Early Maize (*Zea mays*) in the North American Central Plains: The Microbotanical Evidence

Mary J. Adair, Neil A. Duncan, Danielle N. Young, Steven R. Bozarth, and Robert K. Lusteck

*Artifacts, including ceramics, ground stone, and soil samples, as well as dental calculus, recovered from sites in the eastern North American central Plains were submitted to multiple laboratories for analysis of microbotanical remains. Direct accelerator mass spectrometer (AMS) dates of 361–197 cal BC provide evidence for the earliest use of maize (*Zea mays *ssp.* mays*) in this region. Squash (*Cucurbita *sp.), wild rice (cf.* Zizania *spp.), and palm (Arecaceae sp.) microremains were also found. This research adds to the growing evidence of the importance of microbotanical analysis in documenting plant use and in the identification of early maize. The combined data on early maize from the eastern Plains adds to our understanding of the timing and dispersal of this crop out of the American Southwest. Alternative explanations for the adoption and early use of maize by eastern central Plains communities include its value as a secondary resource, as an addition to an existing farming strategy, or as a component of Middle Woodland rituals.*

Key words: maize, microbotanical analysis, North American central Plains, AMS ages, Middle Woodland, ritual

*Artefactos, incluida la cerámica, la piedra de molino, la muestra de suelo, y el cálculo dental recuperados de sitios en el este de las llanuras centrales de América del Norte fueron enviados a varios laboratorios para análisis de los restos micro botánicos. La espectrometría de masas con acelerador indica fechas de 361 a 197 cal BC y proporciona evidencia para el uso más antiguo del maíz (*Zea mays *ssp.* mays*) en estaregión. La presencia de la calabaza (*Cucurbita *sp.), el arroz salvaje (*Zizania *spp.), y la palma (Arecaceae sp.) identifica la selección de otras plantas. Esta investigación añade a la evidencia creciente de la importancia del análisis micro botánico en la documentación del uso de plantas y la identificación del maíz antiguo. La información combinada sobre maíz antiguo de las llanuras orientales añade a nuestro conocimiento del tiempo y la dispersión de esta cosecha desde el suroeste americano. Explicaciones alternativas para la adopción y el uso antiguo de maíz por las comunidades en el este de las llanuras centrales incluyen su valor como recurso secundario, como adición a una estrategia agrícola existente, o como un componente en los rituales del periodo silvícola medio.*

Palabras claves: maíz, análisis micro botánico, llanuras centrales de América del Norte, edades AMS, silvícola medio, ritual

Maize (*Zea mays* ssp. *mays*), or corn, developed as a domesticated crop in central Mexico more than 9,000 years ago and was adopted by Archaic foragers of the North American Southwest by around 2550–2050 cal BC (Hanselka 2018:281). From there, maize dispersed north and east over many regions of North America, with regional histories varying temporally, due to the genetic changes in maize as it adapted to selective

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American Antiquity 87(2), 2022, pp. 333–351

doi:10.1017/aaq.2021.152

environmental conditions, to human manipulation, and to the varying social and economic systems into which it was incorporated. By the time of European contact, maize was a significant crop in many Indigenous cultures. Documenting the arrival of this domesticate and charting its growing economic importance within specific geographical regions have remained of interest to North American archaeologists (e.g., Benz and Staller 2006; Johannessen and Hastorf 1994; Smith and Cowan 2003; Staller et al. 2006). For many Native tribes of the North American Plains, maize came to figure prominently in origin beliefs, ceremonies, rituals, and diet (Gilmore 1977; Will and Hyde 1964; Wilson 1987).

For decades, the earliest references for central Plains maize were isolated kernels and cob fragments from Middle Woodland Kansas City Hopewell (KCH) sites, dated by association to about AD 250. However, direct accelerator mass spectrometer (AMS) ages and δ^{13}C values demonstrated that the remains were either not maize, as reflected by the δ^{13}C isotopic value, or that they were associated with a later occupation than the context suggested (Adair 2003; Adair and Drass 2011). Reported Middle Woodland maize from interior Midwest sites has also been AMS dated to the tenth and eleventeenth centuries AD (Simon 2014, 2017, 2021), suggesting that maize did not arrive in these regions during the Middle Woodland.

Despite these refinements in our understanding of maize, the recovery of microbotanical remains of maize (phytoliths and starch granules) with directly associated AMS ages has provided a new approach to charting its presence and timing in archaeological contexts (Hart et al. 2021; Lusteck 2006; Lusteck and Thompson 2007; VanDerwarker et al. 2016). Maize microremains from 16 sites located in the northeastern United States and Great Lakes region and 31 associated AMS dates on charred residue establish the presence for maize in the first several cal centuries BC (Hart et al. 2021:Supplemental Table 1), centuries earlier than directly dated maize macroremains from the same region and centuries earlier than the macroremains from the Plains and interior Midwest.

As maize diffused from the Southwest to locations north and east, it likely crossed the southern and central Plains (Fritz 2006:440). To account for the maize histories in the Northeast, sufficient time would be needed for maize to adapt to temperate latitudes as it was adopted by different groups. However, the oldest directly dated maize macroremain from the central Plains is AD cal 874 (δ^{13}C of −9.48 and 2σ range of cal AD 777–977) and AD cal 810 (δ^{13}C of −9.4 and 2σ range of cal AD 688–935) from the Avoca site (Adair 2003, 2012), centuries later than the microbotanical evidence for early maize in the Northeast.

Using a combination of direct AMS radiocarbon dates and analyses of plant microremains, we address two issues: can early maize be identified from the central Plains, and if so, can such evidence help elucidate a potential route for the transmission from the Southwest? Thirty-five samples, including 24 ceramics (exhibiting both visible residue and absorbed residue), two ground stone, two soil samples, and seven dental calculus from 16 sites located in the eastern central Plains (Figure 1) were submitted for analysis. AMS dates were obtained from visible ceramic residue and from human remains.

The Eastern Central Plains Region and Sites

The geographic region studied in this article includes the eastern portions of Kansas and Nebraska and the northwest section of Missouri (Figure 1). The Middle Woodland component (ca. 200 BC–AD 400) of this region is characterized by the Kansas City Hopewell (KCH; centered on the confluence of the Missouri and Kansas Rivers), Cuesta (southeast Kansas), Schultz (north-central Kansas), and Valley (eastern Nebraska).

These complexes differ in material culture, especially ceramics, levels of trade and interaction, mobility patterns, burial customs, and subsistence. For example, a foraging economy best describes Schultz, Valley, and Cuesta, with flotation providing evidence of plant cultivation for the KCH. Ceramic decorative styles suggest long-distance interactions with the Eastern Early Woodland complexes (Valley), the southeastern US Hopewell groups (Cuesta and KCH), and the Lower Illinois Valley (KCH). However, each complex likely emerged from earlier local adaptations (Johnson 1992; Keehner

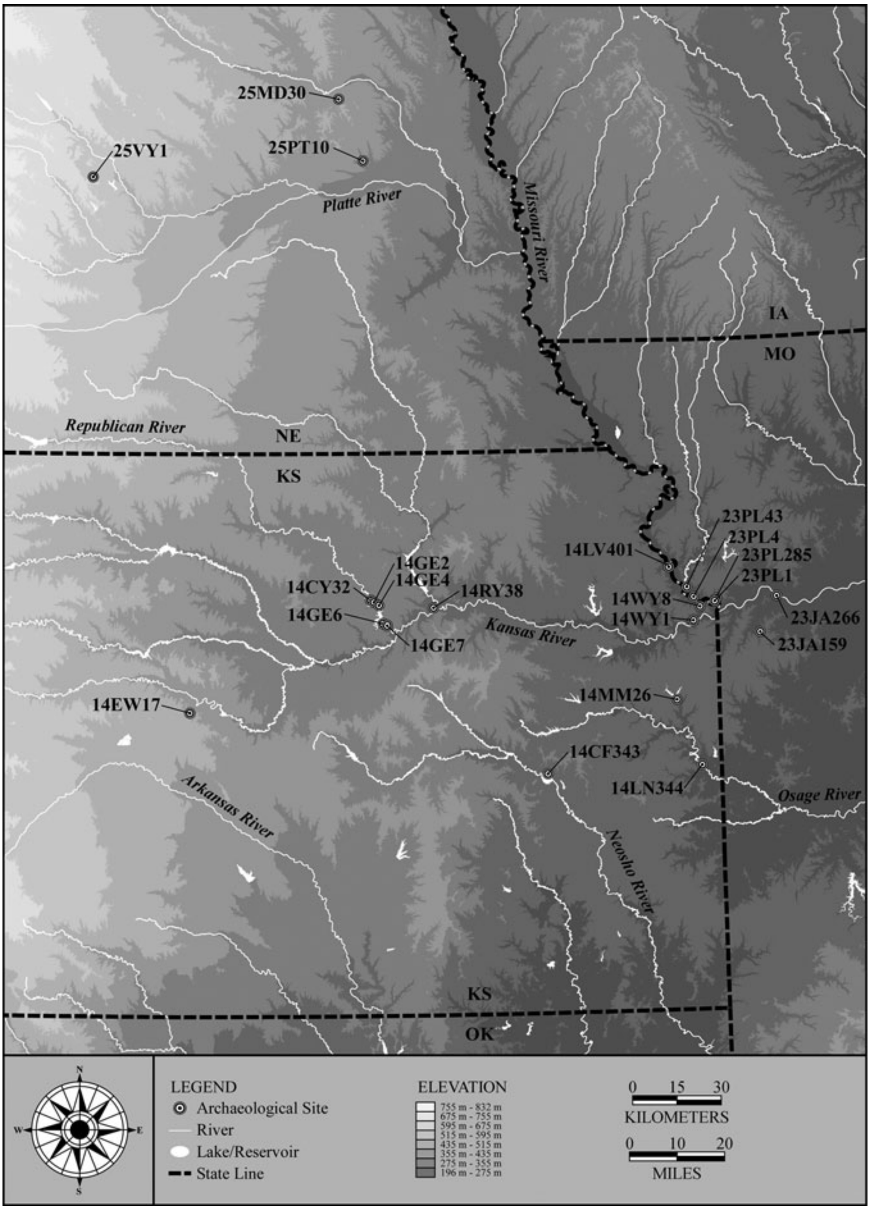

Figure 1. Study area with location of sites discussed in text.

and Adair 2019; Martin 2007; Schmits and Bailey 1989).

Refining the temporal range of these complexes included direct dating annual plant remains, visible ceramic residues, and human skeletal remains (Supplemental Table 1 and Supplemental Text 1). This establishes a temporal contemporaneity (Figure 2) and provides a chronological framework for the current analysis.

Methodology

Curated collections were targeted for this study after a pilot project confirmed the preservation of starch and phytoliths in Plains Middle Woodland artifacts (Adair et al. 2012). Artifacts and samples selected for this current study are listed in Table 1, and a representative sample of the selected pottery sherds is shown

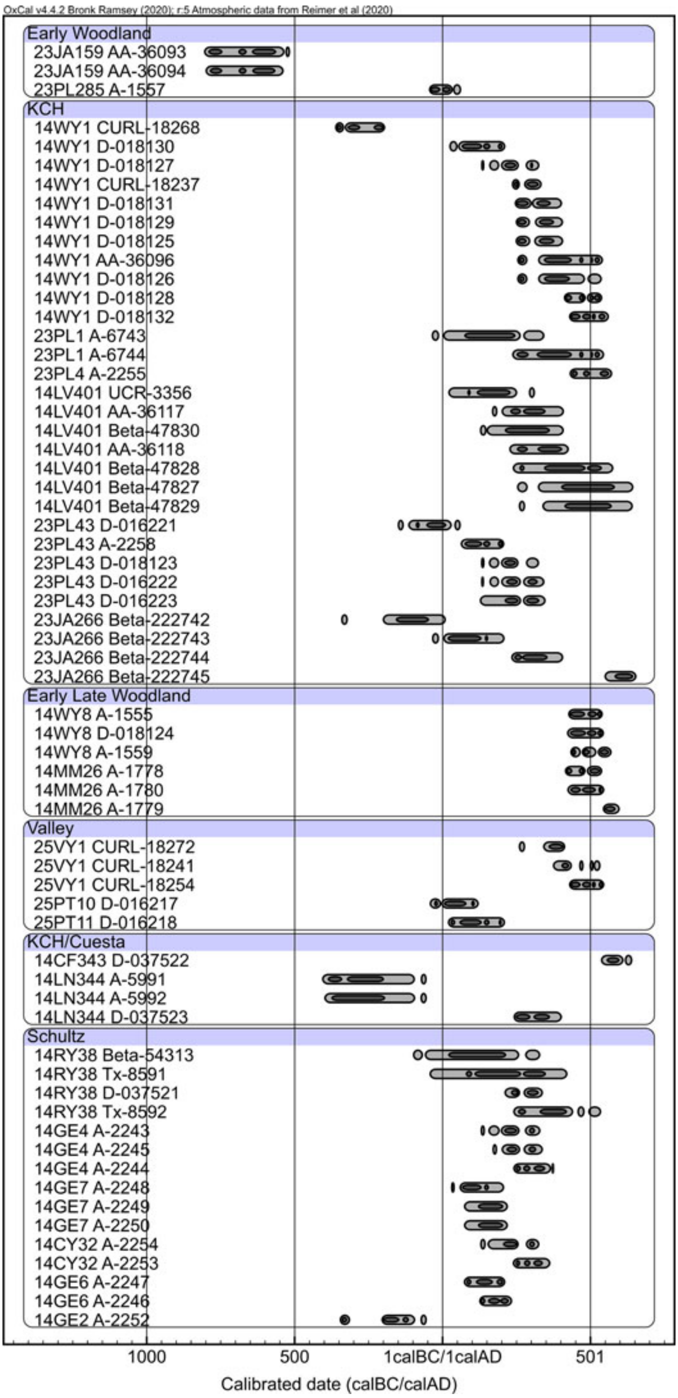

Figure 2. Calibrated AMS radiocarbon ages from sites discussed in text. Calibration was done with OxCal v4.4.2 Brock Ramsey (2020); r:5 IntCal20 atmospheric curve (Reimer et al. 2020).

in Figure 3. Visible residue, identified by its distinctive polymeric char network (Crowther 2012:229), was also used for AMS dating. Dental calculus was collected from both Schultz and KCH burials for a total of seven samples from five sites. The residues were

Table 1. Identified Microbotanical Remains, with Artifact Description and Associated AMS Ages.

Cultural Association	Site	AMS Dates RCYBP	Lab Number*	Calibrated Date (2σ)	Median Probability Date	Material Dated	δ^{13}C value	Nature of Sample Analyzed for microremains	Material Description	Identifications
Early Woodland	23PL285	2005 + 15	A-1557	44 cal BC–cal AD 61	3 cal BC	residue	−27.2	Ceramic fabric	Morton incised rim	globular echinate phytolith (*n* = 1),[3] cf. *Z. mays* starch (n = 1)[7]
KCH	Trowbridge 14WY1	2205 + 15	CURL-18268**	361 cal BC–197 cal BC	287 cal BC	residue	−25.8	Ceramic fabric	Undecorated body with remnants of slip-wash	*Z. mays* starch (*n* = 2), cf. *Z. mays* starch (*n* = 1)[2]
KCH	Aker 23PL43	2041 + 26	D-016221**	150 cal BC– cal AD 59	31 cal BC	residue	−18.4	Ceramic fabric	Lobed vessel with horizontal rocker stamped rim	*Z. mays* starch granule (*n* = 5), cf. *Z.mays* starch granule (*n* = 1)[2]
KCH	Trowbridge 14WY1	1919 + 28	D-018130	cal AD 26–210	AD cal 117	residue	−20.8	Ceramic fabric	Dentate Stamped rim	*Z. mays* starch granule (*n* = 2)[2]
KCH	Aker 23PL43	1819 + 20	D-018123	cal AD 133–324	AD cal 232	residue	−21.7	Ceramic fabric	Stick impressed rim, horizontal cordmarked body	*Z. mays* starch granule (*n* = 2), Damaged *Z. mays* starch granule (*n* = 1)[2]
KCH	Aker 23PL43	1804 + 36	D-016223	cal AD 129– 346	AD cal 251	residue	−25.6	Ceramic fabric	Zoned decorated with rocker stamping and punctates	*Z. mays* starch granule (*n* = 1)[2]
KCH	Aker 23PL43	1803 + 29	D-016222	cal AD 134–342	AD cal 252	residue	−19.3	Ceramic fabric	Crosshatched rim with punctates	*Z. mays* starch granule (*n* = 5)[2]
KCH/ Cuesta	14LN344	1743 + 29	D-037523	cal AD 235–384	AD cal 318	residue	−23.5	Ceramic fabric	Embossed, zoned stamped rim	*Z. mays* starch granule (*n* = 1)[7]
KCH	Trowbridge 14WY1	1737 + 22	D-018131	cal AD 247–402	AD cal 326	residue	−21.2	Ceramic fabric	Dentate Stamped rim	*Z. mays* starch granule (*n* = 11)[2]
KCH	Trowbridge 14WY1	1617 + 20	D-018128	cal AD 413–538	AD cal 472	residue	−22.0	Ceramic residue	Undecorated rim and shoulder with signs of slip-wash	*Z. mays* starch granule (*n* = 1)[2]
KCH	Young 23PL4	1555 + 20	A-2255	cal AD 433–571	AD cal 503	residue	−25.5	Ceramic residue	Classic Hopewell styled rim	*Z. mays* starch granule (*n* = 10), cf. *Z. mays* starch granule (*n* = 2)[1]
Cuesta	14CF343	1504 + 25	D-037522	cal AD 539–639	AD cal 577	residue	−25.7	Ceramic fabric	Decorated rim	No maize detected[7]
KCH	Young 23PL4							Ceramic fabric	Body sherd with rocker stamping	*Z. mays* starch granule (*n* = 5), cf. *Z. mays* starch granule (*n* = 4), *Cucurbita* sp. starch granule (*n* = 1)[1]
KCH	Trowbridge 14WY1							Ceramic residue	Havana Zoned Incised	No maize detected[4]
KCH	Trowbridge 14WY1							Ceramic residue	Naples Stamped Dentate rim with stamped body	No maize detected[4]
KCH	Trowbridge 14WY1							Ceramic residue	Zoned punctate rim	Cf. *Zizania* sp. phytolith[6]
Middle Woodland	Ward 14EW17							Ceramic fabric	Zoned crosshatched rim	*Z. mays* starch granule (*n* = 1) [7]
Schultz	Macy 14RY38	1792 + 25	D-037521	cal AD 213-337	AD cal 290	residue	−27.1	Ceramic fabric	Crosshatched rim	No maize detected[7]
Early Late Woodland	Miller 14WY8	1590±15	A-1555	cal AD 428–540	AD cal 483	residue	−26.6	Ceramic residue	Undecorated body sherd	No maize detected[6]

Table 1. Continued.

Cultural Association	Site	AMS Dates RCYBP	Lab Number*	Calibrated Date (2σ)	Median Probability Date	Material Dated	δ^{13}C value	Nature of Sample Analyzed for microremains	Material Description	Identifications
Early Late Woodland	Miller 14WY8	1588 + 22	D-18124	cal AD 424–544	AD cal 484	residue	N/A	Ceramic fabric	Rim with irregular punctates	No maize detected [7]
Valley	25MD30	2175 + 25	D-021557	360 cal BC –121 cal BC	279 cal BC	residue	−18.8	Ceramic residue	Vertical cordmarked rim, decorated	No maize detected[2]
Valley	Schultz 25VY1	1695 + 15	CURL-18272	cal AD 261–413	AD cal 376	residue	−28.7	Ceramic residue	Vertical cordmarked rim	*Z. mays* phytolith (*n* = 1)[4]
KCH	Deister 23PL2							Grinding stone		*Z. mays* starch granule (*n* = 1)[1]
KCH	Young 24PL4							Mano		*Z. mays* (n = 1), cf. *Zea mays* (*n* = 1)[1],
KCH	Young 23PL4							Soil sample		globular echinate phytolith (*n* = 1)[1]
KCH	Trowbridge 14WY1							Soil sample		globular echinate phytoliths (*n* = 3)[1]
KCH	Aker 23PL43							Dental calculus		*Z. mays* starch granule (*n* = 1)[2]
KCH	23PL386							Dental calculus		No maize detected [2]
Schultz	Berry 14GE4	1815±24	A-2243	cal AD 132–329	AD cal 237	Collagen	−18.4	Dental calculus		*Z. mays* starch granule (*n* = 1)[2], *Z. mays* starch granule (*n* = 1)[5]
Schultz	Berry 14GE4	1805 + 25	A-2245	cal AD 172–337	AD cal 248	Collagen	−10.3	Dental calculus		No maize detected[5]
Schultz	Berry 14GE4							Dental calculus		No maize detected[2]
Schultz	James Younkin 14GE6	1905 + 20	A-2247	cal AD 75–210	AD cal 144	Collagen	−18.4	Dental calculus		*Z.mays* starch granule (*n* = 1)[5]
Schultz	James Younkin 14GE6							Ceramic fabric	Complete miniature vessel, tool impressed rim, zoned punctates	*Z. mays* starch granule (*n* = 3), cf. *Z. mays* starch grain (*n* = 2)[7]
Schultz	Dixon 14GE7	1920 + 20	A-2248	cal AD 32–206	AD cal 113	Enamel	−14.1	Dental calculus		No maize detected [2]

Notes: Identification made by [1]Duncan and Pearsall 2012, [2]Duncan and Young 2018, [3]Bozarth 2011, [4]Bozarth 2014a, [5]Bozarth 2014b, [6]Lusteck 2012, [7]Young and Duncan 2020.

* Lab Designations: A = Illinois State Geological Survey; D = Direct AMS; CURL = University of Colorado, Boulder.

** δ^{13}C values from Direct AMS and University of Colorado, Boulder labs are measured on the reduced graphite by the AMS and may not be an accurate reflection of environmental conditions or trophic and nutritional interpretations. The δ^{13}C values may differ by about 1‰–3‰ when compared to the original material.

Figure 3. Representative ceramic rim sherds from the study area: (a) Aker site, maize starch, 150 cal BC–cal AD 59; (b) James Younkin, maize starch; (c) 14LN344, maize starch, cal AD 243–401; (d) 14EW17, maize starch; (e) Trowbridge maize starch, cal AD 238–333; (f) Miller, cal AD 424–544; (g) 23PL285, cf maize starch, 44 cal BC–cal AD 61 (photos by Mason Niquette).

removed by researchers at the University of Kansas following established protocols (Lovis 1990; Supplemental Text 2).

Two curated soil samples from the lower levels of pit features at Trowbridge and Young were also selected. In both cases, the pits contained diagnostic KCH ceramics and lithics. Context was also a consideration when selecting the grinding stone and mano from the KCH Young and Deister sites, respectively.

Samples were sent to one of the four labs (three analysists) over the course of the past 10 years. At all labs, the methodologies used for residue analysis were similar though not identical. After extraction, each analyst mounted the microremains on standard microscope slides, examined the slides under polarized light at high power, and used extensive comparative collections for the identification. The complete processing techniques, a discussion of lab contamination protocols, and comparative collections for accurate identifications for each lab are provided in greater detail in Supplemental Text 3.

Microscopic starch granules and phytoliths are produced in various plant parts; can be morphologically distinct at the family, genus, or species level (Pearsall 2015; Pearsall and Piperno 1993; Perry et al. 2007; Piperno et al. 2000); and can resist degradation for thousands of years (Barton 2009; Piperno et al. 2004). For dental calculus, plant microremains are preserved during the mineralization process when dental plaque is converted to calculus and protected from breakdown by salivary amylase (Hillson 1996). The microscopic particles can become absorbed in the ceramic fabric[1] and can adhere within flake scars on chipped stone tools, within pockets on ground-stone implements, and within dental calculus (Henry and Piperno 2008; Skibo 1992). Starch found on an artifact represents either direct contact residue from use or from sediment transferred within the first several months of deposition (Haslam 2004).

Microbotanical Analysis Results

Table 1 provides a summary of the microremains identified from the project artifacts. Maize was identified in 60% of the samples, showing that this plant was cultivated or acquired and consumed by Middle Woodland groups in the central Plains. AMS dates provide direct chronological evidence for the use of maize from the cal third century BC through the fifth century AD. The presence of other plant microremains, including squash (*Cucurbita* sp.), wild rice (cf. *Zizania* spp.), and palm (Arecaceae sp.), support the existing macroremain assemblages or identify previously unknown plants.

Starch granules (Figure 4a, b) recovered from ceramic fabric provide the earliest dates of 287 cal BC (range of 361–197 2σ cal BC) from Trowbridge and 31 cal BC (range of 150 2σ cal BC–cal AD 59) from Aker (Figure 3a). Starch granules recovered from the Morton Incised rim (Figure 3g) compare favorably to maize, with the residue dating to 3 cal BC (range of 344 2σ cal BC–cal AD 61). Eleven additional ceramic fabric samples and two visible residue samples produced evidence for maize. Direct dates on these samples range from AD cal 117 (2σ calibrated range AD 26–210) to AD cal 503 (2σ calibrated range of AD 433–571; Table 1, Figure 4c–g) and were recovered from KCH, Schultz (Duncan and Pearsall 2012; Duncan and Young 2018; Young and Duncan 2020), and Valley ceramics (Bozarth 2014a).

Undated maize starch granules were recovered from ceramic fabric from Young and from ground stone implements from Young and Deister (Figure 5a; Duncan and Pearsall 2012). No maize was detected in two Early Late Woodland (ca. AD 400–700) samples from the Miller site ceramics (Figure 3f).

Three dental calculus samples—from the undated KCH Aker burial (Figure 5a) and two Schultz burial mounds—yielded maize starch grains. Maize starch granules (Figure 5b) were identified from the Berry mound (Bozarth 2014b; Duncan and Young 2018) and were associated with an AMS age of AD cal 237 (calibrated 2σ range of AD 132–329). Maize starch from James Younkin (Bozarth 2014b) is associated with an earlier date of AD cal 144 (calibrated 2σ range of AD 75–210). A miniature zoned tool-impressed and punctated vessel (Figure 3b; Young and Duncan 2020) found in direct association with the James Younkin burials (Schultz and Spaulding 1948) also contained maize starch. This provides a positive link between the use of the vessel for holding maize and the consumption of maize from the dental calculus.

Given the evidence for maize in the Schultz burials, Hopewellian sherds from associated habitation sites (Ward and Macy) were added to this study. An AMS date of AD cal 290 (calibrated 2σ range of AD 213–337) was obtained from ceramic residue from the Macy site, but

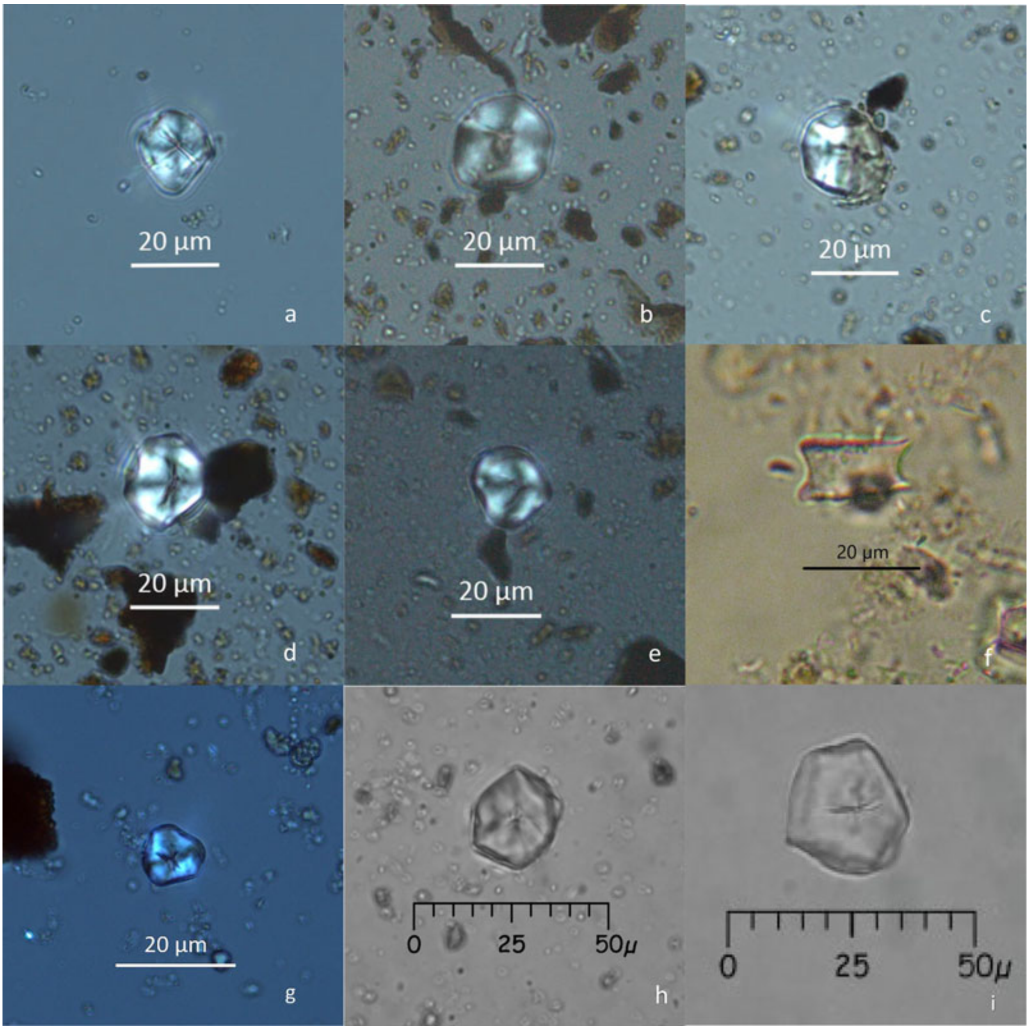

Figure 4. Microbotanical remains of maize from ceramics from Early Woodland, KCH, and Middle Woodland: (a) Trowbridge maize starch granule, 361 cal BC–197 cal BC; (b) Aker maize starch granule, 150 cal BC–cal AD 59; (c) Trowbridge maize starch granule, cal AD 26– 210; (d) Aker maize starch granule, cal AD 129– 346; (e) Trowbridge maize starch granule, cal AD 247–402; (f) Schultz maize cob phytolith, cal AD 261–413; (g) James Younkin maize starch granule from pottery; (h) Young maize starch granule, cal AD 433–571; (i) Young maize starch granule from a mano. (Color online)

maize was not identified from this artifact (Young and Duncan 2020). The zoned cross-hatched rim sherd from the undated Ward site (14EW17; Figure 3d) yielded maize starch (Young and Duncan 2020).

Additional starch granules representing food items are from wild rice (cf. *Zizania* spp.) and squash (*Cucurbita* sp.; Figure 5c, d). Seeds of *C. pepo* were recovered from the Trowbridge site (Johnson 1975). The identification of a possible rice phytolith from ceramic residue (Figure 5c; Lusteck 2012) is the first association of this plant with KCH. Wild rice (*Z. aquatica*) exploitation is recorded from many parts of the Northeast (Arzigian 2000; Boyd and Surette 2010; Crawford and Smith 2003; Lints 2012). Although the natural distribution of *Z. aquatica* does not extend to the eastern Plains, the modern distribution of *Z. palustris* includes backwater marshes and wetlands of the Missouri River

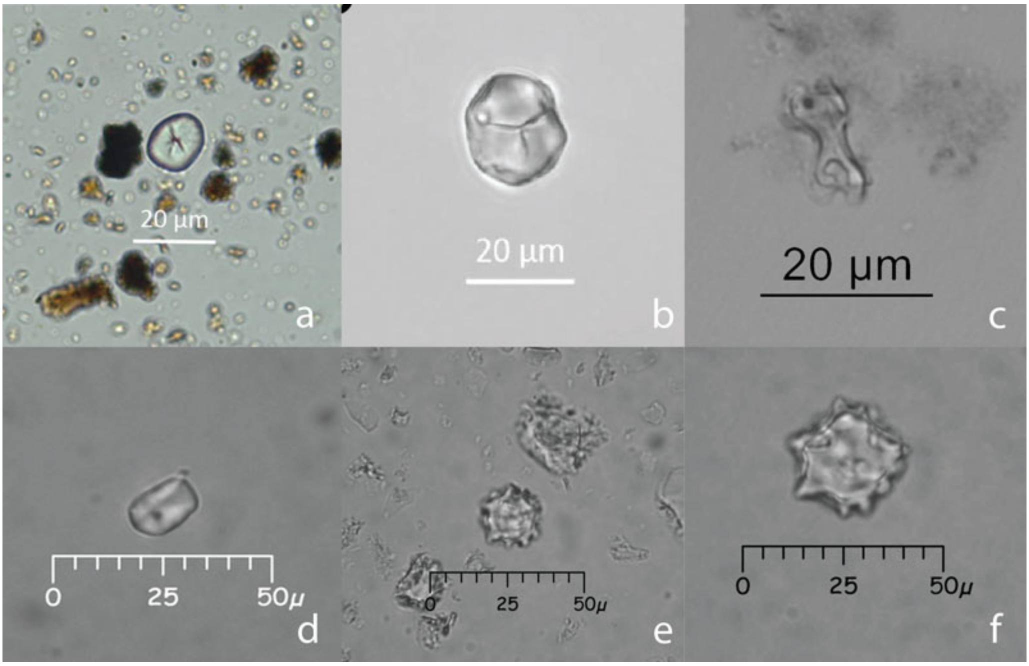

Figure 5. Microbotanical remains from KCH and Schultz: (a) Aker maize starch granule from dental calculus; (b) Berry maize starch granule from dental calculus, cal AD 132–329; (c) cf. *Zizania* spp. phytolith from Trowbridge; (d) Cucurbitaceae starch granule from Young; (e) globular echinate phytolith, Arecaceae sp. from Young; (f) globular echinate phytolith, Arecaceae sp. from Trowbridge. (Color online)

and its tributaries (Great Plains Flora Association 1986), as well as wetlands and lakes in the Nebraska Sandhills (Weaver 1965:43). Gilmore (1909:13) records that wild rice was a common food item for the Omaha-Ponca after they relocated to eastern Nebraska.

The identification of globular echinate phytoliths (also known as spinulose sphere phytoliths) from both soil samples is intriguing. These phytoliths (Figure 5e, f) are produced in members of the nonregional and non-native Arecaceae family (palms) (Duncan and Pearsall 2012) and are found in the leaves, stems, and petioles of palm species (Piperno 1988). The geographical distribution of the palmetto or bluestem palm (*Sabal minor*) includes southern Missouri (Small 1931). The California palm, *Washingtonia filifera*, extends east to central and southern Texas (Miller 1990).

Ethnobotanical accounts (Moerman 1998) identify the use of both the California palm and the palmetto palm as medicine, for basketry and cordage, for unspecified recreational uses, as a stimulant, and as food among many tribes. Archaeologically, palm phytoliths were identified from precontact ceramics recovered from St. Catherine's Island, Georgia, suggesting the consumption of palm (Lusteck and Thompson 2006). Although the presence of globular echinate phytoliths from the study area could be similarly interpreted, they are more likely to have come from fibers used in cordage or basketry. KCH trade with the Southeast is evident in ceramic styles and marine shells (Keehner and Adair 2019; Kozuch 2014), whereas maize originated from the Southwest.

Discussion

The results of this study add to the growing body of data for the presence of early maize use in precontact economies. The recovery of maize microremains from both burial and habitation contexts, which were directly dated from 287 cal BC to cal 503 AD, allows us to discuss *when* and *where* maize arrived in the eastern Plains and *how* it might have been processed and consumed by both foraging and farming groups in a manner that resulted in no or limited macroremains.

Pathways of Maize Dispersal and Adoption

Research in the greater Southwest documents evidence for maize use potentially as early as the fifth to fourth millennium cal BP (Hanselka 2018), when it was adopted by Archaic foragers (Minnis 1992; Wills 1995). The pathway(s) and timing of a transmission out of the Southwest are difficult to identify, partly because of the paucity of directly dated archaeobotanical data from adjacent regions. For example, undated maize from Late Archaic occupations (ca. 1000–250 BC) in the Apishapa region of southeast Colorado suggests a diffusion of the crop out of the northern Southwest (Zier 2018).

Once it became part of the local foraging economy, maize provided a means of securing additional resources as an extension of an existing wild plant gathering and tending practice. Vierra and Ford (2006) suggest that northern Rio Grande populations integrated maize into mobile farming economies by 1000 BC. Similarly, Roth and Freeman (2008) present an ecological framework in which maize was adopted as an extension of a foraging strategy, possibly influencing mobility patterns.

The westernmost evidence for maize in the central Plains comes from the Schultz burials and isolated Hopewellian-styled ceramics. An extensive trade network is reflected in the Schultz funerary objects, including East Coast/Gulf of Mexico and Pacific Coast marine shell, copper, nonlocal lithics, and muscovite (Carlson 1997; Cumming 1958; Hoard and Chaney 2010; Kozuch 2014; Ray 2014). Maize as a trade item could have been adopted and used in a manner similar to that described earlier for the foraging economy.

The temporal relationship between Schultz and KCH and the presence of Hopewellian-designed ceramics in Schultz phase sites suggest that the two groups interacted, providing a mechanism for the movement of maize. Interaction among the KCH and eastern and southeastern Hopewell groups is also evident from trade items and ceramic styles (Keehner and Adair 2019). If maize were a part of the Hopewell Interaction Sphere and traded widely over the eastern portion of the United States, isolated kernels or maize flour could have been a trade item. However, we cannot yet establish adoption trajectories or forms of interaction between the eastern Plains and the Northeast where early maize is identified that would account for the dispersal of this crop outside of the eastern central Plains. This is largely due to a lack of maize microremains from sites in the intervening regions. Therefore, evidence for early maize must be presented and interpreted on a regional basis, because groups may have expressed different strategies to possess maize at different times.

Potential Maize Use and Processing

Did the Plains people adopt or trade for maize as a supplement to wild resources, allowing them to increase their food options, especially in times of low prime resources, as suggested for the Mogollon Highland region of Arizona (Wills 1989)? Sharing of food resources is a common practice among hunter-gatherers, providing a greater assurance and equitable distribution of food, especially in times of food shortage (Keeley 1995; Kelly 1995); this practice also reinforces alliances and social ties. The presence of linear hypoplastic enamel defects on teeth samples from Dan Younkin and Berry burials (Dougherty 2012) may indicate seasonal nutritional stress. But sharing maize to augment available foods does not necessarily mean that maize was grown by Schultz communities.

Sustained maize cultivation requires either a secure method of seed storage or the frequent introduction of new maize germplasm (Simon 2014). With no evidence of plant cultivation for the Schultz phase or earlier Late Archaic occupations in the region, it is more likely that maize kernels or ground maize were traded into the region, rather than grown locally. Stable isotope values from the Schultz burials (Table 1) identify the presence of a C_4 resource. A cautious interpretation that this reflects maize consumption is discussed in Supplemental Text 4.

Unfortunately, samples from Valley and Cuesta occupations provide little information on the use of maize. The single maize phytolith identified from Valley ceramic residue (Figure 4f) dates to AD cal 484 (cal 2σ AD 424–537), a time equivalent to the early Late Woodland period. A single maize starch granule was recovered from the 14LN344 ceramic (Figure 3c), but no maize was detected in the second Cuesta sample from 14CF343. Given the relatively small number of samples analyzed for each complex, it is difficult to determine whether low maize recovery is a sampling bias or only reflects a later or limited adoption of maize.

Kansas City Hopewell subsistence economies represent a combination of hunting, gathering, and farming. Plant remains reflect gathering and cultivation of native plants and introduced squash (Adair and Drass 2011; Johnson 1975; Powell 2009; Schroeder 2012). A more sedentary settlement system than evidenced in Cuesta, Valley, or Schultz complexes can be inferred from the presence of deep and extensive middens, numerous pit features, and evidence for structures. With evidence for farming, maize could have been adopted as another cultigen, with consumption evident in the dental calculus from the Aker burial.

Maize starch on the grinding stone and hammerstone/mano (Figure 4i) suggests the grinding of maize kernels. Maize starch granules in the ceramic residue and from the ceramic fabric suggest the preparation or consumption of foods consisting of maize flour, an interpretation supported by experimental work on maize residue formation in cooking (Raviele 2010, 2011). If dried or dried/ground maize kernels were cooked, it would be unlikely to find phytoliths of maize cobs in the residue, whereas starch would likely be abundant. Although both starches and phytoliths can occur when green kernels are cut from the cob before cooking, green maize use is better revealed by diagnostic cob phytoliths (Raviele 2011). The frequency with which maize starch, rather than phytoliths, was present in the samples suggests the use of maize flour.

If maize were incorporated as another food crop in the existing suite of cultigens for the KCH, we would expect to recover macroremains, even with preservation and recovery issues. The larger Hopewell economy was anchored in the cultivation of native crop plants, with no evidence that maize contributed to the diet in any amount (Emerson et al. 2020; Fritz 2019; Simon 2021). Further, there is little evidence for maize use in the eastern central Plains during the Early Late Woodland and Late Late Woodland of about AD 400–900 (Adair and Drass 2011; Bozarth 1989; Powell 2019), despite the continued presence of Eastern Agricultural Complex crops.

Ritual Usage

Given the microbotanical data for pounded maize, cooked maize, and consumed maize, we should consider another explanation for its early acceptance: one that focuses on maize as a nonsubsistence item.[2] Were there nonculinary virtues of maize that were useful in social or political arenas that could also explain the presence of maize microremains?

Maize use in a sacred or ritual context, perhaps related to feasting, has been proposed for the Middle Woodland period (Boyd and Surette 2010; Mickleburgh and Pagán-Jiménez 2012; Newsom and Deagan 1994; Scarry 1993); this suggests that maize could have been associated with gift giving and the maintenance of social alliances over large territories. For the Lower Illinois Valley, Fie (2006:445) suggests that the most congruent model is based on socially motivated exchange for subsistence-maintenance materials. Mueller (2013) proposes that when different Hopewell communities got together, they exchanged foods and seeds, as well as knowledge. Maize may have therefore been an exotic and traded to be used by select individuals for specific purposes or ceremonies.

We recognize the strong interrelationship among maize, alcohol, and spiritual and social life (Hastorf 2016; Kennedy 1978; Mandelbaum 1965; Marshall 1979) in parts of North America and note that beer made from starchy grains was one of the most widely consumed alcoholic beverages in the ancient world (Guerra-Doce 2015; Logan et al. 2012; Munro 1963; Wang et al. 2016, 2017). Hayden and colleagues (2013:103) note that brewing is also extremely common among horticulturalists and is almost universal among those who grew grains. For example, Liu and coauthors (2018) identify the fermentation of grains by the Natufians about 13,000 years ago, several millennia prior to the domestication of cereals in the Near East. In Mesoamerica, alcohol distillation of mescal was practiced for at least 25 centuries before the arrival of the Spanish (Goguitchaichvili et al. 2018). Smalley and Blake (2003) propose that the rapid spread of maize in Mesoamerica can be modeled after the extensive ethnographic record of maize stalk beer production (*tesgüino*) in the region.

In North America, there is the suggestion of the production of maygrass beer to produce a successful vision quest during the Early Woodland period (Schoenwetter 2001) and accounts of wine production in southern California (Fages 1937:22), the long tradition of maize beer making among the Mescalero Apache of the Trans-Pecos region of Texas (Castetter and Opler 1936), and the use of selected colored maize grains for the production of a fermented alcoholic drink in the Sierra Madre Occidental region (Hernandez Xolocotzi 1985). Modern-day spiritual and ritual functions of the Mandan involve maize as a component of these activities (Bowers 1991:183–205), whereas the ethnographic record documents maize use in rituals and ceremonies associated with planting, harvesting, origins, and well-being among Plains tribes (Will and Hyde 1964).

However, despite these documented uses of grains in a nonsubsistence context, there are no archaeological data to support that maize-related rituals originated in North American prehistory with the initial adoption of maize. Additionally, maize use in a ritual or ceremonial context does not address how it was processed to leave microremains only or why it would have been adopted for such a use. Future research is needed to address these issues. Therefore, the suggestion that the early microbotanical remains of maize on the eastern Plains are a product of fermentation is speculative. Eerkens and Barnard (2007) report that it is difficult to identify fermentation from organic residues adhering to a ceramic vessel.

However, our understanding of the microbotanical residues and biomarkers produced and preserved during the malting, mashing, and fermentation stages of brewing ancient beer is still emerging (Hayden et al. 2013; Wang et al. 2017). Due to variations in temperature and moisture levels, starches are modified differently with various cooking treatments, which can explain the differential survival of starches (Crowther 2012). Experiments demonstrate that preservation of starchy granules happens during the cooking of low-moisture foods when desiccation and carbonization occur before the grains undergo gelatinization (Crowther 2012:230). Zarrillo and colleagues (2008:5009) suggest that the indurate aleurone of the hard endosperm flint maize may protect the endosperm starch from gelatinization. Gelatinization was not observed on microremains in this project.

The presence of maize microremains on grinding tools, within the encrusted residue on the inside of ceramic vessels, and directly in the ceramic fabric from the project area artifacts could be related to the cooking methods used for the malting and mashing processes, rather than to the previous suggestion of maize flour production. For example, malting is the process by which the insoluble sugars in maize are converted to soluble sugars during the steeping of the grain in water in large vessels for several days; this conversion is triggered by enzymes from the germinated grains (previously ground or smashed after being allowed to germinate). Mashing the malted maize in heated water in another vessel for a period of time then converts all of the starches to sugars. Fermentation of the liquid obtained from the mashing produces alcohol (Dineley 2004).

The making of maize beer could therefore leave residues on ground stone and an isotope signature in the ceramic fabric of the vessel used during the cooking process.

Consumption of the fermented drink could leave starch grains in dental calculus. Whether the fermented drink was used during mortuary rites or as a gift to solidify alliances is unknown. In such a context, maize-based alcohol would have a heightened relationship to a ritual event, even perhaps being a crucial component (Dietler 2006). Processed for its sugar rather than for its grain would also explain the near lack of maize macroremains and the growing evidence for maize microremains.

Detailing the transmission of maize from the greater Southwest to the Plains will require additional data. Uses of early maize may also require us to question existing models that see maize as exclusively a food item and adopted by ceramic groups already versed in horticulture. Numerous articles debate the initial role of maize in subsistence economies of the greater Southwest (Adams and Fish 2011:152), with many uses predating the manufacture of ceramics (Fish 2004:145). A growing literature also indicates that farming is not the only pathway to alcohol production (Hayden et al. 2013). New theoretical and methodological approaches are needed as future research addresses the possible uses of early maize and refines the temporal gap between the presence of maize in the micro versus macro form. Understanding preservation biases as related to Middle Woodland processing and cooking methods is a critical component (Barton 2009; Crowther 2012; Dotzel 2021; Haslam 2004; Raviele 2011).

Conclusions

This study demonstrates that maize use by prehistoric human communities of the central Plains has a more complex history than previously envisioned. Starch and phytolith evidence for maize and associated AMS ages document that this crop arrived in the eastern central Plains as early as 361–197 cal BC, more than 900 years earlier than the oldest directly dated macroremain. These data contribute to our understanding of the diverse regional and chronological variations evident in the history of maize in North America. The early Plains dates are consistent with those reported for early low-level maize use in the Northeast, but no direct relationship among peoples in these diverse areas can be made.

Early maize from the eastern Plains is identified from phytoliths and starch granules preserved in 60% of the samples analyzed and reflect possession, processing, and consumption. This early low-level use of maize, however, does not represent maize agriculture as we define it for post–AD 900 Plains groups. The association of the microremains with ceramics and burials is instead suggestive of a ritual context that may have strengthened social ties and political boundaries but was not exclusive to the Hopewell. The suggestion that maize was first adopted as a nonfood item to produce a sugary or fermented drink is not new but needs greater attention for the Middle Woodland period.

The use of maize and the suggested ritual use do not appear to extend into the Early Late Woodland period, a time that witnessed the decline in long-distance interaction and changes in the sociopolitical structure from the Middle Woodland period. The Plains data are suggestive of a pathway for the dispersal of this crop from the American Southwest, although geographical and temporal gaps, along with ecological factors and cultural processes, need to be addressed to refine this in greater detail. It is critically important to determine whether maize kernels or maize flour was the trade item or whether the plant was genetically adapted to temperate environments and grown by Plains Middle Woodland groups.

The starch and phytolith presence of other foods, including squash and wild rice, documents the importance of plants not well represented, if at all, in the archaeobotanical assemblage. Such is the case for the globular echinate phytoliths from the palm family.

Microbotanical remains may be the key to understanding how, when, and in what directions maize diffused throughout North America, the relationship among foraging and sedentary populations, and the suggested uses of maize. The presence of maize microremains in central Plains economies underscores the value of various artifacts in addressing this research, despite their still-limited interpreted potentials. It allows us to ask questions about the manner in which maize was processed and to speculate on its relationship to rituals. As microbotanical analyses increase in archaeobotanical research, and guided by social paleoethnobotany theory (Sayre and Bruno 2017), we may gain a more complete understanding of prehistoric maize use. Existing museum collections, even those artifacts washed and curated for decades, provide a valuable source of materials readily available for further exploration.

Acknowledgments. We extend our appreciation for colleagues John Hart, Jack Hofman, Emily Johnson, and Mary Simon, as well as the three anonymous reviewers, who commented on earlier versions of this article and strengthened it. We thank Trisha Nelson at History Nebraska for access to the Valley phase ceramics and associated records and to Rob Bozell, also with History Nebraska, for arranging the loan of the ceramics from site 25MD30. Collections and records related to the KCH sites are curated at the University of Kansas. Alan Potter drafted Figure 1, Steven Keehner prepared Figure 2, and Mason Niquette assisted with Figure 3. Ellie Holder prepared the Spanish translation of the abstract. Rob Bozell (History Nebraska), Laura Kozuch (independent researcher), and Jack Ray (Missouri State University) assisted with the identification of faunal remains, marine shell artifacts, and lithic sources recovered from Schultz burials. Sean Dougherty (Milwaukee Area Technical College) conducted an analysis of human remains from Schultz burials, providing new information on the health of the individuals interred. We are grateful for their permission to use unpublished reports. Research funds for the AMS dating were provided by the National Science Foundation (BCS 9974895); the Department of Anthropology, University of Kansas, Carlyle S. Smith Fund; and the University of Kansas Endowment Association. Analyses of the microremains were also funded by the Carlyle S. Smith Fund, History Nebraska, and University of Kansas endowment funds from KU alum Kenneth Wilcox.

Supplemental Material. For supplemental material accompanying this article, visit https://doi.org/10.1017/aaq.2021.152.

Supplemental Table 1. Recent AMS radiocarbon ages from Early Woodland to Early Late Woodland occupations in the eastern Central Plains.

Supplemental Text 1. AMS dating of ceramic residue.

Supplemental Text 2. Methodology of ceramic residue and dental calculus removal.

Supplemental Text 3. Lab procedures, contamination protocols, and comparative collections.

Supplemental Text 4. Stable isotopic values for bone and enamel from Middle Woodland Individuals.

Supplemental Text 5. References for Supplemental Table 1.

Data Availability Statement. The images of maize and other plant microremains are curated on the Archaeology Division server at the University of Kansas and in possession of the affiliated analysts. These images can be examined upon request.

Notes

1. We use the term "ceramic fabric" to refer to the interior surface of the ceramic sherd and to the small pockets present in the fired ceramic sherd. In both contexts, microremains can adhere to the surface or be absorbed within the fabric.

2. The terms "nonfood" and "nonculinary" are used to describe the use of maize in ways not related to subsistence. We acknowledge that maize would still need human involvement in planting, harvesting, and storing activities, much like other cultivated plants. However, its suggested use in a ritual context would have likely been associated with activities unrelated to food preparation.

References Cited

Adair, Mary J.
2003 Great Plains Paleoethnobotany. In *People and Plants in Ancient Eastern North America*, edited by Paul E. Minnis, pp. 258–346. Smithsonian Institution, Washington, DC.
2012 Refining Plains Woodland Chronology. *Plains Anthropologist* 57:183–228.

Adair, Mary J., and Richard R. Drass
2011 Patterns of Plant Use in the Prehistoric Central and Southern Plains. In *Subsistence Economies of Indigenous North American Societies: A Handbook*, edited by Bruce D. Smith, pp. 307–352. Rowman & Littlefield, Lanham, Maryland.

Adair, Mary J., Neil Duncan, Robert Lusteck, Mary Malainey, and Linda Perry
2012 Paleodietary Implications from Starch, Lipid, and Phytolith Analysis: A Case from the Kansas City Hopewell. Paper presented at the 70th Annual Plains Anthropological Society Conference, Saskatoon, Saskatchewan, Canada.

Adams, Karen R., and Suzanne K. Fish
2011 Subsistence through Time in the Greater Southwest. In *The Subsistence Economies of Indigenous North American Societies: A Handbook*, edited by Bruce D. Smith, pp: 147–184. Rowman & Littlefield, Lanham, Maryland

Arzigian, Constance
2000 Middle Woodland and Oneota Contexts for Wild Rice Exploitation in Southwestern Wisconsin. *Midcontinental Journal of Archaeology* 25:245–268.

Barton, Huw
2009 Starch Granule Taphonomy: The Results of a Two-Year Field Experiment. In *Archaeological Science under a Microscope: Studies in Residue and Ancient DNA Analysis in Honour of Tom Loy*, edited by Michael Haslam, Gail Robertson, Alison Crowther, Sue Nugent, and Luke Kirkwood, pp. 129–140. ANU E Press, Canberra, Australia.

Benz, Bruce F., and John E. Staller
2006 The Antiquity, Biogeography, and Culture History of Maize in the Americas. In *Histories of Maize: Multidisciplinary Approaches to the Prehistory, Linguistics, Biogeography, Domestication, and Evolution of Maize*, edited by John E. Staller, Robert H. Tykot, and Bruce F. Benz, pp. 665–673. Elsevier, New York.

Bowers, Alfred W.
1991 *Mandan Social and Ceremonial Organization*. University of Idaho Press, Moscow.

Boyd, Matthew, and Clarence Surette
2010 Northernmost Pre-Contact Maize in North America. *American Antiquity* 75:117–133.

Bozarth, Steven R.
1989 Opal Phytolith Analysis for Cultigen Identification: The Quixote and Reichart Sites. In *Archaeological Investigations in the Perry Lake Project Area, Northeastern Kansas: National Register Evaluation of 17 Sites*, edited by Brad Logan, pp. 239–242. Report submitted to the US Army Corps of Engineers, Kansas City District.
2011 *Phytolith Analysis of a Sherd Scraping at 23PL285*. Report submitted to Archaeological Research Center, University of Kansas, Lawrence.
2014a *Opal Phytolith and Starch Grain Analysis of Sherd Scrapings from 14WY1 and 25VY1*. Report submitted to Archaeological Research Center, University of Kansas, Lawrence.
2014b *Opal Phytolith and Starch Grain Analysis of Dental Calculus*. Report submitted to Archaeological Research Center, University of Kansas, Lawrence.

Brock Ramsey, Christopher
2020 Comment on "The Use of Bayesian Statistics for ^{14}C Dates of Chronologically Ordered Samples: A Critical Analysis." *Radiocarbon* 42:199–202.

Carlson, Gayle F.
1997 A Preliminary Survey of Marine Shell Artifacts from Prehistoric Archaeological Sites in Nebraska. *Central Plains Archaeology* 5:11–48.

Castetter, Edward F., and Morris E. Opler
1936 *The Ethnobiology of the Chiricahua and Mescalero Apache: The Use of Plants for Foods, Beverages and Narcotics*. University of New Mexico Press, Albuquerque.

Crawford, Gary W., and David G. Smith
2003 Paleoethnobotany in the Northeast. In *People and Plants in Ancient Eastern North America*, edited by Paul E. Minnis, pp. 172–257. Smithsonian Institution, Washington, DC.

Crowther, Alison
2012 The Differential Survival of Native Starch during Cooking and Implication for Archaeological Analysis: A Review. *Archaeological and Anthropological Sciences* 4:221–235.

Cumming, Robert B., Jr.
1958 Archaeological Investigations at the Tuttle Creek Dam, Kansas.River Basin Survey Papers No. 10. *Bureau of American Ethnology Bulletin* 169:41–78.

Dietler, Michael
2006 Alcohol: Anthropological/Archaeological Perspective. *Annual Review of Anthropology* 35:229–249.

Dineley, Merryn
2004 *Barley, Malt and Ale in the Neolithic*. BAR International Series S1213. Archaeopress, Oxford.

Dotzel, Krista M.
2021 Mind the Gap: Maize Phytoliths, Macroremains, and Processing Strategies in Southern New England 2500–500 BP. *Economic Botany* 75:30–47.

Dougherty, Sean
2012 *Mortality and Morbidity among Three Skeletal Samples from the Republican River Valley*. Report submitted to Archaeological Research Center, University of Kansas, Lawrence.

Duncan, Neil A., and Deborah M. Pearsall
2012 *An Assessment of Microfossil Preservation in Artifact Residue and Soils from Two Hopewell Period Sites, Kansas*. Report submitted to Archaeological Research Center, University of Kansas, Lawrence.

Duncan, Neil A., and Danielle N. Young
2018 *Results of Dental Calculus and Ceramic Residue Analysis for Starch and Phytoliths from Prehistoric Contexts in Kansas*. Report submitted to Archaeological Research Center, University of Kansas, Lawrence.

Eerkens, Jelmer W., and H. Barnard
2007 Introduction. In *Theory and Practice of Archaeological Residue Analysis*, edited by Hans Barnard and Jelmer W. Eerkens, pp. 1–7. BAR International Series 1650. Archaeopress, Oxford.

Emerson, Thomas E., Kristin M. Hedman, Mary L. Simon, Matthew A. Fort, and Kelsey E. Witt
2020 Isotopic Confirmation of the Timing and Intensity of Maize Consumption in Greater Cahokia. *American Antiquity* 85:241–262.

Fages, Pedro
1937 *A Historical, Political, and Natural Description of California: Written for the Viceroy in 1775*. Translated by Herbert Ingram Priestley. University of California Press, Berkeley.

Fie, Shannon M.
2006 Visiting in the Interaction Sphere: Ceramic Exchange and Interaction in the Lower Illinois Valley. In *Recreating Hopewell*, edited by Douglas K. Charles and Jane E. Buikstra, pp. 427–445. University of Florida Press, Gainesville.

Fish, Suzanne K.
2004 Corn, Crops, and Cultivation in the North American Southwest. In *People and Plants in Ancient Western North America*, edited by Paul E. Minnis, pp. 115–166. Smithsonian Institution, Washington, DC.

Fritz, Gayle J.
2006 Introduction and Diffusion of Crops from Mexico. In *Environment, Origins, and Population*, edited by Douglas H. Ubelaker, pp. 437–446. Handbook of North American Indians Vol. 3, William C. Sturtevant, general editor. Smithsonian Institution, Washington, DC.
2019 *Feeding Cahokia: Early Agriculture in the North American Heartland*. University of Alabama Press, Tuscaloosa.

Gilmore, Melvin R.
1909 A Study in the Ethnobotany of the Omaha Indians. Master's thesis, Department of Botany and Horticulture, University of Nebraska, Lincoln.
1977 *Uses of Plants by the Indians of the Missouri River Region*. Reproduced from the 33rd Annual Report of the Bureau of American Ethnology (1919). University of Nebraska Press, Lincoln.

Goguitchaichvili, Avto, Miguel Cervantes Solano, Jesús Carlos Lazcano Arce, Mari Carmen Serra Puche, Juan Morales, Ana María Solar, and Jamie Urrutia-Fucugauchi
2018 Archaeomagnetic Evidence of Pre-Hispanic Origin of Mezcal. *Journal of Archaeological Science; Reports* 21:504–511.

Great Plains Floral Association
1986 *Flora of the Great Plains*. Edited by T. M. Barkley, Ralph E. Brooks, and Eileen K. Schofield. University Press of Kansas, Lawrence.

Guerra-Doce, Elisa
2015 The Origins of Inebriation: Archaeological Evidence of the Consumption of Fermented Beverages and Drugs in Prehistoric Eurasia. *Journal of Archaeological Method and Theory* 22:751–782.

Hanselka, J. Kevin
2018 A Pan-Regional Overview of Archaic Agriculture in the Southwest. In *The Archaic Southwest*, edited by Bradley J. Vierra, pp. 269–295. University of Utah Press, Salt Lake City.

Hart, John P., William A. Lovis, and M. Anne Katzenberg
2021 Early Maize in Northeastern North America: A Comment on Emerson and Colleagues. *American Antiquity* 86:425–427.

Haslam, Michael
2004 The Decomposition of Starch Grains in Soils: Implications for Archaeological Residue Analysis. *Journal of Archaeological Science* 31:1715–1734.

Hastorf, Christine
2016 *The Social Archaeology of Food: Thinking about Eating from Prehistory to the Present*. Cambridge University Press, Cambridge.

Hayden, Brian, Neil Canuel, and Jennifer Shanse
2013 What Was Brewing in the Natufian? An Archaeological Assessment of Brewing Technology in the Epipaleolithic. *Journal of Archaeological Methods and Theory* 20:102–150.

Henry, Amanda G., and Dolores R. Piperno
2008 Using Plant Microfossils from Dental Calculus to Recover Human Diet: A Case Study from Tell al-Raqa'i, Syria. *Journal of Archaeological Science* 35:1943–1950.

Hernandez Xolocotzi, Efraím
1985 Maize and Man in the Greater Southwest. *Economic Botany* 39:416–430.

Hillson, Simon W.
1996 *Dental Anthropology*. Cambridge University Press, Cambridge.

Hoard, Robert J., and Henry W. Chaney
2010 Olivella Shells from Kansas Archaeological Sites. *Plains Anthropologist* 55:293–298.

Johannessen, Sissel, and Christine A. Hastorf (editors)
1994 *Corn and Culture in the Prehistoric New World*. Westview Press, Boulder, Colorado.

Johnson, Alfred E.
1992 Early Woodland in the Trans-Missouri West. *Plains Anthropologist* 17:129–136.

Johnson, Eileen M.
1975 *Faunal and Floral Remains from a Kansas City Hopewell Site: Analysis and Interpretation*. Occasional Papers of the Museum No. 36. Texas Tech University, Lubbock.

Keehner, Steven P., and Mary J. Adair
2019 Modeling Kansas City Hopewell Developments and Regional Social Interactions: A Multisite Ceramic Analysis and New AMS Radiocarbon Ages. *Midcontinental Journal of Archaeology* 44:2–41.

Keeley, Lawrence H.
1995 Protoagricultural Practices among Hunter-Gatherers: A Cross-Cultural Survey. In *Last Hunters, First Farmers: New Perspectives on the Prehistoric Transition to Agriculture*, edited by T. Douglas Price and Anne Birgitte Gebauer, pp. 243–272. School of American Research Press, Santa Fe, New Mexico.

Kelly, Robert L.
1995 *The Foraging Spectrum: Diversity in Hunter-Gatherer Lifeways*. Smithsonian Institution, Washington, DC.

Kennedy, John G.
1978 *Tarahumara of the Sierra Madre: Beer, Ecology, and Social Organization*. AHM Publishing, Arlington Heights, Virginia.

Kozuch, Laura
2014 *Shell Identifications*. Report submitted to Archaeological Research Center, University of Kansas, Lawrence.

Lints, Andrew
2012 Evidence of Domesticates from Early Ceramics of the Northern Plains: An Analysis of Avonlea Cultural Materials (AD 300–1000). Master's thesis, Department of Anthropology, Lakehead University, Thunder Bay, Canada.

Liu, Li, Jiajing Wang, Danny Rosenberg, Hao Zhao, György Lengyel, and Dani Nadel
2018 Fermented Beverage and Food Storage in 13,000 Yr-Old Stone Mortars at Raqefet Cave, Israel: Investigating Natufian Ritual Feasting. *Journal of Archaeological Science: Reports* 21:783–793.

Logan, Amanda, Christine A. Hastorf, and Deborah M. Pearsall
2012 "Let's Drink Together": Early Ceremonial Use of Maize in the Titicaca Basin. *Latin American Antiquity* 23:235–258.

Lovis, William A.
1990 Curatorial Considerations for Systematic Research Collections: AMS Dating a Curated Ceramic Assemblage. *American Antiquity* 55:382–387.

Lusteck, Robert K.
2006 The Migrations of Maize into the Southeastern United States. In *Histories of Maize: Multidisciplinary Approaches to the Prehistory, Linguistics, Biogeography, Domestication, and Evolution of Maize*, edited by John E. Staller, Robert H. Tykot, and Bruce F. Benz, pp. 521–528. Elsevier, New York.
2012 *Phytolith Identifications*. Report submitted to Archaeological Research Center, University of Kansas, Lawrence.

Lusteck, Robert K., and Robert G. Thompson
2006 Phytolith Residues Recovered from Pottery at St. Catherine's Island, Georgia. Paper submitted to David Hurst Thomas, American Museum of Natural History, New York.
2007 Residues of Maize in North American Pottery: What Phytoliths Can Add to the Story of Maize. In *Theory and Practice of Archaeological Residue Analysis*, edited by Hans Barnard and Jelmer W. Eerkens, pp. 8–17. BAR International Series 1650. Archaeopress, Oxford.

Mandelbaum, David G.
1965 Alcohol and Culture. *Current Anthropology* 6:281–293.

Marshall, Mac (editor)
1979 *Beliefs, Behaviors, and Alcoholic Beverages: A Cross-Cultural Survey*. University of Michigan Press, Ann Arbor.

Martin, Terrell L.
2007 Early Woodland Black Sand Occupation in the Lower Missouri Valley, Western Missouri. *Plains Anthropologist* 52:43–61.

Mickleburgh, Hayley L., and Jamie R. Pagán-Jiménez
2012 New Insights into the Consumption of Maize and Other Food Plants in the Pre-Columbian Caribbean from Starch Grains Trapped in Human Dental Calculus. *Journal of Archaeological Science* 39:2486–2478.

Miller, Victor J.
1990 *Washingtonia filifera*: Native Habitats in Arizona. *Principes* 34(4):177–180.

Minnis, Paul E.
1992 Earliest Plant Cultivation in the Desert Borderlands of North America. In *Origins of Agriculture: An International Perspective*, edited by C. Welsey Cowan and Patty Jo Watson, pp. 121–141. Smithsonian Institution, Washington DC.

Moerman, Daniel E.
1998 *Native American Ethnobotany*. Timber Press, Portland, Oregon.

Mueller, Natalie G.
2013 *Mound Centers and Seed Scarcity: A Comparative Analysis of Botanical Assemblages from Middle Woodland Sites in the Lower Illinois Valley*. Springer, New York.

Munro, Neil G.
1963 *Ainu Creed and Cult*. Columbia University Press, New York.

Newsom, Lee A., and Kathleen A. Deagan
1994 *Zea mays* in the West Indies: The Archaeological and Early Historic Record. In *Corn and Culture in the Prehistoric New World*, edited by Sissel Johannessen and Christine A. Hastorf, pp. 203–218. Westview Press, Boulder, Colorado.

Pearsall, Deborah M.
2015 *Paleoethnobotany: A Handbook of Procedures*. 3rd ed. Routledge, London.

Pearsall, Deborah M., and Dolores R. Piperno
1993 The Nature and Status of Phytolith Analysis. In *Current Research in Phytolith Analysis: Applications in Archaeology and Paleoecology*, edited by Deborah M. Pearsall and Dolores R. Piperno, pp. 9–18. University Museum of Archaeology and Anthropology, University of Pennsylvania, Philadelphia.

Perry, Linda, Ruth Dickau, Sonia Zarrillo, Irene Holst, Deborah Pearsall, Dolores Piperno, Mary Jane Berman, et al.
2007 Starch Fossils and the Domestication and Dispersal of Chili Peppers (*Capsicum* spp. L.) in the Americas. *Science* 315:986–988.

Piperno, Dolores. R.
1988 *Phytolith Analysis: An Archaeological and Geological Perspective*. Academic Press, New York.

Piperno, Dolores R., Thomas C. Andres, and Karen E. Stothert
2000 Phytoliths in *Cucurbita* and Other Neotropical Cucurbitaceae and their Occurrence in Early Archaeological Sites from the Lowland American Tropics. *Journal of Archaeological Science* 27:193–208.

Piperno, Dolores R., Ehud Weiss, Irene Holst, and D. Nadel
2004 Processing of Wild Cereal Grains in the Upper Paleolithic Revealed by Starch Grain Analysis. *Nature* 430:670–673.

Powell, Gina S.
2009 Plant Remains from 23JA266. Appendix A. In *Excavations at Sibley Bluff Top (23JA266): A Multiple Component Site at the Fort Osage National Historic Landmark, Jackson County, Missouri*, pp. 220–246. Report submitted to Jackson County Parks and Recreation, Missouri.
2019 Macrobotanical Remains, In *Quixote: A Late Woodland Site in Northeastern Kansas*, edited by Brad Logan, pp. 113–132. Report Submitted to the Kansas Anthropological Association and the Cultural Resources Division, Kansas Historical Society, Topeka.

Raviele, Maria E.
2010 Assessing the Archaeological Cooking Residues: Evaluation of Maize Phytolith Taphonomy and Density through Experimental Residue Analysis. PhD dissertation, Department of Anthropology, Michigan State University, East Lansing.
2011 Experimental Assessment of Maize Phytolith and Starch Taphonomy in Carbonized Cooking Residue. *Journal of Archaeological Science* 38:2708–2713.

Ray, Jack H.
2014 *Notes on ARC Artifacts Loaned to Missouri State University*. Report submitted to Archaeological Research Center, University of Kansas, Lawrence.

Reimer, Paula, William E. N. Austin, Edouard Bard, Alex Bayliss, Paul G. Blackwell, Christopher Bronk Ramsey, Martin Butzin, et al.
2020 The IntCal20 Northern Hemisphere Radiocarbon Age Calibration Curve (0–55 cal kBP). *Radiocarbon* 62:725–757.

Roth, Barbara J, and Andrea Freeman
2008 The Middle Archaic Period and the Transition to Agriculture in the Sonoran Desert of Southern Arizona. *Kiva* 73:321–353.

Sayre, Matthew P., and Maria C. Bruno (editors)
2017 *Social Perspectives on Ancient Lives from Paleoethnobotanical Data*. Springer, New York.

Scarry, C. Margaret
1993 Variability in Mississippian Crop Production Strategies. In *Foraging and Farming in the Eastern Woodlands*, edited by C. Margaret Scarry, pp. 78–90. University Press of Florida, Gainesville.

Schmits, Larry J., and Bruce C. Bailey
1989 Prehistoric Chronology and Settlement-Subsistence Patterns in the Little Blue Valley, Western Missouri. In *Prehistory of the Little Blue River Valley, Western Missouri: Archaeological Investigations at Blue Springs Lake*, edited by Larry J. Schmits, pp. 221–251. Report Submitted to the US Army Corps of Engineers, Kansas City District by Environmental Systems Analysis, Shawnee Mission.

Schoenwetter, James
2001 Paleoethnobotanical Expressions of Prehistoric Ritual: An Early Woodland Case. In *Fleeting Identities: Perishable Material Culture in Archaeological Research*, edited by Penelope Drooker, pp. 273–282. Southern Illinois University, Carbondale.

Schroeder, Marjorie
2012 Archaeobotanical Analysis. In *Recent Limited Investigations at the Renner Site, 23PL1*, compiled by Don L. Booth. Report submitted to the City of Riverside, Missouri by SCI Engineering, St. Charles.

Schultz, Floyd, and Albert Spaulding
1948 A Hopewellian Burial Site in the Lower Republican Valley, Kansas. *American Antiquity* 13:306–313.

Simon, Mary L.
2014 Reevaluating the Introduction of Maize into the American Bottom and Western Illinois. In *Reassessing the Timing, Rate, and Adoption Trajectories of Domesticate Use in the Midwest and Great Lakes*, edited by Maria E. Raviele and William A. Lovis, pp. 97–134. Midwest Archaeological Conference Occasional Papers No. 1. University of Illinois, Champaign.
2017 Reevaluating the Evidence for Middle Woodland Maize from the Holding Site. *American Antiquity* 82:140–150.
2021 New Dates and Carbon Isotope Assays of Purported Middle Woodland Maize from the Icehouse Bottom and Edwin Harness Sites. *American Antiquity* 86:613–624.

Skibo, James M.
1992 *Pottery Function: A Use-Alternative Perspective*. Plenum Press, New York.

Small, John K.
1931 Palms of the Continental United States. *Scientific Monthly* 32:240–255.

Smalley, John, and Michael Blake
2003 Sweet Beginnings: Stalk Sugar and the Domestication of Corn. *Current Anthropology* 44:675–703.

Smith, Bruce D., and Wesley Cowan
2003 Domesticated Crop Plants and the Evolution of Food Producing Economies in Eastern North America. In *People and Plants in Ancient Eastern North America*, edited by Paul E. Minnis, pp. 105–125. Smithsonian Institution, Washington, DC.

Staller, John, Robert H. Tykot, and Bruce F, Benz (editors)
2006 *Histories of Maize: Multidisciplinary Approaches to the Prehistory, Linguistics, Biogeography, Domestication, and Evolution of Maize*. Elsevier, New York.

VanDerwarker, Amber M., Dana N. Bardolph, Kristin M. Hoppa, Heather B. Thakar, Lana S. Martin, Allison L. Jaqua, Matthew E. Biwer, and Kristina M. Gill
2016 New World Paleoethnobotany in the New Millennium (2000–2013). *Journal of Archaeological Research* 24:125–177.

Vierra, Bradley J., and Richard I. Ford
2006 Early Maize Agriculture in the Northern Rio Grande Valley, New Mexico. In *Histories of Maize: Multidisciplinary Approaches to the Prehistory, Linguistics, Biogeography, Domestication, and Evolution of Maize*, edited by John Staller, Robert Tykot, and Bruce Benz, pp. 497–510. Elsevier, New York.

Wang, Jiajing, Li Liu, Terry Ball, Linjie Yu, Yuanqing Li, and Fulai Xing
2016 Revealing a 5000 Year Old Beer Recipe in China. *PNAS* 113:6444–6448.

Wang, Jiajing, Li Lui, Andreea Georgescu, Vivienne V. Le, Madeleine H. Ota, Silu Tang, and Mahpiya Vanderbilt
2017 Identifying Ancient Beer Brewing through Starch Analysis: A Methodology. *Journal of Archaeological Science: Reports* 15:150–160.

Weaver, John J.
1965 *Native Vegetation of Nebraska*. University of Nebraska Press, Lincoln.

Will, George F., and George E. Hyde
1964 *Corn among the Indians of the Upper Missouri*. University of Nebraska Press, Lincoln.

Wills, Wirt H.
1989 Patterns of Prehistoric Food Production in West-Central New Mexico. *Journal of Anthropological Research* 45:139–157.
1995 Archaic Foraging and the Beginning of Food Production in the American Southwest. In *Last Hunters, First Farmers: New Perspectives on the Prehistoric Transition to Agriculture*, edited by T. Douglas Price and Anne Birgitte Gebauer, pp. 215–242. School of American Research Press, Santa Fe, New Mexico.

Wilson, Gilbert L.
1987 *Buffalo Bird Woman's Garden: Agriculture of the Hidatsa Indians*. Reprinted Minnesota Historical Society Press, St. Paul. Originally published 1917 as *Agriculture of the Hidatsa Indians: An Indian Interpretation*, University of Minnesota, Minneapolis.

Young, Danielle N., and Neil Duncan
2020 *Results of Starch Grain Analysis from Prehistoric Ceramics in Kansas*. Report submitted to Paleoethnobotany and Environmental Archaeology Laboratory, University of Central Florida, Orlando.

Zarrillo, Sonia, Deborah Pearsall, J. Scott Raymond, Mary Ann Tisdale, and Dugane J. Ouon
2008 Directly Dated Starch Residues Document Early Formative Maize (*Zea mays* L.) in Tropical Ecuador. *PNAS* 105:5006–5011.

Zier, Christian J.
2018 The Role of Horticulture in the Prehistoric Apishapa Region of Southwestern Colorado. *Review in Colorado Archaeology* 1(Article 2):11–40.

Submitted March 19, 2021; Revised August 1, 2021; Accepted November 3, 2021