PALEODIETARY RECONSTRUCTIONS ON THE NORTH CENTRAL GREAT PLAINS:

Examining the Isotopic Evidence for Subsistence Practice and Change throughout the Woodland and Plains Village Periods

Andreas Paul Wion
Department of Anthropology
University of Colorado Boulder

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Thesis Advisor

Dr. Douglas Bamforth, Department of Anthropology

Examining Committee Members

Dr. Matt Sponheimer, Department of Anthropology

Dr. Nichole Barger, Department of Ecology and Evolutionary Biology

ABSTRACT:

Dietary histories for Native North Americans on the north central Great Plains region are reconstructed through stable carbon isotope analyses from 189 individuals from Kansas, Nebraska, and South Dakota. $\delta13C_{apatite}$ values, which are representative of the isotopic composition of the overall diet, exhibit statistically significant differences across all time periods. $\delta13C_{collagen}$ values are representative of the isotopic composition of dietary protein, and exhibit a significant difference across the Plains Woodland and the Plains Village periods. Plains Woodland groups exhibit δ13C values (collagen and apatite) consistent with predominately C3 inputs. Early Plains Village groups exhibit δ13C values suggest an overall diet consisting of primarily C4 inputs with a mixed C3/C4 dietary protein component. Late Plains Village groups exhibit δ13C values suggestive of a slightly more mixed, but predominately C4, overall diet with a mixed dietary protein component. The ratio of animal to plant tissue consumption remained roughly consistent across the Plains Woodland and Early Plains Village periods; however, the proportion of animal tissues increases significantly during the Late Plains Village period. These results are suggestive of a substantial increase in the proportion of δ13C enriched resources, like maize or bison, with the onset of the Plains Village period.

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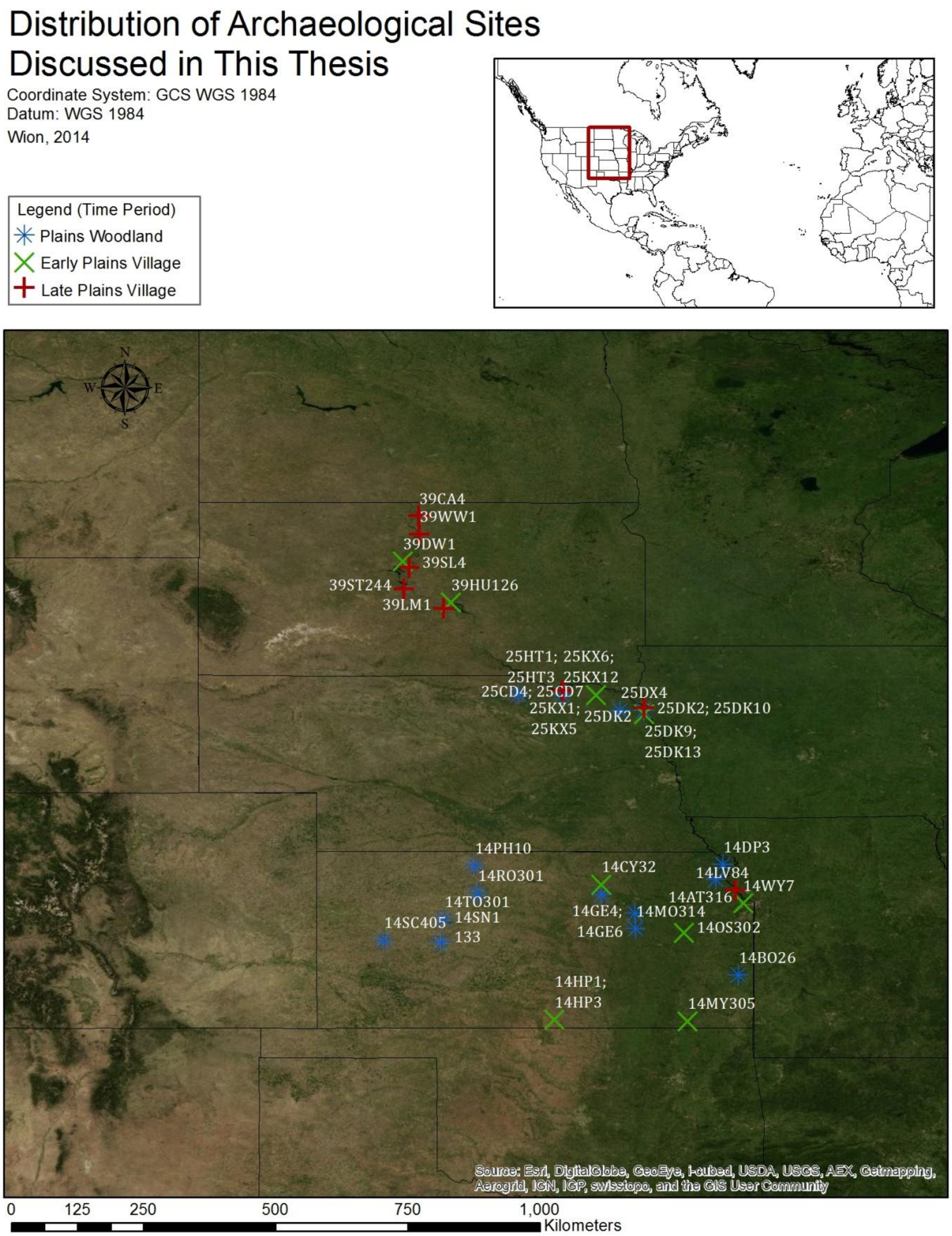
Questions of subsistence have been the focus of a significant quantity of archaeological research for over a century. Two fields of archaeology, zooarchaeology and paleoethnobotany, directly address such questions through the identification and analysis of faunal and floral remains, respectively, in the archaeological record. Both sub-disciplines have made substantial contributions to the field of archaeology as a whole, but their contributions can be supplemented with information from the physical remains of human tissue. Over the lifetime of an organism, elements such as carbon are incorporated into their tissues from its diet. By measuring the ratio of different isotopic forms of particular elements, archaeologists can probe subsistence related questions with a much higher level of precision than afforded by the archaeological record alone.

This thesis analyzes stable carbon isotopes from 189 individuals from 39 archaeological sites on the Great Plains to determine subsistence practices and changes over time. A brief review of the natural and cultural history of the Great Plains is presented to establish the intellectual foundation for this thesis. The zooarchaeological and paleoethnobotanical records are then synthesized in order to provide a background context for the analysis. Results of the analysis are discussed in relation to the archaeological evidence, and a model that attempts to explain the dynamics of subsistence change in this region is presented. The study covers a time depth of approximately 2000 years and all dates, unless otherwise stated, are given in AD calendar years. The geographic distribution of the archaeological sites (Figure 1) spans from southern Kansas to northern South Dakota, approximately 1000 km north-south, and from the Missouri River west to approximately the 100th meridian, approximately 650 km east-west. Data is organized into three broad time periods representing the middle to late Plains Woodland archaeological period (1-1000 AD), the Early Plains Village period (1000-1500), and the Late Plains Village period (1500-1890).

Figure 1



Distribution of Archaeological Sites Discussed in This Thesis
Coordinate System: GCS WGS 1984
Datum: WGS 1984
Wion, 2014
Legend (Time Period)
Plains Woodland
Early Plains Village
Late Plains Village
N
W
E
S
39CA4
39WW1
39DW1
39SL4
39ST244
39HU126
39LM1
25HT1; 25KX6;
25HT3 25KX12
25CD4; 25CD7
25DX4
25KX1;
25KX5
25DK2
25DK2; 25DK10
25DK9;
25DK13
14PH10
14RO301
14TO301
14SC405
14SN1
133
14CY32
14GE4;
14GE6
14MO314
14DP3
14LV84
14WY7
14AT316
14OS302
14BO26
14HP1;
14HP3
14MY305
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
0 125 250 500 750 1,000
Kilometers

The Great Plains are a physiographic region of North America whose boundaries are often disputed and occasionally arbitrary. The western boundary of the Great Plains is generally uncontested, where the dramatic topography of the Rocky Mountains meets the vast interior shield of the continent. These rolling prairies are bounded by the boreal forest of Canada to the north and the deciduous woodlands of the eastern United States, both of which are ecosystems whose boundaries are in a constant state of flux as a result of human modification and climatic variables. In the south, grasslands give way to desert in eastern New Mexico and west Texas. The Great Plains are further divided into several sub-areas based on geographic boundaries or archaeological affiliations. The central Plains are generally considered to include the states of Nebraska and Kansas, whereas the northern Plains include North and South Dakota, Montana, and Canada. This thesis explores human variation across these two regions, but fails to encompass the whole of them. For the purpose of simplification the study area of this thesis is often referred to as the north central Plains, although this distinction is arbitrary and does not demarcate this region as encapsulating social or environmental differences separate from the rest of the Great Plains as a whole.

Popular beliefs about the Great Plains as being a homogenous expanse of flat land and grass are incorrect, as the Great Plains show considerable diversity in climate, topography, and species composition. Likewise, the idea long promoted in American archaeology that human populations on the Great Plains exhibited a similar lack of diversity or remained static throughout their prehistory is also unfounded (Trigger, 1980). Prehistoric human populations on the Great Plains were subject to the same degree of variation which characterizes the Great Plains as a whole. Beginning in the Plains Village period, noticeable distinctions appear between archaeological material from the northern and central Plains.

Plains Village archaeological sites situated along the banks and tributaries of the Missouri River in North and South Dakota are collectively referred to as the Middle Missouri Tradition, while sites located along the tributaries of Missouri River in Nebraska and Kansas are termed the Central Plains Tradition. Other traditions, like the Oneota tradition of the Midwestern US, are present in this area but not analyzed in this thesis. Archaeologists organize similar material cultures that overlap in time and space as distinctive phases, foci, or complexes. These are useful constructions when referring specific time periods or sub regions; however, these groups cannot be thought of as cohesive social units, in contrast to tribes of the Late Plains Village period (Bamforth, *personal communication*). Although this thesis comments on the variation within and across different phases, it should be understood that these are arbitrary constructions of archaeologists and do not necessarily hold significant social meaning.

Since its inception, American archaeology has been guided by a largely unrecognized bias towards excavating archaeological sites which produce remains of large game mammals, especially Pleistocene-era fauna. These sites produce remains which are highly visible from the surface and are likely to garner public attention and inquiry. Artifacts and ecofacts recovered from an overwhelmingly large proportion of Paleoindian sites consist mostly of large animal bones and impressive fluted spear points, both of which are much more visible than sub-surface structures such as hearths or post-holes. As a consequence, the degree of reliance that Paleoindians had on big game hunting has likely been heavily overstated by the archaeological record. Although the contents of this thesis do not address questions of Paleoindian subsistence, this brief digression highlights the difficulties of accurately determining subsistence practices based solely on the scant remains of the archaeological record.

Previous paleodietary studies on the Great Plains have employed stable isotope analyses in highly localized areas (Wilson and Perttula, 2013; Tuross and Fogel, 1994; Habicht-Mauche et al., 1994), and the interpretations are generally specific to individual archaeological sites. This thesis will incorporate data from 39 sites in Nebraska, South Dakota, and Kansas to gain an understanding of the general trends in subsistence across time and space. Using descriptive statistics, this thesis will explore the range of variation among diets across time and space as well as discuss general trends and patterns in the subsistence of early Native American horticulturalists. These results will provide a conceptual framework for archaeologists and anthropologists studying subsistence on the northern or central Plains, and will produce a working model which can be built upon by incorporating data from more individuals as such data become available.

INTELLECTUAL BACKGROUND

Isotopes

Isotopes are elements which share the same number of protons and electrons, but differ in the number of neutrons. Isotope is derived from the Greek words *iso* and *topos*, which translates to equal places in relation to their position in the periodic table (Sponheimer and Cerling, 2014). There are usually multiple possible configurations of neutrons for each element, and often one of these combinations is the most abundant and generally preferred. These are stable isotopes, in contrast to radioactive isotopes, which are unstable and very rare relative to stable isotopes. The stable isotopes of carbon are ^{12}C (6 protons and 6 neutrons) and ^{13}C (6 protons and 7 neutrons), ^{12}C being the preferred configuration and most abundant of the two. Isotopes do not differ significantly in their chemical behavior, but behave slightly differently due to their differences in total mass resulting in different isotopic effects. Isotopic effects affect the physical properties and the reaction rates of molecules, and ultimately lead to varying abundances of natural isotopes in similar substances (van der Merwe, 1982). This process is called isotopic fractionation, and understanding the processes by which this occurs in natural systems allows us to study a wide range of ecological, archaeological, and paleoecological phenomena with an otherwise impossible precision.

Libby (1949) was the first to pioneer radiometric dating techniques of organic material measuring the decay of radioactive ^{14}C via its ratio to ^{12}C, for which he won the Nobel Prize in Chemistry. This ushered in a new era for the field of archaeology and paved the way for later studies. The first paleodietary reconstruction (Vogel and van der Merwe, 1977) used carbon isotopes to identify the timing of the adoption of maize cultivation in New York State. This rested on the earlier study by Smith and Epstein (1971) concluding that plants which exhibit a C4 (Hatch-Slack) photosynthetic pathway are enriched in ^{13}C relative to plants which follow a C3 (Calvin-Benson) photosynthetic pathway, and the assumption that this signature is transferred up the food web to consumers. The first and most widely utilized model of carbon isotope fractionation between diet and bone was published in 1984 (Kruger and Sullivan), and served as a basis for the vast amount of paleodietary studies performed since the early 1990's.

The fundamental premise of paleodietary reconstructions rests on the isotopic distinction between C3 and C4 photosynthetic pathways. The vast majority of domesticated cultigens, including squash, beans, fruits, and nuts, follow a C3 or Calvin-Benson photosynthetic pathway. In this, energy from light reactions power a carbon fixation cycle which combines single CO2 molecule and a 5 carbon ruBP molecule to form two, three carbon chains to be used in metabolic and cell functions (Harley and Sharkey, 1991; Ehleringer and Cerling, 2002). A small number of domesticated cultigens, including maize, sorghum, and millet follow a C4 photosynthetic pathway.

C4 plants combine CO2 with a three carbon PEP molecule, resulting in a single 4 carbon chain molecule. The reaction is catalyzed by a PEP carboxlase molecule, which has a much higher affinity for CO2 than the rubsico catalyst used in C3 photosynthesis and is able to maintain CO2 uptake at much higher temperatures than C3 plants (Hatch and Slack, 1966; Ehleringer and Cerling, 2002). Thusly, C4 photosynthesis is frequently the dominant photosynthetic pathway in tropical or subtropical ecosystems.

A third and relatively minor photosynthetic pathway is known as the CAM (Crassulacean Acid Metabolism) pathway, and is most prevalent in succulent plants like cacti. CAM plants combine elements of both C3 and C4 photosynthesis, and evolved in several lineages of plants as an adaptation to arid environments. The stomata remain closed throughout the day to minimize water loss from respiration and open at night to take in CO2 (Winter and Smith, 1996). The CO2 is catalyzed by a PEP carboxylase molecule resulting in a four carbon chain molecule, as in C4 photosynthesis, but is withheld in storage vacuoles before being sent on to complete the Calvin Cycle (Winter and Smith, 1996). CAM plants include succulents like prickly pear cacti, jade plants, and pineapples.

The differences in carbon fixation among C3, C4, and CAM plants result in varying abundances of ^{13}C and can be measured as a ratio to ^{12}C. Isotope ratios are reported and described by a particular terminology, as defined by an international standard, on which Kruger and Sullivan (1984:212) state:

> *Because the variations in the actual isotopic ratio of carbon are very small, results are reported in "delta" notation, or parts per thousand variation in the ^{13}C /^{12}C ratio from that of the PDB standard. The PDB standard is a calcium carbonate marine shell and is quite rich in ^{13}C. Therefore isotopic analyses of most mammalian tissues are negative relative to PDB. Isotopic analyses are calculated according to the following relationship:*
>
> $$(\delta^{13}C) = [(^{13}C/^{12}C)_{\text{sample}} / (^{13}C/^{12}C)_{\text{PDB}} - 1] \times 1000$$
>
> *Analyses are therefore reported in "per mil" units (‰), or relative difference of the $^{13}C/^{12}C$ in parts per thousand from the $^{13}C/^{12}C$ of the PDB standard.*

The difference in carbon fractionation between C3 and the C4 plants results in differential $\delta^{13}C$ signatures which accumulate in the bone and soft tissues of consumers (van der Merwe, 1982). Isotopic signatures are transferred upwards through trophic levels so that consumers who derive a majority of their diet from C4 resources are also enriched in $\delta^{13}C$ relative to consumers who subsist more heavily on C3 resources. C3 plants tend to produce $\delta^{13}C$ ratios around -26.6‰ whereas C4 plants average approximately -11.5‰ (Kruger and Sullivan, 1984). CAM plants tend to be enriched in ^{13}C relative to C3 plants and depleted relative to C4 plants, averaging around approximately -20‰. Bone collagen tends to be enriched by about +5‰ relative to diet, therefore a diet consisting of purely C3 protein should result in $\delta^{13}C_{collagen}$ values around -21.5‰, pure C4 would be around -6.5‰, and a 50/50 mix of C3 and C4 protein would be around -14‰ (Kruger and Sullivan, 1984). Bioapatite, on the other hand, tends to be enriched by about +9.5‰ relative to diet (Kellner and Schoeninger, 2007). $\delta^{13}C_{apatite}$ values near -2‰ would be suggestive of an overall diet consisting exclusively of C4 resources, $\delta^{13}C_{apatite}$ values near -17‰ for a purely C3 diet, and a 50/50 mix would produce values around -9.5‰.

In early human populations in the Americas, maize was the only widely domesticated cultigen which produced such an elevated signal, and thusly a heavy reliance on the crop can be detected quite easily in early populations. In C3 dominated ecosystems like temperate and boreal woodlands, maize is very easily detected from the background environment (Vogel and van der Merwe, 1977), however in mixed grass prairies like the Great Plains of the North America, grasslands are dominated by a mosaic of C3 and C4 plants. This complicates the interpretation of isotopic dietary signals in this region, but is still possible through careful analysis and corroboration with the archaeological record.

Bone collagen tends to be the most widely available and frequently utilized substance in isotope analyses, and early models suggested collagen was an accurate representation of average dietary intake (Kruger and Sullivan, 1984). The minute differences in isotopic composition of bone collagen allowed researchers like Vogel and van der Merwe (1977) to estimate relative proportions of C3 and C4 plants to the diet. Collagen is the single largest organic component in bone, accounting for 90-95% of the total organic matter (Kruger and Sullivan, 1984). The second major component in bone is a calcium phosphate salt with apatite structures, commonly referred to in research as hydroxyapatite, although this material contains a number of carbonate impurities not found in true hydroxyapatite (Sponheimer and Cerling, 2014). The true nature of this material is complex and contentious, and this thesis will refer to the material herein as bioapatite, or simply apatite. Bioapatite contains significantly less carbon than collagen, and played a relatively minor role in paleodietary reconstructions until fairly recently (Kellner and Schoeninger 2007, Sponheimer and Cerling 2014).

The difference in isotopic abundances between bone collagen and bioapatite is a result of differential fates of dietary macronutrients (carbohydrates, proteins, and lipids) (Kellner and Schoeninger 2007). Different foods provide different dietary macronutrients and the body metabolizes these energy sources in a variety of ways, all of which in turn contribute to varying abundances of carbon isotope ratios across different organic substances. Kruger and Sullivan's (1984) model for fractionation between diet and bone postulated that carbohydrates and lipids, which provide the bulk of dietary energy, should be reflected in the $\delta^{13}C$ values of bioapatite, whereas $\delta^{13}C$ values from collagen would be representative of dietary protein uptake. Experimental studies prompted by Kruger and Sullivan's model suggest that while $\delta^{13}C$ collagen values are affected by protein intake, $\delta^{13}C$ apatite values are more representative of total diet, as opposed to only dietary energy from lipids and carbohydrates (Kellner and Schoeninger, 2007).

Information regarding an organism's relative trophic position can be gleaned from the spacing between the two variables, as well. Herbivorous animals tend to have larger collagen-apatite spacing values in excess of 7‰, whereas carnivores exhibit smaller spacing closer to 4‰. Humans and other omnivores tend to fall between the two (Sponheimer and Cerling, 2014). This approach to determining trophic level is superior to the traditional use of stable nitrogen isotopes, which is still poorly understood relative to stable carbon isotopes (Hedges and Reynard, 2007).

Kellner and Schoeninger's (2007) reassessment of Kruger and Sullivan's (1984) model concludes that relying on any single measure can provide a misleading picture of diet. When dietary protein and energy have different isotopic signatures, such as a reliance on C4 plants like maize in a predominately C3 ecosystem, analyzing collagen can lead to an underestimation of maize contribution to the diet. The inverse of the situation would be in near shore populations, most vegetation is C3 dominated but protein comes from marine sources, which is enriched in $\delta^{13}C$ relative to terrestrial fauna. In these situations, collagen would appear to overestimate the contribution of marine protein to the diet. In order to create accurate reconstructions of paleodiet, $\delta^{13}C$ values of collagen must be taken in combination with $\delta^{13}C$ value of bioapatite.

Great Plains Environment

Grassland production is controlled predominately by precipitation, which decreases on an east-to-west gradient (Sala et al., 1988), resulting in highly productive tallgrass prairies to the east and relatively less productive short grass prairies in the west. The mixed grass prairie connects the two ecosystems and forms a belt of highly productive and diverse forage for grazing animals which stretches from central Canada south to central Texas. The composition of C3 and C4 grasses vary as a function of both light and water, with C4 plants being adaptive under conditions of low water and abundant light. As a result abundances of C4 grasses are highest in the southern Plains and decrease moving northwards. C4 plants are virtually non-existent in central Canada but can reach concentrations as high as 94% in southern Texas (Ricotta et al.,2010). Woodlands are generally restricted to riparian corridors and include species of willow (*Salix spp.)* and cottonwood (*Populus* sect. *Aigerios)*. Areas of significant topographic relief such as the Black Hills and the Pine Ridge support a number of coniferous trees as well, including ponderosa pines (*Pinus ponderosa*) and white spruce (*Picea glauca* var. *densata).*

Grass communities vary considerably across the landscape of the Great Plains. Ricotta (2010) quantified the percentage of C3/C4 grass species for modern Great Plains communities using remote sensing techniques. West of the Missouri river, the percentage of C4 species increases from 29% in the Dakotas to 51% in the Nebraska Sand Hills. C3 grasses like western wheatgrass

(*Agropyron smithii)*, porcupine grass (*Stipa viridulal,)* and needle and thread grass (*Stipa comata*) dominate grassland communities of Northern Great Plains, but coexist with big sagebrush (*Artemisia tridentata*) and gamma grass (*Bouteloua gracili*) in western South Dakota and Nebraska. C4 abundance approaches 80% in southwest Kansas where grassland communities are comprised of little bluestem (*Schizachyrium scoparium*), buffalo grass (*Buchloe dactyloides*), gamma grass, and big sagebrush. East of roughly the 100^{th} meridian, modern grassland composition is relatively more homogeneous and comprised of largely C4 (79%) plants such as big bluestem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*), and Indian grass (*Sorghastrum nutans*).

Historically the Great Plains has provided habitat for a diverse array of fauna; however, this thesis only discusses a very small portion of the total biodiversity. Before its eradication by white settlers, the American bison (*Bison bison*) was the dominant large grazing herbivore on the Plains. Pronghorn (*Antilocapra americana*), mule deer (*Odocoileus hemionus*), and white tailed deer (*Odocoileus virginianus*) existed in considerable numbers across the Plains, and large browsing herbivores like elk (*Cervus elaphus*) and moose (*Alces alces*) existed in greater numbers to the north and west. Predators included grizzly and black bears (*Urus arctos* and *americanus*), gray wolves (*Canis lupus*), coyotes (*Canis latrans*), and bobcats (*Lynx rufus*). Birds such as wild turkey (*Meleagris gallopovo*), a number of species of waterfowl (fam. Anatidae), and golden eagles (*Aquila chrysaetos*) have been identified from archaeological sites on the Plains.

Average annual precipitation on the eastern Plains can often exceed double the amount received on the western Plains (Wedel, 1986); however, climatic variability is the rule rather than the exception on the Great Plains. Precipitation is highly variable on both regional and temporal scales (Weakly, 1965), and results in highly unpredictable patterns of game movement and forage quality. Variable precipitation had equally, if not more, serious consequences for horticultural populations on the Plains. Maize requires no less than 20cm of precipitation distributed over approximately 90 days and daytime temperatures not exceeding 30 degrees Celsius (Wedel 1986).

When these conditions are not met, the total yield from a harvest of a maize crop decreases significantly or fails completely. For sedentary populations dependent upon horticultural crops throughout the year, multiple consecutive years of crop failure could be extremely dangerous.

Native and Introduced Seed Crops on the North central Plains

Sunflowers (*Helianthus* spp.) are found across the Plains environment and constituted an economically valuable crop for Native Americans due its relatively high yield, nutritious value, and ease of storage and transport. Both wild and domesticated sunflower seeds have been recovered from Central Plains Tradition sites, and evidence for their utilization is more widespread in the northern Plains and sporadic in the southern Plains (Adair and Drass, 2011). The practice of harvesting both wild sunflowers and selecting for cultivated varieties is recalled by Buffalobird Woman of the Hidatsa (Wilson, 1917) and is supported by the archaeological record, suggesting a strong continuity of this practice for centuries. The value of sunflower crops on the Plains appears to have fallen around the 1450, when large domesticated sunflower seeds largely disappear from the archaeological record. Smaller, wild sunflower varieties continue to be utilized throughout the Late Plains Village period.

Native seed crops like goosefoot (*Chenopodium* spp.) and marshelder (*Iva annua*) were weedy annuals which had been staples in the Native American plant assemblage since the Archaic period (Adair and Drass, 2011). Goosefoot can be consumed as a leafy vegetable in small quantities, but provides an abundance of small, protein rich seeds. C. quinoa is a species of goosefoot native to South America, harvested primarily for its seeds, which is consumed in significant quantities in modern non-Native American populations. Marshelder was also selected for its protein rich seeds, and domesticated varieties of these plants both appear during the Late Woodland time period (Adair and Drass, 2011). Marshelder is adapted to the moist soils on the eastern margin of the Plains and declines in abundance to the west. Goosefoot, on the other hand, is much more tolerant of drier soils and is found throughout the Central Plains. The utilization of the domesticated varieties of these plants tapers off during the Late Plains Village period, while wild varieties are continuously gathered in modest amounts (Adair and Drass, 2011).

Little barley (*Hordeum pusillum*) makes its first major appearance in paleoethnobotanical assemblages during the Plains Village period. Its seed is often recovered in large quantities, suggesting a strong economic value. Interestingly, it is also frequently found in association with significant quantities of Prairie dropseed (*Sporobolus heterolepis*) on the southern and southwestern Plains (Adair and Drass, 2011). Dropseed matures during the late summer or early fall, whereas little barley matures during the late spring. The harvest and storage of little barley in anticipation for a later harvest of dropseed suggests a possible complimentary relationship between the two plants (Adair and Drass, 2011).

Introduced seed crops played a significant role in the subsistence of CPT villagers, as evidenced by their near ubiquity across the eastern Plains landscape near the end of the Plains Village period. The most common and widely utilized introduced seed crops were squash (*Cucurbita* spp.), maize (*Zea mays*), and the common bean (*Phaseolus* spp.). These three crops become an essential part of the Great Plains subsistence pattern during the Plains Village period and their prevalence continues into the modern era.

Native *Cucurbita* species like squash and gourds are present in assemblages dating to the Early Archaic period (6000 BC) and increase in prevalence from the Late Archaic through the Plains Village period. Due to a number of factors involved with processing of the plant and methods used to determine presence or absence in paleoethnobotanical assemblages, *Cucurbita* possesses very low archaeological visibility. Adair and Drass (2011) suggest this visibility issue often translates into a tendency to underestimate the contribution of these plants to the prehistoric Plains agricultural complex. Despite these issues, *Cucurbita* remains have been recovered from numerous sites on the Plains and show a great diversity in the range of species utilized by later populations.

Species like the native Ozark gourd, pumpkins, bottle gourd, and calabash (*Lagenaria* spp.) are present in pre-contact paleoethnobotanical assemblages, and numerous more varieties are identified from the Late Plains Village period (Adair and Drass, 2011).

The earliest evidence for significant maize cultivation on the central Plains comes from the Avoca site (14JN332) and is dated to around the year 950 AD (Adair and Drass, 2011). It is present in the southwestern US approximately 2000 BC, and spread to eastern North America by approximately 500 BC. It is believed to have contributed to a relatively minor portion of the Plains agricultural complex until the Late Woodland period, and became a ubiquitous staple in the diet of Plains Village farmers shortly thereafter. Maize is widely regarded as the most economically valuable introduced seed crop to the Plains Village farmers. The identification of specific varieties of maize from the archaeological record is difficult due to the lack of extant heritage crops to facilitate a baseline comparison. Adair (2004) identified 3 distinct varieties of maize from paleoethnobotanical assemblages dating from AD 1200-1800 by taking into account quantitative factors such as row number, cob size, and kernel shape/size. Through this method she described three distinct varieties of maize ranging from 8 to 14 rowed varieties, with a small amount of 16 rowed varieties. In addition, the presence of 8 rowed maize tends to increase in protohistoric and historic assemblages, whereas 10 and 12 rowed varieties are consistently present in considerable abundance throughout this period (Adair and Drass, 2011).

The common bean was the last of the three major introduced seed crops to be domesticated on the Plains. It is present in the American southwest by 500 BC but was not intensively cultivated until approximately the 1200's. Direct dates from beans recovered in eastern Nebraska suggest this plant was being cultivated on the central Plains around the year 950, and spread to the eastern Woodlands by the 1200's (Adair and Drass, 2011). Beans are found in small quantities across the Central Plains, but rarely in abundance due to a lack of preservation potential, much like *Cucurbita* species. Despite this, there is evidence for the gathering of wild beans in addition to the cultivation of domesticated varieties throughout Plains Village period.

CULTURAL HISTORY OF THE GREAT PLAINS

Plains Woodland Period

Around 500 BC, human populations on the Plains began to produce the first widespread pottery and also exhibit increased evidence of sedentary lifestyles and agricultural experimentation (Bozel and Winfrey, 1994). This period is termed the Plains Woodland period, a carryover term used to describe similarly dated cultural complexes in the Eastern United States, and is divided into three general classificatory eras: early (500BC- 100BC), middle (100BC-500AD), and late (500-1000 AD). Early Woodland populations on the eastern margins of the Plains mark the advent of a major cultural shift from the predominately nomadic hunting and gathering lifestyle to the increased reliance on stored food and sedentary lifestyles. In the eastern woodlands of Ohio, the Hopewell cultural complex persisted from approximately 200 BC to 500 AD and facilitated continent wide trade networks which followed the major river basins of eastern North America (Yerkes, 2006). Hopewell sites exhibit evidence for distinct pottery styles, platform effigy pipes, elaborate ceremonial earthworks, and large communal burial mounds. Hopewell populations began to settle in large semi permanent villages and exhibit evidence cultivating native domesticates as early as 250 BC (Bender et al., 1981). Evidence for substantial maize production does not appear until the terminal Woodland period in this area, prior to production on the central Plains. The influence of Hopewell interactions on populations on the central Plains is most visible in the form of Hopewell style pottery and mortuary practices, especially at several large sites near the confluence of the Kansas and Missouri rivers. Evidence for significant Hopewell presence in the eastern woodlands declines after the year 500 AD, and the presence of Hopewell material culture on the Plains similarly decreased. The social influences which Hopewell society exerted on Plains Woodland populations persisted for many centuries; however, in the form of mortuary practices, pottery design and manufacture, and settlement patterns.

The taxonomic scheme proposed by Bozel and Winfrey (1994) describes two distinctive variants of which correspond to the Middle Woodland time period in the central Plains: Valley and Kansas City Hopewell. The Kansas City Hopewell variant covers a relatively small area in north eastern Kansas/Missouri, near present day Kansas City. The Valley variant encompasses a considerably larger region than the Kansas City variant, extending along the major tributaries of the Missouri, Platte, Loup, and Niobrara Rivers in east-central Nebraska, central South Dakota, and north central Kansas. In addition to these two Middle Woodland variants, two separate western complexes are recognized (South Platte and Keith variants) as contemporaneous but, "persist centuries after the collapse of these taxa [Valley and Kansas City] and Hopewell influences, circa AD 500." (Bozel and Winfrey, 1994:129). Therefore, the western variants cannot be defined as either Middle or Late Woodland cultures, but encompassing both periods of time. The four Woodland variants exhibit minor differences in material culture but tend to show more marked differences in subsistence and settlement patterns between eastern and western taxa. Valley and Keith variants tend to be organized in smaller hamlets with less ornate material goods and more modest burial mounds, relative to Kansas City Hopewell. In addition cultigens are generally rare or absent from Keith and Valley phases in contrast to their relative abundance at KCH sites, suggesting a greater emphasis on hunting and gathering lifeways outside of the Kansas City Hopewell region.

To the north, Middle Woodland populations termed the Sonata complex exhibit evidence of Woodland influence in the form of mortuary practice through mound building, but shared similar pottery styles and lithic technologies to contemporaneous populations further west. The Besant complex of Wyoming, Montana, and Southern Canada share similar material cultures in this regard. Both differed significantly in terms of subsistence and settlement relative to contemporaneous populations on the Central and Southern Plains. Large scale bison hunting and intensive carcass processing characterized the Sonata complex in a magnitude not seen elsewhere on the Plains during this time, while no evidence for horticulture is present from the any Sonata complex sites (Neuman, 1975). The presence of marine shells from the Pacific coast in North Dakota (Johnson, 2001), and raw lithic material from the western US in the eastern Woodlands (Neuman, 1975) suggests the facilitation of extensive continent-wide trade networks through the Northern Plains during this time, which almost certainly traded bison and bison products in exchange for both exotic and utilitarian goods.

The shift to semi-permanent or permanent settlement patterns following thousands of years of hunting and gathering brought a suite of cultural and physical changes to the Plains landscape. The reason for this transition and the conduits which facilitated this transition have been questions at the forefront of archaeological research since its inception as a discipline. The massive cultural impacts which precipitated from the adoption of semi-sedentary lifestyles and agricultural dependence were profound and would require a separate thesis to adequately explore the issue in depth.

Traditional anthropological dichotomies describe two possible scenarios for the spread of sedentary agricultural lifestyles, labeled the indigenist and the colonist perspectives. The latter asserts a population influx of farming people either displace or replace local hunter gatherer populations, while the former asserts that agriculture was adopted by hunting and gathering groups without a significant population influx. A number of theories try to reconcile these two extremes to varying degrees. Cavalli-Sforza (2002) describes an alternative coined demic diffusion, which incorporates cumulative population movement and growth to suggest agriculture spreads outward from a center of domestication through the random movements of small, possibly familial, groups. Zvelebil and Lille (2000) describe the necessity of individual social networks and kinship ties to explain the spread of agriculture, coined the individual frontier mobility theory. Both of these alternatives differ from the original indigenist/colonist dichotomy by placing value on small groups and gradual diffusion instead of large scale, immediate culture change.

Late Woodland phases in eastern Nebraska exhibit an intensification of the construction of sedentary settlements and early horticulture. The Loseke Creek variant in northeastern Nebraska and the surrounding areas practiced a mixed hunting and gathering subsistence economy with limited horticulture. Late Woodland pottery styles are hypothesized to be derived from earlier Valley variant cord roughened pottery, and ancestral to later Initial Middle Missouri pottery of the Plains Village period. Late Woodland groups are gradually replaced by the westward expanding Plains Village Traditions, beginning around the year 950.

Early Plains Village

Around approximately 950 AD, we see a marked shift in Woodland lifeways in the form of settlement and subsistence. The modifications to hunter gatherer lifestyles which were introduced during the Woodland period crescendo into what is termed the Plains Village period. Populations along the Missouri River and its major tributaries show the first regional evidence of a substantial increase in horticulture and sedentary lifeways. The expression of Plains Village foci on the Central Plains of Nebraska and Kansas are collectively referred to as the Central Plains Tradition (CPT), whereas the slightly later expression of the Plains Village period in the Dakotas is defined as the Middle Missouri Tradition. Following the decline of Mississippian influences in the east during the 13th century, a separate and culturally distinct eastern Woodland population known as the Oneota are believed to have expanded westward onto the Central Plains. The interaction between CPT and Oneota groups are still poorly understood, but it is believed that the two groups experienced relatively little cultural mixing, possibly as a result of violent social interactions or conflicts over natural resources like hunting grounds or raw lithic material (Pugh, 2010).

The Early Plains Village period on the central Plains consisted primarily of small, semi-sedentary village-like structures (hamlets) across Nebraska, Kansas, and adjacent portions of Oklahoma, Iowa, and Missouri (Wedel, 2001). Several phases have been indentified and studied to varying degrees, most notably the Nebraska and Upper Republican phases in east/central Nebraska and northern Kansas, respectively. Artifact assemblages almost consistently feature a bison scapula hoe, a characteristic tool of Plains Village horticulturalists, in spite of an absence of significant quantities of other bison bones in residential contexts on the eastern and central prairies. This discrepancy could reflect the economic importance of trade networks with northern Plains bison hunting populations, or possibly a result of butchery practices which affect visibility (Wedel, 2001) but the evidence for these ideas is limited. Pottery becomes more abundant and complex in form relative to Woodland ceramics during this time period. In addition, subterranean storage pits increase in frequency, possibly as a result of the increased need to store and process foods.

Roper (2006a) describes the construction of autonomous, loosely organized, durable farmsteads or homesteads as the hallmark of the CPT and considers the widely employed pole and beam style lodge to be the prototype of historic earthlodges. The structures are usually built of packed earth and timber, which deteriorate and require replacement likely on the order of every decade (Roper, 2006a). The aggregation several proto-earthlodge structures in a localized area give the appearance of small village settlements in the archaeological record, but these aggregations are inferred to represent cyclical abandonment and rebuilding in the same area (Roper, 2006a) and not true village settlements seen in the roughly contemporaneous Middle Missouri or later Initial Coalescent traditions.

Roper (1995) evaluated the space time pattern of the appearance of the Central Plains Tradition, using century scale time slices of radiocarbon dates across the central Plains. A steep radiocarbon plateau spans much of the late CPT period (Roper, 2012), complicating chronological interpretations; however, the vast majority of early CPT sites are restricted to the eastern margins of the Plains and date to approximately 1000 years before the present. The time-transgressive nature of this Roper's data suggests this expansion is not compatible with a colonist perspective, and Roper (2007) suggests that demic diffusion or individual frontier mobility are currently the most plausible mechanisms for this spread. Variation appears to be geographically ordered, in other words, material culture exhibits gradual differences along drainages and pronounced variation across drainages (Roper, 2007:56). Roper (2012) also notes that due to the short lived occupation of CPT hamlets, attempting to construct a CPT chronology entirely out of individual lodges is a futile task. Rather:

> *"…it will be more productive to evaluate the occupation within localities and drainages, and to evaluate and compare the placements of time and duration of occupations within them."* (Roper, 2012:50).

Middle Missouri

The Middle Missouri tradition consisted of Plains Village people situated along the banks and major confluences of the Missouri River in North and South Dakota. Middle Missouri villages were often fortified and located on bluff sides above the floodplains of major streams, allowing for an ease of access to both upland and bottomland resources and self sufficiency of village units (Wood, 2001). These villages practiced floodplain gardening and bison hunting in near equal amounts, supplemented by locally available plants and game. The first major village populations appear near the confluence of the Big Sioux and Missouri Rivers near the Nebraska/Iowa border. These groups rapidly moved north and westward into the Big Bend region of South Dakota and the major tributaries of the Missouri. Middle Missouri pottery has been recovered from as far west as the Black Hills and the Belle Fourche River (Winham and Calabrese, 1998).

Over time, Middle Missouri populations moved from scattered villages across the western Dakotas into villages along bluffs overlooking the Missouri River Valley. Ubiquitous evidence for fortification appears along the southern portion of the Missouri River around the years 1200-1300. Middle Missouri villages upstream from the Grand River in South Dakota are rarely fortified, suggesting the risk of violent conflicts were greater in the south. Following the year 1400 AD, Middle Missouri populations coalesced into even larger villages between the Heart and Cannonball rivers in North Dakota. Late Middle Missouri sites cover a geographic area about one quarter the entire range of earlier Middle Missouri groups, but village density tends to be more than four times greater than early Middle Missouri sites (Wood, 2001). This coalescence has been interpreted as a consolidation of Middle Missouri villages into a more compact and less autonomous village structure, possibly as a result of conflict with groups to the south. There is a general continuity among material culture and architectural planning throughout the Middle Missouri period; moreover, there is strong continuity across the entire Middle Missouri time period and geographic area in terms of a subsistence economy which focused primarily on bison and floodplain horticulture. Fluctuating climates during this period on the Plains (Wedel, 1965) likely had little impact on the available groundwater needed for horticulture in the Missouri River valley but had greater impacts on bison availability and abundance.

Coalescent Period

The Plains Village Coalescent period represents a migration of central Plains horticulturalists in central and eastern Nebraska and Kansas northward into the Missouri River valley starting in the 14th century. The period is divided into the Initial (1300-1600AD) and the Extended (1450-1650AD) Coalescent periods, which overlap with one another in both time and space. Fluctuating climate patterns during the 13th and 14th centuries resulting in increased aridity have been implicated in the abandonment of the central Plains during this time. A return to somewhat more stable conditions during the 15th century may have exacerbated the pattern of northward migration into the Middle Missouri area, possibly bringing Middle Missouri and Central Plains villagers into violent conflicts (Krause, 2001).

The majority of Initial Coalescent (IC) sites are restricted to the confluences of the White and Bad Rivers with the Missouri River. Tool assemblages included the classic bison scapula hoe, digging tools made from the thick frontal bones of bison skulls, skin scraping tools, and various bone processing tools (Krause, 2001). Pottery was grit tempered, cord wrapped, and grooved paddle-stamped. Villages were composed of mostly Central Plains style earth covered circular or semi-rectangular houses but exhibited fortification systems akin to the Middle Missouri tradition. One of the most distinguishing characteristics of IC sites, according to Johnson (1998:313), is:

> *"…a fortification composed of a ditch, an interior palisade, and protruding bastion set at 120- to 180- foot intervals. All but three of 10 excavated sites (Farm School, Medicine Creek, and Lynch) are fortified, and only at Talking Crow are there indentations rather than bastions."*

The threat of warfare and violent conflicts seems to be particularly prevalent in this area throughout the Middle Missouri period, but the real effects of violent conflict do not fully manifest themselves until the Initial Coalescent period. The Crow Creek Site (39BF11) is situated along the eastern bank of the Missouri River near the confluence of Crow Creek. The site was occupied intermittently from the Late Woodland period until the Initial Coalescent period, after which the site was occupied intensively until the historic period (Bamforth and Thornberry, 2007). During the Initial Coalescent occupation, a massacre of at least 486 individuals occurred at the Crow Creek. The bodies were in varying stages of semi-articulation to disarticulation, and were deposited in the trench surrounding the fortification of the site (Johnson, 1998). The IC occupation at the Crow Creek attests to the real and present threat of serious violence in the Middle Missouri region during this time period.

The Extended Coalescent (EC) period is believed to be a direct outgrowth and dispersal of Initial Coalescent populations out from the Big Bend region in the Missouri River valley north from southern Montana to the Niobrara River in Nebraska and as far west as the Black Hills and White River Badlands (Krause, 2001). Lodges closely resembled IC style earthen homes, and artifact assemblages and styles show general continuity across IC and EC periods. The vast majority of sites are unfortified, small village sites with comparatively thin stratigraphic profiles, inferred to represent relatively brief occupations of these sites. A number of large sites persist along the banks of the Missouri River throughout this period as well. The lack of significant fortification in EC sites suggests that violent conflict or the threat of violent conflict decreased from the IC period. Tool assemblages in EC sites are generally identical to IC sites; however, the appearance of bison and elk metatarsal fleshing tools and elk antler adzes first appear in the Extended Coalescent period.

The Late Plains Village period was a time of significant sociocultural reorganization on the Central Plains and Middle Missouri regions. The precise mechanisms behind the motivation for Early Plains Villagers on the Central Plains to migrate northward into the Middle Missouri region are still poorly understood, and perhaps may never be fully understood. Tree ring records from Weakly (1965, 1971) indicate a severe drought affecting the Plains region around the latter half of the 13th century into the early 14th century. This almost certainly would have affected the behavior and distribution of bison and other big game during this period; although, animals such as pronghorn may have still been present in varying abundances. The increased probability of crop failure as a result of severe drought may have also pushed populations in this area northward in search of more suitable locations for horticulture. Furthermore, conflicts with eastern Oneota groups may have also exacerbated limitations on natural resource and land availability in this area.

The encroachment of Initial Coalescent groups into Extended Middle Missouri territory during the 14th and 15th centuries resulted in violent conflicts among groups, such as the Crow Creek Massacre site. The social and ecological pressures which resulted from the concentration of populations along the Missouri River Valley were relieved during the Extended Coalescent period by means of population redistribution through dispersal across the northern and western Plains. Terminal Middle Missouri groups have been directly connected with early Historic Siouan speaking Mandan and Hidatsa tribes through an unbroken sequence of sites dating from the EMM period onward (Wood, 2001). Caddoan speaking Arikara have been implicated in the continued cultural history of Extended Coalescent tradition, and the ethnographic similarities among these three groups suggest a possible convergence of these groups during the Late Plains Village period (Krause, 2001).

Post-Contact

Francisco Vasquez de Coronado's expedition through the southwest to Kansas in 1541 was one of the earliest explorations of the Great Plains by Europeans. Exact moments of Euro-American contact with Plains Villagers vary considerably, and identifying them in the historical record is often difficult. The earliest written evidence for European contact with northern Plains Villagers is from 1738, but direct and indirect contacts likely took place in the surrounding regions much earlier (Johnson, 1998). The Post Contact period on the Plains is defined by the appearance of Euro-American trade goods like iron, glass, or gunflints in Plains Village sites, beginning around the year 1600 (Johnson, 1998); although, Lehmer (2001) argues the influence of Euro-American trade networks upon Plains societies did not result in significant changes until the last quarter of the 17th century. Historic groups living in the Missouri River valley of the Dakotas included the Mandan, Hidatsa, and Arikara tribes. Numerous groups flourished on the Central Plains during the Post-Contact period and onwards, including but certainly not limited to: the Kansa, Osage, Wichita, Pawnee, Omaha, and Ponca tribes. This thesis discusses subsistence practice in three post-contact groups in particular: the Arikara, Omaha, and Ponca.

Villages were often constructed on high ridges above the floodplains of major streams and rivers, providing adequate access to a wide variety of resources, and rarely fortified. Structures were circular earthlodge style homes, with a fire pit in its center. Ethnographic and archaeological evidence (Will and Hyde, 1917) suggests these villages were used extensively for plant and carcass processing as well as tool manufacturing. Intertribal trade networks connected northern and central Plains villagers with exotic goods from the Gulf of Mexico to Hudson Bay, Canada (Lehmer, 2001). Euro-American trade goods, steel especially, did not become common in Plains Village tool assemblages until the mid 1700's. The adoption of the horse from Euro-Americans fundamentally altered modes of transportation and subsistence, especially in the Northern Plains. The horse gave Plains groups increased mobility to hunt large herds of bison until their near extinction during the late 19th century.

Diseases like smallpox, cholera, measles, and malaria had begun to spread to Plains Villages by the at least the mid 1700's (Lehmer, 2001), and possibly as early as the 1600's (Johnson, 1998). The effects of epidemic diseases across the Plains became a very serious issue by the early 1800's and devastated Plains Village populations throughout the 18th and 19th centuries. Total population declines across the Mandan, Arikara, Hidatsa, Wichita, and Pawnee were well over 80% (Lehmer, 2001:255) by the last decade of the 19th century. The aftermath of these epidemics left Plains Village populations fragmented and vulnerable to attack from other tribes as well as American settlers. Surviving individuals often coalesced into concentrated villages, like the Arikara who settled in two villages at the confluence of the Cheyenne and Missouri Rivers after being all but wiped out by smallpox (Parks, 2001). The Plains Village terminates as a result of the dispossession and confinement of native groups to reservations during the 19th century.

SUBSISTENCE ON THE GREAT PLAINS

The terminal Pleistocene marked a period of significant environmental change in North America which ultimately shaped the landscape as we see it today. The earliest indisputable evidence of human populations in the Great Plains dates to at least 11,000 BC, and it is likely this date is to be pushed further back in time as our understanding of this era increases (Goebel et al., 2008). The earliest inhabitants of the America would have had access to the abundant late Pleistocene megafauna of North America, including the American mastodon (*Mammut* spp.), mammoths (*Mammuthus* spp.), horses (*Equus* spp.), camels (*Camelops* spp.), and ground sloths (family Megatheriidae). These communities would be extinct within a few thousand years after humans arrived, and the landscape would give way to the modern faunal communities of the Great Plains including bison, deer, elk, and pronghorn.

Wild plants constituted an equally, if not more so, important component of the diet, despite the attention often given to big game hunting. Earthen ovens Archaic in age (6000-500 BC) are found across the eastern Plains, and ethnobotanical records of root and tuber processing suggest that plant foods like the prairie turnip, camas, and onions have been important components of Native American diet for thousands of years, despite their lack of preservation in archaeological sites. Native plants like goosefoot, marshelder, wild sunflowers, knotweed, pigweed, and grape have been recovered from the few archaic sites on the Plains that yield archaeobotanical remains (Adair and Drass, 2011). Evidence for the deliberate selection of goosefoot is present from multiple archaic sites, and Adair and Kay (2007) suggest that a codependent relationship between plants and people led to the gradual use and cultivation of native species. Fragmentary wild *Cucurbit* rinds from the Nebo Hill site in Missouri have been dated to approximately 2150 BC, and there is evidence for the increased use of this plant in the late Archaic (Adair and Drass, 2011). Hunting and gathering subsistence characterized Native Americans on the Great Plains for a vast majority of their history in the Americas, and we begin to see the advent of true agriculture only relatively recently in the archaeological record.

Plains Woodland Subsistence

Eastern Plains Woodland variants exhibited a greater reliance on sedentary lifestyles and horticultural experimentation than did contemporaneous populations in the west (Bozel and Winfrey, 1994). Marrow processing is frequently exhibited on the bones of primary game animals, and occurs on canid remains in the western region (Bozel et al, 2011). Significant geographic variation is exhibited and likely reflects the utilization of the local environment and the available resources. Secondary subsistence assemblages often give unique insights into the diversity of local subsistence economies over small areas, but contribute to a relatively smaller portion of the diet.

Kansas City Hopewell sites in show evidence of domesticated *Cucurbita* spp. (squash), marshelder, and sunflower (Adair and Drass, 2011), in addition to wild seeds like amaranth and a variety of nuts. Deer tends to dominate faunal assemblages at these sites. In addition, individuals exhibit evidence of a secondary reliance on fish and wild turkey (Johnson, 2001). Valley sites extending north and west along the Missouri River exhibit the continued use of these plants, in addition to a variety of fruits such as plum, grape, dock, goosefoot, and pigweed. A diverse array of faunal remains are present in Valley variant sites, including deer, small mammals, turtles, fish, mussels, birds, and limited quantities of bison (Johnson, 2001).

The earliest presence of maize east of the Rocky Mountains is often erroneously attributed to the Kansas City Hopewell Variant; however, a reanalysis of this claim suggests that the maize was associated with later occupation levels (Adair and Drass, 2011). Maize did not become a major component of the diet until the late Woodland period around 950 AD. This transition occurred first on the eastern margins of the Plains and moved west over time. Our understanding of this revolutionary period in prehistory is significantly impeded by the lack of sites which yield significant archaeobotanical remains. Adair and Drass (2011) review a total of five Late Woodland sites which produced substantial paleoethnobotanical remains, four of which are located on the eastern Plains. A considerable diversity of wild plants have been recovered from these sites including black walnuts, grapes, plums, hazelnuts, and amaranth. Cultigens include maize, squash, gourds, sunflowers, goosefoot, and marshelder (Adair and Drass, 2011). Remains of deer, elk, pronghorn, bison, and small mammals have been recovered from Loseke Creek sites in northeast Nebraska (Johnson, 2001).

No substantial evidence of horticulture has been recovered from Keith variants in west central Nebraska and Kansas, or from the Sonata or Besant complexes on the northern Plains (Johnson, 2001). Both phases have been described as generalist hunter gatherer subsistence economies, but differ in terms of their take of game. Keith variant sites exhibit evidence for a broad based protein subsistence including pronghorn, bison, deer, and a number of small mammals; moreover, fish, mussels, and waterfowl provide evidence for take of local aquatic resources. Sonata and Besant complexes indicate a strong primary reliance on bison with minimal evidence of extensive plant use (Johnson and Johnson, 1998). These groups are known to have participated in long distance trade with groups to the west and the southeast, and quite possibly traded bison products for plant resources with horticultural groups to the south.

Early Plains Village Subsistence

The ubiquitous feature among all Plains Village sites is the presence of agricultural homesteads or farmsteads. The diversity of paleoethnobotanical remains on the Plains during this time period far surpasses any previous time period or people living on the Plains prior. Populations cultivated both native seed crops as well as crops introduced from surrounding regions. Early Plains Village groups still practiced partial hunting and gathering subsistence economies; however, the presence of native seed crops decreases in the Late Plains Village period and introduced seed crops dominate assemblages.

The most frequently recovered native seed crops included plants already common to earlier Plains subsistence patterns, such as sunflower, marshelder, goosefoot, and little barley, but in greater abundance as a result of more intensive cultivation (Adair and Drass, 2011). These plants prefer the well watered soils in the floodplain of the Missouri River and its immediate tributaries, and decline in abundance to the south and west. Wild nut species like hickory, hazel, and walnut are frequently recovered from sites in the river valleys of the central and eastern Plains, while chokecherry, hackberry, wild plum, and wild grape have frequently been recovered across the central Plains (Roper, 2006). Introduced seed crops such as maize, squash, and beans played a major role in Plains Village subsistence economies throughout the period. Tobacco was cultivated in varying amounts for non-subsistence purposes as well.

Middle Missouri groups primarily exploited bison and a small number of cultigens to provide a relatively complete diet in a relatively marginal environment (Winham and Calabrese, 1998). Maize, sunflower, squash, and beans were supplemented with wild plums, chokecherries, rose hips, and buffaloberries. Early Middle Missouri groups collected and possibly cultivated native weedy annuals like marshelder, dock, lamb's quarter, and pigweed, but decline in abundance over time. Relative to groups on the central and eastern Plains during this time, bison absolutely dominates faunal assemblages in the Middle Missouri region. Winham and Calabrese (1998:291) report that bison constituted over 90% of usable meat from many Middle Missouri faunal assemblages. In addition, a large number of species occur in very small numbers at these sites including pronghorn, beaver, rabbit, fish, mussel, and birds.

The use of animal resources during the Early Plains Village period has been described as a generalized, broad spectrum economy (Bozel et al, 2011) which utilized a diverse array of fauna. Bison are consistently present in low amounts on the central and eastern margins of the Plains, with a greater emphasis on deer, elk, and pronghorn procurement. Turkey, mussel, and catfish are common in to the east and decrease in abundance to the west. Considerable quantities of bison bone are more common from the Middle Missouri region, but vary significantly in terms of their representation in faunal assemblages across the Plains environment as a whole. Large scale, communal bison hunting camps are virtually unknown from the Central Plains but are documented throughout eastern Colorado, Wyoming, and western Nebraska. The exception to this pattern is the McIntosh site, from which considerable amounts of bison and fish bone has been recovered from a camp in the Nebraska Sand Hills (Koch, 1995). CPT subsistence adaptations are generally opportunistic and highly flexible (Pugh, 2010).

The near ubiquitous presence of bison hoe scapulas in horticultural Plains Village sites despite the underrepresentation of other bison bones in eastern central Plains faunal assemblages poses an interesting question for those studying CPT subsistence. The abundance of large ungulates such as deer, elk, and pronghorn suggest other sources of meat related subsistence were readily available. Middle Missouri groups in the Dakotas continued hunting bison in large amounts throughout the Plains Village period, remaining relatively stable in terms of village organization and subsistence economies throughout Late Plains Village period (Bozel et al, 2011).

Trade networks with bison hunting groups to the west and north may have subsidized Plains Village sites with bison products in exchange for horticultural products; however, at the present there is little evidence to support this theory. Exotic goods such as copper, obsidian, and marine and freshwater shells are present in a large number of Early Middle Missouri sites, suggesting trade networks played at least a partial role in Middle Missouri lifeways (Wood, 2001). Wedel (2001:180) suggests the lack of bison bone in eastern village sites may be the result of butchery practices. Large scale communal bison kills on the western or northern Plains often utilize natural traps or arroyos, considerably removed from village sites. A separation in time and space between village and kill sites could be implicated in the apparent lack of bison bone refuse in eastern Plains Village sites; however, if this was the case a single large scale bison kill could reasonably be assumed to have been found following over a century of archaeological field work in this region. In spite of this, any evidence at all of bison kills akin to the western Plains is seriously lacking on the central or eastern Plains (Bozel et al., 2011).

Late Plains Village Subsistence

Late Plains Villagers in the Middle Missouri region are understood to be ancestral to modern day Mandan, Hidatsa, and Arikara tribes. Archaeological and ethnographic evidence from these groups suggest a strong continuity in subsistence from the late Plains Village period well into post-contact society. Subsistence economies were primarily reliant upon horticulture and hunting, exhibiting a decrease in the cultivation of native seed crops to the overall diet. Wild plants, including blackberries, cherry, plum, grape, rose, and buffaloberries were gathered in relatively small amounts, while the maize, squash, sunflower, bean were cultivated in large quantities (Nickel, 1977). Bison continued to be the main source of meat to the diet, constituting between 80-95% (Johnson, 1998), with limited quantities of deer, elk, and pronghorn. Small animals like birds, fish, and canids are also present at a number of Coalescent period sites.

Krause (2001:201) mentions the single most significant limitation on Initial Coalescent subsistence was access to floodplain resources, including timber and farmland, in the face of increased population density and competition among neighboring groups. This limitation was likely instrumental in the later dispersal of Extended Coalescent groups into the northern and western Dakotas. Extended Coalescent groups continued to practice subsistence economies virtually identical to Initial Coalescent groups, exhibiting strong reliance on bison and cultivated seed crops with limited wild plant utilization. Due to the strong continuity of subsistence practices across multiple groups in this region, many anthropologists have turned towards the ethnographic literature to supplement knowledge of Late Plains Village subsistence practices.

Horticultural land was possessed in small family or household plots and was usually tended to by the women of the household and their daughters (Wilson, 1917). Men were the sole tenders of the tobacco gardens, which were kept in separate gardens. Gardens were often about an acre or more in size, the larger of them near 5 acres (Lehmer, 2001). Plants were husked in the fields before being brought to the village to shell, boil, and/or dry prior to storage or immediate consumption. Cache pits were constructed by digging holes several feet deep and lining the walls with bundles of dried grass or animal skins. Strings of maize lined the walls of the pit, and loose maize or beans were stored within the interior of this lining. Dried squash, which was more vulnerable to spoilage than maize, was placed in the very center of the pit and carefully packed with loose grain (Wilson, 1917).

War and disease throughout the 18th and 19th century altered Plains Village lifeways in a fundamental way. The confinement of Plains Villagers to reservations during the mid to late 19th century resulted in the major disruption of Plains Village lifeways and brought the Plains Village period to a close. Reservation land and was slowly whittled away through the breaking of numerous treaties made with Native American Tribes by the United States Government and through shady land deals with private landowners. The Indian Wars of the mid to late 1800's culminated in the massacre of over 100 men, women, and children at Wounded Knee, South Dakota. Bison, which had played a major role in subsistence economies of Plains Villagers for over five centuries, were all but extinct by the end of the 19th century. Bison today exist only as a shadow of their historic populations, confined predominately to National Wildlife Areas and National Parks. The descendants of the Plains Village culture, including the Arikara, Mandan, Hidatsa, and Ponca people, are currently live in metro areas and reservations along the Missouri River.

METHODOLOGY

This thesis utilizes stable carbon isotopes from 189 individuals to track changes in subsistence practices across Woodland, Early and Late Plains Village time periods in Kansas, Nebraska, and South Dakota. Data from four published sources (Foreshoe et al. 1994; Beiningen and Tieszen, 1993; Reinhard et al., 1993; Williams, 1992) and one unpublished Master's thesis (Conner, 2001) was compiled into a single dataset and sorted by both time and geographic area. Per Kellner and Schoeninger's (2007) model of reconstructing prehistoric diet, data lacking both collagen and apatite values were discarded for this analysis. C:N ratios can indicate if a sample has been significantly altered by diagenetic processes and thusly serve as controls on the reliability of this data. Only data with reported C:N ratios in between 2.7- 3.7 are included in this analysis. Data was sorted into Woodland, Early Plains Village, and Late Plains Village based on reported ages or cultural affiliations. Response variables $\delta 13C_{collagen}$ $\delta 13C_{apatite}$ and $\Delta 13C$ were plotted against time period and state categories to create bivariate scatter plots. One-way ANOVAs were performed for each response variable followed by Tukey-Kramer HSD tests to determine statistical significance with a significance level of .05.

RESULTS

$\delta 13C_{apatite}$, which is understood to be representative of the total dietary energy source, shows statistically significant differences across all time periods. Plains Woodland (n=71) individuals exhibit considerable variation with regards to $\delta 13C_{apatite}$ and $\delta 13C_{collagen}$ values, but produced the most negative signal ($\bar{x}$= -15.7‰) in relation to the Early and Late Plains Village groups (n=66 and n=51 respectively). Early Plains Village sites had the highest δ13C$_{apatite}$ signals ($\bar{x}$= -4.7‰) indicating a diet consisting primarily of C4 energy sources. Late Plains Village sites exhibit a decrease in δ13C$_{apatite}$ values from Early Plains Village sites ($\bar{x}$= -7.7‰) suggesting an overall diet with a smaller proportion of C4 resources than Early Plains Village groups. There is notable overlap between time periods with regard to δ13C$_{apatite}$ values, indicating that no single range of values is diagnostic of a particular time period; however, the Tukey Kramer-HSD test shows significant differences between central tendencies (p<.0001) indicating that the overall dietary composition changed considerably over time.

Figure 2: Bivariate scatter plot of δ13C$_{collagen}$ by δ13C$_{apatite}$ for Plains Woodland, Early Plains Village, and Late Plains Village time periods

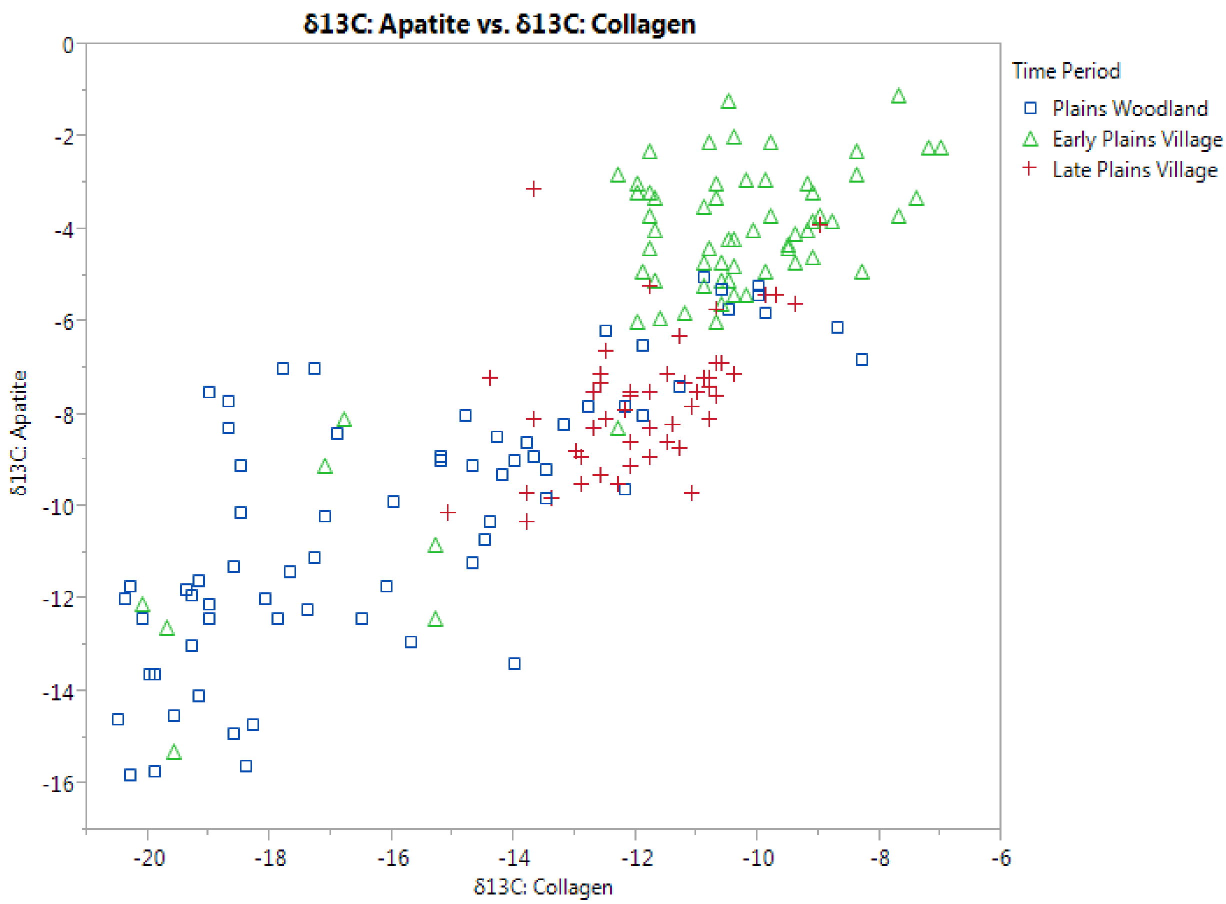


Table 1: Stable Carbon Isotope Values of Individuals Analyzed in this Thesis (n=189)

State	Site #	Site Name	Reported Age	Phase or Tribe	Time Period	$\delta 13C_{Collagen}$	$\delta 13C_{apatite}$	$\Delta 13C$	C:N	Source
Nebraska	25DK2	Ryan		Valley	Plains Woodland	-20.3	-15.8	4.6	3.2	1
Nebraska	25DK2	Ryan			Plains Woodland	-19.9	-13.6	6.3	3.2	1
Nebraska	25DK2	Ryan		Valley	Plains Woodland	-12.8	-7.8	4.9	3.1	1
Nebraska	25DK2	Ryan		Valley	Plains Woodland	-20.5	-14.6	5.8	3.1	1
Nebraska	25DK2	Ryan		Valley	Plains Woodland	-14	-9	5	3.1	1
Nebraska	25DK2	Ryan		Valley	Plains Woodland	-14.3	-8.5	5.8	3.1	1
Nebraska	25DK2	Ryan		Valley	Plains Woodland	-14.7	-9.1	5.6	3.2	1
Nebraska	25DK2	Ryan		Valley	Plains Woodland	-18.4	-15.6	2.8	3.4	1
Nebraska	25DK2	Ryan		Valley	Plains Woodland	-18.3	-14.7	3.7	3.1	1
Nebraska	25DK2	Ryan		Valley	Plains Woodland	-18.6	-14.9	3.7	3.1	1
Nebraska	25DK2	Ryan			Plains Woodland	-9.9	-5.8	4.1	2.7	1
Nebraska	25DK2	Ryan		Valley	Plains Woodland	-10	-5.2	4.8	3.1	1
Nebraska	25DK2	Ryan		Valley	Plains Woodland	-14.5	-10.7	3.8	3.1	1
Nebraska	25DK2	Ryan		Valley	Plains Woodland	-14.8	-8	6.9	3.2	1
Nebraska	25DK2	Ryan		Valley	Plains Woodland	-14.2	-9.3	4.9	3.1	1
Nebraska	25DK2	Ryan		Valley	Plains Woodland	-15.2	-8.9	6.3	3.2	1
Nebraska	25DK2	Ryan		Valley	Plains Woodland	-13.8	-8.6	5.2	3.1	1
Nebraska	25DK2	Ryan		Valley	Plains Woodland	-16	-9.9	6	3.1	1
Nebraska	25DK2	Ryan		Valley	Plains Woodland	-13.7	-8.9	4.8	3.1	1
Nebraska	25HT1	Eagle Creek			Plains Woodland	-14.7	-11.2	3.6	2.8	1

Nebraska	25HT1	Eagle Creek			Plains Woodland	-16.1	-11.7	4.4	2.8	1
Nebraska	25HT1	Eagle Creek			Plains Woodland	-16.5	-12.4	4.1	2.7	1
Nebraska	25HT1	Eagle Creek			Plains Woodland	-19.4	-11.8	7.5	2.7	1
Nebraska	25HT1	Eagle Creek			Plains Woodland	-19	-7.5	11.5	3.3	1
Nebraska	25HT1	Eagle Creek			Plains Woodland	-19.3	-11.9	7.4	3.2	1
Nebraska	25HT3	Redbird			Plains Woodland	-19.2	-14.1	5.2	2.8	1
Nebraska	25HT3	Redbird			Plains Woodland	-19.2	-11.6	7.6	3.2	1
Nebraska	25HT3	Redbird			Plains Woodland	-10.5	-5.7	4.8	2.7	1
Nebraska	25HT3	Redbird			Plains Woodland	-15.7	-12.9	2.8	3.1	1
Nebraska	25KX6	Davis Mounds			Plains Woodland	-14.4	-10.3	4.1	3.1	1
Nebraska	25KX6	Davis Mounds			Plains Woodland	-10.6	-5.3	5.3	3.3	1
Nebraska	25KX6	Davis Mounds			Plains Woodland	-11.9	-6.5	5.5	3.1	1
Nebraska	25KX6	Davis Mounds			Plains Woodland	-14	-13.4	0.6	3.1	1
Nebraska	25KX6	Davis Mounds			Plains Woodland	-13.2	-8.2	5	3.1	1
Nebraska	25KX6	Davis Mounds			Plains Woodland	-15.2	-9	6.1		2
Nebraska	25KX6	Davis Mounds			Plains Woodland	-11.9	-8	3.9	3.1	1
Nebraska	25KX6	Davis Mounds			Plains Woodland	-13.5	-9.2	4.3	3.2	1
Nebraska	25KX6	Davis Mounds			Plains Woodland	-13.5	-9.8	3.7	3.1	1
Kansas	14BO26	Slick Rock			Plains Woodland	-20.3	-11.7	8.6	3.1	3
Kansas	14BO26	Slick Rock			Plains Woodland	-20.4	-12	8.4	3.1	3
Kansas	14RO303			Keith	Plains Woodland	-19	-12.1	6.9		3
Kansas	14SC405			Keith	Plains Woodland	-17.4	-12.2	5.2		3

Kansas	14DP3	Taylor Mound	10 (+/-140)	Valley	Plains Woodland	-19.9	-15.7	4.2		3
Kansas	14AT316	Ingalls Mound	1-600	Valley	Plains Woodland	-10	-5.4	4.6	3	3
Kansas	14NS1 133	Koerner Mound	1-900	Keith	Plains Woodland	-17.1	-10.2	6.9		3
Kansas	14MO314	Morris	200-600	Schultz Focus	Plains Woodland	-12.5	-6.2	6.3	3.1	3
Kansas	14CY26	Robert Younkin	200-600	Schultz Focus	Plains Woodland	-18.5	-9.1	9.4	3.1	3
Kansas	14GE2	Dan Younkin	200-600	Schultz Focus	Plains Woodland	-20.1	-12.4	7.7	3.2	3
Kansas	14GE4	Berry Mounds	200-600	Schultz Focus	Plains Woodland	-11.3	-7.4	3.9	3.1	3
Kansas	14GE4	Berry Mounds	200-600	Schultz Focus	Plains Woodland	-19.6	-14.5	5.1	3.1	3
Kansas	14GE6	James Younkin	200-600	Schultz Focus	Plains Woodland	-12.2	-7.8	4.4	3.1	3
Kansas	14GE6	James Younkin	200-600	Schultz Focus	Plains Woodland	-20	-13.6	6.4	3.2	3
Kansas	14DP3	Taylor Mound	290 (+/-140)	Valley	Plains Woodland	-12.1	-7.6	4.6	3.1	3
Kansas	14TO301		500	Keith	Plains Woodland	-18.6	-11.3	7.3		3
Kansas	14PH10	West Island	600	Keith	Plains Woodland	-18.7	-7.7	11		3
Kansas	14PH10	West Island	600	Keith	Plains Woodland	-18.7	-8.3	10.4		3
Kansas	14RO301	Doak Place	600	Keith	Plains Woodland	-19	-12.4	6.6		3
Kansas	14RO301	Doak Place	600	Keith	Plains Woodland	-18.1	-12	6.1		3
Kansas	14RO301	Doak Place	600	Keith	Plains Woodland	-17.9	-12.4	5.5		3
Nebraska	25DX4		700 - 950	Loseke Cr.	Plains Woodland	-10.9	-5	5.9	2.8	1
Nebraska	25DX4		700 - 950	Loseke Cr.	Plains Woodland	-10	-5.2	4.9	2.8	1
Nebraska	25DX4		700 - 950	Loseke Cr.	Plains Woodland	-17.3	-7	10.4	3.1	1
Nebraska	25DX4		700 - 950	Loseke Cr.	Plains Woodland	-18.5	-10.1	8.4	2.8	1
Nebraska	25DX4		700 - 950	Loseke Cr.	Plains Woodland	-8.3	-6.8	1.5	2.7	1

Nebraska	25DX4		700 - 950	Loseke Cr.	Plains Woodland	-19.3	-13	6.3	2.8	1
Nebraska	25DX4		700 - 950	Loseke Cr.	Plains Woodland	-17.8	-7	10.8	2.8	1
Nebraska	25DX4		700 - 950	Loseke Cr.	Plains Woodland	-8.7	-6.1	2.6	2.7	1
Nebraska	25KX12	Niobrara School	700 - 950	Loseke Cr.	Plains Woodland	-12.2	-9.6	2.6	2.7	1
Nebraska	25KX12	Niobrara School	700 - 950	Loseke Cr.	Plains Woodland	-17.3	-11.1	6.2	3.1	1
Nebraska	25KX12	Niobrara School	700 - 950	Loseke Cr.	Plains Woodland	-17.7	-11.4	6.3		2
Nebraska	25KX12	Niobrara School	700 - 950	Loseke Cr.	Plains Woodland	-16.9	-8.4	8.5	3.1	3
Kansas	14CY32	Timber Creek Mounds		Schultz Focus	Early Plains Village	-11.2	-5.8	5.4	3.1	3
Kansas	14CY32	Timber Creek Mounds		Schultz Focus	Early Plains Village	-10.7	-6	4.7	3.1	3
Kansas	14OS312	Wiley		Pomona Focus	Early Plains Village	-16.8	-8.1	8.7	3.1	3
Kansas	14OS312	Wiley		Pomona Focus	Early Plains Village	-17.1	-9.1	8	3.2	3
Kansas	14HP5	Armstrong	1000-1200	Bluff Creek Complex	Early Plains Village	-7.4	-3.3	4.1		3
Kansas	14HP3	Dow Mandeville	1100-1600	Bluff Creek Complex	Early Plains Village	-7.2	-2.2	5	3.3	3
Kansas	14HP3	Dow Mandeville	1100-1600	Bluff Creek Complex	Early Plains Village	-8.8	-3.8	5	3.1	3
Kansas	14HP3	Dow Mandeville	1100-1600	Bluff Creek Complex	Early Plains Village	-7.7	-1.1	6.6	3.2	3
Kansas	14HP1	Anthony	1100-1600	Bluff Creek Complex	Early Plains Village	-8.3	-4.9	3.4		3
Kansas	14HP1	Anthony	1100-1600	Bluff Creek Complex	Early Plains Village	-7	-2.2	4.8		3
Kansas	14WY7	Calovich Mound	1105 (+/-80)	Steed-Kisker Phase	Early Plains Village	-12	-3.2	8.8	3.1	3
Kansas	14WY7	Calovich Mound	1105 (+/-80)	Steed-Kisker Phase	Early Plains Village	-11.7	-3.3	8.4	3.1	3
Kansas	14WY7	Calovich Mound	1105 (+/-80)	Steed-Kisker Phase	Early Plains Village	-12	-3	9	3.1	3
Kansas	14WY7	Calovich Mound	1105 (+/-80)	Steed-Kisker Phase	Early Plains Village	-10.8	-2.1	8.7	3.1	3
Kansas	14WY7	Calovich Mound	1105 (+/-80)	Steed-Kisker Phase	Early Plains Village	-12.3	-2.8	9.5	3.1	3

Kansas	14WY7	Calovich Mound	1105 (+/-80)	Steed-Kisker Phase	Early Plains Village	-11.8	-3.2	8.6	3.2	3
Kansas	14WY7	Calovich Mound	1105 (+/-80)	Steed-Kisker Phase	Early Plains Village	-10.4	-2	8.4	3.1	3
Kansas	14WY7	Calovich Mound	1105 (+/-80)	Steed-Kisker Phase	Early Plains Village	-11.7	-5.1	6.6	3	3
Kansas	14WY7	Calovich Mound	1105 (+/-80)	Steed-Kisker Phase	Early Plains Village	-10.7	-3	7.7	3.1	3
Kansas	14WY7	Calovich Mound	1105 (+/-80)	Steed-Kisker Phase	Early Plains Village	-11.8	-2.3	9.5	3.1	3
Kansas	14WY7	Calovich Mound	1105 (+/-80)	Steed-Kisker Phase	Early Plains Village	-11.9	-4.9	7	3.1	3
Kansas	14WY7	Calovich Mound	1105 (+/-80)	Steed-Kisker Phase	Early Plains Village	-10.5	-1.2	9.3	3.1	3
Kansas	14WY7	Calovich Mound	1105 (+/-80)	Steed-Kisker Phase	Early Plains Village	-12	-6	6	3	3
Nebraska	25DK9	Murphy/O'Connor	1200 - 1400	St. Helena	Early Plains Village	-9.8	-2.1	7.7	3.2	1
Nebraska	25DK9	Murphy/O'Connor	1200 - 1400	St. Helena	Early Plains Village	-11.8	-3.7	8.1	3.2	1
Nebraska	25DK9	Murphy/O'Connor	1200 - 1400	St. Helena	Early Plains Village	-9.2	-3	6.2	3.1	4
Nebraska	25DK9	Murphy/O'Connor	1200 - 1400	St. Helena	Early Plains Village	-11.8	-4.4	7.4	3.2	4
Nebraska	25DK9	Murphy/O'Connor	1200 - 1400	St. Helena	Early Plains Village	-10.1	-4	6.1	3.2	4
Nebraska	25DK9	Murphy/O'Connor	1200 - 1400	St. Helena	Early Plains Village	-10.5	-4.2	6.3	3.2	4
Nebraska	25DK9	Murphy/O'Connor	1200 - 1400	St. Helena	Early Plains Village	-10.2	-2.9	7.3	3.2	1
Nebraska	25DK9	Murphy/O'Connor	1200 - 1400	St. Helena	Early Plains Village	-10.9	-3.5	7.4	3.2	4
Nebraska	25DK9	Murphy/O'Connor	1200 - 1400	St. Helena	Early Plains Village	-11.7	-4	7.7	3.2	1
Nebraska	25DK9	Murphy/O'Connor	1200 - 1400	St. Helena	Early Plains Village	-10.9	-5.2	5.7	3.2	4
Nebraska	25DK9	Murphy/O'Connor	1200 - 1400	St. Helena	Early Plains Village	-9	-3.7	5.3	3.2	1
Nebraska	25DK9	Murphy/O'Connor	1200 - 1400	St. Helena	Early Plains Village	-9.9	-2.9	7	3.2	1
Nebraska	25DK9	Murphy/O'Connor	1200 - 1400	St. Helena	Early Plains Village	-8.4	-2.3	6	3.2	4
Nebraska	25DK9	Murphy/O'Connor	1200 - 1400	St. Helena	Early Plains Village	-10.7	-3.3	7.3	3.2	1

Nebraska	25DK9	Murphy/O'Connor	1200 - 1400	St. Helena	Early Plains Village	-7.7	-3.7	3.9	3.1	1
Nebraska	25DK9	Murphy/O'Connor	1200 - 1400	St. Helena	Early Plains Village	-8.4	-2.8	5.5	3.2	4
Nebraska	25DK9	Murphy/O'Connor	1200 - 1400	St. Helena	Early Plains Village	-10.6	-5.6	5	3.2	4
Nebraska	25DK9	Murphy/O'Connor	1200 - 1400	St. Helena	Early Plains Village	-10.9	-4.7	6.2	3.2	4
Nebraska	25CD7	Jones/Wynot	1250-	Central Plains Tradition	Early Plains Village	-9.5	-4.3	5.2	3.1	1
Nebraska	25CD7	Jones/Wynot	1250-	Central Plains Tradition	Early Plains Village	-9.4	-4.1	5.3	3.2	1
Nebraska	25CD7	Jones/Wynot	1250-	Central Plains Tradition	Early Plains Village	-9.4	-4.7	4.7	3.4	1
Nebraska	25CD7	Jones/Wynot	1250-	Central Plains Tradition	Early Plains Village	-10.4	-4.2	6.2	3.2	1
Nebraska	25CD7	Jones/Wynot	1250-	Central Plains Tradition	Early Plains Village	-9.1	-4.6	4.5	3.1	1
Nebraska	25CD7	Jones/Wynot	1250-	Central Plains Tradition	Early Plains Village	-10.6	-4.7	5.9	3.1	1
Nebraska	25CD7	Jones/Wynot	1250-	Central Plains Tradition	Early Plains Village	-10.8	-4.4	6.4		1
Nebraska	25CD4	Wiseman M.	1250 -1700	Central Plains Tradition	Early Plains Village	-9.1	-3.8	5.3	3.1	1
Nebraska	25CD4	Wiseman M.	1250 -1700	Central Plains Tradition	Early Plains Village	-9.8	-3.7	6	3.1	1
Nebraska	25CD4	Wiseman M.	1250 -1700	Central Plains Tradition	Early Plains Village	-9.9	-4.9	5	3.1	1
Nebraska	25CD4	Wiseman M.	1250 -1700	Central Plains Tradition	Early Plains Village	-10.4	-4.8	5.6	3.2	1
Nebraska	25CD4	Wiseman M.	1250 -1700	Central Plains Tradition	Early Plains Village	-19.6	-15.3	4.3	3.1	1
Nebraska	25CD4	Wiseman M.	1250 -1700	Central Plains Tradition	Early Plains Village	-10.4	-5.4	5	3.1	1
Nebraska	25CD4	Wiseman M.	1250 -1700	Central Plains Tradition	Early Plains Village	-9.1	-3.2	5.9	3.1	1
Nebraska	25CD4	Wiseman M.	1250 -1700	Central Plains Tradition	Early Plains Village	-10.5	-5.1	5.4	3.1	1
Nebraska	25CD4	Wiseman M.	1250 -1700	Central Plains Tradition	Early Plains Village	-9.2	-4	5.2	3.1	1
Kansas	14MY305	Infinity	1310 (+/- 90)	Pomona Focus	Early Plains Village	-20.1	-12.1	8		3
Kansas	14MY305		970 (+/-80)	Schultz Focus	Early Plains Village	-19.7	-12.6	7.1		3

South Dakota	39DW1	Morrow V	900 - 1700	Extended Coalescent	Early Plains Village	-15.3	-12.4	2.9	3.2	2
South Dakota	39DW1	Morrow V	900 - 1700	Extended Coalescent	Early Plains Village	-15.3	-10.8	4.5	3.3	2
South Dakota	39HU126	Little Cherry	1400 - 1550	Extended Coalescent	Early Plains Village	-12.3	-8.3	4	3.2	2
Nebraska	25DK13	Maxwell	1200 - 1400	St. Helena	Early Plains Village	-10.2	-5.4	4.8	3.1	1
Nebraska	25DK13	Maxwell	1200 - 1400	St. Helena	Early Plains Village	-11.6	-5.9	5.7	3.1	1
Nebraska	25DK13	Maxwell	1200 - 1400	St. Helena	Early Plains Village	-9.5	-4.4	5.1	3.2	1
Nebraska	25DK13	Maxwell	1200 - 1400	St. Helena	Early Plains Village	-10.6	-5.1	5.5	3.1	1
Nebraska	25KX5	Hogan		Ponca	Late Plains Village	-13.4	-9.8	3.6	3.1	1
South Dakota	39SL4	Fort Sully	1650-	Arikara	Late Plains Village	-11.2	-7.3	3.9	3.2	2
South Dakota	39SL4	Fort Sully	1650-	Arikara	Late Plains Village	-12.7	-7.5	5.2	3.3	2
South Dakota	39SL4	Fort Sully	1650-	Arikara	Late Plains Village	-12.1	-7.6	4.5	3.2	2
South Dakota	39SL4	Fort Sully	1650-	Arikara	Late Plains Village	-9	-3.9	5	3.2	2
South Dakota	39SL4	Fort Sully	1650-	Arikara	Late Plains Village	-11.8	-7.5	4.3	3.2	2
South Dakota	39SL4	Fort Sully	1650-	Arikara	Late Plains Village	-10.7	-5.7	5.1	3.2	2
South Dakota	39SL4	Fort Sully	1650-	Arikara	Late Plains Village	-11.3	-6.3	5	3.2	2
South Dakota	39SL4	Fort Sully	1650-	Arikara	Late Plains Village	-11.5	-7.1	4.4	3.2	2
South Dakota	39SL4	Fort Sully	1650-	Arikara	Late Plains Village	-9.4	-5.6	3.8	3.2	2
South Dakota	39SL4	Fort Sully	1650-	Arikara	Late Plains Village	-9.9	-5.4	4.6	3.2	2
South Dakota	39SL4	Fort Sully	1650-	Arikara	Late Plains Village	-11.1	-9.7	1.4	3.2	2
South Dakota	39SL4	Fort Sully	1650-	Arikara	Late Plains Village	-12.5	-6.6	5.9	3.2	2
South Dakota	39CA4	Anton Rygh	1452 (+/- 75)	Arikara	Late Plains Village	-12.6	-7.1	5.5	3.3	2
South Dakota	39CA4	Anton Rygh	1452 (+/- 75)	Arikara	Late Plains Village	-12.6	-7.3	5.3	3.3	2

South Dakota	39CA4	Anton Rygh	1452 (+/- 75)	Arikara	Late Plains Village	-12.5	-8.1	4.4	3.2	2
South Dakota	39LM1	Stricker V	1700 - 1861	Arikara	Late Plains Village	-12.3	-8.3	3.4	3.3	2
Nebraska	25KX1	Ponca Point	1700-	Ponca	Late Plains Village	-10.7	-7.6	3.1	3.1	4
Nebraska	25KX1	Ponca Point	1700-	Ponca	Late Plains Village	-10.6	-6.9	3.6	3.2	4
Nebraska	25KX1	Ponca Point	1700-	Ponca	Late Plains Village	-10.8	-8.1	2.7	3.1	1
Nebraska	25KX1	Ponca Point	1700-	Ponca	Late Plains Village	-10.8	-7.2	3.6	3.2	4
Nebraska	25KX1	Ponca Point	1700-	Ponca	Late Plains Village	-10.7	-6.9	3.8	3.2	4
Nebraska	25KX1	Ponca Point	1700-	Ponca	Late Plains Village	-12.1	-7.5	4.7	3.2	4
Nebraska	25KX1	Ponca Point	1700-	Ponca	Late Plains Village	-11.1	-7.8	3.3	2.7	1
Nebraska	25KX1	Ponca Point	1700-	Ponca	Late Plains Village	-10.8	-7.4	3.4	2.7	1
Nebraska	25KX1	Ponca Point	1700-	Ponca	Late Plains Village	-11.3	-8.7	2.5	2.7	1
Nebraska	25KX1	Ponca Point	1700-	Ponca	Late Plains Village	-10.9	-7.2	3.7	2.7	1
Nebraska	25KX1	Ponca Point	1700-	Ponca	Late Plains Village	-11	-7.5	3.5	3.2	4
Nebraska	25KX1	Ponca Point	1700-	Ponca	Late Plains Village	-11.4	-8.2	3.2	3.2	4
Nebraska	25KX1	Ponca Point	1700-	Ponca	Late Plains Village	-11	-7.5	3.5	3.2	4
Nebraska	25KX1	Ponca Point	1700-	Ponca	Late Plains Village	-10.4	-7.1	3.3	3.1	4
Nebraska	25KX1	Ponca Point	1700-	Ponca	Late Plains Village	-9.7	-5.4	4.3		1
Nebraska	25KX1	Ponca Point	1700-	Ponca	Late Plains Village	-12.6	-9.3	3.2	3.2	4
South Dakota	39WW1	Mobridge V.	1700-1861	Omaha	Late Plains Village	-13.8	-9.7	4.2	3.2	2
Kansas	14LV84	Land	1700-1765	Kansa	Late Plains Village	-15.1	-10.1	5	3.1	3
Nebraska	25DK2	Ryan	1780-1840	Omaha	Late Plains Village	-13.8	-10.3	3.5		2
Nebraska	25DK2	Ryan	1780-1840	Omaha	Late Plains Village	-12.2	-7.9	4.3		2

South Dakota	39ST244	Johnston	1477-1662	Omaha	Late Plains Village	-11.8	-8.3	3.4	3.2	5
Nebraska	25DK10	Big Village	1780-1840	Omaha	Late Plains Village	-11.5	-8.6	2.9	3.1	2
Nebraska	25DK10	Big Village	1780-1840	Omaha	Late Plains Village	-14.4	-7.2	7.2		2
Nebraska	25DK10	Big Village	1780-1840	Omaha	Late Plains Village	-12.1	-9.1	3	3.1	2
Nebraska	25DK10	Big Village	1780-1840	Omaha	Late Plains Village	-12.3	-9.5	2.8	3.1	2
Nebraska	25DK10	Big Village	1780-1840	Omaha	Late Plains Village	-13.7	-8.1	5.6		2
Nebraska	25DK10	Big Village	1780-1840	Omaha	Late Plains Village	-12.7	-8.3	4.4		2
Nebraska	25DK10	Big Village	1780-1840	Omaha	Late Plains Village	-12.9	-9.5	3.4		2
Nebraska	25DK10	Big Village	1780-1840	Omaha	Late Plains Village	-13	-8.8	4.2		2
Nebraska	25DK10	Big Village	1780-1840	Omaha	Late Plains Village	-12.1	-8.6	3.5	3.1	2
Nebraska	25DK10	Big Village	1780-1840	Omaha	Late Plains Village	-11.8	-5.2	6.6		2
Nebraska	25DK10	Big Village	1780-1840	Omaha	Late Plains Village	-13.7	-3.1	3.1		2
Nebraska	25DK10	Big Village	1780-1840	Omaha	Late Plains Village	-12.9	-8.9	4		2
Nebraska	25DK10	Big Village	1780-1840	Omaha	Late Plains Village	-11.8	-8.9	2.9		2

Source Legend	
1	Foreshoe et al. 1994
2	Beiningen and Tieszen, 1993
3	Conner, 2001
4	Reinhard et al, 1993
5	Williams, 1992

Figure 3: δ13C$_{Collagen}$ ANOVA/Tukey-Kramer HSD Test

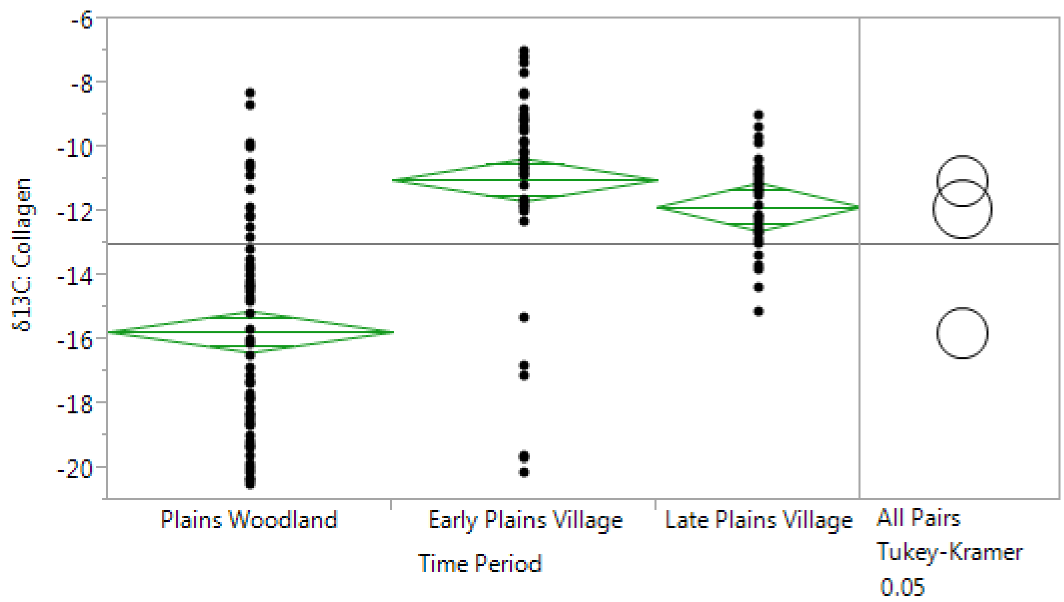


Table 2: δ13C$_{Collagen}$ Means Report

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Plains Woodland	71	-15.746	0.32511	-16.39	-15.11
Early Plains Village	66	-11.002	0.3372	-11.67	-10.34
Late Plains Village	51	-11.845	0.38359	-12.6	-11.09

Table 3: δ13C$_{Collagen}$ HSD Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Early Plains Village	Plains Woodland	4.744964	0.4684	3.63824	5.85169	<.0001
Late Plains Village	Plains Woodland	3.901381	0.502833	2.7133	5.089464	<.0001
Early Plains Village	Late Plains Village	0.843583	0.510733	-0.36317	2.050332	0.2268

Figure 4: δ13C$_{Apatite}$ ANOVA/Tukey-Kramer HSD Test

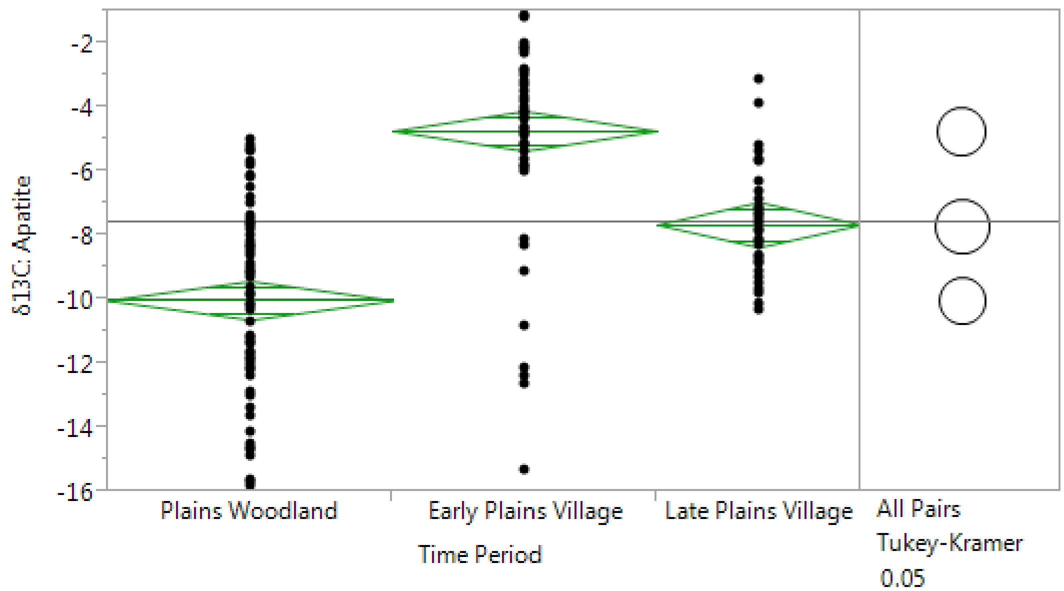


Table 4: δ13C$_{Apatite}$ Means Report

Time Period	Number	Mean	Std Error	Lower 95%	Upper 95%
Plains Woodland	71	-10.03	0.30317	-10.63	-9.431
Early Plains Village	66	-4.739	0.31444	-5.36	-4.119
Late Plains Village	51	-7.671	0.3577	-8.38	-6.965

Table 5: δ13C$_{Apatite}$ HSD Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-value
Early Plains Village	Plains Woodland	5.290184	0.436786	4.258154	6.322213	<.0001
Early Plains Village	Late Plains Village	2.931194	0.476261	1.805893	4.056495	<.0001
Late Plains Village	Plains Woodland	2.358989	0.468894	1.251094	3.466884	<.0001

Figure 5: Δ13C ANOVA/Tukey-Kramer HSD test

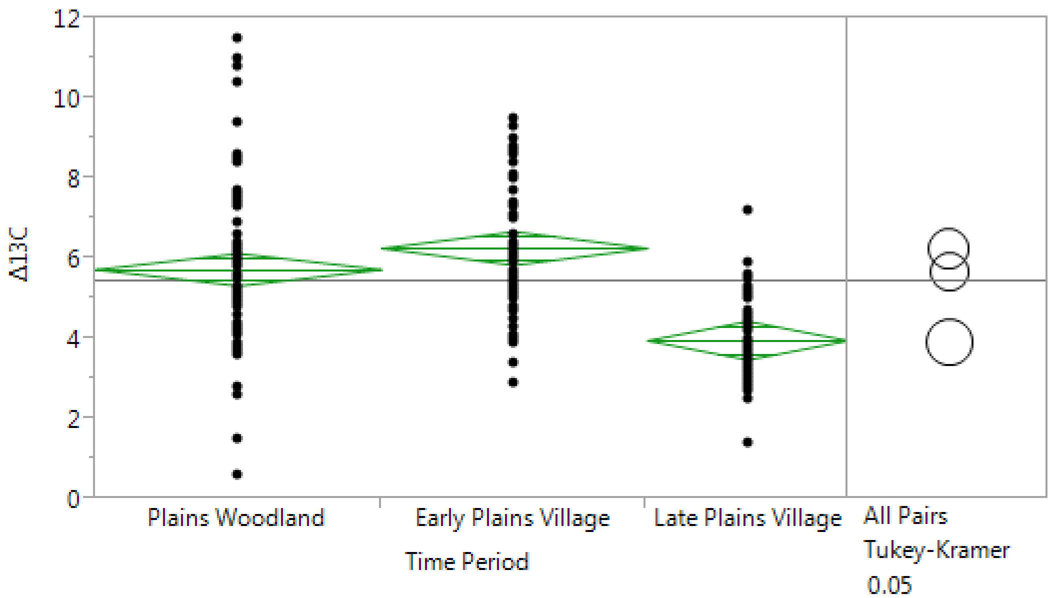


Table 6: Δ13C Means Report

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Plains Woodland	71	5.72254	0.20494	5.3182	6.1269
Early Plains Village	66	6.25455	0.21256	5.8352	6.6739
Late Plains Village	50	3.962	0.24422	3.4802	4.4438

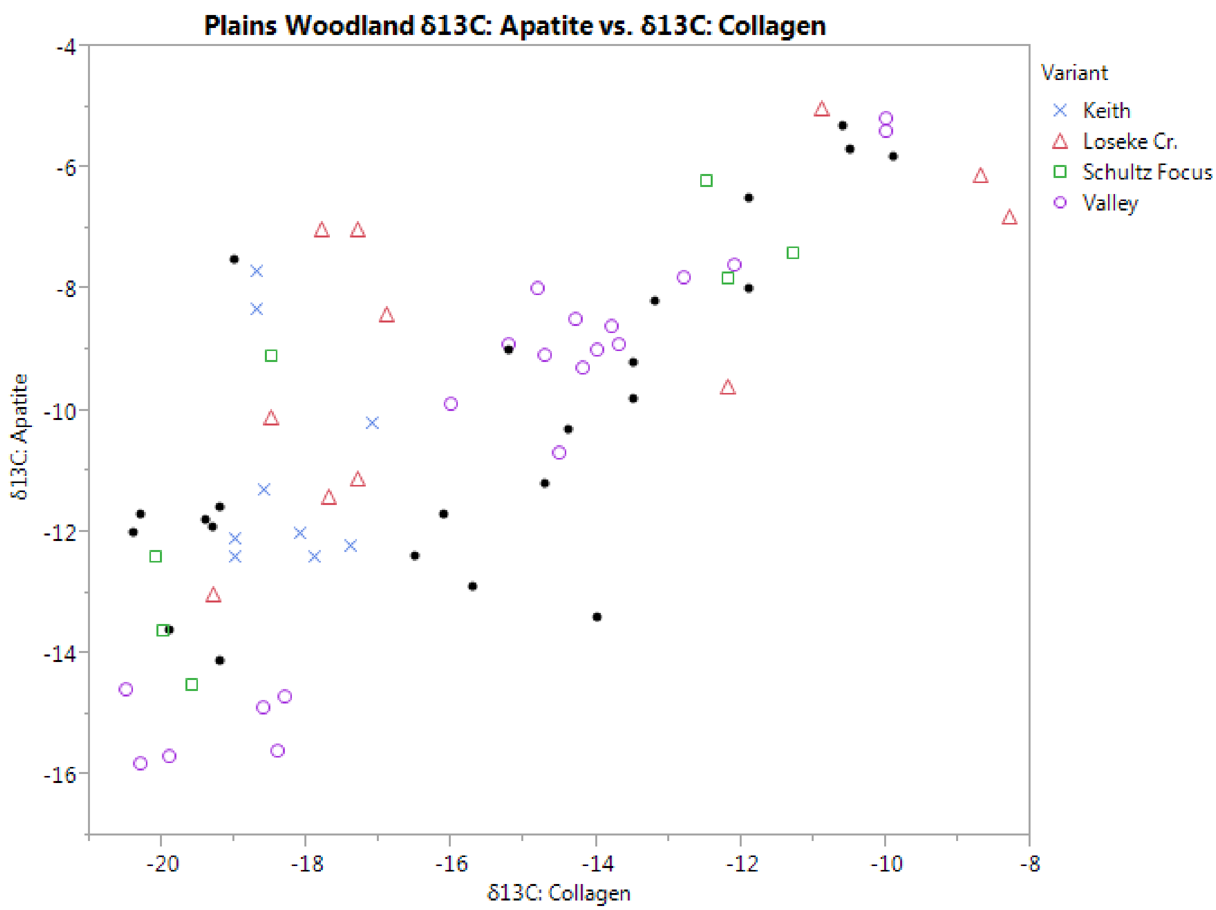
Table 7: Δ13C HSD Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Early Plains Village	Late Plains Village	2.292545	0.323767	1.52752	3.05757	<.0001
Plains Woodland	Late Plains Village	1.760535	0.318815	1.00721	2.51385	<.0001
Early Plains Village	Plains Woodland	0.53201	0.29527	-0.16568	1.2297	0.1718

Plains Woodland Period

δ13C$_{collagen}$ means are not statistically significant (p=.2268) between Early and Late Plains Village periods ($\bar{x}$= -11.0‰ and -11.8‰, respectively), but the Plains Woodland period exhibits a significantly more negative central tendency ($\bar{x}$= -15.7‰, p<.0001). Plains Woodland δ13C$_{apatite}$ values show considerable variation, but the central tendency of the data ($\bar{x}$= -10.0‰) suggests these individuals were exploiting resources relatively depleted in δ13C compared to later groups. Statistically significant differences in δ13C$_{collagen}$ (p=.0187) and Δ13C values (p=.02) are present amongst Plains Woodland individuals from Kansas ($\delta13C_{collagen}$ =-17.2‰; $\Delta13C$= 6.6‰) and Nebraska ($\delta13C_{collagen}$ =-15.1‰; $\Delta13C$=5.3‰). No Plains Woodland sites from South Dakota are represented in this data. $\delta13C_{apatite}$ values were not significant between Kansas and Nebraska (p=.3163).

Figure 6: Plains Woodland Bivariate Scatter Plot of $\delta13C_{collagen}$ by $\delta13C_{apatite}$



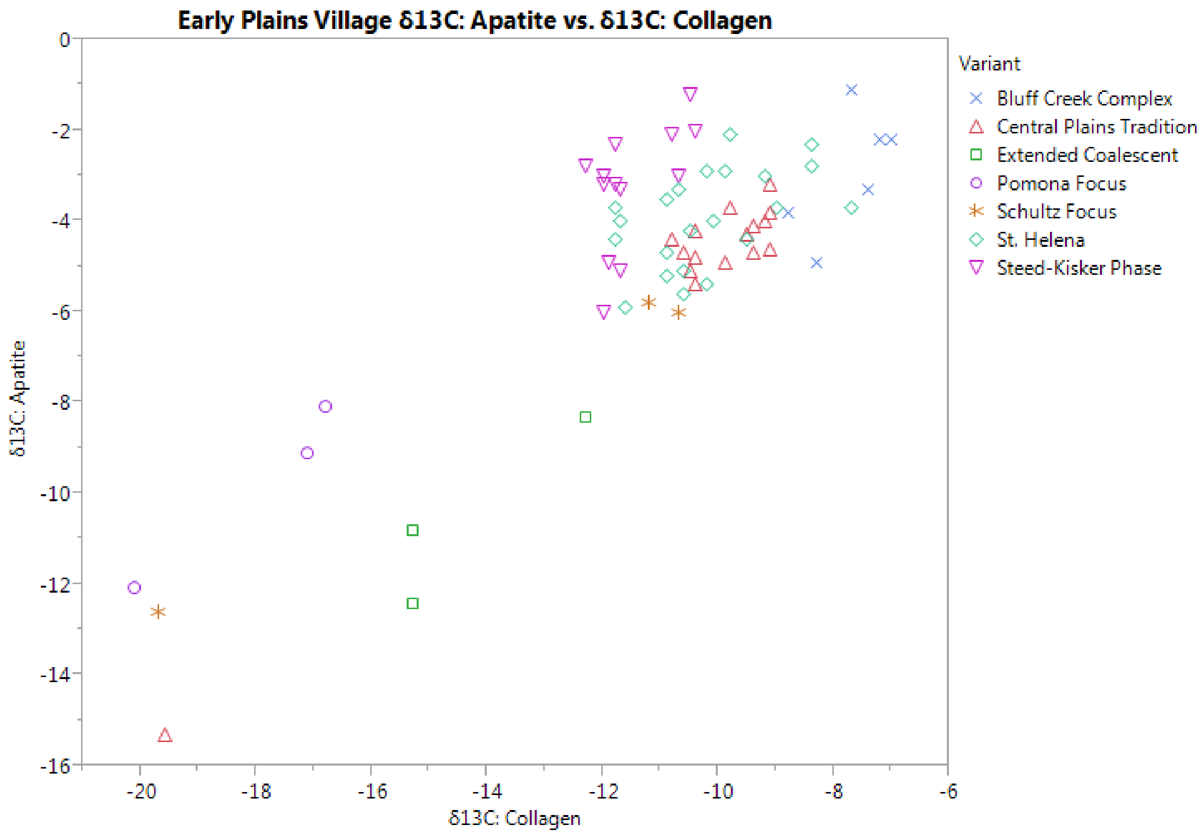
Of the four identified phases of Plains Woodland groups, only the western Keith Focus indicates a exclusively C3 source of dietary protein. Loseke Creek, Schultz Focus, and Valley phases all exhibit much greater ranges of variation, with individuals who consumed primarily C3 dietary protein and individuals who consumed primarily C4 dietary protein sources. Plains Woodland groups which could not be assigned cultural phases exhibit similar variation to the assigned groups. The relatively poor temporal resolution of this dataset makes it difficult to determine whether or not these trends represent an increase in C4 resources over time, possibly as a result of maize horticulture. There is however no clear separation in C3 and C4 resources across each site, that is: all sites consisting of two or more individuals, with the exception of the Keith phase, contain individuals that exhibit relatively high and low $\delta13C_{collagen}$ values. $\delta13C_{apatite}$ values do not show a similar trend, indicating that even individuals with relatively a more δ13C enriched overall diet were still obtaining a majority of their dietary protein from primarily C3 sources.

Collagen-apatite spacing (Δ13C) values are understood to be indicative of relative trophic status. Smaller collagen-apatite spacing is generally indicative of high levels of animal tissue consumption, whereas larger spacing values are consistent with high levels of plant tissue consumption. The central tendency of Δ13C values from the Plains Woodland period is 5.7‰, suggesting a generally omnivorous diet. A number of Loseke Creek individuals have Δ13C values greater than 3‰, suggesting animal protein contributed to a substantial portion of the total dietary protein. Otherwise individuals do not tend to show Δ13C values suggestive of either extreme carnivory or herbivory; on the contrary, these values are consistent with a fairly well balanced, omnivorous diet characteristic of humans.

Early Plains Village

δ13C means for the Early Plains Village period are the most enriched in terms of both collagen and apatite across all three periods. Variability within and across sites is relatively low, contrast to Plains Woodland groups. $\delta13C_{apatite}$ ($\bar{x}$ = -4.7‰) is significantly higher than both Plains Woodland periods and Late Plains Village periods ($p<.0001$). $\delta13C_{collagen}$ ($\bar{x}$ = -11.0‰) shows a significant increase ($p<.0001$) from the Plains Woodland period, but is not significantly different ($p<.2268$) from the Late Plains Village period. In addition Early Plains Village shows the least amount of scatter on the collagen/apatite plot relative to other periods, and most of the outliers have fairly straightforward explanations.

Figure 7: Early Plains Village Bivariate Scatter Plot of δ13C$_{collagen}$ by δ13C$_{apatite}$



Δ13C ($\bar{x} = 6.3‰$) values show no significant differences to the Plains Woodland period, suggesting the ratio of plant to animal tissue consumption was fairly consistent across these two periods. The vast majority of Early Plains Village individuals fall within a narrow range of δ13C values. δ13C$_{apatite}$ values cluster in between -6‰ and -1‰ while δ13C$_{collagen}$ values cluster between approximately -12‰ and -9‰. These values are indicative of a diet containing a large majority of δ13C enriched resources. A small number of individuals fall outside of the Early Plains Village pattern, but overall this period exhibits considerable homogeneity in terms of δ13C$_{apatite}$ and δ13C$_{collagen}$ values.

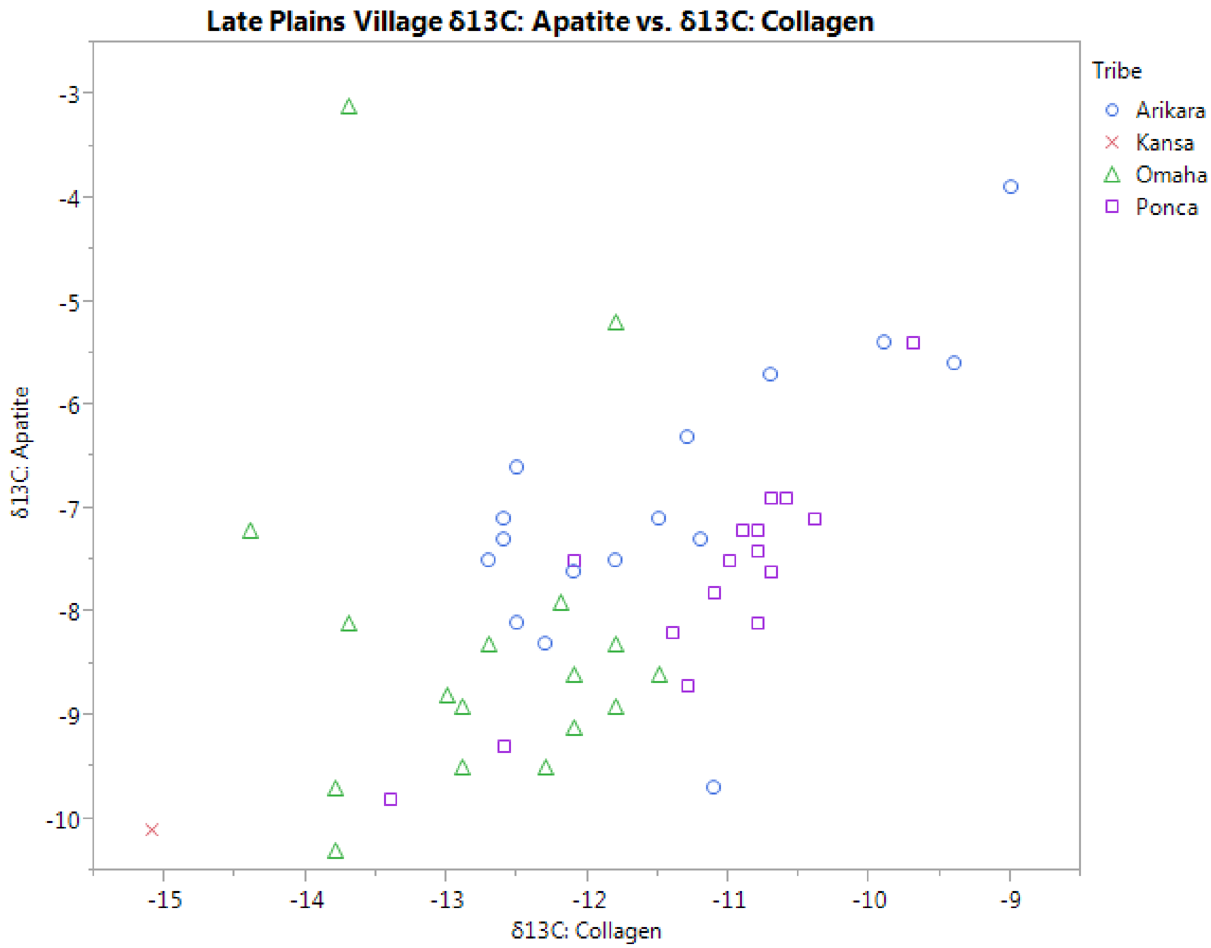
Significant differences across states in this period are present; however, these results should be interpreted with caution given the small sample size (n=3) of individuals from South

Dakota. $\delta 13C_{collagen}$ differs significantly between Nebraska and South Dakota ($p=.0328$), but both of these states do not show significant differences from Kansas ($p=.1114$ and $p=.2260$, respectively). South Dakota $\delta 13C_{apatite}$ is significantly different from Nebraska and Kansas $\delta 13C_{apatite}$ ($p=.0004$ and $p=.0006$, respectively); however, Nebraska and Kansas $\delta 13C_{apatite}$ are remarkably similar ($p=.9836$). Δ13C differs significantly across all states. South Dakota shows the lowest collagen-apatite spacing ($\bar{x} = 3.8‰$) while Kansas exhibits the greatest collagen-apatite spacing ($\bar{x} = 7.1‰$). Nebraska exhibits intermediate values of Δ13C ($\bar{x} = 5.9‰$). Comparisons of the central tendency of Kansas Δ13C values exhibit the strongest statistical significance (South Dakota, $p=.0007$; Nebraska $p=.0024$), and similar differences exist between Nebraska and South Dakota ($p=.0419$).

Late Plains Village

Late Plains Village groups exhibit central tendencies of $\delta 13C_{apatite}$ ($\bar{x} = 7.7‰$) intermediate between Plains Woodland and Early Plains Village groups. Late Plains Village $\delta 13C_{collagen}$ means are slightly more negative than Early Plains Village groups, suggesting a very minor reduction δ13C enriched protein resources. $\delta 13C_{collagen}$ ($\bar{x} = 11.8‰$) during this time period is not significantly different ($p=.2268$) from the Early Plains Village time period suggesting these groups still consumed the majority of their dietary protein from similar resources. Δ13C values ($\bar{x} = 3.9‰$) for Late Plains Village groups are significantly lower ($p<.0001$) than those from Early Plains Village or Plains Woodland time periods, suggesting consumption of animal tissues contributed to a relatively larger portion of the diet during this period of time than any other within the past 1500 years in this region. Late Plains Village groups show relatively more scatter than Early Plains Village groups, although considerably less so than the Plains Woodland group. $\delta 13C_{collagen}$ values cluster in between -14‰ and -10‰ whereas $\delta 13C_{apatite}$ values range from 10.3‰ to -3.1‰. While dietary protein was relatively enriched in δ13C, the isotopic composition of total dietary energy varied considerably.

Figure 8: Late Plains Village Bivariate Scatter Plot of δ13Ccollagen by δ13Capatite



A few minor yet noticeable patterns within the data are clearly visible; however, these may simply reflect spatial or temporal differences inherent within the data itself. A single individual from the Kansa tribe is represented in this data but no significant interpretations can be drawn from this. Therefore, the Kansa individual was excluded from Tukey-Kramer HSD tests performed within the Late Plains Village period. The Omaha (n=17) exhibited the most negative $\delta 13C_{collagen}$ mean ($\bar{x}$ = -12.7‰) relative to the Arikara and Ponca tribes ($\bar{x}$ = -11.4‰ and -11.1, respectively); however, the overall difference in δ13C enriched resources to the protein component of the Omaha diet was minor. The Omaha tribe also exhibited the most negative $\delta 13C_{apatite}$ values ($\bar{x}$ = -8.2) with respect to the Arikara and Ponca tribes ($\bar{x}$ = -6.9‰ and -7.7‰ respectively). Δ13C values were lowest for the Ponca tribe ($\bar{x} = 3.5$) and highest for the Arikara ($\bar{x} = 4.5$), with the Omaha exhibiting intermediate values ($\bar{x} = 3.9$).

The Omaha tribe shows significantly lower $\delta 13C_{collagen}$ values compared to Ponca ($p<.0001$) and Arikara ($p=.0014$) tribes. Arikara tribe exhibits significant difference in $\delta 13C_{apatite}$ values relative to the Omaha tribe ($p=.0283$). Ponca groups show no significant differences in $\delta 13C_{apatite}$ (Arikara comparison: $p=.3164$; Omaha comparison: $p=.4523$). $\Delta 13C$ values showed differences across Arikara and Ponca tribes ($p=.0096$) but Omaha comparisons reveal no significant differences (Arikara comparison: $p= .1998$; Ponca comparison: $p=.3978$). No significant differences are present in $\delta 13C_{collagen}$ ($p=.4296$) or $\delta 13C_{apatite}$ ($p=.1014$) between Nebraska and South Dakota; however, $\Delta 13C$ values for Nebraska ($\bar{x} = 3.7$) and South Dakota ($\bar{x} = 4.4$) exhibit significantly different central tendencies ($p= .0128$).

DISCUSSION

Plains Woodland Period

Plains Woodland subsistence practice has been described as primarily a hunting and gathering economy, with limited inputs from C3 domesticated native seed crops like marshelder, sunflowers, goosefoot, and squash. Wild pigweed, which is a native C4 seed crop on the Plains, was likely collected in small amounts. Bison, which tends to be relatively enriched in $\delta 13C$, is present in limited quantities but faunal assemblages often include greater proportions of deer and pronghorn, especially to the east. Mussel shell and fish are also present in relatively larger quantities to the east. The central tendency $\delta 13C_{collagen}$ indicate a dietary protein source with an isotopic composition near -20.7‰, suggestive of a greater take of C3 game animals like deer and pronghorn as opposed to bison. $\delta 13C_{apatite}$ values indicate an overall diet with an isotopic composition around -19.5‰, suggestive of a total diet focused primarily on C3 resources.

The absence of data from Plains Woodland individuals in South Dakota hampers the ability to draw meaningful interpretations between the Central Plains and the Middle Missouri regions; however, significant differences exist on between Kansas and Nebraska $\delta 13C_{collagen}$ and $\Delta 13C$. Plains Woodland groups in Kansas exhibit greater collagen apatite spacing and lower $\delta 13C_{collagen}$ values than groups in Nebraska. This would suggest that plant tissues contributed to a larger portion of the diet in Kansas than Nebraska during this time. In addition, relatively lower $\delta 13C_{collagen}$ values in Kansas would suggest that these groups were obtaining a slightly greater proportion of their dietary protein from C3 sources than groups in Nebraska. The geographic spread of Plains Woodland sites, as represented in this dataset, is much more restricted in Nebraska than Kansas. The Plains Woodland sites in Nebraska are almost entirely restricted to the northeastern corner of the state, whereas individuals in Kansas are represented from sites across the western and eastern halves of the state.

The inter-site variability in dietary protein consumption in Plains Woodland groups poses an interesting question for anthropologists studying subsistence in this region. Even in Late Woodland groups where limited maize horticulture is believed to be present, there are a number of individuals who appear have eaten primarily C3 diets. This could be explained in a number of ways; however, the chance of determining the most plausible explanation is severely obstructed by a lack of detailed provenience and stratigraphic information from these sites, in addition to the inherently coarse temporal scale. At the present, little to no evidence of social stratification exists from Plains Woodland burial sites, contrary to Hopewellian burials mounds further east (Roper, 2006b). This diminishes the possibility that such observations reflect social differences of individuals relating to differing subsistence practices within Plains Woodland sites.

Prima facie one might interpret these results as reflecting contemporaneous populations which practiced wildly different subsistence economies, even among groups who shared such personal landscapes such as cemeteries. Such interpretations rest on the assumption that the individuals interred at these sites reflect subsets of a population which was not only autonomous but contemporaneous with one another. Despite the poor temporal resolution of these data it is clearly apparent that sites such as the Ryan site (25DK2) were occupied over long periods of time, evidenced by the presence of both Middle and Late Woodland burials. Despite this, a number of Late Woodland individuals from various sites still exhibit isotopic signatures consisting of primarily C3 resources akin to Early and Middle Woodland hunters and gatherers. If only to compound the problem, a number of individuals from the Middle Woodland sites show isotopically enriched $\delta 13C_{collagen}$ signatures relative to Late Woodland populations. If these $\delta 13C_{collagen}$ enriched signatures are primarily the results of maize horticulture, the presence of these distinct isotopic patterns within sites may represent the long term utilization of cemeteries before and after the introduction of significant maize horticulture. This would be relatively simple to determine if each sample was also assigned a radiocarbon date, as is unfortunately not the case.

The probability that Plains Woodland individuals who obtained a majority of their dietary protein from C4 sources were exploiting primarily plant resources (as might be seen in populations with extreme reliance on maize horticulture) is ultimately inconclusive but appears to be unlikely. Individuals who obtained the majority of their protein sources from plants appear to exhibit considerably more negative $\delta 13C_{collagen}$ signals, indicating primarily C3 inputs. $\Delta 13C$ values of Early Plains Village groups are not significant from Plains Woodland groups, indicating meat and plant consumption remained relatively stable across these time periods, despite the surge of maize horticulture during the Early Plains Village period. If anything, the fact that this $\delta 13C_{collagen}$ enrichment is not a result of increased animal protein consumption would appear to lend evidence to maize horticulture; however, maize is notoriously poor in protein and very large amounts of maize would be required to produce such an elevated $\delta 13C$ signal. The archaeological record does not support a substantial reliance on maize horticulture until the Plains Village period, further decreasing the possibility of this scenario.

A shift in the consumption of preferential animal tissues; however, may be able to account for the pattern we see during this period. Marine resources like freshwater mussel, turtle, and fish tend to enriched in δ13C relative to terrestrial fauna and could produce an isotopic signature akin to what is seen during the Plains Woodland period. Bison can also produce isotopic signatures enriched in δ13C relative to other large game such as elk and deer. Differential preferences of δ13C enriched faunal resources while maintaining roughly equal proportions of animal protein to the diet may best describe the apparent pattern in Plains Woodland subsistence practice.

Early Plains Village

The Early Plains Village period exhibits an isotopic signature consistent with predominately C4 dietary inputs. The Early Plains Village pattern exhibits the most elevated $\delta 13C_{collagen}$ and $\delta 13C_{apatite}$ values in this study. The central tendency of $\delta 13C_{collagen}$ and $\delta 13C_{apatite}$ indicates a dietary protein component with a δ13C value near -16‰ and an overall diet with a δ13C value of -14‰. Two phases in particular lie outside of the overall Early Plains Village pattern, the Pomona Focus (n=3) of eastern Kansas and the Extended Coalescent (n=3) group from central South Dakota. An individual from the Schultz Focus in Central Kansas and one individual from the Wiseman M. site in eastern Nebraska also show markedly different isotopic values relative to the Early Plains Village period as a whole. These individuals exhibit δ13C collagen values in between -19‰ and -20‰ and δ13C apatite values near -13‰ and-15‰, respectively, suggesting a very strong C3 component to the diet. Early Plains Village groups have been known to reuse burial mounds from earlier Plains Woodland occupations, and these data could be reflecting individual internments from a time before maize horticulture dominated central Plains lifeways.

A more parsimonious explanation for these trends may be apparent if we assume contemporaneity within sites. Early Plains Village subsistence economies on the central Plains have been categorized as very opportunistic and flexible, or a unique blend between foraging and horticulture in varying amounts; therefore, it seems entirely reasonable to understand these outliers as simply reflecting the diversity of subsistence economies practiced during the Early Plains Village period on the Central Plains.

Roper (2006) interpretations of the Pomona Focus as a largely non-sedentary with very little evidence of horticulture would appear to be supported by the isotopic evidence outlined within this thesis. Individuals appear to have obtained the majority of their protein through C3 resources although $\delta13C_{apatite}$ would suggest some portion of their overall diet came from C4 or other δ13C enriched resources. A single kernel of maize was recovered from a Pomona Focus site (14AT2), suggesting that this crop was somewhat available albeit not widely cultivated by this group, and possibly acquired through trade relations. A considerable quantity of mussel shell has also been recovered from Pomona Focus sites, which could also be implicated in such elevated δ13C apatite signals.

Extended Coalescent individuals also fall outside of the Early Plains Village cluster; however, this may be a function of poor temporal resolution. The individuals come from two sites in South Dakota- the Little Cherry and Morrow Village sites. No direct date has been reported from the Morrow Village site and it is listed only as general Plains Village period (900-1700). The reported age for the Little Cherry site is 1400-1550, which would place these individuals near the terminal Early Plains Village period, and possibly the early Late Plains Village period. The individual from the Little Cherry site falls comfortably within normal δ13C variation during the Late Plains Village period; however, the two individuals from the Morrow Village site exhibit substantially depleted δ13C values relative to both Early and Late Plains Village period means.

Differences across states are much less marked in the Early Plains Village period. The small sample size of Middle Missouri individuals (n=3) complicate the interpretation of spatial differences. Given the issues outlined above with the age of South Dakota Early Plains Village sites, this further compounds the problem of interpretation. South Dakota exhibits statistically significant differences from both Kansas and Nebraska populations in $\delta13C_{collagen}$, $\delta13C_{apatite}$, and $\Delta13C$. Kansas and Nebraska do not exhibit significant differences; in fact, they are remarkably similar in terms of $\delta13C_{collagen}$ and $\delta13C_{apatite.}$ $\Delta13C$ is the only variable which exhibits statistical significance between Nebraska and Kansas individuals. Greater collagen-apatite spacing in Kansas suggests plant tissues contributed to a relatively larger portion of the diet than in Nebraska or South Dakota, similar to the Plains Woodland $\Delta13C$ pattern. $\Delta13C$ values in Kansas and Nebraska both increased by about .55‰ from the Plains Woodland period, indicating a small increase in the contribution of plant resources to the diet during this time. This increase in the central tendency can likely be attributed to the increased importance of horticultural crops at the onset of the Plains Village period.

Late Plains Village

Late Plains Village individuals exhibit a subsistence pattern indicative of largely $\delta13C$ enriched resources, in addition to an increased use of animal resources relative to plant resources. $\Delta13C$ values are suggestive of a diet containing a very large proportion of animal tissues, most likely bison. The central tendency $\delta13C_{collagen}$ is indicative of a dietary protein component with a $\delta13C$ value of -16.8‰, and $\delta13C_{apatite}$ values indicate an overall diet with a $\delta13C$ value of -17.1‰.

$\delta13C_{collagen}$ shows little change from the Early Plains Village period, which would suggest both Early and Late Plains Village groups were obtaining the majority of their dietary protein from bison or other $\delta13C$ enriched game. Intermediate $\delta13C_{apatite}$ values would indicate an overall diet consisting of a smaller proportion of C4 resources, like maize, relative to the Early Plains Village period. This decrease could be explained by the increased importance of seed crops other than maize to the diet such as squash, beans, or sunflowers. Wild plants contributed to a relatively minor portion of the diet relative to seed crops (Nickel, 1977), so the possibility that this decrease in $\delta13C_{apatite}$ is a result of increased gathering during this period seems unlikely.

Variation in $\delta13C_{collagen}$ and $\delta13C_{apatite}$ between Nebraska and South Dakota show no significant differences, although Δ13C central tendencies are significantly higher in South Dakota relative to Nebraska. The vast majority of individuals from South Dakota are of Arikara descent, in addition to two individuals with Omaha affiliations. The Arikara tribe shows significantly higher Δ13C means relative to Ponca groups as well as significantly higher $\delta13C_{apatite}$ means relative to the Omaha tribe. This would suggest that while Arikara were consuming relatively more plant resources than other tribes, the overall diet was generally more enriched in δ13C. In other words, it would appear as though the Arikara practiced a subsistence economy with a greater emphasis on maize relative to the Omaha or Ponca tribes. The Omaha tribe exhibits a significantly lower $\delta13C_{collagen}$ central tendency than either Arikara or Ponca tribes. $\delta13C_{collagen}$ mean of -12.7‰ would suggest a dietary protein source with an isotopic composition near -17.7‰. Such values are suggestive of a slightly greater, but still relatively minor, proportion of C3 resources to the dietary protein relative to the central tendency of the Late Plains Village period.

The Late Plains Village period was a time of major social reorganization and serious disruption of Plains Village lifeways. The changes which occurred during this period were widespread but did not affect every tribe in the same way. It should be acknowledged that each tribe in this study represents a slightly different, but not mutually exclusive, period of time within the Late Plains Village period. Arikara individuals represented in this study represent the earliest Late Plains Village, Ponca are intermediate, and Omaha represent the terminal Plains Village. The comparisons across tribes could be reflecting differences over time, rather than differences among contemporaneous groups. Tribes are understood to operate as distinct social groups, in contrast to phases or traditions which serve as constructs to organize archaeological material in time and space. Despite this, tribes exhibit variation akin to or exceeding Early Plains Village phases, suggesting that individual variation (possibly as a result of personal preferences) remained notable in spite of a primary reliance on select seed crops.

CONCLUSIONS

Through corroboration with the archaeological record, floral and faunal evidence from across the Great Plains, and stable isotope evidence from 189 individuals, a dynamic picture of subsistence on the north central Great Plains is offered. $\delta 13C_{apatite}$ follows the isotopic composition of the overall diet (Kellner and Schoeninger, 2007) and exhibits significant differences across Plains Woodland, Early Plains Village, and Late Plains Village time periods, indicating that groups were exploiting considerably different subsistence resources over time. $\delta 13C_{collagen}$ values closer follow the isotopic composition of dietary protein and is shown to exhibit a significant difference between the Plains Woodland and the Plains Village periods; however, does not differ considerably between the Early and Late Plains Village periods. $\Delta 13C$ is the difference between $\delta 13C_{collagen}$ and $\delta 13C_{apatite}$ values and is generally indicative of an organism's relative trophic status. While this measure was not found to differ significantly between the Plains Woodland and Early Plains Village periods, the Late Plains Village period exhibit significantly lower $\Delta 13C$ values suggesting an increase in the consumption of animal tissues, most likely bison, during this period. Although significant differences were present within time periods across state boundaries, the underrepresentation of Plains Woodland and Early Plains Village individuals from South Dakota in as well as Late Plains Village individuals in Kansas hinder the interpretation of meaningful, large scale patterns between the central and northern Plains regions.

Broad spectrum hunting and gathering was the dominant subsistence economy on the Plains for thousands of years. Beginning with the Plains Woodland period we see the beginnings of the foundation for the Plains Village period, namely horticultural experimentation and the adoption of semi or seasonally sedentary lifestyles. Diets consisted largely of C3 resources consistent with a generalized foraging and hunting subsistence pattern. Wild fruit like grapes, plums, and chokecherries were gathered in varying quantities, in addition to nuts on the eastern Plains. Native seed crops like sunflower, marshelder, goosefoot, and amaranth were collected and sometimes cultivated in limited quantities as well. Large mammals like pronghorn, deer, and bison were hunted in addition to a diverse and often locally specific collection of small mammals, fish, mussel, and birds. Central tendencies of $\delta13C_{collagen}$ and $\delta13C_{apatite}$ values are largely in agreement with these observations; however, this period exhibits considerable variation relative to the Plains Village pattern. A number of individuals exhibit isotopic signatures consistent with $\delta13C_{collagen}$ enriched resources which may reflect the use of mortuary sites prior to and following significant maize horticulture, an increased use of aquatic resources like fish and mussel, or a preferential consumption of δ13C enriched game like bison.

Maize became a staple of the Great Plains horticulturalists beginning around the year 950. This transition began first with Mississippian cultures to the east and spread westward through the Great Plains. The beginning of the Plains Village period marks the onset of horticultural dependency and seasonally sedentary lifestyles, as evidenced by the construction of sizable settlements and a considerable quantity of paleoethnobotanical remains relative to earlier periods. Early Plains Village subsistence is characterized by a combination of both hunter-gatherer and horticultural economies. Seed crops like maize, sunflowers, squash, and beans were cultivated in considerable quantities, in addition to the gathering of wild plants like pigweed, dock, rose hips, and buffaloberries. Large quantities of bison are present in the Middle Missouri sites during this time and are present in limited amounts on the eastern and central plains. Deer and pronghorn make up the majority of large mammal remains on the eastern Plains and are supplemented by catfish, mussel, and turkey. The Early Plains Village period exhibits the highest $\delta13C_{collagen}$ and $\delta13C_{apatite}$ values, consistent with diets consisting of a majority of C4 resources.

The Late Plains Village marked a period of major social reorganization on the Plains. Groups began to coalesce in large fortified villages along major tributaries of the Missouri. Subsistence was primarily focused around floodplain horticulture and bison hunting, supplemented by wild plants like blackberries and plums in small amounts. Large mammals like elk, deer, and pronghorn are believed to make up a relatively small (5-20%) portion of the diet (Johnson, 1998). Δ13C values from this period indicate significantly greater consumption of animal tissues relative to either the Plains Woodland or Early Plains Village periods. $\delta13C_{collagen}$ values do not differ significantly from the Early Plains Village, suggesting a strong C4 component to the dietary protein. $\delta13C_{apatite}$ values intermediate between the Plains Woodland and Early Plains Village period suggests an overall diet containing smaller proportions of δ13C enriched resources, like maize, than the Early Plains Village horticulturalists.

The utilization of stable isotope analyses in paleodietary reconstructions has proved to be an invaluable tool for archaeologists studying subsistence economies. Although the picture of Great Plains subsistence practice offered here is comprehensive, it is by no means complete. Greater sample sizes from a wider geographic area could facilitate a comparison of the north central Plains subsistence pattern with contemporaneous populations on the southern Pains, the eastern Hopewell or Mississippian cultures, or non-sedentary hunter-gatherer populations to the west. A great deal of ambiguity within this study could be resolved with tighter temporal controls. Radiocarbon dates from each sample, or at least each site, could allow for much more detailed conclusions from the data presented here. Data from South Dakota is very limited prior to the Late Plains Village period and the acquisition of such data would facilitate more complex spatial comparisons within the north central Plains subsistence pattern over time. Most importantly, increased collaboration with modern day Native American tribes is essential to continue pursuing meaningful bioarchaeological research on the Plains while also preserving and respecting traditional mortuary customs.

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