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DIET AND HEALTH IN THE NASHVILLE BASIN: HUMAN ADAPTATION AND MAIZE AGRICULTURE IN MIDDLE TENNESSEE

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Since 1977, stable carbon isotope analysis of human remains has virtually revolutionized our view of agricultural intensification in the prehistoric Midcontinent. The argument linking maize cultivation and Middle Woodland (Hopewell) based on palaeobotanical evidence and material culture, (e.g., Griffin [1967], Streuver and Vickery [1973]), has been weakened considerably by the discovery that significant ^{13}C enrichment is found only in subsequent Late Woodland and Mississippian palaeopopulations (Bender et al. 1981: van der Merwe 1978, 1982; van der Merwe and Vogel 1978; Vogel and van der Merwe 1977). Regional studies of diachronic sequences have also provided new insight concerning the process of agricultural intensification and the degree to which Mississippian and maize cultivation are contemporaneous developments. In the Central Mississippi Valley, for instance, $\delta^{13}C$ sequences document the relatively late addition of maize to Mississippian subsistence strategies already dependent upon the cultivation of plants native to eastern North America (Boutton et al. 1984; Lynott et al. 1986).

Closely associated with the issue of prehistoric dietary patterns is the question of population health. Poor nutrition due to overreliance on maize has been implicated as one of several related factors explaining the apparent ill health of certain Mississippian communities (Cassidy 1972, 1980, 1984; Cook 1984; Goodman et al. 1984; Lallo 1979; Lallo and Blank 1977; Milner 1982, 1987; Perzigian et al. 1984; Sciulli 1977, 1978). Some of the most positive $\delta^{13}C$ values reported for North American human remains occur among Ft. Ancient Mississippian peoples from the Midcontinent (Broida 1983, 1984; Conard 1985; Farrow 1986; Wagner 1987), where there is also conspicuous evidence for disadvantaged health status (Cassidy 1984; Lallo 1979; Lallo and Blank 1977; Perzigian et al. 1984; Robbins 1977; Sciulli 1977, 1978).

To understand the interaction of diet and health in these late prehistoric contexts, where evidence of marked dependence on maize and inferior community health contrasts with less extreme conditions elsewhere (Cook 1984; Milner 1982; Powell 1985), diachronic sequences of remains must be studied. Previous analyses of pathology in Ft. Ancient and antecedent populations have tended to focus only on the near beginning (Late Archaic) and the end of the prehistoric record. For example, in her study of the Ft. Ancient Hardin Village skeletal series, Cassidy (1972, 1980, 1984) reports cortical thinning, anaemia in juveniles and young adult women, frequent dental hypoplasias, and elevated infectious disease rates when compared to Late Archaic Indian Knoll remains. Reports of temporally intermediate Woodland samples (Cassidy 1984; Perzigian et al. 1984; Sciulli 1977, 1978) commonly emphasize the small size and biased nature of these collections, citing limitations due to incomplete archaeological recovery and the lack of representative samples from spatially segregated Woodland cemeteries. In addition, no $\delta^{13}C$ determinations have been reported for midcontinental Woodland groups.

Studies of well-documented sequences, including both health status and $\delta^{13}C$ values, are required if we are to (1) evaluate the degree to which the model described for the Mississippi Valley and Southern Ontario is appropriate for the Central Midcontinent, and (2) establish the chronologic associations of health changes and the shift to apparent extreme dietary dependence upon maize. The present study represents a first step in this process by reporting a diachronic sequence of $\delta^{13}C$ values from an adjacent region where Mississippian populations show evidence of focal dependence upon maize and disadvantaged health at least as extreme as the Ft. Ancient example. These data are presented as an initial stage in investigating the interrelationship between health and diet in Middle Tennessee, concentrating on populations from the Cumberland River drainage. In order to provide a context for discussing the Middle Tennessee $\delta^{13}C$ values, we include a review of other diachronic studies from eastern North America.

REGIONAL CARBON ISOTOPE STUDIES

In their landmark 1977 publication, Vogel and van der Merwe offered a diachronic perspective on the development of maize agriculture in New York State. Using Archaic (2500–2000 B.C.), Early Woodland (400–100 B.C.), Late Woodland (A.D. 1000–1300), and Historic period (A.D. 1450 ± 100) remains, they identified initial evidence for maize dependence in two Late Woodland skeletons that show somewhat contrastive $\delta^{13}C$ values of -14.0‰ and -16.6‰. Subsequent chronologic studies by van der Merwe (1978, 1982, van der Merwe and Vogel 1978), using samples from Ohio and Illinois, emphasized the rapid development of maize dependence, based on "steeply" rising $\delta^{13}C$ values after A.D. 500. The proportion of C_4 carbon in the diet by A.D. 1200 (Turpin, a Ft. Ancient site from Ohio) was estimated at ca. 70%, based on a $\delta^{13}C$ value of -11.8‰.

Boutton et al. (1984) and Lynott et al. (1986), using a diachronic sample of 20 individuals from 14 Late Archaic to Historic period archaeological sites in northeastern Arkansas and southeastern Missouri, also argue for a rather rapid and late (after A.D. 1000) development of agricultural intensification in this region, with 35 to 72% of the diet consisting of corn ($\delta^{13}C$ values range from -10.4‰ to -15.8‰). Samples dating to A.D. 900 and 1000 show no evidence of maize consumption. Boutton et al. (1984) and Lynott et al. (1986) use their results to argue that maize agriculture in their study area post-dated the appearance of Mississippian culture by nearly half a millenium. Working in the same region, Rose et al. (1987) also emphasize the absence of stable carbon isotope evidence for maize consumption in Central Mississippi Valley sites prior to Middle Mississippian, with the single exception of an adolescent from Late Baytown period Little Cypress Bayou site, which they interpret as evidence for ceremonial use of maize.

Boutton et al. (1984) and Lynott et al. (1986) tend, however, to understate the differences between their sequence and those from adjacent regions. They (Boutton et al. 1984:199; a virtually identical statement appears in Lynott et al. 1986:61) argue that "nearby archaeological sites in Illinois show a similar pattern of $\delta^{13}C$ values through time, with significant maize consumption beginning between 1000 and 1200 A.D." This statement is somewhat misleading since the source they cite (van der Merwe and Vogel 1978) reports that by A.D. 1000 $\delta^{13}C$ values for the Illinois Valley average -18.1 ± 2.2‰, which the authors associate with an average of 24% of the dietary carbon derived from C_4 plants. The earliest archaeobotanic evidence for maize in this area occurs in a seventh century A.D. site (Asch and Asch 1985a).

Lynott et al. (1986:61) also report that the

> results of this study conflict only slightly with data reported by Bender et al. (1981)

> from sites in Wisconsin, Iowa, and Illinois. In their sample, substantial maize ingestion is first recorded in individuals attributed to the Fairmont phase, A.D. 900 to A.D. 1050, at Cahokia.

While it is true that the four burials from Mound 72, dating to the Fairmont phase (A.D. 900–1050), do show evidence of maize consumption ($\delta^{13}C$ mean value of -17.6‰), Bender et al. also report (1981:350) two values for the Fingerhut cemetery that average -15.6‰, suggesting that in excess of 30% of dietary carbon originated with maize. If the Fingerhut site dates between A.D. 800 and A.D. 950, as Bender et al. (1981) suggest, then initial maize intensification in the Cahokia area may rather substantially predate its appearance in southeast Missouri and northeastern Arkansas. Johannessen's (1984) archaeobotanic evidence also supports this model.

These criticisms do not, however, contradict Boutton et al. (1984) and Lynott et al.'s (1986) basic thesis—that Mississippianization in their study area substantially predated the intensification of maize agriculture. It should be emphasized, however, that the same may not necessarily be true for Cahokia or for other portions of the Mississippi valley. $\delta^{13}C$ values of -18.1‰ and -17.1‰ have been reported for two Late Woodland remains from Jo Davies County, Illinois, indicating the presence of maize by A.D. 950 (Penman 1985). Late Woodland and Emergen Mississippian sites from west-central Illinois also provide clear evidence for maize consumption by A.D. 1000 (Buikstra et al. 1987; van der Merwe 1978, 1982).

Schwarcz et al. (1985) report a diachronic sequence for southern Ontario, dating from 2300 B.C. to A.D. 1650. Populations that predate A.D. 700 show a range of $\delta^{13}C$ site average values of -19.0‰ to -21.9‰ and presumably were not consuming significant amounts of maize. This contrasts with sites postdating A.D. 1150, where averages range from -11.3‰ to -15.8‰ and are interpreted as representing C_4 carbon percentages of between 30 and 57%. (Schwarcz et al. use an algorithm for estimating percentage of dietary carbon from C_4 plants based on a value of -9‰ for C_4 plants, which produces a more conservative estimate than the strategy followed by other researchers cited here.) Unfortunately, there are no data points for Ontario sites within the A.D. 700 to 1150 time range, which would be the period of initial intensification.

A comparison of the Ontario pattern with other data sets from the Upper Mississippi Valley and New York State (Bender et al. 1981; van der Merwe and Vogel 1978; Vogel and van der Merwe 1977) led Schwarcz et al. (1985) to conclude that in all three regions there was a gradual shift in percentage carbon derived from C_4 plants as maize gradually supplanted "other cultigens and native food sources" (Schwartz et al. 1985:200). Their reworking of the percentage carbon values for this area suggests that the "true porportion of maize as a primary component of the diet was probably never greater than 50% of the total carbon intake" (1985:200). This generalization is also applied to the west-central Illinois series reported by Bender et al. (1981) and by van der Merwe (1978, 1982; van der Merwe and Vogel 1978).

In contrast to the chronologically changing pattern of plant utilization just described for Ontario, Katzenberg and Schwarcz (1986) argue that animal protein consumption in this region remained relatively stable through time. Their interpretation, based on trace element and nitrogen isotope analyses, emphasizes that the primary dietary change associated with maize agriculture was the substitution of maize for other plant resources. A similar argument, based on trace element analysis, has been made by Buikstra et al. (1987) for west-central Illinois.

Broida (1983, 1984) and Conard (1985) report that late prehistoric peoples from Ohio and Kentucky have $\delta^{13}C$ values more positive than those of Mississippian peoples to the west: -11.64‰ for Hardin Village site; -11.3‰ for the Incinerator site; and -9.65‰ for the Sloan site. This is consistent with the -11.8‰ previously reported for the Ft. Ancient Turpin site (van der Merwe and Vogel 1978) and the range of -12.99‰ to -9.06‰ reported for Late Monongahela sites from the West Virginia panhandle (Farrow 1986). A key problem in interpreting these more positive $\delta^{13}C$ values is the absence of research on diachronic sequences of skeletal remains from antecedent Woodland populations. Although such exist for palaeopopulations to the west and to the north, there are no such regional sequences in areas where late prehistoric populations regularly present $\delta^{13}C$ values less than -12.0‰.

STUDY SAMPLE

As illustrated in Figure 1, the six sites reported here are located in a physiographic region known as the Nashville Basin (Fenneman

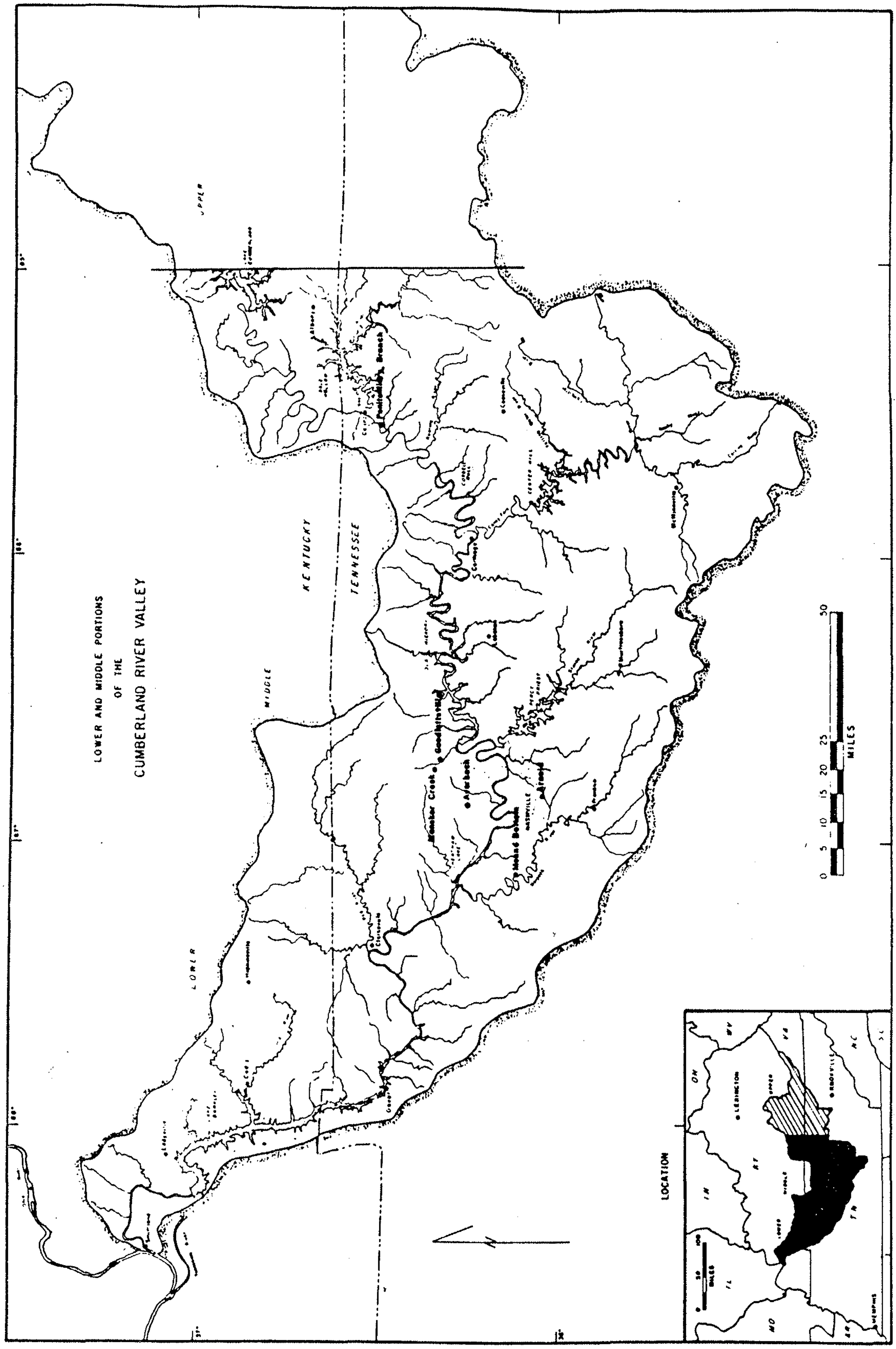

Figure 1: Map of Nashville Basin Showing Location of Sites.

Table 1: Cumberland Drainage $\delta^{13}C$ Measurements.

Site	Period	Burial	Sex	$\delta^{13}C$(‰)
Penitentiary Branch	Term Archaic	1	M	-20.6
Penitentiary Branch	Term Archaic	5	M	-21.3
Penitentiary Branch	Term Archaic	6	F	-21.6
Penitentiary Branch	Term Archaic	10	M	-21.3
Mansker Creek	MW/LW	1	F	-20.8
Mansker Creek	MW/LW	5	F	-20.5
Mansker Creek	MW/LW	7	F	-20.9
Mansker Creek	MW/LW	10	F	-20.4
Mansker Creek	MW/LW	13	F	-20.9
Mansker Creek	MW/LW	16	M	-20.9
Mansker Creek	MW/LW	4	M	-20.9
Mansker Creek	MW/LW	9	M	-20.0
Mansker Creek	MW/LW	20	M	-20.8
Arnold	Term. Miss.	A008	M	-7.2
Arnold	Term. Miss.	A015	M	-7.8
Arnold	Term. Miss.	A038	M	-6.7
Arnold	Term. Miss.	A049	M	-7.6
Arnold	Term. Miss.	A075	M	-7.1
Arnold	Term. Miss.	A076	M	-7.7
Arnold	Term. Miss.	A078	M	-7.0
Arnold	Term. Miss.	A087	M	-8.8
Arnold	Term. Miss.	A091	M	-7.8
Arnold	Term. Miss.	A117	M	-8.5
Arnold	Term. Miss.	A009	F	-7.9
Arnold	Term. Miss.	A017A	F	-7.9
Arnold	Term. Miss.	A038A	F	-7.3
Arnold	Term. Miss.	A064	F	-9.0
Arnold	Term. Miss.	A065	F	-7.4
Arnold	Term. Miss.	A107	F	-9.5
Arnold	Term. Miss.	A110	F	-7.4
Arnold	Term. Miss.	A112	F	-7.9
Arnold	Term. Miss.	A143	F	-8.1
Averbuch	Term. Miss.	15	M	-6.8
Averbuch	Term. Miss.	16	F	-8.7
Averbuch	Term. Miss.	28	M	-7.4
Averbuch	Term. Miss.	33	M	-9.1

1938). Samples were selected from the remains of 61 adults by Emanuel Breitburg and William Autry. Site names, temporal assignment, burial numbers, sex, and $\delta^{13}C$ values (generated in van der Merwe's laboratory according to standard procedures) appear in Table 1 and 2 and are summarized in Table 3.

Given that there exist few published accounts for these sites, brief contextual descriptions are presented here.

The earliest site in the sequence is the Penitentiary Branch site (40JK25), which dates to the second millenium B.C. (Cridlebaugh 1983). This Terminal Archaic period habitation site was occupied during the summer, and is interpreted as a base encampment where large mammal hunting, mussel and fish collecting, and wild and domesticated plant (pigweed, maygrass, goosefoot, knotweed, and squash) harvesting dominated subsistence activities. Seventeen burials were recovered from pits within the midden. The $\delta^{13}C$ values for this site conform to expectations for a C_3 plant diet, averaging -21.2‰.

Mansker Creek (40DV53) is a small site located in the outer margins of the Nashville Basin and dating to approximately A.D. 600—the time of the Middle to Late Woodland transition (Autry 1978; Autry et al. 1982; Autry and Breitberg, in preparation). Twenty burials were recovered from shallow features. No maize was identified among the floral remains. Archaeobotanic and faunal analysis suggest that the primary subsistence activities conducted at the site emphasized large mammal procurement, along with wild plant gathering and harvesting. An average $\delta^{13}C$ value of -20.7‰ confirms the absence of maize in the diet.

A marked positive shift in the $\delta^{13}C$ average is noted at the early Mississippian Mound Bottom site. This mound centre is located in the western Highland Rim section of the Interior Lower Plateau and contains ca. 14 mounds, a plaza, and residential buildings (Autry 1983; O'Brien 1977). The site may have been occupied for over four centuries, as indicated by radiocarbon dates ranging from A.D. 860 to ca. 1300. One hundred sixty-four burials were excavated from the site by participants in WPA projects. Autry (1983) infers that the population burying at Mound Bottom represented a ranked society, based on evidence for a differentiated burial program. Maize was recovered from the site, as well as a diversity of wild plants and faunal materials. The Mound Bottom $\delta^{13}C$ values for nine individuals average -9.3‰.

Goodlettsville (40SU20), Arnold (40WM5), and Averbuch (40DV60) are all later Mississippian sites located within the Nashville Basin (Autry 1983; Autry et al. 1982; Eisenberg 1986; Ferguson 1972; Klippel and Bass 1984). Post-A.D. 1200 dates are reported for all three. Autry (1983) interprets these centres as part of a Late Mississippian system in which fortified villages replace the mound centres characteristic of early Mississippian. The large size of these cemeteries—some containing nearly 1000 remains—is due to a burial "catchment" greater in size than individual farmsteads. Such sites are located away from the main river valley. Nevertheless, the phosphate content of the limestone underlying these soils renders them suitable for maize cultivation (Crites 1984). The $\delta^{13}C$ values support a model of marked dietary dependence upon maize with the average for both the Goodlettsville and Arnold sites being -7.8‰. Averbuch is only slightly less positive at -8.0‰.

DISCUSSION

A comparison of the Tennessee $\delta^{13}C$ sequence with a previously reported series from the central Mississippi valley (Buikstra et al. 1987) suggests that agricultural intensification was more rapid and extreme in the Nashville Basin (Figure 2). The Mississippian tradition and maize agriculture appear together, in contrast to Lynott et al.'s (1986) model for the Mississippi valley and that described by Schwarcz et al. (1985) for southern Ontario. This pattern would, however, be compatible with the model that Wagner (1987) proposes for the northern Ft. Ancient sites. Basing her interpretation on palaeobotanical evidence, she argues for a "single general introduction of seed" of Northern Flint corn into the Ohio Valley region. If the Nashville Basin diachronic pattern pertains to Ft. Ancient, we would also emphasize the speed and intensity of adaptation to cultivation of the 8 to 10-rowed cultigen.

The values reported here for Nashville Basin Mississippian samples are among the most positive reported for any human skeletal remains north of Mexico. Although a dietary argument seems compelling, other possible explanations should be considered. These include the possibility of diagenesis and laboratory error, as well as issues related to plant genetics and physiology.

In assessing the probability of contamination or laboratory error, it should be emphasized that

Table 2: More Cumberland Drainage δ^{13}C Measurements.

Site	Period	Burial	Sex	$\delta^{13}C(^o/_{oo})$
Mound Bottom	Early Miss.	118CH26	F	-8.8
Mound Bottom	Early Miss.	118CH11	F	-7.8
Mound Bottom	Early Miss.	136CH 2	F	-10.7
Mound Bottom	Early Miss.	136CH14	F	-10.6
Mound Bottom	Early Miss.	137CH 5	M	-8.4
Mound Bottom	Early Miss.	136CH10	M	-13.1
Mound Bottom	Early Miss.	118CH 9	M	-7.4
Mound Bottom	Early Miss.	136CH15	M	-8.4
Mound Bottom	Early Miss.	136CH 1	M	-8.3
Goodlettsville	Late Miss.	7	M	-6.7
Goodlettsville	Late Miss.	26	M	-6.8
Goodlettsville	Late Miss.	27	M	-7.5
Goodlettsville	Late Miss.	33	M	-7.9
Goodlettsville	Late Miss.	46	M	-7.3
Goodlettsville	Late Miss.	78	M	-7.2
Goodlettsville	Late Miss.	81	M	-7.5
Goodlettsville	Late Miss.	96	M	-7.6
Goodlettsville	Late Miss.	04	F	-8.5
Goodlettsville	Late Miss.	14	F	-7.0
Goodlettsville	Late Miss.	18	F	-8.4
Goodlettsville	Late Miss.	31	F	-9.1
Goodlettsville	Late Miss.	64	F	-7.8
Goodlettsville	Late Miss.	68	F	-9.1
Goodlettsville	Late Miss.	83	F	-9.5
Goodlettsville	Late Miss.	90	F	-7.3

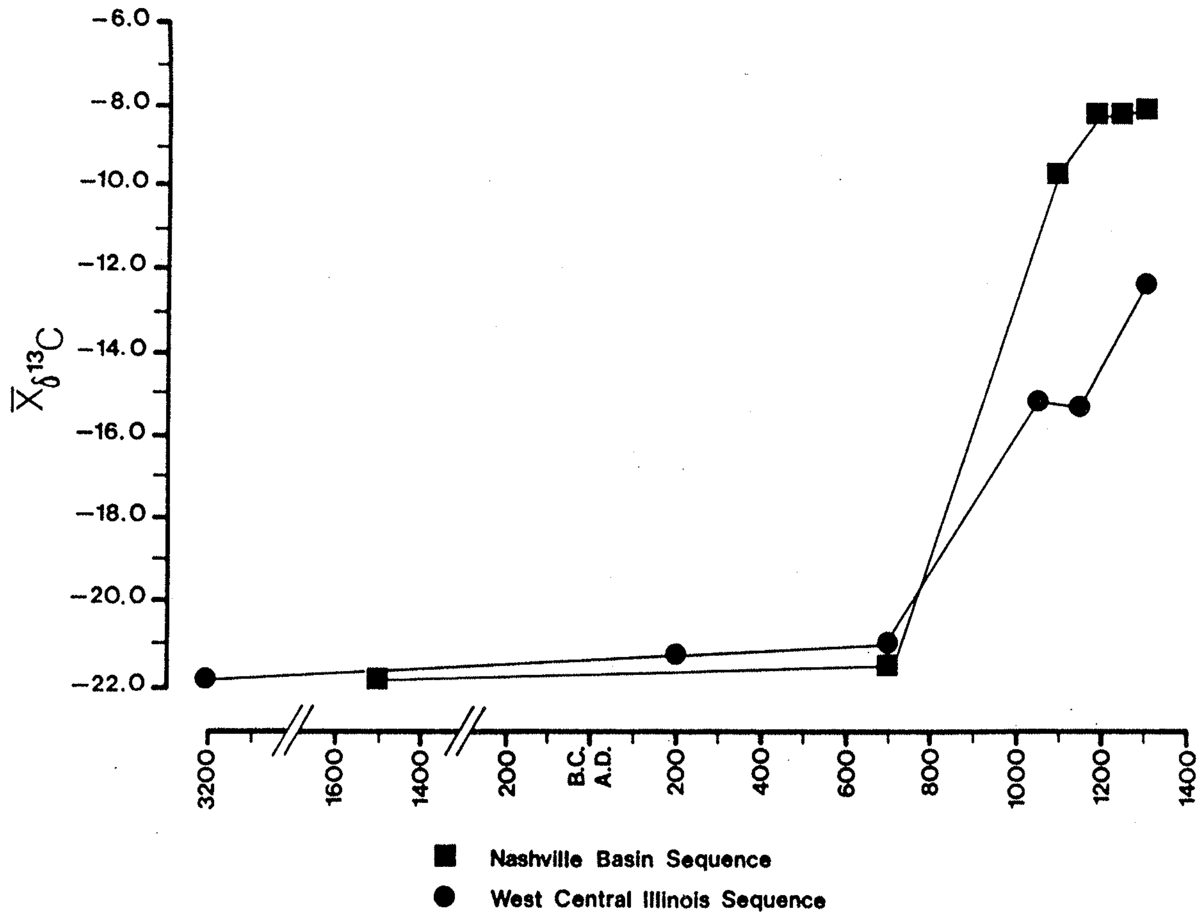

Figure 2: Plot of mean $\delta^{13}C$ values for sites from the Nashville Basin and from West-Central Illinois.

Table 3: Mean $\delta^{13}C$ for Illinois and Tennessee Sites.

Site	Period	Mean $\delta^{13}C$(‰)	Std. Dev.	N
Koster	Archaic	-21.7	.38	5
Gibson	MW	-20.9	.71	5
Koster	Early LW	-20.9	1.48	5
Ledders	Late LW	-17.4	2.50	17
Helton 47	Early Emerg. Miss.	-18.3	3.20	10
Helton 47	Middle Emerg. Miss.	-18.8	3.42	5
Helton 47	Late Emerg. Miss.	-15.3	3.80	7
Schild Knoll B	Mississippian	-12.3	1.90	19
Penitentiary Branch	Term. Archaic	-21.2	.42	4
Mansker Creek	MW/LW	-20.7	.32	9
Mound Bottom	Early Miss.	-9.3	1.83	9
Goodlettsville	Late Miss.	-7.8	.86	16
Arnold	Term. Miss.	-7.8	.72	19
Averbuch	Term. Miss.	-8.0	1.08	4

all samples were analyzed in the van der Merwe laboratory, using comparable methods. Values other than those for the four Nashville Basin Mississippian samples conform to expectations. Further, the $\delta^{13}C$ figures obtained by van der Merwe (1982) and van der Merwe and Vogel (1978) are vitually identical to those reported by Bender et al. (1981) for the same Illinois series. If these positive values are due to diagenetic changes or laboratory error, only the Nashville Basin Mississipian samples seem to be affected. This seems unlikely.

A further possibility that should be explored is the suggestion that the maize from the prehistoric Interior Low Plateau was ^{13}C enriched compared to that from the Mississippi Valley. This could be due to different rates and efficiency in enzymatic activity during carbon fixation, either as an evolutionary adaptation of Northern Flint corn to temperate North America or as a local response to micro-environmental stresses. The genetic distinctiveness of Northern Flint has recently been underscored by Doebley et al. (1986), who emphasize rapid evolution and marked selection in the differentiation of Northern Flint from other North American landraces.

Although most researchers emphasize expected inter-specific rather than intra-specific variation among plants in $\delta^{13}C$ values, significant intra-specific variation has been reported. Smith and Epstein (1971), for example, present distinctive values for two subspecies of *Atriplex canescens*. A drought-adapted *A. c. linearis* is reported to have a $\delta^{13}C$ value of -12.6‰; *A. c. typica*, -18.0‰. The authors note that ^{13}C enrichment appears to be associated with "life under difficult conditions" (Smith and Epstein 1971:383).

Various experimentally induced stresses have been shown to alter metabolic processes in corn. For example, heat stress can modify the pattern of protein production (Baszczynski and Walden 1982). Water stress apparently induces qualitative rather than quantitative changes in protein synthesis (Bewley et al. 1983). Luna et al. (1985) also report that experimentally induced drought conditions can affect protein content and enzymatic activity in maize. These researchers indicate that water stress "drastically lowers the activity of two enzymes involved in the primary fixation of CO_2" (Luna et al. 1985:154).

Maize has been described as particularly cold sensitive (McWilliam and Naylor 1967). Teeri and Stowe (1976) report that, in general, temperature seems to be a limiting mechanism for C_4 grasses in temperate climates. Thus it would seem logical that the environmental stresses associated with the initial adaptation of maize to the North American temperate regions could lead to significant and systematic variation in $\delta^{13}C$ values that could affect carbon isotope patterns in consumers.

In order to examine this notion, an overview of $\delta^{13}C$ values reported for modern and archaeologically recovered maize was generated (Tables 4 and 5). Not included here is the extreme case offered by DeNiro and Epstein (1978), who experimentally induced a $\delta^{13}C$ value of -22.6‰ in corn seedlings, which they attribute to the nature of CO_2 sources.

Table 4: $\delta^{13}C$ Values for Archaeological Samples of Corn.

Origin	Part of Plant	$\delta^{13}C$(‰)	Reference
Aztalan site, WI	Kernel	-11.1	Bender 1968
Loyd site, IL	Kernel	-10.3	Crane and Griffin 1968
Southern Ontario	Kernel 14 samples	-9.1	Schwarcz et al. 1985
Orendorf site, IL	?	-9.3	Bender et al. 1975
Aztalan site, WI	?	-11.3	Bender et al. 1981
Clement site, OK	Cob	-12.4	Bender 1968
Marr site, OK	Cob	-12.6	Bender 1968
Aravaipa Canyon, AZ	Cob	-12.4	Bender 1968
Tehuacan	?	-8.8	DeNiro and Epstein 1981

Immediately obvious from Tables 4 and 5 is the fact that there is considerable variation between the samples. In general, values for kernels are more positive than those reported either for the cob or leaves of the corn plant. Theoretically, therefore, a meal consisting of immature corn ears should be less enriched in ^{13}C than one of mature corn kernels. In addition, as Schoeller et al. (1980) illustrate, lipids are less enriched than are the high carbohydrate components of corn. Thus one might expect corn $\delta^{13}C$ values to vary, dependent upon the ratio of fat to carbohydrate in the portion of the plant consumed.

The most positive $\delta^{13}C$ values reported for maize kernels come from Orendorf and the Ontario sites, where cobs are reported to have low row numbers and presumably would be classified as Northern Flint (Blake 1987). Loyd site corn is stated to have a higher average row number (11.1), compared to a value of 10.0 for Orendorf and 8.9 for DeWaele, an early Ontario Iroquoian site (Blake 1987). Aztalan corn, with the least positive $\delta^{13}C$ values, has the highest average row number (12) (Lynne Goldstein, personal communication). Obviously, these few data points do not confirm an association between the low row numbered Northern Flint corn and ^{13}C enrichment. Additional $\delta^{13}C$ values for morphologically classified North American maize samples from well documented contexts are needed. At present, the possibility that non-dietary factors may confound estimates of dietary dependence upon maize remains an unresolved and potentially significant issue. Future research should be designed to determine whether or not there exists systematic variation in $\delta^{13}C$ values for North American samples. In addition, it may also be significant to determine whether or not the ^{13}C-enriched maize kernels are also carbohydrate enriched, when compared to fat and protein content. This could have health-related implications in a focal agricultural community.

Health and Diet in the Nashville Basin

Of the Middle Tennessee skeletal series reported here, the most intensively studied is the Averbuch site, where analysis has focussed upon rather spectacular evidence for ill health. High infant mortality and low adult survivorship coupled with striking evidence for infectious pathology and anaemia are characteristic of the Averbuch population. Healed and active periostitis and osteomyelitis of the long bones, a likely unrelated tuberculosis-like pathology, and cribra orbitalia among juveniles and young adults are conspicuous in the sample (Eisenberg 1986).

Unfortunately, it is difficult to fill out the chronological sequence of health-related changes leading up to the obvious pathology at Averbuch. Although adequate for isotopic work, the other samples reported here are, in general, relatively small or poorly preserved. Periosteal remodelling has been observed among the adults at the Early Mississippian Mound Bottom site and both cribra orbitalia and significant amounts of periostitis have been observed in adults from the Woodland Mansker Creek site (William Autry and Emanuel Breitburg, unpublished notes). These data are suggestive, but it is obvious that further, systematic studies of temporal sequences and larger series are necessary if the timing of health changes is to be specified and compared to $\delta^{13}C$ values.

The evidence for ill health at Averbuch remains impressive when contrasted with that for Mississippian groups from other regions. As

Table 5: $\delta^{13}C$ Values for Modern Corn.

Origin	Part of Plant	$\delta^{13}C$ Value (‰)	Reference
Miracle Food Mart Ontario, Canada	Kernels 9 samples	-10.6	Schwarcz et al. 1985
Ottawa, Ontario Morden, Manitoba	Kernels 4 samples 5 samples	-9.5	Lowdon 1969 Lowdon and Dyck 1974
?	Kernels	-10.0, -11.2 and -12.6	Troughton, Card, and Hendy 1974
London	grain, coll 1976 meal, coll 1977	-11.52 -10.83	Burleigh and Brothwell 1978
Price Co, WI	Cob	-13.2	Bender 1968
Ottawa, Ontario Morden, Manitoba	Leaves 4 samples 5 samples	-11.0	Lowdon 1969 Lowdon and Dyck 1974
?	?Leaves	-14.0	Smith and Epstein 1971
Kaysville, Utah	?Leaves	-13.6	"
?	Leaves	-13.6	Smith and Brown 1973
?	Leaves	-13.9	Troughton, Card, and Hendy 1974
Jewel Foods Chicago, IL	Corn flour	-10.7	Schoeller et al. 1980
"	Corn syrup	-11.8	"
"	Corn oil	-14.8	"

noted by Eisenberg (1986), shortened length of life, elevated levels of periosteal reaction, and increased prevalence of anaemia are characteristic of Averbuch, compared to other Mississippian samples from the Southeast and Midwest. Other groups may match the Averbuch pattern for one attribute, but Averbuch tends to be extreme in all cases. The single possible exception is the Toqua mounds sample, which also is characterized as a highly stressed Mississippian series (Parham 1982).

Evaluation of Averbuch community health must however be tempered by the realization that many of the lesions noted here are healed at the time of death, a pattern also noted by Milner (1982, 1987) among the A.D. 1250–1400 East St. Louis Stone Quarry series and in the remains from the Kane Mounds site (A.D. 1150–1250). Significant numbers of affected juveniles did survive, at least to young adulthood.

The demographic profile for Averbuch also requires comment. It has usually been evaluated as a normal cemetery sample, the gradual product of mortality in one or more communities over a century. In that the probability of dying values are apparently similar to the Crow Creek massacre site (Buikstra and Konigsberg 1985), the possibility that at least part of the sample represents one or more catastrophic events should be entertained. Palisades and evidence of burning provide compelling evidence of warfare among Late Mississippian peoples of the Nashville Basin (Autry 1983; Klippel and Bass 1984).

A second form of catastrophic event which may have significantly impacted the Averbuch community was epidemic disease. Eisenberg notes significant periostitis among young juveniles at Averbuch (1986), as well as high rates of skeletal evidence of anaemia. This, in association with elevated young adult mortality, is the expected pattern for a tuberculosis-like disease, as noted by Buikstra and Cook (1981). The Averbuch case appears to be an extreme example of the pattern noted among other Mississippian peoples for a new disease not found among Late Woodland groups. Again, a diachronic study of health patterning in the Nashville Basin should clarify the issue.

Among the topics which should be addressed in future research include factors affecting the nutritional quality of maize among Ft. Ancient and Nashville Basin late Mississippian peoples, including the impact of storage and cooking of maize, as well as the degree to which warfare and raiding may have affected harvesting and storage efficiency. Above-ground storage facilities characteristic of Averbuch (Klippel and Bass 1984), likely advantageous in a seasonally hot and humid climate, would have been a ready target for destruction by raiding groups, in contrast to hidden, below-ground pits such as those found at the Ft. Ancient sites (Wagner 1987). In addition, the possibility of significant nutritional differences between the strains of corn grown in the Kentucky/Tennessee region, when compared to those characteristic of the central Mississippi valley, should be entertained.

$\delta^{13}C$ Values for Cultivated Plants Other than Maize

To assess the degree to which δ^{13}C values from human bone reflect, either directly or indirectly, carbon derived from maize, it is important to know of other possible C_4 plants utilized by prehistoric peoples. Particularly crucial for studies of North American remains are the indigenous cultivated species of the Eastern Agricultural complex, such as maygrass (*Phalaris caroliniana*), knotweed (*Polygonum erectum*), and goosefoot (*Chenopodium berlandieri*). Seeds from these plants dominate the archaeobotanic record for Woodland sites across the Midcontinent (Asch and Asch 1985a; Johannessen 1984; Schwarcz et al. 1985; Watson 1986; Wagner 1987).

We therefore generated δ^{13}C values for two prehistoric charred seed samples and two types of modern seeds of plant species thought to have been cultivated in prehistory. The two charred seed samples were recovered from Illinois sites, as was the modern *Chernopodium berlandieri* (goosefoot). The modern *Phalaris* (maygrass) sample was harvested from southeastern Arkansas by David and Nancy Asch. The Asches provided all plant specimens, both prehistoric and modern.

As indicated in Table 6, the δ^{13}C values for these modern and charred seeds provide no evidence that maygrass, knotweed, or goosefoot are C_4 plants. These results are consistent with those of Schwarcz et al. (1985): -26.7‰ and -28.2‰ for *Chenopodium hybridium* and *C. glaucum*, respectively; and of Bender (1971): -28.1‰ for *C. album*. Of the C_4 plants other than maize cited as potential dietary items among North American prehistoric peoples, *Amaranthus* spp. appear the most likely to have affected δ^{13}C values (Bender 1971; DeNiro and Epstein 1981; Schwarcz et al. 1985; Smith and Epstein 1971). Asch and Asch (1985b) report, however, very little *Amaranthus* from archaeological sites in west-central Illinois and comment upon its low productivity. *Amaranthus* seeds are also not conspicuous among the palaeobotanical evidence reported by Crites (1984) for Averbuch or for the Nashville Basin sequence reported by Gremillion and Yarnell (1986). This supports the argument that the positive shift in δ^{13}C ratios reported here for human remains reflects the presence of carbon, ultimately derived from maize, either due to direct dietary consumption or by eating the flesh of browsers or omnivores such as deer and raccoon, who dined in the fields. Obviously, additional testing of modern and prehistoric seeds from other archaeological contexts would strengthen this argument.

Fauna

As underscored by Katzenberg (this volume), a possible source of carbon enriched in ^{13}C in humans would be the flesh of animals whose diet included C_4 plants. Likely candidates include deer, duck, turkey, and dog. There exist no δ^{13}C values for animals from the Nashville Basin sites reported here. Relevant, however, are 12 δ^{13}C determinations for deer bone reported by Bender and co-workers (1970, 1981) from Mississippian components of Cahokia, Millville, and Aztalan sites. These values cluster tightly around a mean of -22.1‰ (range -21.1 to -23.3‰). Of the other animals reported by Bender et al. (1981), only the -19.4‰ δ^{13}C value for the turkey suggests enrichment. Further study, including bones from domestic dogs, is needed. However, at this point, the probability of secondary enrichment through consuming flesh of corn-eating herbivores appears low.

CONCLUSION

We have reported here a sequence of δ^{13}C values for the Nashville Basin that contrasts with series previously generated for Southern Ontario and the Central Mississippi valley. This pattern of relatively rapid intensification and extensive dependence upon maize, apparently coincident with the initial phases of Mississippian, culminates in the most positive δ^{13}C values reported for North American skeletal series. At least one of the more recent sites shows evidence of extensive pathology, which is attributable to a variety

Table 6: $\delta^{13}C$ Values for Seeds.

Species	Origin	Lab-#	$\delta^{13}C$(‰)
Chenopodium berlandieri	Calhoun Co Illinois	UCT-289	-29.5
Phalaris caroliniana	SE Arkansas	UCT-288	-27.4
Mixed *Phalaris*, *Chenopodium*, and *Polygonum*	John Roy site: F5	ISGS-971	-25.6
Mixed *Chenopodium* and *Polygonum*	Newbridge site: F6	ISGS-1427	-25.8

of health and social stresses. To be emphasized is that however tempting simple or unicausal arguments may be, it is obvious that the relationship between health status and diet among Mississippian peoples is complex. Explanations require intensive study of skeletal remains in diachronic sequences in local regions. Quite clearly, the most satisfying arguments must address issues ranging from the chemistry of bone to social factors that could have restricted access to food and other resources.

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