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STABLE ISOTOPE ANALYSIS AND DIET IN EASTERN OKLAHOMA

J. Daniel Rogers

Over the last three decades, significant quantitative information on prehistoric diets has come to light from a variety of locations in the Caddoan archaeological area, a region encompassing eastern Oklahoma, western Arkansas, northeast Texas, and northwest Louisiana. Most of this research is based on macro-botanical and faunal remains analysis. As an additional line of evidence for the growing body of botanical and faunal data, stable carbon and nitrogen isotopes in bone collagen were analyzed from 82 human and faunal samples from the Arkansas basin and Ozark Highlands in eastern Oklahoma. The research investigates the role of maize in diets through time and across sex and status dimensions. Spanning six phases, within the time range 300 B.C. to A.D. 1650, mean $\delta^{13}\text{C}$ values increase from -19.2 to -12.7 parts per million (‰). Although present prior to A.D. 1000 substantial increases in the use of maize do not begin until the Harlan phase (A.D. 1050–1250). Even with increased use, maize never dominates the diet to the extent seen in Mississippian period sites farther east.

In recent decades stable isotope studies have made significant contributions to the analysis of human diets. Within the Eastern Woodlands of North America these studies altered interpretations of the role of maize (and other dietary components) and the relationship between agricultural intensification and the development of social complexity. Although the relationship between maize and social complexity was once a fundamental part of interpretations, it is now well established that the emergence of stratified societies of the Mississippian period, between A.D. 750 and 1050, is not closely tied to the extensive consumption of maize (Lynott et al. 1986; Vogel and van der Merwe 1977). In most areas maize became a major part of the diet only after about A.D. 1000 (Ambrose 1987:97; Hastorf and Johannessen 1994:432), although it was often eaten in smaller quantities as early as the Woodland period (between A.D. 200 and 400; Rose 2008; Smith and Cowan 2003:117). Whether maize is linked to the beginnings of the Mississippian societies or not, it is true that this one Mesoamerican cultigen did become a dietary staple and sustaining crop between A.D. 900 and 1000 (Lynott et al. 1986; Smith and Cowan 2003:117–118).

Severing the tie between maize and the rise of social complexity coincides with an increase in the exploration by archaeologists of other subsistence strategies

and social variation across the spectrum of indigenous stratified societies in the Eastern Woodlands and elsewhere (e.g., Drennan and Uribe 1987; Pauketat 2007; Rogers and Smith 1995; Scarry 1996; Yerkes 2005). Revelations about maize parallels analytical shifts in the study of Mississippian societies over the last 15 years away from the search for the attributes of the ethnographically defined generic chiefdom toward an exploration of variation and the shifting landscape of economic, social, and political factors that structured trajectories of change.

Variability in the consumption of maize may not be directly linked to the development of social complexity; however, it is directly linked to a variety of other processes. Although maize was present in most areas for hundreds of years during the Woodland period as a minor dietary component, its rapid rise as a staple, often in a span of only 50 to 100 years, points to links with the role of exchange and interaction in the spread of technology, change in subsistence strategies, relative health status, demographics, as well as climate change events and their effects on agricultural potential and stability.

Some of these issues become extremely important in analysis of long-term social change in areas at the geographical margins, either environmentally or culturally. The study region composed of the Arkansas basin and Ozark Highlands, bordering the Great Plains (Figure 1), represents the westernmost extension of the Mississippian cultural system. By A.D. 900 people in the area lived in dispersed settlements and practiced horticulture within the Caddoan Tradition (Perttula 1996; Rogers 1991; Wyckoff 1980). Although cultural changes in the study area followed a somewhat different trajectory than adjoining Caddoan areas, there are close similarities to developments in southwestern Arkansas, northern Louisiana, and eastern Texas (Brown 1996:28; Schambach 1982:191; Story 1981:149). Within the eastern Oklahoma portion of this larger region a series of human and faunal samples spanning the time range of 300 B.C. to A.D. 1650 were analyzed for stable carbon and nitrogen isotopes. The primary objective of the study is to identify the role of maize in subsistence changes.

Environmental conditions in the study area were somewhat more marginal for agriculture compared to the floodplain adaptations characteristic of the Mississippian in many areas of the Southeast and Midwest. While not all prehistoric societies of the Mississippian period are characterized by intensive agriculture (e.g., Fritz and Kidder 1993; Widmer 1988), the general

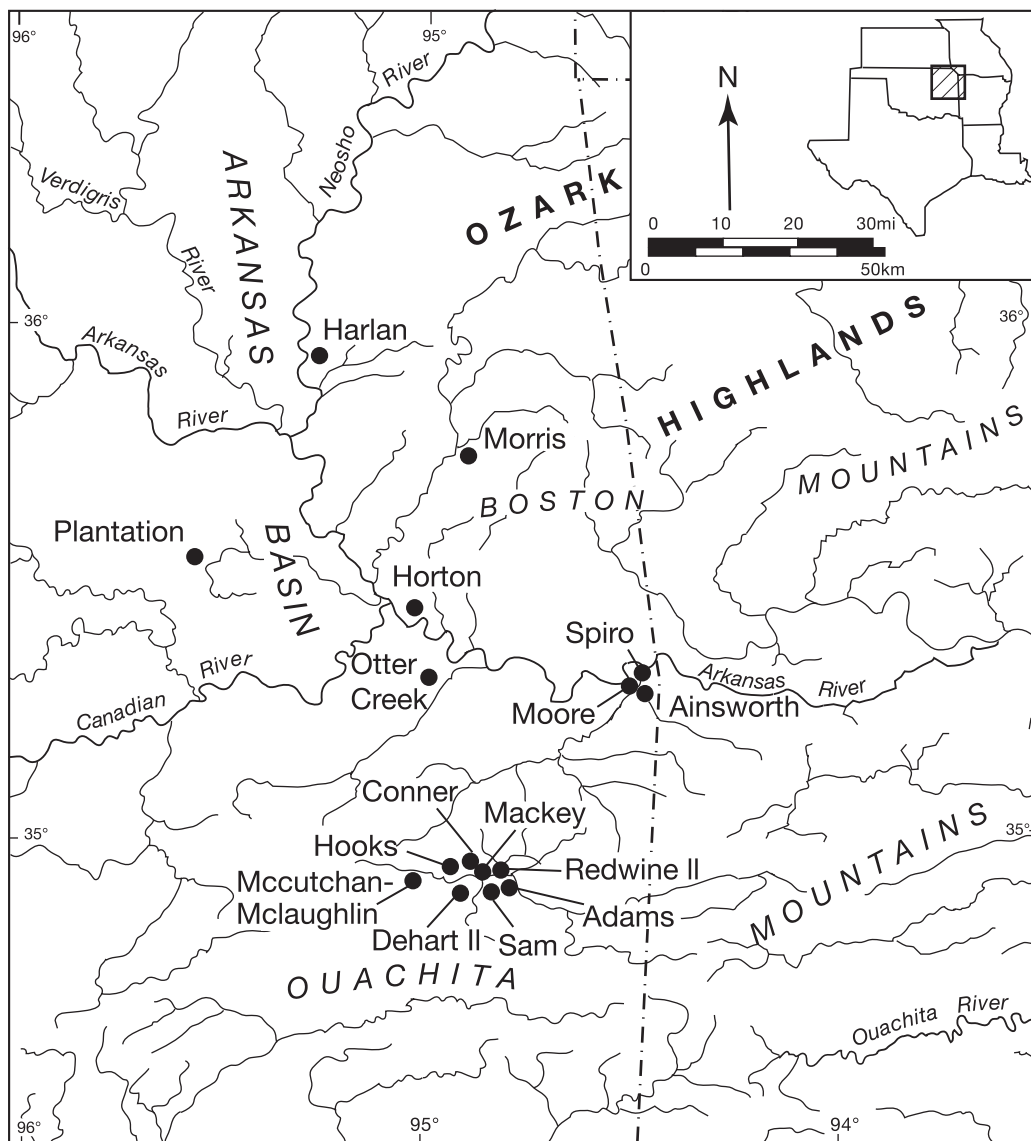


Figure 1. Map of eastern Oklahoma and western Arkansas showing the location of sites used in the study.

pattern is still associated with field agriculture exploitation of riverine environments, combined with the use of a variety of wild faunal and floral resources (Smith 1978:483–484). While the available data is far from conclusive, this pattern of intensive floodplain exploitation may not be appropriate for understanding the adaptive system in the study area (Fritz 1989, 1993). The very limited and scattered evidence now available from northern Texas and western Arkansas supports the idea that maize was a relatively minor component of subsistence, at least until after A.D. 1200 (Fritz 1989; Pertulla and Bruseth 1983; Raymer 1987, 1989; Rose and Hoffman 1989), and perhaps throughout the prehistoric Caddoan sequence in those areas (Schambach 1982:191). The maintenance of a mixed economy based on hunting and gathering with some use of cultivated plants (and a dispersed settlement pattern) through the

Woodland to Mississippian transition would have served to buffer against all but the most severe climatic changes. Such an adaptive pattern may characterize social systems at environmental margins.

Methods

A number of studies in the Eastern Woodlands have identified maize as the primary dietary plant that uses the C_4 biosynthetic pathway and therefore the principal human diet component accounting for changes in the resulting carbon isotope ratios (Ambrose 1987; Vogel and van der Merwe 1977). These studies have produced a variety of interesting results about the timing of maize introduction and its relative importance to the diet. While the timing of maize introduction is an important

issue, it should be acknowledged that it may be difficult to detect very low levels of maize consumption. Collagen is primarily protein and maize is very low in protein. When maize is a rare component of the diet, collagen isotope analysis may be biased toward foods higher in protein (Harrison and Katzenberg 2003). Nitrogen isotope ratios have also been used in dietary reconstruction because of the verification of a stepwise relationship in trophic level enrichment of nitrogen values in animal tissues (DeNiro and Epstein 1981; Hare et al. 1991). Recent research, however, confirms the complexities of using nitrogen isotopes due to variation resulting from environmental differences (Ambrose 1993; Heaton et al. 1986; Sealy et al. 1987). Nevertheless, nitrogen isotope ratios are used here to monitor changes in meat consumption and especially potential effects on the carbon isotope ratios from the consumption of grazers by humans. Since grazers, primarily bison in this region, consume grasses, which are C_4 plants like maize, there is the potential of confusing maize consumption with bison consumption.

Stable carbon and nitrogen isotope ratios were measured for a series of 105 human bone samples and 29 faunal bone samples. Human bone samples (approximately 5 g each) were taken from the petrous portion of the skull or, if not available due to the fragmentary nature of the skeleton, from the shaft of a long bone. A recent study by Joerkov (2007) provides additional insights into isotopic variations in different skeletal elements. Samples from faunal bone were collected on the basis of availability of skeletal portions.

Samples were selected from a series of well-dated sites in eastern Oklahoma (Figure 1, Table 1). Each individual burial was assessed for chronological placement using the recently revised chronology developed by James Brown (1996:153–167; cf. Rogers 1991:225; Sievert et al. 2011) based on the Spiro Mounds site grave sequence. This chronology is slightly modified here to reflect new radiocarbon dates from a series of smaller sites in the region. The sequence begins with the Fourche Maline phase (300 B.C. to A.D. 900). The people of this phase are Woodland period gatherer-hunters with a settlement pattern reflecting seasonal mobility (see Galm 1984). By the subsequent Evans phase (A.D. 900–1050) there is extensive evidence for mound construction and dispersed settlements of pole-constructed wattle-and-daub houses. These patterns are elaborated further in the Harlan (A.D. 1050–1250) and Norman (A.D. 1250–1350) phases and culminate in the Spiro phase (A.D. 1350–1450). The Fort Coffee phase (A.D. 1450–1650) encompasses the late prehistoric and protohistoric periods in the region. Mound construction and related ceremonial activities cease at the transition from the Spiro phase to the Fort Coffee phase (Rogers 2006).

The collection strategy for the human samples called for selection from sites in valley and upland settings,

from different types of sites (camp, farmstead, and mound sites), relatively equal numbers from each time period, comparable proportions of adult males and females from each site, and a cross section of adult age categories. Faunal samples were collected from many of the same sites and included grazers, browsers, and carnivores. These factors were judged to be the principal criteria that might account for variation in the resulting isotope values. While all of the above attributes were considered, the actual sample set was also affected by the reality of sampling heavily eroded bone with low collagen content.

Following application of a series of selection criteria the resulting carbon and nitrogen isotope data was reduced from the original sample size of 105 human and 29 faunal to 58 human and 24 faunal specimens. Individual analysis results were excluded from the study on the basis of a series of criteria. These criteria included (1) an evaluation of the carbon/nitrogen ratio (samples with values outside the range of 2.9–3.6 were excluded from the analysis) (see DeNiro 1985; cf. Ambrose 1993; van Klinken 1999); (2) the percentage by weight of carbon in the collagen extract; (3) repeatability of results through multiple extractions drawn from the same original sample; and (4) subjective ranking of the physical integrity of the collagen.

All samples were prepared and analyzed by Larry Tieszen at Augustana College, South Dakota. Collagen samples were prepared for analysis by acid demineralization, specifically EDTA (ethylenediaminetetraacetic acid) treatment, further purification by sodium hydroxide (NaOH) washing, gelatinization, and filtration. The mass 45-to-44 ratio of CO_2 from the sample material was compared to that of a standard gas of known isotopic composition, as in the following equation (DeNiro 1985; Tuross and Fogel 1994):

$$\delta^N E = [(R_{sample} - R_{standard}) \times 10^3] R_{standard}$$

Results and Discussion

Samples plotted in chronological sequence show a clear shift from low to high $\delta^{13}C$ values over time, indicating a steady increase in the use of C_4 plants, most likely maize and/or an increase in the consumption of bison (Figures 2 and 3). Research has shown that $\delta^{13}C$ fractionation occurs between the diet and the consumer bone collagen within the range of 1.5–5.0 parts per million (‰) (Hare et al. 1991; Tieszen et al. 1983). Considering first the faunal data, all of the mean $\delta^{13}C$ values range from -21.2 to -18.3 ‰, except for bison which has a mean of -10.3 ‰. Excluding bison for the moment, these faunal $\delta^{13}C$ values would produce mean $\delta^{13}C$ values in the human consumer roughly in the range of -26.2 ‰ to -19.8 ‰. Mean

Table 1. Isotope data for human samples presented in chronological order by phase.

Sample #	Period ^a	Site and Burial No.	Mass Mg.	C/N	$\delta^{13}\text{C}$ ‰	$\delta^{15}\text{N}$ ‰	%C	Collagen Yield
72	FC	LF31, L. Moore #12	1.26	3.33	-21.61	10.44	51.6	2.3
82	FC	LF31, L. Moore #36	1.44	3.28	-11.71	- ^b	13.2	0.1
81	FC	LF31, L. Moore #55	1.52	3.57	-11.29	10.35	43.2	0.7
83	FC	LF80, Ainsworth #9	1.20	3.31	-11.23	8.49	45.1	4.4
84	FC	LF80, Ainsworth #4	1.46	3.41	-11.61	10.22	10.2	2.2
85	FC	LF80, Ainsworth #93	1.27	3.33	-11.29	9.77	42.1	6.7
80	FC	LF31, L. Moore #47	1.77	3.56	-10.48	8.63	48.3	4.5
79	FC	LF31, L. Moore #44	1.57	3.58	-12.15	9.66	46.5	2.8
101	SP	LF40, Spiro #132	6.31	3.42	-14.39	10.49	43.8	0.7
66	SP	LF31, E. Moore #69	1.07	3.33	-10.08	10.25	45.0	3.4
59	SP	LF31, E. Moore #1	1.17	3.25	-12.02	11.10	52.2	5.4
104	SP	LF40, Spiro #94	2.00	3.22	-17.20	9.04	46.0	4.9
52	NOR & SP	SQ11, Horton #14	1.38	3.50	-12.68	10.53	42.6	6.6
48	NOR & SP	SQ11, Horton #5	1.16	3.26	-12.71	9.75	49.4	6.8
49	NOR & SP	SQ11, Horton #11	1.70	3.28	-14.22	10.02	44.2	1.2
50	NOR & SP	SQ11, Horton #8	2.44	3.19	-14.97	10.86	30.0	2.6
51	NOR & SP	SQ11, Horton #28	1.72	3.51	-12.25	10.43	42.2	8.1
54	NOR & SP	CK39, Morris #5	1.36	3.27	-11.85	10.65	45.1	1.5
55	NOR & SP	CK39, Morris #11	0.99	3.41	-15.04	11.03	43.2	12.1
56	NOR & SP	CK39, Morris #10	1.29	3.27	-16.02	11.63	41.8	7.5
57	NOR & SP	CK39, Morris #22	1.24	3.15	-19.81	11.21	44.3	10.4
58	NOR & SP	CK39, Morris #14	1.99	2.91	-20.09	11.41	52.3	7.5
99	NOR & SP	LF40, Spiro #178	2.28	3.44	-12.23	10.54	30.2	1.0
47	NOR & SP	SQ11, Horton #17	0.98	3.66	-13.15	11.25	45.6	5.3
98	NOR	LF40, Spiro #122	1.07	3.26	-20.12	8.37	43.5	11.9
93	HA	LF40, Spiro #10	1.88	3.29	-11.86	10.44	41.5	13.3
40	HA	Mi63, Plantation #6	1.02	3.59	-21.94	-	48.8	4.1
46	EHA	HS25, O. Creek #4	4.29	3.27	-18.86	10.09	49.2	7.3
45	EHA	HS25, O. Creek #3	1.27	3.66	-19.25	11.07	28.3	2.9
44	EHA	HS25, O. Creek #2	1.39	3.49	-19.43	-	38.7	3.0
43	EHA	HS25, O. Creek #1	1.44	3.86	-20.88	-	45.9	4.6
33	EHA	CK6, Harlan #68C	2.66	3.27	-17.27	10.48	35.0	2.2
23	EHA	CK6, Harlan #86B	1.08	3.29	-17.27	9.47	44.8	9.2
25	EHA	CK6, Harlan #116	1.19	3.26	-16.53	9.59	49.9	7.1
26	EHA	CK6, Harlan #38	1.21	3.32	-14.44	-	24.6	2.5
31	EHA	CK6, Harlan #86/1	1.52	3.22	-16.14	9.45	43.1	10.4
28	EHA	CK6, Harlan #34	1.18	3.42	-15.06	11.18	40.2	7.9
92	EV	LF40, Spiro #27	1.38	3.22	-16.38	9.52	42.8	15.6
24	EV	CK6, Harlan #77	1.13	3.32	-19.23	9.32	44.0	3.7
30	EV	CK6, Harlan #112	1.93	3.56	-17.99	-	10.2	3.7
10	LFM	LF28, Sam #15	1.43	3.47	-20.09	10.25	40.4	4.2
7	LFM	LF21, Conner #7	2.29	3.21	-19.66	10.82	45.2	3.4
6	LFM	LF19, Hooks #67B	1.96	3.68	-16.01	10.13	37.2	5.0
5	LFM	LF19, Hooks #55A	1.10	3.33	-18.31	10.15	49.6	5.8
4	LFM	LF19, Hooks #13A	1.43	3.55	-19.24	9.66	39.0	4.3
3	LFM	LF17, DeHart II #5B	2.81	3.26	-19.04	11.36	20.8	5.9
11	LFM	LF 29, Mackey #157A	1.08	3.53	-21.78	10.56	29.5	5.4
12	LFM	LF33, Adams #42	2.17	3.35	-19.36	9.47	39.2	3.4
13	LFM	LF33, Adams #48	1.70	3.35	-19.85	8.97	47.4	6.3
1	LFM	LF15, Redwine II #5F	1.61	3.44	-17.82	10.38	35.2	6.0
22	LFM	LF 43, Phillips #48	1.67	3.50	-19.07	8.94	32.6	3.7
16	LFM	LT11, McCutchan-McLaughlin #7	1.51	3.13	-19.71	9.73	42.9	9.6
17	LFM	LT11, McCutchan-McLaughlin #6J	1.87	3.34	-18.81	9.19	52.2	4.0
21	LFM	LF43, Phillips #16	1.86	3.46	-19.14	10.00	47.8	7.1
20	LFM	LT11, McCutchan-McLaughlin #6H	3.75	3.18	-19.13	11.02	41.4	5.9
15	EFM	LT11, McCutchan-McLaughlin #8A	2.77	3.33	-21.40	9.51	40.4	7.9
14	EFM	LT11, McCutchan-McLaughlin #19B	1.13	3.62	-18.76	9.52	44.4	3.2
18	EFM	LT11, McCutchan-McLaughlin #23A	1.26	3.47	-18.76	10.48	45.2	8.3

^aFC = Fort Coffee Phase (A.D. 1450–1650); SP = Spiro Phase (A.D. 1350–1450); NOR = Norman Phase (A.D. 1250–1350); EHA = early Harlan Phase (ca. 1050–1175); HA = Harlan Phase (1050–1250); EV = Evans Phase (A.D. 900–1050); EFM = early Fourche Maline Phase (ca. 300 B.C.–A.D. 400); LFM = late Fourche Maline Phase (ca. A.D. 400–900).

^b – = Not Recorded.

values within this range occur only in the gatherer-hunter Fourche Maline phase (300 B.C. to A.D. 900). Although a few individual samples from later phases do fall within this range.

In nitrogen isotope values there is a 3–4‰ stepwise enrichment from plants to herbivores to carnivores (Ambrose 1993:97). Therefore, if humans were consuming a large quantity of bison, for instance, here with a $\delta^{15}\text{N}$ mean value of 6.1‰, then the human $\delta^{15}\text{N}$ mean value should be on the order of 9–10‰. The

human-collagen stable nitrogen isotope values ($\delta^{15}\text{N}$) have means for each phase ranging from 9.4 to 10.5‰ (Table 2 and Figure 4). These values are consistent with bison consumption; however, there is no corresponding increase in $\delta^{13}\text{C}$ values as would be expected if there was a measurable amount of bison consumption. It has also been noted by Schwarcz (1991) that $\delta^{15}\text{N}$ values higher than 7.5‰ may indicate a freshwater aquatic aspect to the diet. This is certainly possible, considering that fish bones and bivalve shells are

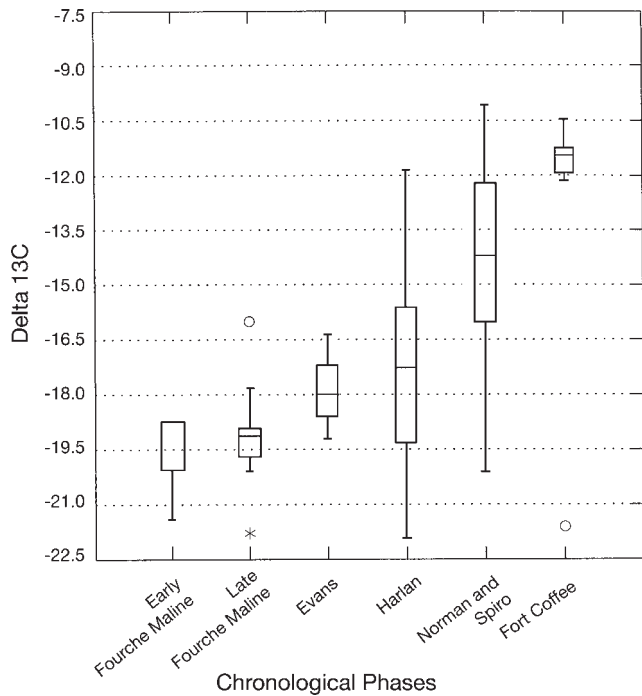


Figure 2. Box plot of mean $\delta^{13}\text{C}$ values for human samples in chronological order (with ranges and standard deviations).

common in many sites. The range of $\delta^{15}\text{N}$ values for the present sample is very similar to those for maize and premaize populations in the Illinois River Valley where there is no evidence for bison consumption (Hedman et al. 2002:240; Schober 1998). Given the level of precision (standard deviations of 0.1–0.8) in the use of means, these values are consistent with a diet including the fauna listed in Tables 3 and 4. Certainly this is only a partial listing of potential faunal foods and does not include plants that may also have contributed to the diet. It is also recognized that bone collagen may disproportionately reflect carbon from dietary protein, thus causing an underestimation of the nonprotein portion of the diet (Ambrose and Norr 1993; Tieszen and Fagre 1993).

Individual sample results are presented in chronological order in Figure 3. This ordering is based on a detailed contextual analysis of individual interments using radiocarbon dates, stratigraphy, horizontal placement, artifact associations, burial attribute styles, and consultation with archaeologists who have studied the individual sites. Burials that might have been intrusive or were otherwise difficult to place chronologically were eliminated from the analysis. Even with these efforts to develop a fine-grained chronology, some interments could only be grouped by phase, as discussed below. The analytical sequence begins with the Fourche Maline phase (300 B.C.–A.D. 900), which is partitioned into early Fourche Maline (EFM; 300 B.C.–A.D. 400) and late Fourche Maline (LFM; A.D. 400–900). The mean $\delta^{13}\text{C}$ value for the combined subphases

is -19.2‰ , although there are two individuals with values below -21‰ and two others with values above -18‰ . The small sample of three individuals for the Evans phase shows an increase in the mean to -17.9‰ . While it is likely that maize was available late in the Fourche Maline phase, evidence for consumption is modest. For both the Fourche Maline and Evans phases the results are consistent with a diet with little or no maize consumption. It is during the very late Fourche Maline phase and the Evans phase that the first evidence appears for the emergence of formalized social hierarchies.

By the following Harlan phase (Early Harlan phase, EHA, A.D. 1050–1175; Late Harlan phase, LHA, A.D. 1175–1250) the mean is -17.4‰ , but still with a considerable range of variation between individuals, with one sample at -21.9‰ and another at -11.9‰ . The former value indicates no maize consumption, while the latter shows maize to be a dietary staple for this individual. Considering that the Harlan phase encompasses 200 years, it is easy to imagine one individual from early in the phase and the other from much later in the phase. For the Harlan phase, most of the available samples fall within the EHA; however, the two individuals representing extremes for this phase can only be identified to somewhere within the overall phase. The individual $\delta^{13}\text{C}$ values for the Harlan phase suggest a time of differential adoption of maize. Paleobotanical evidence from Copple Mound (ca. A.D. 1150–1300) at the Spiro site confirms the presence of maize in conjunction with a wide variety of plant remains, including four of the leading plants in the starchy grain crop complex: *Chenopodium*, *Polygonum*, maygrass, and little barley (Fritz 1989:80–81). Although there is always room to improve the dating, most of the samples from the Harlan phase are likely to fall between A.D. 1100 and 1175 (Figure 3). If this is correct, then this period of 75 years shows the most variation within the entire sequence and represents a glimpse into the different ways in which maize production was intensified.

For the following Norman (A.D. 1250–1350) and Spiro (A.D. 1350–1450) phases, most of the samples can only be assigned to the combined phases due to the lack of more detailed chronologically diagnostic information. These 17 individuals produced a mean $\delta^{13}\text{C}$ value of -14.6‰ , consistent with a diet high in maize consumption but still considerably less than in some other regions of North America (e.g., Spielmann et al. 1990; Yerkes 2005:244). Additionally, there remains a considerable amount of variation in $\delta^{13}\text{C}$ values within these two phases, with a few individuals showing no evidence of maize consumption. One pattern that may be related to the role of maize and the process of its adoption is the fact that all of the increase in maize consumption is occurring among individuals buried in mounds at the Harlan and Spiro

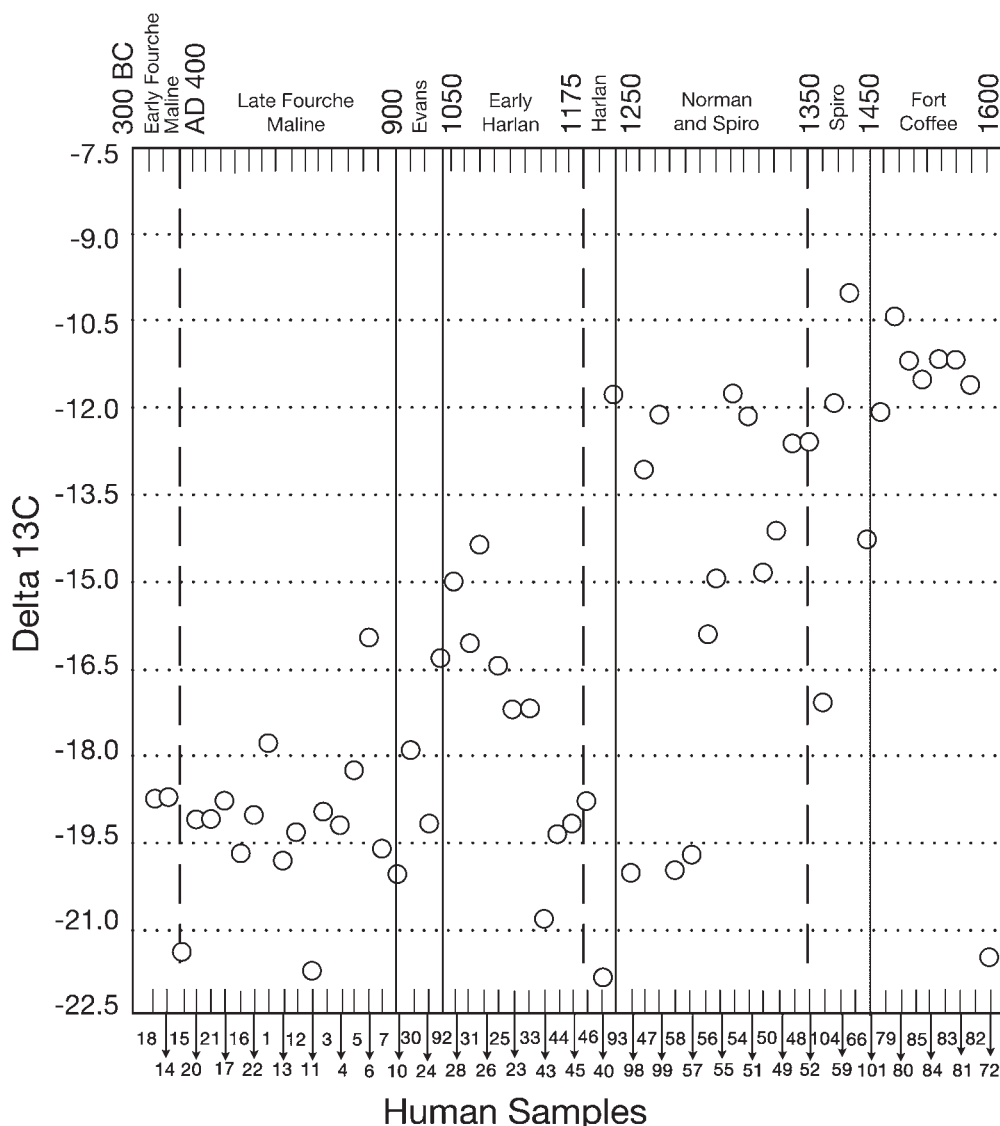


Figure 3. Individual $\delta^{13}\text{C}$ values for human samples in chronological order by phase and within phase where possible. Chronological phase names associated with each sample are presented at top of graph.

sites. Small nonmound sites (Otter Creek and Plantation) of the same age show a strong continuity in $\delta^{13}\text{C}$ values with the earlier Fourche Maline phase.

Among the 10 individuals from mounds in the Evans and Harlan phases, six are classed as high status and four as low. Status distinctions are based on the presence of prestige goods (often made of exotic materials), the degree of effort invested in the interment process, the range of variability in interment

processing, and the physical context of interment. Detailed analyses of status variability in the study area are presented in Brown (1971, 1996), Rogers (1983), and Rohrbaugh (1982). Although the sample size is very small, five of the six high-status individuals have higher $\delta^{13}\text{C}$ values than the four low-status individuals. This implies a positive correlation between high status and high maize consumption, at least early in the adoption of maize. A similar pattern was recognized by

Table 2. Basic statistics for isotopic compositions of human samples by phase.

Phase	$\delta^{13}\text{C}$ % N	Mean	Range	St. Dev.	$\delta^{15}\text{N}$ % N	Mean	Range	St. Dev.
Fort Coffee (A.D. 1450–1650)	8	-12.7	-21.6 to -10.5	3.6	7	9.6	8.5 to 10.4	0.8
Norman & Spiro (A.D. 1250–1450)	17	-14.6	-20.1 to -10.1	3.1	17	10.5	8.4 to 11.6	0.8
Harlan (A.D. 1100–1250)	12	-17.4	-21.9 to -11.9	2.9	8	10.2	9.4 to 11.2	0.7
Evans (A.D. 900–1100)	3	-17.9	-19.2 to -16.4	1.4	2	9.4	9.3 to 9.5	0.1
Fourche Maline (300 B.C.–A.D. 900)	18	-19.2	-21.8 to -16.0	1.2	18	10.0	8.9 to 11.4	0.7

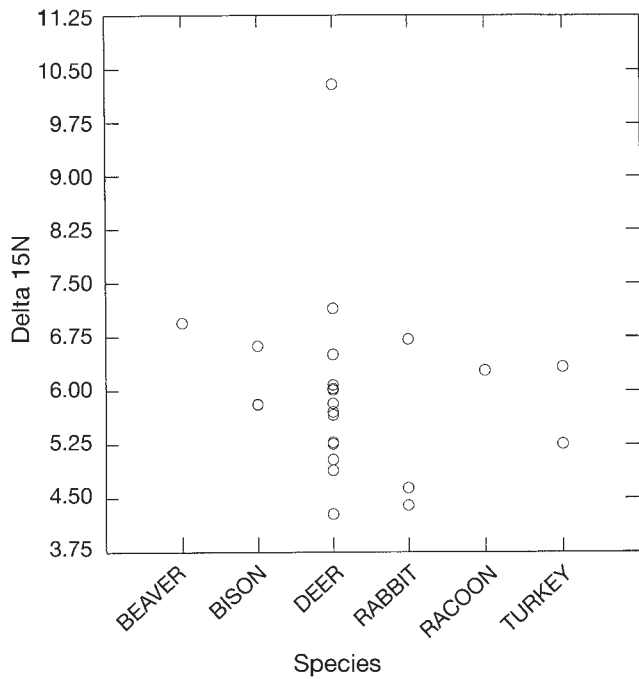


Figure 4. Individual $\delta^{15}\text{N}$ values for six faunal species.

Bender et al. (1981) at the Terminal Late Woodland Ledders site in the lower Illinois Valley and at Cahokia during the Fairmont phase. Correlations with status are not necessarily consistent, as Rose (2008) has shown at five sites in west-central Illinois. Rose, Marks, and Tieszen (1991:20) and Beavers (1982) have offered the argument that the ideological incorporation of maize was a prelude to its growth as a dietary staple. This explanation is

consistent with the data presented here. It also may point to the role of chiefs and other high-status individuals as “early adopters” in change processes.

During the Norman and Spiro phases (A.D. 1250–1450) the situation noted in the earlier Evans and Harlan phases appears to shift to one in which most of the maize consumption is by individuals buried at the village sites rather than by those buried in the mounds. That is, over time high-status individuals seem to have shifted back to a low maize consumption diet. There are, however, only four mound burial samples available, all from Spiro. Of the four, three are low status and one is high status. Three of these four individuals show lower maize consumption than the bulk of the nonmound samples.

In the final Fort Coffee phase (A.D. 1450–1650), all eight individuals sampled were buried at sites in the near vicinity of Spiro. Around the beginning of this phase, mound construction and related ceremonial activities cease throughout the region (Rogers 2006). Although it appears that populations remain in the area and continue to practice basic subsistence and domestic activities as in former times, there are actually only a few sites dated to this phase. Wyckoff (1980:339) suggests that the nature of the villages and the increase in the number of camp sites associated with this time frame is indicative of less sedentary, more seasonal occupations linked with increased hunting. This phase is also witness to the many changes associated with the arrival of Europeans in the Southeast. By the early 1700s, at the time of the first substantial European observations of the region, there are Wichita-related

Table 3. Isotope Data for Faunal Samples presented by species.

Sample #	Site	Species ^a and Element	Mass Mg.	C/N	$\delta^{13}\text{C}$ ‰	$\delta^{15}\text{N}$ ‰	%C	Collagen Yield
106	HS25, O. Creek, 0-W5	White Tailed Deer, metapodial	1.48	3.60	-19.27	7.14	39.8	0.9
107	HS25, O. Creek, 0-W5	White Tailed Deer, metapodial	4.50	3.19	-20.91	6.01	51.5	8.5
108	CK39, Morris, B10	White Tailed Deer, metapodial	1.25	3.39	-21.09	5.26	49.9	7.0
109	LF40, Spiro, B70	White Tailed Deer, metapodial	1.44	3.21	-21.31	5.82	48.6	14.4
112	LF31, L. Moore, B55	White Tailed Deer, acetabulum	1.28	3.23	-20.48	10.29	48.4	6.8
113	LF40, Spiro, UB-1	White Tailed Deer, radius	2.48	3.04	-21.35	5.28	43.3	12.5
114	LF40, Spiro, B34-3	White Tailed Deer, humerus	1.16	3.48	-9.88	6.03	45.9	6.1
116	LF11, Scott, OL1	White Tailed Deer, ulna	1.19	3.34	-19.48	6.08	43.3	9.6
117	CK39, Morris, #140	White Tailed Deer, ulna	2.67	3.13	-20.39	5.70	40.0	4.3
119	CK6, Harlan, #493	White Tailed Deer, humerus	1.42	3.32	-20.41	4.28	45.4	5.2
120	LF31, E. Moore, B41	White Tailed Deer, radius	2.25	3.22	-21.61	5.04	41.8	10.4
124	LF27, Wann, N2-W2	White Tailed Deer, humerus	1.99	3.34	-20.77	4.89	54.6	4.0
125	LF27, Wann, S2-W5	White Tailed Deer, astragalus	1.06	3.37	-20.25	5.66	48.9	1.3
126	LF27, Wann, N2-W2	White Tailed Deer, metatarsal	1.23	3.32	-20.77	6.50	36.8	7.7
130	LT37, Tucker, Grid B, S5-W70	Bison, astragalus	2.25	3.27	-11.21	6.62	41.8	- ^b
131	MS76, Wybark, Area B, F2	Bison, toe	4.48	3.28	-10.56	5.80	43.0	-
134	LF31, Moore, F9	Bison, scapula	2.21	3.08	-9.15	5.81	46.6	-
111	LF40, Spiro, B34-3	Rabbit	1.44	3.74	-13.46	4.40	43.5	3.4
123	LF27, Wann, S2-W5	Rabbit	1.61	3.59	-21.56	4.64	41.8	2.1
133	LF31, Moore, F8	Rabbit, mandible	1.67	3.13	-23.22	6.71	47.5	-
110	LF40, Spiro, B34-3	Turkey	1.90	3.35	-19.39	6.33	39.9	4.5
128	CK39, Morris, B25	Turkey, metatarsus	1.34	3.15	-17.28	5.26	46.8	-
132	LF11, Scott, S4-R1	Raccoon, mandible	1.79	3.18	-19.80	6.28	45.2	-
127	HS25, O. Creek, S1-W7	Beaver, tibia	1.35	3.23	-21.23	6.94	47.1	-

^aSee Table 4 for specific species names.

^b- = Not recorded.

Table 4. Basic Statistics for Isotopic Compositions of Faunal Samples.

Species	$\delta^{13}\text{C}$ ‰ N	Mean	Range	St. Dev.	$\delta^{15}\text{N}$ ‰ N	Mean	Range	St. Dev.
White-Tailed deer (<i>Odocoileus virginianus</i>)	14	-19.8	-21.6 to -9.9	2.9	14	6.0	4.3 to 0.3	1.4
Bison (<i>Bison bison</i>)	3	-10.3	-11.2 to -9.1	1.0	3	6.1	6.2 to 6.8	0.5
Rabbit (<i>Sylvilagus</i> cf. <i>aquaticus</i> , <i>Sylvilagus floridanus</i> , <i>Lepus californicus</i>)	3	-19.4	-23.2 to -3.5	5.2	3	5.2	4.4 to 6.7	1.3
Turkey (<i>Meleagris gallapovo</i>)	2	-18.3	-19.4 to -7.3	1.5	2	5.8	5.3 to 6.3	0.8
Raccoon (<i>Procyon lotor</i>)	1	-	-19.8	-	1	-	6.3	-
Beaver (<i>Castor Canadensis</i>)	1	-	-21.2	-	1	-	6.9	-

and possibly other groups in the area (Wedel 1981). The connection between these groups and the earlier Mississippian phases remains tenuous.

The mean $\delta^{13}\text{C}$ value of -12.7‰ for the Fort Coffee phase implies extensive consumption of maize (Figure 2), although still less than at many late Mississippian sites in the Midwest and Southeast and at Puebloan sites in the Southwest (Spielmann et al. 1990; Yerkes 2005). Although maize is certainly present in Fort Coffee phase contexts, there is also more bison bone in comparison with earlier phases (Rohrbaugh 1982:563). Since bison are grazers consuming large quantities of C^4 plants, humans eating bison meat will have $\delta^{13}\text{C}$ values similar to individuals with a largely maize diet. Review of $\delta^{15}\text{N}$ values through the entire chronological sequence, however, shows a very consistent pattern of meat consumption (Figure 5). In other words, there is no significant evidence for increased meat consumption in the Fort Coffee phase. If there was an increase in bison consumption, it was being offset by a decrease in other types of meat. The high $\delta^{13}\text{C}$ values for the Fort Coffee phase are therefore more likely to be the result of increasing maize consumption, although the present evidence remains far from conclusive.

Conclusions

Carbon and nitrogen isotopes provide a method for analyzing the timing and relative significance of maize in the diet of people living in what is now eastern Oklahoma between 300 B.C. and A. D. 1650. As part of the analysis nitrogen isotopes provided a check on the nature of meat consumption and served as a proxy indicator for possible consumption of grazing animals and their impact on what would otherwise be assumed to be a high maize diet. The carbon and nitrogen isotope data used in this study provides a strong representation of the sequence of change in maize consumption over time in eastern Oklahoma.

The analytical sequence begins with the Fourche Maline phase (300 B.C.–A.D. 900). This phase represents primarily a gatherer-hunter subsistence pattern, with minimal social ranking, although at the very end of the phase there is evidence for increasingly formalized patterns of social differentiation associated

with more permanent residences and the construction of mounds. This transition becomes increasingly formalized in the Evans phase (A.D. 900–1050), with clear evidence for social hierarchies based on mortuary analyses at the Spiro site (Brown 1996).

There may be some maize in the diet by the Evans phase (A.D. 900–1050), based on the upward trend over time, although it is during the following Harlan phase (A.D. 1050–1250) that significant evidence is present. Throughout the sequence there is evidence for considerable individual variation in maize consumption. The Harlan phase is especially interesting in this regard since it was likely during this time, specifically between A.D. 1100 and 1175, that considerable but highly variable adoption of maize was underway. By the following Norman and Spiro phases (A.D. 1250–1450) there is more consistent evidence for significant maize consumption, continuing on through the Fort Coffee phase (A.D. 1450–1650). The question of increasing bison consumption based on faunal evidence remains open, although consistent patterns in $\delta^{15}\text{N}$ values coupled with a rising trend in $\delta^{13}\text{C}$ values suggests that increasing maize consumption rather than increasing bison consumption is involved.

It is significant to note that throughout the sequence, the level of maize consumption never approaches that noted in the Midwest, the Southeast, or the Puebloan sites of the same period. For eastern Oklahoma, evidence derived from faunal, paleobotanical, and bioarchaeological sources point to the presence of a mixed subsistence pattern that did not involve a heavy reliance on maize. Biological stress indicators and high caries rates, often associated with high maize (starch) consumption, are substantially less for eastern Oklahoma than those noted in other parts of the Caddoan region (e.g., northern Texas and southeast Arkansas) or in Mississippian sites in the Midwest, lower Mississippi Valley, and other areas of the Southeast (Buikstra et al. 1988; Harmon and Rose 1989; Mayes 1996:88; Mires 1982:46; Rose and Hoffman 1989). Climate variability in eastern Oklahoma may be a major factor in understanding the relative level of maize consumptions, although considerably more research is needed to clarify potential links.

The results indicate that maize consumption was increasing over time but arguably was significant only after about A.D. 1175. For the study area, the rise in

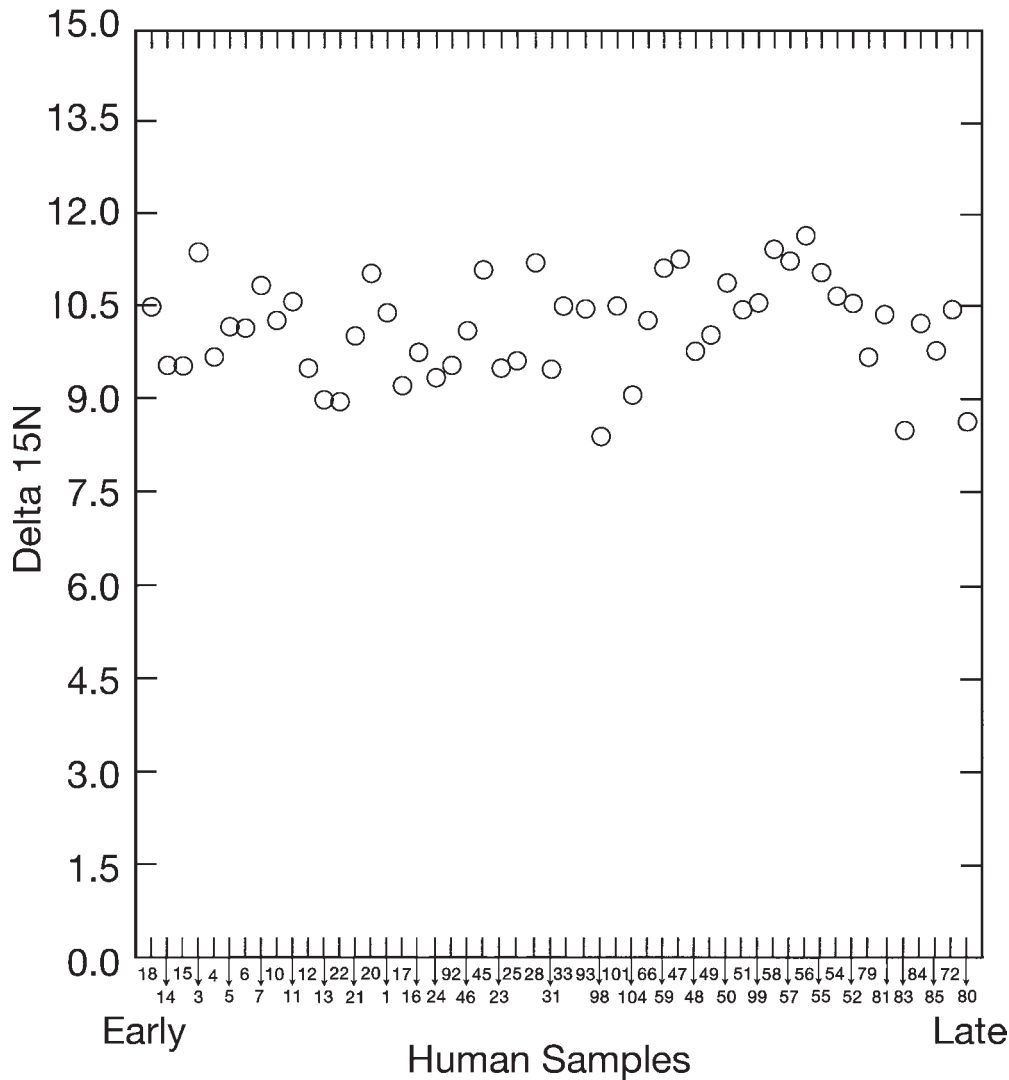


Figure 5. Individual $\delta^{15}\text{N}$ values for human samples ordered chronologically from early to late.

maize consumption is consistent with the timing noted from other regions of the Midwest and Southeast. This evidence supports the paleobotanical and skeletal indicators that point to a diet that was less specialized than that of eastern Mississippian maize farmers. In eastern Oklahoma, complex chiefdoms were based on a subsistence pattern that combined maize with a variety of starchy seed cultigens, nut gathering, and the hunting and fishing of a wide variety of animals.

Notes

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