcoal samples are TPQ values, generally for Mantle, and very particularly for the later contexts at the site. These TPQ ranges constrain the possible placement of the dates on the short-lived plant material from Mantle and resolve the previous 16th-century ambiguity. Since the dates on the charcoal samples are TPQ ages by varying amounts and, note, for early contexts at Mantle, we have to find a solution whereby within the available dating probability, the dates on the charcoal samples lie earlier than the dates on the short-lived samples (and certainly

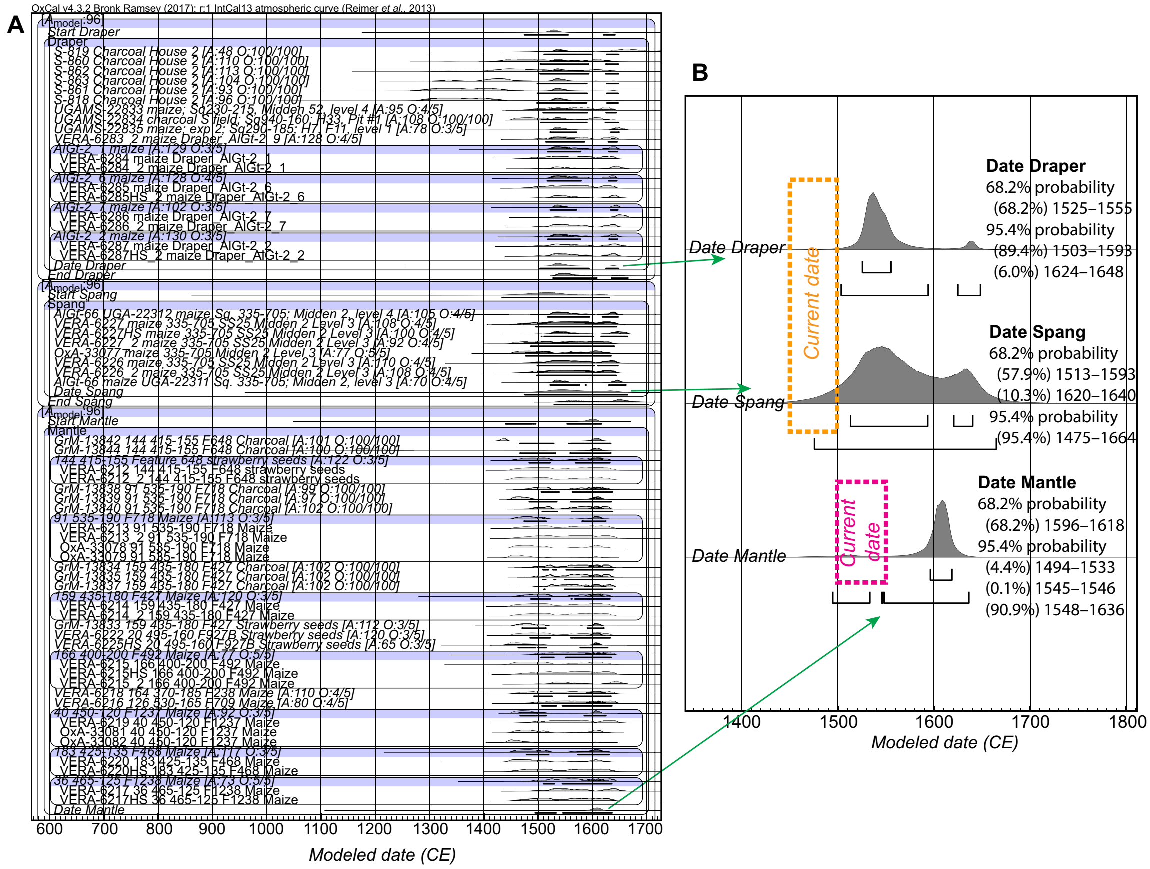

Fig. 3. The ^{14}C-derived chronology for the Draper, Spang, and Mantle sites with each site modeled as an independent phase. (**A**) The OxCal (*32*, *35*) model for each of the three site Phases (Draper, Spang, and Mantle) using IntCal13 (*34*). All the data in table S1 except those four dates with suspect δ^{13}C values are included. The Charcoal Outlier model is specified for the wood charcoal samples (*35*), and the General Outlier model (*35*) is specified for all other materials. Compare results using the modified Charcoal Plus Outlier model (*30*, *37*) in fig. S6. The OxCal agreement indices both indicate good agreement between the data and the model (A_{model} = 96.4 and $A_{overall}$ = 93.5, both >60). There are still a few minor possible outliers: compare with the results in fig. S7. The nonmodeled calibrated dating probabilities are indicated by the light gray distributions; the modeled probabilities are shown by the smaller black distributions. The lines under these modeled distributions indicate the 95.4% hpd ranges. (**B**) The modeled Date estimates for the Draper, Spang, and Mantle sites are shown in detail and compared with the currently accepted date estimates ("current date") for each site (*3*, *14*).

those from the later contexts at Mantle). The only solution is for the TPQ dates on the charcoal samples to lie in the period before, or into, the late 16th century, whereas the dates on the short-lived plant materials lie in the period from the later 16th century to the early 17th century. The OxCal modeling of this situation quantifies a resolved, precise date for the Mantle site (Fig. 3 and fig. S9).

We then implemented an analysis using the Order function in OxCal (*32*) to determine the probabilities of the relative temporal order of the three sites, Draper, Spang, and Mantle, based solely on the ^{14}C data (see the Supplementary Materials). This resulted in a chronological sequence, with Draper determined as likely older than both Spang ($P = 0.56$) and Mantle ($P = 0.67$) and with Spang determined as likely older than Mantle ($P = 0.63$) (table S4). This ^{14}C-determined relative site sequence of Draper, then Spang, and then Mantle is exactly consistent with, but entirely independent of, existing relative archeological assessment. These archeological assessments are based on changing material culture traits, including seriation of ceramic decorative traits, seriation of changes in pipe form, and absence/presence of European-manufactured goods. Such analysis had previously proposed the same relative temporal order of the three sites: Draper, then Spang, and then Mantle (*3*, *14*, *16*).

Since we now have a definite, independently verified, relative order among the three sites, Draper, Spang, and Mantle, we therefore consider a Bayesian Sequence model (*32*) using the data and Phase models in Fig. 3 to determine the best calendar age estimates for these three sites in view of this additional prior knowledge. Because we assume that the three sites are successive iterations of the same community (*3*, *14*), and thus the end of one site will have overlapped with the beginning of its successor, we used trapezoidal phases to permit the consecutive Phases to overlap (Fig. 4 and Table 2) (*41*). The analysis neatly resolves a site sequence within the overall period ~1530–1615 (68.2% hpd ranges), completely at odds with the previously accepted chronology of ~1450–1550.

DISCUSSION

Our data and analyses indicate a revised absolute chronology for the sites we investigated and, by implication, raise important questions

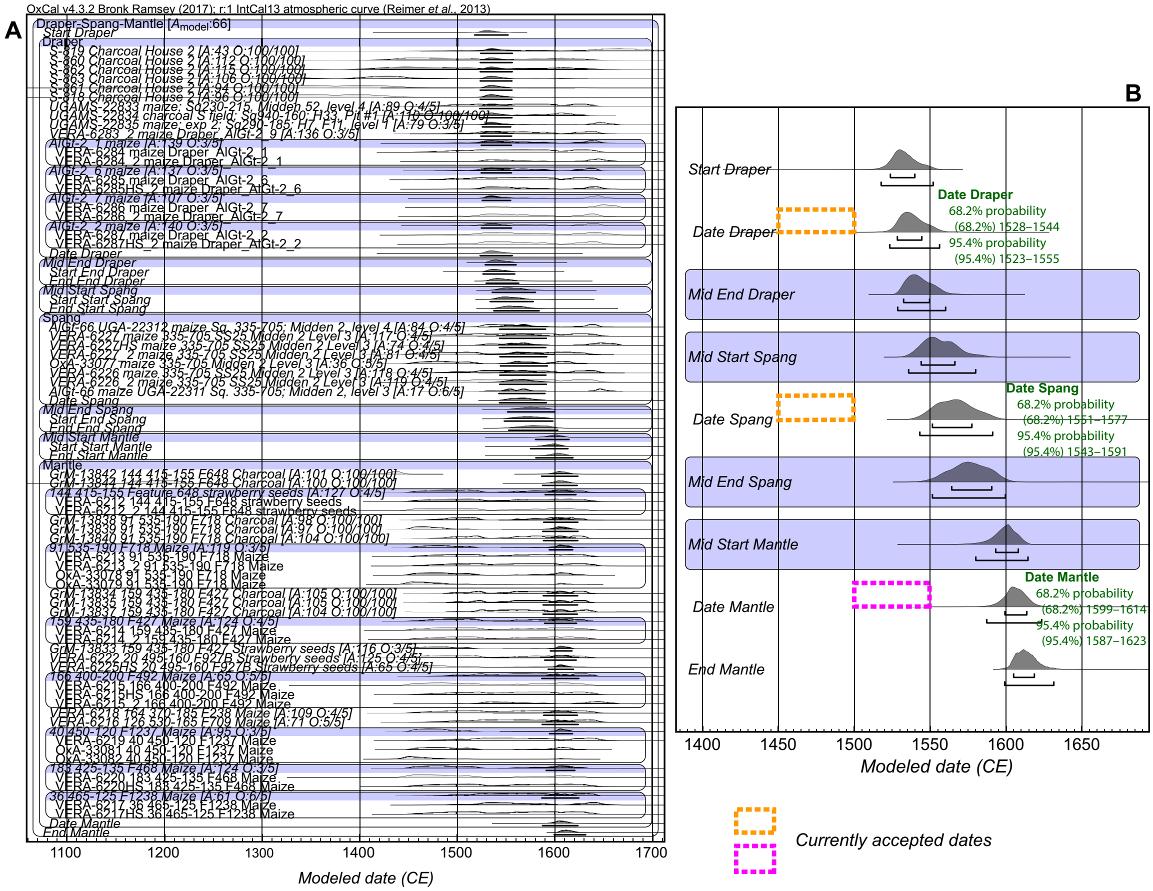

Fig. 4. The Rouge River-West Duffins site sequence of the successive Draper, Spang, and Mantle sites modeled as an ordered sequence of sites as indicated by the ^{14}C data (see text) and existing archeological assessments (*3*, *14–16*) with intervening trapezoidal boundaries (*49*) to allow for some overlaps. (**A**) The site sequence uses the data from Fig. 3 with analysis using OxCal (*32*, *35*), including the Charcoal Outlier model for dates on wood charcoal (*35*) and using IntCal13 (*34*). The A_{model} and $A_{overall}$ values of 65.7 and 64.8 are above the satisfactory value of 60. (**B**) Details on the modeled dates for the Draper, Spang, and Mantle sites—contrasted with the currently accepted dates for the sites (*3*, *14*)—and for the transitions between Draper and Spang and between Spang and Mantle (see also Table 2).

about wider chronology in the pre– and early contact-era periods in northeastern North America that now require investigations of the type undertaken for the four cases in this paper. The revised dates for the Draper, Spang, and Mantle sequence already suggest substantial changes in the previous understandings of the pace and timing of indigenous social, economic, and political changes in northeastern North America, such as processes of coalescence and conflict, substantially shortening the previously assumed time frame and moving these transformations later into the contact-era period in the 16th century. While our modeling and results accord with the relative seriation of ceramic decorative motifs as currently understood, additional efforts need to be directed toward the assessment of ceramic chronologies through independently verifiable means. The fact that the chronology based on the presence/absence of trade goods has been found to be so much in error, by ~50–100 years, raises fundamental questions about the role of European contact in transforming or influencing fluctuations in indigenous economic and sociopolitical networks during the 16th century (see the Supplementary Materials). In particular, such questions focus around the timing of the appearance and distribution of European-manufactured items at indigenous sites and whether finds and frequencies of such items can be used as a reliable temporal measure by archeologists. Until now, the general underlying assumption has been that European trade goods were distributed in a regular fashion throughout ancestral Wendat territory (*42*). However, this must now be questioned with the new understanding that occupation at Mantle and Warminster may have been at least partly contemporary (fig. S10), with the former containing scant European-derived metals and the latter containing a substantial assemblage of both European metals and glass beads. Critical approaches, along with archeological and ethnohistorical examples, point to variations and even conflict over access to or participation in trade of European goods, or groups blocking access to such goods and networks, or of some indigenous groups rejecting European contact and goods [(*6*), vol. 15, pp. 15–22; (*13*, *23*, *43*–*45*)]. In addition, the revised chronology has relevance for how developments in Iroquoia may be associated with climate: the transformative coalescent and postcoalescent Phases [(*3*, *14*); see the Supplementary Materials] now occur across the peak of the Little Ice Age (LIA) from the mid-1500s to the early 1600s and not across the previous century or so. Just as White (*18*) carefully correlates and elucidates the European encounter with North America with this peak LIA era, so do key transformations in Iroquoian

Table 2. The calendar date ranges or periods (in calendar years) determined for selected Dates, Spans, and Boundaries in the Draper-Spang-Mantle site sequence model shown in Fig. 4 and compared with a rerun of this model but using (i) the Charcoal Plus Outlier model (*30*, *37*) and (ii) after excluding the six minor possible outliers noted in the Supplementary Materials and fig. S5. This rerun model runs with typical values of A_{model} of 86.5 and $A_{overall}$ of 84 each above the satisfactory threshold value of 60. Calendar dates CE in regular font, calendar years (duration) in italics.

	Figure 4 model		Rerun revised model	
	68.2% hpd	***95.4% hpd***	***68.2% hpd***	***95.4% hpd***
Start Draper	1523–1539	1517–1551	1522–1540	1515–1553
Date Draper	1528–1544	1523–1555	1527–1544	1521–1557
Span Draper	*1–13*	*0–25*	*1–13*	*0–26*
Mid end Draper	1532–1549	1528–1559	1531–1550	1527–1561
Duration end Draper	*0–5*	*0–15*	*0–5*	*0–16*
Mid start Spang	1543–1566	1535–1580	1543–1567	1535–1581
Duration start Spang	*0–6*	*0–19*	*0–6*	*0–19*
Date Spang	1551–1577	1543–1591	1551–1578	1542–1592
Span Spang	*4–23*	*1–38*	*4–23*	*1–39*
Mid end Spang	1564–1590	1551–1599	1564–1591	1550–1600
Duration end Spang	*0–7*	*0–23*	*0–7*	*0–23*
Mid start Mantle	1593–1608	1580–1614	1593–1608	1579–1615
Duration start Mantle	*0–7*	*0–23*	*0–6*	*0–21*
Date Mantle	1599–1614	1587–1623	1599–1614	1586–1623
Span Mantle	*2–19*	*0–37*	*1–17*	*0–38*
End Mantle	1604–1618	1599–1631	1604–1618	1596–1631

societies—especially the intensification of conflict and confederacy formation [(*3*, *22*); see the Supplementary Materials]—correlate with this same particularly challenging climate period. Looking more widely across North America, our data indicate the urgent need now for new sustained efforts at modern, independent chronology building, using science-based methods, which have the power to transform traditional archeological narratives and to highlight issues of agency and historical contingency in the late prehistoric and early colonial eras.

Some caveats and comments on future developments are in order by way of conclusion. We note that our study uses data from only four sites. We selected Warminster as one of the only Iroquoian sites with an often-proposed direct historical association to investigate and confirm that ^{14}C dating could and should offer independent but compatible information and with reasonably good precision. The other three sites offer a well-known site relocation sequence from the supposed Late Iroquoian period before substantial European contact (Table 1) (*3*, *14*). Needless to say, to now test and further establish the wider relevance of the revised chronological implications suggested by our results, additional ^{14}C dates need to be obtained and analyzed from samples from a variety of other Iroquoian (and related) sites in northeastern North America to create a wider chronological (re)understanding. In particular, the methods we use have the potential to resolve the previous problem of a lack of subcentury resolution for the 16th century, which has been noted as a limiting problem for the field until now (*13*). The accuracy of the calibrated ^{14}C dates is of course central to the validity of the chronology presented here. We have run ^{14}C dates at several different laboratories, each using slightly varying methods, and obtained compatible ^{14}C ages for similar or the same samples and contexts (table S1); thus, the ^{14}C dates we report appear generally robust (see the Supplementary Materials). The calendar dates determined from these ^{14}C ages depend on the accuracy of the ^{14}C calibration curve for the mid-latitude Northern Hemisphere in this period (*34*). Available data from known-age mid-latitude Northern Hemisphere material indicate findings for the mid-second millennium largely compatible with the IntCal13 dataset (*38*, *39*, *46*–*48*), in support of the accuracy of the approximate range of the calibrated calendar age estimates presented here. However, it should be noted that future revisions of the calibration curve, particularly as additional annual resolution data become available, may lead to minor (likely <10 to 20 years) revisions.

We must also highlight that some flexibility remains. The 68.2 and 95.4% modeled calendar age ranges in Figs. 2 to 4 and Table 2 are as stated: ranges within which the dated elements lie according to these probability levels. Thus, to take the most notable example above, the modeled ages suggest that the Mantle and Warminster site occupations may be at least partially contemporary (Figs. 2 to 4 and fig. S10). This may well be the case, but it is also still possible within the modeled calendar age ranges and probabilities that, for example, the Mantle site ended before ~1615–1616, when Champlain stayed at Cahiagué, and for Warminster to date so as to include Champlain's stay. Critics will undoubtedly query how, for example, the Warminster site has a substantial assemblage of European trade goods, but Mantle does not, if Mantle is of similar or even contemporary date (and this was of course part of the reason the Mantle site was previously dated ~1500–1550). We also acknowledge that the Mantle site contained a diverse ceramic assemblage interpreted as representing an extensive interaction network (*14*), and that this raises questions about why those interactions may not have included the acquisition of more European-manufactured materials. Aware of such concerns and previous expectations, we undertook a detailed dating program specifically to resolve Mantle's placement within the overall 16th-century plateau in the ^{14}C calibration curve as discussed above. Both in isolation and as part of the Draper-Spang-Mantle sequence, we found that Mantle lies in the late 16th to the early 17th century, some 50 to 100 years later than previously thought, and thus it is at least close to or even contemporary with the Warminster site (Figs. 3 and 4 and figs. S6, S7, S9, and S10). In such a case, confronted by the differences in trade goods recovered, we must instead reflect on the very different trade histories, routes, and connections of sites and areas in the greater northeastern North American region. These differences relate to both temporal and spatial dimensions, as well as the social dimension reflecting differences in how such goods were used and valued and deposited across different social groupings (for example, Ontario Iroquoian evidence of European trade goods in earlier periods largely comes from mortuary contexts) (*13*). These differences themselves are varying, expressing a number of (changing and changeable) factors through time and across space, reflecting both internal and external issues as well as geography and geopolitics. The contrast between Warminster and Mantle is potentially explicable in such terms. For example, Champlain's visit and related links with the trading of European goods down the French River from Quebec, as controlled and mediated by indigenous groups in this area (*49*), may largely explain the substantial assemblage of European trade goods at the Warminster site and various sites close by (*12*, *49*). This may be in contrast to a settlement like Mantle, nearly 80 km south, in an area not so directly linked to the French-European trade at this time.

MATERIALS AND METHODS

Experimental design

Organic samples comprising short-lived (annual-growth) plant materials and wood or wood charcoal were selected and obtained from the collections from four archeological sites from northern Iroquoia (Ontario, Canada): Warminster, Draper, Spang, and Mantle (Fig. 1). These materials were examined and ^{14}C dated to provide independent age estimates of the samples and sites and to allow testing and comparison of these age estimates versus existing dates determined largely from culture-historical approaches (Table 1). The ^{14}C ages from each of the sites were then analyzed. The first step involved the analysis of each site group as separate (i.e., independent) site Phases using the OxCal software (*32*) and the IntCal13 ^{14}C calibration dataset (*34*). The second step for the three sites, Draper, Spang, and Mantle, argued to belong to successive iterations of the same community, was analysis via the OxCal Order function to determine the likely chronological order of the three sites. The third step, in the case of these three sites understood from archeological investigation to form a successive series of site relocations by the same community, since the analysis of the ^{14}C data independently confirmed this assumption, was analysis of the three sites as a Sequence using the Bayesian probability methods available in the OxCal software (*32*). This should yield best (most resolved) age estimates, since the analysis involves multiple constraints within such a Sequence analysis. Since the successive site occupations are assumed to be contiguous, we assumed that it is likely that the ends and beginnings of the successive site occupations were at least partly overlapping, and so we employed a model assuming trapezoidal Phases (*41*).

Archeology

A summary discussion of the archeological sites and data used in this study is provided in the Supplementary Materials.

Dendrochronology

Sample WAR-1, House 4 Feature 13 post, from the Warminster site comprised an *L. laricina* sample comprising in all 57 extant tree rings. The outer rings to the original bark of the sample were not preserved. The sample was prepared for dendrochronological study and the tree rings were measured (fig. S4). Five defined tree-ring segments, comprising tree rings 9 to 17, 19 to 27, 29 to 37, 39 to 47, and 49 to 57, were dissected from the sample with a steel blade under a binocular microscope and ^{14}C dated. The resultant tree ring–sequenced ^{14}C dates were then wiggle matched (*36*) to obtain a best calendar age estimate for the final extant tree ring, ring 57, which sets a TPQ for the original cutting date and use of the sample.

Radiocarbon (^{14}C) samples and dates

Details on the samples and the 86 ^{14}C dates used in this paper (from 90 original dates, 4 excluded, see table S1) and a summary of the methods used at each of the four laboratories are provided in the Supplementary Materials.

Calibration and Bayesian chronological modeling

Calibration and Bayesian chronological modeling used the OxCal software (*32*) and forms of outlier analysis (*30*, *35*, *37*) and the IntCal13 ^{14}C calibration dataset (*34*), with curve resolution set at 1 year. We used capitalized forms of words such as Sequence, Phase, Boundary, Date, Span, and Order to refer to OxCal terminology. The models and elements are described in the Supplementary Materials and shown in Figs. 2 to 4 and figs. S6 to S11, and the OxCal runfiles for Figs. 2 to 4 and figs. S8 and S9 are listed in tables S5 to S9. We note that for reasons of space and legibility in the figures, we did not include the OxCal keywords. Please refer to the OxCal runfiles in tables S5 to S9 for the full model specifications. (Note: OxCal assumes that IntCal13, the current Northern Hemisphere ^{14}C calibration curve at the time of writing, is the calibration dataset to use, and this does not need to be specified.) Details on the Bayesian chronological modeling are provided in the Supplementary Materials.

SUPPLEMENTARY MATERIALS

Supplementary material for this article is available at http://advances.sciencemag.org/cgi/content/full/4/12/eaav0280/DC1

Supplementary Materials and Methods

Fig. S1. A comparison of the ^{14}C ages [conventional radiocarbon years before the present (BP)] reported on samples of short-lived plant remains in table S1 by site (excluding the four dates with problematic δ^{13}C values—see table S1).

Fig. S2. The nonmodeled, individual, calibrated calendar dating probability ranges for the ^{14}C dates reported in table S1 (excluding the four with problematic δ^{13}C values—see table S1).

Fig. S3. The nonmodeled, individual, calibrated calendar dating probability ranges for the ^{14}C dates reported in table S1 shown against the IntCal13 calibration curve and the (nonmodeled) calibrated age probabilities for the subset of dates on samples just from Mantle early contexts.

Fig. S4. Photos and ring-width measurements, WAR-1 sample.

Fig. S5. Comparison of the ^{14}C range (overall 1σ) of the set of ^{14}C dates on short-lived plant remains from Warminster (see table S1) against the modeled (mid-point) and raw (constituent) IntCal13 (*34*) data (shown with 1σ errors) (raw data from: http://intcal.qub.ac.uk/intcal13/) placed within the calendar period, ~1596–1619, identified in the analysis reported in Fig. 2.

Fig. S6. Results from an alternative run of the dataset in Fig. 3 as summarized in Fig. 3B but using the Charcoal Plus Outlier model.

Fig. S7. Results from an alternative run of the dataset in Fig. 3 as summarized in Fig. 3B but after excluding the six minor possible outliers identified by the SSimple Outlier model in the various R_Combines (VERA-6286 O:8/5, OxA-33079 O:8/5, VERA-6215_2 O:12/5, VERA-6219 O:12/5, OxA-33082 O:16/5, and VERA-6217 O:6/5).

Fig. S8. Revised model of the Spang site data as a Sequence with the Midden 2 Level 4 date treated as earlier than the Phase of Midden 2 Level 3 dates.

Fig. S9. Revised model of the Mantle site as a Sequence using those samples best associated with the intrasite phasing.

Fig. S10. Comparisons of the Warminster Date Estimate probability density function (PDF) from Fig. 2D with the Date Mantle PDF from Fig. 3.

Fig. S11. Comparison of the PDFs for the Date Mantle estimate from 10 runs of the Mantle model in Fig. 3.

Table S1. The samples and conventional radiocarbon dates used in this study.

Table S2. UGAMS radiocarbon dates on the Warminster Feature 12 *Prunus Americana* (plum) sample using several different pretreatment approaches (data as listed in table S1).

Table S3. Details of the results from the Mantle internal site sequence model in fig. S9.

Table S4. Order calculation from OxCal determining the probability that t_1 is less than (i.e., older than) t_2.

Table S5. OxCal runfiles for the Warminster site in Fig. 2.

Table S6. OxCal runfile for the Draper, Spang, and Mantle site analysis shown in Fig. 3.

Table S7. OxCal runfile for the Spang Sequence analysis shown in fig. S8.

Table S8. OxCal runfile for the Mantle Sequence analysis shown in fig. S9 and with results in table S3.

Table S9. The OxCal runfile for the Draper-Spang-Mantle sequence analysis shown in Fig. 4 and with results in Table 2.
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