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Associations between Agricultural Intensification and Social Complexity: An Example from the Prehistoric Ohio Valley

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Many different theories have been advanced to explain the existence of non-state complex societies (often described as chiefdoms). Explanations of the appearance or decline of chiefdoms have historically emphasized the relations between a society's productive base and its social organization, but more recently, studies of the dynamics of chiefdoms have shifted away from economic or material explanations. This study examines the relationship between social complexity and human stable carbon-isotope ratios as a measure of agricultural intensification for late prehistoric (after A.D. 1000) tribal and chiefdom-level societies of the Ohio Valley of eastern North America. We show that there is a strong association between social complexity and agricultural intensification (reflected in increased maize consumption) in this region during the late prehistoric period.

INTRODUCTION

"Chiefdom" is a convenient term to use when discussing those diverse societies intermediate in complexity between tribes and states. Although extremely diverse, chiefdoms can be distinguished from simpler or more complex societies because a chiefdom has a decision-making hierarchy that lacks internal differentiation and has no more than two or three hierarchical levels above the level of local production (Wright 1984). Although chiefdoms were originally discussed primarily within the context of the evolution of more complex forms of society, it has become widely accepted that prehistoric chiefdoms are of significant interest in their own right because chiefdoms are no longer available for direct ethnographic study (Caniero 1981; Drennan and Uribe 1987; Earle 1991).

During the late prehistoric period (A.D. 1000–1540), eastern North America was populated by Middle Mississippian chiefdoms in the Southeast as well as tribal-level organizations in the midcontinent and the northeast. The term "Middle Mississippian" was originally used to describe shell-tempered pottery with a geographic distribution centered on the Middle Mississippi Valley (Holmes 1886), but Middle Mississippian is now used to characterize the late prehistoric societies of eastern North America possessing both hierarchical social organizations based on ascribed ranking and a specialized adaptation to the river valley ecosystems based in part on maize agriculture (Peebles and Kus 1977; Smith 1978). The origin and evolution of Middle Mississippian chiefdoms has been, and continues to be, an important research topic.

Many different theories have been devised to explain the evolution of chiefdoms. A noncomprehensive list of the many different motivating factors includes exchange (Sahlins 1958; Service 1962), warfare (Caniero 1970; Larson 1972), interactions between population growth and environmen-

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tal conditions (Sanders and Webster 1978), information management (Peebles and Kus 1977), and population growth (Johnson and Earle 1987). Theories about both the economic and the ideological bases of chiefdoms have been nicely reviewed by Earle (1991, 1987) and it is clear from his introductory remarks for the 1991 volume that there is little common agreement about the mechanisms which trigger the development of chiefdoms.

Materialist explanations were once widely accepted and have an especially long history in anthropology. The unilineal evolutionists of the 19th century, such as Morgan (1963) [1877] and Tylor (1958) [1871], did not recognize chiefdoms in the modern sense, but they thought that increased social complexity was tied directly to economics, and Morgan wrote that "It is accordingly probable that great episodes of human progress have been identified, more or less directly, with the enlargement of sources of subsistence" (1963:19). Although the concept of unilineal, progressive evolution was discarded by early 20th century American archaeologists, the reemergence of evolutionary perspectives of cultural development and classification in the influential formulations of Service (1962) and Fried (1967) reemphasized the close connection between the productive base of a society and its organization as originally formulated in the 19th century.

In the study of New World chiefdoms, there has recently been a trend away from materialist explanations to perspectives which concentrate on the political and ideological dynamics of chiefdoms, to the extent that ". . . populations seem to have been drawn into sociopolitical systems in part through manipulated 'smoke and mirrors,' an ideology of religiously sanctioned centrality symbolized by the ceremonial constructions and exchanges in foreign objects of sacred significance" (Earle 1991:8).

Historically, explanations for the appearance of Middle Mississippian chiefdoms (and for their absence outside the Southeast) have followed the general trends outlined above. Until recently, the appearance of Middle Mississippian chiefdoms was primarily attributed to their locations in settings highly favorable for intensified maize agriculture (Griffin 1967). More recently, attempts to explain the evolution of Mississippian chiefdoms have often concluded that there was little direct relationship between agricultural intensification and social complexity in the region during the late prehistoric period (Buikstra et al. 1987; Buikstra and Milner 1991; Steponaitis 1991; Welch 1990), an idea now common in studies of New World chiefdoms and put most succinctly by Drennan: "maze agriculture may simply have played the permissive role of making possible (but not necessary) regional populations of a size and density without which significant complexity cannot exist" (1991:281–282).

But in many regions of the New World where chiefdoms appeared, their appearance was immediately preceded by or coincided with intensified maize production, especially in the early stages of their evolution (Feinman 1991, p. 248; Steponaitis 1991; Welch 1991). It is thus worthwhile to investigate the role that agricultural intensification played in the appearance and maintenance of maize-cultivating New World chiefdoms. We focus on a series of late prehistoric sites in the Ohio Valley drainage of eastern North America (Fig. 1). During the period following the introduction of maize agriculture, roughly contemporaneous societies existed there, some of which were organized at the tribal level (the Fort Ancient tradition), along with others that were chiefdoms (the Middle Mississippian tradition). The Middle Mississippian occupations of the Ohio Valley were located on or immediately adjacent to the broad alluvial floodplains of the lower valley. The Fort Ancient occupations were located along the narrower valleys of the middle Ohio and its tributaries and in upland settings.

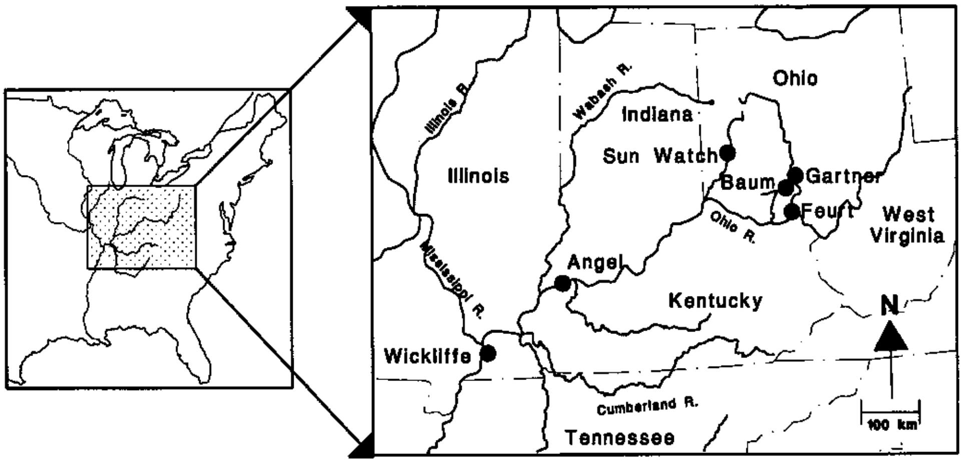

FIG 1. Site locations.

The two traditions appear to have been largely contemporaneous, but both Middle Mississippian and Fort Ancient societies exhibited substantial regional and chronological variations within their respective traditions, which are reflected in material culture, settlement patterns, social organization, and subsistence adaptations as well. In general, however, the Fort Ancient populations were less strongly organized into hierarchical systems compared to Middle Mississippian societies. Where Middle Mississippian societies are conceptualized as chiefdoms (Peebles and Kus 1977; Steponaitis 1978), Fort Ancient societies are though to have been organized at the tribal level (Griffin 1992; Henderson 1992:5).

Explanations of the relations between agricultural productivity and social complexity in this relatively limited region have followed disciplinary trends and shifted from the general acceptance that Middle Mississippians were more agricultural than their Fort Ancient neighbors (Griffin 1964) to the idea that the Fort Ancient populations were actually more agricultural than their more complex neighbors (Rosen and Edging 1987; Wagner 1987). The region thus makes an excellent setting in which to evaluate the extent to which there are associations between subsistence productivity and social complexity for late prehistoric maize agriculturalists of eastern North America.

SITES USED IN THE STUDY

To determine whether there was a relationship between agricultural productivity and social complexity in the Ohio Valley region during the late prehistoric period, we obtained stable carbon-isotope ratios from prehistoric humans and of the maize they consumed at several Fort Ancient and Middle Mississippian sites to provide the best possible measure of maize consumption (Schoeninger and Schurr 1993). Six sites representing four Fort Ancient and two Middle Mississippian occupations of the Ohio Valley drainage are used in this study. The Fort Ancient occupations are represented by the sites of Baum (Mills 1906), Gartner (Mills 1904), Feurt (Mills 1917), and Incinerator (Heilman and Hoefer 1980; Wagner 1987, hereafter called Sun Watch). Middle Mississippian occupations of the lower Ohio Valley are represented by the Angel site (Black 1967) and Wickliffe Mounds (King 1939; Wesler 1991). These sites were occupied between roughly A.D. 1000 and A.D. 1450. The Fort Ancient sites of Baum and Gartner were occupied between approximately A.D. 975 and 1225 (Henderson 1992; Prufer and Shane 1970).

Two sequential Fort Ancient occupations were present at Feurt and the sample available to us appears to represent the latest occupation of the site during the Middle Fort Ancient period (A.D. 1200–1400) (Henderson et al. 1992; Robbins 1968). Sun Watch radiocarbon dates are consistent with an occupation during the 12th century (Heilman and Hoefer 1980). The skeletal samples from the Middle Mississippian sites of Angel (Schurr 1989) and Wickliffe (Wesler, personal communication) are roughly contemporary and date to the period between A.D. 1350 and 1450. The occupations at these six sites represent a range of solutions to the problems faced by maize agriculturalists in the Ohio Valley during the relatively brief late prehistoric period. Many late prehistoric sites in the Ohio Valley have produced small samples of human skeletal remains or of maize, but relatively few have produced large samples of both. The sites in this sample are unusual because they have produced skeletal series suitable for stable carbon-isotope analysis along with abundant samples of prehistoric maize. This sample is therefore very well suited toward examining the relations between agricultural intensification and social organization in societies ranging from tribes to chiefdoms.

Another characteristic shared by these sites is the high quality of the excavations conducted at each. The dates of the excavations at these sites span a period of almost a century. Mills's excavations at Baum, Gartner, and Feurt were the earliest conducted, and they are truly remarkable for their period. Although Mills did not use screens or flotation to recover small remains, he collected small artifacts and floral and faunal remains, excavated in well-defined rectilinear units, recognized many different types of features, numbered each burial, and provided detailed reports, photographs, and excavation plans that are in marked contrast to the often sketchy descriptions common in his day. The techniques and approaches he used would not become common practice in eastern North American archaeology for several decades. He also excavated with specific problems in mind. For example, at the Baum site, he examined several different parts of the site during three expeditions "... to discover, if possible, the extent of the village, as well as to ascertain the mode of life in various sections, and whether the same people inhabited the village in all its parts" (Mills 1906:55). Excavations at Angel were conducted by Glenn Black (1967) over several decades. Black was trained by Clyde Shetrone (who was trained by Mills and worked for him at the Feurt site), was a meticulous field worker, and an innovator who supervised early experiments in geophysical surveys at Angel (Johnston 1964). Excavations at Wickliffe have a more checkered past, as the site was originally developed as a tourist attraction (King 1939; Wesler 1991). In 1983, the site became a research station of Murray State University, and a series of carefully designed and meticulously implemented excavations have since been conducted at the site under the direction of Kit Wesler. Sun Watch is the only site in the sample entirely excavated with modern techniques. Extensive professional excavations uncovered approximately 60% of this circular village, which covered a total area of approximately 1.3 ha (Heilman and Hoefer 1980; Wagner 1987).

Evidence for Variations in Social Complexity among the Sites

Because late prehistoric agricultural societies of eastern North America ranged from tribal level societies to complex chiefdoms, they do not fit neatly into the categories defined by Fried (1967), Service (1962), or others. Rather, they cross-cut major divisions of these schemes, and multivalued scales are therefore needed to measure complexity (Feinman and Neitzel 1984). Although clear dichotomies cannot be expected, certain variables are consistently associated with societal complexity. Among these are status or societal differentiation as indicated by mortuary remains, house size and location, overall community size and population, interregional exchange, and monumental constructions requiring communal labor (Drennan 1991; Feinman 1991; Feinman and Neitzel 1984).

Four of these measures of social complexity correlate well with the anticipated differences in social complexity between Middle Mississippian and Fort Ancient societies of the Ohio Valley. These include: (1) site size; (2) site hierarchies; (3) mortuary treatments; and (4) evidence for large communal labor projects. Less clear evidence is provided by data on exchange because such information has not yet been systematically studied for any of the sites included in our sample.

Site size provides a rough indication of community size, which has been widely used in studies of population size and density in the region (Green and Munson 1978; Henderson 1992; Muller 1986). Feinman and Neitzel (1984) found that historic-period aboriginal societies of eastern North America exhibited strong correlations between *maximal* community size and the number of status markers; their analysis suggests that the number "is correlated with the degree of social differentiation, *maximal community size,* and total population" [our emphasis] (1984:76). This strong correlation between maximal community size and complexity leads us to conclude that maximum community size can be used as an indirect measure of complexity, especially when comparisons are restricted to communities within a single geographic area as in this study. The ideal measure of community size should be based on carefully conducted excavations designed to accurately determine the number of inhabitants present at each site at a given period of time. As most of the sites (except Sun Watch) used in this study were excavated using methods that preclude such detailed demographic reconstructions, we are forced to rely on site size as the best available estimate of maximal community size. This is a reasonable approach, however, given that there is an extremely close relationship between site area and the number of houses that were occupied at any given time for Middle Mississippian sites of the Lower Ohio Valley (Muller 1986:210); and many Ohio Fort Ancient sites, such as Sun Watch (Heilman and Hoefer 1980; Henderson et al. 1992:261; Wagner 1987), were compact communities surrounded by a stockade so that site size is correlated with the number of houses present. Site area is a less reliable estimator of population size for multicomponent sites, but it still remains a useful estimator of community size and complexity as long as the results are used intelligently and possible problems are taken into account.

The occupied portions of these sites (i.e., site sizes) range from approximately 0.8 to greater than 5 ha (Table 1). The Angel site is unusual because the area enclosed by the palisade is much greater than the area actually occupied. Black (1967:547) noted that approximately one-eighth of the site area enclosed by the stockade (circa. 5 ha) had been inhabited. The maximum size of the Baum site (estimated at less than 4 ha) is inflated by the presence of a Middle Woodland earthwork and mound at the site. Excavations by Mills determined that the Fort Ancient occupation at the site was restricted to an area of 0.8 ha (Mills 1906:55). As shown in Table 1, there is a clear difference in maximal site size between the two Middle Mississippian sites on the one hand and the four Fort Ancient sites on the other, a difference that indicates that larger population aggregates inhabited the Middle Mississippian sites or that these sites served as central places for regional populations.

Site hierarchies have also proven ex-

TABLE 1
Evidence for Variations in Social Complexity

Site	Size (ha)	Settlement type	Mortuary differentiation	Number of mounds	Overall organization
Baum	0.8[a]	Village	Minor	0[b]	Tribal
Sun Watch	1.3	Village	Minor	0	Tribal
Gartner	1.2–1.6	Village	Egalitarian with mound burial based on age or achievement	1	Tribal
Feurt	1.6–2.0	Village	Egalitarian with mound burial based on age or achievement	1	Tribal
Wickliffe	≤4	"Simple" mound center	Elites in mounds	6	"Simple" Chiefdom
Angel	ca. 5[c]	"More complex" mound center	Elites in mounds or charnal houses	11	"Slightly more complex" chiefdom

[a] For the Fort Ancient occupation only. The combined Fort Ancient and Middle Woodland occupation area totaled ca. 4 ha.
[b] A single mound at this site is probably Middle Woodland.
[c] Inhabited area only. Area surrounded by palisade totals ca. 40 ha.

tremely useful as archaeological indicators of social complexity (Drennan and Uribe 1987:60; Earle 1987:2; Feinman 1991:237; Steponaitis 1991). For example, Steponaitis (1978) distinguished simple chiefdoms from complex ones by the presence of multiple mound centers in the latter and successfully compared settlement patterns between the Moundville region (where a paramount center was present) and the Pocahontas region of Mississippi (where a paramount center never developed) to examine contrasting patterns of Mississippian development (Steponaitis 1991).

The Fort Ancient sites (Baum, Gartner, Feurt, and Sun Watch) were villages within nonhierarchical settlement systems. The Fort Ancient settlement pattern was probably composed of two types of sites: a village occupied during most of the year; and secondary sites occupied by small family groups who dispersed during the winter months (Fitting and Cleland 1969; Henderson et al. 1992; Wagner 1987:46). The sites of Sun Watch, Baum, Gartner, and Feurt all represent the village portion of this nonhierarchical pattern and are therefore the largest sites occupied by each population.

Wickliffe was a relatively small multiple mound center that appears to have been part of a hierarchical system with perhaps only two levels. Little is known about the distribution of other nonmound Mississippian sites in the vicinity of Wickliffe (Wesler 1991), but it now appears that the site was apparently a small independent polity which was not integrated into a larger chiefdom and which served as a central place for residents of the site and perhaps for small outlying farmsteads or hamlets as well. In contrast, Angel was a much larger mound center with several groups of mounds arranged around at least one large central plaza (Black 1967). The Angel phase settlement pattern is composed of a hierarchy of sites ranging from extractive camps through farmsteads, hamlets, and villages and culminates with the Angel site, the paramount center of the multitier settlement hierarchy (Black 1967; Green and Munson 1978).

The Wickliffe settlement pattern appears to fit most closely to that expected for a simple chiefdom (Steponaitis 1978). The Angel settlement pattern does not fit as neatly into the simple/complex dichotomy defined by Steponaitis because the Angel settlement pattern is thought to lack secondary mound centers (Green and Munson 1978), although it does contain secondary villages without mounds. The Angel site was apparently the paramount center of a chiefdom intermediate in complexity between a simple chiefdom, with a single mound center, and a complex chiefdom, with secondary mound centers. Angel's settlement system was hierarchically more complex than Wickliffe's or those of the Fort Ancient sites.

Mortuary treatments provide information about social ranking and stratification, with more complex societies generally having more complex mortuary programs (Binford 1971; Saxe 1970). Mortuary evidence for ranking at the Fort Ancient sites consists of artifactual associations at all the sites and of mound burial at the sites of Feurt and Gartner. At Baum and Sun Watch, individuals were interred in family groups with differences in status indicated by relatively minor differences in artifactual associations or interment location within the site. At Gartner and Feurt, some individuals were interred in accretional burial mounds (where additional earth was added each time a burial was made), while others were interred in habitation areas. Individuals in young and middle adulthood were more likely to have been interred in mounds compared to infants, children, and older adults. Mounds contained relatively large numbers of burials, indicating that mound burial was open to many members of society. Although mound burial at Gartner and Feurt appears to represent a more complex mortuary ritual compared to Baum and Sun Watch where burial mounds were not constructed, mound burial seems to have been primarily determined by age or by achievement in physically demanding activities, patterns that are consistent with an egalitarian social organization (Charles and Buikstra 1983). Mortuary treatments at these Fort Ancient sites appear to represent achieved statuses within a nonhierarchical society even in cases where burial mounds were constructed.

Peebles' (1974) classic study of mortuary treatments at the Moundville site demonstrated that Middle Mississippian mortuary treatments were composed of two primary dimensions. The *subordinate dimension* contained the nonelite individuals who comprised most of the Moundville population. Internal ranking within the subordinate dimension was based on achievement. The *superordinate dimension* contained the elite members of Moundville society and access to superordinate burial treatments was predicated on membership in the paramount lineage. Ranking within the superordinate lineage was partially based on achievement; some mortuary treatments, such as burial with artifacts that seem to symbolize the position of paramount chief or of war leader, were restricted to adult males. The Moundville study shows how Middle Mississippian mortuary treatments reflect both achieved and ascribed statuses.

Mortuary treatments at the Angel site (Schurr 1989) follow the pattern outlined by Peebles. The bulk of the Angel skeletal series represents the remains of a nonelite segment of Angel society. The ascribed status of elites is indicated by their burial in mounds or charnel houses. The sample of burials from Mound C at Wickliffe also appear to represent the remains of nonelites. Elite individuals at Wickliffe may be represented by several elite males (distinguished by artifactual associations) that were interred in Mound D (these individuals are not included in our sample). At Angel and Wickliffe, nonelite segments of the community were apparently interred in community cemeteries and elites were interred in mounds or charnel houses. There is little evidence for status distinctions within the nonelite cemeteries except at Angel, where individuals who were not natal members of Angel society were apparently distinguished by minor differences in body position (Schurr 1989; 1992). At Angel, there is also little evidence of status distinction within the elite stratum and there is no evidence that elites were buried with elaborate grave goods. Black deliberately tested locations that he thought might contain elite burials with elaborate grave goods (Black 1967:346), but never found them, and it thus appears that the lack of internal status differentiation for the existing sample of elite burials accurately characterizes Angel mortuary patterns. The Angel chiefdom thus appears to possess the characteristics of a group-oriented as opposed to an individualizing chiefdom (Renfrew 1974). Mortuary patterns for all of the sites (both Middle Mississippian and Fort Ancient) reflect relatively small-scale societies with strong communal orientations. The Middle Mississippian burials reflect two social strata (elites and commoners) with little differentiation within each stratum.

Mound construction (Table 1) provides the best evidence for differences in the mobilization of communal labor between the Fort Ancient and Middle Mississippian sites. The burial mounds at the Fort Ancient sites of Gartner and Feurt were accretional mounds that were constructed by the periodic addition of a few burials at a time so that the labor demands during each construction episode were relatively small. The platform mounds at both Middle Mississippian sites were constructed either in single episodes or in a series of stages when mound volumes were dramatically increased during each episode. Where the Fort Ancient sites have at most a single mound, 6 mounds were constructed at Wickliffe, and 11 at Angel. The Angel site was also enclosed by an enormous palisaded stockade, which was reconstructed several times (Black 1967). It is clear that the inhabitants of Wickliffe and Angel invested more labor in communal constructions.

Other indicators of social complexity, such as evidence for interregional exchange or the presence of craft specialization, are more difficult to evaluate. Interregional exchange in eastern North America was widespread and had a long time depth, going back to the Late Archaic period (ca. 2000 B.C.) or before, but systematic studies of late prehistoric exchange in the Ohio Valley or at the six sites in this study have never been conducted. Copper artifacts, marine shell, chert hoes, galena, and fluorite recovered at Angel (Kellar 1967) must have all been imported, but it is not known if these exchanges occurred at the household level or if they were mediated and controlled by elites. The variety of imported artifacts may be an indicator that the Angel chiefdom was supported by a prestige-goods economy as has been proposed for Moundville (Welch 1991), but additional investigations will be required to understand the role of exchange within the Angel and Wickliffe systems. A lesser variety of exotic artifacts was recovered from the Fort Ancient sites. Marine shell artifacts were found at Baum (Mills 1906), Gartner (Mills 1904), Feurt (Mills 1917), and Sun Watch (Heilman and Hoefer 1980). This single class of artifact forms the most abundant type of exotic artifact at these sites, suggesting that Fort Ancient societies engaged in interregional exchanges that were less varied and intense than those of the Middle Mississippians.

In combination, the characteristics of the sites in this sample fit very closely with expectations about the differences in social complexity between Fort Ancient and Middle Mississippian occupations (Table 1). They are consistent with social organizations ranging from a tribal level, with very little evidence for internal stratification (Baum and Sun Watch); to tribal societies with mortuary evidence indicative of minor individual differences in status consistent with an egalitarian organization (Gartner and Feurt); to chiefdom-level societies that range from a relatively simple chiefdom (Wickliffe) to a slightly more complex chiefdom (Angel). These sites thus span the range of forms between tribal societies and chiefdoms, but even the most complex chiefdom in the sample is a relatively simple form of "complex" society.

Measuring Agricultural Intensification

The prehistoric populations of the Ohio Valley had only a limited number of ways in which they could increase the efficiency of their productive base. The lack of domesticated animals meant that production could not be increased by the use of animal labor or of dung for fertilization. Intensified harvesting of wild resources would soon lead to their depletion. Thus, agricultural intensification of maize production was the most significant route available for increasing the subsistence base. Possible options for increasing agricultural yields included cultivation of the most productive soils, technological advances to improve labor or storage efficiency, increasing the amount of labor devoted to food production by increasing the number of acres in cultivation or by expending more effort weeding and protecting the crop from predators, or selection of the most productive maize varieties. Cultivating more than one crop of maize in a season was not a viable option because the growing season was too short (Muller 1986:222).

The term "agricultural intensification" is defined as rate of output per unit area, a measure that is difficult to calculate even for contemporary swidden agriculturalists and must therefore be represented by surrogate measures (Turner and Doolittle 1978). Because agricultural intensification in the strict sense is virtually impossible to measure directly for prehistoric agriculturalists, archaeologists use intensification as a more general term to denote increased reliance on domesticated food and use many indirect indicators of agricultural intensification in the archaeological sense. These measures include location of sites on the most productive agricultural soils, increases in the size of storage facilities, technological advances such as the use of chipped stone hoes, evidence of increased forest clearance, increased frequencies of cultigens compared to wild plants in botanical assemblages (Lopinot 1992:59–60), decreased phenotypic diversity of cultigens because of selection for the most productive varieties (Scarry 1986), and for maize agriculturalists, increases in the ^{13}C content of human bone collagen because of increased maize consumption [reviewed by Schwarcz and Schoeninger (1991)]. Many of these measures cannot be applied to the sites in our sample. For example, increased forest clearance can be reflected in botanical samples by an increase in the proportion of early successional plant species (Scarry 1986) or in small-animal faunal assemblages by increases of field taxa compared to woodland ones (Scott 1983:361–363). As all but one of the sites in our study were excavated prior to the use of flotation recovery techniques, these measures are not available.

Other widely used measures, such as soil fertility, cannot readily be compared between the sites in our study. For example, site catchment analysis has been used to examine the relationships between site location and environmental productivity in the Moundville region (Bozeman 1982; Peebles 1978), but this technique is not applicable to our sample for several reasons. The Moundville phase covered a single physiographic zone contained within two counties across a span of 40 km and where data on soil fertility were available from the period prior to the introduction of modern mechanized agriculture. The sites in our sample are separated by distances of up to 600 km, lie within several different physiographic zones, and in a region without uniform soil classifications (let alone uniform measures of soil fertility). Comparisons of surrogate measures, such as soil fertility, must therefore be made on a very general level.

Evidence for increased maize consumption will provide a very strong indication of agricultural intensification because maize consumption should be highly correlated with maize production. Maize consumption can be assessed by measuring stable carbon-isotope ratios of bone collagen. Controlled feeding experiments (Bender et al. 1981; DeNiro and Epstein 1978) have demonstrated that the stable carbon-isotope ratio ($^{13}C/^{12}C$) in an animal's bone collagen reflects the isotope ratios of the foods eaten by the animal. Significant differences in stable carbon-isotope ratios (reported as $\delta^{13}C$ values in units of per mil [‰]) have been identified between plants that fix carbon by the C3 and C4 pathways (Smith and Epstein 1971) with C3 plants having significantly lower $\delta^{13}C$ values than C4 plants. The $\delta^{13}C$ values of modern C3 plants average around –26‰ and those of modern C4 plants average around –12‰. These differences are reflected in the stable carbon-isotope ratios of animals that feed on one or the other type of plant. The natural biome of eastern North America consists largely of C3 plants and maize was apparently the only C4 plant of any dietary significance. The $\delta^{13}C$ values of bone collagen from prehistoric humans should thus be largely a function of the amount of maize in the diet, and stable carbon-isotope ratios of prehistoric humans show a dramatic increase in $\delta^{13}C$ values after maize becomes available (Lynott et al. 1986; Stothers and Bechtel 1987; Vogel and van der Merwe 1977).

Uncertainties about the magnitude of the shift between collagen and diet, which ranges from 3‰ in small laboratory animals (Bender et al. 1981; DeNiro and Epstein 1978) to 5–6‰ in large wild animals consuming a C4 diet (Vogel 1978), make it difficult to calculate precisely the exact proportion of maize in prehistoric human diets based on stable carbon-isotope ratios (Schoeninger and Schurr 1993). It has also been proposed that different strains of maize have different stable carbon-isotope ratios (Wagner 1987), although this does not seem to be the case for maize samples from these six sites (see below) or from other sites (Tieszen and Fagre 1993). In spite of the uncertainties associated with the magnitude of the shift between diet and collagen, stable carbon-isotope ratios are accurate indicators of changes in maize consumption, if not of the exact magnitude of the change.

It can be argued that intensified maize production could occur without changes in human $\delta^{13}C$ values. For example, maize production might be increased to support a larger population without a change in per capita maize consumption. Given that the populations in this study relied heavily on wild resources for the animal protein component of the diet (Peebles 1978; Smith 1978; Wagner 1987) and that these resources could not be harvested more intensively without eventually depleting them, it is likely that larger populations would be supported by intensified exploitation of both domesticated and wild resources rather than just agricultural intensification alone. An increase in population size should be accompanied by some combination of increased maize consumption (reflected in more positive $\delta^{13}C$ values) and by changes in the procurement of wild plants and animals. Such changes should be archaeologically visible, but, as noted above, the requisite faunal and botanical samples are not available from these sites. Stable carbon-isotope ratios of human collagen, in conjunction with the carbon-isotope ratios of maize actually consumed by the humans, therefore provide the best available measure of the amount of maize consumed (and indirectly, of agricultural intensification).

Procedures Used in the Isotopic Analysis

Samples for stable carbon-isotope analysis were taken from burials from Baum, Gartner, Feurt (all curated at the Smithsonian Institution), Angel (curated at the Glenn A. Black Laboratory of Archaeology, Indiana University), and Wickliffe (curated at the Wickliffe Mounds Research Center). The sample from Angel includes results for 41 specimens analyzed previously (Schurr 1989; 1992) and results for six additional specimens, including two from Mound F and one from a charnel house adjacent to Mound A thought to represent the remains of elite burials at Angel. Table 2 lists the specimens analyzed from each site, along with the results of the analyses and summary statistics. When possible, collagen was extracted from rib fragments of adult burials of known sex. When burials did not have available ribs, tibia fragments and in one case a sternum fragment were used. The bone fragments were carefully cleaned using procedures previously described in detail (Schurr 1989) and collagen was extracted from the clean bone fragments by slow demineralization (Moore et al. 1989; Sealy 1986). Weights of clean bone and the dried collagen extracts were used to calculate the percentage yields of the extractions. Collagen samples were converted to carbon dioxide and nitrogen gas by combustion in sealed tubes (Stump and Frazier 1973) followed by cryogenic distillation. Details of these procedures have also been reported previously (Schurr 1989). The carbon-to-nitrogen (C/N) ratio of each collagen sample was calculated after the yields of each gas were determined manometrically. Stable isotope ratios were determined using a Finnegan Delta E mass spectrometer and the isotopic compositions are reported using the usual delta (δ) notation in units of per mil (‰),

$$\delta = (R_{\text{sample}} - R_{\text{standard}})/R_{\text{standard}} \times 1000‰,$$

where $R = {}^{13}C/{}^{12}C$ and the PeeDeeBelemnite (PDB) is used as the standard. The overall precision (extraction and analysis) of the isotope analysis was ± 0.10‰ and the precision of the C/N ratio determination was ± 0.2.

The extraction yields, stable carbon-isotope ratios, and C/N ratios are shown for each of the 121 burials in Table 2. Stable carbon-isotope ratios were not obtained for three of the burials and extraction yields were not obtained for 30 Angel burials that were analyzed previously. The specimens produced extraction yields that were quite variable, but all were above the minimum yield of 2.0% generally accepted for reliable specimens (Ambrose 1990; Fogel et al. 1989; Schoeninger et al. 1989). Seven specimens had C/N ratios outside of the acceptable range (DeNiro 1985) of 2.9–3.6 and the stable isotope ratios of these specimens are not included in the discussions that follow.

RESULTS

Two specimens (one each from Baum and Gartner) produced very low stable carbon-isotope ratios (around –21.5‰) indicating that these individuals consumed no maize. These specimens probably represent the remains of Middle Woodland burials (Middle Woodland sites are common in the area and Baum has a Middle Woodland component) and are not included in the following discussion. For the 110 burials that produced reliable $\delta^{13}C$ values, average human stable carbon-isotope ratios for the six sites ranged from –11.7‰ for the sample of 7 burials from the Baum site to –9.0‰ for the sample of 47 burials from Angel (Table 2). The human stable carbon-isotope ratios of the Middle Mississippian samples and the Fort Ancient ones are clearly different.

TABLE 2
Extraction Yields, C/N Ratios, and Stable Isotope Ratios

Burial	Extraction yield (%)	C/N ratio	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
Angel (12 VG 1)				
O13D02	12.00	3.34	−9.0	8.3
O13D03	7.71	3.09	−8.8	9.3
P15A01	6.62	3.47	−8.5	8.2
R12A02		3.50	−8.4	7.9
S11D07		3.45	−8.1	7.7
U12A01		3.03	−9.5	9.0
U12A03	2.49	3.38	−9.0	8.1
W10D01	10.20	3.36	−8.8	8.2
W10D03	3.62	3.56	−9.1	8.4
W10D20		3.56	−9.4	7.9
W10D26		3.45	−9.2	8.3
W11A11		3.14	−8.0	7.7
W11A18		3.42	−8.3	9.7
W11A20	8.68	3.42	−8.6	7.6
W11A42		3.41	−8.8	8.9
W11A47		3.08	−8.9	8.4
W11A54		3.52	−8.8	8.4
W11B01	4.89	3.17	−7.9	8.6
W11B02	12.45	3.24	−8.8	8.6
W11B06		3.15	−9.6	8.7
W11B12		3.38	−9.2	7.3
W11B24		3.19	−8.2	
W11B26		3.41	−7.3	7.4
W11B27		3.41	−8.2	6.6
X10C01		2.99	−9.8	8.8
X11B17		3.05	−8.6	8.0
X11B20		3.35	−11.7	8.7
X11B22	18.15	3.25	−9.1	8.8
X11B23		3.05	−10.3	8.5
X11B24		3.23	−13.0	9.4
X11B32		3.47	−9.2	8.2
X11B34		3.50	−11.4	6.5
X11B50	18.47	3.29	−9.4	8.9
X11C05		3.57	−8.0	7.0
X11C08		3.21	−8.2	7.6
X11C15		3.44	−9.0	7.8
X11C16		3.42	−7.4	8.4
X11C21		3.38	−7.8	7.9
X11C25		3.54	−8.4	8.5
X11C36		3.38	−9.2	8.4
MNDF03	3.74	3.34	−9.5	9.3
MNDF11	13.25	2.91	−9.1	9.7
O13D01	8.08	3.11	−8.4	8.9
R12A04	5.31	3.24	−9.8	8.6
S11D04	8.25	3.09	−10.4	9.7
W11A17	14.29	3.19	−8.1	7.5
X11C18		3.51	−9.6	9.0

TABLE 2—*Continued*

Burial	Extraction yield (%)	C/N ratio	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
Mean	9.31	3.31	−9.0	8.3
SD	4.72	0.17	1.1	0.7
Min	2.49	2.91	−13.0	6.5
Max	18.47	3.57	−7.3	9.7
Number	17	47	47	46
Baum (33 RO 4)				
B329.111	6.13	3.14	−11.9	8.0
B329.112	4.69	3.00	−11.0	7.8
B329.119	25.51	3.25	−10.3	7.2
B329.146	7.35	3.24	−12.5	7.9
B329.149	21.39	2.86	−10.1	7.8
B329.172	22.46	3.45	−13.0	7.3
B329.175	6.56	3.17	−21.0	6.1
B329.178	5.36	3.42	−11.7	8.3
B329.185	4.51	3.76	−11.9	8.5
B329.216	4.60	3.05	−11.7	8.2
Mean	10.86	3.23	−12.5	7.7
SD	8.13	0.25	2.9	0.7
Min	4.51	2.86	−21.0	6.1
Max	25.51	3.76	−10.1	8.5
Number	10	10	10	10
Feurt (33 SC 6)				
F328.893	3.48	3.32	−12.1	7.8
F328.895	14.41	3.13	−11.1	7.1
F328.897	5.23	3.52	−12.0	8.3
F328.910	6.56	3.45	−9.7	7.6
F329.218	18.59	3.41	−9.9	8.1
F329.221	4.77	3.32	−11.1	8.3
F329.232	4.82	3.21	−11.6	8.5
F329.238	5.94	3.47	−10.6	8.4
F329.241	4.80	3.40	−11.9	7.0
F329.272	5.14	3.64	−11.8	8.1
F329.346	14.57	3.53	−10.3	8.0
F329.360	7.03	3.30	−10.0	7.1
F329.367	14.21	3.50	−9.3	8.3
F329.373	11.83	3.60	−10.7	7.9
F329.387	4.23	3.47	−11.0	7.8
F329.389	18.46	3.07	−11.4	7.8
F329.392	4.63	3.38	−10.4	6.5
F329.396	6.75	3.25	−9.9	7.5
F328.917	15.60	3.47	−9.7	7.9
F329.241	4.80	3.30	−11.9	
Mean	8.79	3.39	−10.83	7.78
SD	5.08	0.15	0.87	0.52
Min	3.48	3.07	−12.14	6.48
Max	18.59	3.64	−9.35	8.46
Number	20	20	20	19

TABLE 2—*Continued*

Burial	Extraction yield (%)	C/N ratio	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
Gartner (33 RO 19)				
G328.780	14.55	3.10	−11.2	8.7
G328.781	21.71	3.03	−9.4	7.9
G328.782	7.51	3.33	−10.4	8.0
G328.783	22.83	3.13	−10.2	8.2
G328.785	6.90	3.36	−10.6	7.8
G328.786	8.44	3.22	−11.2	8.3
G328.788	5.43	3.13	−11.1	7.9
G328.789	5.51	3.20	−10.7	8.0
G328.792	20.71	3.11	−12.3	9.0
G328.793	15.02	3.12	−10.3	8.2
G328.796	8.53	3.07	−11.5	8.5
G328.797	6.69	3.34	−12.7	8.7
G328.802	10.11	3.16	−13.8	8.3
G328.790	7.72	3.31	−10.6	8.0
G329.087	14.72	3.29	−20.5	8.1
Mean	11.76	3.19	−11.8	8.2
SD	5.86	0.10	2.6	0.3
Min	5.43	3.03	−20.5	7.8
Max	22.83	3.36	−9.4	9.0
Number	15	15	15	15
Sun Watch (or Incinerator, 33 MY 57)				
SV01-83	7.00	2.90	−10.4	8.5
SV02-71	5.34	2.97	−11.0	7.7
SV03-76	14.93	3.55	−11.0	7.8
SV03-78	6.98	3.06	−10.9	8.2
SV05-79	6.18	3.10	−11.4	8.0
SV05-80	6.45	3.36		9.0
SV06-75	8.56	2.88	−9.8	8.2
SV08-77	5.46	3.05	−11.2	8.7
SV09-77	15.95	3.02	−11.2	7.9
SV12-72II	3.39	3.74	−11.9	8.5
SV13-73	9.49	3.04	−11.3	8.3
SV14-73	11.95	3.07	−11.9	7.9
SV15-74	6.43	2.88	−11.7	7.6
SV17-72	8.27	2.70	−10.5	8.7
Mean	8.31	3.09	−11.1	8.2
SD	3.52	0.27	0.6	0.4
Min	3.39	2.70	−11.9	7.6
Max	15.95	3.74	−9.8	9.0
Number	14	14	13	14
Wickliffe (15 BA 4)				
W88-004	11.42	3.04	−7.9	7.8
W88-006	18.88	3.01	−10.2	7.6
W88-018	5.53	2.97	−9.8	8.3
W88-030	7.52	3.20	−10.5	8.4
W88-058	6.84	3.17	−10.3	
W88-083	18.26	2.94	−9.8	8.5
W88-086	13.27	3.16	−9.2	8.1
W88-090	16.34	3.12	−8.8	8.3
W88-104	10.61	3.05	−8.9	8.1
W88-105	9.44	3.11	−9.8	8.4
W88-108	13.95	2.79	−8.6	9.4
W88-131A	5.45	3.02	−9.2	8.5
W88-135	17.41	3.05	−11.0	8.0
W88-141	3.83	3.07	−9.3	7.5
Mean	11.34	3.05	−9.5	8.2
SD	4.94	0.10	0.8	0.5
Min	3.83	2.79	−11.0	7.5
Max	18.88	3.20	−7.9	9.4
Number	14	14	14	13

The $\delta^{13}C$ values for three of the Fort Ancient sites (Baum, Gartner, and Sun Watch) were, on average, more negative than −11.0‰. In contrast, average values for the two Middle Mississippian sites were less negative than −10.0‰. The average for the Feurt sample (at −10.8‰) was intermediate in value. According to an analysis of variance comparing the six sites, the sites can be placed in two groups that are significantly different from each other, but that are not significantly different within each group (Table 3). One group is composed of the Middle Mississippian sites of Angel and Wickliffe. The average values for these sites are not significantly different from each other, but they are significantly different from any of the Fort Ancient sites. An identical pattern holds among the Fort Ancient sites when they are compared to the Middle Mississippian ones. Human stable carbon-isotope ratios clearly show that Middle Mississippian and Fort Ancient populations in this sample consumed diets of significantly different isotopic composition.

The standard deviations of the samples are relatively small (Schurr 1992), indicating relatively little dietary variation within each population. Even at Angel, the most complex site, the stable carbon-isotope ratios of three possible elite burials from Angel charnel houses (Burials MNDF03,

Table 3
Analysis of Variance: Human $\delta^{13}C$ Values by Site

Site	Number of specimens	Mean $\delta^{13}C$ (‰)	Standard deviation	Groups without significant differences	
Baum	7	−11.7	0.90	***	
Gartner	14	−11.1	1.13	***	
Sun Watch	9	−11.1[a]	0.41	***	
Feurt	20	−10.8	0.87	***	
Wickliffe	13	−9.6	0.82		***
Angel	47	−9.0	1.07		***

[a] Identical to value of −11.2 ± 0.6 previously reported (Conard 1988) for 26 burials from the site.
*** Analysis of variance: $F_{(5,104)} = 23.7625$, $p < .0001$.

MNDF11, and R12A04) were within one standard deviation of the average for all burials from the site. Our sample therefore suggests that elite and nonelite diets at Angel contained identical amounts of maize, a finding that further reinforces our concepts about the relatively small scale of this society.

The isotopic composition of maize (Fig. 2) from the sites indicates that the carbon-isotopic variation within a maize sample from a single site is greater than the variation between sites, results consistent with a recently reported study of isotopic variability in modern and archaeological maize (Tieszen and Fagre 1993). There appears to be no significant difference in the $\delta^{13}C$ values of the maize from the individual sites, and the most reasonable interpretation of the human $\delta^{13}C$ values is that the people from the Middle Mississippian sites of Wickliffe and Angel ate significantly more maize than those at the Fort Ancient sites of Baum, Gartner, Feurt, and Sun Watch. We conclude that there is a significant association between human $\delta^{13}C$ values as measures of agricultural intensification and of social complexity for our sample. This is evidence that the difference in social complexity between the Fort Ancient tribes and the Middle Mississippian chiefdoms was supported by agricultural intensification.

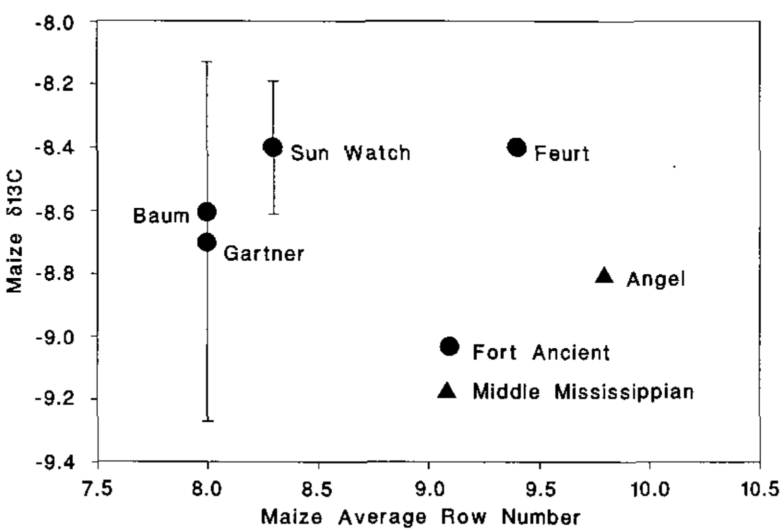

FIG. 2. Maize $\delta^{13}C$ values by maize row number.

DISCUSSION

The results of the stable carbon-isotope analyses can be compared with other indirect measures of agricultural intensification to identify how the differences in maize consumption might have been created and maintained. As noted above, the nature of the database requires generalized comparisons at this time. The following discussions of the relations between maize consumption and other indirect indications of agricultural intensification from these sites therefore provide tentative hypotheses that can be refined through more systematic studies in the future. Variations in several different indirect measures of agricultural intensification are summarized in Table 4.

General comparisons of the soil fertility in the vicinity of each site indicates that Angel and Wickliffe appear to have been located in close proximity to greater areas of agriculturally productive soils than was the case for the Fort Ancient sites of Baum, Gartner, Feurt, and Sun Watch. The Angel site is located on a low terrace above extensive tracts of floodplain (Black 1967) and Wickliffe is located on the edge of a loess-covered bluff above the Mississippi River floodplain in close proximity to fertile soils that were easily worked. The agricultural potential of the soils adjacent to the Fort Ancient sites of Baum, Gartner, Feurt, and Sun Watch are more difficult to determine because there is no regional standard that can be used to compare soils throughout the Ohio drainage. Based on site location, however, the Feurt site was probably in a setting with slightly higher fertility than those of the other sites, as it was located along the Scioto River near its confluence with the Ohio; Mills (1917) commented on the high agricultural productivity of the area relative to the settings of Baum and Gartner. With respect to soils, the Feurt site location appears intermediate between the locations of the three other Fort Ancient sites (which are on interior drainages) and those of the Middle Mississippian sites (immediately adjacent to large segments of fertile floodplain).

These observations are consistent with previous studies, which noted that Middle Mississippian sites were preferentially located where soils of high agricultural productivity were readily available (Ward 1965), especially floodplain soils that could be annually renewed (Peebles 1978; Smith 1978). Fort Ancient occupations were less closely tied to highly fertile soils. In the Ohio Valley, there is a striking correlation between the limits of Middle Mississippian settlement and the presence of wide floodplains, with Middle Mississippian sites being exclusively confined to the lower Ohio Valley where the floodplains are relatively broad and being absent upriver from the Anderson River in Indiana and adjacent parts of Indiana and Kentucky where unglaciated landscapes exhibit narrow flood-

Table 4
Comparisons between Some Indirect Measures of Agricultural Intensification

Site	Availability of productive soils	Hoes[a] Shell	Hoes[a] Stone	Storage	Maize av row number	Maize consumption ($\delta^{13}C$, ‰)
Baum	Low	++	+	Below ground	8.0	-11.7 ± 0.9
Sun Watch	Low	++	–	Below ground	8.3	-11.1 ± 0.4
Gartner	Low	++	+	Below ground	8.0	-11.1 ± 1.1
Feurt	Medium	++	–	Above ground	9.4	-10.8 ± 0.9
Wickliffe	Very high	+	++	Above ground	ca. 9.8	-9.6 ± 0.8
Angel	High	+	++	Above ground	9.8	-9.0 ± 1.1

[a] Key: (++) common, (+) present but rare, (–) absent.

plains (Black 1967; Green and Munson 1978; Muller 1986; Redmond 1991). It is thus difficult to escape the conclusion that Ohio Valley Middle Mississippians were deliberately selecting the most productive agricultural soils.

Access to fertile floodplain soils was apparently maintained in part by the use of above-ground storage facilities. The satisfactory storage of an annual surplus is an important precondition for the maintenance of completely sedentary populations and of surpluses that could be utilized by elites. Subsurface storage pits were reported from the Fort Ancient sites of Baum (Mills 1906), Gartner (Mills 1904), and Sun Watch (Heilman and Hoefer 1980; Wagner 1987:39) but not at Feurt (Mills 1917). Neither were they present at the Middle Mississippian sites of Angel (Black 1967), or Wickliffe (Wesler, personal communication). Above-ground corn cribs or barbacoas were presumably used for storage at these three sites. Subsurface pits would be advantageous if the village was abandoned during part of the year because the stored crops would be hidden. The occupants of Baum, Gartner, and Sun Watch may have abandoned their villages for at least part of the year during the winter months in a subsistence pattern similar to that recorded ethnographically for the Miami and Potawatomi (Fitting and Cleland 1969). Above-ground storage at Feurt, Angel, and Wickliffe may indicate that the sites were occupied throughout the year, or they may simply indicate that these sites were located on soils that were unsuitable for subsurface storage. Such is certainly the case at Angel, where the high water table and clay subsoil made subsurface storage completely impractical. At the very least, subsurface storage facilities restricted the occupants of Baum, Gartner, and Sun Watch to site locations with good drainage. The occupants of Angel, Wickliffe, and Feurt did not face this restriction and could occupy locations in close proximity to productive floodplain soils even when these locations had poorly drained soils.

Technological advances are reflected in artifactual evidence, such as the presence of chipped stone versus shell hoes. The technology of Ohio Valley maize production was apparently a relatively simple form of swidden cultivation. The most demanding tasks in this form of cultivation were the clearing of land prior to planting and tilling of the soil during planting or subsequent cultivation. The tools used were limited to stone celts for girdling trees and mussel shell or stone hoes for cultivation. Chipped stone hoes of Mill Creek chert from Illinois or of Dover chert from Tennessee were widely distributed at Middle Mississippian sites across the Southeast, and debris from resharpening hoes are commonly found at households at the lowest levels of the Mississippian settlement hierarchy (Brown et al. 1990; Muller 1986:194; Welch 1991:173–174). Although the distribution of chipped stone hoes has been studied, there has been little discussion of exactly why these artifacts were manufactured and traded in relatively large numbers beyond the assumption that they were more efficient tools than digging sticks or shell hoes for cultivating floodplain soils (Griffin 1964:250). Chipped stone hoes could have been used to till heavy soils, but this does not seem to be the case based on Mississippian site locations. Perhaps stone hoes were most useful for tilling and cultivation in fields that had been cultivated for several years and contained dense growths of weeds with tough root systems or for deep tillage used to produce ridged fields (Turner and Doolittle 1978) that have been reported from some Mississippian sites (Gallagher 1992:115,122; Muller 1986:196). Mussel shell shoes (made of *Unio plicatus*), on the other hand, must have been used only for relatively light cultivation. At the Fort Ancient sites, shell hoes were most common, whereas stone hoes used for heavy cultivation predominate at the Middle Mississippian sites.

Both kinds of hoes were found at Baum and Gartner but stone (slate) hoes were much less common than shell hoes (Mills 1904, 1906). Only mussel shell hoes were found at Feurt and Sun Watch; stone hoes were absent (Mills 1917; Wagner, personal communication). In marked contrast, stone hoes of limestone or chert, hoe fragments, and over 300 flakes from bits of hoes (identified by their characteristic soil polish) were recovered during excavations at Angel but mussel shell hoes were relatively rare (Kellar 1967:442,462). Stone hoes are also known from Wickliffe where mussel shell hoes are rare as well (Wesler, personal communication). The predominance of stone hoes at Middle Mississippian sites compared to Fort Ancient sites could be an indication that Middle Mississippians were reusing the same fields for longer periods of time, implying more intensive use of the land.

Determining whether or not inhabitants of the sites selected the most productive maize varieties depends on certain assumptions because no direct data are available on the productivity of prehistoric races of maize grown under swidden cultivation. The principal races of maize grown in eastern North America can be distinguished by differing average numbers of rows of kernels on the cob (Blake 1986). During the late prehistoric period, the two most important races were Eastern Eight Row (similar to historic Northern Flint maize with 8 rows of kernels per cob) and Midwestern Twelve Row (a race with an average of 12 rows of kernels on each cob). Eastern Eight Row was primarily grown north of the Ohio Valley and in the Northeast, while Midwestern Twelve Row and modified forms of 8-rowed maize with slightly higher average row numbers (presumably a flour corn or a cross between Midwestern Twelve Row and Eastern Eight Row) were the predominant varieties grown in the Southeast between A.D. 1000 and 1600 (Blake 1986). Although it is now recognized that these general categories are an overly simplistic description of prehistoric maize varieties (Scarry 1993), the average row number is an easily measured quantity and remains the single most important morphological feature used to characterize prehistoric maize remains.

The prehistoric distribution of maize varieties is generally similar to the historic distribution of varieties around the turn of the century before scientifically improved varieties and commercial hybrids were available. At the end of the 19th century, 8-rowed flint corns predominated in the northeast and at high altitudes, flour corns (with higher row numbers) were most common in the south, and several varieties of dent corns (high row-numbered varieties introduced to North America during the historic period) were the dominant varieties in the corn belt where conditions were best for commercial maize farming (Bowman 1915; Galinat 1985; Myrick 1915). Agricultural handbooks written before the introduction of commercial hybrids (Bowman 1915; Myrick 1915) stress the great variability and adaptability of maize and the need to select varieties adapted to local conditions. The northerly distribution of 8-rowed maize is a reflection of the shorter growing season required by this race (Galinat 1985). During the historic period, Northern Flint was the preferred variety only in locations where more productive, higher row-numbered dent and flour corns would not reliably mature because the growing season was too short. The general similarities between late prehistoric and historic distributions of 8-rowed Northern Flint lead us to conclude that similar factors governed the distribution of this race during both periods. We assume that each prehistoric culture selected and cultivated the maize variety (or varieties) that were most reliable and productive under local conditions (Scarry 1993).

The maize samples from the Fort Ancient sites of Baum, Gartner, and Sun Watch had average row numbers near or equal to 8.0 rows of kernels per cob because Eastern Eight Row (or Northern Flint) was the sole or predominant maize variety grown at these sites. Fort Ancient maize exhibits relatively little racial variability between sites during the entire span of the Fort Ancient period, and the general uniformity of the Fort Ancient maize, both within and between sites, suggests that the Fort Ancient peoples practiced careful selection of seed for crops (Wagner 1987:229–230). The higher average row numbers of 9.4 to 9.8 for the maize samples from Feurt, Angel, and Wickliffe indicate that a mixture of 8-rowed and 12-rowed maize varieties were used at these sites. At Angel, the 8-rowed maize varieties appear to have been significantly different from the Northern Flint cultivated by the Fort Ancient peoples, suggesting that a slightly different 8-rowed maize was grown there. One or more additional varieties of maize with cobs having average row numbers of 10 to 12 were grown at Angel, along with forms of Midwestern Twelve Row maize commonly grown in the Southeast (Wagner 1991).

There is a significant linear relationship ($r^2 = 0.7793$) between human $\delta^{13}C$ values and the average row number of the maize they cultivated (Table 4), with higher maize consumption correlated with increased row number. There could be several possible explanations for this relationship. It could suggest that the higher rowed maizes produced higher yields than Northern Flint under certain conditions, and the greater variability and higher row numbers of the maize from Feurt, Angel, and Wickliffe may indicate experimentation with more productive varieties, or the cultivation of several varieties needing different growing conditions to optimize yields for local conditions or to minimize risks of crop failure. It may also indicate that the Fort Ancient populations faced climatic limits on the types of maize they could grow because they are at slightly higher latitudes than the Middle Mississippian sites. Or, as the sites of Baum, Gartner, and Sun Watch were occupied slightly earlier than the sites of Wickliffe, Angel, and Feurt, the higher average row numbers at the later sites may reflect an increase in the use of higher-row-number maizes over time in the Ohio Valley as the more productive, higher-row-numbered varieties were adapted to northern conditions, just as the cultivation of Northern Flint was extended northward during the 19th century (Mangelsdorf 1974). Finally, the greater number of maize varieties consumed at Angel and Wickliffe may reflect a more complex cuisine or maize ceremonialism at Middle Mississippian sites. Existing data on the relative productivities of prehistoric maize varieties are too limited for us to discriminate between these possible explanations for the observed relationship between average maize row number and human $\delta^{13}C$ values in this sample.

There is an especially striking correlation between site size and human $\delta^{13}C$ values (Fig. 3). There is a very strong ($r = 0.9951$) linear correlation between the occupied areas of sites and the stable carbon-isotope ratios of the humans that inhabited the sites for the six sites in our sample. The relationship between site size and maize consumption apparently holds true for other Fort Ancient and Middle Mississippian sites in the Ohio drainage region where both $\delta^{13}C$ values and site sizes have been reported. When the Fort Ancient sites of Slone and Hardin Village (Broida 1983) and the Mississippian sites of Averbuch and Arnold (Buikstra et al. 1988; Eisenberg 1991:72; Ferguson 1972) are added to the six sites in our sample, the correlation coefficient declines (to $r^2 = 0.7414$) but still remains significant. The differences in both maximal site size and in maize consumption between Fort Ancient and Middle Mississippian sites in

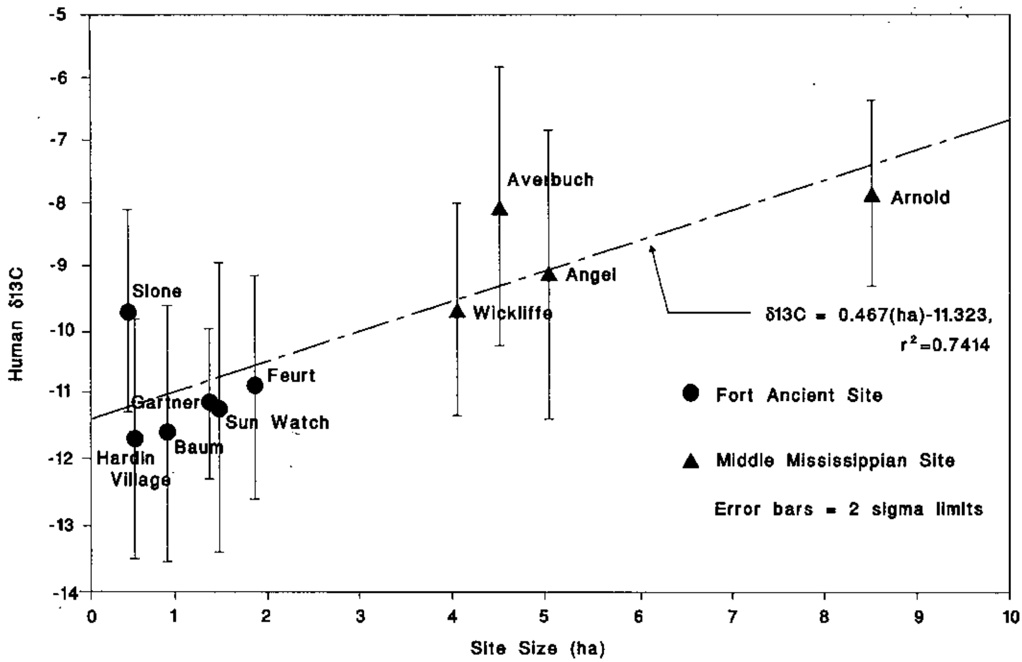

FIG. 3. Human $\delta^{13}C$ values by site size.

the Ohio Valley region are especially obvious in Fig. 3. The correlation between site size and $\delta^{13}C$ values could be improved by eliminating the Slone site from the regression. This site appears to have an anomalously high maize consumption, which may be a result of its location in a setting with limited wild and agricultural resources (Broida 1983). In such settings, a relatively high level of agricultural intensification may have been necessary to maintain the population of even a tribal-level community. Among the Middle Mississippian sites, the Averbuch site has the highest maize consumption relative to its size. This is consistent with the high population densities thought to have been present in the Nashville Basin, an environment removed from highly productive floodplains of major river valleys (Buikstra et al. 1988; Eisenberg 1991). The relationship between maize consumption and maximal site size is extremely strong evidence that increases in community size were supported by increased maize consumption in the Ohio Valley drainage.

CONCLUSION

This study has shown that there was a strong association between intensified maize consumption and social complexity for late prehistoric societies of the Ohio Valley, with the populations of the more complex Middle Mississippian chiefdoms consuming more maize than those of the less complex Fort Ancient tribal societies. The clear association between social complexity and maize consumption identified for this region is due to several factors. First, the sites used in this study represent a relatively short span of time lasting only three to four centuries at the longest. Second, the sites are confined to a relatively limited geographic area within a major river drainage of the midcontinental United States. This careful control over the temporal and geographic limits of the study has allowed the basic relationship between agricultural intensification and social complexity within this set of tribal- and chiefdom-level societies to stand out clearly.

Agricultural intensification is both a highly variable process and a relative one. Late prehistoric populations of eastern North America were supported by subsistence systems that combined maize agriculture with the cultivation of C3 plants such as squash and small-seeded starchy or oily annuals, along with the harvesting of many different wild plants and animals. In the Ohio Valley, both Middle Mississippian and Fort Ancient populations that inhabited locations with relatively limited wild resources (primarily locations far removed from large floodplains) apparently increased their reliance on maize. For other populations in locations with more abundant wild resources, agricultural intensification may have not been necessary. As noted above, this is reflected in the $\delta^{13}C$ values for Middle Mississippian sites from the Nashville Basin and for the Fort Ancient Woodside component at the Slone site in eastern Kentucky, where relatively high levels of maize consumption were maintained in relatively unproductive settings. Parallel relationships between maize intensification and environmental productivity apparently existed for both Ohio Valley Middle Mississippian and Fort Ancient societies but with an overall difference in the minimum level of intensification that each type of society maintained. In other regions with higher environmental productivities, the relations between maize intensification and social complexity may have been much weaker. For example, the American Bottom region was dominated by the Cahokia site (the largest and most complex Middle Mississippian site in eastern North America), but stable carbon-isotope ratios reported from that region are generally lower than those for the Ohio Valley sites. The inhabitants of the American Bottom may have been able to intensify their exploitation of wild foods or other domesticates instead of producing more maize (Buikstra and Milner 1991; Lopinot 1992). In combination, these studies reaffirm the importance of carefully examining relations between population size, the productive system, and the local environment within each region.

This study also provides some clues about the factors which limit the long-term stability of one group of relatively simple chiefdoms. Both Angel and Wickliffe were able to maintain chiefdoms for several centuries, but these sites were both abandoned by the 15th century, and population densities in the lower Ohio Valley and the Ohio–Mississippi confluence region appear to have been so low during the period after A.D. 1400 that this region has been called the Vacant Quarter (Williams 1990). Middle Mississippian populations of the lower Ohio Valley may not have been able to sustain indefinitely the level of agricultural intensification necessary for long-term maintenance of their populations. The slow regeneration of fertility in temperate forest ecosystems undoubtedly placed severe limits on the agricultural productivity of a swidden system without domesticated animals or more advanced technologies that would allow shorter fallow periods.

The Fort Ancient tribes utilized a subsistence system that required less intensive maize consumption and that appears to have been more stable than the Middle Mississippian system. Over time, Fort Ancient populations adopted some features of Middle Mississippian culture, such as shell-tempered pottery, but they apparently never developed hierarchical societies. Some Fort Ancient populations persisted into the historic period (Henderson et al. 1992), so the Fort Ancient subsistence system was evidently stable enough to support the long-term existence of these societies.

The relative stabilities of these two ways of life—Fort Ancient tribes with less agricultural intensification and Middle Mississippian chiefdoms supported by agricultural intensification—may ultimately be a product of the evolutionary trajectories of these populations. The Fort Ancient adaptation appears to have developed *in situ* in the middle Ohio Valley and was apparently well attuned to the long-term limits of the Ohio Valley ecosystem. The Middle Mississippians, on the other hand, represent at the very least a cultural intrusion into a region that is well recognized as lying at the northernmost limits of the Southeastern biome, which supported the most complex Middle Mississippian societies (Black 1967; Muller 1986). The Middle Mississippian populations of the Ohio Valley, with a more intensive agricultural adaptation that may have been difficult to maintain on the northern border of the Southeast, did not share the long-term success of their less complex neighbors. Thus the relative stabilities of these two cultures may partly reflect their very different histories. We were forced to adopt a comparative approach in this study because occupations in the Ohio Valley just prior to the late prehistoric period and their relationships to later occupations are poorly known. It would now be very useful to conduct diachronic studies that could define the roles of increased maize consumption in the early evolution of both of these types of societies.

It is important to remember that we are contrasting Middle Mississippian chiefdoms with tribal societies. At other levels of contrast, these same relations between social complexity and intensified maize consumption may not be significant. For example, in comparisons of regions where large, complex chiefdoms appeared with regions which were inhabited by smaller scale chiefdoms, other factors, such as access to prestige goods via external trade networks, may have been critical for the appearance of the complex chiefdoms (Steponaitis 1991; Welch 1990). This conclusion is consistent with the stable carbon-isotope ratios from Angel and Wickliffe, where the two chiefdoms show no significant difference in maize consumption in spite of their differences in complexity. Intensified maize consumption may have been especially important in the transition from tribe to chiefdom, but less so in the transformation of simple chiefdoms into complex ones.

We clearly do not mean to imply that intensified maize production is the sole source or reason for increased social complexity in late prehistoric North America. However, it does seem likely that chiefdoms create conditions that encourage agricultural intensification compared to tribal societies in a given environment. This example shows how social complexity can be meaningfully related to indirect measures of agricultural intensification. Many such carefully constructed studies across many dimensions will be necessary to pick apart the complex phenomena so succinctly described by the term chiefdom.

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