

# Modeling the Chronology of a Late Precontact Site Using Radiocarbon and Trade Good Dates: Middle Grant Creek

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Jack N. Fenner,<sup>a, b</sup> Mark R. Schurr,<sup>b</sup> Madeleine McLeester,<sup>c</sup> and Laure Dussubieux<sup>d</sup>

<sup>a</sup> Archaeology and Natural History, The Australian National University, Canberra, ACT 2600, Australia

<sup>b</sup> Department of Anthropology, University of Notre Dame, South Bend, IN 46556

<sup>c</sup> Department of Anthropology, Dartmouth College, Hanover, NH 03755

<sup>d</sup> Elemental Analysis Facility, Field Museum, 1400 S. Dusable Lake Shore Drive, Chicago, IL 60605

#### ABSTRACT

Late precontact- and contact-period sites often produce multiple sources of chronological information, including stratigraphy, radiocarbon dates, European trade goods, and pottery seriation patterns. In this article, we describe a step-by-step approach to incorporating such information in an OxCal-based Bayesian chronology model, with special emphasis on incorporating trade-good dating into radiocarbon-based modeling. The Middle Grant Creek site in Illinois is an American Indian site that has yielded a number of European copper and brass trade goods along with extensive ceramic, faunal, floral, and lithic artifacts. Our modeling addresses issues resulting from an inversion in the radiocarbon calibration curve during the late precontact period and produces surprisingly different results depending on the boundary conditions applied to the model. We consider the probabilities produced by the models, propose the most likely chronology for Middle Grant Creek, and provide detailed OxCal scripts and examples that other researchers may adapt to their circumstances and preferences. We also describe lessons learned related to chronological modeling of sites where the radiocarbon curve contains significant inversions.

#### **KEYWORDS**

OxCal; radiocarbon modeling; nonradiocarbon dates; Oneota Tradition; copper; brass; glass bead

The occupation dates of late precontact and early colonial period sites in North America are often estimated using a variety of evidence, including historical information, pottery seriations, manufacture and import dates for introduced European goods, site stratigraphy, and increasingly, radiocarbon dates on excavated organics. Usually, each form of evidence is considered, and then the evidence is informally weighed and combined to produce an occupation date estimate. This is a straightforward and reasonable approach. However, recent work has shown that additional insight may be obtained by integrating chronological data into a more formal model using OxCal scripts (Lulewicz 2018; Thompson et al. 2019, 2020).

**CONTACT** Jack N. Fenner 🔯 jack.fenner@anu.edu.au © 2023 Midwest Archaeological Conference

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The Bayesian statistical approach employed by OxCal (Bronk Ramsey 2009a) may then use the modeled chronological information to produce a more quantitative and statistically reliable estimate of the site occupation dates than was previously available. This process also forces the analyst to assess the reliability and suitability of each piece of evidence, documents each assumption, and produces a rough assessment of the reliability of the model itself (in the form of OxCal agreement indices). On the other hand, modeling the full suite of chronological information for a particular site may not be straightforward, and a poor model that produces incorrect results is misleading and, in fact, worse than no model at all. Furthermore, modeling tends to obscure the chronological argument in a haze of terminology and programming scripts.

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This article describes our attempt to model the full suite of chronological information available for Middle Grant Creek (MGC), a site located near the Kankakee and Des Plaines Rivers southwest of what is now Chicago, Illinois (Figure 1). Rather than simply present the outcome of the modeling as is commonly done (i.e., Lulewicz 2018; Thompson et al. 2019, 2020), we build up the model step by step, incorporating an additional type of chronological information with each step and then evaluating its impact on the model and the chronological understanding of the site. This approach allows us to improve our understanding of which chronological data are important in establishing the chronology and how the different types of data influence each other within the model. We also provide a detailed description that allows other researchers to evaluate our model and potentially adopt a similar





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approach for other archaeological sites. All OxCal scripts, relevant OxCal output, and related spreadsheets used in our analysis are provided in supplementary files.

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## **The Middle Grant Creek Site**

Middle Grant Creek (11WI2739) is an Indigenous late precontact period<sup>1</sup> agricultural village located between a restored wetland to the west and restored prairie to the east at Midewin National Tallgrass Prairie (McLeester and Schurr 2020). A Euro-American farmstead was located at the southern end of the site during the nineteenth and early twentieth centuries until the area was incorporated into the U.S. Army Joliet Arsenal in the 1940s. Midewin National Tallgrass Prairie was established in 1996 after the arsenal was decommissioned (McLeester et al. 2022). We interpret Middle Grant Creek as an agricultural village based on the high density of crops (notably maize) in the macrobotanical record, the agricultural and crop processing tools recovered in excavation, and the large number of storage pits at the site, which could have stored enough maize to support at least 150 people for a decade (McLeester and Schurr 2020; Schurr et al. 2021). Although no dwellings have been identified at the site, aerial images (McLeester et al. 2018) and a soil resistivity anomaly (Schurr et al. 2021) consistent with a Huber phase house indicate possible structures. Extensive earthmoving activities at the site may have destroyed shallow house basins (Schurr et al. 2023).

Excavations and geophysical surveys indicate that Middle Grant Creek is 3.4 ha to 20 ha in size and contains hundreds of refilled storage pits that appear to be organized in geographic clusters (Figure 2; Haas et al. 2012; Schurr et al. 2021). Three of the clusters have been designated "East," "West," and "Night Bunker East" (NBE) based on their geographic locations. A fourth cluster is referred to as "2006" because one pit feature in the cluster was excavated during a Phase II project conducted in 2006 (Haas et al. 2012). Based on its geographic position, the 2006 cluster may in fact be a part of the West cluster; we will evaluate this below using chronological information. Aside from the 2006 feature, all other storage pit feature data and locations were identified using magnetometry and excavation. We estimate that there are about 91 subterranean features within the surveyed area of the site (Schurr et al. 2021). Seventeen features have been fully or partially excavated. Those features identified as storage features had an average depth of 156 cm below the current surface and are unusually large for this period. Nearly all features show multiple refill episodes (McLeester and Schurr 2020; Schurr et al. 2021). All excavated features contain a mix of artifacts—such as pottery, lithics, faunal remains, and macrobotanicals—typical of late-precontact Indigenous sites in this region; however, the quantities of each vary significantly by pit.

When a pit feature was identified during excavation, it was cross-sectioned by removing one half in arbitrary10 cm thick layers. This created a profile of the cross section that was documented. The unexcavated half was then removed in stratigraphic levels. Soils were screened through 6.3 mm (1/4-inch) mesh and flotation

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**Figure 2.** Map of MGC showing the general extent and clustering. Excavated features included in this article are also identified.

samples were collected from levels and strata, with additional samples from levels and strata that contained visible botanical remains.

All artifacts used in this analysis were recovered from the refilled storage pits. Most ceramics suggest that Middle Grant Creek was a Huber phase site within the Oneota Tradition, the terminal precontact archaeological phase in the region, which is typically dated to 1500 CE to 1670 CE (McLeester and Schurr 2020). The beginning and end of the late precontact period in the region have not been clearly established. We use 1500 CE for the beginning as an early estimate to accommodate the first appearance of European trade goods sometime in the sixteenth century and 1670 CE as a terminal date because of the apparent absence of Huber occupations when the French entered the region (see Model 7 discussion below). Maize kernels were the most abundant macrobotanical remains recovered and were located in most pits, along with a mix of cultivated and collected botanical remains. Faunal material included a mix of bones, freshwater shell, and fish scales; all of these were abundant at the site. Together the macrobotanical and faunal remains indicate a mixed subsistence strategy centered on maize agriculture, with the utilization of wild plant resources combined with animal procurement in multiple environments, especially wetlands (McLeester et al. 2022). Of particular interest is a marine shell, likely originating along the west coast of Florida, and evidence of marine shell processing on-site (McLeester et al. 2019). A number of small brass, copper, and iron pieces of European origin were also recovered (Table 1), along with one Period 2

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Artifact Id	Materialª	<sup>14</sup> C age (BP)	±1σ	Location	Cluster	Feature	Level or Zone <sup>b</sup>
210	SEC			2006 Excavation	2006	1	E
213	brass			2006 Excavation	2006	1	Н
232	brass			2006 Excavation	2006	1	PP 12
226	brass			2006 Excavation	2006	1	PP 6
D-AMS 032854	maize cupule	275	25	2006 Excavation	2006	1	unknown
D-AMS 032855	maize cupule	385	30	2006 Excavation	2006	1	unknown
423.01	SEC			E 102-103 N 137-138	East	1	5
423.02	brass alloy			E 102-103 N 137-138	East	1	5
422	SEC			E 102-103 N 137-138	East	1	6
D-AMS 032848	maize kernel frag.	415	25	E 102-103 N 137-138	East	1	7
D-AMS 038001	maize kernel frag.	400	25	E 102-103 N 137-138	East	2	3
1320	SEC			E 100-102 N 136-138	East	3	5
1340	blue glass bead			E 100-102 N 136-138	East	3	6
D-AMS 032849	maize kernel frag.	370	20	E 100-102 N 136-138	East	3	8
D-AMS 032850	maize kernel frag.	355	35	E 100-102 N 136-138	East	3	8
1328.02	SEC			E 100-102 N 136-138	East	3	12
421	brass			E 104-106 N 153-155	East	4	10
1324.01	SEC			E 104-106 N 152-153	East	4	10
1324.02	SEC			E 104-106 N 152-153	East	4	10
D-AMS 032846	maize kernel frag.	310	40	E 104-106 N 153-155	East	4	10
D-AMS 032847	maize kernel frag.	310	30	E 104-106 N 153-155	East	4	10
D-AMS 032851	hazel nutshell	295	25	E 104-106 N 152-153	East	4	10
1332	SEC			E 104-106 N 152-154	East	4	15
UCI 198868	maize kernel frag.	345	15		East	4	12
1329	SEC			E 106-108 N 158-160	East	5	4
D-AMS 032852	maize cupule	330	25	E 106-108 N 158-160	East	5	7
D-AMS 032853	Prunus sp. seed	290	20	E 106-108 N 158-160	East	5	13
2076	brass			E 102-104 N 144-146	East	6	3
1336	SEC			E 102-104 N 144-146	East	6	5
2077	SEC			E 102-104 N 144-146	East	6	7
2071	SEC			E 102-104 N 144-146	East	6	8
2078	brass			E 102-104 N 144-146	East	6	8
2072	SEC			E 102-104 N 144-146	East	6	9
2079	SEC			E 102-104 N 144-146	East	6	9
2081	SEC			E 102-104 N 144-146	East	6	10
D-AMS 038002	maize kernel frag.	380	25	E 102-104 N 144-146	East	6	10
3513	SEC			E 102-104 N 144-146	East	6	14
3516	SEC			E 102-104 N 144-146	East	6	16
D-AMS 038003	maize kernel frag.	420	25	E 108-110 N 137-138	NBE	1	9
D-AMS 038009	maize cupule/ glume	490	30	E 108-110 N 137-138	NBE	1	14
3924	brass			E 178.5-180 N 124-125	NBE	3	3
D-AMS 038005	maize kernel frag.	410	35	E 85-86 N 132.5-134	West	10	Zone 10
D-AMS 038004	maize kernel frag.	420	30	E 85-86 N 132.5-134	West	10	Zone 2
D-AMS 038006	Phaseolus sp. seed	385	15	E 78-80 N 139.5-142	West	11	8
D-AMS 038007	maize kernel frag.	400	25	E 78-80 N 139.5-142	West	11	10
3528.01	SEC			E 78-80 N 139.5-142	West	11	12
D-AMS 038008	Cucurbita sp. rind	395	25	E 78-80 N 139.5-142	West	11	10-11
3527	SEC			E 83-85 N 128-130	West	12	11
3529	SEC			E 83-85 N 128-130	West	12	Zone 6
D-AMS 038011	maize kernel frag.	435	35	E 83-85 N 128-130	West	12	Zone 11
D-AMS 038010	maize kernel frag.	410	30	E 86-87.5 N 133-135	West	13	13

 Table 1. Radiocarbon Dates and European Trade Objects from Middle Grant Creek.

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<sup>a</sup> SEC: Smelted European copper; brass alloy artifact contains significant quantities of tin in addition to zinc.

<sup>b</sup> Larger layer numbers indicate lower layers.

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blue glass trade bead (McLeester and Schurr 2020). It is likely that the European artifacts arrived via down-the-line trade with other Indigenous groups rather than via direct contact with Europeans at Middle Grant Creek (McLeester and Schurr 2020).

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Excavation and analysis thus have produced an abundance of chronological data relevant to Middle Grant Creek (MGC). This includes the following:

- a series of radiocarbon dates on short-lived organics
- stratigraphic relationships within the pit features
- historical information related to American Indian occupations in the region
- ceramic seriation
- a glass bead of European origin
- brass and smelted copper artifacts of European origin

Relevant aspects of each of these data sets will be described in detail below as they are incorporated into the modeling.

### Model 1: Basic Radiocarbon

We begin by examining the available radiocarbon data in isolation. Twenty-two radiocarbon dates are available from MGC pits (see Table 1). All were obtained from maize kernels or other short-lived plant material using accelerator mass spectrometry (AMS). One additional radiocarbon date from MGC is based on the marine shell (McLeester et al. 2019). It is not possible to directly compare the radiocarbon dates of samples from terrestrial and marine environments because of the marine reservoir effect (expressed as  $\Delta R$ ), which causes marine samples to date earlier than contemporaneous terrestrial ones that obtain their carbon from the atmosphere. Radiocarbon dates from marine carbonates must be corrected for the reservoir effect, which is highly variable depending on local environmental conditions (Hadden et al. 2023). Although the marine shell was probably obtained from somewhere on the west coast of Florida (McLeester et al. 2019), published  $\Delta R$  data are variable over such a large region and are too imprecise for this analysis.

One of the challenges of using radiocarbon dates during the sixteenth and seventeenth centuries is that there are a number of inversions of the radiocarbon calibration curve within that time frame. Figure 3 shows an example calibration using the average of the 22 MGC radiocarbon dates, a typical standard deviation, and the calibration curve. We emphasize that averaging uncalibrated dates is not an appropriate means of evaluating chronology; instead, we use it simply to gain an understanding of the significance of the calibration inversion during our period of interest. Note that there is a large calibration inversion creating a bimodal probability distribution and that about 65% of the calibrated period falls in the early "hump" of the two-mode calibration, with about 30% in the later hump. This will be of interest below when we evaluate our models. The remaining 5% of the probability curve falls outside or between the two main humps.

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**Figure 3.** Example radiocarbon dates across a calibration inversion. Uses the average of uncalibrated radiocarbon dates from Middle Grant Creek and a typical standard deviation.

All radiocarbon dates were calibrated using the IntCal20 calibration curve (Reimer et al. 2020) using OxCal v4.4 (Bronk Ramsey 2009a). Each radiocarbon date was assigned a 5% probability of being an outlier, with the outlier model set to

# Outlier\_Model("RCOutlier",T(5),U(0,4),"t")

where RCOutlier is the name of the model, T(5) indicates that the outlier distribution is the Student's t distribution with 5 degrees of freedom, U(0,4) indicates scaling of up to 1,000 years, and "t" indicates it is a potential time outlier. This is a widely used standard outlier model for radiocarbon dates from short-lived materials, as recommended by Bronk Ramsey (2009b). Allowing for potential outliers provides the model with the statistical flexibility to deal with uncertainty beyond that of the date measurement and calibration curve. That is, it allows the model to compensate for dates that do not otherwise fit the model, such as happens with minor stratigraphic inversions. When outlier compensation is performed by OxCal, it degrades the model agreement index and can cause the model to fail (more on this below).

The Basic Radiocarbon model is simply a list of the 22 radiocarbon dates (with outlier modeling) within a single phase.<sup>2</sup> (Note that an OxCal "phase" is different from *phase* as used in cultural historical or pottery sequences; it simply indicates that the items within the phase do not have known chronological relationships with each other.) The resulting plot in Figure 4 shows the modeled calibrated radiocarbon distributions (also known as the posterior distributions), as well as their

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likelihood distributions.<sup>3</sup> The modeled radiocarbon distributions are all situated in the early (left) part of their likelihood distributions. We believe that this is a result of having about 65% of the average distribution in the earlier portion of the calibration inversion. Having so many dates and a "heavy" early portion causes the statistical inference that the earlier dates (predating about 1550 CE) are more likely to be correct than the later dates, so all the modeled dates are "pulled" to the early part of their likelihoods. Thus, the site occupation is shown to be earlier than a casual look at the calibrated radiocarbon dates might suggest.

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Just how early can be examined via the modeled overall site distributions MGC Start and MGC End (see Figure 4). The probabilities indicated by such distributions, however, can be difficult to grasp based only on their posterior curves. Therefore, we present distributions by showing plots of summation under the

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**Figure 5.** Basic Radiocarbon model of MGC start and end dates. Curves obtained by integrating under the MGC Start and MGC End curves in Figure 4. See the supplementary file set for the model script, output data, and calculations.

posterior curves (Figure 5). These show the probability that Middle Grant Creek started (or ended) by a certain year, assuming the model correctly represents the situation.<sup>4</sup>

A note is needed about the probabilities discussed here. Those researchers accustomed to working with single calibrated radiocarbon dates or Student's *t* tests and similar frequentist statistical tools have a tendency to use 95% or 2 $\sigma$  regions to characterize a distribution. That is appropriate and even necessary with such tools. However, the posterior probabilities in Figure 5 represent actual computed probabilities and incorporate calibration and modeling uncertainties; they are not the probability that an outcome may occur by chance but rather the actual probability of an event. Therefore, when using these posterior distributions, we use different ranges and terminology to describe the distributions. We term the 50% probability date—the year in which there is a 50% chance a site or cluster had started by then and a 50% chance that it started later—as the "most likely" start date. Similarly, the 20% and 80% dates are termed the "early" and "late" dates, respectively. All probabilities are included in the provided data and figures, so other analysts can choose probabilities and terminology that suit their preferences.

The most likely Middle Grant Creek start and end dates in this model are 1435 CE and 1548 CE, respectively (see Figure 5; Table 2). These dates—especially the end date—are surprisingly early for a site with abundant Huber pottery and European-origin artifacts. Nevertheless, assuming the model was implemented

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	Sta	Started by (Year AD)			Ended by (Year AD)			
	20%	50%	80%	20%	50%	80%		
		Most likely			Most likely			
MGC or Cluster	Early date	date	Late date	Early date	date	Late date		
Basic Radiocarbon	Model (A <sub>model</sub>	= 127)						
MGC	1426	1435	1443	1536	1548	1571		
Radiocarbon with	Clusters and S	tratigraphy Mod	del (A <sub>model</sub> = 155)					
MGC	1377	1409	1427	1555	1584	1632		
NBE	1413	1429	1440	1450	1465	1495		
East	1447	1462	1480	1534	1554	1583		
West	1444	1452	1460	1462	1470	1480		
2006	1447	1481	1516	1531	1550	1583		
Bounds Added Mo	del (A <sub>model</sub> = 15	54)						
MGC	1376	1407	1426	1558	1590	1645		
NBE	1413	1428	1439	1450	1465	1496		
East	1446	1461	1479	1537	1557	1590		
West	1444	1452	1460	1462	1470	1480		
2006	1446	1482	1519	1532	1553	1591		
Bead Added Mode	I (A <sub>model</sub> = 138)							
MGC	1350	1389	1416	1628	1661	1717		
NBE	1401	1422	1435	1453	1474	1521		
East	1445	1467	1567	1607	1623	1638		
West	1442	1451	1459	1463	1471	1481		
2006	1433	1478	1533	1553	1599	1649		
Metal Added Mode	$eI(A_{model}=34)$							
MGC	1591	1598	1603	1605	1610	1620		
NBE	1597	1602	1605	1602	1605	1610		
Fast	1597	1601	1605	1602	1606	1610		
West	1598	1602	1605	1602	1605	1609		
2006	1598	1602	1607	1602	1607	1615		
Revised Metal Mod	lel ( $A_{model} = 90$ )	)						
MGC	1356	1393	1418	1642	1666	1712		
NBF	1400	1421	1435	1467	1594	1644		
Fast	1591	1597	1602	1606	1612	1620		
West	1447	1592	1602	1478	1605	1612		
2006	1574	1595	1610	1621	1634	1648		
Tight Bounds Mod	el (A= 79)							
MGC	1587	1508	1603	1605	1610	1625		
NRE	1507	1600	1605	1603	1606	1610		
Fact	1507	1602	1605	1602	1606	1611		
Wort	1508	1602	1605	1602	1605	1600		
2006	1598	1603	1607	1603	1607	1618		

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#### Table 2. Modeled Start and End Dates for MGC and Its Clusters.

*Note*: A<sub>model</sub> is the agreement index produced by OxCal; values over 60 are considered acceptable (Bronk Ramsey 2009a). A<sub>overall</sub> is not reported because A<sub>model</sub> is the preferred index for OxCal v4 (Bronk Ramsey 2009a).

correctly and OxCal computed the resulting distributions correctly, those are the correct dates for a radiocarbon-based chronology. The dates using this model would raise complex questions about the site, the dating of the Huber phase, and our understanding of the late precontact period. Fortunately, we have additional chronological information that can be incorporated into the model.

Note also that the modeled duration of occupation (i.e., the gap between the start and end curves in Figure 5) appears to be only about 110 years and is fairly

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consistent across a wide range of probabilities. This can be quantitatively evaluated using the OxCal Span command (Supplemental Figure S2). The most likely span is 112 years, with short and long spans of 95 and 140 years, respectively. This is despite the fact that the unmodeled calibrated radiocarbon ranges in Figure 4 cover more than 250 years. This demonstrates the power of multiple radiocarbon dates and the Bayesian model to reduce the uncertainty inherent in a calibration curve inversion.

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### Model 2: Radiocarbon with Stratigraphy and Clusters

The stratigraphy of refill episodes within the storage pits at Middle Grant Creek allows relative sequencing of artifacts recovered from a particular pit. While the stratigraphy at MGC appears to be largely intact, there is always the possibility that some dated artifacts were displaced from their original stratigraphic contexts or that the refill contained older elements within it. This could result in chronological inversions that decrease a model's OxCal agreement index; this will be discussed below where appropriate. This second model incorporates that stratigraphy, using the feature and layer information in Table 1. The model also incorporates the clustering of pit features in Table 1, which will provide insight into whether the clusters were simultaneously or sequentially refilled. The model script along with OxCal output is provided in supplemental folder RCwithStrat.

The most likely MGC start date for this model is 1409 CE, while the most likely end date is 1584 CE (see Table 2). Compared to the previous model, the start date is earlier and the end date is later. This may be due to the addition of stratigraphy to the model, but it may also be an artifact of having added clusters to the model. Incorporating the multiple boundary conditions necessary for dating the clusters adds a sort of modeling uncertainty. This modeling uncertainty is likely responsible for the gaps between the MGC start and the start of the earliest cluster, as well as the gap between the MGC end and the end of the latest cluster (Figure 6).

Regarding the cluster ordering, it appears that the NBE cluster starts earliest and may end earliest as well, though there is a substantial overlap with the West cluster end. This may be quantitatively assessed using the OxCal Order command; there is a 25% chance that NBE ends before West starts.<sup>5</sup> Otherwise there is much overlap among the clusters (see Figure 6). This model suggests the site was not produced by the sequential creation of different clusters.

### Model 3: Bounds Added

Middle Grant Creek has abundant Fine Trailed ceramics and 92% of ceramics have plain surfaces, which places it within the Huber phase (McLeester and Schurr 2020). Ten out of 5,876 shell-tempered sherds (0.2%) are possibly Medium Trailed ceramics, which suggests a possible small component from an earlier phase termed Late Fisher.<sup>6</sup> No Early Fisher ceramics were recovered, so the end

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**Figure 6.** Radiocarbon with stratigraphy and clusters model start and end date curves. Startdate curves are dotted lines, while end-date curves are not dotted.

of Early Fisher provides a terminus post quem (TPQ) date for the site. Early Fisher is thought to have started in the late twelfth century CE and ended around 1350, though these dates are debated (Emerson 2017). We therefore use a uniform distribution spanning 1250 CE to 1350 CE as a conservative TPQ date range.

A Government Land Office Public Land Survey conducted in the area between 1821 and 1838 makes no mention of an American Indian village in the Middle Grant Creek area (McLeester and Schurr 2020). While Huber sites were probably long since abandoned by that time, we use a uniform distribution from 1821 to 1838 as a very conservative terminus ante quem (TAQ) date range.

The model and its results are provided in the supplemental folder Bounds-Added. Adding TPQ and TAQ dates had little effect on the model output except to shorten low-probability dates for the start of MGC (see Table 2; Figure 7). This was expected because the TPQ and TAQ date ranges are largely outside the high-probability start and end ranges of Model 2. We explore the impact of less conservative TPQ and TAQ assumptions later in this analysis.

#### Model 4: Bead Added

As noted previously, a blue glass trade bead was recovered from Middle Grant Creek (McLeester and Schurr 2020). It was recovered from East cluster Feature 3, layer 6 (see Table 1). It is consistent with beads from Glass Bead Period 2; Fitzgerald and colleagues (1995) date the import of such beads to between 1600 CE and 1630 CE. While OxCal modeling usually only uses radiocarbon and stratigraphic information,

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Figure 7. Bounds Added model start- and end-date curves.

nonradiocarbon date information can be included in an OxCal model, and thus, it is possible to incorporate artifacts with known manufacture or import dates. We use a uniform distribution from 1600 CE to 1630 CE to represent the glass bead:

#### Date("Glass Bead", U(AD(1600), AD(1630)))

As with radiocarbon dates, an outlier model is assigned to the bead. Given the uncertainty associated with the introduction of European-origin materials in the area, we assign a 10% probability of the bead being an outlier. Because postcontact materials have a restricted possible time frame for appearing in American Indian sites and all artifacts were recovered from pit features that minimize stratigraphic displacement, we use an outlier model that restricts the potential offset to 100 years, using a normal distribution with a mean of zero and a standard deviation of 100:

### Outlier\_Model("NonRCOutlier",N(0,100),0,"t")

This provides OxCal with the flexibility to shift modeled nonradiocarbon dates (using a model averaging approach to explore combinations of potential outliers) but only within a fairly narrow range (Bronk Ramsey 2009b). Of course, too much shifting reduces the OxCal agreement index, which may invalidate the model.

The model and its results are provided in the supplemental folder BeadAdded. The East cluster start curve is essentially the same as that of the previous model until a deviation starts at about 1500 CE and the curve bends to the right (Figure 8B, orange arrow). This corresponds to the transition between modes in the East Start plot (Figure 8A, gray arrow). We interpret the presence of the second mode

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Figure 8. Bead Added model output: (A) East cluster plot and (B) start- and end-date curves. Note the curve deviation (orange and gray arrows).

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to be due to the bead date range "pulling" the Feature 3 radiocarbon dates to the right, which in turn has a similar but less strong pull on other East cluster dates. This pull, however, is not powerful enough to affect the curve until the influence of the left modes of the radiocarbon dates is reduced, which happens around 1500 CE. Similar impacts will be apparent when metal artifacts are added to the model. The most likely MGC start date for this model is 1389 CE, while the most likely end date is 1661 CE (see Table 2).

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#### Model 5: Metal Added

Thirty-nine metal artifacts and fragments were recovered from Middle Grant Creek, 28 of which are used in this analysis (see Table 1).<sup>7</sup> The composition of the artifacts, obtained with laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) analysis, indicates that 6 of the 27 are brass, 1 is a brass alloy containing tin in addition to zinc, and 20 are smelted European copper. More details on the use of LA-ICP-MS to characterize copper-based artifacts found in North America is available in Dussubieux et alia (2008).

Fitzgerald and colleagues (1993) argue that European copper trade goods only became widespread in eastern North America with the expansion of the beaver-pelt trade after 1580 CE and that brass import began around 1600 CE. We have therefore modeled the date of each copper artifact as a normal distribution with a mean of 1600 CE and a standard deviation of 20 years. Each brass artifact is also modeled as a normal distribution, with a later mean of 1620  $\pm$  20 years. This provides about a 10% chance each that a copper artifact dates before 1575 CE or after 1625 CE and a brass artifact before 1595 CE or after 1645 CE (Supplemental Figure S3). Note that, given the relatively early radiocarbon dates from MGC, the end dates of these distributions are less important than the start dates. Each metal artifact was assigned the same outlier probability and model as described for the glass bead in Model 4. The resulting OxCal model and its output are provided in supplemental folder MetalAdded.

This model produced an OxCal agreement index  $A_{model}$  of 34 (see Table 2). The usual  $A_{model}$  minimum for an acceptable model is 60 (Bronk Ramsey 2009a), and all previous MGC models have  $A_{model}$  values above 100. The Metal Added value of 34 indicates that, for OxCal calculations to converge on a valid result, the program had to shift individual date ranges an unacceptable amount and indicates a problem either with some dates or the model itself. We therefore rejected the Metal Added model and examined the agreement index (A) values for individual dates to identify specific problems.<sup>8</sup>

While there are 11 artifacts with individual agreement index values below 60, this is in itself not necessarily a problem for a model with 51 dated artifacts. The low A values are, however, good indicators of which artifacts to examine for issues. There are several low A values grouped in West cluster Features 10 through 12, and an examination of the dates indicates that one artifact is clearly out of

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stratigraphic order, perhaps as a result of a feature fill episode consisting of redeposited materials. In Feature 11 layer 12, a copper artifact was found below three nearly identical and probably earlier radiocarbon dates. We therefore removed the Feature 11 layer 12 copper artifact from the model.

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Radiocarbon date D-AMS 032853 found in East cluster Feature 5 layer 13 has a very low A value of 4. Examination of its likelihood and posterior distributions showed that OxCal had shifted its date range to the empty space between the two "humps" of its probability distribution (Supplemental Figure S4). We therefore also removed this date from the model.

### **Model 6: Revised Metal**

The revised model with the two dates removed and its output are provided in supplemental folder RevisedMetal. The revised model's A<sub>model</sub> is 90, which indicates it is a valid model. This model incorporates all currently available chronological information while using conservative boundary conditions and, in that sense, may be considered to provide the best Middle Grant Creek chronology.

Using this model, MGC has a most likely start date of 1393 CE and an end date of 1666 CE (see Table 2). It is clear from the distribution curves that the MGC start date is driven by the NBE cluster start date (Figure 9). NBE may also end before the other clusters start; there is a 33% chance that the NBE cluster ends before the West cluster begins and a 51% chance it ends before either of the other two clusters start.<sup>9</sup> We also note that the 2006 cluster tends to be later than other clusters (see Figure 9). Quantitatively, there is a 47% chance that the West cluster ends before the 2006 cluster starts, which supports treating the 2006 features as constituting a different cluster than the West cluster.<sup>10</sup>

It is interesting that the West and NBE clusters in this model have "bent" curves and bimodal distributions (similar to those of the East cluster after the glass bead was added in Model 4), while the East and 2006 clusters have smooth curves. The West and NBE clusters have more radiocarbon dates than metal dates, while the other two clusters have more metal than radiocarbon dates. (Or to put it another way, the West and NBE clusters have a lower abundance of European-derived artifacts than the other two clusters.) Thus, in the West cluster, the early "humps" of the radiocarbon distribution have more influence in the early years, but the radiocarbon dates are eventually dragged into their later humps by the influence of the metal dates (Supplemental Figure S5). In the East and 2006 clusters, the more abundant metal immediately drags the radiocarbon distributions into their later humps. The narrowness of the later radiocarbon humps is likely the reason the gaps between the cluster start and end dates are so small, particularly for the East cluster.

The span of occupation (or more precisely, the span represented by the dated materials) is between 458 and 598 years, with a mostly likely (50% probability) span of 530 years (Supplemental Figure S6). This represents the probable time period between the start and end dates but does not imply a continuous occupation.

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Figure 9. Revised Metal model start- and end-date curves.

#### Model 7: Tight Bounds

To this point, we have used the very conservative (i.e., loose) boundary conditions discussed for Model 3. Here we evaluate the impact of using less conservative but reasonable boundary conditions. The TPQ date range of 1250 CE to 1350 CE was based on the end of the Early Fisher phase. Because only 10 possible Late Fisher sherds were found among 5,895 sherds—and they might in fact be Huber sherds (see Note 6)—a TPQ date within the Late Fisher range may be more appropriate. In this model, we use a uniform distribution spanning 1350 CE to 1400 CE as the TPQ date range.

The TAQ date range was based on a postcontact land survey that started in 1821, but Europeans were in the area much earlier. Marquette and Joliet canoed up the Des Plaines River (about 6 km from the MGC site) in 1673, and Marquette traveled the same river twice in 1675 without mentioning or mapping an American Indian village in the area (Marquette 1966). Perhaps more significantly, La Salle's expedition down the Kankakee River in 1679 passed about 4 km from MGC without locating any American Indian villages, despite expedition members having been eager to find one due to a food shortage (Anderson 1901).<sup>11</sup> Europeans continued to visit the area, with La Salle making at least six more trips before 1684 and Allouez continuing Marquette's missionary work starting in 1677 (Delanglez 1940; Thwaites 1901). In addition, Iroquois enemies of the local Illinois tribes were in the area by 1680, and a large Iroquois force mounted a six-day siege of Fort St. Louis (about 70 km from MGC on the Illinois River) in 1684 (Walczynski 2020). It seems unlikely that an American Indian village such as MGC could have existed in

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this time frame without having been noticed by Europeans or destroyed by the Iroquois. Furthermore, LA-ICP-MS composition analysis places the MGC blue glass bead within Walder's (2018) "Co-colored Mg-low-P" type, which predates 1700 CE (Supplemental Table S2). In this model, we therefore use a uniform distribution spanning 1650 CE to 1700 CE as a TAQ date range. Except for the TPQ and TAQ date ranges, this model is identical to the Revised Metal model.

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This model produced a surprising result that differs greatly from the Revised Metal model<sup>12</sup> (Figure 10). The MGC most likely start date shifts more than 200 years, from 1393 CE to 1598 CE. In fact, the probability curves converge such that there is only a gap of about 38 years between the MGC early start date and its late end date.<sup>13</sup> In essence, all the clusters converge for most of their probability distributions, with substantial variation confined to the low-probability start and end regions (see Figure 10). This is a dramatic departure from the previous model's results and is produced by what seem to be minor changes to TPQ and TAQ ranges.

In all our models that incorporate cluster information, the MGC start date curve is clearly driven by the NBE cluster start date curve (see Figures 5–8). In the Revised Metal model, the NBE cluster start date curve is largely determined by the two radiocarbon dates rather than the one brass date. That is the expected behavior because the radiocarbon dates substantially predate the metal date and are from a different feature than the metal date. However, in the current Tight Bounds model, the early "humps" of the radiocarbon likelihood distributions are not used, and their posterior distributions are placed near the rightmost edge of their likelihood ranges, in line with the metal date (Supplemental Figure S7). This



Figure 10. Tight Bounds model start and end dates.

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TPQ Timeframe	TPQ Range	TAQ Timeframe	TAQ Range	MGC Timeframe	MGC Most Likely Start Date	Model
Early	1250–1350	Early	1650–1700	Early	1389	BoundsTest4
Early	1250-1350	Late	1821–1838	Early	1393	RevisedMetal
Medium	1325–1375	Early	1650–1700	Late	1598	BoundsTest1
Medium	1325–1375	Late	1821–1838	Early	1397	BoundsTest2
Late	1350-1400	Early	1650–1700	Late	1598	TightBounds
Late	1350-1400	Late	1821–1838	Late	1599	BoundsTest3
None	None	None	None	Early	1392	NoBounds

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Table 3. Model Results for a Series of IPO and I/	40 Date Ranges.
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*Note*: The MGC Most Likely Start Date is the 50% probability date. All models with "early" MGC Most Likely Start Dates around AD 1390 have probability curves closely resembling the Revised Metal curves (see Figure 8), while those with "late" dates around AD 1598 have curves closely resembling the Tight Bounds curves (see Figure 9). See the Supplemental file set for detailed model specifications and results. Dates are year AD.

substantial shift is reflected in much lower A values for the two radiocarbon date distributions (18 and 30 in the Tight Bounds model vs. 96 and 108 in the Revised Metal model<sup>14</sup>). The overall A<sub>model</sub> value, however, remains acceptable at 79.

To better understand what caused the shift in the NBE start date, we ran a series of models with varying TPQ and TAQ date ranges (Table 3). An early TPQ range of 1250–1350 produced an early MGC start date (and curves resembling the Revised Metal curves in Figure 9) regardless of the TAQ date range. Similarly, a late TPQ range of 1350–1400 produced a late MGC start date (and curves resembling the Tight Bounds curves in Figure 10) regardless of the TAQ range. It appears that a late TPQ tends to "push" the NBE radiocarbon dates off their early humps, causing the entire MGC model to line up closely with the metal dates. (This is despite the humps almost entirely postdating 1400 CE, the end of the TPQ range; see Supplemental Figure S8.) An early TPQ, on the other hand, allows the humps in the NBE radiocarbon likelihood distributions to have a strong impact on the model.

However, using a medium TPQ range of 1325–1375 with an early TAQ range produced a late MGC start date, whereas using the same medium TPQ range with a late TAQ range produced an early MGC date (see Table 3). This indicates that the TAQ range does have an impact in cases where the TPQ range is on the borderline in its influence; in those cases, an earlier TAQ exerts a sufficient "pull" on the radio-carbon distributions to cause them to shift off their early humps and line up with the metal date. Clearly, there are complex interactions at work within the OxCal model implementation.

While we have focused in this analysis on the NBE cluster as the driver of the MGC start date ranges, the NBE cluster model is not operating in isolation. In fact, a model that includes only the NBE cluster produces an early MGC start date even when using the Tight Bounds TPQ and TAQ ranges (Supplemental Figure S9). Thus, as expected for a Bayesian analysis, the entire model is interacting. It seems that the abundance of metal-based dates from outside the NBE cluster has some effect on how influential the metal-based date is within the NBE cluster.

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### Conclusions

Our stepwise model-building approach allows us to better document and interpret the impact of each set of chronological data. We began with a radiocarbon-only model, which produced a surprisingly early MGC end date of 1548 CE. With this model, the OxCal Bayesian algorithm consistently selected the earlier of the likelihood distribution "humps" caused by a large calibration curve inversion. Adding stratigraphy and boundary conditions gradually produced earlier MGC start dates and later end dates, though the earlier likelihood humps continued to be favored within most clusters. The inclusion of a single glass bead with an early seventeenth-century date resulted in neighboring radiocarbon-calibrated dates using their later likelihood humps, thus pushing the East cluster and MGC end dates out about 70 more years into the mid-seventeenth century. The start dates for all clusters remained surprisingly early.

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Our initial attempt to add date information for 28 European metal artifacts resulted in an unacceptable A<sub>model</sub> agreement index, indicating that the model was "broken." That is, the model had internal conflicts that could not be resolved by an appropriate amount of date shifting within likelihood and outlier constraints. We used the individual date agreement indices to identify one metal fragment that appears to be out of stratigraphic sequence and one radiocarbon date that could not be acceptably incorporated into the model because its likelihood distribution happens to have a gap just where the model needs to place its posterior distribution. We therefore removed these two dates from the model.

The resulting model, termed the Revised Metal model, used the full suite of acceptable chronological information to quantitatively identify the start- and end-date ranges for Middle Grant Creek and its individual clusters. The MGC occupation is shown to have most likely started around 1400 and ended around 1670, with the start of the NBE cluster likely predating the other clusters by about 170 years (see Table 2). Further modeling, however, raised doubts about the Revised Metal model results.

The Revised Metal model used what we consider to be conservative boundary conditions: that is, boundaries that are wide enough to only impact low-probability regions of the date distributions. These conservative boundaries do not, however, seem to us to be the best representation of the current state of knowledge of American Indian occupation in the area. The TPQ date range seems too early based on the regional pottery sequence, and the TAQ date range seems too late given that no mention is made of a local American Indian village by early European explorers. A key strength of Bayesian analysis is its ability to incorporate such thinking into the model as prior information, so we reran the Revised Model using tighter boundary conditions that we believe more accurately represent the situation.

The Tight Bounds model produced a surprising result. Rather than a minor compaction of the MGC occupation span, the MGC start date is more than 200 years later, and the overall MGC span is condensed into a short period around the

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turn of the seventeenth century CE. Further modeling revealed that this result is produced by a complex interaction of boundary and model conditions.

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So, which is correct? Was MGC—and particularly the NBE cluster—occupied for hundreds of years starting around 1400 CE, or was it a relatively brief occupation focused on the turn of the seventeenth century? First, we would like to point out that both models may be correct: Both are probability-based results and low-probability events do occur. While we have been discussing "most likely," "early," and "late" dates, there is always the possibility that the occupation started and/or ended during low-probability portions of the posterior distribution curves. The only way to address this is to add more dates and constraints, thus making the low-probability regions even less likely (or, should the occupation actually be within the low-probability regions, making them more likely).

Archaeologists, however, are accustomed to confronting uncertainty and accepting probability-based scenarios as providing our best current understanding of the past. In our view, the model that best reflects the full suite of archaeological and historical information currently available for the Middle Grant Creek site is the Tight Bounds model. We, therefore, accept the Tight Bounds result and consider MGC to most likely be a fairly short occupation focused on the turn of the seventeenth century.

Several broader lessons may be drawn from our modeling. The first is that dating a late precontact site (or any site straddling substantial calibration curve inversions) using radiocarbon dates alone may be misleading and that increasing the number of such dates may, in fact, make a model worse by increasing the weight assigned to a particular likelihood distribution hump caused by an inversion. Second, it is critically important to carefully consider all aspects of a chronology model—including boundary conditions or the lack thereof—and to undertake additional modeling as needed to understand the impact of alternate scenarios.

Finally, we would like to point out a concern that may arise whenever radiocarbon dates are modeled along with dates derived from nonradiocarbon sources, such as imported trade goods. As noted in the discussion of Model 6, an imbalance in the number of each type of date affects which type dominates the result and in what time frame it does so. The number of trade good-based dates is largely determined by what the site produces during excavation (though different decisions may be made regarding which metal artifacts to include in the models; Supplemental Table S1). The number of radiocarbon dates, on the other hand, is determined by other factors, including the project budget and reporting time frame, the number of site features, and the level of interest in chronological precision. Short-lived organics are abundant at MGC, and we could have produced many more radiocarbon dates than metal dates. Note, however, that an imbalance in radiocarbon and nonradiocarbon dates can only have a relative impact: It can affect the timing of when the probability distributions transition from less to more likely, but it cannot "drag" the dates outside their original likelihood ranges without degrading the A<sub>model</sub> value and, in effect, breaking the model. So, while

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this is an important concern to keep in mind and bends in the curves such as are present for the West cluster in Figure 9 should be carefully considered, it is not fatal to the approach. After all, if the radiocarbon and nonradiocarbon dates cannot be reconciled, then they must be dating different things, such as different site occupations. This possibility can be minimized by ensuring that there are radiocarbon dates scattered among the stratigraphy in a similar manner as with the nonradiocarbon artifacts. It is important to note the artifacts essential for the model (the short-lived botanicals, the bead, and the metal items) were collected by flotation processing, illustrating the importance of recovering small artifacts useful for chronological modeling.

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#### Notes

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- 1. The late precontact or protohistoric period is the time frame when European trade goods appear in a region but there is not yet a written historical record of local activities or other evidence of direct contact with Europeans. For the Chicago region, the first known written record dates to 1673, when Marquette and Joliet passed within several kilometers of MGC on their way to Lake Michigan from the Mississippi. The earliest date for European trade goods in the region has not been determined, but it was probably sometime in the sixteenth century based on European activities on the Atlantic Coast.
- See the OxCal code in supplemental file BasicRC/MGC\_RCmodel\_BasicRC.oxcal for details. Model output is provided in the same folder.
- 3. For those unfamiliar with such plots, see Supplemental Figure S1 and associated text.
- 4. For a straightforward example of how to perform this computation using "prior" files downloaded from OxCal, see supplemental file MGC\_RC\_Cht\_BasicRC.xlsx. Other such curves presented here were created using a combination of a spreadsheet and the R script CumulativeProb.R provided in the supplemental files.
- Cluster probabilities for each model with clusters are provided in files named *model*ClusterProbabilities\_Output.txt created by the ClusterPubs.R R script using data from OxCal's Order command in files named MGC\_Date\_Order.csv. All files are provided in the supplemental file set.
- 6. These 10 sherds are medium trailed by line width, but the trailing does not have typical Late Fisher motifs, such as chevrons or nested triangles. They may be from the Huber phase, as are most identifiable sherds from MGC, but the sherds are very small and phase attribution is uncertain. While they are treated as Late Fisher in this model, Model 7 evaluates the chronological impact if they are assigned to the Huber phase. The sherd counts herein are updated from the counts presented in McLeester and Schurr (2020:Table 2).
- See Supplementary Table S1 for a description of the unused metal artifacts. Artifacts made from North American copper are unused here because their possible dates of manufacture span a time period too wide to be of use in this analysis.
- 8. Individual artifact A values are provided in supplemental file MetalAdded/MGC\_RCmodel \_\_MetalAdded.csv.
- 9. See RevisedMetal/RevisedMetalClusterProbabilities\_Output.txt and MGC\_Date\_Order.csv.
- 10. See RevisedMetal/RevisedMetalClusterProbabilities\_Output.txt.
- 11. The first American Indian village La Salle's party encountered in the region was at the mouth of the Kankakee River where it joins the Des Plaines River to form the Illinois River. Interestingly, it was deserted (the residents were assumed to have been in winter

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hunting camps) but had an abundance of maize stored in "trenches underground" (Anderson 1901:104).

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- 12. The model and its detailed output are in the supplemental folder TightBounds.
- 13. Using the full distributions, the occupation span range is 238–363 years with a most likely span of 302 years. This is 228 years shorter than the most likely span under the Revised Metal model.
- See files MGC\_RCmodel\_TightBounds.csv and MGC\_RCModel\_RevisedMetal.csv in the supplemental file set.

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#### **Supplementary Materials**

Supplementary material for this article can be found at https://www.midwestarchaeology.org /mcja/supplemental-materials.

Supplemental Figures S1 through S9.

Supplemental Tables S1 and S2.

Supplemental file set (zip file, 4.2 MB) containing 282 files with R scripts, OxCal scripts, Oxcal output data and figures, and spreadsheets for each chronology model.

### **Declaration of Interest Statement**

The authors have no conflicts of interest to disclose.

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### **Notes on Contributors**

Jack N. Fenner is an archaeologist with interest in quantitative and spatial approaches. He retired from the faculty of The Australian National University in 2021 and is currently an honorary senior lecturer at ANU, as well as an affiliated scholar at the University of Notre Dame. He received a doctorate in anthropology from the University of Wyoming in 2007, a master's in anthropology from Eastern New Mexico University in 2002, and a couple of other degrees. He was a computer engineer before becoming an archaeologist.

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*Mark R. Schurr* (PhD Indiana 1989) is professor of anthropology at the University of Notre Dame. He has worked in the midcontinent for his entire career and considers himself a hard-core midwestern archaeologist. Schurr is a generalist who enjoys both prehistoric and historic archaeology. He has worked on the Late Prehistoric of the Ohio Valley, the Middle Woodland Goodall tradition of northwestern Indiana, and the Removal period Potawatomi (1795–1840 CE). His most recent fieldwork centers on the mysteries of Fisher/Huber, most recently via excavations at the Middle Grant Creek site. Schurr is especially interested in applications of archaeological science, especially the uses of stable isotopes in archaeology. He is currently president of the Midwestern Archaeological Conference.

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**Madeleine McLeester** is an environmental archaeologist specializing in late precontact agricultural communities in the Eastern Woodlands. She investigates agricultural practices, plant collection, human-environment entanglements, and early colonial encounters throughout the eastern United States. She received her PhD in anthropology from the University of Chicago in 2017 and is currently a postdoctoral fellow at Dartmouth College. Her analytic work uses pollen and stable isotopic approaches as well as historical records, like aerial photography and ethnobotanical texts, to locate otherwise invisible aspects of past communities. She is currently directing archaeological projects in Illinois, Wisconsin, and Maine.

*Laure Dussubieux* is a chemist specializing in the determination of the elemental composition of ancient artifacts made from synthesized or natural glass, metal, and stone. She obtained her PhD in chemistry from the University of Orléans (France) in 2001. Prior to her appointment at the Field Museum, she was a postdoctoral fellow at the Smithsonian Institution (Museum Conservation Institute, Maryland). Since 2004, she has managed the Elemental Analysis Facility (EAF) at the Field Museum in Chicago, and her current title is senior research scientist. Her own research focuses on ancient glass from South and Southeast Asia.

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