Maize, Mounds, and the Movement of People: Isotope Analysis of a Mississippian/Fort Ancient
Region

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Abstract

The development of farming traditions has long interested archaeologists worldwide. The relationship between this process and human movement has become increasingly well defined in recent years. Here we examine this issue in a case study concerning the longstanding question of the spread of maize agriculture and Mississippian cultural traditions throughout much of the Eastern U.S. Although it has long been common to interpret the spread of Mississippian maize agriculture partially as a result of human migration, there have been very few direct studies of the question. We do so here by analyzing human tooth enamel from burials for $^{87}\text{Sr}/^{86}\text{Sr}$ and $\delta^{13}\text{C}$. Our results suggest that Fort Ancient societies adopted maize agriculture quickly with high levels of consumption at early sites. The intensity of maize consumption declined over time, however, in contrast to the current model. There is evidence for the presence of non-local individuals at early Fort Ancient sites, particularly Turpin, with the majority likely attributable to neighboring Mississippian regions. These developments occurred at some of the larger Fort Ancient sites by the mouths of the Great and Little Miami Rivers in Ohio where the most abundant evidence for Mississippian house styles and objects is concentrated.

The development of farming traditions has long interested archaeologists and anthropologists more generally, and the spread of agriculture by way of human movement has become a regular focus of study in recent years (e.g., Bellwood, 2005). More specifically, there has long been an interest in the spread of maize agriculture in the Eastern U.S. and particularly its intensification during Mississippian times. The use of this domesticate as a dietary staple and the often associated shift to village life is poorly understood. Of particular concern has been whether or not human movements were related to this process. Although it has been demonstrated that humans can be directly provenienced for some time (Price et al. 1994a), surprisingly few such studies have been done in the Eastern U.S. At the same time, arguments for long-distance human migration based on the distribution of Mississippian trade items and architecture have continued (e.g., Cook, 2008; Cook and Schurr, 2009; Pauketat, 2007). The Fort Ancient region in the Eastern U.S. is well-suited to explore this issue as it borders several Mississippian culture complexes. The recent standard narrative has been that Mississippians had little to do with this shift to maize agriculture and that the development of Fort Ancient villages and the intensification of maize was a relatively gradual process.

Initial interpretation of the origin of Fort Ancient culture posited that the founders were Mississippians that migrated into the region from the south and/or west. The main reason for the resulting development of the relatively less complex Fort Ancient societies was argued to be due to an environment less conducive to intensive maize agriculture (see Griffin, 1967) (**FIGURE 1**). More recently, attention has turned to the similarities between Fort Ancient and Mississippian cultures in social structure as reflected in household organization, authority positions, and village layout around central poles (Cook, 2008). Specific studies of the spread of shell-tempered pottery and maize agriculture also revealed a close connection between these Fort

Ancient sites and a number of Mississippian objects (Cook and Schurr, 2009). But what has been lacking is an indication of where the people themselves came from. In other words, as suggestive of Mississippian migration as the results from pottery temper, architecture, mortuary practices, and diet are, they are patterns with alternate explanations. What was needed to further refine the picture were direct measures of maize consumption and human movement in a controlled temporal context. Specifically, what is the trajectory of maize intensification and are there non-locals in the Fort Ancient region? If non-locals are present, at which sites are they located and when do they appear in the temporal sequence? Are sites with greater material evidence for extrarregional interaction more diverse in dietary and provenience measures? With these issues in mind, the following study examines two hypotheses:

Hypothesis 1: The consumption of maize intensified over time, with the earlier sites consuming less maize than the more recent ones.

It has long been assumed that the intensification of maize was a relatively slow process in the Fort Ancient region, with early sites (ca., A.D. 1000-1200) considered to mainly consist of hamlets with a few households that consumed less maize than the subsequent villages (ca., A.D. 1200-1400), and final sites being larger villages with more intensive maize consumption (ca., A.D. 1400-1650). Testing this hypothesis is critical for understanding the subsistence trajectory.

Hypothesis 2: Mississippians came into the Fort Ancient region. If so, this most likely occurred about A.D. 1400 or more recently. These individuals ate more maize than the locals and were more often associated with Mississippian artifacts.

Determining when Mississippians appear in the Fort Ancient region has important implications regarding the development of Fort Ancient culture and the intensification/spread

of maize agriculture more generally. If they are relatively early (circa A.D. 1000-1400), they clearly can be seen as contributors to initial developments in the cultural tradition. If they are relatively late (post-A.D. 1400), the contribution they had on Fort Ancient development is minimized, as the culture was well-established by that time. Refining our understanding of these two hypotheses has the combined benefit of linking the development of village life with subsistence shifts and the relationship of both processes with non-local movements of people. Furthermore, data gathered are also potentially useful for understanding intra-regional movements, reuse of monuments, and the specific ages individuals were when movement and dietary shifts occurred.

Previous Studies

The isotopic chemistry of the human skeleton is a regular part of the study of past diet and human movement. Isotopic ratios have been regularly employed in the environmental sciences and ecological studies to map the geographic movement of various materials and species (e.g., Blum et al., 2000, Feranec et al., 2007, Koch et al., 1994). The isotopic proveniencing of human remains was introduced in archaeology more than three decades ago for the investigation of residential change among prehistoric humans (Ericson, 1985; Krueger, 1985). Stable isotope ratios of several different elements have been investigated as possible indicators of movement by prehistoric peoples, including strontium, lead, sulfur, and oxygen (Katzenberg and Harrison, 1996; Slovak and Payton, 2011).

Studies have been conducted on human remains from a wide range of past times, locales, and societies and have regularly demonstrated the utility of strontium isotope analysis in

mobility studies (e.g., Copeland et al., 2011; Ezzo et al., 1997; Grupe et al., 1997; Knudson et al., 2004, 2005; Montgomery et al., 2000; Müller et al. 2003; Price et al., 1994a, 1994b, 1998, 2000, 2001, 2005; Price and Gestsdottir, 2005; Sealy 1989; Sealy et al. 1995). These studies have generally focused on one of two questions: the origins and life history of a specific individual or the question of migration in a group or population from a particular site or area. Other issues that may be influenced by or related to differences in place of origin are also of interest including status and gender differences, marriage rules, and demographic variation.

Several investigations have been conducted to date in the Midwest U.S. Hedman et al. (2009) measured $^{87}\text{Sr}/^{86}\text{Sr}$ in faunal remains from various archaeological sites in the U.S. Midwest to identify variation in strontium isotope ratios across the region. Samples of from white tailed deer were used in the study. These samples came from 18 archaeological sites in Illinois, Iowa, Indiana, Kentucky, Missouri, and Wisconsin. Their results demonstrated measurable variation in strontium ratios and indicate the potential of strontium analysis for addressing questions of origin and population movement in the region. Beehr (2011) used strontium isotopes to investigate levels of population movement in the Illinois and Ohio regions during the Middle Woodland period. This was accomplished by subjecting samples of human remains at two Illinois sites (Utica Mounds and Albany Mounds) and one Ohio site (the Hopewell Mound Group) to strontium isotopic analysis in order to detect non-local individuals to the site, along with faunal specimens to provide a baseline for comparison. The results of the study indicated three likely foreigners at Albany Mounds in Illinois, and seven at the Hopewell Mound Group in Ohio. All ratios for the individuals at the Utica Mounds were within the local range. Price et al. (2007) analyzed human remains from the site of Aztalan in southern Wisconsin, often considered an outpost of the Mississippian culture. The similarities between

the artifacts and architecture at Aztalan and Mississippian period sites to the south in Illinois have long been noted. The largest center of the Mississippian culture at Cahokia near East St. Louis, Illinois, has been cited as the likely home of the founders of Aztalan. The results from the analysis of strontium isotopes in human teeth and bone suggest that there were a number of foreign individuals among the locals at Aztalan. The isotopic signal for some of the foreigners' matches values from Cahokia, but does not prove that this was their place of origin. Slater et al. (2014) reported the first strontium isotope measurements on human remains from Cahokia itself along with a substantial number of baseline measurements from archaeological fauna. They utilized a local $^{87}\text{Sr}/^{86}\text{Sr}$ range of 0.7089-0.7097 to distinguish locals and non-locals among the burials. Approximately one-third of the human individuals analyzed exhibited non-local isotope ratios. Values fell both above and below the local Cahokia baseline range suggesting that non-local individuals were from a number of different areas. Non-local individuals were found in a variety of burial contexts documenting their integration into Cahokia society.

Methods

There are two primary sources of variation in ^{13}C in human diet — ^{13}C is more abundant in the oceans and in certain kinds of plants including maize (e.g., Schoeninger and Deniro, 1984; Tauber, 1981; van der Merwe and Vogel, 1978). Relative maize consumption is measured using the ratio $^{13}\text{C}/^{12}\text{C}$ (reported as $\delta^{13}\text{C}$, the standardized difference between the ratio in the sample and in a reference material). $\delta^{13}\text{C}$ values primarily reflect diet rather than geographic origins, but can be used as a tool to provenience individuals from different homelands if the plants in the human diets were significantly different.

We examined carbon isotopes in tooth enamel apatite to determine childhood diet. $\delta^{13}\text{C}$ values in enamel are not the same as in collagen due to apatite-collagen spacing, typically $\Delta_{\text{apa-col}}$ ranges from $4 \pm 1\%$ or greater (Hedges, 2003, Ambrose and Norr 1993, Tykot 2004). Enamel forms incrementally and reflects whole diets (Ambrose and Norr, 1993) but suffers from isotopic overprinting (see Sponheimer et al., 2009). When enamel forms initially, it contains between 20% and 33% of its final mineral content, which can take several months to complete (Balasse, 2002; Passey and Cerling, 2002). As a result of this extended process, there is considerable temporal mixing of $\delta^{13}\text{C}$ values in enamel. Here we focus on the whole cusp which should reflect the broader diet.

The basic approach for establishing the isotopic provenience of human remains involves the comparison of strontium isotope ratios in human tooth enamel to local, or baseline, levels from the place of burial. ^{87}Sr is a radiogenic isotope, a product of the slow decay of rubidium-87. The ratio of ^{87}Sr to ^{86}Sr ($^{87}\text{Sr}/^{86}\text{Sr}$) varies depending on the age and the amount of original rubidium in the rock. In general, older rocks and rubidium-rich rocks have more radiogenic ^{87}Sr . Strontium enters human tissue through the food chain, coming ultimately from local rocks and sediments. Because the half-life of ^{87}Rb is 49 billion years, the geologic ratio is unaffected on time scales of human history. To adjust for variation in the total amount of strontium, ^{87}Sr is measured relative to non-radiogenic ^{86}Sr .

Tooth enamel forms in the early years of life and remains chemically unchanged and is extraordinarily robust against post-depositional alteration (diagenesis) (e.g., Budd et al., 2000; Kohn et al., 1999; Lee-Thorp and Sponheimer, 2003). Enamel is largely a mineral, hydroxyapatite, $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$, composed primarily of calcium, phosphorous and oxygen.

$^{87}\text{Sr}/^{86}\text{Sr}$ from all water and food sources utilized by an individual are incorporated into skeletal tissue, with plants being the major contributor to strontium signatures (Burton and Price, 2000; Buzon and Simonetti, 2013). Tooth enamel has a dense structure that greatly minimizes diagenesis (Budd et al., 2000), is not affected by remodeling, and can be associated with particular developmental periods (Price et al., 2002; Sponheimer and Lee-Thorp, 1999). Non-local foods can also impact strontium ratios in human populations. Strontium is an indicator of what was eaten, where food was obtained, and so on. Therefore, we cannot rule out that non-local contributions of maize may be a contributing factor to anomalous $^{87}\text{Sr}/^{86}\text{Sr}$ values. That is, if identified, either people or the plants they consumed in large quantities originated in a separate locale.

Tooth enamel was sampled by lightly abrading the surface of a single cusp of a molar using a dental drill with a diamond burr to remove surface dirt and calculus. This cusp was then cut from the tooth with a crosscut blade, and any remaining dentine removed with a drill burr. If a clean cusp was not present, after abrading the surface a small chip was removed from the entire side of the molar. Samples weighing approximately 5 mg were dissolved in 5M nitric acid (HNO_3). The strontium fraction was purified using EiChrom Sr-Spec resin and eluted with nitric acid followed by water. Isotopic compositions were obtained on the strontium fraction using a VG (Micromass) Sector 54 thermal ionization mass spectrometer (TIMS) in the Department of Geological Sciences, University of North Carolina at Chapel Hill. All $^{87}\text{Sr}/^{86}\text{Sr}$ values from the UNC-CH laboratory are reported relative to a value of 0.710250 for the NIST SRM 987 standard (e.g., if the $^{87}\text{Sr}/^{86}\text{Sr}$ values for the standards analyzed with the samples average 0.710260, a value of 0.000010 is subtracted from the ratio for each sample). Total

procedural blanks for strontium typically are below 100 picograms, which is insignificant relative to the amounts of strontium in the samples.

$\delta^{13}\text{C}$ of tooth enamel carbonate was measured at the University of Arizona using an automated carbonate preparation device (KIEL-III) coupled to a gas-ratio mass spectrometer (Finnigan MAT 252). Powdered samples were reacted with dehydrated phosphoric acid under vacuum at 70°C in the presence of silver foil. The isotope ratio measurement is calibrated based on repeated measurements of NBS-19 and NBS-18 and precision is $\pm 0.1\text{ ‰}$ for $\delta^{18}\text{O}$ and $\pm 0.06\text{ ‰}$ for $\delta^{13}\text{C}$ (1s). The carbonate CO_2 fractionation for the acid extraction is assumed to be identical to calcite.

Sample Descriptions

Burials from seven sites are included in the present study: Anderson (n=12), Guard (n=12), Madisonville (n=16), State Line (n=9), SunWatch (n=23), Taylor (n=10), and Turpin (n=17 [this study]; n=50 [McCall, 2013]) (**TABLE 1**). The burial populations available for study are variable in terms of collection and curation practices. Anderson, Madisonville, and SunWatch have the most representative populations as these sites have been extensively excavated including burials from a wide variety of locations within the villages. The populations from Taylor and Turpin consist of individuals mainly excavated from mound contexts. Guard burials are from a small segment of the village in the southern part of the site, and none are from mound contexts. Few State Line individuals were available for study, and these were from the least systematically excavated contexts but did contain individuals from both mound and non-mound contexts.

Selection of individuals for analysis in this study involved consideration of several criteria. A relatively equal number of males and females from each site were included when possible. Also, representation both of higher status individuals (i.e., exotic grave goods, mound burial) and those lacking such distinctions were included as available. Both first molars and third molars were analyzed for this study. Comparing these teeth may be useful for refining our understanding of when long-distance moves may have occurred or whether there were any notable dietary preferences at different ages. In addition, premolars and canines analyzed in a recent study from the Turpin site were also included (see McCall [2013] for methods of analysis used in that study). That study was restricted to the Turpin site and focused on strontium, carbon, and nitrogen isotopes to examine potential relationships between diet, migration, and paleopathologies. The main findings were that maize was a significant part of the diet, women were deficient in protein, and relatively few individuals migrated into the area (McCall 2013: ii).

The sampled sites are distributed along the Great and Little Miami Rivers within two distinct glacial terrains (**FIGURE 2**). Guard and State Line are located near the mouth of the Great Miami River, while Madisonville and Turpin are located near the mouth of the Little Miami River. SunWatch is located in the upper part of the Great Miami River, and Anderson and Taylor are located in the upper part of the Little Miami River. SunWatch is the only site located within the recent (14-24,000 B.P.) Wisconsinan glacial till. The others are located to the south on or near the boundary of much older (130-300,000 B.P.) Illinoian glacial tills. The Illinoian settings are isotopically higher than the Wisconsin ones on the basis of previous studies of $^{87}\text{Sr}/^{86}\text{Sr}$ differences in Ohio's surface waters (Curtis and Stueber, 1972; Ohio Division of Geological Survey, 2005; Steele and Pushkar, 1973; Stueber et al., 1972). Given the geologic context, SunWatch should have an average $^{87}\text{Sr}/^{86}\text{Sr}$ of about 0.709 and the other sites should

have an average $^{87}\text{Sr}/^{86}\text{Sr}$ of about 0.710. These values are distinct from many neighboring regions including several with Mississippian cultural expressions long thought to be the source areas for individuals that may have moved into the Fort Ancient region (see **FIGURE 2**).

The study sites vary in terms of size and can be readily grouped into larger villages with multiple plazas (Madisonville, State Line, Turpin) and smaller villages with single plazas (Anderson, Guard, SunWatch, Taylor) (**FIGURE 3**). Site plans have been revealed through long-term excavations at these sites (Anderson [Essenpreis, 1982], Madisonville [Drooker, 1997], SunWatch [Heilman et al., 1988; see also Cook, 2008]), recent geophysical survey by the senior author and Jarrod Burks at three sites (Guard, Taylor, Turpin [Cook and Burks 2011]), and salvage excavations at one site (State Line [Vickery et al., 2000]) supplemented by inspection of historic aerial photographs by the senior author. Madisonville, State Line, and Turpin are not only substantially larger than the other sites but they are also on high terraces in areas of substantial environmental productivity in terms of arable land and diverse wetlands (oxbow lakes and backwater swamps).

All of the study sites contain Mississippian objects, most often are which a variety of pipes, pottery vessels, and pendants (**FIGURE 4**). However, State Line and Turpin contain an abundance of such items as well as the clearest evidence to date for numerous Mississippian wall trench houses (Cook and Genheimer, 2015; Vickery et al., 2000). Some of the Mississippian objects are clearly related to one or several neighboring Mississippian regions. For example, cross-in-circle shell gorgets illustrate connections between the study region and several neighboring Mississippian regions, whereas annular shell gorgets and Ramey knives are more specifically linked with the Cahokia region and the Illinois River (**FIGURE 5**). It has been

suggested that the large frog effigy pipe from Turpin is similar to those from the Cahokia region (Drooker 1997: 90). The large human effigy “prisoner” pipe is also relatable to forms seen in the Illinois Valley as well as the lower Ohio Valley (Drooker 1997: 90). However, others have suggested that this pipe may be from Tennessee (Cowan 1987: 29). Prisoner pipes are not common in Tennessee; they are more frequent in the Central Mississippi Valley. In short, this pipe has been likened to forms ranging geographically from the Middle Cumberland to the Central Mississippi Valley. These places were clearly connected in Mississippian times, thus this style or even particular pipe could easily have moved across this entire area. Pottery forms including Ramey-like and negative painted motifs are more relatable to Cahokia and Angel, respectively. Objects such as the whelk shell pendant, spud, and chunky stone are more widespread in their distribution but clearly common in Mississippian assemblages.

Chronological control has recently been well-established through an intensive AMS radiocarbon dating project focused on all sites except Madisonville and SunWatch as they are already well-dated. The main temporal question was which sites were attributable to the earlier part of the Fort Ancient sequence (ca. A.D. 1000-1400). In general, it had been assumed that there was minimal occupation of the region at this time, with Mississippian influences arriving later in the cultural sequence (after A.D. 1400) (e.g., Cook and Schurr, 2009; Pollack and Henderson, 1992, 2000). However, the new dates considerably alter this interpretation with the earliest sites (ca., A.D. 1000-1300) being Guard, State Line, and Turpin, followed by Anderson, SunWatch, and Taylor (ca., A.D. 1150-1450) (Cook and Comstock, 2014). Madisonville has long been known to have been in use mainly during the final Fort Ancient period (ca., A.D. 1400-1650) but a recent study also found that Anderson contained a notable occupation at this time as well (Cook and Comstock, 2014). On the basis of this refined chronology, it is clear that

Mississippian influence is earlier than we thought. The nature of that influence, particularly whether it involved movement of people and intensification of maize, is the focus of the present study.

In order to geographically contextualize the human strontium isotopic ratios, it is necessary to have baseline information on isotopic variation in an area under consideration (Price et al., 2002). To this end, enamel samples from animal teeth were obtained from each of the villages in the study and neighboring Mississippian sites. Rodents were selected with the assumption being that they are more likely to reflect local values as their feeding ranges are small and they are less likely traded as food or prestige items. In addition, previous studies of surface water sources in the study region (Stueber et al., 1972; Slovak and Paytan, 2011) as well as a recently established local range for $^{87}\text{Sr}/^{86}\text{Sr}$ in the Cahokia region (based on archaeological rodent samples) were considered (Slater et al., 2014). However, it remains difficult to specify a single place of origin as several different areas may have similar ranges of $^{87}\text{Sr}/^{86}\text{Sr}$ values.

Results

Box plots of human $\delta^{13}\text{C}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ values reveal considerable variation (**FIGURE 6; see also TABLE 2**) that was explored through a series of Kruskal-Wallis tests as the data are not normally distributed. Consideration of $\delta^{13}\text{C}$ values for first molars reveals a significant decrease in values over time with the highest values (less negative) at the earliest sites (Guard, State Line, Turpin) and the lowest values (more negative) at the more recent sites (Anderson, SunWatch, Taylor, and most notably Madisonville). This is the case for all sites ($p=0.002$) but also applies to the difference between the Early and Middle Period sites (i.e., excluding Madisonville)

($p=0.01$). Statistical comparison of $^{87}\text{Sr}/^{86}\text{Sr}$ ratios for first molars ($p<0.0001$) and third molars ($p<0.0001$) were also significant when comparing the seven sites.

Box plots of human $\delta^{13}\text{C}$ are also instructive when comparing first and third molars for individual sites. The Guard comparison revealed the only significant difference ($p=0.002$). At State Line and Taylor, the first molars have a narrower range than the record from the third molars, although neither case is significant. For Madisonville, the $\delta^{13}\text{C}$ values are higher for the third molars but this difference is also not significant. These distinctions do not appear to be simply related to uniform biological processes and may record distinctive weaning practices or changes in diet, among other possibilities. There are also several clear cases of individuals that consumed very little if any maize as part of their diet. This is most notable at Taylor and Turpin (see **FIGURE 6**).

On the basis of the box plot of $^{87}\text{Sr}/^{86}\text{Sr}$ values for first molars, the Turpin site is clearly anomalous as it contains the widest range with five distinct outliers (see **FIGURE 6**). Ranges of $^{87}\text{Sr}/^{86}\text{Sr}$ values for SunWatch third molars and Guard first molars are much narrower than for the other sites. Guard and State Line have significantly lower means than the other sites, for both first and third molars (see **TABLE 2**). The narrow range for Guard first molars may be due to the fact that the samples are all from the same part of the village. However, it is interesting that the range for third molars at Guard is much broader although this difference is not significant (see above). A potential reason for this pattern is that food sources became more variable in early adult diets (post-weaning). A similar trend is notable for Madisonville but again this difference is not significant. However, several other sites depict the opposite pattern, the range of $^{87}\text{Sr}/^{86}\text{Sr}$ values is significantly smaller by early adulthood at SunWatch ($p=0.001$). A similar trend is present at Turpin and State Line, although neither case is significant. Anderson

and Taylor do not exhibit notable or significant changes between the first and third molars in the ranges of their $^{87}\text{Sr}/^{86}\text{Sr}$ values.

Box plots and significance testing reveal much about the variation of $\delta^{13}\text{C}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ ratios. However, some potentially important patterns get lost if we restrict the analysis to this form of comparison. While other sites are accurately described in this way, Guard and State Line reveal more detailed information in scatterplots (**FIGURE 7**). Consideration of the $\delta^{13}\text{C}$ values indicates a slight increase in the third molar at Guard but not at State Line, perhaps reflecting something different about their respective diets. Consideration of $^{87}\text{Sr}/^{86}\text{Sr}$ values for first and third molars at Guard and State Line revealed bimodal distributions (see **FIGURE 7**). This could reflect two groups that utilized different sources for food procurement, particularly plants (see above), among other possibilities. More detailed studies need to be completed to better understand the variation between first and third molars in terms of $\delta^{13}\text{C}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ variation, although these cases show promise.

A more detailed plot of $^{87}\text{Sr}/^{86}\text{Sr}$ values for first molars along with all geographic ranges based on local surface water studies and/or rodent tooth samples from archaeological sites sheds light on the geographic origins of people sampled. A total of 27 (18%) individuals are potentially non-local to the region. Given the fact that strontium isotope analysis can only identify first generation migrants, this is a high proportion for sites that were occupied for several centuries. Turpin clearly possesses the broadest range of $^{87}\text{Sr}/^{86}\text{Sr}$ values for a single site, indicating that individuals analyzed from this site originated from the widest number of geographic locales or ate foods from the wider area, with seven individuals above the local range (**FIGURE 8**; see **TABLE 1**). One individual from Madisonville also has a $^{87}\text{Sr}/^{86}\text{Sr}$ value above the local range. The bulk of the SunWatch samples were consistent with the range of values

from the local Wisconsinan till. However, one individual buried at SunWatch better fits in the nearby Illinoian till, suggesting they originated from a site on that terrain. Nine individuals have $^{87}\text{Sr}/^{86}\text{Sr}$ values between the two local ranges: Anderson (n=2), SunWatch (n=1), Turpin (n=5), and Madisonville (n=1). Six individuals have $^{87}\text{Sr}/^{86}\text{Sr}$ values that are in a position of overlap between the local Illinoian range and a non-local one (Middle Cumberland): Guard (n=1), Turpin (n=4), and Madisonville (n=1). As expected, the majority of the samples fall within local ranges. The bulk of the Anderson, Guard, Taylor, Turpin, and Madisonville samples are consistent with the rodent samples from these sites that are located in the Illinoian terrain, and the majority of the SunWatch sample overlaps with the local range from the Wisconsinan till where the site is located.¹ However, while the State Line site is located on Illinoian till, the sample is divided, with 67% in the Illinoian one and 33% in either the Wisconsinan one or Cahokia. While the most parsimonious interpretation would be to assume the State Line population represents an aggregation of folks from the two local regions, three observations give us pause. First, when State Line was initially occupied, Fort Ancient sites were not yet established in the other local terrain. Second, the range for Cahokia is also consistent with the State Line group in question. Third, State Line has among the most abundant examples of Mississippian trade items and wall trench housing. In other words, there is reason to leave the option open for the longer-distance provenience.

The $^{87}\text{Sr}/^{86}\text{Sr}$ outliers are attributable to a wide number of neighboring Mississippian locales, including a few specific regions on the basis of the rodent samples gathered in the present study (see **FIGURE 8 and TABLE 1**), but it remains difficult to specify place of origin as several different areas have similar $^{87}\text{Sr}/^{86}\text{Sr}$ values. In addition to the possible connections between State Line and Cahokia, the low outliers from Anderson, SunWatch, Turpin, and

Madisonville are also consistent with this possibility. The high outliers from Guard, Turpin, and Madisonville are primarily comparable to the rodent samples from the Middle Cumberland and Prather Regions of central Tennessee and southern Indiana, respectively. One of the outliers at Turpin best fits with the Angel site, located in southwest Indiana. There is also the possibility that some of the high $^{87}\text{Sr}/^{86}\text{Sr}$ outliers originated to the north of the study region, in the Cuyahoga valley near Cleveland, Ohio where the South Park site is located. This region was not sampled randomly as there are notable connections between it and the study region (Drooker, 1997: 329-331).

To enrich our understanding of the potential outliers, we consider demographic, mortuary, and dietary characteristics (**TABLE 2**). There is no clear difference in sex for the outliers at Anderson, State Line, and Turpin; they include even numbers of males and females. However, only female outliers are present at Guard, Madisonville, and SunWatch, although the sample sizes at these sites are much smaller. The age profile of the potential non-locals appears to be representative of the population as a whole. The graves of two of the outliers at Turpin contain Mississippian objects, a chunky stone and a pottery vessel. The adult female with the chunky stone is best associated with our rodent samples from the Angel site, while the “Old Village” pottery vessel with an adult male is most likely from a different region but curiously not likely Cahokia, which is where this style and Ramey designs more generally are concentrated (see Hall 1991). These two individuals were also regular consumers of maize ($\delta^{13}\text{C} = -3.4\text{‰}$, -4.1‰). In contrast, the individual in the Late Woodland stone mound at Turpin had a diet with little maize ($\delta^{13}\text{C} = -14.7\text{‰}$). One of the Madisonville outliers consumed little to no maize ($\delta^{13}\text{C} = -11.9\text{‰}$) and also exhibited indicators of poor health and the bones appeared to have weathered, perhaps indicating transport some distance after death. One of the Turpin outliers

had a marked shift in diet between the formation of the first ($\delta^{13}\text{C} = -11.3\text{‰}$) and third ($\delta^{13}\text{C} = -2.3\text{‰}$) molars, with the former indicative of little to no maize and the latter a diet heavy on maize. The only other demonstrable shift occurred for a SunWatch individual that was unique is being interred with the whelk shell pendant (**FIGURE 9; see also FIGURE 4**). This individual is particularly interesting as he appears to be of local origin, based on strontium, but was a village authority based on the occurrence of the Mississippian status symbol (Cook 2008).

Temporal indicators gained through direct AMS radiocarbon dating of human bone add important information for several outliers. At State Line, one individual in each of the two main modes was located in a mound although lack of further provenience information makes it impossible to determine whether or not it was the same mound. These individuals are adult males and have been directly dated to the Early Fort Ancient Period (A.D. 1052-1278). The mounds in which they were interred were likely constructed during Middle Woodland times (ca. 100 B.C. to A.D. 400) on the basis of local artifact collections (Vickery et al., 2000). If so, the inclusion of Fort Ancient burials into these mounds were subsequent acts, perhaps a means of non-locals establishing a connection to local traditions (see Mann, 2005). At Turpin, one of the outliers is an adult male in the Late Woodland stone mound that dates to the corresponding time period (A.D. 651-867), and two of the outliers are associated with the Fort Ancient mound (an adult male and female, dated to A.D. 1024-1207 and A.D. 1169-1295, respectively). The individual at Turpin that transitioned to maize dates to A.D. 981-1162, while the individual at SunWatch with a marked uptake in maize consumption dates to A.D. 1240-1400. One individual at Taylor also consumed little-to-no maize (**see FIGURE 6**) and has been directly dated. In contrast to other dates from the site, this individual dates to the Hopewell period (A.D. 138-385). Furthermore, he was located in the only known mound at the site. This individual had copper

staining on his skull and mandible. The presence of a Hopewell individual suggests either that the Fort Ancient reused an earlier mound, or they disinterred him from elsewhere and incorporated him into a mound they constructed. The former seems more likely, and the mound is located on a bluff top, typical of many other examples of Hopewell mounds. The two outliers at Guard, one of which may be of a non-local origin, are young adult females (late teens or early 20s) that date to A.D. 1043-1250 and A.D. 1168-1274. A single grave good accompanied one of these individuals, a modified femur from another individual. In the main group at Guard, one individual (20-30 year old adult male) was interred with a Ramey Knife in his right hand. He was also directly dated (A.D. 1040-1251), which fits well with the time of the rapid development of Cahokia as a major Mississippian center. Interestingly, the strontium ratio for this individual indicates he was local in birth. This finding challenges simplistic models of migration based solely on the presence of exotic artifacts.

Three sites (Anderson, Madisonville, Sunwatch) have been excavated extensively enough to examine intrasite patterning of $^{87}\text{Sr}/^{86}\text{Sr}$. The two outliers in the Anderson population are positioned closest to the plaza in key burial groups located in the northwest and southwest parts of the village. Madisonville's two outliers are in the south and northwest portions of the main village pattern at the site. At SunWatch, the two clear outliers to the site population are located in unusual locations in the village (**FIGURE 10**), well outside the main burial zone but near the areas of the site previously interpreted to represent the main loci of Mississippian material culture and architectural forms (Cook, 2008). One of these individuals is an adult female, and the other's age and sex are indeterminate; neither had grave goods. Interestingly, these two individuals were the heaviest maize consumers at the site ($\delta^{13}\text{C} = -1.9\text{‰}$ and -1.5‰ [site mean for $\delta^{13}\text{C} = -3.8\text{‰}$]). This observation, along with the high $^{87}\text{Sr}/^{86}\text{Sr}$ values, supports the

inference that they likely came from the other local glacial terrain or possibly further away.

Additional support for an origin on the other glacial terrain is derived from a previous study of the provenience of shell-tempered pottery, where SunWatch was linked with the area near State Line (Cook and Fargher, 2008).

Conclusion

In this study, we focused on two hypotheses, related to changes in maize consumption over time and if and when Mississippians moved into the Fort Ancient region. The first hypothesis, that maize consumption intensified over time, is not supported by our findings. In fact, maize consumption significantly decreased over time. The second hypothesis, that Mississippians came into the Fort Ancient region, is supported by our findings. However, the expected timing of these movements is much earlier than hypothesized, occurring mostly in two parts of the earlier portion of the Fort Ancient cultural sequence (median dates cluster between A.D. 1071-1105 and A.D. 1231-1251). This finding supports the conclusion that Mississippian people were more instrumental in the origins of Fort Ancient culture than previously thought. As expected, the majority of these individuals were regular maize consumers and were sometimes interred with Mississippian-style artifacts. However, this was not always the case, revealing complex relationships between objects, people, and diet. A particularly good illustration of this is the local individual at SunWatch that was buried with a Mississippian-style authority symbol (whelk shell) and represents a significant shift toward maize over the course of his early years. A similar shift occurred for an individual at the Turpin site, although he lacked associated grave goods.

Consideration of $\delta^{13}\text{C}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ values from human enamel apatite provides important data for refining our understanding of the geographic origins and transition to a maize-focused diet during the Late Woodland/Fort Ancient transition in the study region. For sites considered here, $^{87}\text{Sr}/^{86}\text{Sr}$ values are most variable for the two earliest and largest sites (State Line, Turpin) positioned near the mouths of the Great and Little Miami rivers, respectively. These two sites are also the locales from which the majority of the Mississippian artifacts and houses have been located. Occupants of these villages (and Guard) consumed higher amounts of maize, based on $\delta^{13}\text{C}$ levels, than did the inhabitants of the upriver sites. This finding is consistent with an earlier study based on human bone collagen (Cook and Schurr, 2009). However, we are now in the position of being able to better examine temporal patterns and the relationship between individual diet and strontium indications of provenience such as we found with the individual at Turpin with a date range that spans the Late Woodland/Fort Ancient transition and his diet reflects a marked shift to maize. In the Great Miami Valley, some of the people buried at State Line could have been from the younger glacial terrain where SunWatch is located. However, given the lack of regional specificity in strontium isotope provenience, a longer distance origin cannot be ruled out.

The outlying $^{87}\text{Sr}/^{86}\text{Sr}$ values at State Line and Turpin support the conclusion that there were non-local individuals within these populations. These are most consistent with samples from rodent enamel at Angel, Middle Cumberland, and Prather which are contemporary Mississippian sites; however other locations cannot be ruled out (see **FIGURE 8**). The Turpin case is further interesting because the potential non-locals date to both Late Woodland and early Fort Ancient times. The individuals from the Fort Ancient period are coeval with the rapid coalescence of populations at Cahokia at about A.D. 1050 (Beck et al., 2007; Pauketat, 2007; see

also Slater et al. 2014). State Line is problematic as we cannot discern between the younger glacial terrain, where SunWatch is located, and Cahokia. Local strontium isotope ratios for SunWatch, overlap with that of Cahokia determined by archaeological fauna. So determining whether nonlocal individuals at State Line might represent immigrants from SunWatch or from the more distant Cahokia region is not possible on the basis of strontium isotope ratios alone. Furthermore, it is not possible to determine if anyone from the bulk of the SunWatch $^{87}\text{Sr}/^{86}\text{Sr}$ values could be from the Cahokia region. For example, the individual at SunWatch with the whelk shell appears to be local, but we cannot rule out a distant origin. The Cahokia comparison is not pulled randomly as there is ample evidence for some type of relationship and there are several other outliers in our study for which we have no other “fit” than Cahokia (see **FIGURE 7**). Regardless of where the outliers to the State Line region were from, one of them was interred in a mound that was likely initially constructed by Middle Woodland peoples. Similarly, at Taylor one of the earliest acts at the site involved burial in what we also interpret to have initially been a Middle Woodland mound. Furthermore, it is noteworthy that many of the non-locals at Cahokia ($^{87}\text{Sr}/^{86}\text{Sr}$ ranges from 0.7097 to 0.7110) (see Slater et al. 2014: Figure 5) are consistent with the local Illinoian glacial terrain examined here. While there are certainly other geographic locations that fit this range, it is possible that some of the non-locals at Cahokia were from the Middle Ohio Valley. Undoubtedly, movements between regions were both ways (see Anthony, 1990). In support of this scenario, there is Fort Ancient pottery at the Angel site (Black 1967), Kincaid (Cole 1951), and likely elsewhere.

Given the material connections between State Line and Turpin with the Angel, Cahokia, and Middle Cumberland regions (Cowan, 1987; Drooker, 1997; Oehler, 1973; Vickery et al., 2000) and early dates on several of the individuals in question, it is clear that there were likely

early movements of people and/or food from some of these areas as well as objects into the Fort Ancient region. This is not surprising, though it provides direct evidence from people themselves which was lacking in the original model (Griffin, 1943, 1967; see also Prufer and Shane, 1970). Fort Ancient culture is not wholly attributed to Mississippian migrants, although it is likely that they factored heavily into their origins making it vital to factor this into our understanding of the fabric of Fort Ancient culture. Reasons for a Mississippian presence in the Middle Ohio Valley are likely related to a variety of factors associated with the spread of a new way of life and could well have included would-be leaders, captives, marriage alliances, religious proselytizers, the quest for resources or markets, or all of the above. Importantly, there is little evidence that major centers such as Angel or Kincaid were intensively occupied if at all at this early point in time. In other words, the origin of Fort Ancient appears largely to have been coeval with that of neighboring Mississippian places.

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Note

¹ SunWatch was the only site with a major discrepancy in $^{87}\text{Sr}/^{86}\text{Sr}$ values between rodent samples obtained from the site and the human samples. While more samples from the site may clarify this issue, the human samples do match rather well previously obtained data from throughout the Upper Miami Valleys (see text). Therefore, we see the bulk of the SunWatch population as being from the general region where the site is located.

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Figure 1. Map of the Eastern U.S. with generalized locations of Mississippi regions with arrows denoting likely routes of movement (after Griffin 1967: Figure 5).

Figure 2. Map of the U.S. with location of study sites and associated glacial terrains (inset).

Figure 3. Schematic maps of sample sites, grouped into larger multi-plaza sites and smaller single plaza villages.

Figure 4. Select examples of Mississippian-style objects from the study sites (not to scale): a, Ramey knife [Guard]; b, human effigy pin [Turpin]; c, human effigy prisoner pipe [Turpin]; d, human effigy pin [Guard]; e, human effigy prisoner pipe [Turpin]; f, ceramic platform pipe [Turpin]; g, frog effigy pipe [Turpin]; h, negative painted pottery bowl rim [Turpin]; i, “Old Village” pottery jar rim sherd [Turpin]; j, Ramey-like design on pottery jar [Turpin]; k, spud [Guard]; l, whelk shell pendant [SunWatch]; m, cross-in-circle gorget [Anderson]; n, chunky stone [Turpin]; o, effigy pipe [Taylor]; p, annular shell gorget [Madisonville]).

Figure 5. Distribution maps for three trade items; cross-in-circle gorgets (top [after Drooker 1997: Figure 8-22]), annular shell gorgets (middle [after Drooker 1997: Figure 8-20]), and Ramey knives (bottom [after Vermilion et al. 2003: Figure 6]). (Note the more generalized connections for the cross-in-circle gorgets and the more specific connection for the annular gorgets and Ramey knives with the Cahokia and Central Illinois River valley region.)

Figure 6. Box plots for $\delta^{13}\text{C}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ values for the study sites (M1=first molar, M3=third molar).

Figure 7. Scatterplots comparing $\delta^{13}\text{C}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ values for the Guard and State Line sites (M1=first molar, M3=third molar).

Figure 8. Scatterplot of $^{87}\text{Sr}/^{86}\text{Sr}$ values for the study sites and known local and non-local ranges. (All data are shown except one outlier at Turpin [see Table 1]).

Figure 9. Absolute differences for $\delta^{13}\text{C}$ (top) and $^{87}\text{Sr}/^{86}\text{Sr}$ (bottom) values for the study sites.

Figure 10. Location of $^{87}\text{Sr}/^{86}\text{Sr}$ outliers at the SunWatch site.

Table 1. Strontium and carbon isotope values for all human and rodent samples. (M1 denotes first molar, M2 denotes third molar, * denotes samples from previous study (McCall 2013), # denotes a canine sample from the previous study when all others in that analysis were premolars, and shaded boxes denote the same individuals sampled by both studies [different teeth for each].)

Guard	⁸⁷ Sr/ ⁸⁶ Sr (M1)	⁸⁷ Sr/ ⁸⁶ Sr (M3)	δ ¹³ C _{apa} (M1)	δ ¹³ C _{apa} (M3)
Bur 10	0.71015	0.71055	-1.5	0.0
Bur 15	0.71001	0.70992	-1.1	-1.1
Bur 2	0.71004	0.70981	-3.1	-1.7
Bur 21	0.71015	0.71036	-2.9	-1.6
Bur 3	0.71013	0.70980	-1.3	-1.5
Bur 8	0.71080	0.71045	-1.1	-0.2
Bur 9	0.70979	0.70972	-2.8	-1.1
Bur 11	0.71011	0.70997	-2.7	-0.8
Bur 12	0.71017	0.70988	-2.0	-1.2
Bur 14	0.71011	0.70983	-3.2	-1.6
Bur 20	0.71009	0.71033	-2.9	-0.5
Bur 5	0.71004	0.70990	-2.2	-0.3

State Line	⁸⁷ Sr/ ⁸⁶ Sr (M1)	⁸⁷ Sr/ ⁸⁶ Sr (M3)	δ ¹³ C _{apa} (M1)	δ ¹³ C _{apa} (M3)
502 (2nd ind) Miller Pit	0.70894	0.70914	-5.8	-7.1
507 Bur. 6	0.70913	0.70914	-3.1	-5.0
A 15482	0.70985	0.70970	-2.2	-0.0
A 24471 (no prov.) acc. 1991.44	0.70975	0.70966	-0.7	0.00
503 - 6 (mound)	0.70987	-	-2.0	-
503-4 (mound)	0.70908	0.70894	-2.6	-3.3
A 15481	0.70993	-	-2.7	-
502 (1st ind) Miller Pit	0.71028	0.70977	-3.4	-0.4
506 Bur. 5	0.70971	0.70972	-2.3	-3.5

SunWatch	⁸⁷ Sr/ ⁸⁶ Sr (M1)	⁸⁷ Sr/ ⁸⁶ Sr (M3)	δ ¹³ C _{apa} (M1)	δ ¹³ C _{apa} (M3)
B1/76	0.70916	0.70891	-2.9	-1.8
B12i/72	0.70889	0.70876	-4.0	-2.5
B6/72	0.70933	0.70900	-2.6	-1.1
Smith B 18	0.70912	0.70886	-4.1	-2.0
B1/77	0.70899	0.70899	-4.3	-2.3
B2/71	0.70901	0.70892	-3.7	-2.2
B2/78	0.70902	0.70910	-7.3	-7.0
B2/82	0.70895	0.70887	-2.1	-2.2
B5/79	0.70931	0.70894	-4.1	-5.1
B6/75	0.70874	0.70892	-3.1	-2.0
B9/77	0.70917	0.70905	-2.3	-5.8
B12iii/72	0.70920	0.70906	-4.4	-1.2
B14/73	0.70912	0.70896	-4.4	-3.0
B16/72	0.70926	0.70905	-2.8	-3.5
B3/71	0.70884	-	-5.5	-
B4/78	0.70927	-	-3.1	-
B9/74	0.70916	0.70909	-3.2	-5.2
Smith B29	0.70918	0.70902	-5.3	-2.3
B2/79	0.70934	0.70898	-4.9	-7.2
B4/77	0.70954	0.70894	-1.5	-2.3
B5/78	0.70923	0.70912	-8.4	-2.4
B8/74	0.70925	-	-6.5	-
Smith B 3	0.70963	0.70883	-1.9	-1.1

Anderson	⁸⁷ Sr/ ⁸⁶ Sr (M1)	⁸⁷ Sr/ ⁸⁶ Sr (M3)	δ ¹³ C _{apa} (M1)	δ ¹³ C _{apa} (M3)
Bur 39	0.70999	0.71015	-4.1	-3.2
Bur 41	0.71002	0.70992	-3.9	-1.3
Bur 56	0.71013	0.70979	-2.1	-2.0
Bur 57	0.71026	0.70998	-2.6	-1.8
Bur 60	0.70940	0.70937	-1.8	-2.1
Bur 67	0.70947	0.70912	-4.9	-4.3
Bur 69	0.70984	-	-3.1	-
Bur 77	0.70971	0.70957	-3.3	-2.0
Bur 78	0.71004	0.70977	-3.9	-0.9
Bur 89	0.71008	0.70988	-3.6	-4.5
Bur 91	0.70984	0.70969	-5.2	-1.8
Bur 92	0.71022	0.71027	-6.8	-4.2

Taylor	⁸⁷ Sr/ ⁸⁶ Sr (M1)	⁸⁷ Sr/ ⁸⁶ Sr (M3)	δ ¹³ C _{apa} (M1)	δ ¹³ C _{apa} (M3)
41580A	0.70970	0.70958	-4.2	-4.4
41573	0.70993	0.70978	-2.6	-1.3
41574	0.71009	0.70998	-3.7	-6.6
41578A	0.70999	0.71014	-4.6	-5.8
41581	0.70981	0.71013	-15.3	-15.0
41592	0.70999	0.70989	-6.9	-3.8
41575	0.71025	-	-1.6	-
41591	0.70991	0.70961	-3.9	-0.5
41577B	0.71044	0.71011	-2.9	-1.9
41588	0.71027	-	-4.6	-

Madisonville	⁸⁷ Sr/ ⁸⁶ Sr (M1)	⁸⁷ Sr/ ⁸⁶ Sr (M3)	δ ¹³ C _{apa} (M1)	δ ¹³ C _{apa} (M3)
57668.0.1	0.71051	-	-6.1	-
57555.0.2	0.71066	0.71071	-2.5	-1.8
57570.0.2	0.71059	0.71091	-4.6	-4.6
57612.0.1	0.71073	0.71074	-2.4	-2.3
57591a.1	0.71059	0.70958	-11.5	-8.2
57592A.1	0.71065	-	-6.6	-
58473.0.1	0.70993	-	-7.1	-
59732.0.1	0.71046	0.71032	-9.5	-6.9
57643.0.2	0.71022	0.71033	-10.1	-11.9
57716.0.1	0.71089	-	-5.9	-
58005.0.1	0.71006	-	-6.9	-
57546.0.1	0.71025	-	-11.0	-
58041.0.1	0.70944	-	-11.9	-
N192.0.2	0.71070	0.71032	-1.6	-2.6
57691.0.1	0.71026	-	-4.8	-
58541.0.2	0.71002	0.70973	-1.6	-1.3
58562.0.1	-	0.71076	-	-4.4
61575.0.2	-	0.71067	-	-4.4
58020.0.2	-	0.71073	-	-4.5

Turpin (this study)	$^{87}\text{Sr}/^{86}\text{Sr}$ (M1)	$^{87}\text{Sr}/^{86}\text{Sr}$ (M3)	$\delta^{13}\text{C}_{\text{apa}}$ (M1)	$\delta^{13}\text{C}_{\text{apa}}$ (M3)	Turpin (McCall 2013)	$^{87}\text{Sr}/^{86}\text{Sr}_{\text{apa}}$	$\delta^{13}\text{C}_{\text{col}}$
952/144 #94	0.71043	0.71010	-2.1	-0.5	952/47*	0.70935	-9.7
952/156 #75	0.70953	0.70942	-2.7	-1.6	952/50*	0.70975	-10.6
952/171 Bur 23	0.71000	0.71012	-0.9	-1.7	952/53*	0.70963	-10.2
952/184 Bur 158	0.70995	0.70972	-3.4	-1.6	952/56*	0.71069	-9.1
952/225 #131	0.71015	0.70984	-4.1	-2.9	952/57*	0.70991	-12.2
952/244 #116	0.71119	0.71022	-11.3	-2.3	952/59*	0.70961	-9.1
952/134 #62	0.71019	0.70985	-3.6	-1.5	952/65*	0.70969	-9
953/91	0.71152	0.71065	-14.7	-14.5	952/66*	0.70994	-9.9
952/117 Bur 167	0.71085	0.71098	-2.5	-1.4	952/69*	0.70946	-9.8
952/146 #73	0.71040	0.71012	-2.9	-0.7	952/70*	0.71016	-9.6
952/50 Bur 4	0.71004	-	-2.6	-	A25.011*	0.71047	-10.2
952/75	0.70982	-	-3.2	-	A25.014-061*#	0.71065	-9.8
952/81	0.71059	0.71005	-2.9	-1.8	A25.013*	0.71250	-11.1
A25, 060	0.71101	0.71046	-4.1	-3.2	A25.015-139*	0.70965	-10.3
245-252	0.70949	0.70931	-15.2	-14.3	A25.017*	0.71032	-10.4
952/213 #117	0.70996	0.70979	-1.4	-0.3	A25.018*#	0.70973	-9.1
952/282 #243	0.70987	-	-1.9	-	A25.022*	0.70969	-13.4
					A25.023*	0.70979	-8.3
					A25.044*	0.71035	-10
					952/153*	0.71346	-11.4
					952/155*	0.71032	-10.4
					952/176*	0.70985	-10.9
					952/115*	0.71032	-9.6
					952/119*	0.71092	-9.5
					952/125*	0.70981	-11.9
					952/156*	0.70974	-12.3
					952/152*	0.70977	-8.1
					952/163*	0.70999	-9.6
					952/123*	0.70982	-12.9
					952/143*	0.70983	-9.5
					952/111*	0.71026	-9.7
					952/131*	0.71000	-11
					952/161*	0.71032	-9.7
					952/102*	0.71004	-9.7
					952/101*	0.70991	-9.7
					952/113*	0.70983	-9.5
					952/128*	0.71181	-10.3
					952/151*	0.70990	-9.8
					952/197*	0.70986	-9.5
					952/200*	0.70981	-9.3
					952/213*	0.70991	-8.6
					952/192*	0.71084	-8.6
					952/212*	0.71039	-9.4
					952/237*	0.70983	-9.1
					952/37*	0.70948	-9.7
					952/222*	0.71090	-8.7
					952/223*	0.71275	-11.1
					952/211*#	0.70963	-9.8
					952/231*	0.70987	-8.5
					952/227*	0.70970	-9.1

SunWatch		⁸⁷ Sr/ ⁸⁶ Sr _a
squirrel	incisor	0.7099
squirrel	incisor	0.7101
squirrel	incisor	0.7101
squirrel	incisor	0.7100
rodent	molar	0.7101

Madisonville		
beaver	incisor	0.7100
groundhog	incisor	0.7104
groundhog	incisor	0.7107

State Line		
squirrel	incisor	0.7099
squirrel	incisor	0.7101
squirrel	incisor	0.7101

Taylor		
groundhog	incisor	0.7105
Squirrel	incisor	0.7105
Rabbit	incisor	0.7104

Turpin		
mole	incisor	0.7099
beaver	incisor	0.7096
beaver	incisor	0.7104
raccoon*	tooth	0.7100
raccoon*	tooth	0.7103
raccoon*	tooth	0.7109
porcupine*	tooth	0.7106
opossum*	tooth	0.7118

Guard		
groundhog	incisor	0.7104
squirrel	incisor	0.7106
squirrel	incisor	0.7109

Anderson		
beaver	incisor	0.7098
groundhog	incisor	0.7105
squirrel	incisor	0.7097

Jarman		
rodent	incisor	0.7117
rodent	incisor	0.7107
rodent	incisor	0.7107

Castalian Springs		
rodent	incisor	0.7118
rodent	incisor	0.7114
rodent	incisor	0.7112

South Park		
beaver	incisor	0.7124
woodchuck	incisor	0.7118
beaver	incisor	0.7107
rodent	incisor	0.7132

Angel		
rodent	molar	0.7129
rodent	molar	0.7137

Prather		
rice rat	molar	0.7113

Table 2. Descriptive Statistics for $^{87}\text{Sr}/^{86}\text{Sr}$ and $\delta^{13}\text{C}$ Values for First (M1) and Third (M3) Molars for Each Study Site. (M1 Denotes First Molar, M3 denotes Third Molar, and * Denotes that Outliers Were Removed)

SunWatch M1	$^{87}\text{Sr}/^{86}\text{Sr}$	$\delta^{13}\text{C}$
No. of observations	23	23
Minimum	0.7087	-8.3
Maximum	0.7096	-1.5
Range	0.0009	6.8
Median	0.7092	-4.0
Mean	0.7092	-4.0
S.D.	0.0002	1.7

SunWatch M3	$^{87}\text{Sr}/^{86}\text{Sr}$	$\delta^{13}\text{C}$
No. of observations	22	22
Minimum	0.7088	-7.5
Maximum	0.7091	-1.1
Range	0.0004	6.5
Median	0.7090	-2.3
Mean	0.7090	-3.5
S.D.	0.0001	2.1

Guard M1	$^{87}\text{Sr}/^{86}\text{Sr}$	$\delta^{13}\text{C}$
No. of observations	12	12
Minimum	0.7098	-3.2
Maximum	0.7108	-1.1
Range	0.0010	2.1
Median	0.7101	-2.4
Mean	0.7101	-2.2
S.D.	0.0002	0.7

Guard M3	$^{87}\text{Sr}/^{86}\text{Sr}$	$\delta^{13}\text{C}$
No. of observations	12	12
Minimum	0.7097	-1.7
Maximum	0.7106	0.0
Range	0.0008	1.7
Median	0.7099	-1.1
Mean	0.7100	-1.0
S.D.	0.0003	0.6

Turpin M1*	$^{87}\text{Sr}/^{86}\text{Sr}$	$\delta^{13}\text{C}$
No. of observations	17	17
Minimum	0.7095	-4.1
Maximum	0.7115	-0.9
Range	0.0020	3.2
Median	0.7101	-2.8
Mean	0.7103	-2.7
S.D.	0.0006	0.9

Turpin M3*	$^{87}\text{Sr}/^{86}\text{Sr}$	$\delta^{13}\text{C}$
No. of observations	14	14
Minimum	0.7093	-3.2
Maximum	0.7110	-0.3
Range	0.0017	2.9
Median	0.7101	-1.6
Mean	0.7100	-1.6
S.D.	0.0004	0.9

Taylor M1*	$^{87}\text{Sr}/^{86}\text{Sr}$	$\delta^{13}\text{C}$
No. of observations	10	10
Minimum	0.7097	-6.8
Maximum	0.7104	-1.6
Range	0.0007	5.2
Median	0.7100	-3.9
Mean	0.7100	-3.9
S.D.	0.0002	1.4

Taylor M3*	$^{87}\text{Sr}/^{86}\text{Sr}$	$\delta^{13}\text{C}$
No. of observations	8	8
Minimum	0.7096	-6.6
Maximum	0.7101	-0.5
Range	0.0006	6.1
Median	0.7099	-3.8
Mean	0.7099	-3.5
S.D.	0.0002	2.2

State Line M1	$^{87}\text{Sr}/^{86}\text{Sr}$	$\delta^{13}\text{C}$
No. of observations	9	9
Minimum	0.7089	-5.8
Maximum	0.7103	-0.7
Range	0.0013	5.2
Median	0.7098	-2.6
Mean	0.7096	-2.8
S.D.	0.0004	1.3

State Line M3	$^{87}\text{Sr}/^{86}\text{Sr}$	$\delta^{13}\text{C}$
No. of observations	7	7
Minimum	0.7089	-7.1
Maximum	0.7098	0.0
Range	0.0008	7.1
Median	0.7097	-3.3
Mean	0.7094	-2.8
S.D.	0.0003	2.5

Anderson M1	$^{87}\text{Sr}/^{86}\text{Sr}$	$\delta^{13}\text{C}$
No. of observations	12	12
Minimum	0.7094	-6.8
Maximum	0.7103	-1.8
Range	0.0009	4.9
Median	0.7100	-3.7
Mean	0.7099	-3.8
S.D.	0.0003	1.3

Anderson M3	$^{87}\text{Sr}/^{86}\text{Sr}$	$\delta^{13}\text{C}$
No. of observations	11	11
Minimum	0.7091	-4.5
Maximum	0.7103	-0.8
Range	0.0011	3.6
Median	0.7098	-2.0
Mean	0.7098	-2.5
S.D.	0.0003	1.2

Madisonville M1	$^{87}\text{Sr}/^{86}\text{Sr}$	$\delta^{13}\text{C}$
No. of observations	16	16
Minimum	0.7094	-11.9
Maximum	0.7109	-1.6
Range	0.0015	10.4
Median	0.7105	-6.3
Mean	0.7104	-6.5
S.D.	0.0004	3.4

Madisonville M3	$^{87}\text{Sr}/^{86}\text{Sr}$	$\delta^{13}\text{C}$
No. of observations	11	11
Minimum	0.7096	-11.9
Maximum	0.7109	-1.3
Range	0.0013	10.6
Median	0.7107	-4.4
Mean	0.7104	-4.8
S.D.	0.0004	3.0

Table 3. Demographic and Mortuary Data for All Potential $^{87}\text{Sr}/^{86}\text{Sr}$ Outliers. (*Denotes data from a previous study [McCall, 2013]) wherein $^{87}\text{Sr}/^{86}\text{Sr}$ values were from enamel on premolars and canines and $\delta^{13}\text{C}$ values were from bone [see Table 1]. These $\delta^{13}\text{C}$ values were converted for the present comparison using an offset of 7‰ based on comparison with local measurements in the study region [Cook and Schurr, 2009]).

Potential High $^{87}\text{Sr}/^{86}\text{Sr}$ Outliers (0.7107-0.7135)								
Site	Burial	Sex	Age	Position	Location	Grave Goods	$\delta^{13}\text{C}$ (M1, M3)	Date
Turpin	A25.013	male	55-64	?	?	?	-4.1*	
Turpin	952/128	female	35-44	extended, most of skull gone	mound	no	-3.3*	
Turpin	952/223	female	45-54	?	burial pattern (west)	?	-4.1*	
Turpin	952/153	female	35-44	extended	mound	chunkey stone	-3.4*	
Turpin	952/91	female	25-34	?	stone mound	?	-14.7, -14.5	651-867
Turpin	952/244	male	20-24	extended	burial pattern (west)	no	-11.3, -2.3	981-1162
Turpin	A25.060	male	20-30	?	?	“Old Village” pot	-4.1, -3.2	1023-1207
Turpin	952/119	indet.	6-9	?	mound	?	-2.5*	
Turpin	952/222	female	10-14	?	?	?	-1.7*	
Turpin	952/192	male	45-54	?	?	?	-1.6*	
Turpin	952/117	female	15-19	?	mound	beads	-2.5, -1.4	1169-1295
Madisonville	58020	female	24-30	semi-flexed, hands by face	B-18 (south)	pottery handle	undet., -4.5	
Madisonville	57716	indet.	5-8	disarticulated, secondary	1-43 (northwest)	projectile point tip	-5.9, undet.	
Guard	8	female	18-20	extended?	south	no	-1.1, -0.2	1168-1274
Potential Low $^{87}\text{Sr}/^{86}\text{Sr}$ Outliers (0.7089-0.7097)								
Site	Burial	Sex	Age	Position	Location	Grave Goods	$\delta^{13}\text{C}$ (M1, M3)	Date
Turpin	245-252	male	25-34	?	?	?	-15.2, -14.3	
Turpin	952/156	male	30-40	extended	mound	flintknapping kit	-2.7, -1.6	1024-1207
Turpin	952/47	female	20-24	?	?	?	-2.7*	
Turpin	952/69	female	15-19	?	burial pattern (northeast)	?	-2.8*	
Turpin	952/37	male	25-34	?	burial pattern (west)	?	-2.7*	
Madisonville	58041	female	30-35	extended, weathered bones	B-42 (south)	projectile point	-11.9, undet.	
State Line	502 #2 (Miller)	?	20-40	indet.	indet.	indet.	-5.8, -7.1	
State Line	503-4	male	20-24	indet.	mound	indet.	-2.6, -3.3	1052-1278
State Line	507 #6	female	30-34	indet.	indet.	indet.	-3.1, -5.0	
Anderson	60	male	46-50	?	northwest	no	-1.8, -2.1	
Anderson	67	female	46-50	?	southwest	no	-4.9, -4.3	
SunWatch	4/77	female	20-24	fully flexed	northwest	no	-1.5, -2.3	
SunWatch	Smith 3	indet.	indet.	fully flexed	northeast	no	-1.9, -1.1

Figure 1

Multiple-Plaza Villages

Single-Plaza Villages

Figure 3

Figure 4

Figure 5

Figure 6

Guard

State Line

Figure 7

Figure 8

Figure 9

Figure 10