Testing Assumptions on the Relationship between Humans and their Environment: Case Studies from Cahokia Mounds, Illinois

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Testing Assumptions on the Relationship between Humans and their Environment: Case Studies from Cahokia Mounds, Illinois

by

Caitlin G. Rankin

A dissertation presented to
The Graduate School
of Washington University in
partial fulfillment of the
requirements for the degree
of Doctor of Philosophy

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# Table of Contents

List of Figures ................................................................. vi

List of Tables ...................................................................... x

Acknowledgments ............................................................... xi

Abstract ............................................................................. xvii

Chapter 1: Acceptable Assumptions in the Relationship between Humans and the Environment  1

1.1 Introduction ................................................................... 1

1.2 Cahokia Mounds as a Case Study ..................................... 4

1.3 Geoarchaeology as a Method .......................................... 18

1.4 Structure of the Dissertation ......................................... 20

1.5 References Cited ........................................................... 22

Chapter 2: Evaluating Narratives of Ecocide with the Stratigraphic Record at Cahokia Mounds State Historic Site, Illinois, USA ......................................................... 29

2.1 Introduction ................................................................... 29

2.2 Site Setting ................................................................... 32

2.3 Methods ........................................................................ 36

2.3.1 Field Methods .......................................................... 36

2.3.2 Laboratory Methods .................................................. 39

2.4 Results .......................................................................... 44

2.4.1 Mound 5 Excavations ............................................... 44
2.4.2 Mound 16 Excavations ............................................................................................................ 48
2.4.3 Canteen Creek Excavations ................................................................................................. 51
2.4.4 Sediment Coring ................................................................................................................... 56
2.5 Discussion ............................................................................................................................... 59
2.6 Final Thoughts: Why Old Theories of Collapse Persist through Time ..................................... 65
2.7 References Cited ....................................................................................................................... 66

Chapter 3. Correlating Climate Change and Population Dynamics at Cahokia Mounds .......... 72
3.1 Introduction ............................................................................................................................. 72
3.2 Materials and Methods .......................................................................................................... 76
  3.2.1 Archaeological and Modern Soil Samples ............................................................................ 76
  3.2.2 Stable Carbon Isotope Analysis .......................................................................................... 81
3.3 Results .................................................................................................................................... 82
  3.3.1 Stable Carbon Isotopes ....................................................................................................... 82
3.4 Discussion ................................................................................................................................ 86
3.5 References Cited ....................................................................................................................... 93

Chapter 4. The Exceptional Setting of the North Plaza, Cahokia Mounds, Illinois ............. 98
4.1 Introduction ............................................................................................................................. 98
4.2 Environmental Setting ........................................................................................................... 103
4.3 Methods .................................................................................................................................. 105
  4.3.1 Field Methods ..................................................................................................................... 105
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.3.2 Laboratory Methods</td>
<td>108</td>
</tr>
<tr>
<td>4.4 Results</td>
<td>110</td>
</tr>
<tr>
<td>4.4.1 Excavation and Sediment Core Stratigraphy</td>
<td>110</td>
</tr>
<tr>
<td>4.4.2 Ceramic Rim Assemblage and Chronology</td>
<td>117</td>
</tr>
<tr>
<td>4.4.3 Stable Carbon Isotopes</td>
<td>122</td>
</tr>
<tr>
<td>4.5 Discussion</td>
<td>124</td>
</tr>
<tr>
<td>4.6 References Cited</td>
<td>133</td>
</tr>
<tr>
<td>Chapter 5: Conclusions</td>
<td>139</td>
</tr>
<tr>
<td>5.1 Introduction</td>
<td>139</td>
</tr>
<tr>
<td>5.2 Chapter Summaries</td>
<td>139</td>
</tr>
<tr>
<td>5.3 Final Thoughts on Acceptable Assumptions</td>
<td>142</td>
</tr>
<tr>
<td>5.4 Future Direction</td>
<td>144</td>
</tr>
<tr>
<td>5.6 References Cited</td>
<td>147</td>
</tr>
<tr>
<td>Appendix A: Cahokia Grid Coordinates (x,y,z) of 2017 Sediment Cores</td>
<td>150</td>
</tr>
<tr>
<td>Appendix B: Cahokia Grid Coordinates (x,y,z) of 2017 and 2018</td>
<td>151</td>
</tr>
<tr>
<td>Appendix C: Raw Data Table of Ceramic Rim Assemblage from Mound 5</td>
<td>152</td>
</tr>
<tr>
<td>Appendix D: OxCal Codes for Bayesian Chronological Model of Mound 5</td>
<td>153</td>
</tr>
<tr>
<td>Appendix E: Raw Data Table of Ceramic Rim Assemblage from Mound 16</td>
<td>154</td>
</tr>
<tr>
<td>Appendix F: Probability Distributions for Mound 16 Radiometric Age</td>
<td>155</td>
</tr>
</tbody>
</table>
Appendix G: Context of all current radiometric age estimates from the North Plaza Project.... 156
List of Figures

Figure 1.1. Cahokia Mounds is located in the American Bottom floodplain of Mississippi River. The North Plaza at Cahokia Mounds is the area of investigation for this dissertation. The North Plaza is an ideal location to study local signals of droughts and floods because its low elevations makes it vulnerable water table fluctuations................................. 5

Figure 1.2. Generalized chronology of Cahokia Mounds. Phases are defined by ceramic traditions. It is important to note that the radiometric ages (AD) for these phases are constantly evolving with new data and new methods. ................................................................. 7

Figure 1.3. Line plots of Cahokia population dynamics. Estimates of population dynamics in “downtown” Cahokia are from Lopinot and Pauketat 1997. Estimates of population dynamics in the American Bottom region are from Milner 1998. The chronology of population dynamics is based on ceramic phases, see Figure 1.2 for current radiometric age estimates of ceramic phases. ................................................................. 9

Figure 1.4. Locations of relevant areas of investigation in and around the American Bottom mentioned in the literature review. Basemap is a 30 meter digital elevation model obtained from the Illinois Geospatial Data Clearinghouse................................................................. 13

Figure 2.1. Location of Cahokia Mounds within the American Bottom floodplain............. 33

Figure 2.2. Locations of investigations within the precinct of Cahokia Mounds ............. 35

Figure 2.3. Results of the 2016 magnetometer survey conducted by Horsley and Barrier, revealing extensive anthropogenic activity and landform modification along the edge of the Edelhardt Meander Scar and at least one former course of Canteen Creek............................ 37

Figure 2.4. Schematic drawing of Mound 5 stratigraphy. Numbers listed for each stratigraphic layer refer to full descriptions found in Table 2. ............................................................................. 42

Figure 2.5. Photomicrographs of micromorphology results. (a) Ab rip-up clast in fluvial material. (b) Graded beds of sand, silt, and clay. (c) 3mm thick incipient A-horizon between fluvial sand deposits. (d) Planar void (indicated by arrows) marks the clear boundary between the fluvial deposit and Mound fill. This contact was observed as abrupt in the field but is clear microscopically. There is microscopic evidence for bioturbation between the contact, but no evidence for incipient soil formation. (e) Three different fluvial sand facies can be observed in one micromorphology thin section............................................................. 45

Figure 2.6. Probability distributions and Bayesian model for radiocarbon dates from the Mound 5 excavation. ................................................................................................. 46

Figure 2.7. Probability distributions from model presented for dates from the Mound 5 excavation. a) Calibrated and modeled boundary for the start of the sequence; b) Calibrated and modeled date for Ab horizon, this is considered a terminus post quem for the start of Mound 5’s construction; c) Calibrated and modeled date for the fluvial sediment, this is considered a terminus post quem for the start of Mound 5’s construction; d) Calibrated and modeled date for mound construction phase, this is considered a terminus ante quem for the deposition of the fluvial sediment and Ab horizon; e) Calibrated and modeled date for mound construction phase,
this is considered a *terminus ante quem* for the deposition of the fluvial sediment and Ab horizon; f) Calibrated and modeled date for wall trench dug into mound construction fills, this is considered a *terminus ante quem* for the mound construction phase. ........................................ 47

Figure 2.8. Schematic drawing of Mound 16 stratigraphy. Numbers listed for each stratigraphic layer refer to full descriptions found in Table 2.3. ................................................................. 50

Figure 2.9. Schematic drawing of the South profile stratigraphy from the Canteen Creek excavations. Numbers listed for each stratigraphic layer refer to descriptions found in Table 2.4. Also displayed are the locations of recovered organic samples used for 14C AMS dating (note: samples 14C-1 and 14C-2 were removed from the North profile wall, but its mirror-image location is shown here). ........................................................................................................ 52

Figure 2.10. Probability distributions and Bayesian model for radiocarbon dates from the Canteen Creek excavation........................................................................................................ 54

Figure 2.11. Probability distributions from model presented for dates from the Canteen Creek excavations. a) calibrated and modeled date for sample 14C-1, which is considered a close proxy for the start of infilling of the channel and the formation of Stratum 2 alluvium; b) undated end boundary for Phase 1; c) calibrated and modeled date for sample 14C-2; d) calibrated and modeled date for sample 14C-3. ........................................................................................................ 55

Figure 2.12. Cross section drawings for the soil transects west and south of Mound 5. .............. 57

Figure 2.13. Cross section drawing for the soil transect through Mound 14. .......................... 58

Figure 2.14. 3D model of North Plaza landscape during Mississippian occupation, based on Ab elevations from excavations and sediment cores. a) 3D model of modern ground surface created in Golden Software’s Surfer 13 from Madison County LiDAR derivatives obtained from the Illinois Height Modernization Project web application viewer; b) Modeled Mississippian ground surface with an overlay of the modern ground surface in gray; c) Modeled Mississippian ground surface based on Ab elevations from excavations and sediment cores. ........................................................................................................ 64

Figure 3.1. Locations of soil organic matter samples collected from archaeological excavations, sediment cores, and modern baseline environments for stable carbon isotope analysis. .......... 77

Figure 3.2 Schematic drawing of Mound 5 excavation profile with results of stable carbon isotope analysis of soil organic matter collected from the Ab horizon below Mound 5 construction fills. Results described are the predictive groupings made by linear discriminant analysis. (W) stands for wetland and (P) stands for prairie. ................................................................. 79

Figure 3.3 Schematic drawing of Mound 16 excavation profile with results of stable carbon isotope analysis of soil organic matter collected from the Ab horizon below and adjacent to Mound 16 construction fills. Results described are the predictive groupings made by linear discriminant analysis. (W) stands for wetland and (SW) stands for seasonal wetland.............. 80

Figure 3.4 Photos from the three environments sampled in American Bottom for stable carbon isotope modern baselines, A) depicts the wetland environment, B) depicts the prairie environment, and C) depicts the seasonal wetland environment. .............................................. 83
Figure 3.5 Differences between Stable carbon isotope values from three modern baseline environment groups of prairie, wetland, and season wetland are statistically significant, making these data a good comparison for archaeological samples. .................................................. 87

Figure 3.6 Modeled dates for Mound 5 construction sequence................................................................. 89

Figure 4.1 The central precinct of Cahokia Mounds is arranged as a cosmogram, with Monks Mound in the center and four mound and plaza groups in each of the cardinal directions. .......... 100

Figure 4.2 The North Plaza is accepted as a mound and plaza groups because it is an empty, rectangular-shaped space define by mounds in each of the cardinal directions. ......................... 103

Figure 4.3 Wetland images of the North Plaza and surrounding Edelhardt meander scar. A) shows Mound 14 inundated by water after a one-day rainfall event in March 2018; B) shows a wetland environment in the Edelhardt meander scar, located 2km from the North Plaza; C) shows flooding that occurred to the south of Mound 16 after a heavy rain event in August 2018. ................................................................................................. 104

Figure 4.4 Location of archaeological excavations, sediment cores, and modern baseline environments for stable carbon isotope analysis. ................................................................. 106

Figure 4.5 Photos of modern baseline environments where soil organic matter (SOM) was collected for stable carbon isotope analysis, A) depicts the wetland environment, B) depicts the prairie environment, and C) depicts the seasonal wetland environment. ................................. 108

Figure 4.6 Schematic drawing of Mound 5 excavation profile with results of stable carbon isotope analysis of soil organic matter collected from the Ab horizon below Mound 5 construction fills. Results described are the predictive groupings made by linear discriminant analysis. (W) stands for wetland and (P) stands for prairie. Abundance of ceramic rims with depth, and radiometric age estimates are also depicted on the profile drawing. ......................... 113

Figure 4.7 Photomicrographs of micromorphology results. A) Ab rip-up clast in fluvial material. B) Graded beds of sand, silt, and clay. C) 3mm thick incipient A-horizon between fluvial sand deposits. D) Planar void (indicated by arrows) marks the clear boundary between the fluvial deposit and Mound fill. This contact was observed as abrupt in the field but is clear microscopically. There is microscopic evidence for bioturbation between the contact, but no evidence for incipient soil formation. E) Three different fluvial sand facies can be observed in one micromorphology thin section. ................................................................................................. 114

Figure 4.8 Preserved mudcracks found in sub-mound contexts. A) Mudcracks were found at the contact between mound fill and the Ab horizon at 140 cmbs (123.74 cmbs) in the Mound 16 excavations. These mudcracks were preserved through rapid burial by Mound 16 fill material. B) Mudcracks were found at the contact between fluvial sediment and the Ab horizon at 236 cmbs (123.09 masl) in the Mound 5 excavation. The mudcracks were preserved through rapid burial by fluvial sediment...................................................................................................................... 115

Figure 4.9 Schematic drawing of Mound 16 excavation profile with results of stable carbon isotope analysis of soil organic matter collected from the Ab horizon below and adjacent to Mound 16 construction fills. Results described are the predictive groupings made by linear
discriminant analysis. (W) stands for wetland and (SW) stands for seasonal wetland. Abundance
of ceramic rims with depth, and radiometric age estimates are also depicted on the profile
drawing. ................................................................. 116

Figure 4.10 Counts of vessel type, surface treatment, and temper for the 19 ceramic rims
analyzed from Mound 5 excavations. ................................................................. 117

Figure 4.11 Bayesian model for radiocarbon dates from the Mound 5 excavation, descriptions of
sample material and provenience can be found in Table 4.1................................. 119

Figure 4.12 Counts of vessel type, surface treatment, and temper for the 17 ceramic rims
analyzed from Mound 16 excavations. ................................................................. 121

Figure 4.13 δ¹³C values from modern baseline groups of prairie, wetland, and season wetland are
statistically different from each other, making these data a good baseline for archaeological
samples................................................................. 123

Figure 4.14 Image of crayfish in burrow hole from Mound 5 excavations. ......................... 128
List of Tables

Table 2.1. Context of samples used in radiometric dating models. ............................................. 41
Table 2.2. Soil and sediment descriptions for Mound 5 excavation. ............................................. 43
Table 2.3. Soil and sediment descriptions for Mound 16 excavation. ............................................. 49
Table 2.4. Soil and sediment descriptions for Canteen Creek excavation. ........................................... 51
Table 3.1 Results of stable carbon isotopic analysis for modern baselines. ..................................... 84
Table 3.2 Results of stable carbon isotopic analysis for archaeological samples. ............................. 85
Table 4.1 Context of samples used for radiometric dating. ................................................................. 120
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May 2020
To Bill
ABSTRACT OF THE DISSERTATION

Testing Assumptions on the Relationship between Humans and their Environment: Case Studies from Cahokia Mounds, Illinois

by

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Doctor of Philosophy in Anthropology

Washington University in St. Louis, 2020

Professor Tristram R. Kidder, Chair

Many archaeologists argue that studying past human response to climate change can be helpful in informing future strategies to adapt to modern effects of climate change; however, archaeological research is rarely utilized in climate change policy. Much of archaeological research involves forming hypotheses to explain observations of past phenomena. However, the advancement of knowledge requires a back and forth between hypothesis forming and hypothesis testing. I argue that a lack of engagement in hypothesis testing has stalled the advancement in archaeological knowledge on the relationship between humans and their environment. Ultimately, it is this stall in the advancement of knowledge that makes archaeological research irrelevant to the fast paced and evolving demands of climate change policy. In this dissertation, I use Cahokia Mounds as a case study of an archaeological site where untested hypotheses related to the relationship between humans and their environment have persisted in academic literature and public discourse for decades. First, I address a hypothesis that deforestation caused increased flooding at the end of Cahokia’s occupation. I use stratigraphic analysis of archaeological excavations conducted in the floodplain of Cahokia Creek to demonstrate that geomorphic
conditions were stable from Mississippian occupation (AD 1050 – 1400) until the Industrial Era (mid-1800s). The presence of a stable ground surface from Mississippian occupation to the Industrial Era does not support the expectations of the deforestation hypothesis. Ultimately, this research demonstrates that pre-Colombian ecological change does not inherently cause geomorphic change, and narratives of ecocide related to geomorphic change need to be validated with the stratigraphic record. Second, I address a hypothesis that regional trends of drought caused food insecurity at the end of Cahokia’s occupation. I rely on stable carbon isotope data of buried soil horizons as a proxy of dominant vegetation ground cover changes through time. These data show local ecological resilience to regional trends of drought, demonstrating that the assumed ecological effects of climate change are not universally inherent. Third, I address the hypothesis that the North Plaza complex was drier than modern times during the construction and utilization of this space. The hypothesis that the North Plaza was dry during Mississippian occupation is generally accepted because it fits into preconceived notions about the use of plaza space. I rely on stratigraphic and stable carbon isotope datasets to demonstrate that the North Plaza was a wetland during the construction and utilization this space. Ultimately, the North Plaza hypothesis is great example of how preconceived notions in archaeology can give leeway to accept untested hypotheses. Moving forward, I suggest archaeologists need to be more conscious of the assumptions that are built into explanations of past phenomena and that we should continue to develop research agendas capable of testing these assumptions.
Chapter 1: Acceptable Assumptions in the Relationship between Humans and the Environment

1.1 Introduction

Turtles all the way down is an expression of the concept of infinite regress; or that scientific truths are only true because they are supported by a previous truth. Another common phrase that could be used to express this sentiment is “standing on the shoulders of giants,” in which current scientific research can only uncover new truths by building on previous discoveries. The advancement of science does not necessarily have to be as linear as these common phrases imply; especially in archaeology where researchers must “make explicit a range of assumptions and inferential steps [because they] lack direct access to the articulate beliefs of cultural subjects who ‘literally do not exist’” (Wylie 2002:162). While I understand there are many different ways in which science moves, I believe that at the fundamental level where science is grounded in argumentative logic, advancements in science are made through the interplay of inductive and deductive reasoning (Kuhn 1962). Deductive reasoning starts out with a general statement, or hypothesis, and uses observations to either support or reject the statement. Inductive reasoning is the opposite of deductive reasoning. Inductive reasoning starts with observations. Based on patterns in these observations, a statement or hypothesis is made. I follow Kuhn’s model of “normal science”, where advancements in scientific knowledge, within a particular theoretical paradigm, are often an interplay of inductive and deductive approaches (Kuhn 1962). Inductive reasoning is used to develop hypotheses and deductive reasoning is used to test the validly of these hypotheses under a particular set of conditions; and so on and so forth.
In this dissertation, I make the observation that previous archaeological scholarship on the relationship between humans and the environment relies heavily on inductive reasoning. This heavy reliance on inductive reasoning is problematic because the validity of hypotheses made based on observations are not being tested. Instead, these hypotheses become informally accepted as truths – or what I am calling “acceptable assumptions”. An example of an acceptable assumption in the relationship between humans and the environment is the climate-agriculture-population narrative. This narrative explains how negative effects of climate change (we will use drought as an example) cause food insecurity, which in turn can contribute to people abandoning an environment. Both the statements that drought causes food insecurity and that food insecurity contributes to peoples’ decision to abandon an area are based on previous observations, which is an example of hypothesis forming with inductive reasoning. In most sciences, the next logical step would be to evaluate the conditions under which drought leads to food insecurity or when food insecurity leads to human migration, which is an example of hypotheses testing with deductive reasoning. In archaeological research, observations of correlating periods of drought and human migration are sometimes explained by food insecurity, which is an example of inductive reasoning based on previous inductive reasoning – or in other words, forming a hypothesis based on a previous hypothesis. In this example, rather than testing the validity of the food insecurity theory under a specific set of conditions, the food insecurity theory is accepted as true and applied to various sets of conditions. When we apply these acceptable assumptions to archaeological sites of different time periods and regions, we create a sea of individual floating turtles rather than a stack of turtles on top of turtles. So essentially, the continuous reliance on inductive reasoning stalls the advancement of archaeological knowledge. To advance our
discipline, future work should focus on determining the set of conditions under which hypotheses generated from inductive reasoning do or do not occur.

Evaluating the conditions under which hypotheses on the relationship between humans and the environment do or do not occur is important to advance archaeological knowledge, but it is also needed to better inform future strategies for adaptation to future climate change effects. Many archaeologists argue that studying past human response to climate change can be helpful in informing future strategies to adapt to modern change (Anderson et al. 2013; Chase and Scarborough 2014; Van de Noort 2011; Jackson et al. 2017; Hudson et al. 2012; Rockman 2012; Sandweiss and Kelley 2012; Pétursdóttir 2017). Food insecurity related to loss of ecosystem resources is just one example of a future climate change effect to which people need to adapt; but how can archaeology be helpful in informing future strategies to climate related food insecurities if we assume that the effects of climate change, like drought, always causes food insecurity and food insecurity always leads to human migration? We already know climate change effects like drought have the potential to cause food insecurity and we also know that food insecurity can cause people to migrate to a different region. What we do not know is under which set of conditions does drought led to food insecurity. What role do factors like duration and intensity of drought, agricultural system resilience, cultural preparedness, and cultural support networks play in determining if loss of ecosystem services leds to food insecurity? The specifics of what conditions led to successful or unsuccessful adaptation strategies are needed to provide policy makers with decision options. A deductive logical approach is needed to determine the set of conditions under which the hypotheses regarding the relationship between humans and the environment do or do not occur. I do not mean to say that every archaeologist falls into the acceptable assumptions trap. Karl Butzer’s work is a great example of research that examines
how specific aspects of political structure and community organization buffer negative effects related to a loss of ecosystem resources (Butzer 2012; Butzer and Endfield 2012). However, researchers like Karl Butzer seem to be the exception rather than the rule (Naudinot and Kelly 2017; Coombes and Barber 2005; Contreras 2017).

In this dissertation, I use Cahokia Mounds as a case study of an archaeological site where previous research on the relationship between past peoples and the environment has relied heavily on inductive logic. By using a deductive approach to examine the validly of previous hypotheses, I demonstrate that many of these hypotheses are not supported by geoarchaeological datasets.

1.2 Cahokia Mounds as a Case Study

By 1050 A.D. a large, complex society developed in the American Bottom floodplain of the central Mississippi River valley (Figure 1.1). Cahokia was the largest pre-Columbian settlement north of Mexico and persisted as a complex chiefdom until its eventual abandonment by 1400 A.D. Many researchers have hypothesized about the decline of Cahokia; citing contamination of local water supplies, changing climatic conditions, disease, resource overexploitation, overreliance on maize agriculture, warfare, and internal political dissent (Lopinot and Woods 1993; Woods 2004; Benson et al. 2009; Tainter 2019; Kelly 2008; White et al. 2019; Munoz et al. 2015; Hall 1991; Baerreis and Bryson 1965; Meeks and Anderson 2013; Emerson and Hedman 2016). The most persistent hypotheses of decline at Cahokia are those related to environmental change. Environmental hypothesis of decline at Cahokia fall into two categories; natural climatic change, and environmental change due to resource overexploitation. Despite differences in the actual environmental changes that are proposed to have occurred
Figure 1.1. Cahokia Mounds is located in the American Bottom floodplain of Mississippi River. The North Plaza at Cahokia Mounds is the area of investigation for this dissertation. The North Plaza is an ideal location to study local signals of droughts and floods because its low elevations makes it vulnerable water table fluctuations.
during Cahokia’s decline, all these hypotheses ultimately suggest that the environment change(s) that occurred were too severe to maintain an agricultural system capable of supporting the dense population at Cahokia.

To understand what is meant by “decline” at Cahokia, we must first examine what Cahokia declined from. Cahokia belonged to a widespread cultural stage in the North American Southeast called Mississippian (ca. 1050 A.D. – 1600 A.D.). The Mississippian cultural stage is broadly defined as a set of material and ideological traits that include intensive agriculture, large earthen mounds with artificially leveled plazas, social and political ranking, fortified communities, and a religious ideology concerned with fertility and the ancestors (Anderson and Sassaman 2012; Knight 1986). Few Mississippian communities exhibit all these characteristics, thus regional and local variations of the Mississippian cultural stage have been identified (Griffin 1967). Cahokia belongs to a regional variant called Middle Mississippian (Griffin 1967). The Middle Mississippian culture is defined by monumental mound building, artificially leveled plazas, intensive maize-based agriculture, widespread trade networks, social ranking, and settlement hierarchy confined regionally in the central Mississippi River Valley, the lower Ohio River Valley, and parts of the Mid-South (Griffin 1967; Yerkes 1988). Cahokia represents the largest mound complex in the Mississippian cultural stage. Like so many of its kindred, Cahokia experienced the classic Mississippian cycle of emergence, florescence, decline, and then abandonment (Milner 1998; Blitz 1999).

Cahokia’s early emergence as a Mississippian center began around 900 A.D., (Figure 1.2) when people nucleated in plaza-courtyard group settlements (Kelly 1990). By 1050 A.D. people began constructing earthworks on a monumental scale and resided in mound and plaza groups (Kelly 1990; Schilling 2010). Agricultural production of eastern agricultural complex (EAC)
crops and maize intensified (Fritz 2019), and population grew to an estimated maximum of 15,000 people in a 1.8km² area (Pauketat and Lopinot 1997). Populations begin to steadily decline around 1200 A.D. (Milner 1998), and palisade wall construction around the core of the site begins around 1300 A.D. (Krus 2016). Cahokia was abandoned by 1400 A.D., after abandonment of Cahokia we see small populations continue to reside in the American Bottom whose material culture looks similar to the Oneota ceramic tradition in the north (Kelly 2007; White et al. 2020).

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Figure 1.2. Generalized chronology of Cahokia Mounds. Phases are defined by ceramic traditions. It is important to note that the radiometric ages (A.D.) for these phases are constantly evolving with new data and new methods.
The simplest way to define the temporal boundaries of emergence, florescence, and decline is to trace changes in population through time. Cahokia’s population dynamics follow the general trend of increasing population during the Lohmann phase, peak population during the Stirling phase, and population decline during the Moorehead and Sand Prairie phases (Milner 1998; Pauketat and Lopinot 1997). Pauketat and Lopinot (1997) estimate population change using only the densely occupied “downtown” area of Cahokia, while Milner (1998) calculates regional populations (Figure 1.3). Lopinot and Pauketat (1997) estimate that 1,400-2,800 people were living within a 1.8km² area of downtown Cahokia during the Edelhardt phase (1000-1050 A.D.) of the Emergent Mississippian. Population increases in the Lohmann phase (1050-1100 A.D.) to 10,200-15,300 people in a 1.8km² area of Cahokia’s downtown (Pauketat and Lopinot 1997). Populations seem to peak in downtown Cahokia near 1050 A.D., whereas regionally the population peaks in the Stirling phase (1100-1200 A.D.) (Milner 1998; Pauketat and Lopinot 1997). Regional estimates of the American Bottom from the Stirling phase range from 20,000 to 50,000 people (Milner 1998). Population decline begins both regionally and in downtown Cahokia during the Moorehead phase (1200-1275 A.D.) and Sand Prairie phase (1275-1375 A.D.) (Milner 1998; Pauketat and Lopinot 1997). The ultimate abandonment of Cahokia is not a unique event as it fits into a broad regional trend of depopulation in the Mississippi and Ohio rivers valleys (Williams 1990). Based on population change through time, Cahokia emerges in the Lohmann phase (1050-1100 A.D.), fluoresces and peaks in the Stirling phase (1100-1200 A.D.), declines in the Moorehead phase (1200-1275 A.D.), and is abandoned during the Sand Prairie phase (1275-1375 A.D.). It is important to note that the chronology of population dynamics was created based on ceramic phases (Pauketat and Lopinot 1997; Milner 1998, 1986). Radiometric ages for these phases are constantly evolving with new methods and data, so any
temporal correlation between environmental change and population dynamics that relies on radiometric dating are tentative and uncertain. A new study using fecal stanols from lake core sediments to estimate population trends at Cahokia relies on independent radiometric dates from the same lake core (White et al. 2018). This study suggests that populations at Cahokia began a general trend of decline around 1050 A.D. (White et al. 2018:Figure 6), while current radiometric ages of ceramics phases suggest populations did not start to generally decline until 1200 A.D. (Milner 1998). With the current state of the literature, it is difficult to determine a radiometric age to use for the start of population decline at Cahokia.

![ESTIMATES OF POPULATION DYNAMICS](image)

Figure 1.3. Line plots of Cahokia population dynamics. Estimates of population dynamics in “downtown” Cahokia are from Lopinot and Pauketat 1997. Estimates of population dynamics in the American Bottom region are from Milner 1998. The chronology of population dynamics is based on ceramic phases, see Figure 1.2 for current radiometric age estimates of ceramic phases.
Correlations between Mississippian population decline and climate change were first described by David Baerreis in the 1960s. Baerreis and Bryson (1965) used palynology studies to define climate fluctuations in the late Holocene. The premise of using palynology as a proxy for climate change is that vegetation is sensitive to variations in temperature and moisture, and thus represents a relatively accurate proxy for climatic change. Palynology samples can be collected in terrestrial, fluvial, or lacustrine environments. The ultimate aim is to identify changes in abundance of vegetation types (boreal forest, grasslands, etc.) through time. Different types of vegetation preferentially grow in specific moisture and temperature regimes. Changing vegetation abundancies reflect changing environmental conditions related to temperature and moisture. Within the Eastern Woodlands region three distinct climatic episodes, named the Scandic, Neo-Atlantic and Pacific I (Baerreis and Bryson 1965), are identified within the occupational time frame of Cahokia. The Neo-Atlantic climate episode ranged from around 900 A.D. to 1200 A.D in the Eastern Woodlands. The Neo-Atlantic climate episode in North America temporally correlates with the Medieval Warm Period in Europe (Baerreis and Bryson 1965). The Neo-Atlantic climate episode is defined by warm, moist condition caused by influxes of moist tropical air (Baerreis and Bryson 1965). Many researches have recognized that this wetter climate was more favorable to maize agriculture than the previous drier Scandic climate episode (300 –900 A.D.) (Hall 1980; Ehrenhard 1972; Penman 1988; Anderson 1999). Griffin (1961) specifically correlates the emergence of intensive maize agriculture in the Upper Mississippi Valleys and in the Great Lakes with the optimal growing environment of the Neo-Atlantic climate episode. The subsequent Pacific I climate episode (1200 –1500 A.D.) was a period of lower temperature and decreasing moisture, and thus not an optimal environment for maize agriculture. Baerreis and Bryson (1965) and Benson et al. (2009) correlate this climate
episode with decreasing populations generally observed across the Mississippi and Ohio River valleys. This Pacific I period would have been less conducive for maize agriculture, thus crop yields began to decrease, and people were forced to disperse across the landscape (Anderson 1999).

Keith Little (2003) combined multiple climate proxies from both geologic and archaeological records to develop a late Holocene climate chronology of the southeastern United States. By combining shell-fish utilization, sea-level oscillation, dendrochronology, lake varves, ice core data, and global historic records, Little identified three climate episodes in the southeastern region of the Unites States that occurred during Cahokia’s occupation. The approximate time period of 450 to 900 A.D. was a cool, dry period, followed by a warmer and wetter period from 900 to 1450 A.D., and finally another cool/dry period from 1450 A.D. until the onset of twentieth century human induced global warming (Little 2003). Little’s multi-proxy analysis supports the climate chronology of Baerreis and Bryson. Previous researchers had already made the connection between climate change and the decline of Mississippian societies in the southeast:

It is probably no coincidence that the spread of Mississippian corresponds to the Medieval Warm Period from ca. A.D. 900 to 1400, a time favorable for agriculture, and that the later part of the era, after the onset of the Little Ice Age, when agriculture would have been more difficult, is a time of increased warfare and settlement nucleation, and decreased long distance exchange and monumental construction (Anderson 1999:26).

Larry Benson, Timothy Pauketat and Edward Cook (2009) used the Palmer Drought Severity Index (PDSI) to determine relative dryness during the time of expansion and decline at Cahokia. PDSI is a measure of available soil moisture calculated from temperature and precipitation.
Prehistoric PDSI values are calculated using a grid network of archival tree-ring data. Negative values indicate dry conditions, while positive values indicate wet conditions. Benson et al. (2009) determined PDSI values are positive for 28 out of 50 years during the Lohmann phase, 18 out of 50 years during the early Stirling phase, and 11 out of 50 years during the late Stirling phase. Benson et al. correlate the time of rapid development at Cahokia (Lohmann phase, 1050-1100 A.D.) with “one of the wettest 50-year periods during the last millennium” (Benson et al. 2009: 467), while the beginnings of regional population decline (late Stirling phase) are correlated with increasing droughts, when crop yields would have been reduced from drought conditions. Benson et al. (2009) suggest that the extended periods of drought conditions reduced maize yields in upland farming complexes (Figure 1.4). Benson et al. (2009) believe the maize grown in the upland farming complexes were essential to feeding the people in the floodplain of Cahokia and that after the abandonment of these upland complexes in 1150 A.D., populations in the American Bottom begin to disperse.

Scott Meeks and David Anderson (2013) also used tree-ring based records of water availability (PDSI) to examine the relationship between soil moisture availability and large-scale population change in the mid-continent. Meeks and Anderson’s results mirror Benson et al. in recognizing that periods of drought-related food stress temporally correlate with population change throughout the mid-continent (Meeks and Anderson 2013).

A recent study by Munoz et al. (2015), using a different type of climatic proxy, contradicts previous research on regional climate change. Munoz et al. (2015) use the sedimentological record from an abandoned Mississippi River channel called Horseshoe Lake(Figure 1.4). During periods of high flood stage, the floodwaters of the Mississippi inundate abandoned channels located in the American Bottom. The sediments from these floodwaters
Figure 1.4. Locations of relevant areas of investigation in and around the American Bottom mentioned in the literature review. Basemap is a 30 meter digital elevation model obtained from the Illinois Geospatial Data Clearinghouse.
create unique identifiable layers within the sedimentological record of abandoned channels. Munoz et al. (2015) determined that no large floods capable of depositing sediment in Horseshoe Lake occurred on the Mississippi River during the emergence and development of Cahokia (600 A.D. - 1200 A.D.). Sometime around 1200 A.D. an extremely large flood “with a magnitude to inundate croplands, food caches, and settlements across most of the floodplain” (Munoz et al. 2015:6323) occurred on the Mississippi River. Immediately after this flood event people would have had to retreat to the uplands. As the Mississippi River typically floods during the growing season, this large flood event likely destroyed the year’s harvest as well as agricultural surpluses stored from previous years. Much labor would have been invested to remove the sediment and debris and restore food production to pre-flood yields. The people living in the floodplain would have had to rely heavily on their upland neighbors for food until they were able to plant and harvest in the following growing season. Munoz et al. (2015) suggest that this flood and subsequent smaller floods played a role in settlement migration to higher elevations (Milner and Oliver 1999) and the population decline and dispersal that occurred in the Moorehead and Sand Prairie phases (1200 A.D. - 1350 A.D.).

The most recent analysis correlating climate and culture change uses δ18O values from sediment lake cores from Martin Lake, Indiana to evaluate changes in the Pacific North American teleconnection (PNA), a low-frequency climate variability in the Northern Hemisphere that is strongly influenced by the El Niño–Southern Oscillation (Bird et al. 2017). During negative PNA phases, the atmospheric circulation pattern increases midcontinental precipitation. Increased precipitation results in an enrichment of δ18O. During positive PNA phases, precipitation is reduced in the midcontinent and δ18O values are depleted. The strongest correlation between PNA phase and precipitation in North America is located over the central
Mississippi and lower Ohio River valleys. Their results suggest that negative PNA conditions prevailed at Martin Lake during the Medieval Climate Anomaly, while positive PNA conditions prevailed at Martin Lake during the Little Ice Age. Bird et al.’s results support the PDSI datasets (Benson et al. 2009; Meeks and Anderson 2013) that suggest a wetter climate at the emergence of Cahokia, and a drier climate at the time of Cahokia’s abandonment. The manifestation of negative and positive PNA conditions is the opposite in the western portion of the continent. Bird et al. argue that the flooding recorded at the end of Cahokia’s occupation by Munoz et al. was from the Missouri River watershed, where positive PNA conditions result in increased precipitation. Bird et al. connect their new climate change dataset to culture change by arguing for a climate-agriculture-population dynamic where climate affects agricultural yields and agriculture yields affect population. Thus, less favorable environmental conditions for agriculture leads to population decline.

In the above paragraphs I summarized six different publications, representing the past 52 years of research on the relationship between climate change and population decline at Cahokia Mounds. Each publication uses rough temporal correlations between proxies for climate change at spatially distinct locations and estimates of population dynamics to make a hypothesis that climate change caused food insecurity, which contributed to the abandonment of Cahokia. None of these publications contains data suggesting that food insecurity occurred. Only one study used an environmental proxy from within the American Bottom region (Munoz et al. 2015). The focus of all previous research has been on determining how the environment changed and theorizing on how these changes may have adversely impacted maize agricultural systems. Ultimately, the past 52 years of research is just repeating the same inductive reasoning framework. The only difference between the existing literature is that they use different types and scales of proxies to
obtain data on climate change. With the current literature review of external environment changes that the people who constructed and occupied Cahokia may have experienced complete, I now shift the focus to studies on human-influenced environment change at Cahokia.

Given the high population estimates for Cahokia, many researchers have alluded to environmental overexploitation as a cause for Cahokia’s decline (Diamond 2005; Woods 2004; Kelly 2008; Iseminger 1997). Lopinot and Woods (1993) were the first to systematically assess overexploitation theories, specifically the wood overexploitation theory. The wood overexploitation theory suggests the construction and fuel demands for wood were of such a magnitude that they resulted in upland deforestation and increased sediment erosion into Cahokia Creek, which ultimately resulted in higher flood frequencies (Lopinot and Woods 1993). Increased rates of flooding negatively affected the floodplain agricultural fields, resulting in decreased crop yields, which forced people to abandon Cahokia and to retreat to higher ground (Lopinot and Woods 1993). An extremely high demand for wood by the large regional population of 25,000 people required 800,000 wall posts for housing construction alone (Lopinot and Woods 1993). In addition to housing construction, wood to supply 25,000 people with fuel would have put stress on forest resources. Additionally, the construction of a large (2.8 km long) stockade wall starting as late as 1250 A.D. (Krus 2016), around the central core of Cahokia would have required 20,000 large logs (Iseminger 1997). This log estimate is likely a bit low as the stockade wall was reconstructed four times (Iseminger 1997).

Archaeobotanical remains of wood charcoal show high use of nonlocal woods during the Lohmann and early Stirling phases, suggesting that preferred types of wood were transported to Cahokia (Lopinot and Woods 1993). During the late Stirling and Moorehead phases the importation of nonlocal woods decreased, and wood exploitation became localized in the uplands
(Lopinot and Woods 1993). Population started to decline in the late Stirling phase and declined further during the Moorehead phase, maker demand for house construction and fuel materials lower than in the Lohmann and early Stirling phases. However, demand for wood to construct the 2.8 km long palisade would have put much pressure on locally exploited bluff-line and upland forest resources during the late Stirling and Moorehead phases (Iseminger 1997).

Localized deforestation along the bluff in the uplands would have increased erosion and sedimentation into Cahokia Creek, which would ultimately result in increased rates of flooding in the floodplain region occupied by Cahokia (Lopinot and Woods 1993). Evidence for increased upland erosion is seen at the Goshen site (Woods 2004). The Goshen site is located on an alluvial fan in the bluff-line zone between the uplands and the floodplain, ca. 10 km upstream from Cahokia (Figure 1.4) (Woods 2004). At the Goshen site, an Emergent Mississippian community had once lived on a stable soil horizon. Mississippian period artifacts can be found within the context of a sequence of erosional laminated sediments covering the stable Emergent Mississippian occupation (Woods 2004). On top of the erosional Mississippian period sediments is an A horizon, representing a stable ground surface developed after Cahokia’s abandonment (Woods 2004). This A horizon is buried by later historic erosional events related to Euro-American forest clearance and coal surface mining in the uplands (Woods 2004).

Localized forest exploitation in the uplands likely created the erosional sediments of the Mississippian Period observed at the Goshen site (Woods 2004); however, the effect of increased erosion in the uplands on the floodplain is not clear. Woods (2004) argues that erosion from the uplands filled Cahokia Creek, resulting in higher frequencies of unseasonable flooding in the floodplain during summer periods. Cahokia’s low-elevation fields would have been subjected to flooding, standing water, and saturated soil conditions (Woods 2004). If flooding occurred
during the growing season, crops could be drowned or stunted by the lack of free oxygen in the soil (Woods 2004). Woods (2004) suggests Cahokia was ultimately abandoned because increased flooding reduced crops yields to a level that could no longer maintain the population of Cahokia.

It is important to note that the wood-overuse hypothesis is based entirely on observations of wood use. The statement that increased erosion from local wood exploitation caused higher frequencies of flooding is a hypothesis. There are currently no data to support the hypotheses that increased frequency of flooding did occur. It has been 26 years since the wood-overuse hypothesis was proposed, and so far no one has tested the validity of this hypothesis.

The above paragraphs summarize the current state of literature on environmental change and population dynamics at Cahokia Mounds. With this literature review, I show how previous research on the relationship between humans and their environment has exclusively been conducted within an inductive framework. The current state of the literature contains untested hypotheses that external environmental change caused food insecurity and human-caused environmental change destabilized agricultural systems. In this dissertation I use new geoarchaeological data from the Cahokia Mounds site to test the validity of these previous hypotheses.

1.3 Geoarchaeology as a Method

Geoarchaeology stands out as the method most likely to yield data on changes of flood frequency and the local manifestations of regional climate change. Geoarchaeology uses concepts and methods from earth sciences to address archaeological questions (Rapp et al. 2006; Goldberg and Macphail 2006). These methods typically include field-based approaches such as
stratigraphic and sedimentological analysis, and general site formation processes analysis as well as laboratory-based approaches to study earth materials like optical microscopy, isotopic analyses, and chemical composition analyses (Rapp et al. 2006; Goldberg and Macphail 2006). To evaluate previous hypotheses about the relationship between environmental change and culture change, geoarchaeological approaches were applied to investigations of the North Plaza at Cahokia Mounds (Figure 1.1).

The North Plaza is an ideal place to test previous hypotheses related to environmental change because it occupies the lowest elevation of Cahokia (Fowler 1997; Milner 1998), in a space at least 4 meters lower than the other three plazas of Cahokia’s central precinct (Rankin 2016). Its low elevation makes the North Plaza the most vulnerable plaza and mound group to water table fluctuation. Located in the Edelhardt meander scar and the floodplain of Cahokia Creek (Figure 1.1) (Hajic 1993; White et al. 1984), the North Plaza would have been at least seasonally inundated in all but the driest years (Milner and Oliver 1999; Milner 1998).

A geoarchaeology approach to North plaza investigations provides an opportunity to utilize an archaeological context to determine localized environmental variability related to flood and drought at the end of Cahokia’s occupation. Additionally, investigations of the North Plaza also allow us to evaluate environmental conditions prior to and during the construction and utilization of the North Plaza. Mound and plaza groups are typically used for daily public activities, so there is a long-held assumption that the area where the North Plaza was constructed was drier during Mississippian occupation than it is now (Fowler 1997; Iseminger 2010). However, the validity of this assumption has never been tested. By placing archaeological excavations at the edge of human-constructed earthen mounds, I use the mounds as a chronological marker to determine which soils and sediments were deposited before and after
mound construction. Stratigraphic and sedimentological analyses, micromorphology, and stable carbon isotopic analyses of these soils and sediments are then used as proxies for environmental conditions. Additionally, terrestrial sediment cores are used to expand the investigation area beyond archaeological excavations.

This article-style dissertation employs a geoarchaeological approach to collect data that could support or reject hypotheses and assumptions in the current Cahokian literature. The methods and resulting datasets used to address different hypotheses are the same; however, they are conceptualized in different ways to address different three different existing hypotheses.

1.4 Structure of the Dissertation

In this dissertation I use geoarchaeological data collected from the North Plaza, the lowest-elevation architectural feature at Cahokia Mounds, to evaluate previous hypotheses and assumptions regarding 1) human-influenced environmental change, 2) localized effects of regional climate change, and 3) the environmental conditions during the construction and utilization of this low-elevation architectural feature. Specifically, each article-style chapter addresses one of these three main questions:

1) Did Cahokia and Canteen Creek flood frequency increase at or near the end of Cahokia’s occupation?

2) Is there evidence for local manifestations of the regional trends of drought at the end of Cahokia’s occupation?

3) What were environmental conditions like during the construction and utilization of the North Plaza?
Chapter 2: Evaluating Narratives of Ecocide with the Stratigraphic Record at Cahokia Mounds State Historic Site, Illinois, USA addresses question 1. Specifically, my co-authors (Casey Barrier and Timothy Horsley) and I use geophysics and stratigraphic analysis from archaeological excavations and terrestrial sediment cores in the floodplain of Cahokia and Canteen creek to determine if increased flooding occurred at the end of Cahokia’s occupation. Geophysical investigations and the Canteen Creek excavation were conducted by Casey Barrier and Timothy Horsley, and any text or figures referencing geophysical surveys or the Canteen Creek excavations were completed by Barrier and Horsley. I am responsible for all writing and figures that do not specifically address these two aspects of the chapter. This chapter follows the formatting style for the journal Geoarchaeology.

Chapter 3: Correlating Climate Change and Population Dynamics at Cahokia Mounds addresses question 2. This chapter relies on stable carbon isotopes from buried A horizons in the North Plaza as a proxy for dominant vegetation ground cover changes through time. These data show local ecological resilience to regional trends of drought. These data demonstrate that assumed ecological effects of regional climate change are not universal at the local scale, and local environmental datasets taken from within the archaeological record are necessary to test the validity of theoretical links explaining the correlation between climate change and population dynamics. I am responsible for all data collection and analysis. Dr. Rachel Reid provided guidance and supervision while conducting the isotopic analysis. I am solely responsible for the text in Chapter 3. This chapter follows the formatting style for the journal Antiquity.

Chapter 4: The Exceptional Setting of the North Plaza, Cahokia Mounds, Illinois addresses question 3. This chapter relies on the same stratigraphic analyses and stable carbon isotopic data presented in Chapters 1 and 2 to evaluate a hypothesis that the area in which the North Plaza was
constructed was drier during Mississippian occupation than it is today. I argue that this hypothesis is an “acceptable assumption” because it complies with archaeological conceptions of what plazas are and how plazas are used. The North Plaza is an anomaly in the archaeology of the Eastern Woodlands that requires archaeologists to re-envision how we define plazas. I am solely responsible for the text in Chapter 4. This chapter follows the formatting style of the journal *American Antiquity*.

Data collected and produced as a result of this dissertation will be curated in two places. All images and digital data will be curated in the digital repository of the Washington University in St. Louis Library system. All artifacts, original notes and maps, as well as copies of all digital data will be curated at the Illinois State Museum.

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Yerkes, Richard W.
Chapter 2: Evaluating Narratives of Ecocide with the Stratigraphic Record at Cahokia Mounds State Historic Site, Illinois, USA

2.1 Introduction

Environmental explanations for the collapse of complex societies have been popular topics since William Thomas’ 1956 volume on “Man’s Role in Changing the Face of the Earth” (Thomas, 1956). This seminal work established the philosophical argument that humans are inherently destructive to the environment (Middleton, 2017; Ponting, 1991; Thomas, 1956); a philosophy that is widely applied in anthropology (Oliver-Smith & Hoffman, 1999), geology (Nianfeng et al., 1999; Wilkinson, 2005), biology (Ceballos et al., 2015; Meyer & Turner, 1992; Vitousek et al., 1997), environmental ethics (Attfeld, 2008), and general public discourse today (Diamond, 2005; Goudie, 2019; Montine et al., 1990; Ponting, 1991; Ward, 2009). Following this philosophy, environmental explanations for the collapse of complex societies often conform to the ecocide model, ecocide referring to ecological decline resulting from human activities. The ecocide model cites known land-use practices of past peoples and the potential resulting environmental consequences of these activities as contributions to societal collapse (Middleton, 2012; Redman, 1999).

Ecocide narratives of collapse often recognize that the environment is not the only contributing factor to societal collapse; however, these accounts tend to ignore the capacity of past peoples to respond to environmental decline beyond abandonment and migration (Middleton, 2012, 2017). Additionally, ecocide narratives rely heavily on evidence of past human activities, while the resulting environmental consequences are often hypothetical (Kull, 2000; McAnany & Yoffee, 2009; Mt. Pleasant, 2015). Although much of collapse theory has
since moved beyond these simplistic correlation narratives to more nuanced understandings of adaptation and resilience, as well as the role of localized environmental change, modern concerns about human influences on the environment perpetuate the popularity of these older narratives in both academic and public discourses (Butzer, 2012; Diamond, 2005; Faulseit, 2016; Middleton, 2017; Tainter, 2008, 2016). Archaeologists who study many of the complex societies used in these older comparative works have since responded to the proposed ecocide scenarios with more nuanced understandings of social response to change and social resilience (Kull, 2000; McAnany & Yoffee, 2009). In some cases the ecocide scenario can be supported with new datasets; however, there are still many case studies that are mired in old narratives without data to support that these consequences of land use practices actually occurred. One good example of a major archaeological site where these narratives persist can be found in some environmental explanations for the collapse of the Cahokia polity.

Cahokia Mounds is the largest pre-Columbian settlement north of Mexico (Milner, 1998). Cahokia emerged as a large center around AD 1000 (Milner, 1986, 1998; Pauketat & Lopinot, 1997; White et al., 2018). At its peak around AD 1100, central Cahokia had an estimated maximum population size of 15,000 (Pauketat & Lopinot, 1997), but population began to decline regionally around AD 1200, with ultimate abandonment of the site by AD 1400 (Milner, 1986, 1998; Pauketat & Lopinot, 1997; White et al., 2018). The abandonment of Cahokia fits into the larger depopulation of the central Mississippi and lower Ohio River valleys by AD 1500 (Cobb & Butler, 2002). Many environmental and social explanations have been proposed for Cahokia’s abandonment (Benson et al., 2009; Emerson & Hedman, 2016; Kelly, 2008; Samuel E. Munoz et al., 2015; White et al., 2019); but the ecocide scenario, or the “wood-overuse hypothesis”, proposed by Lopinot and Woods in 1993 has been one of the most persistent environmental

The wood-overuse hypothesis suggests tree-clearance in the uplands surrounding Cahokia led to erosion in upland watersheds, causing increasingly frequent and unpredictable floods of the local creek drainages in the floodplain where Cahokia Mounds was constructed (Lopinot & Woods, 1993). More frequent and unpredictable flooding in the floodplain would increase the risks involved within bottomland agriculture to “a point where less productive, but more predictable, upland agricultural strategies became the optimal solution to a growing problem” (Lopinot and Woods, 1993: 210). The relocation of agriculture activities from the bottomlands to the uplands would have increased the erosion problem and further exacerbated flooding issues. It is important to note that the wood-overuse hypothesis relies almost exclusively on evidence of land-use practices, in both an evaluation of the amount of deforestation that would have taken place for construction and fuel resources as well as a trend of increased habitation in the uplands toward the end of Cahokia’s occupation (Lopinot & Woods, 1993). The statement that there was increased habitation in the uplands at the end of Cahokia’s occupation is based on Woods’ unpublished dissertation (Woods 1986). This statement is not supported by other archaeological research in the uplands (Benson et al. 2009). There is very little evidence that erosion did increase during Cahokia’s occupation and no evidence that flooding in the bottomlands became increasingly frequent and unpredictable (Holley & Brown, 1989; Lopinot & Woods, 1993; Woods, 2004). Lopinot and Woods clearly state they do not believe they have enough data for their narrative to be used as a probable explanation for the collapse of Cahokia, yet this hypothesis has been cited in academic research and public discourse as a potential cause.
for collapse at Cahokia (Delcourt & Delcourt, 2004; Emerson, 1997; Emerson & Hedman, 2016; Hayashida, 2005; Hornborg & Crumley, 2006; Kelly, 2008; Mann, 2005; Pauketat, 2004; Tainter, 2006; Woods, 2004). In this article we specifically address the lack of data to support the hypothesized consequences of the known land-use practices described by Lopinot and Woods. We present new data from geoarchaeological investigations at the North Plaza in the central precinct of Cahokia Mounds, a mound and plaza group built in the flood plains of Cahokia and Canteen creeks, as well as evidence of historic era alluvial deposition and infilling of Canteen Creek. Our results reject the wood-overuse hypothesis.

2.2 Site Setting

Cahokia Mounds is located in the American Bottom, a broad expanse of floodplain on the Illinois side of the Mississippi River that was created at the end of the Pleistocene by the scouring action of postglacial meltwaters flooding at the confluence of the Missouri and Mississippi rivers (Hajic, 1993; Iseminger, 1997). The American Bottom floodplain is bounded by sedimentary bluffs on its eastern border, creating a distinct 160km north-south oriented floodplain (Hajic, 1993) (Figure 2.1). The headwaters of several local low-order tributaries of the Mississippi River are located in these bluffs, causing high sedimentation and drainage issues when the local tributaries flow into the less than 1% gradient of the American Bottom floodplain (Helm, 1905). Standing water was a major issue for the European settlers of this area; during his visit to the American Bottom in 1842, Charles Dickens remarked that “few people can exist in such a deadly atmosphere … [where] everywhere was stagnant, slimy, rotten, filthy water” (Dickens, 1972:221-222). In 1905 a local engineer, Edwin Helm, published a demand to improve flood and drainage control by forming one centralized agency to plan and maintain flood infrastructure for the entire American Bottom (Helm, 1905) – a cry that was answered in 1908
with the formation of the East Side Levee and Sanitary District, which was empowered to construct a cohesive and all-encompassing system of canals and levees throughout the entire floodplain (Colten, 1990). The diversion canals of Cahokia and Canteen creeks were completed in 1921 (Colten, 1990; Moorehead, 1929). The system of canals and levees developed in the early 20th century are the primary determinates of the hydrologic system we observe in the American Bottom landscape today.

Figure 2.1. Location of Cahokia Mounds within the American Bottom floodplain.

The central precinct of Cahokia Mounds is believed to have been arranged as a cosmogram, with Monks Mound (the largest mound north of Mexico) at the center and four mound and plaza groups in each of the four cardinal directions (Kelly, 1996; Kelly & Brown,
The North Plaza was created at the lowest elevation of the central precinct, in an abandoned meander scar of the Mississippi River as well as the floodplain of Cahokia and Canteen Creeks (Fowler, 1997; Milner, 1998). This low-elevation wetland is an exception to the normal setting for Mississippian mound groups throughout Eastern North America which are typically placed in areas not subject to frequent inundation (Cobb & Butler, 2017; Kassabaum, 2019; Lewis et al., 1998; Lewis & Stout, 1998). Investigations at the Grand Plaza of Cahokia Mounds demonstrated that the plaza was constructed to divert water away from plaza space (Dalan et al., 2003). The North Plaza at Cahokia is bounded by four mounds; three smaller oval mounds (Mounds 14, 15, and 16) and one large rectangular platform mound (Mound 5) (Figure 2.2). The mounds constraining the North Plaza have also been referred to as the Creek Bottom mound group because of their location in the low-elevation flood plain of Cahokia and Canteen Creeks (Fowler, 1997). Today, the North Plaza and its mounds are still seasonally flooded despite human efforts to drain the American Bottom. Data collected from archaeological excavations at Mounds 5 and 16 as well as sediment coring conducted through Mound 14 and the North Plaza by Caitlin Rankin under the auspices of Washington University in St. Louis, will be used to discuss the sedimentological signature of pre-Columbian land use practices (Figure 2.2). Additionally, geophysical survey in the Edelhardt meander scar and subsequent ground-truthing excavations conducted approximately 240 meters east of the North Plaza by Casey Barrier, Timothy Horsley, Robin Beck (University of Michigan), and Timothy Schilling (Midwest Archaeological Center, US National Park Service) confirmed the location of an abandoned channel of Canteen Creek. Data from these geophysical surveys and excavations demonstrate the extent of post-Columbian industrial landscape change, which has dramatically altered the pre-Columbian landscape.
Figure 2.2. Locations of investigations within the precinct of Cahokia Mounds.
2.3 Methods

2.3.1 Field Methods

Archaeological excavations were conducted on the western side of Mound 5 and the eastern side of Mound 16 (Figure 2.2). The Mound 5 excavations consisted of a 2x5 meter trench to a maximum depth of 245 centimeters below ground surface (cmbs), and a 1x2 meter trench to a maximum depth of 200 cmbs. The Mound 16 excavations consisted of a 1x4 meter trench to a maximum depth of 160 cmbs, and a 1x2 meter trench to a maximum depth of 160 cmbs. Soil was extracted with shovel and trowel at 10 cm and 20 cm intervals. All units were excavated as individual 1x1 meter quads. Every fourth bucket of soil from the plow zone was screened through 12.7 mm mesh. Outside the plow zone, all soil was screened through 12.7 mm mesh and soil from features was screened through 6.35 mm mesh. Detailed profile drawings were made for all excavations, and three-dimensional photographic models of the excavation were created in Agisoft Photoscan. Basic stratigraphy data, including Munsell color, soil texture, soil structure, soil horizonation, redoximorphic features, and bioturbation were recorded for all stratigraphic features following standard descriptions (Birkeland, 1999; Soil Survey Staff, 1999; Vasilas et al., 2010; Vogel, 2002). Block micromorphology samples were collected from excavation profiles by driving plastic electric conduit boxes continuously up-column. Bulk soil samples of 50 g were collected from each soil or stratigraphic horizon for particle size and stable carbon isotope analyses. Flotation samples were collected at each 20 cm level and from features for radiocarbon dating and investigation of subsistence activities.

Excavation of a portion of a relict channel of Canteen Creek was conducted in 2017 following a 2016 magnetometer survey of a portion of the Edelhardt Meander by Horsley and
Barrier (Figure 2.3). An area of 9.4 hectares was surveyed using a Bartington Grad601-2 dual fluxgate gradiometer, with readings recorded at 0.125 meter intervals along traverses spaced 0.5 meters apart. This survey detected the infilled creek channel as a distinctive positive magnetic anomaly produced by magnetically enhanced topsoil and, potentially, other cultural deposits contained within the fill. The strongest readings within the channel likely reveal the meandering thalweg. Subtler negative magnetic responses were detected on either side of the inferred channel and suggest constructed levees. Based on the geophysical results, the buried channel measures between 7-8 meters across and the levee responses extend a further 4-6 meters from the channel banks.

Figure 2.3. Results of the 2016 magnetometer survey conducted by Horsley and Barrier, revealing extensive anthropogenic activity and landform modification along the edge of the Edelhardt Meander Scar and at least one former course of Canteen Creek.
The magnetometer results also reveal the extent of occupation and anthropogenic modifications along the northern edge of the East Plaza that is outside the Edelhardt Meander. In addition to the distinctive positive anomalies associated with probable house basins, pits, and hearths, several complex, larger scale responses are interpreted as indicating areas of landscape modification, although further work will be required to verify this. This modification includes the construction of Mound 17 that was formerly visible and recorded in the late 19th century (Fowler 1997:72). The base of this mound has been detected in a similar manner to other denuded mounds in the region (e.g. the Washausen site [Horsley et al., 2014] and the Pulcher Mound Group) and corresponds to observations on Native American mound construction (Sherwood & Kidder, 2011). With the exception of recent plow scar responses, the magnetometer data reveal no evidence for occupation or other anthropogenic features in the Edelhardt Meander and around Mound 5. From the geophysical data alone, it is impossible to determine whether this is due to a lack of such features or an indication that the earlier pre-Columbian land surface lies beyond the detection limits with this instrument.

Although Canteen Creek was diverted to its current location by 1921, the earliest map of central Cahokia, drawn in 1876 by John Patrick (Fowler 1997:Figure 3.1), shows the creek’s course as matching the shape of the magnetic anomaly. It is uncertain whether Patrick witnessed Canteen Creek flowing in this channel in the 1870s or whether he only saw remnants of an abandoned channel by that time. In fact, a map of this same area published six years later in 1882 has Canteen Creek in a different location (Fowler 1997:Figure 3.2). No subsequent maps of Cahokia display the creek in the area shown on Patrick’s map, except ones that copied his original 1876 map. A 1922 aerial photograph taken just after Canteen Creek was moved to its
current location (Fowler 1997:Figure 2.6), however, does show a stretch of dense vegetation oriented linearly in a location and at an angle that appears to match the detected anomaly.

A 1x8 meter trench was excavated to a maximum depth of 140 cmbs to confirm the presence of an infilled channel and to investigate the features producing the negative magnetic responses. The unit was aligned perpendicular to the creek and placed to expose a portion of its western bank and transect an area of the adjacent negative magnetic anomaly (Figure 2.3). Plow zone was removed as a single layer, while underlying materials were excavated in arbitrary levels. All soil was screened through 12.7 mm mesh. Profiles were mapped and basic stratigraphy data were recorded. Organic samples were collected at various depths for radiocarbon dating.

In addition to archaeological excavations, 43 continuous sediment cores were collected by Rankin to a maximum depth of 3.6 meters with a GeoProbe 54TRs mounted on a tractor with a DT-21 sampling device. The sample tube is 3 cm in diameter. Four sampling transects were created, two placed around Mound 14 and two placed around Mound 5 (Figure 2.2). At Mound 5, a 35 m transect on the N550 line was established with core locations spaced at 5 m and 10 m intervals and a 25 m transect on the E355 line spaced at 5 m and 10 m intervals. At Mound 14, a 215 m transect on the N725 line was spaced at 5 m and 10 m intervals and an 85 m transect on the E120 line was spaced at 5 m and 10 m intervals. Additionally, a 20 m transect was placed “outside” of the North Plaza on gridline N735 at 10 m intervals.

2.3.2 Laboratory Methods

Only two sediment cores were cut and described in the field; the rest of the cores were transported to the Paleoclimatology and Sedimentology Laboratory at Indiana University-Purdue
University Indianapolis where there were cut, cleaned, imaged, analyzed for magnetic
susceptibility, described, and sampled for particle size analysis and stable carbon isotopes at 10
cm intervals. High resolution imagery and magnetic susceptibility at 1 cm intervals were collected
with a GeoTek Multi-Sensor Core Logger. These raw data are archived at the Illinois State
Museum. The N725 transect was archived at the Geoarchaeology Laboratory at Washington
University in St. Louis.

Block micromorphology samples were sent to Applied Petrographic Services, Inc.
(Latrobe, PA, USA) where they were impregnated with epoxy, trimmed to size, and then
mounted on 50x75 mm glass slides. All samples were ground to a uniform thickness of 30 μm.
Thin sections were described and analyzed using standard micromorphological nomenclature
(Bullock et al., 1985; FitzPatrick, 1993; Stoops, 2003). Analysis was conducted with a under
plane-polarized (PPL) and cross-polarized (XPL) light at 8-15x magnification with a binocular
microscope and 15-200x magnification with a petrographic microscope.

Descriptions of organic sample context, uncalibrated AMS ages, and laboratories utilized
for AMS dating can be found in Table 2.1. Radiocarbon ages were calibrated and modeled using
OxCal v4.3.2 and the IntCal13 atmospheric curve (Bronk Ramsey, 2017; Reimer et al., 2013).
Calibrated and modeled dates were rounded to the nearest ten years.
Table 2.1. Context of samples used in radiometric dating models.

<table>
<thead>
<tr>
<th>Lab #</th>
<th>Sample Number</th>
<th>Provenience</th>
<th>Stratigraphic Context</th>
<th>Material Notes</th>
<th>Radiocarbon Age (BP)</th>
<th>$\delta^{13}$C ($/_{oo}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beta - 474938</td>
<td>14C-1</td>
<td>Canteen Creek Excavation</td>
<td>base of Stratum 2†</td>
<td>unidentified wood charcoal</td>
<td>140 +/- 30</td>
<td>-26.90</td>
</tr>
<tr>
<td>Beta - 474939</td>
<td>14C-2</td>
<td>Canteen Creek Excavation</td>
<td>Stratum 6†</td>
<td>unidentified wood charcoal (branch fragment)</td>
<td>120 +/- 30</td>
<td>-24.70</td>
</tr>
<tr>
<td>Beta - 474937</td>
<td>14C-3</td>
<td>Canteen Creek Excavation</td>
<td>Stratum 20‡</td>
<td>unidentified wood charcoal</td>
<td>150 +/- 30</td>
<td>-25.50</td>
</tr>
<tr>
<td>OS-140346</td>
<td>50-57-4</td>
<td>2017 Mound 5 Excavation</td>
<td>Feature 5 - Wall trench dug into mound fill</td>
<td>Carya illinoensis¶</td>
<td>885 +/- 15</td>
<td>Not reported</td>
</tr>
<tr>
<td>D-AMS 019338</td>
<td>1960-19 Bag19-3</td>
<td>1960 Mound 5 Excavation§</td>
<td>Burn layer in inner mound</td>
<td>lower pre-molar deer tooth</td>
<td>903 +/- 24</td>
<td>Not reported</td>
</tr>
<tr>
<td>D-AMS 019339</td>
<td>1960-19 Bag19-12</td>
<td>1960 Mound 5 Excavation§</td>
<td>Burn layer in inner mound</td>
<td>Carya cordiformis¶</td>
<td>887 +/- 26</td>
<td>Not reported</td>
</tr>
<tr>
<td>OS-140345</td>
<td>50-58-14</td>
<td>2017 Mound 5 Excavation</td>
<td>Fluvial sand deposit underneath mound fill</td>
<td>Zea Mays kernel¶</td>
<td>1000 +/- 25</td>
<td>Not reported</td>
</tr>
<tr>
<td>OS-140221</td>
<td>N550 E110</td>
<td>Sediment Core N550 E310</td>
<td>2 mm thick charcoal lens at base of Ab</td>
<td>unidentified wood charcoal</td>
<td>985 +/- 15</td>
<td>Not reported</td>
</tr>
</tbody>
</table>

† Sample removed from North profile wall, but its mirror-image location is shown on Figure 2.9.
‡ Sample removed from South profile wall. See Figure 2.9 for horizontal and vertical context.
§ Approval for destructive analysis was obtained through the Illinois State Museum for ISM Accession Number 1960-19
¶ Organic material identification from the 1960 Mound 5 excavations were made by Marjorie Schroeder, organic material identification from 2017 Mound 5 excavations were made by Grace Ward.
Figure 2.4. Schematic drawing of Mound 5 stratigraphy. Numbers listed for each stratigraphic layer refer to full descriptions found in Table 2.
<table>
<thead>
<tr>
<th>Label</th>
<th>Munsell</th>
<th>Texture</th>
<th>Additional Notes</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10YR 5/3</td>
<td>Silt loam</td>
<td>Bioturbation common, plow scars observed at 35cmbd</td>
<td>Modern topsoil/Plowzone</td>
</tr>
<tr>
<td>2</td>
<td>10YR 2/1</td>
<td>Silty clay loam</td>
<td>Bioturbation many, wall trench dug through this stratigraphic layer</td>
<td>Mississippian ground surface on top of mound</td>
</tr>
<tr>
<td>3</td>
<td>10YR 4/3</td>
<td>Silt loam</td>
<td>Few mottles, few bioturbation</td>
<td>Stratiform mound fill</td>
</tr>
<tr>
<td>4</td>
<td>10YR 3/2</td>
<td>Silty clay loam</td>
<td>Mottles many</td>
<td>Stratiform mound fill</td>
</tr>
<tr>
<td>5</td>
<td>10YR 3/1</td>
<td>Silty clay loam</td>
<td>Mottles many, clay inclusions (ca. 10cm) many</td>
<td>Stratiform mound fill</td>
</tr>
<tr>
<td>6</td>
<td>10YR 4/1</td>
<td>Silt loam</td>
<td>Mottles many, redox common, clay inclusions (ca. 10cm) common</td>
<td>Stratiform mound fill</td>
</tr>
<tr>
<td>7</td>
<td>10YR 5/1</td>
<td>Clay loam</td>
<td>Redox stains and concretions many</td>
<td>Basketload mound fill</td>
</tr>
<tr>
<td>8</td>
<td>10YR 4/1</td>
<td>Clay loam</td>
<td>Redox stains and concretions common</td>
<td>Basketload mound fill</td>
</tr>
<tr>
<td>9</td>
<td>10YR 2/1</td>
<td>Clay</td>
<td>Redox stains and concretions few</td>
<td>Basketload mound fill</td>
</tr>
<tr>
<td>10</td>
<td>10YR 5/2</td>
<td>Very fine to fine sand</td>
<td>Muscovite mica few, discontinuous redox lens</td>
<td>Stratiform mound fill</td>
</tr>
<tr>
<td>11</td>
<td>10YR 5/2</td>
<td>Silt loam</td>
<td></td>
<td>Stratiform mound fill</td>
</tr>
<tr>
<td>12</td>
<td>10YR 5/2</td>
<td>Sandy loam</td>
<td>Muscovite mice few, mottles few, redox concretions and lens common</td>
<td>Stratiform mound fill</td>
</tr>
<tr>
<td>13</td>
<td>10YR 5/4</td>
<td>Fine quartz sand</td>
<td></td>
<td>Stratiform mound fill</td>
</tr>
<tr>
<td>14</td>
<td>10YR 3/2</td>
<td>Silty clay loam</td>
<td>Mottled with 11, redox lens present</td>
<td>Stratiform mound fill</td>
</tr>
<tr>
<td>15</td>
<td>10YR 5/3</td>
<td>Silty Clay</td>
<td>Mottles many</td>
<td>Stratiform mound fill</td>
</tr>
<tr>
<td>16</td>
<td>10YR 5/3</td>
<td>Sandy Loam</td>
<td>Many redox stains, many mottles</td>
<td>Stratiform mound fill</td>
</tr>
<tr>
<td>17</td>
<td>10YR 5/4</td>
<td>Silty Loam</td>
<td>Bioturbation many</td>
<td>Stratiform mound fill</td>
</tr>
<tr>
<td>18</td>
<td>10YR 4/6</td>
<td>Sandy Loam</td>
<td>Redox few, bioturbation from 2</td>
<td>Stratiform mound fill</td>
</tr>
<tr>
<td>19</td>
<td>10YR 3/1</td>
<td>Silt Loam</td>
<td></td>
<td>Stratiform mound fill</td>
</tr>
<tr>
<td>20</td>
<td>10YR 5/2</td>
<td>Sandy Clay Loam</td>
<td>Muscovite mica few, many redox concretions</td>
<td>Stratiform mound fill</td>
</tr>
<tr>
<td>21</td>
<td>10YR 4/1</td>
<td>Sandy Clay Loam</td>
<td>Muscovite mica few</td>
<td>Stratiform mound fill</td>
</tr>
<tr>
<td>22</td>
<td>10YR 5/3</td>
<td>Sandy Clay Loam</td>
<td>Redox common</td>
<td>Stratiform mound fill</td>
</tr>
<tr>
<td>23</td>
<td>N/A</td>
<td>Clay to medium sand</td>
<td>Fine sequences of graded beds of clay to medium sand</td>
<td>Fluvial deposit</td>
</tr>
<tr>
<td>24</td>
<td>10YR 3/1</td>
<td>Silty clay loam</td>
<td>Mudcracks observed in plan-view at 235 cmbd</td>
<td>Ab</td>
</tr>
<tr>
<td>25</td>
<td>10YR 5/2</td>
<td>Clay loam</td>
<td>Gradual boundary with Ab</td>
<td>B-horizon</td>
</tr>
</tbody>
</table>
2.4 Results

2.4.1 Mound 5 Excavations

Mound 5 excavations were conducted to a final elevation at 22.99 masl. Four distinct depositional facies were identified in the field; the oldest is a natural soil sequence with buried A and C horizons, the natural soil sequence is overlain with fluvial deposits, Mound 5 construction fill materials were placed directly on top of the fluvial deposits, and finally there is a modern plow zone on top of the Mound 5 construction fill material. A schematic drawing of Mound 5 stratigraphy can be found in Figure 2.4, with complete soil descriptions in Table 2.2. The pre-occupation natural soil sequence is identified at 123.09 masl and continues until the excavation’s maximum depth at 122.99 masl. An Ab horizon occupies the top 20 cm of the buried natural soil sequence. The contact between the Ab horizon and the fluvial deposit is abrupt and smooth. An artifact scatter of ceramic and bone, as well as preserved mudcracks, were found in the top 2 cm of the Ab horizon. Micromorphology of the contact between the Ab and fluvial deposits shows micro-Ab rip-up clasts within the fluvial deposit (Figure 2.5a).

Micromorphology of the fluvial deposits shows graded beds of fine sand, silt, and clay (Figure 2.5b). Three different depositional micro-facies can be observed in one slide (Figure 2.5e), suggesting that this fluvial deposit represents multiple events rather than one single deposition. There is also a 3 mm incipient A horizon within the fluvial deposits (Figure 2.5c), suggesting a temporary hiatus in fluvial deposition. The contact between the fluvial deposit and mound construction material is abrupt and smooth. This contact between the fluvial deposition and mound fill shows bioturbation between the two depositional facies (Figure 2.5d), but no evidence for incipient soil formation on-top of the fluvial deposit (Figure 2.5d). Mound 5
construction fill materials start at 123.24 masl and continued to 124.84 masl. The lower portion of Mound 5 construction fills are characterized by clay loam basketloads (Figure 2.4), at 123.94 masl construction fill become characterized by loamy stratiform fills (Figure 2.4). The upper 70 cm of the excavation is characterized as plowing of rapidly aggregating alluvium, with historic artifacts found to 70 cmbs and plow marks observed at 35 cmbs and 60 cmbs.

Figure 2.5. Photomicrographs of micromorphology results. (a) Ab rip-up clast in fluvial material. (b) Graded beds of sand, silt, and clay. (c) 3mm thick incipient A-horizon between fluvial sand deposits. (d) Planar void (indicated by arrows) marks the clear boundary between the fluvial deposit and Mound fill. This contact was observed as abrupt in the field but is clear microscopically. There is microscopic evidence for bioturbation between the contact, but no evidence for incipient soil formation. (e) Three different fluvial sand facies can be observed in one micromorphology thin section.

A Bayesian model of Mound 5 construction was created using five samples collected from within Mound 5 and sub-mound contexts (Table 2.1). Both the samples from the Ab horizon and the fluvial sediment serve as terminus post quem for Mound 5 construction (Figure 2.6). The latest end boundary for the start of mound construction is estimated to occur after cal
AD 1150 (19.2% probability and 18.8% probability), but likely occurred after cal AD 1050 (76.3% probability and 76.6% probability) (see Figure 2.7b and 2.7c for full probability distributions). The nutshell and deer tooth from the mound construction phase provide a *terminus ante quem* for the deposition of the fluvial sediment (Figure 2.6). The earliest start boundary for the mound construction phase is cal AD 1030 (95.4% probability) (Figure 2.7b). Taken together, it is likely that both the fluvial sediment and the Ab horizon were deposited prior to Mississippian occupation (*circa* AD 1050-1400).

![Figure 2.6. Probability distributions and Bayesian model for radiocarbon dates from the Mound 5 excavation.](image)

46
Figure 2.7. Probability distributions from model presented for dates from the Mound 5 excavation. a) Calibrated and modeled boundary for the start of the sequence; b) Calibrated and modeled date for Ab horizon, this is considered a terminus post quem for the start of Mound 5’s construction; c) Calibrated and modeled date for the fluvial sediment, this is considered a terminus post quem for the start of Mound 5’s construction; d) Calibrated and modeled date for mound construction phase, this is considered a terminus ante quem for the deposition of the fluvial sediment and Ab horizon; e) Calibrated and modeled date for mound construction phase, this is considered a terminus ante quem for the deposition of the fluvial sediment and Ab horizon; f) Calibrated and modeled date for wall trench dug into mound construction fills, this is considered a terminus ante quem for the mound construction phase.
2.4.2 Mound 16 Excavations

Mound 16 excavations were conducted to a final elevation of 123.30 masl. Four distinct depositional facies were identified in the field; the oldest is a natural soil sequence with buried A and C horizons, the natural soil sequence is overlain with Mound 16 construction fills, which is buried by historic fluvial deposits, and finally there is a modern plow zone on top of the historic fluvial deposits. A schematic drawing of Mound 16 stratigraphy can be found in Figure 2.8, with complete soil descriptions in Table 2.3. The 1x4 meter excavation was conducted at the edge of Mound 16, while the 1x2 meter excavation was completely outside of the Mound 16 footprint. In the Mound 16 excavation unit the natural soil sequence appears at 123.88 masl and continues until the excavation’s maximum depth at 123.53 masl. The contact between mound fill and Ab is abrupt. The Ab horizon is discontinuous underneath Mound 16, suggesting that there was some degree of soil removal prior to the construction of Mound 16. Underneath Mound 16, the Ab is 10 cm at its thickest location. In the 1x2 meter excavation that is completely outside of the Mound 16 footprint, the Ab is 50 cm thick, with the start at 123.60 masl and the end at 124.08 masl. The upper 10 cm of the Ab in the 1x2 meter excavation contains coal clinker material from industrial development, indicating that this ground surface was stable from Mississippian occupation until industrial development in the middle 1800s. In the 1x4 meter unit, homogeneous mound fill is buried by historic fluvial deposits in the eastern portion of the unit, but overlain by plow zone in the western portion of the unit; this difference in stratigraphic relationship is because Mound 16 is sloping to the east (Figure 2.8). The fluvial deposits which buried the Ab in the 1x2 meter excavation and the eastern portion of Mound 16 in the 1x5 meter excavation are horizontally graded beds of fine sand, silt, and clay which begin at 124.08 masl.
and end at 124.55 masl. The presence of coal clinker material throughout the fluvial deposit suggests this material was deposited after industrial development.

Table 2.3. Soil and sediment descriptions for Mound 16 excavation.

<table>
<thead>
<tr>
<th>Label</th>
<th>Munsell</th>
<th>Texture</th>
<th>Additional Notes</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10YR 4/2</td>
<td>Silt loam</td>
<td>Many roots in upper 25 cm, angular blocky structure</td>
<td>Modern Ap</td>
</tr>
<tr>
<td>2</td>
<td>N/A</td>
<td>Clay to fine sand</td>
<td>Finely bedded clay to fine sand (1-2mm thick), Fe concretions and stains in biopores, contains coal clinker</td>
<td>Post-industrial fluvial deposit</td>
</tr>
<tr>
<td>3</td>
<td>N/A</td>
<td>Clay to silt</td>
<td>Finely bedded clay and silt, rootlets present, bioturbated fine sand, contains coal clinker</td>
<td>Post-industrial fluvial deposit</td>
</tr>
<tr>
<td>4</td>
<td>N/A</td>
<td>Clay to fine sand</td>
<td>Same as 2, but with thicker beds (~10mm), contains coal clinker</td>
<td>Post-industrial fluvial deposit</td>
</tr>
<tr>
<td>5</td>
<td>10YR 2/1</td>
<td>Clay to silt</td>
<td>Very dark, thin clay lens contains coal clinker</td>
<td>Post-industrial fluvial, lower energy than 3 and 4</td>
</tr>
<tr>
<td>6</td>
<td>10YR 3/1</td>
<td>Clay Loam</td>
<td>Many redox concretions, angular blocky structure, few roots and biopores</td>
<td>Ab</td>
</tr>
<tr>
<td>7</td>
<td>10YR 5/2</td>
<td>Clay loam</td>
<td>Many Fe stains and Mn concretions, gradual boundary with 6, Few rootlets, angular blocky structure, slicken-sides</td>
<td>B-horizon</td>
</tr>
<tr>
<td>8</td>
<td>10YR 3/1</td>
<td>Sandy Loam</td>
<td>Homogenous</td>
<td>Mound Fill</td>
</tr>
<tr>
<td>9</td>
<td>10YR 4/1</td>
<td>Clay Loam</td>
<td>Mottles of 2 many, plow mark shape</td>
<td>Plow Scar</td>
</tr>
<tr>
<td>10</td>
<td>10YR 4/1</td>
<td>Sandy Loam</td>
<td>Bioturbation many, broken boundary with 2</td>
<td>Plow Zone</td>
</tr>
<tr>
<td>11</td>
<td>10YR 5/2</td>
<td>Clay Loam</td>
<td>Many Fe and Mn concretions, many Fe redox stains, slicken-sides, few rootlets</td>
<td>C-horizon</td>
</tr>
</tbody>
</table>
Figure 2.8. Schematic drawing of Mound 16 stratigraphy. Numbers listed for each stratigraphic layer refer to full descriptions found in Table 2.3.
2.4.3 Canteen Creek Excavations

Canteen Creek excavations were conducted to a final elevation at 123.20 masl. At this depth the water table was reached, and excavations were ceased. Nine distinct strata were identified in the field based on color, texture, and abundance of inclusions. A schematic drawing of the Canteen Creek excavation stratigraphy is displayed in Figure 2.9, with soil descriptions in Table 2.4.

Table 2.4. Soil and sediment descriptions for Canteen Creek excavation.

<table>
<thead>
<tr>
<th>Label</th>
<th>Munsell†</th>
<th>Texture†</th>
<th>Additional Notes†</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10YR 4/3</td>
<td>Silt Loam</td>
<td>Redox concretions common; massive structure; roots common; lower boundary is abrupt</td>
<td>Modern Plowzone</td>
</tr>
<tr>
<td>2</td>
<td>10YR 3/2</td>
<td>Clay Loam</td>
<td>Blocky angular structure; few roots; well sorted silt and clay laminations ranging from .5 to 2cm in thickness; lower boundary is abrupt</td>
<td>Channel fill alluvium</td>
</tr>
<tr>
<td>3</td>
<td>10YR 4/2</td>
<td>Silty Clay Loam</td>
<td>Redox concretions common; blocky angular structure; few bioturbation; lower boundary is diffuse</td>
<td>Overbank Alluvium</td>
</tr>
<tr>
<td>4</td>
<td>10YR 5/2</td>
<td>Silty Clay Loam</td>
<td>Redox concretions common; blocky angular structure; few roots</td>
<td>Overbank Alluvium</td>
</tr>
<tr>
<td>5</td>
<td>10YR 3/1</td>
<td>Clay</td>
<td>Granular Structure</td>
<td>Possible Fill for embankment construction</td>
</tr>
<tr>
<td>6</td>
<td>10YR 3/1</td>
<td>Silty Clay Loam</td>
<td>Common 10 YR 5/3 silt mottles; few 10 YR 4/1 silty clay loam mottles</td>
<td>Possible Fill for embankment construction</td>
</tr>
<tr>
<td>7</td>
<td>10YR 3/1</td>
<td>Clay</td>
<td>Granular Structure</td>
<td>Overbank Alluvium</td>
</tr>
<tr>
<td>8</td>
<td>10YR 2/1</td>
<td></td>
<td>~2cm thick laminations of 10YR 6/3</td>
<td>Overbank Alluvium</td>
</tr>
<tr>
<td>9</td>
<td>2.5Y 6/4</td>
<td>Silty Clay Loam</td>
<td>Massive Structure</td>
<td>Overbank Alluvium</td>
</tr>
</tbody>
</table>

†Descriptions made in the field by Timothy Schilling
Figure 2.9. Schematic drawing of the South profile stratigraphy from the Canteen Creek excavations. Numbers listed for each stratigraphic layer refer to descriptions found in Table 2.4. Also displayed are the locations of recovered organic samples used for 14C AMS dating (note: samples 14C-1 and 14C-2 were removed from the North profile wall, but its mirror-image location is shown here).
Stratum 2 is interpreted as Canteen Creek channel fill based on morphology (Figure 2.9), suggesting that all underlying strata were deposited prior to channel infilling. All strata are generally characterized as alluvial deposition based on texture and sorting, except for Strata 5 and 6. Strata 5 and 6 contain mottle inclusions and have a morphology that is consistent with human-constructed embankment for stream channelization. Coal clinker was found to a maximum depth of 123.85 masl within Stratum 4, suggesting Stratum 4 and all overlaying strata were deposited after the mid-1800s. To further support the industrial and modern age of alluvial deposition indicated by coal clinker material, three organic samples were removed from the profile and submitted for radiocarbon dating (Figure 2.9; Table 2.1). Sample 14C-1 was removed from a 0.5 cm thick lens of charcoal at the interface of strata 2 and 3. Sample 14C-2 is a small carbonized branch recovered from Stratum 4. Sample 14C-3 was a fragment of wood charcoal removed from the western toe slope of Stratum 5 as it feathers out between strata 4 and 7. Because the boundaries between strata 4, 5, and 7 are diffuse, the exact stratigraphic association of Sample 14C-3 is not certain.

Bayesian modeling treats these radiocarbon data as two uniform phases ordered sequentially. Samples 14C-2 and 14C-3 are treated as a single phase (Phase 1) since the stratigraphic integrity of Sample 14C-3 is suspect. This phase is modeled with an undated start and end boundary. Sample 14C-1 is modeled as a phase (Phase 2) that follows in time. The model fits well with the data (Amodel = 95.9) (Figure 2.10). Sample 14C-1 is considered a suitable *terminus post quem* for Stratum 2 deposition (Figure 2.11a). This phase is estimated to begin by cal AD 1740-1780 (5.4% probability) or cal AD 1790-1960 (90.0% probability), but probably between cal AD 1830-1890 (28.0% probability) or cal AD 1900-1950 (40.2% probability). Modeled dates for Strata 4 and 5, which underlie Stratum 2, appear earlier.
Figure 2.10. Probability distributions and Bayesian model for radiocarbon dates from the Canteen Creek excavation.

The undated end boundary for these strata ranges between cal AD 1690 and cal AD 1930 (95% probability), but these strata had probably formed by cal AD 1720-1890 (68% probability) (Figure 2.11b). The undated start boundary for Phase 1 is less informative due to the long probability tails that are likely caused by there being only two dates for this phase (Bayliss et al., 2011). Therefore, we rely on the modeled dates themselves (Figure 2.11c and Figure 2.11d) to estimate a period of activity probably in the late 17th through 19th centuries. Thus, using data currently available it is estimated that strata 4 and 5 – with Stratum 5 being of possible anthropogenic origin – accumulated in the AD 1700s or 1800s. A single coal clinker was recovered from Stratum 4, which could signal a post-AD 1853 date for this layer unless the artifact has relocated from overlying strata (see later discussion of historic era coal mining).
Subsequent infilling of the Canteen Creek channel began sometime following the formation of Strata 4 and 5, and most likely no earlier than AD 1800. Nine pieces of coal clinker were recovered from Stratum 2 suggesting that the infilling of this channel was ongoing in the mid-1800s or later.

Figure 2.11. Probability distributions from model presented for dates from the Canteen Creek excavations. a) calibrated and modeled date for sample 14C-1, which is considered a close proxy for the start of infilling of the channel and the formation of Stratum 2 alluvium; b) undated end boundary for Phase 1; c) calibrated and modeled date for sample 14C-2; d) calibrated and modeled date for sample 14C-3.
2.4.4 Sediment Coring

Complete soil descriptions and cross section drawings for the two analyzed sediment core transects west and south of Mound 5 can be found in Figure 2.12. The depositional facies relationship of an Ab covered with fluvial sediments around 123.00 masl observed in the Mound 5 excavation is also observed in both the N550 transect to the west of Mound 5 and the E355 transect to the south of Mound 5 (Figure 2.12). Many of the cores in these transects contain graded beds of sand, silt, and clay (interpreted as fluvial sediment) that continue until the modern Ap. Core N550 E320 contains 2 mm thick coal lenses within a fluvial sequence at 123.90 masl, suggesting that these upper fluvial sediments were deposited after industrial development. Figure 2.13 shows the cross section drawing and soil descriptions for the Mound 14 transect. In the E120 transect, the base of Mound 14 appears to be around 122.00 masl, as indicated by the presence of an Ab underneath mound construction material. In Core N700 E120, an Ab that formed on top of Mound 14 construction fills is buried by graded beds of fine sand, silt, and clay starting at 123.70 masl and ending around 124.00 masl where the fluvial sediment is buried by the modern Ap. There is no direct evidence within the E120 transect fluvial sediments to suggest they were deposited after industrial development, but their associated elevations with other fluvial sediments in the N550 transect and the Mound 16 excavations suggests that these sediments were deposited after industrial development. The association of fluvial sediments below the modern Ap is continuous throughout the E120 transect (Figure 2.13).
Figure 2.12. Cross section drawings for the soil transects west and south of Mound 5.
Figure 2.13. Cross section drawing for the soil transect through Mound 14.
2.5 Discussion

Lopinot and Woods (1993) proposed the wood-overuse hypothesis based on a decline in the use of nonlocal woods during the Stirling Phase, the most densely occupied phase of Cahokia’s history. They hypothesize the high population demand for local wood resulted in the deforestation of the uplands surrounding the American Bottom floodplain (Lopinot & Woods, 1993). This deforestation led to increased soil erosion in the uplands, which would have caused more “frequent, severe, and unpredictable local floods” (Lopinot & Woods, 1993, p. 230) in the floodplain. Lopinot and Woods argue that by the Moorehead Phase, more people were living and farming in the uplands; thus, increased land clearance related to these activities could have further exacerbated erosion in the uplands (Lopinot & Woods, 1993). Lopinot and Woods correlate the temporal changes in land use activities to the general trend of population decline starting in the late Stirling Phase and suggest the wood-overuse hypothesis as a potential explanation for the abandonment of Cahokia (Lopinot & Woods, 1993).

When this hypothesis was originally published, the only evidence for soil erosion during the Mississippian occupation was from the Goshen site buried in an alluvial fan in the intermediate zone between the upland and bottomland (Holley & Brown, 1989; Lopinot & Woods, 1993). The original report for the Goshen site was written prior to the publication of the wood-overuse hypothesis (Holley & Brown, 1989), and no investigations to evaluate depositional processes at the Goshen site were conducted after the hypothesis was proposed (Woods, 2004). Additionally, there is no direct evidence suggesting that regular increased flooding of Cahokia and Canteen Creeks did occur in the American Bottom floodplain at the end of Cahokia’s occupation (Lopinot & Woods, 1993; Woods, 2004). Increased habitation in the uplands near the end of Cahokia’s occupation is the only line of evidence used to support
increased frequency of flooding (Lopinot & Woods, 1993; Woods, 2004). Munoz et al. found evidence of a large flood from the Mississippi River occurring around AD 1200 (2015). Flooding of the American Bottom from the Mississippi River is typically driven by external weather events happening in the upper Mississippi River Valley or the Missouri River. Our article is a discussion of how localized human activities impacted the local hydrology of the American Bottom; since flood events from the Mississippi River are not primarily driven by the local hydrology of the American Bottom, the Munoz et al. dataset is outside the scope of our discussion (Munoz et al., 2015).

Results from investigations in the North Plaza, a mound group constructed at the lowest elevation in the central precinct of Cahokia and in the floodplain of Cahokia and Canteen creeks, indicates the floodplain was stable after the construction of the mounds which define the North Plaza. At Mound 5, the presence of fluvial deposits between an Ab horizon and mound construction sediments indicate that the human response to flooding was to invest labor into mound construction. The radiometric dating model of Mound 5 construction suggest that this human response to flooding happened early in Cahokia’s development as opposed to the end of Cahokia’s occupation (Figure 2.6). Associated stratigraphy in terrestrial sediment cores outside of the Mound 5 footprint indicates the landscape remained stable after the construction of Mound 5 until the industrial era. The presence of an Ab horizon underneath Mound 16 that remains stable until industrial development indicates landscape stability prior to the construction of Mound 16 until the establishment of coal mines in the uplands during the middle 1800s. The upper 10 cm of the Ab horizon contains coal clinker, suggesting that this stable ground surface was exposed when the Mall & Williams Mine opened in 1853, the first coal mine established within the Cahokia Creek watershed (Stehman, 1992). The Ab horizon is buried under 50 cm of
fluvial deposit, all which contains coal clinker material. Additionally, associated fluvial deposits in core samples near Mound 5 contain lenses of coal, suggesting the high sedimentation related to increased flooding rates in the Cahokia Creek floodplain are a result of historic coal mining activities in the uplands, which occurred after European settlement of the American Bottom. Because early miners would use creek drainages to find coal seams, increased sediment influx to the Canteen and Cahokia creeks was likely a result of both mining and deforestation related to land clearance in the industrial era (James, 2019; Munoz et al., 2014; Stehman, 1992).

The results of the North Plaza investigation at Mound 16 show a sedimentological signal of landscape stability after Mississippian mound construction until industrial development of the region. Floods along Cahokia and Canteen creeks do become more frequent after industrial development. While no unambiguous evidence for the pre-contact record was recovered during the Canteen Creek excavation, there is evidence for flooding after the mid-19th century with at least 0.65 m of observed flood deposits post-dating this period. If Stratum 4 dates to no earlier than the mid-1800s, then at least 1.1 m of alluvium is now observed for this area of the site that is temporally related to historic era industrialization.

The post-European settlement sedimentological signal for flooding is so strong that it has concealed the North Plaza landscape beneath ca. 1.5 m of fluvial sediment. Given that the first coal mine was established in 1853 and Cahokia and Canteen Creeks were canalized by 1921, sedimentation rates from industrial era flooding are calculated at 2.2 cm/yr. Using elevations from sediment cores and excavations of the Mississippian occupation Ab horizons, we constructed a 3D model of what the North Plaza landscape would have looked like during Mississippian occupation (Figure 2.14). Our results clearly show strong evidence of increased
fluvial sedimentation post-contact, while the pre-Columbian stratigraphy indicates low sediment accumulation and landscape stability.

A recent study on the impacts of pre- vs. post-colonial land use on floodplain sediment in temperate North America has called this phenomenon the “paradox of precolonial geomorphic stability” in which archaeological, ecological, and historical studies indicate a pre-Colombian humanized landscape, whereas floodplain stratigraphic studies indicate stable landscapes (James, 2019). This paradox can be resolved in accepting that ecological change does not inherently equal geomorphic change (James, 2011, 2019). By studying pollen and sedimentation rates from lacustrine cores from the Black Bottom floodplain in southern Illinois, Bird et al. demonstrate that sedimentation rates changed independently of pre-Columbian periods of land clearance, while increased sedimentation post-1820 is linked to industrial land clearance activities (Bird et al., 2019). A palynology study of lacustrine cores from the American Bottom floodplain, adjacent to Cahokia, shows the abundance of upland and floodplain arboreal species decreased prior to the emergence of Cahokia as a large center, while the abundance of arboreal species remained stable throughout Cahokia’s occupation (Munoz et al., 2014). This palynology study suggests that there were no significant land clearance events during Cahokia’s occupation (1050-1400 AD) (Munoz et al., 2014). Abundances of upland and floodplain arboreal species increased after Cahokia’s abandonment ca. AD 1400, and decreased post-1800s (Munoz et al., 2014). The decrease in upland oak and hickory trees is consistent with deforestation activities related to industrial development post-1800 (James, 2019; Munoz et al., 2014; Stehman, 1992). The lack of consistency between palynological and archaeological studies of wood consumption at Cahokia is puzzling; however, a recent re-evaluation of the wood required to construct the palisade fortification around Cahokia suggests previous estimates of wood exploitation are too high
(Krus, 2011). We reject the wood-overuse hypothesis as a potential contributor to the collapse of the Cahokia polity on the basis that human-caused ecological change did not lead to geomorphic change. Additionally, new palynological data and new evaluations of wood needed for construction suggest previous estimates of wood use by the people who built Cahokia were overestimated. Mt. Pleasant, an indigenous agronomist and soil scientist, argues that archaeologists tend to underestimate and/or ignore conservation strategies employed by North American pre-Colombian peoples in agricultural and arboricultural activities (Mt.Pleasant, 2015). Perhaps in attempt to push away from the pristine myth of the pre-Colombian landscape, we have ignored the capabilities of these people as purposeful conservationists of their landscape and resources.
Figure 2.14. 3D model of North Plaza landscape during Mississippian occupation, based on Ab elevations from excavations and sediment cores. a) 3D model of modern ground surface created in Golden Software’s Surfer 13 from Madison County LiDAR derivatives obtained from the Illinois Height Modernization Project web application viewer; b) Modeled Mississippian ground surface with an overlay of the modern ground surface in gray; c) Modeled Mississippian ground surface based on Ab elevations from excavations and sediment cores.
2.6 Final Thoughts: Why Old Theories of Collapse Persist through Time

Although many archaeologists have moved beyond classic narratives of ecocide made popular in the 1990s and early 2000s (Kull, 2000; McAnany & Yoffee, 2009), there are still major archaeological sites where the methods for understanding past environmental change have advanced, but the theory used to interpret these data has remained static (d’Alpoim Guedes et al., 2016). Using Cahokia as a case study, we have identified the following causes for the persistence of hypotheses through time:

1) **Lack of Data.** Lopinot and Woods (1993) made it clear in their chapter on the wood-overuse hypothesis that there was insufficient data to move their narrative from hypothesis to a probable cause for collapse at Cahokia. The only evidence that the erosional effects of deforestation occurred came from a buried Mississippian site in the intermediate zone between upland and bottomland (Holley & Brown, 1989) that was never evaluated for site-formation processes. Despite the lack of data to support this hypothesis, the ecocide narrative has been maintained in the literature as a potential contributor to Cahokia’s abandonment (Kelly, 2008; Mann, 2005; Woods, 2004). Since the publication of the wood-overuse hypothesis, no attempts have been made to evaluate if erosion in the uplands and/or increased flooding of local low-order streams did indeed occur during Cahokia’s occupation.

2) **Lack of environmental data taken from the archaeological record.** Many studies of environmental change rely on proxies taken from the general region of the society in
question. These regional datasets are unable to account for localized variability of change and also lack the direct link between environmental change and human activity.

3) **Lack of interdisciplinary training.** There is a shortage of archaeologists who are trained in interdisciplinary work, making it necessary for archaeologists to rely on collaborators for evaluations of site-formation and proxies of environmental change. These collaborators might not be accustomed to working at the hyperlocal scale of archaeology or sufficiently versed in current anthropological theory. Insights concerning the relationship between humans and the environment can be improved by ensuring the proposed dataset is at a scale capable of obtaining information that can address the more localized scale of interactions between humans and their environment.

Moving forward, we propose that to move past these older narratives of ecocide there needs to be increased engagement with obtaining both archaeological and environmental data to address these older theories, a need for researchers who are trained in interdisciplinary research, as well as increased support for long-term, interdisciplinary collaborations. The interdisciplinary field of geoarchaeology is especially equipped to help us move forward, as long as the members of the field remain engaged with developing anthropological theory.

2.7 References Cited


Chapter 3. Correlating Climate Change and Population Dynamics at Cahokia Mounds

3.1 Introduction

Although the global climate is becoming gradually warmer with each passing decade, the lived experience of modern climate change is one where weather patterns and seasonality are becoming increasingly severe and unpredictable (Chen et al. 2018). In the United States, climate models anticipate regional effects of climate change will vary greatly; some regions will become drier, while some places will become wetter, some areas will experience more severe weather patterns, while seasonality will decrease in other regions (Climate Science Special Report: Fourth National Climate Assessment, Volume I 2017). Now that climate scientists have constructed models of global and regional effects for various climate change scenarios, they have begun to develop downscaling methods for models of climate change effects to focus on local adaptation and resilience planning (Steinschneider et al. 2015). An understanding of the resilience or vulnerability of local environments to past regional climate change is essential to anticipate how local ecosystem services will be affected by future climate change. Many archaeologists argue that studying past human response to climate change can be helpful for informing future strategies to adapt to modern change (Anderson et al. 2013; Chase & Scarborough 2014; Van de Noort 2011; Pétursdóttir 2017; Jackson et al. 2017; Hudson et al. 2012; Rockman 2012; Sandweiss & Kelley 2012). However, very few archaeologists are working with datasets that provide the temporal and spatial resolution necessary to study the local manifestations and responses to past climate change (Naudinot and Kelly 2017; Coombes and Barber 2005; Contreras 2017).
Many archaeologists explain the correlation between climate change and population change as driven either by losses or gains in ecosystem services for human subsistence (Coombes & Barber 2005; Contreras 2017; Naudinot & Kelly 2017; Sandweiss & Kelley 2012). These climate change narratives often contain aspects of Malthusian environmental determinism, in which population grows because new environmental conditions can support a surplus of food resources, and declines when environmental conditions are no longer suitable for food production and/or procurement (Arponen et al. 2019; Wainwright & Ayala 2019; Davis 2019). These climate-driven collapse narratives are not particularly helpful in informing modern strategies to adapt to climate change because they rely on assumptions of universal environmental effects rather than evaluating the set of conditions in which these losses or gains occur (Naudinot & Kelly 2017; D. Contreras et al. 2018; Davis 2019; Sandweiss & Kelley 2012).

Using new, temporally resolved data from Cahokia Mounds, the largest pre-Columbian mound center in North America, I offer a case study that examines how the use of paleoenvironmental proxies obtained from within the archaeological record demonstrates that the assumption of universal environmental effects built into the climate-agriculture-population narrative does not hold true in all environments.

Cahokia Mounds, located in the American Bottom floodplain of the Mississippi River, is a significant archaeological site where archaeologists have explained shifting population dynamics as driven by environmental change (Kelly 2008; Tainter 2019). Cahokia Mounds is part of the Mississippian Cultural Tradition (circa AD 1050-1600), which is characterized as a set of material and ideological traits including intensive agriculture, construction of large earthen mounds with artificially leveled plazas, social and political ranking, fortified communities, and a religious ideology concerned with fertility and the ancestors (Knight 1986; Milner & Schroeder...
1999; Lewis et al. 1998; Pauketat & Emerson 1997). Cahokia Mounds emerged as a supraregional political/ritual center that was unique in overall size and population density for the Mississippian Cultural Tradition (Pauketat & Emerson 1997).

Cahokia emerged as a large nucleated center by circa AD 1000, with peak populations in the site core estimated up to 15,000 people (Pauketat & Lopinot 1997), and with regional populations estimated between 20,000 to 50,000 people (Milner 1986; Milner 1998). Around AD 1150 many residential structures and compounds in the downtown area of Cahokia were replaced with monumental architecture (Pauketat & Emerson 1991). This residential shift contributes to the decreasing population in the Cahokia center (to circa 7,000-8,000 people) (Pauketat & Lopinot 1997) but increasing population in the region (to as high as 50,000 people) (Milner 1986; Milner 1998). After AD 1150, populations decline both regionally and in the downtown area until the final abandonment of Cahokia by circa AD 1400 (Kelly 2008). Population decline at Cahokia fits into the pattern of regional depopulation of mound centers in the central Mississippi and lower Ohio river valleys known as the Vacant Quarter (Williams 1990). Mound centers throughout the Vacant Quarter region were abandoned by AD 1500, with Cahokia being one of the earliest large mound centers to be abandoned (Cobb & Butler 2002; Meeks & Anderson 2013). Population growth and decline in this region are temporally correlated with the Medieval Climate Anomaly (MCA) (circa AD 900-1000) and the Little Ice Age (LIA) (circa AD 1300-1800) (Baerreis & Bryson 1965; Anderson 2001). Because environmental conditions associated with both the MCA and LIA vary across the northern hemisphere, archaeologists working in the Eastern Woodlands cultural region have sought to understand the regional effects of these events at a scale more relevant to regional patterns of cultural change in eastern North America.
Evaluations of regional climate change during Mississippian occupation (AD 1050 – 1600) in eastern North America are extensive and diverse; with proxies ranging from pollen (Baerreis & Bryson 1965), dendrochronology (Benson et al. 2009; Meeks & Anderson 2013), lake core sedimentology (Munoz et al. 2015; White et al. 2019), and isotopes (Bird et al. 2017). Although each study uses high resolution environmental proxies, none of these proxies are taken from a spatial context that is directly associated with the archaeological record. All proxies yield data suggesting Cahokia and other Mississippian settlements in the central Mississippi and lower Ohio river valleys emerged during a regional climatic regime that was warm and wet. Benson et al. describe the period of rapid development and population growth at Cahokia (Lohmann phase, AD 1050-1100) as “one of the wettest 50-year periods during the last millennium” (Benson et al. 2009: 467), and many scholars argue that this warmer, wetter period was conducive to maize agriculture and created a food surplus that led to increased populations and cultural complexity (Baerreis & Bryson 1965; Hall 1980; Benson et al. 2009; Bird et al. 2017).

The beginnings of regional population decline correlate with frequent and persistent droughts in all proxies except for Munoz et al.’s lake core sedimentology proxy. Causal links between drought and depopulation have focused exclusively on reduced crop yields and food insecurity from persistent drought conditions (Meeks & Anderson 2013; Benson et al. 2009; Hall 1980; Griffin 1961; Bird et al. 2017). Munoz et al. was the only study to use environmental proxies nearby Cahokia Mounds (Munoz et al. 2015). By examining a core from Horseshoe Lake, located 5 km northwest of Cahokia Mounds, they determined that no large floods capable of depositing sediment in the lake occurred on the Mississippi River during the emergence and development of Cahokia (AD 600-1200) (Munoz et al. 2015). Sometime around AD 1200 an extremely large flood “with a magnitude to inundate croplands, food caches, and settlements
across most of the [American Bottom] floodplain” (Munoz et al. 2015:6323) occurred on the Mississippi River. These localized datasets complicate the black and white narrative of a wet to dry climatic transition at the end of Cahokia’s occupation; however they still rely on food insecurity to explain the relationship between a catastrophic flood and depopulation of the region. Additionally, other studies cast doubt on the validity of the large flood argument based on sediment sourcing (Bird et al. 2017), the interpretation of the sediment as flood deposits (Pompeani et al. 201), the lack of archaeological data to support the narrative of a large flood, and concerns about accuracy of age depth models (Baires et al. 2015). The following research presents new evidence for the local manifestation of regional climate change by providing a paleoenvironmental dataset of localized ecological change taken from within the archaeological record at Cahokia Mounds.

3.2 Materials and Methods

3.2.1 Archaeological and Modern Soil Samples

Stable carbon isotope values from soil organic matter (SOM) can be used to reveal the type of vegetation that dominated a landscape (Driese et al. 2004; Huang et al. 2001). Stable carbon isotopes from SOM with -16 to -10 ± 1.1 ‰ PDB indicates C₄ plants dominated the landscape, while -33 to -24 ± 2.3‰ PDB indicates that C₃ plants dominated the landscape (Ehleringer & Cerling 2002; Cerling et al. 1997). Based on previous observations on vegetation dynamics in mid-latitude floodplain environments (Johnson et al. 2007), C₃ sedges and forbs would have dominated the North Plaza landscape during wetter periods, while more drought tolerant tall grass prairie C₄ plants would have taken over the North Plaza during drier years. Because prairie environments often contain a mix of C₃ and C₄ plants (Still et al. 2003; Johnson
et al. 2007), I first need to establish a local baseline for stable carbon isotopes in different vegetative environments to compare to SOM from archaeological contexts.

Figure 3.1. Locations of soil organic matter samples collected from archaeological excavations, sediment cores, and modern baseline environments for stable carbon isotope analysis.

Modern baseline SOM from three different vegetative environments (prairie, wetland, and seasonal wetland) in the American Bottom were collected during September and October 2018. The native prairie was established in the early 1980s by the Cahokia Mounds State Historic Site and has not been disturbed by plowing since its establishment (J. Kelly, personal communication). Aerial imagery of the permanent wetland and seasonal wetland locations from 1941 to the present show no signs of plowing or agricultural activities. Distinctions between wetland and seasonal wetland were made based on a survey of aerial photography, where the
wetland location contains permanent standing water through time, and the seasonal wetland experiences periods of dryness. A 50m transect was set up at each sample location. General plant identification (Mohlenbrock 2013; Whitley et al.; Kirt 1995) and the top 5cm of soil were collected with a trowel at 10m increments along the 50m transect. All baseline sample locations were within 2km of the North Plaza archaeological excavations (Figure 3.1).

Soil organic matter from archaeological context was analyzed from Ab horizons found in archaeological excavations and sediment cores (Figure 3.1). Schematic soil profile drawings for the context of these samples can be found in Figure 3.2 and Figure 3.3.
Figure 3.2 Schematic drawing of Mound 5 excavation profile with results of stable carbon isotope analysis of soil organic matter collected from the Ab horizon below Mound 5 construction fills. Results described are the predicted groupings made by linear discriminant analysis. (W) stands for wetland and (P) stands for prairie.
Figure 3.3 Schematic drawing of Mound 16 excavation profile with results of stable carbon isotope analysis of soil organic matter collected from the Ab horizon below and adjacent to Mound 16 construction fills. Results described are the predictive groupings made by linear discriminant analysis. (W) stands for wetland and (SW) stands for seasonal wetland.
3.2.2 Stable Carbon Isotope Analysis

Analysis of baseline and archaeological SOM from modern topsoil and Ab horizons were carried out at Washington University in St Louis using a Flash 2000 elemental analyzer coupled to a Thermo Delta V Plus continuous-flow isotope ratio mass spectrometer. Oven dried (70 °C for 24 hours) samples were homogenized in a ceramic mortar and pestle, then sieved to a particle size of <250μm. Samples were treated for carbonate removal with 10ml of 2 M HCl until effervescence ceased (~24 h), rinsed 5 times with MQ water, dried in a 70 °C oven for 24 hours, re-homogenized with a mixing straw, and weighed into 5 × 9mm tin capsules. Results are expressed in δ¹³C as parts per thousand (‰) relative to Vienna Pee Dee Belemnite standards. The average analytical precision for C was 0.05 ‰ based on the standard deviation of 10 replicates of an in-house standard (Bob’s Red Mill millet flour) and 5 replicates of a second in-house standard (acetanilide). Weight percentage C are estimated based on standards of known elemental composition (acetanilide). To account for the atmospheric Suess effect in modern organic samples, where organisms are depleted in ¹³C compared to ancient samples as a result of the release of carbon from fossil fuels in the last two centuries, carbon isotopic values are adjusted by +1.5‰ (Bownes et al. 2017; Revelle & Suess 1957). All statistical analyses were conducted after modern baseline samples had been adjusted for the Suess effect. One-way analysis of variance (ANOVA) was used to identify significant difference in the means of carbon isotopic values between three difference modern environments. The Shapiro-Wilk test of normality and Levene’s Test for homogeneity of sample were conducted for the modern baseline dataset prior to ANOVA. The Tukey post-hoc test was used to determine which of the three environments contributed to the differences identified with ANOVA. A linear discriminant analysis (LDA) with one predictor variable (δ¹³C values) was used to build a model for
environmental group membership. The 16 modern baseline samples from three different environmental settings were used to create the discriminant analysis model, this model was then used to group the 24 archaeological samples with either prairie, seasonal wetland, or wetland baseline samples.

3.3 Results

3.3.1 Stable Carbon Isotopes

Images of the three different baseline environments can be found in Figure 3.4. The prairie environment contains a mix of C₃ and C₄ plants, while both the seasonal wetland and wetland vegetation is dominated by C₃ plants (Figure 3.4). The δ¹³C values from the prairie environment range from -19.18 to -17.22‰, with a mean of -18.36 ± .681‰ (Table 1). The δ¹³C values from the wetland environment range from -23.85 to -22.82‰, with a mean of -23.31 ± .400‰ (Table 3.1). The δ¹³C values from the seasonal wetland environment range from -26.99 to -25.16‰, with a mean of -26.16 ± .717‰ (Table 3.1). The Shapiro-Wilk test of normality shows that the modern baseline dataset has a normal distribution (W=.894, p=.063), each environmental group also has a normal distribution of δ¹³C values. Levene’s test for homogeneity of variance shows that the modern baseline dataset has equal variance between groups (W=.993, p=.397). One-way analysis of variance (ANOVA) shows significance differences in δ¹³C values between the three different environmental groups (F=175.681, p=.000). The Tukey post-hoc test shows that each environment group is significantly different from the other. For the linear discriminant analysis, one variable (δ¹³C) was used to discriminate between three groups (prairie, wetland, and seasonal wetland). The Box’s Test for Equivalence of Covariance Matrices shows covariance matrices are equal across groups (M=2.248, F=1.014, p=.364). The Wilks’ Lambda
test shows that the $\delta^{13}C$ have high discriminatory ability, and that the discriminant function does better than chance at separating the groups ($\Lambda=.036, p=.000$). In this model, there is only one independent variable used to predict grouping, so the Canonical Coefficient for $\delta^{13}C$ values is 1. The discriminant function correctly grouped 100% of cases in each environmental group.

Figure 3.4 Photos from the three environments sampled in American Bottom for stable carbon isotope modern baselines, A) depicts the wetland environment where duckweed, spurge, dock, rushes, and various algae were observed B) depicts the prairie environment where Big Bluestem, Indiangrass, Switchgrass, as well as sedges and vetches were observed C) depicts the seasonal wetland environment where cattails, cottonwood trees, dock, rushes, sedges, cane, and various mosses were observed.
Table 3.1 Results of stable carbon isotopic analysis for modern baselines.

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Context</th>
<th>Provenience</th>
<th>Depth below surface</th>
<th>δ¹³C permil (corrected for Suess)</th>
<th>Predicted Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kunneman Prairie</td>
<td>10m on Transect</td>
<td>0-5cm</td>
<td>-18.589</td>
<td>Prairie</td>
</tr>
<tr>
<td>2</td>
<td>Kunneman Prairie</td>
<td>20m on Transect</td>
<td>0-5cm</td>
<td>-19.186</td>
<td>Prairie</td>
</tr>
<tr>
<td>3</td>
<td>Kunneman Prairie</td>
<td>30m on Transect</td>
<td>0-5cm</td>
<td>-18.471</td>
<td>Prairie</td>
</tr>
<tr>
<td>4</td>
<td>Kunneman Prairie</td>
<td>50m on Transect</td>
<td>0-5cm</td>
<td>-17.222</td>
<td>Prairie</td>
</tr>
<tr>
<td>5</td>
<td>Wetland</td>
<td>0m on Transect</td>
<td>0-5cm</td>
<td>-23.853</td>
<td>Wetland</td>
</tr>
<tr>
<td>6</td>
<td>Wetland</td>
<td>10m on Transect</td>
<td>0-5cm</td>
<td>-23.679</td>
<td>Wetland</td>
</tr>
<tr>
<td>7</td>
<td>Wetland</td>
<td>20m on Transect</td>
<td>0-5cm</td>
<td>-22.828</td>
<td>Wetland</td>
</tr>
<tr>
<td>8</td>
<td>Wetland</td>
<td>30m on Transect</td>
<td>0-5cm</td>
<td>-23.138</td>
<td>Wetland</td>
</tr>
<tr>
<td>9</td>
<td>Wetland</td>
<td>40m on Transect</td>
<td>0-5cm</td>
<td>-22.993</td>
<td>Wetland</td>
</tr>
<tr>
<td>10</td>
<td>Wetland</td>
<td>50m on Transect</td>
<td>0-5cm</td>
<td>-23.399</td>
<td>Wetland</td>
</tr>
<tr>
<td>11</td>
<td>Seasonal Wetland</td>
<td>0m on Transect</td>
<td>0-5cm</td>
<td>-26.250</td>
<td>Seasonal Wetland</td>
</tr>
<tr>
<td>12</td>
<td>Seasonal Wetland</td>
<td>10m on Transect</td>
<td>0-5cm</td>
<td>-26.997</td>
<td>Seasonal Wetland</td>
</tr>
<tr>
<td>13</td>
<td>Seasonal Wetland</td>
<td>20m on Transect</td>
<td>0-5cm</td>
<td>-26.687</td>
<td>Seasonal Wetland</td>
</tr>
<tr>
<td>14</td>
<td>Seasonal Wetland</td>
<td>30m on Transect</td>
<td>0-5cm</td>
<td>-26.469</td>
<td>Seasonal Wetland</td>
</tr>
<tr>
<td>15</td>
<td>Seasonal Wetland</td>
<td>40m on Transect</td>
<td>0-5cm</td>
<td>-25.447</td>
<td>Seasonal Wetland</td>
</tr>
<tr>
<td>16</td>
<td>Seasonal Wetland</td>
<td>50m on Transect</td>
<td>0-5cm</td>
<td>-25.169</td>
<td>Seasonal Wetland</td>
</tr>
</tbody>
</table>

The groupings for archaeological samples in Table 3.2 were determined by the linear discriminant analysis. The 12 samples analyzed from Mound 16 ranged from -26.26 to -22.89‰; all samples from Mound 16 group with wetland or seasonal wetland baselines. Five samples from Mound 16 group with wetland baselines, and the remaining seven samples group with seasonal wetland baselines. Four of the samples which group with wetland baselines occupy the lowest and highest elevations sampled at Mound 16, the fifth wetland is located in the middle of sample profile (Figure 3.3). The three samples analyzed from Mound 5 range from -22.38 to -19.37‰. The two lowest samples group with prairie baselines (-19.37‰ and -20.65‰), while the uppermost sample groups with wetland baselines (-22.38‰). This shift from prairie to wetland is also observed in a core south of Mound 5, where the lower elevation Ab (sample 39) groups with prairie baselines (-20.76‰); while the higher elevation Ab (sample 40) groups with wetland.
baselines (-23.97‰). The remaining samples from cores around Mound 5 group with wetland baselines; excluding sample 35, which groups with season wetland. Samples from underneath Mound 14 and within the North Plaza perimeter all group with wetland baselines. The samples from outside of the North Plaza perimeter group with seasonal wetland baselines.

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Context</th>
<th>Provenience</th>
<th>Depth below surface</th>
<th>δ¹³C permil</th>
<th>Predicted Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>Archaeological Excavation</td>
<td>Mound 16</td>
<td>90-95cm</td>
<td>-22.897</td>
<td>Wetland</td>
</tr>
<tr>
<td>18</td>
<td>Archaeological Excavation</td>
<td>Mound 16</td>
<td>95-100cm</td>
<td>-24.633</td>
<td>Wetland</td>
</tr>
<tr>
<td>19</td>
<td>Archaeological Excavation</td>
<td>Mound 16</td>
<td>100-105cm</td>
<td>-24.989</td>
<td>Seasonal Wetland</td>
</tr>
<tr>
<td>20</td>
<td>Archaeological Excavation</td>
<td>Mound 16</td>
<td>105-110cm</td>
<td>-25.307</td>
<td>Seasonal Wetland</td>
</tr>
<tr>
<td>21</td>
<td>Archaeological Excavation</td>
<td>Mound 16</td>
<td>110-115cm</td>
<td>-24.582</td>
<td>Wetland</td>
</tr>
<tr>
<td>22</td>
<td>Archaeological Excavation</td>
<td>Mound 16</td>
<td>115-120cm</td>
<td>-25.516</td>
<td>Seasonal Wetland</td>
</tr>
<tr>
<td>23</td>
<td>Archaeological Excavation</td>
<td>Mound 16</td>
<td>120-125cm</td>
<td>-25.463</td>
<td>Seasonal Wetland</td>
</tr>
<tr>
<td>24</td>
<td>Archaeological Excavation</td>
<td>Mound 16</td>
<td>125-130cm</td>
<td>-26.266</td>
<td>Seasonal Wetland</td>
</tr>
<tr>
<td>25</td>
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<td>Mound 16</td>
<td>130-135cm</td>
<td>-24.788</td>
<td>Seasonal Wetland</td>
</tr>
<tr>
<td>26</td>
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<td>Mound 16</td>
<td>125-130cm</td>
<td>-24.783</td>
<td>Seasonal Wetland</td>
</tr>
<tr>
<td>27</td>
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<td>130-135cm</td>
<td>-24.347</td>
<td>Wetland</td>
</tr>
<tr>
<td>28</td>
<td>Archaeological Excavation</td>
<td>Mound 16</td>
<td>135-140cm</td>
<td>-24.699</td>
<td>Wetland</td>
</tr>
<tr>
<td>29</td>
<td>Archaeological Excavation</td>
<td>Mound 5</td>
<td>246-253cm</td>
<td>-19.378</td>
<td>Prairie</td>
</tr>
<tr>
<td>30</td>
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<td>240-247cm</td>
<td>-20.654</td>
<td>Prairie</td>
</tr>
<tr>
<td>31</td>
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<td>Mound 5</td>
<td>239-244cm</td>
<td>-22.381</td>
<td>Wetland</td>
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<tr>
<td>32</td>
<td>Sediment Core Outside Plaza South of Mound 14</td>
<td>70-75cm</td>
<td>-25.319</td>
<td>Seasonal Wetland</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Sediment Core South of Mound 14</td>
<td>70-75cm</td>
<td>-24.68</td>
<td>Wetland</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Sediment Core South of Mound 14</td>
<td>100-105cm</td>
<td>-24.211</td>
<td>Wetland</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Sediment Core West of Mound 5</td>
<td>115-120cm</td>
<td>-25.613</td>
<td>Seasonal Wetland</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>Sediment Core Mound 14</td>
<td>180-185cm</td>
<td>-22.435</td>
<td>Wetland</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>Sediment Core West of Mound 5</td>
<td>95-100cm</td>
<td>-22.896</td>
<td>Wetland</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Sediment Core South of Mound 5</td>
<td>130-135cm</td>
<td>-21.082</td>
<td>Wetland</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>Sediment Core South of Mound 5²</td>
<td>130-135cm</td>
<td>-20.766</td>
<td>Prairie</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Sediment Core South of Mound 5²</td>
<td>110-115cm</td>
<td>-23.975</td>
<td>Wetland</td>
<td></td>
</tr>
</tbody>
</table>

¹ Indicated samples came from the same core south of Mound 14.
² Indicates samples came from the same core south of Mound 5.
3.4 Discussion

Our localized baselines of modern prairie environments show a mean $\delta^{13}C$ value of $-18.36 \pm .681\%o$, which is lower (more negative) than the values for a $C_4$ plant dominated landscape. It is not unexpected to have a prairie outside the range of a $C_4$ plant dominated landscape, as $C_3$ ground cover plants (sedges and vetches) were also observed within the modern $C_4$ tallgrass prairie plants. With drier conditions, we do not expect all $C_3$ plants to disappear from the environment (Johnson et al. 2007; Still et al. 2003), so our $\delta^{13}C$ baselines of a modern native prairie in the American Bottom are likely a more accurate comparison of vegetative change than a landscape completely dominated by $C_4$ plants. Both the seasonal wetland and wetland baselines fall within a range expected for a $C_3$ dominated landscape. The statistically significant difference in $\delta^{13}C$ values between these three environments indicates they are good comparative baselines of vegetation cover for the archaeological samples (Figure 3.5).

The majority (87%) of the 24 archaeological samples analyzed for stable carbon isotopes group with either seasonal wetland (n=9) or wetland (n=12) baselines. Only three archaeological samples group as prairie, and all three of these samples are associated with Mound 5. The Ab horizon underneath Mound 5 contains samples that group with both wetland and prairie baselines, with the wetland samples at a higher elevation than the prairie samples. Between the Ab horizon and Mound 5 construction fills is fluvial sediment (Figure 3.2), suggesting that the evolution from prairie to wetland was a precursor to the period of active fluvial sedimentation prior to the construction of Mound 5. Outside of the Mound 5 footprint, the highest elevation Ab collected from sediment cores groups with seasonal wetland baselines and is subsequently buried by 77 cm of historic fluvial deposits, indicating this area never returned to its prairie-like environment (Table 3.1). Because a sparse artifact scatter was found at the contact of the Ab
horizon and overlying fluvial sediment, it is possible that the higher (less negative) δ^{13}C values observed for Ab that groups with prairie baselines can be attributed to maize agriculture practiced by the pre-contact inhabitants (Tankersley et al. 2019). However, there is no independent evidence to suggest that maize agriculture took place in the specific context of the Ab horizon below Mound 5.

**Figure 3.5** Differences between Stable carbon isotope values from three modern baseline environment groups of prairie, wetland, and season wetland are statistically significant, making these data a good comparison for archaeological samples.
Whether or not the transition to more negative δ¹³C values in the Ab horizon underneath Mound 5 is caused by vegetative change or a shift away from maize agriculture in this specific context, the stratigraphic association of a buried soil underlying a fluvial deposit (Figure 3.2) still indicates a shift from a stable landscape to one of active sedimentation prior to the construction of Mound 5. A Bayesian model of Mound 5 construction was created using five samples collected from within Mound 5 and sub-mound contexts. Both the samples from the Ab horizon and the fluvial sediment serve as terminus post quem for Mound 5 construction (Figure 3.6). The latest end boundary for the start of mound construction likely occurred after circa cal AD 1050 (76.3% probability). Material collected from the interior of Mound 5 provide a terminus ante quem for the deposition of the fluvial sediment (Figure 3.6). The earliest start boundary for the mound construction phase is circa cal AD 1030 (95.4% probability). Taken together, it is likely that the shift from prairie to wetland below Mound 5 occurred at the beginning of Cahokia’s aggregation in the early half of the eleventh century.

In the Ab horizon underneath Mound 16, the two lowest elevation samples group with wetland baselines, while the highest elevation sample groups with seasonal wetland baselines. There are preserved mudcracks at the contact of the Ab horizon and Mound 16 construction fills. The stratigraphic evolution from wetland to seasonal wetland and the presence of preserved mudcracks below Mound 16 construction materials suggests that the people who built Mound 16 took advantage of seasonal dryness to construct the mound. The δ¹³C values from the Ab horizon outside the Mound 16 footprint suggest that the area around Mound 16 remained a seasonal wetland after mound construction, with at least one period when the area was more like a wetland. The area became more like a wetland around European settlement and was subsequently buried by fluvial sediment (Figure 3.3). All samples from underneath Mound 14

88
and within the North Plaza perimeter group with wetland baselines. These data suggest that the North Plaza was a wetland prior to mound construction and remained wet with intermittent seasonal dryness until the modern era. There is no evidence to suggest the vegetation in and around the North Plaza transitioned into a prairie because of multi-decadal droughts observed in the mid-continent region at the end of the thirteenth century (Benson et al. 2009; Benson et al. 2007).

Figure 3.6 Modeled dates for Mound 5 construction sequence.
The isotopic dataset demonstrates that low elevation areas in the floodplain, like the Edelhardt meander scar, were ecologically resilient to regional trends of sustained drought. It is important to remember that the typical climate-agriculture-population narrative is built on the assumption that regional trends of drought have universal effects across different environments in the region. In these narratives, little to no consideration is given to how regional climate change will affect local environments (e.g. uplands vs. floodplains) or microlocal environments (e.g. ridges vs. swales) differently. In this paper I have used a localized dataset taken from within the archaeological record at Cahokia Mounds to demonstrate that the assumed effects of regional trends of drought did not occur in the micro-local environment of the Edelhardt meander scar, demonstrating that regional climate change does not universally result in the loss of ecosystem services.

In the specific case of Cahokia, recognizing that micro-environments in the floodplain were resilient to drought is not enough to push back against previous climate change collapse narratives because researchers have also relied on the premise that floodplain agriculture alone was not enough to support the large populations of Cahokia (Benson et al. 2009; Bird et al. 2017). However, Jane Mt. Pleasant and Gayle Fritz have recently demonstrated that the American Bottom floodplain contained enough highly productive soil on ridges, terraces, and fans for pre-Columbian people to sustain their large population (Mt.Pleasant 2015; Fritz 2019). Given the high productivity of soils in the region, Mt. Pleasant specifically states that the people of Cahokia were unlikely to experience food insecurity, even during periods of drought:

It is hard to imagine a scenario in which Cahokia would suffer from food shortages given the enormous quantities of highly fertile land and the productive capacity of maize. Even if crops suffered from drought or other catastrophic events, maize can be stored safely for years. Cahokia's leaders, with their complex and hierarchical governance structures,
would surely have stored excess grain for less agriculturally productive years. (Mt. Pleasant 2015: 407)

Given Mt Pleasant and Fritz’s recent work demonstrating the agricultural productivity of the floodplain and the new dataset from this paper demonstrating the resilience of particular microenvironments to drought, it seems that the American Bottom floodplain would have been a suitable environment to sustain the large populations of Cahokia with agriculture during regional episodes of drought.

Despite the American Bottom floodplain being a fine place to sustain the population of Cahokia during periods of drought at the end of the thirtieth century, people still gradually left Cahokia. Although people abandoned regions in the central Mississippi and lower Ohio river valleys during periods of regional drought, people remained in the upper Ohio and lower Mississippi river valley region throughout drought conditions. Bird et al. cite “local climatic conditions . . . smaller population size that could be supported on floodplain agriculture alone . . . [and/or] local socio-political autonomy that was more resilient and responsive to drought-induced resource stress” (Bird et al 2017: 9), as potential reasons why Fort Ancient populations in the upper Ohio River Valley persisted while Mississippian populations in the central Mississippi and lower Ohio river valleys declined. I have demonstrated that local environments in the floodplain where Cahokia was constructed were unlikely to be significantly affected by regional trends of drought. Mt. Pleasant and Fritz have shown that agriculture in the American Bottom floodplain around Cahokia were capable of supporting Cahokia’s large population. Two of the three reasons cited for why Fort Ancient populations persisted through periods of drought also hold true for the American Bottom floodplain, yet the American Bottom floodplain populations still decreased during periods of regional drought. The only remaining difference between Fort Ancient populations, which persisted through drought, and populations in the
American Bottom, which declined, is socio-political autonomy. Fort Ancient communities became less sedentary and lived in smaller communities with greater buffer zones between villages after *circa* AD 1500 (Bird et al. 2017; Drooker & Cowan 2001). In comparison, Cahokia maintained its centralized hierarchical structure after AD 1200, despite gradual population decline. With a gradually decreasing population, individuals who remained at Cahokia sustained an increasingly higher per capita labor burden to support the complex hierarchical structure and public works at Cahokia (Tainter 2019). According to Tainter (2019), the cost of maintaining the centralized structure of Cahokia was too great a burden for the decreasing population. This comparison between Fort Ancient cultures and Mississippian cultures that both experienced regional trends of sustained droughts suggests that cultural resilience is primarily driven by social factors rather than environmental factors. It is rare to find examples where environmental effects are the sole cause of societal collapse, it is often the socio-political structure of that society that determines its resilience to various environmental stressors.

This article has demonstrated that localized paleoenvironmental datasets taken from within the archaeological record can provide evidence at the scale necessary to test hypothesis about the correlation between known climate change and known cultural change. Counter to the narratives created with regional scale data, the localized datasets suggest that people could have sustained their population size with floodplain agriculture, despite regional trends of drought. This is an important contribution to the climate change driven collapse narratives because it demonstrates that people still abandon areas even when the environment is not a limiting factor. This conclusion demonstrates the value of localized datasets that provide environmental proxies with direct spatial and temporal association to human actions and response. Previous researchers have done an excellent job in obtaining regional datasets that demonstrates the variability of
environmental effects from hemispheric and global climate change. To advance our understanding of the nuances and local manifestations of these environmental effects that would have required localized adaptation strategies, future work needs to be at temporal and spatial scales directly linked to the archaeological record to establish the links between climate change and human response. We know from our own experience that the effects of climate change are, in most instances, subtle and complex. If archaeology is going to help inform best strategies to future adaptations to climate change, we must first obtain datasets that elucidate the past complexities of climate change.

3.5 References Cited


Chapter 4. The Exceptional Setting of the North Plaza, Cahokia Mounds, Illinois

4.1 Introduction

Plazas are defined by open space surrounded by or adjacent to structures. Functionally, plazas serve as public space for communal gatherings and ceremonial activities (Lewis and Stout 1998). The incorporation of plazas into community organization of Eastern Woodland archaeological sites can be traced back to the Archaic period (Kassabaum 2019; Cobb and Butler 2017). The oval-shaped open space surrounded by 11 earthen mounds at the Middle Archaic site of Watson Brake (ca. BC 3500) is one of the earliest examples of plaza incorporation into site design (Saunders et al. 2005) in the Eastern Woodlands. By the Mississippian period (ca. AD 1000 – 1500) plazas are almost ubiquitous in southeastern community design (Cobb and Butler 2017). These Mississippian architectural features exhibit degrees of conformity in their rectangular shape, location in the center of a settlement, containment by earthen mound(s) and/or public buildings, and functional use as an arena for public activities (Cobb and Butler 2017).

Plaza space often yields few archaeological materials. Because of the lack of material culture found in plaza space, plazas have been historically ignored by archaeologists in favor of investigations into domestic-use areas and earthworks (Kidder 2004; Holley et al. 1993). The construction of earthworks and mounds has long been associated with historical myths, and scholars argue that the process of mound building is a symbolic and physical expression of indigenous worldview (Knight 1989; Kidder and Sherwood 2016). The more recent work focusing specifically on plaza space emphasize that it is the plaza ground itself, not the just the constraining architectural components, that is central to community design and layout (Kidder 2004; Cobb and Butler 2017; Holley et al. 1993). These works emphasize that plazas are not just
passive space defined by other types of architecture, but that the process of constructing and maintaining a plaza were just as symbolic of indigenous worldview as mound building (Kidder 2004; Cobb and Butler 2017; Holley et al. 1993; Lewis and Stout 1998). Using historic and mythological discussions of ritual activities associated with maintaining ceremonial grounds, Knight argues that mounds may have first developed as a consequence of sweeping and purification of the empty ceremonial ground, where the removal of earth and debris from the ceremonial space resulted in ridges and mounds adjacent to the space (Knight 1989). Knight’s argument demonstrates the symbolic and physical connections between mounds and plazas; and based on these connections, others have argued that mound and plaza groups must be analyzed as one coherent architectural form rather than as two different components (Kidder 2004).

The community layout of Cahokia Mounds, the largest Mississippian mound complex in the Eastern Woodlands, is composed of mound and plaza groups (Kelly 1996; Lewis and Stout 1998). The central precinct of Cahokia (Figure 4.1) is arranged as a cosomogram, with Monks Mound as the central focal point and four mound and plaza groups in each of the cardinal directions (Kelly 1996; Kelly and Brown 2014). Although mound and plaza groups are ubiquitous in Mississippian community design, the creation of multiple mound and plaza groups for one community is unique to Cahokia Mounds (Byers 2013; Iseminger 2010). At the center of the community plan is Monks Mound, the largest pre-Columbian earthwork in the Americas. Monks Mound is the most obvious feature on the landscape, covering 7.2 hectares and standing roughly 30 meters in height (Fowler 1997). To the south of Monks Mound is the Grand Plaza. The Grand Plaza covers approximately 16 hectares and is delimited by mounds to the east, south, and west (Fowler 1997).
Figure 4.1 The central precinct of Cahokia Mounds is arranged as a cosmogram, with Monks Mound in the center and four mound and plaza groups in each of the cardinal directions.
Investigations into the Grand Plaza show that the natural ridge and swale topography was leveled and filled to create the Grand Plaza surface by the Lohmann Phase (AD 1050-1100) (Holley et al. 1993; Dalan et al. 2003). The six hectares of the East Plaza are flanked by Monks Mound to the west, and various other mounds to the north, south, and east. The defining feature of the East Plaza space is the lack of Lohmann Phase materials (Kelly 1996). The West Plaza is bounded by mounds to the east, south, and west and by the Edelhardt meander scar to the north. This space was recognized as a plaza by the lack of residential occupation in the Lohmann Phase (Wittry and Vogel 1962). The North Plaza is a rectangular-shaped open area bounded by four mounds on each of the cardinal sides (Figure 4.2) (Kelly 1996). The North Plaza is unusual in its low-elevation placement in the Edelhardt meander scar and the floodplain of Cahokia and Canteen Creeks (Fowler 1997). The mounds which constrain the North Plaza are sometimes referred to as the Creek Bottom Group because of their location in the low-elevation floodplain. Although no previous investigations have yielded chronological data on the North Plaza, Kelly hypothesized that this plaza was established during the Lohmann (AD 1050-1100) or Stirling Phases (AD 1100-1200) when contemporary settlements existed at lower elevations in the American Bottom (Kelly 1996). Despite the lack of previous research on the mounds or open space thought to define the North Plaza, it has been accepted as a mound and plaza group because it is an empty, rectangular-shaped space clearly defined by mounds in each of the cardinal directions (Figure 4.2).

The North Plaza has puzzled archaeologists because of its unique location in the wetlands of an abandoned Mississippi River meander scar that serves as the floodplain of Cahokia and Canteen Creeks (Fowler 1997; Iseminger 2010; Byers 2006). Traditional conceptions view plazas as a dry, flat, open, public space for daily community activities and ceremonial events.
The construction of a mound and plaza group in a wetland that is, at least today, regularly inundated with water is unprecedented in the archaeological record of the Eastern Woodlands and contradicts the traditional archaeological conception of plaza space. Previous scholars dealt with the conundrum of the North Plaza by hypothesizing that the area was drier during the construction and occupation of this space than it is in modern times (Fowler 1997:70). However, an alternative explanation is that the North Plaza does not fit the typically archaeological conceptions of plazas, and that the North Plaza is a unique feature that was constructed to be inundated with water. If the North Plaza was constructed as some type of water feature, then it is an anomaly that requires archaeologists to re-envision what a plaza is and/or how plazas are used.

In this article, I will present localized paleoenvironmental data from the North Plaza to determine what environmental conditions were like during the construction and utilization of this space. After I determine if environmental conditions were wet like modern times or drier than modern times, I will discuss the implications of the North Plaza anomaly on archaeological conceptions of mound and plaza groups in the Mississippian world.
Figure 4.2 The North Plaza is accepted as a mound and plaza groups because it is an empty, rectangular-shaped space defined by mounds in each of the cardinal directions.

### 4.2 Environmental Setting

Cahokia Mounds is located in the American Bottom, a broad expanse of floodplain on the Illinois side of the Mississippi River that was created at the end of the Pleistocene by the scouring action of postglacial meltwaters flooding at the confluence of the Missouri and Mississippi rivers (Hajic 1993; Iseminger 1997). The American Bottom floodplain is bounded by sedimentary bluffs on its eastern border, creating a distinct 160km north-south orientated floodplain (Hajic, 1993). The headwaters of low order tributaries of the Mississippi River are in these bluffs, creating alluvial fans at the contact between bottomland and upland. The dramatic gradient change causes high sedimentation and drainage issues when the local tributaries flow into the less than 1% gradient of the American Bottom floodplain (Helm 1905). Standing water
was a major issue for the post-contact settlers of this area; during his visit to the American Bottom in 1842, Charles Dickens remarked that “few people can exist in such a deadly atmosphere … [where] everywhere was stagnant, slimy, rotten, filthy water” (Dickens 1972:221-222). Despite the recent creation of canals and levees to control water, the American Bottom still faces issues of related to standing water today (Colten 1990). Modernly, the North Plaza is typically driest in the in the winter season. During the spring and summer, heavy rain fall events can inundate the North Plaza (Figure 4.3). The North Plaza is most likely to be dry in the winter season.

Figure 4.3 Wetland images of the North Plaza and surrounding Edelhardt meander scar. A) shows Mound 14 inundated by water after a one-day rainfall event in March 2018; B) shows a wetland environment in the Edelhardt meander scar, located 2km from the North Plaza; C) shows flooding that occurred to the south of Mound 16 after a heavy rain event in August 2018.
Based on data from the 1800s General Land Office (GLO) surveys, Milner identified areas in and around Cahokia that were regularly inundated with water (Milner 1998:Figure 2.16). Within the central precinct of Cahokia, the North Plaza is the only mound and plaza group located in an area classified as “minimum wetlands,” meaning that this space was considered to be permanently inundated with water during the early 1800s (Milner 1998:Figure 2.16). To add to the expected wetness of the North Plaza, geoarchaeological research has revealed that the mounds that define the North Plaza were built on a landscape almost two meters lower than the modern ground surface (see Chapter 2 of this dissertation), making this area even more likely to have been seasonally if not permanently inundated with water during Cahokia’s occupation. Unless environmental conditions were much drier than previously recorded, the North Plaza would only have been available for public gatherings during the driest years.

4.3 Methods

4.3.1 Field Methods

The North Plaza is bounded by five mounds; three smaller oval mounds on the north, south, and west (Mounds 14, 15, and 16) and one large rectangular platform mound on the east (Mound 5) (Fowler 1997; Kelly and Brown 2014) (Figure 2). Archaeological excavations were conducted on the western side of Mound 5 and the eastern side of Mound 16 (Figure 4.4). The Mound 5 excavations consisted of a 2x5 meter trench to a maximum depth of 245 centimeters below ground surface (cmbs), and a 1x2 meter trench to a maximum depth of 200 cmbs. The Mound 16 excavations consisted of a 1x4 meter trench to a maximum depth of 160 cmbs, and a 1x2 meter trench to a maximum depth of 160 cmbs. Soil was extracted with shovel and trowel in arbitrary levels. Every fourth bucket of soil from the plow zone was screened through 12.7 mm
mesh. Outside the plow zone, all soil was screened through 12.7 mm mesh and soil from features was screened through 6.35 mm mesh. Profile drawings were made for all excavations, and three-dimensional photographic models of the excavation were created in Agisoft Photoscan. Basic stratigraphy data, including Munsell color, soil texture, soil structure, soil horization, redoximorphic features, and bioturbation were recorded for all stratigraphic features following standard descriptions (Birkeland 1999; Soil Survey Staff 1999; Vasilas et al. 2010; Vogel 2002). Block micromorphology samples were collected from excavation profiles using plastic electric conduit boxes continuously up-column. Bulk soil samples of 50 g were collected from each soil or stratigraphic horizon for particle size and stable carbon isotope analyses. Flotation samples were collected at each 20 cm level and from features for radiocarbon dating.

Figure 4.4 Location of archaeological excavations, sediment cores, and modern baseline environments for stable carbon isotope analysis.
In addition to archaeological excavations, 43 continuous sediment cores were collected to a maximum depth of 3.6 meters with a GeoProbe 54TRs mounted on a tractor with a DT-21 sampling device. The sample tube is 3 cm in diameter. Four sampling transects were created, two placed around Mound 14 and two placed around Mound 5. At Mound 5, a 35 m transect on the N550 line was established with core locations spaced at 5 m and 10 m intervals and a 25 m transect on the E355 line spaced at 5 m and 10 m intervals. At Mound 14, a 215 m transect on the N725 line was spaced at 5 m and 10 m intervals and an 85 m transect on the E120 line was spaced at 5 m and 10 m intervals. Additionally, a 20 m transect was placed “outside” of the North Plaza on gridline N735 at 10 m intervals.

Modern baseline soil organic matter (SOM) from three different vegetative environments (prairie, wetland, and seasonal wetland) in the American Bottom were collected during September and October 2018 (Figure 4.5). All baseline sample locations were within 2 km of the North Plaza archaeological excavations (Figure 4.4). The native prairie was established on formerly plowed farmland in the early 1980s by the Cahokia Mounds State Historic Site and has not been disturbed by plowing since its establishment (J. Kelly, personal communication). Aerial imagery of the permanent wetland and seasonal wetland locations from 1941 to the present show no signs of plowing or agricultural activities. Distinctions between wetland and seasonal wetland were made based on a survey of aerial photography, where the wetland location contains permanent standing through time, and the seasonal wetland experiences periods of dryness. A 50 m transect was set up at each sample location. General plant identification (Mohlenbrock 2013; Whitley et al 1990.; Kirt 1995) and the top 5 cm of soil were collected at 10 m increments along the transect.
4.3.2 Laboratory Methods

Only two sediment cores were cut and described in the field; the rest of the cores were transported to the Paleoclimatology and Sedimentology Laboratory at Indiana University-Purdue University Indianapolis where they were cut, cleaned, imaged, analyzed for magnetic susceptibility, described, and sampled for particle size analysis and stable carbon isotopes at 10 cm intervals. High resolution imagery and magnetic susceptibility at 1 cm intervals were collected with a GeoTek Multi-Sensor Core Logger. The N725 transect was archived at the Geoarchaeology Laboratory at Washington University in St. Louis.

Figure 4.5 Photos of modern baseline environments where soil organic matter (SOM) was collected for stable carbon isotope analysis, A) depicts the wetland environment, B) depicts the prairie environment, and C) depicts the seasonal wetland environment.
Block micromorphology samples were sent to Applied Petrographic Services, Inc. (Latrobe, PA, USA) where they were impregnated with epoxy, trimmed to size, and then mounted on 50x75 mm glass slides. All samples were ground to a uniform thickness of 30 µm. Thin sections were described and analyzed using standard micromorphological nomenclature (Bullock et al. 1985; FitzPatrick 1993; Stoops 2003). Analysis was conducted with a under plane-polarized (PPL) and cross-polarized (XPL) light at 8-15x magnification with a binocular microscope and 15-200x magnification with a petrographic microscope.

Ceramic rim sherds from Mound 5 and Mound 16 excavations were inventoried as to vessel form, temper, surface treatment, as well as rim modification and lip treatment. The basis for ceramic descriptive categories follow conventions established by Vogel (1975). Vessel metrics taken for all ceramic rim sherds include orifice diameter, percentage of orifice, rim length, wall thickness, and rim weight. Orifice diameters could not be reliably calculated if less than 5% of the orifice was present. Ceramic rim analysis was on conducted on rims less than 1 cm in diameter.

Analysis of baseline and archaeological SOM from modern topsoil and Ab horizons were carried out at Washington University in St Louis using a Flash 2000 elemental analyzer coupled to a Thermo Delta V Plus continuous-flow isotope ratio mass spectrometer. Oven dried (70 °C for 24 hours) samples were homogenized in a ceramic mortar and pestle, then sieved to a particle size of <250 μm. Samples were treated for carbonate removal with 10 ml of 2 M HCl until effervescence ceased (~24 h), rinsed 5 times with MQ water, dried in a 70 °C oven for 24 hours, re-homogenized with a mixing straw, and weighed into 5 × 9-mm tin capsules. Results are expressed in δ¹³C as parts per thousand (‰) relative to Vienna Pee Dee Belemnite standards. The average analytical precision for C was 0.05 ‰ based on the standard deviation of 10
replicates of an in-house standard (Bob’s Red Mill millet flour) and 5 replicates of a second in-house standard (acetanilide). Weight percentage C are estimated based on standards of known elemental composition (acetanilide). To account for the atmospheric Suess effect in modern organic samples, where organisms are depleted in $^{13}$C compared to ancient samples as a result of the release of carbon from fossil fuels in the last two centuries, carbon isotopic values are adjusted by $+1.5\%$ (Bownes et al. 2017; Revelle and Suess 1957). All statistical analyses were conducted after modern baseline samples had been adjusted for the Suess effect. One-way analysis of variance (ANOVA) was used to identify significant difference in the means of carbon isotopic values between three difference modern environments. The Shapiro-Wilk test of normality and Levene’s Test for homogeneity of sample were conducted for the modern baseline dataset prior to ANOVA. The Tukey post-hoc test was used to determine which of the three environments contributed to the differences identified with ANOVA. A linear discriminate analysis (LDA) with one predictor variable ($\delta^{13}$C values) was used to build a model for environmental group membership. The 16 modern baseline samples from three different environmental settings were used to create the discriminant analysis model, this model was then used to group the 24 archaeological samples with either prairie, seasonal wetland, or wetland baselines.

4.4 Results

4.4.1 Excavation and Sediment Core Stratigraphy

Archaeological excavations at Mound 5 reveal that clay loam basketload construction fill was placed directly on top of fluvial sediment (Figure 4.6). The contact with mound construction materials and the underlying fluvial sediment is described as abrupt and smooth in the field.
Micromorphology of the contact between mound construction material and fluvial sediment shows bioturbation between the two strata, but no evidence of incipient soil formation (Figure 4.7d). Micromorphology of the fluvial deposits shows graded beds of fine sand, silt, and clay. Three different depositional micro-facies can be observed in one slide, suggesting that this fluvial deposit represents multiple events rather than one single deposition (Figure 4.7b). There is also a 3 mm incipient A horizon within the fluvial deposits, suggesting a temporary hiatus in fluvial deposition (Figure 4.7c). Below the fluvial deposits is an Ab horizon (Figure 4.6). Preserved mudcracks that were infilled with sandy material were found in the plan-view contact between fluvial sediment and the Ab horizon (Figure 4.8). A sparse artifact scatter of bone and ceramic was also found at this contact (Figure 4.8). Micromorphology of the contact between the Ab and fluvial deposits shows micro-Ab rip-up clasts within the fluvial deposit, which also suggest that the sand was a natural fluvial deposit (Figure 4.7a). Mound 5 excavations did not extend beyond the Mound 5 footprint, but four sediment cores to the south of Mound 5 and five sediment cores to the west of Mound 5 extend our stratigraphic relations beyond archaeological excavations. The stratigraphic sequence of mound fill-fluvial sediment-Ab horizon is continuous in the sediment cores to the south of Mound 5, but is not observed in the sediment cores to the west of Mound 5.

Archaeological excavations at Mound 16 reveal homogenous loamy mound fills directly overlaying a discontinuous Ab horizon (Figure 4.9). Preserved mudcracks were observed in plan-view at the contact between mound fill and the Ab horizon (Figure 4.8). The Ab is discontinuous underneath Mound 16, suggesting that there was some degree of soil removal prior to the construction of Mound 16 (Figure 4.9). Geological excavations outside the Mound 16 footprint reveal a 50 cm thick Ab horizon buried by fluvial sediments (Figure 4.8). Coal clinker material
was found in the top 10 cm of this Ab horizon, suggesting that this ground surface was exposed in the mid-1800s.
Figure 4.6 Schematic drawing of Mound 5 excavation profile with results of stable carbon isotope analysis of soil organic matter collected from the Ab horizon below Mound 5 construction fills. Results described are the predictive groupings made by linear discriminant analysis. (W) stands for wetland and (P) stands for prairie. Abundance of ceramic rims with depth, and radiometric age estimates are also depicted on the profile drawing.
Figure 4.7 Photomicrographs of micromorphology results. A) Ab rip-up clast in fluvial material. B) Graded beds of sand, silt, and clay. C) 3mm thick incipient A-horizon between fluvial sand deposits. D) Planar void (indicated by arrows) marks the clear boundary between the fluvial deposit and Mound fill. This contact was observed as abrupt in the field but is clear microscopically. There is microscopic evidence for bioturbation between the contact, but no evidence for incipient soil formation. E) Three different fluvial sand facies can be observed in one micromorphology thin section.
Figure 4.8 Preserved mudcracks found in sub-mound contexts. A) Mudcracks were found at the contact between mound fill and the Ab horizon at 140 cmbs (123.74 cmbs) in the Mound 16 excavations. These mudcracks were preserved through rapid burial by Mound 16 fill material. B) Mudcracks were found at the contact between fluvial sediment and the Ab horizon at 236 cmbs (123.09 masl) in the Mound 5 excavation. The mudcracks were preserved through rapid burial by fluvial sediment.
Figure 4.9 Schematic drawing of Mound 16 excavation profile with results of stable carbon isotope analysis of soil organic matter collected from the Ab horizon below and adjacent to Mound 16 construction fills. Results described are the predictive groupings made by linear discriminant analysis. (W) stands for wetland and (SW) stands for seasonal wetland. Abundance of ceramic rims with depth, and radiometric age estimates are also depicted on the profile drawing.
4.4.2 Ceramic Rim Assemblage and Chronology

I analyzed 19 ceramic rims from the Mound 5 excavations (Figure 4.10). Vessels forms include jars (n=13), bowls (n=3), a plate (n=1), and a short neck bottle (n=1). Most of these vessels do not have any surface treatments (n=13). The most common temper materials are shell (n=8) and grog (n=4). Four of the jar vessels are tempered with Madison County Shale that is diagnostic of the Late Bluff Tradition in the Emergent Mississippian culture. Two red slipped bowls are diagnostic of the Pulcher Tradition in the late Emergent Mississippian culture.

Figure 4.10 Counts of vessel type, surface treatment, and temper for the 19 ceramic rims analyzed from Mound 5 excavations.
A Bayesian model of Mound 5 construction was created using five samples collected from within Mound 5 and sub-mound contexts (Table 4.1). Both the samples from the Ab horizon and the fluvial sediment serve as *terminus post quem* for Mound 5 construction (Figure 4.6). The latest end boundary for the start of mound construction is estimated to occur after cal AD 1150 (19.2% probability), but likely occurred after cal AD 1050 (76.3% probability). Illinois State Museum collections of nutshell and deer tooth from a 1960 salvage excavation in Mound 5 conducted by Warren Wittry provides age estimates for the mound building phase, as well as a *terminus ante quem* for the deposition of the fluvial sediment (Figure 4.11). The earliest start boundary for the mound construction phase is cal AD 1030 (95.4% probability). Taken together, it is likely that both the fluvial sediment and the Ab horizon were deposited prior to Mississippian occupation (*circa* AD 1050-1400). Pecan shell collected from 2017 excavations at Mound 5 taken from a wall trench dug into mound construction fills provides a *terminus ante quem* for Mound 5 construction (Figure 4.6). According to this model, construction of Mound 5 ended around cal AD 1150-1220 (64.2% probability) (Figure 4.11).

I analyzed 27 ceramic rims from the Mound 16 excavations (Figure 12). Vessel forms include jars (n=11), bowls (n=6), seed jars (n=3), a plate (n=1), and a funnel (n=1). Vessels surfaces are mostly plain (n=22). The most common temper materials are grog with shell (n=15) and shell (n=9). The predominance of plain, grog with shell tempered vessels suggest that this assemblage belongs to the Sand Prairie phase (AD 1275 – 1375). An age estimate of cal AD 1280 – 1390 (95.4% probability) from a *Zea mays* glume taken from inside Mound 16 corroborates the ceramic chronology (Figure 4.9).
Figure 4.11 Bayesian model for radiocarbon dates from the Mound 5 excavation, descriptions of sample material and provenience can be found in Table 4.1.
Table 4.1 Context of samples used for radiometric dating.

<table>
<thead>
<tr>
<th>Lab #</th>
<th>Sample Number</th>
<th>Provenience</th>
<th>Stratigraphic Context</th>
<th>Material Notes</th>
<th>Radiocarbon Age (BP)</th>
<th>$\delta^{13}$C (%oo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OS-140346</td>
<td>50-57-4</td>
<td>2017 Mound 5 Excavation</td>
<td>Feature 5 - Wall trench dug into mound fill</td>
<td><em>Carya illinoinensis</em></td>
<td>885 +/- 15</td>
<td>Not reported</td>
</tr>
<tr>
<td>D-AMS 019338</td>
<td>1960-19 Bag19-3</td>
<td>1960 Mound 5 Excavation¹</td>
<td>Burn layer in inner mound</td>
<td>lower pre-molar deer tooth</td>
<td>903 +/- 24</td>
<td>Not reported</td>
</tr>
<tr>
<td>D-AMS 019339</td>
<td>1960-19 Bag19-12</td>
<td>1960 Mound 5 Excavation¹</td>
<td>Burn layer in inner mound</td>
<td><em>Carya cordiformis</em></td>
<td>887 +/- 26</td>
<td>Not reported</td>
</tr>
<tr>
<td>OS-140345</td>
<td>50-58-14</td>
<td>2017 Mound 5 Excavation</td>
<td>Fluvial sand deposit underneath mound fill</td>
<td><em>Zea Mays kernel</em>²</td>
<td>1000 +/- 25</td>
<td>Not reported</td>
</tr>
<tr>
<td>OS-140221</td>
<td>N550 E110</td>
<td>Sediment Core N550 E310</td>
<td>2 mm thick charcoal lens at base of Ab</td>
<td>unidentified wood charcoal</td>
<td>985 +/- 15</td>
<td>Not reported</td>
</tr>
<tr>
<td>OS-148496</td>
<td>2-W-8</td>
<td>2018 Mound 16 Excavation</td>
<td>Inner mound fill</td>
<td><em>Zea Mays glume</em>²</td>
<td>655 +/- 20</td>
<td>Not reported</td>
</tr>
</tbody>
</table>

¹Approval for destructive analysis was obtained through the Illinois State Museum for ISM Accession Number 1960-19, organic materials were identified by Marjorie Schroeder.
²Organic materials identification for radiocarbon dating from the 2017 and 2018 excavations were made by Grace Ward.
Figure 4.12 Counts of vessel type, surface treatment, and temper for the 17 ceramic rims analyzed from Mound 16 excavations.
4.4.3 Stable Carbon Isotopes

The modern prairie environment contains a mix of C$_3$ and C$_4$ plants, while both the seasonal wetland and wetland vegetation is dominated by C$_3$ plants. The $\delta^{13}$C values from the modern prairie environment range from -19.18 to -17.22‰, with a mean of -18.36 ± .681‰. The $\delta^{13}$C values from the modern wetland environment range from -23.85 to -22.82‰, with a mean of -23.31 ± .400‰. The $\delta^{13}$C values from the modern seasonal wetland environment range from -26.99 to -25.16‰, with a mean of -26.16 ± .717‰. The Shapiro-Wilk test of normality shows that the modern baseline dataset has a normal distribution (W=.894, p=.063), each environmental group also has a normal distribution of $\delta^{13}$C values. Levene’s test for homogeneity of variance shows that the modern baseline dataset has equal variance between groups (W=.993, p=.397). One-way analysis of variance (ANOVA) shows significance differences in $\delta^{13}$C values between the three different environmental groups (F=175.681, p=.000) (Figure 4.13). The Tukey post-hoc test shows that each environment group is significantly different from another (all have p-values of .000). For the linear discriminant analysis, one variable ($\delta^{13}$C) was used to discriminate between three groups (prairie, wetland, and seasonal wetland). The Box’s Test for Equivalence of Covariance Matrices shows covariance matrices are equal across groups (M=2.248, F=1.014, p=.364). The Wilks’ Lambda test shows that the $\delta^{13}$C have high discriminatory ability, and that the discriminant function does better than chance at separating the groups (Λ=.036, p=.000). In this model, there is only one independent variable used to predict grouping, so the Canonical Coefficient for $\delta^{13}$C values is 1. The discriminant function correctly grouped 100% of cases in each environmental group.
Figure 4.13 δ¹³C values from modern baseline groups of prairie, wetland, and season wetland are statistically different from each other, making these data a good baseline for archaeological samples.

The groupings for archaeological samples were determined by the linear discriminant analysis. The 12 samples analyzed from Mound 16 ranged from -26.26 to -22.89‰. Five samples from Mound 16 fall into the wetland baseline group, and the remaining seven samples fall into the seasonal wetland baseline group (Figure 4.9). Four of the samples that group with wetland baselines occupy the lowest and highest elevations sampled at Mound 16, the fifth sample that groups with wetland baselines is located in the middle of sample profile (Figure 4.9). The three samples analyzed from Mound 5 range from -22.38 to -19.37‰. The two lowest samples group with prairie baselines (-19.37‰ and -20.65‰), while the uppermost sample groups with the wetland baselines (-22.38‰) (Figure 4.6). This shift from prairie to wetland is also observed in a core south of Mound 5, where the lower elevation Ab (sample 39) groups with prairie baselines (-20.76‰); while the higher elevation Ab groups with wetland baselines (-23.97‰). The
remaining samples from cores around Mound 5 group with wetland baselines; excluding one sample, which fall into the seasonal wetland group. Samples from underneath Mound 14 and within the North Plaza all group with the wetland baseline samples.

4.5 Discussion

Immediately prior to the construction of Mound 5, the ground surface which Mound 5 was constructed on was in an area of active fluvial sedimentation. This is indicated by the presence of fluvial sediment directly below mound construction materials. Additionally, stable carbon isotopes taken from the Ab horizon underlaying the fluvial sediment indicate a gradual change from a prairie to a wetland environment prior to the period of active sedimentation. The presence of preserved mudcracks and artifact scatter at the contact (Figure 4.8) between the Ab horizon and the fluvial sediment suggest that there were some periods of seasonal desiccation in this wetland that people may have taken advantage of prior to the period of active fluvial sedimentation.

The stable carbon isotope data from Ab horizons below and adjacent to Mound 16 show variation between seasonal wetland and wetland groupings. Preserved mudcracks (Figure 4.8) at the contact between Mound 16 construction fills and the Ab horizon suggest that the people who built Mound 16 took advantage of seasonal desiccation to construct Mound 16. The predictive grouping of isotopic data adjacent to Mound 16 suggest that the North Plaza area remained a wetland/seasonal wetland until the modern era.

Taken together, the North Plaza was constructed in a wetland setting that experienced some periods of seasonal desiccation. The construction of a mound and plaza group in a wetland that is regularly inundated is unprecedented in the archaeological record of the Eastern
Woodlands. The traditional archaeological conception of plazas emphasizes the plaza’s purpose as a gathering space for public life and ceremonial performances. The creation of a plaza in an area that is inundated with water for most of the year contradicts the traditional conception of plaza space as a dry, flat, open, public space for daily community activities and ceremonial events. The North Plaza is an anomaly in the Eastern Woodlands that now requires archaeologists to re-envision what a plaza is and how plazas are used.

The North Plaza is accepted as a mound and plaza group because it is a rectangular-shaped, empty space that is surrounded by earthen mounds in each of the cardinal directions. When Fowler considered the North Plaza, his hypothesis that the North Plaza must have been drier than it is modernly was based on a conceptual understanding that mound and plaza groups must be located in dry environments to facilitate everyday public activities (Fowler 1997). Upon collecting data to determine what environmental conditions were like during the construction and utilization of the North Plaza, I have found that environmental conditions were wet, and that this area would have been inundated for most of the year with some periods of seasonal dryness. Theoretical frameworks utilizing indigenous ontology better explain the existence of the North Plaza as a type of water feature than the traditional historic and ethnohistoric analogies from the etic perspective which emphasize the functional day-to-day aspects of community layout.

Our conception of mound and plaza groups in the Eastern Woodlands are largely based on historic and ethnohistoric analogies from the etic perspective where monumental architecture in Mississippian societies have traditionally been explained as signs of social hierarchy and/or elite power (Bartram 1792; Hally 1993, 1996; Livingood 2008; Swanton 1998; Wesler 2006). From a more emic perspective, Knight (1989) finds that Indigenous terms applied to platform mounds are associated with autochthony, the underworld, birth, fertility, death, burial, the
placation of spirits, emergence, purification, and supernatural protection, suggesting that mounds are related to native world view and that the people who built these mound viewed them as a type of physical manifestation of their worldview. Although less analysis has been conducted on plazas, Knight argues that the use of the Muskogee term *tadjo* to describe both the earthworks, and the debris sweepings that created the earthworks, demonstrates the symbolic and physical connections between maintained open space and earthen constructions (Knight 1989). Power and ritual activity are not mutually exclusive, Holt envisions Cahokia as a theater state where people were ruled through the enactment and participation in ritual activity (2009). Globally, ethnographers recognize that complex, yet decentralized societies organize by using ritual and ceremony as a means of integration (Johnson 1994; Tuzin 2001; Weissner 2002). The construction of monumental architecture like mound and plaza groups can be seen as a necessary component of ensuring continuity in the world as well as forging bonds to establish social order and control (Schilling 2010).

In Southeastern Native American mythology, earthen mounds are important cosmological symbols associated with autochthony, the underworld, birth, death, and supernatural protection (Knight 1989). The act of mound building was a reenactment of the creation of the world and enacting this creation story would transform elements of the natural world into a symbolic integration of the cosmos (Knight 1989). Although the creation of plaza space and the maintenance of these ceremonial grounds has received less attention, the symbolic and physical connections demonstrated by Knight suggests a metaphysical link between the creation of low (the plaza) and high (the mounds) spaces.

Following traditional conceptions of mound and plaza groups that focus on the day-to-day public use and ceremonial activities, the existence of a wetland mound and plaza group is a
contradiction. However, when we consider the ontological perspective that these people recreated a physical manifestation of their cosmic worldview, it is not so surprising that they created a space where earthen mounds arise from a watery world. The Native American universe of the Mississippian period contained three levels; the Above World, the Middle World, and the Underworld; all connected by an axis mundi (Knight 1986; Hall 1997; Reilly III 2004). The Above World is represented by the sky, the Middle World is represented by earth, and the Underworld is represented by a primordial sea. The Earth-Diver myth is considered one of the oldest and most ubiquitous creation stories in Native American mythology (Hall 1997:19; Köngäs 1960:151). The earth diver myth explains how the earthen Middle World was created using mud from the bottom of the watery Underworld (Reilly III 2004; Hall 1997). Although there are regional variations of the Earth-Diver myth, the story always contains a primordial sea, a cultural hero, a diver, and the creation of the earthen world. In the myth, the cultural hero sends various animals, birds, and aquatic creatures to dive to the bottom of the primordial sea to bring up mud and sand. When a creature is finally successful at bringing mud up from the bottom of the sea, the mud spreads across the watery Underworld to form the earthen Middle World. The construction of earthen mounds in an area that is inundated with water, could represent the physical manifestation of the earth-diver creation myth; with the water itself representing the elements of the underworld and the mounds representing the middle world. In the Osage, Shawnee, Creek, and Yuchi variations of the Earth-Diver myth, the Crayfish is depicted as the successful diver (Boles 2017). During the excavations at Mound 5, I regularly encountered crayfish around the mound and in excavation units (Figure 4.14). When these crayfish burrowed below ground to reach the water table, they would bring up pieces of mud to the ground surface and pile them on top of each other to create mud chimneys. I think it is likely that the people who
constructed the North Plaza and its mounds also observed how the crayfish would create small earthen mounds out of mud brought up from below the ground surface.

Figure 4.14 Image of crayfish in burrow hole from Mound 5 excavations.

I am not the only researcher to observe connections between the Earth-Diver myth and construction of monumental architecture at Cahokia. Lopinot et al. (2015) and Schilling (2010, 2012) argue that parts of Monks Mound were constructed with wetland soil most likely extracted from the low-lying Edelhardt meander scar. The decision to use this mucky, saturated soil likely reflects ritual activity associated with reconstructing the Earth-Diver myth (Lopinot et al. 2015; Schilling 2010). The use of soil from the lowest elevations to build the highest elevation feature on the landscape demonstrates the creation of a physical link between the dichotomy of high and low spaces.
Beyond the dichotomy of the Underworld being the source material for the creation of high spaces, there is also the dichotomy of the Underworld association with both fertility and death, day and night, and summer and winter (Hall 1997:138). The Underworld is where the spirits rest, but it is also where seeds germinate. The Underworld is typically seen as the domain of the night sky; however, the Underworld is where the goes sun at night. Winter is the season generally associated with the Underworld; however, aspects of fertility and world renewal associated with the Underworld are related to summer. In his review of reverse behavior in Native ceremonies in the American Southwest, Hall argues that contradictory behaviors may have been associated with the control of fertility in nature (Hall 1997:138). The legitimacy of leaders was confirmed by their ability to maintain balance between opposing cosmic forces. In the Pacific Northwest coast, the reputation of the chief or shaman was advanced by his ability to intercede with the spirits in the Underworld, who controlled the natural food supply (Hall 1997:138). In some native groups in North America, winter was the season when people directed their attention to ceremonials associated with the Underworld (Hall 1997:137).

In Siouan mythology, the grandmother patroness or the “Old Woman Who Never Dies” most imbibes these dichotomies. The Old Woman Who Never Dies is an immortal figure who bathes in the river to become young again. She controls all vegetation as well as the change in the seasons. She keeps an underworldly water serpent as her consort and retires to an island residence in the winter (Mueller and Fritz 2016). I have evidence of a wet/dry duality in the North Plaza in the form of preserved mudcracks from seasonal desiccation of the wetland. Preserved mudcracks underneath Mound 16 suggest that the people who built this mound took advance of seasonal dryness (Figure 4.8). So it is very likely that the people who constructed the North Plaza knew about this area’s wet/dry duality. It is possible that the North Plaza was
constructed in this location because of its duality. The leaders of Cahokia were those who could control and maintain the balance of dichotomous cosmic forces (Emerson 1997). As an agricultural society, the ability to intercede with the spirits to ensure successful crop yields would have been essential to reaffirm the legitimacy of leaders (Scarborough 1998; Butzer 1976; Lansing 1981). Based on previous experiences from conducting field work in the North Plaza, it can be hard to predict when the North Plaza will be completely desiccated. However, anticipate that the North Plaza is most likely to be dry in winter. So it is also possible that the North Plaza was used as a ceremonial performance space for rituals related to plant fertility and world renewal during the driest winter months (Byers 2006). Many of the crops in the Eastern Agricultural Complex are floodplains plants (*Iva annua*, *Polygonum erectum*, *Chenopodium berlandieri*, and *Cucurbita pepo*), so it is also possible that this wetland setting was purposely chosen to pay homage to the original progenitors of these crops. Additionally, it is also possible that the water levels in the North Plaza could have served as a marker of seasonal environmental conditions. The use of the North Plaza as a seasonal marker may have been deliberate or unconscious. The idea that the North Plaza was marker of environmental conditions is somewhat speculative, but aligns well with other narratives regarding the relationship between monumental architecture and ritual activity as a form of risk management (Butzer 1976; Lansing 1981; Scarborough 1998).

There is also a unique longevity in the maintenance of the North Plaza complex that indicates the importance of this space to the people of Cahokia. The ceramic and radiometric chronology of Mound 5 (Figure 4.6) suggest that construction of Mound 5 occurred between the Lohmann and Moorehead phases (ca. cal AD 1050 – 1275). Ceramic and radiometric dating of Mound 16 (Figure 4.9) indicate that Mound 16 was constructed in the Sand Prairie phase (cal
AD 1277 – 1375). Unlike the Mound 5 excavations, the excavations at Mound 16 did not reach the inner part of the mound. It is possible that construction of Mound 16 began earlier, and the excavations only revealed a later Sand Prairie stage of mound construction. Mound construction in the Sand Prairie phase is somewhat unusual, as this phase is typically viewed as the period of decline at Cahokia. The continued investment and maintenance of the North Plaza complex in a time of population decline demonstrates that this place was significant to the people who remained at Cahokia.

Other researchers recognize the role of water in the creation of space in the Cahokia world. Recent research in both the floodplain and the uplands in and around Cahokia Mounds cite indigenous ontologies to discuss the role of water in the hierophanization of space (Baires 2015; Skousen 2018; Pauketat et al. 2017; Emerson et al. 2000) Examinations of a mortuary ridgetop mound that is connected to the center of Cahokia by an earthen embankment causeway were used to discuss how the people who built Cahokia created a physical manifestation of their tripartite world view. In this example, a mirrored lunar alignment of the constructed causeway represents the celestial bodies of the Upper World, the earthen embankment represents the built landscape of the Middle World, and the low-elevation bogs which surround the causeway represents the Underworld (Baires 2014, 2015, 2017). At Emerald Mounds in the uplands surrounding Cahokia, modern observations of springs and water seeps paired with archaeological observations of waterlain silt, lunar alignments, and the presence of plasters are used to argue that Emerald Mounds represents a type of water shrine that could have used for pilgrimage activities (Pauketat et al. 2017; Skousen 2018). The BBB Motor site, where a flint clay figurine of the Old Woman Who Never Dies was found (Mueller and Fritz 2016; Prentice 1986; Emerson et al. 2000), was constructed on a ridge surrounded by wetlands (Emerson 1989). There are
speculations that the BBB motor site was placed on this ridge as a symbolic representation of the island residence of the Old Woman Who Never Dies. Given the increasing engagement with ontological perspectives, I expect that we will continue to see more research that engages with symbolic and ritual explanations for the creation of space.

Whether the North Plaza was a physical manifestation of Earth-Diver creation story, a space for seasonal ceremonials associated with plant fertility or a world renewal cult (Byers 2006), an indicator of environmental conditions, all of the former mentioned, or none of the former mentioned; ultimately, the deliberate creation of a mound and plaza group in a wetland that is inundated with water for most of the year is an anomaly in the archaeological record of the Eastern Woodlands. The anomaly of the North Plaza forces archaeologists to re-examine preconceptions of what plazas are and how they are used. When Fowler created the Cahokia Atlas, he assumed that the North Plaza was constructed when environmental conditions were drier because he could not conceive that people would construct a mound and plaza group in a swamp (Fowler 1997:70). Based on archaeological expectations of what plazas are and how plazas are used, the assumption that environmental conditions were drier was acceptable. The North Plaza anomaly is an excellent example of why archaeologists should not assume things based on pre-conceived notions about the past. Moving forward, we need to be more conscious of the assumptions that are built into explanations of past phenomena and work on developing research agendas capable of testing these assumptions.
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Chapter 5: Conclusions

5.1 Introduction

At the beginning of this dissertation, I made the observation that archaeology relies heavily on inductive reasoning. This means that much of archaeological research involves forming hypotheses to explain observations of past phenomena. As a historical science, it is not surprising that archaeology aligns closely with inductive reasoning frameworks because traditional archaeological investigations, like excavations, rarely allow an archaeologist total control over the types of observations they make. In this dissertation, I used Cahokia Mounds as a case study of an archaeological site where untested hypotheses related to the relationship between humans and their environment have persisted in the academic literature and public discourse for decades. I argue that these hypotheses have persisted through time as acceptable assumptions simply because no one sought to test them. Over the course of three article-style chapters, I demonstrate how it is possible to test hypotheses related to the relationship between humans and their environment using the archaeological record to answer basic questions about environmental conditions.

In the following section I will summarize the research chapters of this dissertation. I will then go back and reconsider the broader implication of this research on the acceptable assumption problem posed in Chapter 1. I will end with some thoughts on future research directions revealed by this research.

5.2 Chapter Summaries

In Chapter 1, I lay out the problem of acceptable assumptions in archaeological research on the relationship between humans and their environment. An acceptable assumption is
something that is accepted as true, even though is it technically an untested hypothesis. An example of an acceptable assumption is that drought causes food insecurity. These acceptable assumptions are often used to form new hypotheses about the relationship between environmental effects and population dynamics. I use Cahokia Mounds, the largest pre-Columbian archaeological site in North America, as a case study of human-environmental relationship hypotheses that rely on acceptable assumptions. I review previous scholarship on the relationship between climate change and depopulation of Cahokia to demonstrate that all these previous studies rely on the assumption that the effects of climate change (droughts or floods) caused food insecurity. I then review previous scholarship on ecocide scenarios at Cahokia to demonstrate that the wood-overuse hypothesis relies on the assumption that deforestation caused increased flooding. Finally, I discuss how previous environmental conditions were described as drier than modern times in the North Plaza, because scholars assume that mound and plaza groups were used for year-round daily activities and ceremonial events. In these literature reviews, I identify three untested hypotheses that I intend to evaluate with geoarchaeological investigations of the North Plaza over the course of the next three chapters. The first hypothesis that I will address is that deforestation caused increased flooding at the end of Cahokia’s occupation. The second hypothesis I will address is that regional trends of drought caused food insecurity at the end of Cahokia’s occupations. The third hypothesis I will address is that the North Plaza was constructed when environmental conditions were drier than they are modernly.

In Chapter 2, I address the hypothesis that deforestation caused increased flooding at the end of Cahokia’s occupation. The wood-overuse hypothesis suggests tree clearance in the uplands surrounding Cahokia led to erosion, causing increasingly frequent and unpredictable floods of the local creek drainages in the floodplain where Cahokia Mounds was constructed.
These floods were suggested to be a reason why people left Cahokia at the end of the fourteenth century. I use stratigraphic analysis of archaeological excavations conducted on the toe slope of Mound 16, located in Cahokia Creek floodplain, to demonstrate that the Ab horizon on which the mound was constructed remained stable until industrial development in the mid-1800s. The presence of a stable ground surface from Mississippian occupation to the Industrial Era does not support the expectations of the wood-overuse hypothesis. Ultimately, this research demonstrates that pre-Colombian ecological change does not inherently cause geomorphic change. Narratives of ecocide related to geomorphic change need to be validated with the stratigraphic record.

In Chapter 3, I address the hypothesis that regional trends of drought caused food insecurity at the end of Cahokia’s occupation. I rely on stable carbon isotope data from soil organic matter of Ab horizons collected in the archaeological excavations of Mounds 5 and 16, as well as sediment cores in the North Plaza, as a proxy of dominant vegetation ground cover changes through time. These data show local ecological resilience to regional trends of drought. These data demonstrate the assumed ecological effects of climate change are not universal, and local environmental datasets taken from within the archaeological record are necessary to test the validity of hypothesized links explaining the correlation between climate change and population dynamics.

In Chapter 4, I address the hypothesis that the North Plaza was drier than modern times during the construction and utilization of the space. Traditional conceptions view plazas as a dry, flat, open, public space for daily community activities and ceremonial events. The hypothesis that the North Plaza was dry during Mississippian occupation is generally accepted because it fits into preconceived notions about the use of plaza space. I rely on the same stratigraphic and stable carbon isotope datasets presented in Chapters 2 and 3 to demonstrate that the North Plaza was a
wetland during the construction and utilization this space. Evidence of mudcracks underneath Mound 16 suggest that the people who constructed the mound did take advantage of seasonal dryness to construct Mound 16. Citing indigenous ontologies, I argue that the mounds which define the North Plaza were constructed to be inundated with water. I argue that the North Plaza is an architectural feature that serves as a representation of the creation of the earthen Middle World from the watery Underworld. I suggest that people may have utilized the North Plaza space during dry seasons as a location for world renewal ceremonies. Additionally, water levels in the North Plaza may have served as markers of seasonality and environmental conditions for the people of Cahokia. Ultimately, the North Plaza is an anomaly in the archaeology of the Eastern Woodlands that requires archaeologists to re-envision how we define and conceive of plazas. This chapter is a great example of how preconceived notions in archaeology can give leeway to accept untested hypotheses.

5.3 Final Thoughts on Acceptable Assumptions

In sum, this research demonstrates that the archaeological record can be used to test hypotheses relating to the relationship between humans and their environment. At Cahokia Mounds, the climate-agriculture-population narrative has persisted for over half a century (Baerreis and Bryson 1965). Although new data have been obtained since the first iteration of this narrative, the narrative itself has persisted (Benson et al. 2009; Meeks and Anderson 2013; Bird et al. 2017). Advancements in knowledge require a back and forth between inductive and deductive questioning (Kuhn 1962). In this specific case at Cahokia, I believe knowledge on the relationship between humans and their environment has stalled because researchers are not questioning the assumptions used to build previous arguments. In these climate-agriculture-population narratives, researchers were more focused on obtaining new, high-resolution datasets
of climate change than they were on questioning the relationship between climatic shifts and food security implied in previous research (Benson et al. 2009; Meeks and Anderson 2013; Bird et al. 2017; Baerreis and Bryson 1965). The result is a series of articles all making the same observation that climate change and population decline happened at roughly the same time and explaining this observation with a hypothesis about food insecurity. So basically, we have a half century of research but no real advancement in knowledge.

The International Panel on Climate Change is tasked with the responsibly of providing policymakers scientific data on issues related to modern climate change. A common phrase used by policymakers on climate change issues is “based on the best available science” (IPCC 2014). What this phrase is ultimately implying is that issues related to modern climate change are being dealt with faster than the scientific research community can produce new knowledge. Many archaeologists argue that studying past human response to climate change can be helpful in informing future strategies to adapt to modern change (Anderson et al. 2013; Chase and Scarborough 2014; Van de Noort 2011; Jackson et al. 2017; Hudson et al. 2012; Rockman 2012; Sandweiss and Kelley 2012; Pétursdóttir 2017). However, the reality is that archaeological research is not being used to inform policy makers on climate change issues. Some scholars suggest that increased temporal and spatial scales as well as a longue durée approaches will increase the relevance of archaeological research to modern climate change issues (d’Alpoim Guedes et al. 2016). Based on the Cahokia case study, there seems to be a more fundamental issue with the pace of knowledge production in archaeological research on the relationship between humans and their environment. I believe that a major reason why archaeological research is not used by policy makers is that the production of knowledge is not keeping pace
with the information demand from policy makers to develop adaptation strategies to future change.

At this point in the modern climate change crisis, generalized assumptions are not helpful to policy makers. Using Cahokia as a case study, all the previous hypotheses presented in this dissertation were formed based on assumptions about the relationship between humans and their environment. The wood-overuse hypothesis was formed based on an assumption that upland deforestation inherently causes bottomland flooding. The climate-agriculture-population narratives assumed that drought inherently causes food insecurity. The dry North Plaza hypothesis was built on the assumption that people did not build mound and plaza groups in swamps. These assumptions represent generalized knowledge and preconceived expectations about the relationship between humans and their environment. Policy makers are already aware of these generalizations. What policymakers now need is more specific information on where, when, how, and why these generalizations did or did not occur. Ultimately, the only way for archaeology to move from the general to the specific is to start questioning the fundamental assumptions built into previous research.

5.4 Future Direction

From the ending of my previous section, you can probably guess that I think future research questions should generally take a more deductive approach by testing hypotheses that exist in the current literature. So, I am now going to shift my focus to discuss some specific questions and problems that I have run into over the course of engaging with research at Cahokia Mounds.
First, I think it is time to address the chronology issue at Cahokia. The Cahokia ceramic sequence is well established; however, the radiometric ages for these phases need to be reevaluated. In the introduction, I discussed how comparisons of population estimates using ceramic phases and those using independent radiometric ages are offset by about 150 years (White et al. 2018). With the current state of the literature, it is difficult to accurately compare independently dated data to dynamics happening at Cahokia. A future project that would greatly benefit all scholars concerned with Cahokia is a re-assessment of radiometric ages for ceramic phases using Bayesian modeling. After these radiometric age estimates are re-evaluated, then we can revisit the temporal correlations between external and internal processes at Cahokia.

In Chapter 4, I presented the North Plaza as a mound and plaza group that was constructed to be inundated with water. I also implied that the rectangular-shaped empty space between the four mounds which define the North Plaza was used for ceremonies during dry seasons. However, it is possible that this space was never used during dry times. My excavations were limited to Mound 5 and Mound 16. Large block excavations in the center of the North Plaza may yield data to suggest if this space was used in dry periods. The center of the plaza space would be a good place to target, since some plazas contain large post pits at their center. However, large block excavation in the plaza area will be logistically difficult because of the deep burial of Mississippian occupation in this area.

Much of the literature regarding human-environmental relationships at Cahokia seeks to use environmental change as a contributing factor for the abandonment of this large mound center. The palynology work by Munoz (Munoz et al. 2014), demonstrates that land clearance was happening in the American Bottom and upland regions starting around AD 450. I find it interesting that the stratigraphy and stable carbon isotope values from below Mound 5 suggest a
shift from a stable prairie landscape to a wetland, and then an actively flooding landscape. Based on the chronology associated with Mound 5 construction, this shift likely happened before the Mississippian period occupation. It would be interesting to explore the idea that pre-Mississippian land clearance may have caused a geomorphic shift in the bottomlands. This has implication for resilience studies, because it means that people at Cahokia constructed their landscape in the floodplain despite increased occurrences of flooding.

Following the topic of resilience, the ceramic chronology and radiometric age estimates for Mound 16 show continued investment in maintaining the North Plaza complex during the Sand Prairie phase. The Sand Prairie phase is generally viewed as the period of decline and abandonment at Cahokia mounds, so it is unusual to see investment in monumental architecture during this phase. White et al. (2020) recently published a new article using fecal stanols as population estimated to discuss the continued occupation of the American Bottom after the abandonment of Cahokia. The fecal stanols suggest that an indigenous population remained in the American Bottom, despite a lack of archaeological evidence for continued occupation (White et al. 2020). Pairing together the fecal stanols data and the Mound 16 construction chronology, there seems to be a new picture of native persistence emerging. Future work focused on exploring the Sand Prairie component of the North Plaza as well as increased engagement with post-Mississippian occupation in the American Bottom could reveal more about population persistence and resilience in this region. In general, I think we should shift our focus away from trying to explain collapse with environmental causes to describing examples of resilience despite environmental change. Specific examples of persistence and resilience to environmental stressors will ultimately be more relevant for informing future adaptation strategies than narratives of collapse and abandonment.
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d’Alpoim Guedes, Jade A., Stefani A. Crabtree, R. Kyle Bocinsky, and Timothy A. Kohler  

Hudson, Mark J., Mami Aoyama, Kara C. Hoover, and Junzō Uchiyama  
Jackson, Rowan, Andrew Dugmore, and Felix Riede  
2017  Towards a new social contract for archaeology and climate change adaptation.  
Archeological Review from Cambridge 32(2):197–221.

Kuhn, Thomas S.  

Meeks, Scott C., and David G. Anderson  

Munoz, S. E., S. Schroeder, D. A. Fike, and J. W. Williams  

Pétursdóttir, Þóra  

Rockman, Marcy  

Sandweiss, Daniel H., and Alice R. Kelley  

Van de Noort, Robert  

White, A. J., Samuel E. Munoz, Sissel Schroeder, and Lora R. Stevens  
White, A. J., Lora R. Stevens, Varenka Lorenzi, Samuel E. Munoz, Carl P. Lipo, and Sissel Schroeder
## Appendix A: Cahokia Grid Coordinates (x,y,z) of 2017 Sediment Cores

<table>
<thead>
<tr>
<th>Mound 14 East-West Core Transect</th>
<th>Mound 14 North-South Core Transect</th>
<th>Mound 5 West Core Transect</th>
<th>Mound 5 South Core Transect</th>
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## Appendix B: Cahokia Grid Coordinates (x,y,z) of 2017 and 2018 Archaeological Excavations

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### Appendix C: Raw Data Table of Ceramic Rim Assemblage from Mound 5

| Bag Number | Level (cm) | Unit | Quad | Feature | Weight (g) | Form | Temper | Ext. Surface | Int. Surface | Decoration | Lip Type | Rim Type | Rim Length (mm) | Rim Thickness (mm) | Orifice Diameter (cm) | Orifice % | Notes |
|------------|-----------|------|------|---------|------------|------|--------|--------------|--------------|------------|----------|----------|-----------|----------------|-------------------|---------------------|----------|-------|
| 51-60-1    | 0-40      | 1    | NE/N/A | Jar     | 9.6        | Grog with Shell | Plain | Plain | Plain/N/A | Rounded | Everted | 24       | 5               | 18                 | 7                  |          |       |
| 51-60-2    | 40-50     | 1    | NE/N/A | Jar     | 1.1        | Shell | Plain | Plain | N/A | Extruded | Insantling | 8       | 3         | 14       | Less than 5     |                      |                    |          |       |
| 50-60-2    | 40-60     | 1    | SE/N/A | Jar     | 0.7        | Grog with Shell | Plain | Plain | Plain/N/A | Extruded | Vertical | 6        | 4         | 12       | Less than 5     |                      |                    |          |       |
| 50-60-3    | 40-60     | 1    | SE/N/A | Bowl    | 8.2       | Shell | Plain | Plain | N/A | Squared | Vertical/Oncurred | 6       | 7         | 14       | 10                |                      |                    |          |       |
| 51-59-4    | 130-140   | 1    | NW/N/A | Jar     | 27.5      | Grit and Grog | Plain | Plain | Plain/Cordmarked | Squared | Insantling | 5        | 6         | 16       | 9                | Z twist cordmarked |                    |          |       |
| 51-56-1    | 0-40      | 2    | South | Jar     | 9.8        | Grog | Plain | Plain | Notching on lip | Rounded | Vertical | 7        | 7         | 24       | 5                | Flared Bluff Jar, Madison County Shale |                    |          |       |
| 50-56-5    | 80-92     | 2    | South | 2       | 16.8      | Jar      | Shell | Plain | Plain | N/A | Rounded | Everted | 22       | 6         | 32       | 6                |                      |                    |          |       |
| 51-56-9    | 120-130   | 2    | North | 7.7     | Jar       | Grog     | Plain | Plain | Vertical Notching on lip | Squared | Insantling/Incurved | 9       | 8         | Indeterminate | Less than 5 | Bluff Jar, Madison County Shale |                    |          |       |
| 51-53-2    | 30-50     | 3    | North | 10.6    | Jar       | Shell   | Pink Slip | Pink Slip | N/A | Squared | Everted | 13       | 7         | Indeterminate | Only everted part of rim |                      |                    |          |       |
| 50-53-3    | 50-70     | 3    | South | 1.9     | Bowl      | Grit    | Dark Red Slip | Dark Red Slip | Notching on lip | Extruded | Incurved | 6        | 5         | Indeterminate | Less than 5 | Merrell Red Film |                      |                    |          |       |
| 50-53-3    | 50-70     | 3    | South | 2.5     | Indeterminate | Shell | Plain | Plain | N/A | Squared | Insantling | 6       | 6         | 16       | Less than 5     | Monks Mound Red |                    |          |       |
| 51-53-5    | 89-90     | 3    | North | 8.1     | Jar       | Shell   | Red Slip | Red Slip | N/A | Rounded | Flared | 4        | 6         | 24       | 6                |                      |                    |          |       |
| 50-57-2    | 40-60     | 4    | SW/N/A | 20.3    | Plate     | Shell   | Pink Slip | Pink Slip | N/A | Squared | Vertical/Oncurred | 9       | 10        | Indeterminate | Too large, greater than 32cm |                      |                    |          |       |
| 51-57-3    | 60-79     | 4    | NW     | 4       | 2.4       | Jar      | Grog    | Plain | Plain | N/A | Extruded | Verticle | 8        | 6         | Indeterminate | Less than 5 | Emerald Mississippian |                    |          |       |
| 51-58-5    | 90-110    | 4    | NE/N/A | 20.6    | Jar       | Grog    | Plain | Plain | Lug on Lip | Squared | Insantling | 5       | 6         | 16       | 6                | Bluff Jar, Madison County Shale |                    |          |       |
| 50-58-11   | 110-130   | 4    | SE/N/A | 3.5     | Jar       | Grit    | Pink Slip | Pink Slip | Notching on lip | Extruded | Outsantling | 9       | 7         | Indeterminate | Less than 5 | Bluff Jar |                    |          |       |
| 50-57-10   | 226       | 4    | SW/N/A | 4.8     | Jar       | Grit and Grog | Plain | Plain | Plain | Notching on lip | Extruded | Vertical | 12       | 6         | 14       | Less than 5 | Emerald Mississippian, lip is an applique |                    |          |       |

**Notes:**
- Grog with Shell: Grog embedded in the clay matrix.
- Shell: Shell tempered, which is a natural material used to add weight and strength to the ceramic.
- Grit: Small pebbles or sand used to temper the clay.
- Dark Red Slip: Dark red clay slip applied to the surface.
- Pink Slip: Pink clay slip applied to the surface.
- Red Slip: Red clay slip applied to the surface.
- Plain: No additional decoration or tempering materials.
- Everted: Rim that curves outward.
- Insantling: Rim that curves inward.
- Vertical/Oncurred: Rim that curves both inward and outward.
- Squared: Rim that is flat and square.
- Incurved: Rim that curves inward.
- Flared: Rim that is broad and expands outward.
- Vertical: Rim that is flat and straight.
- Inslanting: Rim that curves outward.
- Inslanting/Incurved: Rim that curves both outward and inward.
- Indeterminate: Rim shape cannot be accurately determined.
- Too large, greater than 32cm: Rim diameter is too large to measure accurately.
- Emerald Mississippian: A culture known for its distinctive ceramic styles.
- Flared Bluff Jar, Madison County Shale: A specific type of jar associated with the Flared Bluff culture in Madison County, Shale.
Appendix D: OxCal Codes for Bayesian Chronological Model of Mound 5

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            Before("Fluvial Deposit")
            {
                R_Date("Fluvial Deposit", 1000, 25);
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            Phase("Mound Construction")
            {
                R_Date("Inner Mound Fill deer tooth", 903, 24);
                R_Date("Inner Mound Fill nutshell", 887, 26);
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            After("Wall Trench Fill")
            {
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        }
    }
    Boundary("End 1");
}
### Appendix E: Raw Data Table of Ceramic Rim Assemblage from Mound 16

| Bag | Number | Level (cm) | Unit | Quad | Feature | Weight (g) | Form | Temper | Ext. Surface | Int. Surface | Decoration | Lip Type | Rim Type | Rim Length (mm) | Rim Thickness (mm) | Orifice | Diameter (cm) | Orifice % | Notes                  |
|-----|--------|------------|------|------|---------|------------|------|--------|-------------|-------------|------------|----------|----------|-----------|----------------|---------------------|--------|---------------|----------|------------------------|
| 2-W-2 | 6-20   | 2          | West | N/A  | Indeterminate | 1.3        | Grit    | Plain   | Plain       | Plain       | N/A        | Squared  | Indeterminate | N/A        | N/A                | Indeterminate | less than 5% | Less than 1cm |
| 2-W-4 | 44.5   | 2          | West | N/A  | Bowl     | 9.5        | Shell   | Plain   | Plain       | Plain       | Slanted to Interior | Vertical | 10         | 9         | Indeterminate | less than 5% |  |
| 2-W-2 | 40-60  | 2          | West | N/A  | Jar      | 7.3        | Shell   | Plain   | Plain       | N/A        | Squared  | Everted | 5         | 6         | Indeterminate | less than 5% |  |
| 2-W-4 | 40-60  | 2          | West | N/A  | Bowl     | 28.7       | Grog with shell | Plain   | Plain       | N/A        | Rounded | Vertical | 7         | 9         | 24        | 8         | Indeterminate | less than 5% |  |
| 2-W-4 | 40-60  | 2          | West | N/A  | Jar      | 1.4        | Indeterminate | Grog with shell | Plain   | Plain       | N/A        | Rounded | Everted | 9         | 7         | Indeterminate | less than 5% |  |
| 2-W-4 | 40-60  | 2          | West | N/A  | Jar      | 21.6       | Shell   | Grog with shell | Plain   | Plain       | N/A        | Rounded | Vertical | 12        | 7         | Indeterminate | less than 5% |  |
| 2-W-4 | 40-60  | 2          | West | N/A  | Jar      | 8.2        | Shell   | Grog with shell | Plain   | Plain       | N/A        | Rounded | Vertical | 9         | 8         | 18        | 9         | Indeterminate | less than 5% |  |
| 2-W-5 | 60     | 2          | West | N/A  | Seed Jar | 2.2        | Shell   | Grog with shell | Plain   | Plain       | N/A        | Rounded | Indeterminate | N/A        | Squared | Indeterminate | less than 5% |  |
| 2-W-6 | 66-70  | 2          | West | N/A  | Grog with shell | 1        | Shell   | Grog with shell | Plain   | Plain       | N/A        | Squared | Everted | 12        | 11        | Indeterminate | less than 5% |  |
| 2-W-6 | 62     | 2          | West | N/A  | Bowl     | 29.7       | Shell   | Red Slip | Red Slip   | Plain       | N/A        | Squared  | Outslanting | 12        | 40        | 7         |  |
| 2-W-7 | 70-80  | 2          | West | N/A  | Jar      | 5.3        | Grog with shell | Plain   | Plain       | N/A        | Squared | Outslanting | 8         | 7         | 6         |  |
| 2-W-7 | 70-80  | 2          | West | N/A  | Jar      | 3.4        | Bowl    | Grog with shell | Plain   | Horizontal etching on exterior | Rounded | Squared | Outslanting | 6         | 7         | Indeterminate | less than 5% |  |
| 2-W-7 | 70-80  | 2          | West | N/A  | Jar      | 2.8        | Shell   | Grog with shell | Plain   | Plain       | N/A        | Rounded | Outslanting | 6         | 5         | Indeterminate | less than 5% |  |
| 2-W-10 | 80-90  | 2         | West | N/A  | Jar      | 3.6        | Jar     | Shell    | Plain       | Plain       | N/A        | Rounded | Outslanting | 4         | 6         | Indeterminate | less than 5% |  |
| 2-W-10 | 80-90  | 2         | West | N/A  | Seed Jar | 2.4        | Jar     | Shell    | Dark Red Slip | Plain       | N/A        | Rounded | Outslanting | 6         | 7         | Indeterminate | less than 5% |  |
| 2-W-10 | 89.5   | 2         | West | N/A  | Jar      | 89.1       | Grog with shell | Plain   | Plain       | N/A        | Squared | Everted | 41        | 11        | 32        | 20        | Same seed jar vessel as 2-E-7 |
| 2-E-1 | 0-20   | 2          | East | N/A  | Indeterminate | 4        | Grit    | Plain   | Plain       | N/A        | Squared  | Vertical | 6         | 6         | 14        | 5         | Only have everted part of rim |
| 2-E-2 | 20-40  | 2          | East | N/A  | Jar      | 4.3        | Shell   | Plain   | Plain       | N/A        | Rounded | Everted | 11        | 6         | Indeterminate | less than 5% |  |
| 2-E-3 | 40-60  | 2          | East | N/A  | Seed Jar | 5        | Grog with shell | Plain   | Plain       | N/A        | Rounded | Insulating | 12        | 12        | 8         | 10        | Only have everted part of rim |
| 2-E-3 | 40-60  | 2          | East | N/A  | Jar      | 1.8        | Indeterminate | Grog with shell | Plain   | Plain       | N/A        | Rounded | Insulating | 4         | 5         | 8         | 10        | Only have everted part of rim |
| 2-E-5 | 60-80  | 2          | East | N/A  | Jar      | 10.7       | Shell   | Pink Slip | Pink Slip  | Plain       | N/A        | Rounded | Everted | 23        | 10        | Indeterminate | less than 5% |  |
| 2-E-7 | 100-120 | 2         | East | N/A  | Seed Jar | 11.6       | Grog with shell | Dark Red Slip | Plain   | Plain       | N/A        | Rounded | Outslanting | 4         | 6         | 20        | 20        | Same seed jar vessel as 2-W-10 |
| 3-E-3 | 60-80  | 3          | East | N/A  | Jar      | 2.7        | Grog with shell | Plain   | Plain       | N/A        | Rounded | Vertical | 6         | 6         | 26        | 10        | Only have everted part of rim |
| 3-E-3 | 60-80  | 3          | East | N/A  | Jar      | 10.9       | Grog with shell | Plain   | Plain       | N/A        | Rounded | Everted | 4         | 6         | 14        | 5         | |
| 3-E-3 | 60-80  | 3          | East | N/A  | Jar      | 10.9       | Grog with shell | Plain   | Plain       | N/A        | Rounded | Insulating | 8         | 9         | Indeterminate | less than 5% |  |
| 3-W-3 | 60-80  | 3          | West | N/A  | Funnel   | 19.1       | Grog with shell | Plain   | Plain       | N/A        | Rounded | Insulating | 11        | 6         | Indeterminate | less than 5% |  |

**Legend**
- **Bag**: Bag number
- **Number**: Level in centimeters
- **Unit**: Unit of measurement
- **Quad**: Quad number
- **Feature**: Feature described
- **Weight (g)**: Weight in grams
- **Form**: Form of the object
- **Temper**: Temper of the object
- **Ext. Surface**: Exterior surface of the object
- **Int. Surface**: Interior surface of the object
- **Decoration**: Decoration on the object
- **Lip Type**: Type of lip on the object
- **Rim Type**: Type of rim on the object
- **Rim Length (mm)**: Length of the rim in millimeters
- **Rim Thickness (mm)**: Thickness of the rim in millimeters
- **Orifice**: Orifice of the object
- **Diameter (cm)**: Diameter of the object in centimeters
- **Orifice %**: Percentage of the orifice
- **Notes**: Additional notes about the object
Appendix F: Probability Distributions for Mound 16 Radiometric Age Estimate
## Appendix G: Context of all current radiometric age estimates from the North Plaza Project

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<td>Not reported</td>
<td>-85.94</td>
</tr>
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<td>OS-148548</td>
<td>2-W-21</td>
<td>2019 Mound 16 Excavation</td>
<td>Zea Mays kernel³</td>
<td>&gt;Modern</td>
<td></td>
<td>Not reported</td>
<td>2.92</td>
</tr>
</tbody>
</table>

¹Approval for destructive analysis was obtained through the Illinois State Museum for ISM Accession Number 1960-19
²Organic material identification from the 1960 Mound 5 excavations were made by Marjorie Schroeder at the Illinois State Museum
³Organic material identification from 2017 Mound 5 excavations and 2018 Mound 16 excavations were made by Grace Ward at Washington University in St. Louis