

Dental Caries as an Archaeological Problem-Solving Tool: Reconstructing Subsistence Patterns in Late Prehistoric West-Central Tennessee

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ABSTRACT The dentition from two Middle Mississippian period (~AD 1100-1350) site samples (Gray Farm [~AD 1100-1350], Link/Slayden [~AD 1100-1400]) from the Kentucky Lake Reservoir of west-central Tennessee area are examined for caries prevalence by tooth type, lesion size, and crown-root location to assess whether a maize-intensive subsistence economy is evident. Given the paucity of local archaeological context, comparative caries prevalence and pattern operate as a critical archaeological problem-solving tool. The Middle Mississippian samples are compared to a Kentucky Lake Late Woodland period (~AD 400-900) horticulturist site sample (Hobbs) as well as three unequivocal maize-intensive agriculturalist site samples from the Late Mississippian period of East Tennessee (~AD 1300-1550). The caries patterns (tooth type, location, size) in the Gray Farm sample is consistently not statistically different from the maize-intensive samples; Link/Slayden is consistently statistically different and resembles the caries pattern and prevalence of the Hobbs sample. The adoption of maize as a primary cultigen in the Kentucky Lake Reservoir is evidently geographically variable. This may reflect local ecological contexts or differential socio-economic contacts with neighboring Mississippian economies. Or, more likely, it may reflect temporal differences in Mississippianization between the Kentucky Lake Reservoir sites.

Paleopathological data in sample-based bioarchaeological inquiry are a well-established adjunct to archaeological problem-solving (e.g., Buikstra and Beck, 2017; Larsen, 2015; Martin et al., 2013). Although the reconstruction of extinct cultures is largely the purview of archaeology, many archaeological contexts, such as mortuary sites and salvage projects, lack the associated material culture to address basic questions about subsistence, settlement pattern, and social organization. In these circumstances, bioarchaeological data can be an effective primary archaeological problem-solving tool (e.g., Armelagos, 2003; Larsen, 2015; Mosher et al., 2015; Smith et al., 2016; Stojanowski & Duncan, 2015). Dental caries prevalence and severity can be particularly effective as a benchmark of agricultural intensification and the dietary primacy of particular fermentable carbohydrates (e.g., Caselitz, 1998; Karsten et al., 2015; Larsen, 1991, 2005; Lubell et al., 1994; Lukacs, 1992; Patterson, 1986; Šlaus et al., 2011; Temple & Larsen, 2007; Turner, 1979). Carious lesions are the consequence of the demineralization of tooth enamel by the metabolic processes of certain oral bacteria (e.g., *Streptococcus mutans*) in the presence of refined carbohydrates. In the

Americas, the primary cariogenic carbohydrate of agricultural intensification (post AD 900 - Contact) is maize (*Zea mays*) (e.g., Simon, 2017; Smith, 2017; VanDerwarker et al., 2017), particularly the variant known as northern “flint corn” (*Zea mays indentata*) (Simon, 2017). It is commonly asserted that caries incidence rises dramatically with the adoption of maize (e.g., Emerson et al., 2005; Larsen, 1981; Powell, 1985; Watson, 2005). However, the increase is not simply a reflection of absolute carbohydrate consumption as other, likely synergistic factors (e.g., rate of attrition, hypoplastic defects, and malocclusion), affect individual vulnerability to cariogenesis. Complicating the subsistence inferences, documentation of caries prevalence across the late prehistoric site samples from the contiguous United States can be variable and uneven. Often this

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reflects sample preservation, as dental data are differentially available: loose teeth, *in situ* presence, and antemortem (alveolar resorption) and post-mortem (empty sockets) tooth loss. Recording can consist of the prevalence of carious individuals, the prevalence of carious teeth, prevalence of carious teeth by tooth class, and/or the application of caries correction factors. The result is often a lack of inter-site comparability. This can be interpretively problematic as the temporal transition to maize-intensive agriculture is ecologically, geographically, and socio-politically variable (Emerson et al., 2005; Hutchinson et al., 1998; Scarry, 1993; Wilson, 2017). The adoption of stable isotope analysis (i.e., C³/C⁴ ratios prevalence) allowed archaeologists to sidestep the shortcomings of osteological preservation and the quantitative methodology issues. However, this option is not available for many pre-Columbian human osteological samples in the contiguous United States as destructive analysis is not permitted.¹

The intensive adoption of maize as a primary cultigen across the eastern continental United States throughout the middle and lower Mississippi River Valley, the lower Ohio River Valley, and the Southeastern United States north of Florida occurs with the most recent pre-Columbian cultural horizon, the Mississippian Period (~AD 1000 – 1500) (Bense, 2016; King, 2017; VanDerwarker, 2017; Wilson, 2017). The horizon reflects the most complex sociopolitical organization north of Mesoamerica (Bense, 2016; Smith, 1990) and is archaeologically manifested by the presence of large aggregated village settlements, often palisaded, that were organized around a central plaza. The plaza, in turn, was flanked by one or more quadrilateral flat-topped mounds with variable functions (e.g., mortuary, domiciliary, temple) (Dalan, 1997; Kidder, 2004; King, 2001; King, 2017; Lewis et al., 1998). Some level of centralized authority (arguably chiefdom-level) is evident (Beck, 2003; Cobb, 2003; King, 2017; Pauketat, 2007). The Mississippian Period is also characterized by a complex iconography (i.e., the “Southeastern Ceremonial Complex” [SECC] or “Southeastern Ceremonial Exchange Network” [SCEN]) of sociopolitical as well as cosmological meaning (Knight, 2006; Knight et al., 2001; Muller, 1989; Reilly and Garber, 2007). The apex of Mississippian culture occurred in the Middle period (CE 1200-1400) when the hallmarks of Mississippian culture are present throughout the middle and lower Mississippi River Valley, the lower Ohio River Valley, and the Southeastern United States north of Florida.

Plant domestication has a long trajectory in the pre-Columbian eastern US (e.g., Fritz, 1990; Scarry, 2008; Smith, 2006, 2011; Smith and Yarnell, 2009). Prior to the dedicated adoption of maize, cultigens consisted of a suite of native oily (e.g., sunflower and marsh elder) and starchy seed grasses (e.g., maygrass, knotweed, lamb’s quarter, little barley) referred to as the Eastern Agricultural Complex (EAC) (Scarry, 2008; Smith, 2006; Smith and Yarnell, 2009). The transition from native grasses to maize cultivation was not temporally or geographically uniform and may have been influenced by ecological constraints or peripheral geographic location relative to the Mississippian cultural heartland (e.g., Fritz, 1990; Smith, 2011; 2017). Within this Mississippian culture area, regional polities occur that differed in social complexity and the adoption of Mississippian cultural elements. One of these variants, the Middle Cumberland Culture (MCC), is physiographically concentrated in the Nashville Basin of central Tennessee (Dowd, 2008; Ferguson, 1972; Moore et al., 2006; Smith, 1992) and extends from the Cumberland River drainages between the confluence of the Caney Fork and Cumberland Rivers in the east to the confluence of the Red and Cumberland Rivers in the west (Figure 1). It has been archaeologically observed that the Nashville Basin had a high population density in late prehistory and mirrored the Mississippian socioeconomic pattern of mound centers and agriculturalization (Beahm, 2013; Jolley, 1983). Maize cultivation, likely intensive, is evident in MCC sites (Beahm, 2013; Buikstra, et al., 1988; Crites, 1984).

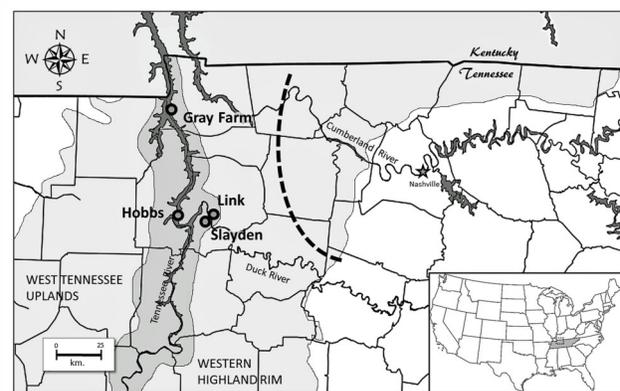


Figure 1. Map of west-central Tennessee identifying the location of the site samples in the Tennessee River Valley. The valley is flanked by two highland areas: the West Tennessee Uplands and the Western Highland Rim. The dashed line demarcates the western most extent of the middle Cumberland Culture.

There are numerous Middle Mississippian sites in the Tennessee River valley west of the highland areas and beyond the western boundary of the MCC in, and adjacent to, what is now the Kentucky Lake Reservoir. Maize-intensive agriculture is ubiquitous in the Late Mississippian period (~AD 1350-1550) (Bense, 2016; King, 2017; VanDerwarker, 2017; Wilson, 2017), but geographically variable in the Middle Mississippian period. Identifying the subsistence patterning is particularly important in the Kentucky Lake area because there are no Late Mississippian components for any site as the region was inexplicably abandoned by circa AD 1450 (Bass, 1985; Cobb and Butler, 1992; Williams, 1990). With little evaluated archaeological material culture from Kentucky Lake, the dental caries data from sites in this apparent cultural frontier provide critical insight into the dietary importance of maize.

Materials and Methods

The three Kentucky Lake Reservoir sites examined for caries prevalence and patterns are physiographically located in the Western Valley of the Lower Tennessee River, which is situated between two highland areas (see Figure 1). To the west, are the Western Tennessee Uplands and to the east, the Western Highland Rim of the Nashville Basin. The sites were excavated as salvage archaeological projects prior to the completion of the Kentucky Dam (Gilbertsville, Kentucky) (1938-1944). Two of the west-central Tennessee archaeological sites, Link (40HS6) and Slayden (40HS1), are located on river bluffs above the Duck River, a tributary of the Tennessee River, at the confluence of its tributary, the Buffalo River. The sites are within twenty kilometers of the confluence of the Duck River with the Tennessee River. They are argued to be the same settlement context and are thus evaluated together. Link/Slayden was a multi-mound Mississippian context dating to the Early-to-Middle Mississippian period (~AD 1100-1350) (Bass, 1985; Dye, 2002, 2003; Kuemin Drews, 2000; Lunn, 2013). The Link site is the source of the Duck River Cache, arguably the most spectacular collection of Native American stone work (i.e., circa four dozen stone maces, stone knives, stone daggers) recovered in the Eastern United States (Brehm, 1981; Dye, 2007). The Gray Farm site (40SW1) is a Middle Mississippian multi-mound site located on the eastern bank of the Tennessee River just north of the confluence of the Big Sandy River (Bass, 1985; Kuemin Drews, 2001). Temporally it appears to be as old as Link/Slayden, but archaeological evidence (ceramics and

domestic structure types) suggests it was occupied longer (Bass, 1985). It is approximately 50 air kilometers north of Link/Slayden. The third Kentucky Lake Reservoir site assessed for dental caries dates to the Late Woodland (~AD 500-900) period (Kuemin Drews, 2001). Hobbs (40HS44) is a mound mortuary context located downstream from Link/Slayden on the main channel of the Tennessee River (see Figure 1). Archaeologically it co-occurs with the cultivation of the native grasses of the Eastern Agricultural Complex (Smith and Yarnell, 2009).

The permanent dentition of adult burials from the Kentucky Lake site samples was canvassed for the presence of carious lesions. All skeletons had previously been assessed for age and sex using standard non-metric osteological criteria (e.g., Buikstra and Ubelaker, 1994). Individuals were included in the sample if they were skeletally assessed as adults (Buikstra and Ubelaker, 1994) or the preserved third molars (loose or in-situ) were present as, at least, a developmentally complete crown.

The teeth were examined for carious lesions which were scored by size and location on the crown (occlusal, smooth surface [e.g., interdental, buccal, lingual], and/or the cemento-enamel junction [CEJ]). Lesions that involved adjacent teeth were attributed to both teeth. A carious lesion was recognized by a pit measuring at least 1 mm in diameter (Figure 2a) with evidence of demineralization at the orifice (Figure 2b, 2c) to distinguish it from pit-fissure irregularities on the occlusal and buccal surfaces. Assessment was aided by a 2x-4x hand lens. Carious lesions circa 4 mm in diameter were classified as medium and non-pulp-penetrating lesions greater than 4 mm were classified as large. Pulp exposures were included based on the likelihood that they resulted from carious lesions from the crown or CEJ. Where preservation permitted, a necrotic tooth represented only by the roots or a pulp exposure associated with alveolar pocketing was not included (as periodontal disease could not be etiologically excluded). This exclusion did not seem to affect caries prevalence, as necrotic roots were isolated occurrences. Teeth exhibiting antemortem breakage were also excluded. These were identified by sharp-edged concavities with non-demineralized surfaces with evidence of masticatory use (i.e., polish or attrition) (Figure 2d, e, f).

Preservation ranged from fair to poor at all sites. Few individuals preserved complete enough maxillae or mandibles to reliably calculate dental caries

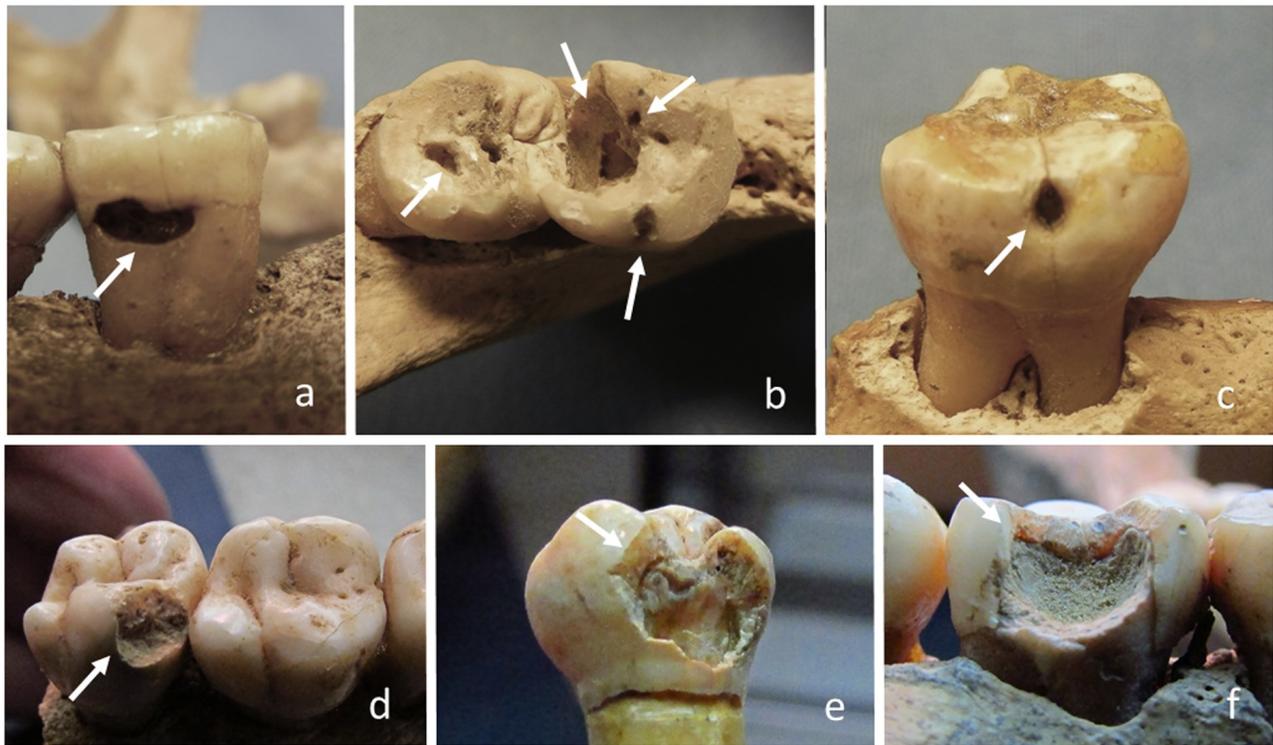


Figure 2. Examples of the extent of carious lesions from the Link (40HS6) sample. a) Burial 6 (Unit 19) exhibits a pulp-penetrating carie at the cemento-enamel junction, b) the first and second molars of Burial 3 (Unit 21) displaying (arrows) pulp exposure, pit-fissure occlusal cavities larger than 1 mm, and a carious lesion in the buccal pit, c) and Burial 3 (Unit 67) illustrates a carious buccal pit. Non-carious antemortem cusp breakage (sharp perimeter, no demineralization) is exemplified in d) Burial 30 (Unit 21) with non-carious dentin-exposing breakage exhibited in e) Burial 32 (Unit 21) and f) Burial 38 (Unit 21).

prevalence by individual or to apply a Caries Correction Factor. The present study assesses dental caries by three tooth type categories irrespective of arch or antimere: incisors and canines (I/C), premolars (PM), and molars. Molars were also assessed by position in the tooth row (M1-M3). The samples were compared for sex differences within the site sample and between site samples. Adults were also segregated into three age-at-death categories: young (18 to ~35 years), middle (35 to 50 years), and mature (50+ years) based on the skeletal age-at-death range provided in the computer database.

A local comparative context was needed to assess whether the Middle Mississippian period Kentucky Lake samples were maize-intensive agriculturalists or whether they continued to cultivate native grasses. As no data sample is available (either published or available for research) from the Middle Cumberland Culture or the Mississippi River Valley of Tennessee, three unequivocal Late Mississippian (~1300-1450 AD) period maize-

intensive agriculturalist site samples from East Tennessee were utilized. The sites are also pre-reservoir archaeological salvage projects and are located along the Tennessee River or its tributary, the Little Tennessee River. The Little Tennessee River valley samples are from the sites of Toqua (40MR6) and Citico (40MR7) (i.e., Tellico Reservoir), and the Dallas (40HA1) site located along the Tennessee River (i.e., Chickamauga Reservoir) (Betsinger and Smith, 2013, 2018). The data were previously collected by the authors and reflect the same collecting protocols as the Kentucky Lake site samples.²

The prevalence rates of caries by the three tooth types were compared utilizing the Fisher's Exact Test ($p \leq 0.05$). Intra-site comparisons were based on sex, while inter-site comparisons were made for the entire sample, for males, for females, and by age cohort. Further segregating the samples into age categories by sex yielded sample sizes too small for statistical assessment (e.g., $n < 10$).

Results

Caries by tooth type

In the Link/Slayden total sample (Table 1), two percent of all preserved teeth exhibit at least one carious lesion. This is the lowest frequency of the three Kentucky Lake samples. When assessed by tooth class, Link/Slayden carious teeth are restricted to the posterior dentition. Over seven percent of all molars exhibit a carious lesion with the third molar the most frequently affected. However, this differential involvement is likely due to the paucity of first and second molars consequential to observed antemortem tooth loss. There are also no carious lesions in the incisiform dentition from the Late Woodland Hobbs site sample. The proportion of carious molar teeth is also circa seven percent. The percent of caries in the Hobbs premolar sample generates the only statistically significant difference between the two samples (Table 2) affect-

ing the significant difference for all dentition ($p = 0.0219$). The Gray Farm sample has the highest frequency of any carious teeth (17.3%) with caries present in all the tooth classes. Gray Farm has significantly higher caries prevalence for all but the third molar (5/17, 29.4%) compared to the Link/Slayden sample (5/33, 15%). The relatively higher caries rates by tooth class in the Hobbs sample relative to Link/Slayden generate fewer statistically significant differences compared to the Gray Farm sample. Only the more frequent carious second molars in Gray Farm (33.3% vs 4.8%) are significantly different compared to Hobbs ($p = 0.0448$).

Sex differences in caries prevalence

Given that females in many agriculturalist archaeological samples are likely more predisposed to dental caries (e.g., Lukacs, 1996, 2008; Lukacs and Largaespada, 2006), each site sample was tested for

Table 1. Caries presence, location, and severity by tooth type

TOOTH CLASS	LINK/SLAYDEN													
	all adults		males		females		caries location			caries severity				
	cases/n	%	cases/n	%	cases/n	%	occl	CEJ	ss ²	s	m	l	p ex ³	
I/C ¹	0/121	0	0/17	0	0/74	0	---	---	---	---	---	---	---	
PM	0/98	0	0/21	0	0/55	0	---	---	---	---	---	---	---	
M1	3/55	5.5	0/6	0	3/24	12.5	2/3	1/3	0/3	1/3	1/3	0/3	1/3	
M2	2/48	4.2	0/6	0	1/15	6.6	1/2	1/2	0/2	0/2	0/2	0/2	2/2	
M3	5/33	15.1	1/2	---	2/11	18.0	2/5	2/5	1/5	2/5	1/5	0/5	2/5	
ALL M	10/138	7.2	1/14	7.1	6/50	12.0	5/10	4/10	1/10	3/10	2/10	2/10	3/10	
ALL DENT	10/493	2.0	1/52	1.9	6/179	3.4	5/10	4/10	1/10	3/10	2/10	2/10	3/10	
TOOTH CLASS	HOBBS													
	all adults		males		female		caries location			caries severity				
	cases/n	%	cases/n	%	cases/n	%	occl	CEJ	ss ²	s	m	l	p ex ³	
I/C ¹	0/38	0	0/8	0	0/22	0	---	---	---	---	---	---	---	
PM	3/30	10.0	1/12	8.0	2/16	12.5	0/3	3/3	0/3	3/3	0/3	0/3	0/3	
M1	2/16	12.5	2/4	---	0/7	0	1/2	1/2	0/2	2/2	0/2	0/2	0/2	
M2	1/21	4.8	1/4	---	0/15	0	1/1 ⁴	1/1 ⁴	0/1	1/1	0/1	0/1	0/1	
M3	1/17	5.9	1/2	---	0/6	0	1/1	0/1	0/1	1/1	0/1	0/1	0/1	
ALL M	4/54	7.4	4/11	7.1	0/28	0	3/4	2/4	0/4	4/4	0/4	0/4	0/4	
ALL DENT	7/110	6.4	5/31	16.1	2/66	3.0	3/7	5/7	0/7	7/7	0/7	0/7	0/7	
TOOTH CLASS	GRAY FARM													
	all adults		males		females		caries location			caries severity				
	cases/n	%	cases/n	%	cases/n	%	occl	CEJ	ss ²	s	m	l	p ex ³	
I/C ¹	4/48	8.3	3/12	25.0	1/21	4.8	0/4	1/4	3/4	3/4	1/4	0/4	0/4	
PM	4/58	6.9	1/12	8.0	1/22	4.5	1/4	2/4	1/4	3/4	1/4	0/4	0/4	
M1	10/29	34.0	2/10	20.0	1/10	10.0	3/10	3/10	4/10	8/10	2/10	0/10	0/10	
M2	7/21	33.3	1/11	9.0	4/9	44.4	6/7	0/7	1/7	7/7	0/7	0/7	0/7	
M3	5/17	29.4	0/4	0	2/10	20.0	4/5	0/5	1/5	5/5	0/5	0/5	0/5	
ALL M	22/67	3.3	3/25	12.0	7/29	24.1	14/22	3/22	6/22	20/22	2/22	0/22	0/22	
ALL DENT	30/173	17.3	7/49	14.3	9/72	12.5	15/30	5/30	7/30	26/30	4/30	0/30	0/30	

¹ Incisors and canines are pooled, ² smooth surface, ³ pulp exposure, ⁴ teeth with more than one carious lesion

Table 2. Intra- and inter- Kentucky Lake sample caries prevalence by tooth type

	Link/Slayden	Hobbs	Gray Farm
sex differences within samples			
I/C	----	----	0.1250
PM	----	1.0000	1.0000
M1	----	----	1.0000
M2	----	----	----
M3	----	----	----
All M	1.0000	0.0040	0.3095
All Dent	1.0000	0.0091	0.7904
caries in the total sample			
I/C	----	0.0059	0.1264
PM	0.0119	0.0179	0.6787
M1	0.3137	0.0009	0.1641
M2	1.0000	0.0025	0.0448
M3	0.6498	0.2768	0.1748
All M	1.0000	0.0001	0.0007
All Dent	0.0219	0.0001	0.0003
sample comparisons by males			
I/C	----	0.0602	0.2421
PM	0.3824	0.3824	1.0000
M1	----	----	----
M2	----	----	----
M3	----	----	----
All M	0.1333	1.000	0.1665
All Dent	0.0254	0.0281	1.0000
sample comparisons by females			
I/C	----	0.2292	1.0000
PM	0.0582	0.2857	0.5619
M1	1.0000	1.0000	1.0000
M2	----	----	----
M3	----	1.0000	----
All M	0.0825	0.2110	0.0104
All Dent	1.0000	0.0144	0.0577

sex differences. There is an under-enumeration of males by molar type within both the Link/Slayden and Hobbs samples and for the M3 in the Gray Farm sample (see Table 1), therefore the between sex comparisons are restricted. There are no carious teeth in the I/C and PM categories in the Link/Slayden sample but the collective molar and collective dentition tests (including I/C and PM) are not significantly different by sex (see Table 2). In the tests by tooth type in the Gray Farm comparisons, males and females are not significantly different. The Hobbs sample exhibits a statistically different higher prevalence for males in the total

tooth sample (16% versus 3%), undoubtedly effected by the higher male prevalence in the (small) male collective molar sample (36.4% versus 0%). In the absence of definitive differences between the sexes in caries prevalence, the samples can be pooled for statistical testing.

Caries prevalence compared to maize-intensive samples
The total-sample comparisons of caries presence by tooth type of Link/Slayden with the Toqua, Citico, and Dallas samples generated statistically significant differences for all tests except the third molar (Table 3). In contrast, all the total sample compari-

Table 3. Caries prevalence in the Kentucky Lake samples compared to maize-intensive samples

	TOQUA			CITICO			DALLAS		
	Total samples			Total samples			Total samples		
	Link/ Slayden	Gray Farm	Hobbs	Link/ Slayden	Gray Farm	Hobbs	Link/ Slayden	Gray Farm	Hobbs
I/C	0.0001	1.0000	0.1070	0.0001	0.0649	1.0000	0.0034	0.5195	0.2444
PM	0.0001	0.4999	1.0000	0.0001	0.4514	0.0575	0.0001	0.4816	1.0000
M1	0.0001	0.6742	0.1587	0.0005	0.3728	0.3784	0.0001	1.0000	0.1499
M2	0.0004	0.6059	0.0303	0.0003	0.0318	0.6086	0.0001	0.2352	0.0084
M3	0.1273	1.0000	0.0425	0.3657	0.1267	0.5691	0.1780	1.0000	0.0449
All M	0.0001	0.4796	0.2811	0.0001	0.0015	0.2441	0.0001	0.7780	0.0001
All Dent	0.0001	0.5131	0.0058	0.0001	0.0030	0.7503	0.0001	1.0000	0.0017
	male samples			male samples			male samples		
I/C	0.3833	0.1145	---	1.0000	1.0000	---	0.6043	0.0425	---
PM	0.0512	0.6982	---	0.2279	1.0000	---	0.1344	1.0000	---
M1	---	0.4930	---	---	0.1947	---	---	0.2140	---
M2	---	0.2900	---	---	1.0000	---	---	0.2757	---
M3	---	---	---	---	---	---	---	---	---
All M	0.1216	0.0995	0.5077	0.1980	0.4823	0.2163	0.0458	0.0938	0.7334
All Dent	0.0089	0.8434	1.0000	0.0090	0.5987	0.8300	0.0033	1.0000	1.0000
	female samples			female samples			female samples		
I/C	0.0182	1.0000	0.3794	0.0004	0.1534	0.4900	0.0349	1.0000	0.6075
PM	0.0319	1.0000	0.6307	0.0001	0.5374	0.0559	0.0020	0.4783	1.0000
M1	0.0782	0.7194	---	0.0526	0.0991	---	0.0160	0.0762	---
M2	0.1137	---	0.0199	0.1903	---	0.2507	0.0034	---	0.0006
M3	0.7201	0.7189	---	1.0000	0.3330	---	0.7089	0.7127	---
All M	0.0017	0.6690	0.0002	0.0219	0.0004	0.8287	0.0045	0.1448	0.0001
All Dent	0.0001	0.4142	0.0112	0.0001	0.0001	0.1247	0.0001	0.1925	0.0004

sons by tooth type of the Gray Farm sample were not significantly different (Table 4). The Late Woodland Hobbs sample was significantly different in the posterior teeth from two (Dallas and Toqua) of the three East Tennessee Mississippian samples.

The number of statistical tests in the male cohort between the Kentucky Lake samples and the maize-intensive samples were restricted because of poor sample sizes in the male cohort. However, the congruence of the collective Gray Farm sample with the collective maize-intensive samples is maintained in the male sample comparisons (see Table 3). The under-enumeration of males in the Hobbs and Link/Slayden samples limits the number of

teeth available to test. However, the pooled male dentitions in Link/Slayden are significantly different from the Toqua, Citico, and Dallas samples. The few tests available for the Hobbs sample are not significantly different for any of the maize-intensive samples. With larger samples available for the females, more tests are possible. Missing only a test for M2, there are otherwise no female sample differences between Gray Farm and any of the maize-intensive samples. The absence of caries in the incisiform teeth and premolars in the Link/Slayden sample is significantly different from all the maize-intensive samples. The lower frequency of dental caries in the first molars of Link/Slayden is significantly different ($p \leq 0.05$) from the Citico

Table 4. Comparison of site samples by caries location and severity

Link/Slayden x Hobbs				Link/Slayden x Gray Farm				Hobbs x Gray Farm				
	occlusal	CEJ	ss ¹		occlusal	CEJ	ss ¹		occlusal	CEJ	ss ¹	
All M	0.5804	1.000	----		0.6993	0.1655	0.3871		1.0000	0.5633	----	
All M	s	m	l	p ex ²	s	m	l	p ex ²	s	m	l	p ex ²
All M	0.0699	1.0000	1.0000	0.5055	0.0010	0.5717	0.0907	0.0242	1.0000	1.000	----	----
TOQUA												
Link/Slayden				Gray Farm				Hobbs				
	occlusal	CEJ	ss ¹		occlusal	CEJ	ss ¹		occlusal	CEJ	ss ¹	
All M	0.4997	1.0000	0.6885		0.0183	0.0092	0.5791		0.1404	1.0000	0.5832	
All M	s	m	l	p ex ²	s	m	l	p ex ²	s	m	l	p ex ²
All M	1.0000	1.0000	0.6183	1.0000	<0.0001	0.3754	0.1356	0.0003	0.0158	1.0000	1.0000	0.3033
CITICO												
Link/Slayden				Gray Farm				Hobbs				
	occlusal	CEJ	ss ¹		occlusal	CEJ	ss ¹		occlusal	CEJ	ss ¹	
All M	0.7558	0.2425	0.6933		0.5004	0.5771	0.5997		0.6303	0.2229	0.5765	
All M	s	m	l	p ex ²	s	m	l	p ex ²	s	m	l	p ex ²
All M	0.0978	1.0000	0.3481	0.1185	0.0039	0.3779	0.1348	0.1348	0.1537	1.0000	1.0000	1.0000
DALLAS												
Link/Slayden				Gray Farm				Hobbs				
	occlusal	CEJ	ss ¹		occlusal	CEJ	ss ¹		occlusal	CEJ	ss ¹	
All M	0.5008	0.7239	1.0000		1.0000	0.1213	0.1121		1.0000	0.5906	1.0000	
All M	s	m	l	p ex ²	s	m	l	p ex ²	s	m	l	p ex ²
All M	0.1823	1.0000	0.1737	0.4472	0.0029	0.3615	0.6030	0.0135	0.1383	1.0000	1.0000	0.5818

¹ smooth surface, ² pulp exposure

and Dallas samples, but not for the Toqua sample ($p = 0.07194$). The caries prevalence for females in the Link/Slayden samples for M2 and M3 are only significantly different for M2 in the Dallas sample. However, the pooled molar sample indicates that the fewer carious teeth in the Link/Slayden sample is significantly different from all of the maize intensive samples.

In general, the tests for Gray Farm reveal a similar pattern of caries prevalence compared to Toqua, Citico, and Dallas. In contrast, the Link/Slayden sample is significantly different from the same samples. The Late Woodland Hobbs sample, collectedly and segregated by sex, exhibits caries prevalence congruence with the Citico sample. Hobbs does have a lower case prevalence of caries in the posterior teeth when compared to the Toqua and Dallas samples.

Caries in Kentucky Lake by location and lesion size

Inter-sample comparisons are limited to the posterior teeth as Link/Slayden and Hobbs have no carious I/C dentition (see Table 4). The most common locations for carious lesions are the occlusal surfaces followed by the CEJ. Smooth surface caries, that is, those that occur buccolingually and mesiodistally are infrequent and most often occur in a buccal pit (e.g., see Figure 2b, c). There is no statistically significant difference among the Kentucky Lake sites for crown/CEJ location of carious lesions. Lesion size in the four carious molars from the Hobbs sample are all small and there are no cases of pulp exposure. The larger samples of Link/Slayden and Gray Farm (see Table 4) generated statistically significant differences in the prevalence of small diameter caries and pulp exposures. The trend is toward larger size carious lesions in the Link/

Slayden sample and smaller size caries in Gray Farm.

Lesion size and location compared to maize-intensive samples

The comparisons for location of carious lesions on the tooth appear to not distinguish a maize-intensive diet in any patterned way. Locations for Link/Slayden and Hobbs do not differ from the Toqua, Citico, or Dallas samples (see Table 4). Gray Farm distinguishes from Toqua by having more occlusal relative to CEJ dental caries. Lesion size also does seem to discriminate the maize-intensive diet; neither Link/Slayden nor Hobbs differ from Citico or Dallas. The Hobbs sample differs in the proportion of small lesions from Toqua, but the prevalence difference in the expression of small lesions in Hobbs is likely an issue of sample size (4/4, 100%). The almost exclusive expression of dental caries as small lesions and the absence of pulp exposures (see Table 1) does distinguish Gray Farm from all three maize-intensive samples, as well as Link/Slayden.

Age-at-death differences in caries prevalence among Kentucky Lake samples

The paucity of burials classified as mature (50+ years of age) meant that age-at-death comparisons are restricted to the young (< 35 years) and middle

age (35-50 years) cohorts. There are no carious teeth in the young adult samples of Hobbs (0/21) and Link/Slayden (0/65). Whereas 12.5% of the dentition (9/72) in the Gray Farm sample are carious. The prevalence difference is statistically significant between Link/Slayden and Gray Farm (Table 5). All of the carious teeth identified for the Hobbs sample belonged to ageable adults and fall into the middle age-at-death category (7/57, 12.3%). Only four carious teeth are ageable in the Link/Slayden sample and reflect 8.7 percent (4/46) of the middle age cohort. Hobbs and Link/Slayden are not significantly different from each other ($p=0.7506$). The larger proportion of carious teeth in the Gray Farm sample (6/31, 19.3%) is not statistically different either from Link/Slayden or Hobbs (see Table 5).

Given that the preponderance of carious teeth are molars, the molar teeth are compared by age-at-death. In the young age-at-death category, the Link/Slayden absence of caries (0/27) is significantly different from the Gray Farm sample (7/37, 18.9%) ($p=0.0125$) but the small sample of molars in the Hobbs sample (0/7) was not significantly different from Gray Farm or Link/Slayden (see Table 5). In the middle age-at-death category, Link/Slayden (4/21, 19%), Hobbs (4/23, 17.4%), and Gray Farm (1/10, 10%) are not significantly different from each other (See Table 5).

Table 5. Comparison of site samples by age at death

	Link/Slayden x Hobbs		Link/Slayden x Gray Farm		Hobbs x Gray Farm	
	young	middle	young	middle	young	middle
All teeth	----	0.7506	0.0033	0.1891	0.2010	0.5304
All molars	1.0000	1.0000	0.0125	1.0000	0.3126	1.0000
TOQUA						
	Link/Slayden		Gray Farm		Hobbs	
	young	middle	young	middle	young	middle
All Teeth	0.0096	0.0806	0.1830	1.0000	0.3989	0.2221
All molars	0.0174	0.2279	0.4490	0.1735	0.5988	0.1618
CITICO						
	Link/Slayden		Gray Farm		Hobbs	
	young	middle	young	middle	young	middle
All teeth	0.0001	0.1582	0.8579	0.8078	0.0979	0.4638
All molars	0.0011	0.6095	0.8285	0.4614	0.2020	0.4610
DALLAS						
	Link/Slayden		Gray Farm		Hobbs	
	young	middle	young	middle	young	middle
All teeth	<0.0001	0.2620	0.5971	0.6086	0.0561	0.6827
All molars	0.0002	0.7757	0.3989	0.4433	0.1073	0.5824

Age-at-death differences in caries prevalence compared to maize-intensive samples

Although Link/Slayden is a Middle Mississippian site sample, it has consistently statistically significant lower caries prevalence in the young age-at-death category compared to Toqua, Citico, and Dallas. Antithetically, Gray Farm is statistically similar to all three. Hobbs does not differ from Toqua, but does for Dallas, and for Citico at a lower level of statistical reliability ($p = \leq 0.10$). All samples are similar in the middle age category (see Table 5).

Age-at-death difference for size and location of caries

The preponderance of carious molars in the ageable Kentucky Lake sample ($n=17$) are found on the occlusal surface (14/17). The absence of carious teeth in the young age-at-death category of Link/Slayden and Hobbs means that no comparisons could be made among the Kentucky Lake samples. In the middle age-at-death category, there are nine molars in the collective sample. The molars in Hobbs and Link/Slayden have the same proportion of occlusal to cervical caries: three-to-one; the Gray Farm site has a single molar with an occlusal carious lesion. There is a subtle difference between the molars of Hobbs and Link/Slayden in the middle age-at-death category. All four of the lesions on the molars in the Hobbs sample are small in size while two of the occlusal carious lesions in the Link/Slayden sample are medium-sized. Link/Slayden also exhibits the only ageable carious lesion (at the CEJ) with pulp exposure. The absence of a statistically valid sample in the Kentucky Lake samples negated comparisons with the maize-intensive samples.

Discussion

The archaeological context

The bioarchaeological co-association of the intensive cultivation of specific cariogenic carbohydrates with dental caries prevalence (i.e., number of carious teeth) greater than 10 percent is commonly reported world-wide (e.g., Caselitz, 1998; Karsten et al., 2015; Larsen, 1991, 2005; Lubell et al., 1994; Lukacs, 1992; Patterson, 1986; Šlaus et al., 2011; Temple and Larsen, 2007; Turner, 1979) as well as in the late prehistoric contiguous United States (e.g., Emerson et al., 2005; Larsen, 1981; Powell, 1985; Watson, 2005). The utility of dental caries to flag agricultural intensification and/or the cultivation of particular cariogenic carbohydrates is particularly critical in archaeological contexts

where material culture is wanting. The Mississippian sites of the Kentucky Lake Reservoir are located in a cultural frontier between the Middle Cumberland Culture of the Nashville Basin and the various Mississippian period phases of the Mississippi River watershed located west of the West Tennessee Uplands (see Figure 1) (see Mainfort, 1996; Mainfort and Moore, 1998; Smith, 1990). The socioeconomic context of the Kentucky Lake Mississippian sites is poorly understood, as are the geographically adjacent late prehistoric cultures from the Mississippi River watershed of west Tennessee. The Mississippi River valley (MRV) archaeological contexts are frequently compromised by historic period development (e.g., cultivation, urbanization, transportation [railroad and highway construction]), major changes in the meander pattern of the Mississippi river, and, unfortunately, looting (Mainfort and Moore, 1998). To date, much of the late prehistoric MRV archaeological assessment centers on ceramic patterns and their geographic distributions. However, there is archaeobotanical evidence of maize at the Chucalissa site (40SY1) (AD 1250-1500) located in the south-western corner of the state of Tennessee near the present-day city of Memphis (Smith, 1990). The general paucity of bioarchaeological data in the Mississippi River Valley limits comparisons with the Kentucky Lake samples to all but the most well-known Middle-to-Late Mississippian period site of Chucalissa (McNutt et al., 2012). Dental caries data for Chucalissa are restricted to the number of carious teeth (271/1386, 19.6%) (Robinson, 1976), which compares favorably ($p = 0.7465$) with the Gray Farm site sample (30/173, 17.3%), and contrasts with Link/Sladen ($p = 0.0001$) and Hobbs ($p = 0.0041$).

Whether maize presence as a staple crop in the Mississippi River Valley influenced a diffusion toward, at least, Gray Farm, is problematic. There is scarce evidence of Mississippian occupation east of the Mississippi River floodplain in the West Tennessee Uplands (Mainfort, 1996; Smith, 1990) suggesting little or no cultural influence from the Mississippi River Valley. Indeed, according to the seminal archaeological overview of Mississippian sites in the Kentucky Lake Reservoir by Quentin Bass, Mississippianization was an *in situ* development rather than culture-bearing in-migration(s) of populations into the area (1985:93).

In contrast, the mortuary pattern of interment characterized by the lining of the grave pit with stone slabs ("stone box burials") associated with the Middle Cumberland Culture (AD 1250-1450,

Thruston phase) of the Nashville Basin (Figure 1) (Dowd, 2008; Ferguson, 1972) frequently occurs in Kentucky Lake Reservoir Mississippian sites (Bass, 1985; Wamsley, 2018). Relative to the present study, the mortuary pattern of the Gray Farm site includes stone boxes as well as secondary interments of charnel house burials, whereas the entirety of the mortuary treatment at Link/Slayden is stone box (Bass, 1985; Wamsley, 2018). Predictably, no stone box interments occur at the Late Woodland Hobbs site (Kuemin Drews, 2000; Wamsley, 2018). Unfortunately, no caries data are available from Middle Cumberland Culture sites.

The socioeconomic circumstance of the Kentucky Lake samples is temporally important, as no Late Mississippian occupation (i.e., AD 1400-1600) is evident (Bass, 1985). This pre-Columbian abandonment of the lower Tennessee River valley is part of a larger post-AD 1450 regional depopulation phenomenon centered in the lower Ohio River valley known as “the Vacant Quarter” (Cobb and Butler, 2002; Williams, 1990). The abandonment is not well understood (Cobb and Butler, 2002; Williams, 1990), but may very well co-associate with precipitation corollaries of major climate change (i.e., “Little Ice Age,” circa AD 1400-1850) (e.g., Anderson, 2001; Meeks and Anderson, 2013; Stinchcomb et al., 2011).

The maize-intensive patterns

The frequency of carious teeth by tooth type and caries prevalence segregated by age-at-death in the Gray Farm sample compared to the unequivocal maize-intensive samples from East Tennessee (e.g., Chapman, 2014; Polhemus, 1987) strongly suggests that it reflects a maize-intensive subsistence strategy. The strategic location of the Gray Farm site straddling the Cumberland and Tennessee River Valleys (see Figure 1) may have eco-culturally influenced the adoption of maize as a primary cultigen. That is, the Gray Farm site is located downstream from the communities of the Middle Cumberland Culture who are archaeologically identified as maize intensive (e.g., Beahm, 2013; Crites, 1984).

A singularity of the Gray Farm dental caries pattern occurs in lesion size and location relative to the Link/Slayden sample as well as the three Late Mississippian sites (Table 4). Gray Farm has an over enumeration of small carious lesions and an under-representation of pulp exposures. A number of variables could explain this finding. It could suggest a qualitatively different cariogenic food consumption pattern. That is, processing and/or

consumption of maize that limits the metabolic activity of the oral bacteria. Or, more likely, a biased dental sample relative to antemortem tooth loss. The proportion of molar teeth out of the total tooth sample available for study is consistent across the age-at-death categories for Hobbs (7/28, 33% versus 23/57, 40%) and Link/Slayden (27/67, 40.3% versus 19/44, 43.2%). However, in the young age-at-death category for Gray Farm, over 50 percent of the dental sample is composed of molars (37/71); in the middle age-at-death category, the proportion is reduced to a third (10/30). Given that neither Hobbs nor Link/Slayden register any carious lesions among the young adults, the retention of teeth with more advanced lesions in middle age is plausible. Whereas, cariogenesis initiated in (at least) early adulthood would inevitably progress to necrosis and tooth loss by middle age. A directed examination of antemortem tooth loss would corroborate this.

The Link/Slayden patterns

The archaeological context of the Link/Slayden site sample indicates a Mississippianized settlement pattern of a multiple-mound aggregated village (Bass, 1985), but it is clear that the subsistence pattern is different from Gray Farm and the East Tennessee Late Mississippian sites. The congruence of many of the dental caries comparisons with the Late Woodland Hobbs site and significant difference of the Link/Slayden sample with the maize-intensive samples affirms this. Interpretively important, the pattern and prevalence of dental caries is not consistent with pre-agricultural data. The total tooth sample caries prevalence for three Late Archaic hunter-gatherer samples from this reservoir is 2.7 percent (93/3414) (Smith, 1982) and is significantly different from Hobbs ($p=0.0352$) and Link/Slayden ($p=0.0316$). The location of carious lesions on all teeth in the Archaic sample is almost exclusively at the CEJ (53/58, 91.4%), in contrast to Hobbs where half of all carious lesions are on the occlusal surface.

The congruence of Link/Slayden and Hobbs in caries prevalence as well as the similarity of certain caries frequencies of Hobbs with the maize-intensive samples is consistent with the history of plant domestication in the Kentucky Lake Reservoir area. That is, west-central Tennessee is part of the core area within which the Eastern Agricultural Complex developed that was well-established by the Late Woodland period (e.g., Smith, 2006, 2011; Smith and Yarnell, 2009). In particular, archaeobotanical data from sites upstream in the Duck River

Valley (Normandy Reservoir) indicate there was a shift in the Late Woodland from the ceremonial use of maize to dietary use (Cobb and Faulkner, 1978; Shea, 1977). However, an elevation in caries prevalence does not necessarily indicate a shifting reliance toward maize as high prevalence has been observed in Woodland contexts pre-dating the introduction of maize (e.g., Alfonso-Durruty et al., 2014; Rose and Marks, 1985; Rose et al., 1991).

Although the location of Link/Slayden may be geographically remote relative to the core area of the maize-intensive MCC, it is more likely that the site sample is temporally earlier than Gray Farm. A recent assessment of the ceramics at the Slayden site suggests a primary occupation at the earlier end of the temporal spectrum (~ AD 1100-1200) (Lunn, 2013), implying that maize-intensive agriculture, and perhaps the primary occupation of Gray Farm, post-dated circa AD 1200 in the Kentucky Lake Reservoir area.

Dental caries as an archaeological problem-solving tool. The progressive nature of carious lesions ultimately results in tooth necrosis and exfoliation. The geometry and length of time particular teeth are in occlusion certainly affect pathogenesis and vulnerability. However, the process is not simply linear as many intrinsic (e.g., general health, hypoplastic defects, attrition, periodontal disease, pregnancy/lactation) and extrinsic (e.g., food processing, food preparation) factors are involved. In short, dental caries is not simply a proxy for the dietary reliance of one or another fermentable carbohydrate. However, as the Kentucky Lake samples illustrate, the complexities of cariogenesis can be modulated to address particular archaeological questions despite the analytical constraints imposed by poor preservation and small sample size. The results of the present study suggest that maize-intensive agriculture temporally occurred in the Middle Mississippian period (~ AD 1100-1350) of the Kentucky Lake Reservoir area of west-central Tennessee post-dating the primary occupation of the Link/Sladen sites (~ AD 1200). All Mississippian period occupation of west-central Tennessee terminated by ~ AD 1450.

Endnotes

¹ The research protocols of the osteoarchaeological samples currently curated by the Frank H. McClung Museum, inclusive of the samples in this study, are not eligible for any form of destructive analysis.

² In accordance with NAGPRA regulations, the

osteoarchaeological samples currently curated by the Frank H. McClung Museum are no longer eligible for research purposes pending repatriation and reburial.

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