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MIDDLE TO LATE HOLOCENE (7200-2900 CAL. BP) ARCHAEOLOGICAL SITE FORMATION PROCESSES AT CRUMPS SINK AND THE ORIGINS OF ANTHROPOGENIC ENVIRONMENTS IN CENTRAL KENTUCKY, USA

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DISSERTATION

A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in the
College of Arts and Sciences
at the University of Kentucky

By
Justin Nels Carlson

Lexington, Kentucky

Director: Dr. George M. Crothers, Professor of Anthropology

Lexington, Kentucky

2019

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ABSTRACT OF DISSERTATION

MIDDLE TO LATE HOLOCENE (7200-2900 CAL. BP) ARCHAEOLOGICAL SITE FORMATION PROCESSES AT CRUMPS SINK AND THE ORIGINS OF ANTHROPOGENIC ENVIRONMENTS IN CENTRAL KENTUCKY, USA

Though some researchers have argued that the Big Barrens grasslands of Kentucky were the product of anthropogenic land clearing practices by Native Americans, heretofore, this hypothesis had not been tested archaeologically. More work was needed to refine chronologies of fire activity in the region, determine the extent to which humans played a role in the process, and integrate these findings with the paleoenvironmental and archaeological record. With these goals in mind, I conducted archaeological and geoarchaeological investigations at Crumps Sink in the Sinkhole Plain of Kentucky. The archaeological record and site formation history of Crumps Sink were compared with environmental and archaeological data from the Interior Low Plateaus and Southern Appalachian Mountains for an understanding of how the site fits into the larger story of human-environmental interactions in the Eastern Woodlands. Based on the data recovered, I argue that through land burning Archaic hunter-gatherers were active managers of ecosystems to a greater degree than previously acknowledged.

Excavations at Crumps Sink revealed stratified archaeological deposits spanning the late Middle Archaic to Terminal Late Archaic periods. Radiocarbon dates and an analysis of projectile point typologies provided information on the chronological and cultural history of the site. Magnetic susceptibility, loss-on-ignition, plant available phosphorous, and soil micromorphological analyses were conducted to examine landform dynamics in response to environmental change and to trace the anthropogenic signature created by human activities at the site. Masses of lithic debitage, animal bone, and burned sediment nodules per ten-cm-level provide an indication of human occupation intensity and shifting activities over time. Radiocarbon dates were used to reconstruct rates of sediment accumulation in the sink. These varying datasets were considered together for a holistic understanding of localized environmental and anthropogenic impacts on the landform.

Between 7200 and 5600 cal. BP, during the Middle Holocene Thermal Maximum and corresponding with the late Middle Archaic period, sediment accumulation was sustained with one identifiable episode of very weak soil development. Background magnetic and chemical signatures in the soils were greater than they were at pre-occupation levels, demonstrating that human activities left a lasting imprint in soils as early as the late

Middle Archaic period. Between 5600 and 3900 cal. BP, periods of diminished sedimentation led to more pronounced episodes of soil formation. However, these soil horizons are interposed by pulses of enhanced sediment accumulation. These soil data may signal shifting environmental regimes during the Middle to Late Holocene transition. Between 5600 and 3900 cal. BP scattered plant ash, elevated masses of burned sediment nodules, and pestle fragments in Late Archaic deposits suggest that hunter-gatherers were intensively processing nut mast, potentially in association with early forest clearance and silviculture. Botanical assemblages from a coincident archaeological sequence at the Carlston Annis site in the nearby middle Green River region has demonstrated woodland disturbance and potential silviculture in central Kentucky during this time.

During the Late Archaic and Terminal Late Archaic periods (3900-3000 cal. BP), substantial plant ash deposition occurred in a stratum that accumulated relatively quickly. Very low burned sediment nodule masses in this deposit indicate that combustion features were not common in the immediate vicinity and that elevated frequencies of plant ash were the result of burning on a broader expanse of the surrounding landform. Chronologically, the zone with enhanced plant ash deposition is coeval with previously demonstrated occurrences of increased forest fires, grassland expansion, and a shift to early horticultural economies throughout the region. Soil development occurred after 3000 cal. BP, and this episode of landform stability may have lasted for over two millennia until being capped by sediment accumulation from historic agriculture.

The late Middle Archaic through Terminal Late Archaic data from Crumps Sink demonstrates that hunter-gatherer activities left lasting signatures in soils in Kentucky. The data from the Late Archaic to Terminal Late Archaic periods (ca. 5600-3000 cal. BP) may indicate intentional land burning by hunter-gatherers to create anthropogenic environments, first for silviculture and then for early plant domestication. This forces a rethinking of labor and subsistence systems within hunter-gatherer societies. Thus, if hunter-gatherers were utilizing long-term forest management methods, they were employing a delayed-return economic system relying on labor investment and negotiated understandings about land tenure. Further characterization of the origin of fire management activities will help us to elucidate the nature of incipient indigenous plant domestication in the Eastern Woodlands.

KEYWORDS: Big Barrens Grasslands, Geoarchaeology, Karst Environments, Archaic Hunter-Gatherers, Historical Ecology, Fire Histories

Justin Nels Carlson

04/30/2019

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Date

DEDICATION

To my parents, Lynn and Bruce Carlson.

In loving memory of Bruce Carlson.

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Through the years working on my dissertation project, I have received the support of many people. First, I would like to express my gratitude to the members of my dissertation committee: George Crothers, Chris Pool, Dick Jefferies, Alice Turkington, and Gary Stinchcomb. Through a Cave Archaeology course at Mammoth Cave, George Crothers first captivated my interest in the archaeology of the region. His support, guidance, and enthusiasm during the Crumps Sink excavations was motivating and encouraging. He also provided extensive editorial feedback on multiple drafts of the dissertation. Chris Pool was the first to suggest I use soil micromorphology for a project in his Geoarchaeology class and I am thankful for the opportunities and insights that have resulted from learning the method. Dick Jefferies was a thoughtful sounding board who shared much knowledge as I pieced together the data from the Archaic archaeological record at Crumps Sink. Alice Turkington guided my research paper on karst terrains in her Fundamentals of Geomorphology class, which was foundational for my environmental background chapter. Gary Stinchcomb hosted visits to the Stinchcomb Lab at Murray State University and he assisted me in interpreting the soil geomorphology at Crumps Sink. In addition, Gregory Luhan served as the outside reader for my dissertation defense, and I thank him for his availability and thoughtful comments.

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CHAPTER 1. INTRODUCTION

In the Interior Low Plateaus and Southern Appalachian Mountains of the Eastern United States, marked increases in fire activity (Delcourt et al. 1998; Fesenmyer and Christensen Jr. 2010; White 2007), changes in vegetation patterns (Delcourt et al. 1998; Wilkins et al. 1991), independent domestication of weedy annuals (Smith 2006; Watson 1985), shifts in ground stone tool technology (Applegate 2008; Jefferies 2008), and the decline of the Shell Midden Archaic (Crothers 2008) began in the Late Archaic and intensified during the Early Woodland period. These significant changes suggest that humans impacted surrounding ecosystems in complex and diverse new ways (Baskin et al. 1994; Crawford 2005; Delcourt et al. 1998; Wagner 2003, 2005; Wilkins et al. 1991). While many data have been gathered and models developed to explain the origins of agriculture between the Late Archaic and Early Woodland periods (see Crothers 2008; Smith 2006; Watson 1985), there has not been a comprehensive effort to interweave environmental proxy data with cultural developments during this time, or in the preceding millennia.

In my dissertation, I attempt to understand how cultural events relate to environmental variability in the Midcontinent during the transition from the Middle Holocene (ca. 9000-4200 cal. BP) to early Late Holocene (ca. 4200-3000 cal. BP) (Walker et al. 2012), while also considering the developments in Middle Archaic (ca. 9000-5800 cal. BP) human-environmental interactions that set the stage for the origins of agriculture in the Late Archaic (ca. 5800-3200 cal. BP) and Terminal Late Archaic (ca. 3200-2500 cal. BP) periods (Jefferies 2009). I explore these larger questions with data collected from excavations at Crumps Sink (15Wa6), an archaeological site that spans both the Middle-

Late Holocene and Middle-Late Archaic transitions, and also having a Terminal Late Archaic component (7200-2900 cal. BP). I consider the archaeological record (cultural developments) in conjunction with soil geomorphology (environmental change) at Crumps Sink, and assess human adaptations to Holocene climatic conditions as well as the possibility that hunter-gatherers were creating anthropogenic environments through land burning in south-central Kentucky by the Late Archaic period and perhaps even as early as the late Middle Archaic period. Baskin et al. (1994) make a convincing case for the Big Barrens of Kentucky being the product of anthropogenic land clearing practices, although heretofore this hypothesis has not been tested archaeologically.

The latter half of the Middle Archaic period was marked by the increased importance of formalized ground stone tool technologies including pestles and grooved-axes and the intensive processing and consumption of hickory nuts, acorns, and black walnuts, trends that continued through the Late Archaic period (Gardner 1997; Jefferies 2008, 2009; Moore and Dekle 2010; Simon 2009; Stafford 1994, 2000). Through management of arboreal nut crops, Native Americans were already modifying and cultivating the landscape (Gardner 1997; Wagner 2003, 2005). Based on botanical work conducted on nut shell collected from the Carlston Annis site in the middle Green River region of Kentucky, Wagner (2003, 2005) has argued that Late Archaic hunter-gatherers in central Kentucky created anthropogenic ecosystems, through woodland disturbance, perhaps in relation to silviculture. Corroborating Wagner's findings, Crawford (2005) identified plant remains from Carlston Annis that indicated increased forest disturbance.

Debate on the Origin of the Big Barrens

Native American land management by fire has been hypothesized to have occurred in the south-central Kentucky karst region (Baskin et al. 1994). Within the south-central Kentucky karst, the Sinkhole Plain is a holokarst landscape with no surficial drainage and only subterranean rivers (Hess et al. 1989; Wells 1973). Water can only be accessed through sinkholes, cave entrances, and karst windows, which would have made them important places on the landscape for hunter-gatherers. The lack of surface water also would have made the environment more amenable to fire management. In the late eighteenth and early nineteenth century, the first European visitors to south-central Kentucky noted the prairie-like landscape characterized by expansive grasslands composed of grasses, forbs, shrubs, and scattered trees, calling it the "Big Barrens" (Baskin et al. 1994).

Originally assumed to be a climate-induced extension of Midwestern Tallgrass Prairies (Transeau 1935) that occurred during the Middle Holocene Thermal Maximum (ca. 9000-4200 cal. BP), the grasslands and limestone prairies that spanned parts of Kentucky, Tennessee, Indiana, Illinois, Ohio, and Missouri are now believed to have been created by indigenous land burning (Anderson et al. 2000; Baskin et al. 1994; Chester et al. 1997; Guyette et al. 2003; Heikens and Robertson 1994; Jefferies 2009; Wilkins et al. 1991). A variety of prairie species are found in barren-like ecosystems in the south-central Kentucky karst, with the most dominant one being little bluestem (Schizachyrium scoparium) (Baskin et al. 1994; Chester et al. 1997).

Baskin et al. (1994) argue that the Big Barrens should not be considered part of a climate-induced extension of the Prairie Peninsula and provide several lines of evidence to make their case, including expected climax vegetation in the region being forest, types of soils, paleoecological studies, and indigenous plant and animals species (see Chapter 3). This evidence led the authors and others to argue that the barrens are of anthropogenic origin resulting from indigenous use of fire (Anderson et al. 2000; Baskin et al. 1994; Baskin et al. 1997; Chester et al. 1997; Guyette et al. 2003; Heikens and Robertson 1994; Jefferies 2009; Wilkins et al. 1991). However, not all agree on the origins of barrens ecosystems. Among potential catalysts for changing vegetation structure from forest to grassland are climate, lightning strikes, trampling by large animals such as bison, and human fire regimes (Ray 1997). It is likely that all played a role in the creation and maintenance of the barrens. However, today, when fire is suppressed these environments gradually transition back to woodlands (Anderson et al. 2000; Baskin et al. 1994), suggesting that fire and disturbance was a key element in maintaining this successional habitat.

The timing and origin of the Big Barrens is not known, but it seems possible that they originated during the Middle Holocene Thermal Maximum (ca. 9000-4200 cal. BP), also known as the Hypsithermal or Climatic Optimum (Walker et al. 2012). This was a period of generally warmer and drier conditions throughout the Interior Low Plateaus. By the early Late Holocene, environmental conditions began trending to a cooler and wetter regime, more similar to the climate we see today. Despite the wetter and cooler conditions of the early Late Holocene, pollen records from a sediment core at Jackson Pond in Larue County, Kentucky, show that grassland species became more prominent in central Kentucky by at least 4000 years ago (Delcourt and Delcourt 1979; Wilkins et al. 1991; Jefferies 2008). The continuation and expansion of grasslands in south-central Kentucky, despite Late Holocene environmental conditions favoring forest development, suggests another factor aside from climate may have played a role. Wood charcoal abundance in ponds, deep cave sediments, and upland forest stand soils throughout the Interior Low Plateaus and Southern Appalachian Mountains demonstrate an increased landscape burning by at least 4000 years ago. Increased fire activity occurred contemporaneously with plant domestication in the region, which does not seem to be a coincidence. Based on this data, it is plausible that indigenous populations perpetuated these grasslands by land burning through fire regimes that persisted over four millennia (Baskin et al. 1994; Delcourt et al. 1998; Fesenmyer and Christensen Jr. 2010; White 2007; Wilkins et al. 1991).

This leads us to ask when did Native Americans begin to modify the landscape with fire in the Sinkhole Plain and how does it relate to the archaeological record? Few paleoecologists have comprehensively incorporated the archaeological record into their discussions of regional vegetation and fire histories (Delcourt et al. 1998 is an exception). Similarly, few archaeologists have adequately considered the historical particulars of environmental and cultural developments in preceding millennia that would have preceded or played a role in the origins of agriculture. While Baskin et al. (1994) were able to demonstrate that the origin and maintenance of the barrens does not match expectations based on the climate, more work is needed to refine chronologies of fire activity in the region, determine the extent to which humans played a role in the process, and integrate these findings with the paleoenvironmental and archaeological record. Here, I test Baskin et al.'s (1994) hypothesis that barrens ecosystems in the south-central Kentucky karst were created and maintained by indigenous land burning by at least 4000 years ago. I will argue that Native Americans played a significant, complex role in managing ecosystems through prescribed burns as early as the Archaic period.

Theoretical Background

I employ an historical ecological approach that challenges the nature-culture dichotomy and recognizes that humans and the environment are not disconnected, but rather are historically intertwined, mutually affecting each other (Balée 1998a, 2006). The historical ecological perspective also acknowledges that even small-scale societies such as hunter-gatherers and horticulturalists can transform the environment, resulting in persistent ecosystem legacies (Hayashida 2005; Lightfoot et al. 2013). I view forest management as long-term investment in land, drawing from the concept of landesque capital (Håkansson and Widgren 2014). I utilize an institutional economic perspective to model how hunter-gatherers in Kentucky may have begun managing their environments through collective action. Social negotiations over land as a common-pool resource are fundamental to successful management (Ostrom 1990). These investments in land are historically contingent and change over time depending on the values and needs of the users (Widgren and Håkansson 2014). Diachronic changes in human land use may leave traces in the soil geomorphological record, even if only evident at a microscopic level. These traces can be interpreted in conjunction with archaeological and environmental data for a holistic understanding of human-environmental relations in the past (Balée 1998b, 2006; Crumley 1994, 1998). Shifts in property rights regimes, silviculture, fire ecology, plant domestication, changing tool technologies, and changes in vegetation structure in central Kentucky, and throughout the Eastern Woodlands, were likely mutually dependent and historically contingent. To identify the relationship between cultural and environmental developments, an interdisciplinary data set is needed.

Research Questions

1. What is the relationship between natural climatic/environmental regimes and humans intentionally manipulating the environment beyond these climatic proxies in the grassland barrens of the Sinkhole Plain?

2. What is the chronology for human manipulation of barrens ecosystems by fire?

3. What evidence distinguishes human induced fire regimes from a natural fire history?

4. What were the effects of prehistoric vegetation change and human land modification on sediment deposition and soil formation in sinkholes of the south-central Kentucky karst?

Geoarchaeology at Crumps Sink

In 2015, I conducted excavations in Crumps Sink in the Sinkhole Plain of south-central Kentucky and collected an interdisciplinary and complementary dataset, including (1) soil and sediment samples to understand the environmental history of the site, (2) artifacts to understand technological developments in relation to environmental change, and (3) botanical and faunal records to understand human diet over time. Archaeological deposits were hand excavated to 3.8 meters, until reaching archaeologically sterile colluvium, likely redeposited loess. Bucket augering of this lower deposit extended an additional 1.4 meters until reaching rock, possibly roof fall from the cave when the sinkhole collapsed. Thousands of artifacts were recovered, including flaked stone projectile points, ground stone tools, bone awls and needles, a gorget and shell beads. Refuse representing hunter-gatherer diet over a 4300-year time span included thousands of fragments of animal bone from deer, turkey, and aquatic species, mussel shell, and a high density of charred nutshell. Pit and hearth features were also encountered suggesting humans were occupying or doing activities within the sinkhole, aside from trash disposal.

A series of twelve radiocarbon dates show archaeological deposits at the site date between 7200 and 2900 cal. BP. The dates reveal very little mixing and demonstrate that consistent colluvium and sheet-wash accumulation from the sinkhole edge capped archaeological remains relatively quickly during the 4300-year sequence, resulting in a deposit with exceptional stratigraphic integrity. Upon documentation of the soil profile, it was evident that the deposit was stratified with a succession of four buried soils, and the modern A horizon at the surface. Being in a catchment basin, these soils are cumulative, meaning that they are constantly receiving sediment at varying rates. However, these former surfaces indicate decreased sedimentation and some degree of landform stability. Colluvium and sheet-wash were deposited during periods of enhanced sedimentation indicating some degree of landform instability. With extensive radiocarbon dating, the soil geomorphology of the sinkhole could also be correlated with the climatic pulses of the Middle to Late Holocene periods and with key cultural developments and perhaps human impacts on the landform during the late Middle Archaic, Late Archaic, Terminal Late Archaic periods.

After profile documentation, I collected loose soil/sediment samples in a vertical column at 5 cm intervals for bulk sediment analyses including magnetic susceptibility, loss-on-ignition, and plant available phosphorous. Magnetic susceptibility and loss-on-ignition lab analyses helped further establish that these were buried soils, while also providing information on human impacts on the landform. Plant available phosphorous analyses also provided information concerning human impacts on the landform. To assess anthropogenic impacts, I quantified anthropogenic “inputs” of lithic material, burned sediment, and animal bone at 10 cm intervals throughout the vertical extent of the archaeological deposit. Non-culturally modified rock, which may be evidence of exposed bedrock around the sinkhole, was also weighed to provide information on erosion at the site.

In addition to bulk sediment analyses, I conducted soil micromorphological analyses to better understand soil development and sediment deposition at the site. I also considered a key anthropogenic input that may provide information on prescribed fire regimes at the site; plant ash manifested as microscopic calcium carbonate spherical nodules and rhombs. These nodules form during the combustion of plant cells. The data collected from the Crumps Sink investigations are compared with comprehensive climatic data indicated in sedimentological sequences from central Kentucky and the greater Interior Low Plateau and Southern Appalachian regions. To my knowledge, no site like Crumps Sink within a sinkhole has been excavated in Kentucky, and this study provides new information on how humans used these landforms. It is evident that as sedimentary catchment basins, sinkhole landforms have significant potential for archaeological and paleoenvironmental studies.

In Chapter 2, I outline the theoretical concepts that guide this study. Chapters 3 and 4 discuss the environmental and archaeological background, respectively, for the study area. Chapter 5 summarizes the 2015 archaeological investigations and materials recovered at Crumps Sink. Chapter 6 assesses data gathered from field and lab analyses to discuss soil geomorphology and environmental change over time around Crumps Sink and integrates these data into the larger context of the Middle to Late Holocene environmental transition. In Chapter 6, I also explore anthropogenic impacts on the site and the role of Archaic hunter-gatherers in managing ecosystems, including barrens, surrounding Crumps Sink through burning, as well as when and how this may have occurred. Chapter 7 evaluates the diachronic trends in soil formation, erosion, and human activities at Crumps Sink derived from this study and models how hunter-gatherers may have made decisions concerning sustainable management of the resources in and around the sink. This is followed by a discussion of larger environmental and cultural developments in the region, considering how early anthropogenic environments may have established social and ecological legacies contributing to the advent of horticultural economies in Central Kentucky.

Implications

This research is significant for a variety of reasons: (1) the implications of changing human-land interactions in relation to the origins of agriculture in the Eastern U.S. (Crothers 2008; Smith 2006; Watson 1985); (2) further assessment of recent research suggesting that prehistoric small-scale societies were more active agents in transforming their landscapes than previously believed (Lightfoot et al. 2013); (3) developing a model of how hunter-gatherers and horticulturalists occupy and utilize holokarst landscapes; (4) determining the catalysts for prehistoric origins of grasslands in the Interior Low Plateaus (Baskin et al. 1994); (5) contributing to contemporary dialogue concerning barren grassland management in the Midwestern United States (Anderson et al. 2000); (6)

elucidating the Holocene history of geogenic, biogenic, and anthropogenic sediment deposition in a karst setting; and (7) offering a framework for distinguishing between human activities and environmental processes over time.

Through studies of land management in hunter-gatherer and horticultural societies, I argue that these groups were active managers of the landscape to a greater degree than previously acknowledged. This forces a rethinking of labor and subsistence systems within these societies, as well as the social and ritual elements that play a role prohibiting or enabling specific types of land-use (Lightfoot et al. 2013). Thus, if hunter-gatherers in Archaic Period Kentucky were utilizing long-term forest management methods to increase nut yields, or perhaps for a variety of other social, ritual, and economic reasons, then this suggests a delayed-return economic system relying on labor investment and negotiated understandings about land tenure. Characterizing the origin of fire management activities in central Kentucky will help us to further elucidate the nature of incipient indigenous plant domestication.

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CHAPTER 2. THEORETICAL BACKGROUND

Anthropogenic Environments

Landscape modification predates the industrial age by thousands of years and few ecosystems are truly pristine (Denevan 1992; Hayashida 2005). Recent literature has demonstrated that, throughout history, humans have modified landscapes in a variety of ways through terraforming and creating raised fields, complex geoglyphs, monumental architecture, irrigation systems, anthropogenically enhanced soils, and land burning (Balée 1998a, b; Crumley 1994; Doolittle 2000; Håkansson and Widgren 2014; Pyne 1998, Smith and Wishnie 2000). Depending on the social, political, and economic needs of the users, these anthropogenic environments were created, maintained, and abandoned throughout their history, though the signatures of such activities may remain and influence later use (Dean 2010; Zaro 2014).

While examples of environmental degradation are evident in the archaeological record, many modifications, such as land burning, had beneficial ecological effects including enhancing floral and faunal diversity or overall biological productivity and mitigating the severity of future forest fires (Håkansson and Widgren 2014; Pyne 1998; Roos 2008). For example, ethnohistoric accounts show that Native Americans used fire in North America to supplement cultivation practices, increase forest and prairie biodiversity, and improve hunting success (Williams 2002). This evidence challenges the "Pristine" and "Forest Primeval" myths that the forests of the Americas encountered by early European visitors had never been modified by indigenous populations (Denevan 1992, 2011; Doolittle 2000; Hicks, Jr. 2000).

In the Cumberland Plateau, prescribed fire has been implemented by restoration ecologists as a tool to manage forest structure and composition and increase floral and faunal biodiversity. Royse et al. (2010) conducted controlled burns in the Daniel Boone National Forest of the Cumberland Plateau. They were primarily concerned with white oak (*Quercus alba*) and chestnut oak (*Quercus prinus*) regeneration (i.e., the success rates of acorns developing into trees). Fire suppression in the Cumberland Plateau since the 1930s had allowed fire intolerant mid-story species such as red maple (*Acer rubrum*) and white pine (*Pinus strobes*) to dominate canopy space and restrict sunlight to oak seedlings. Monitoring revealed that oak mortality was largely correlated with how deeply acorns were buried within leaf litter and the amount of sunlight available to the seedlings and saplings. In burned areas, leaf litter was shallower and more sunlight passed through the canopy, allowing for more successful regeneration of oak seedlings (Royse et al. 2010).

Throughout the Southeastern United States, it has been shown that prescribed burns can promote the carrying capacity of animals that thrive in edge areas between woodlands and grasslands, such as deer and some birds. For example, Key deer on Big Pine Key Island in south Florida seek environments with a range of diverse stands for cover and subsist on herbs in open habitats formed by fire in rockland pine ecosystems (Carlson et al. 1993). In the Blue Ridge Mountains of Western North Carolina, bird species richness increased after high-intensity controlled burns, and it potentially increased after low-intensity controlled burns (Greenberg et al. 2013). In the Southern Appalachian uplands of Georgia, bird species diversity increased 26 to 44 percent after low- and high-intensity burns (Klaus et al. 2010). However, ecosystems can vary in their response to fire, requiring land managers to consider season, fire intensity, species composition, and goals of burning prior to this applied approach. For example, prescribed fires affected bird species in east-central Missouri differently; certain species favor disturbed areas over others. This suggests that burns should be prescribed in a way to maintain both burned and unburned stands (Blake 2005). In pine forests of the Atlantic Coastal Plain of Georgia, burning helps maintain brood habitat for wild turkey populations, though it was suggested that prescribed burns should be conducted in the winter after the spring nesting season (Sisson and Speake 1994).

The preceding examples from restoration ecology literature are important for understanding how Native Americans may have improved landscapes for subsistence in the past, and archaeological evidence demonstrates that certain resources that would increase from fire activity were prominent food sources. For example, hardwood tree nut crops were a major food source for Native Americans, and it is probable that they were practicing a form of silviculture through land clearing by fire to encourage nut-bearing trees (Abrams and Nowacki 2008; Gardner 1997; Munson 1986; Wagner 2003, 2005). Prescribed burning and land clearance also may have played a role in the early domestication of plants in the Cumberland Plateau (Delcourt et al. 1998; Ison 2000). Additionally, records of animals from archaeological sites in the Eastern Woodlands and Midwest demonstrate that species such as white-tailed deer were a large component of the Native American diet (Crothers 2005; Styles and McMillan 2009). To address the research questions presented in Chapter 1, we must consider past environments and archaeology in in a holistic way. Below, I outline the theoretical foundation for such an analysis.

Historical Ecology

The historical ecological approach challenges the nature-culture dichotomy and recognizes that humans and the environment are not disconnected, but rather are historically intertwined and mutually affect each other to varying degrees (Balée 1998a, 2006). It also acknowledges that even small-scale societies, such as hunters and gatherers, can transform the environment resulting in persistent ecosystem legacies (Hayashida 2005; Lightfoot et al. 2013). An historical ecological approach attempts to account for the diachronic changes in a landscape over time or the *longue durée* (Balée 1998; Crumley 1994, 1998). To do this, interdisciplinary efforts involving the "hard" and "soft" sciences must be undertaken for a holistic understanding of a region (Crumley 1998).

The *landscape* is an important focus of an historical ecological study (Balée 1998b, 2006; Crumley 1994). Historical ecology postulates that (1) humans have impacted nearly all landscapes on earth in some way and few places are truly pristine, (2) humans do not only leave landscapes in environmental ruin, (3) human impacts differ depending on cultural and historical conditions and in some cases they can actually improve species diversity, and (4) the manifestations of human action can be studied in interdisciplinary ways over large areas (Crumley 1994; Balée 2006; Hayashida 2005).

Societies and ecosystems are not static or unilineal in their trajectory and have long, dynamic histories (Crumley 1994; Winterhalder 1994). Because of this, the ways in which people negotiate use of land resources are historically contingent. Additionally, ecosystem "adaptations are a response to an exact historical sequence of environmental conditions" and species do not always respond as expected in an ecological systems approach that emphasizes equilibrium (Winterhalder 1994:31). Rather, ecosystems are dynamic and human induced disturbance may leave lasting signatures in the environment (Winterhalder 1994). These transformed ecosystems may influence cultural or ecological circumstances that occur after their development.

Historical ecology builds on a variety of earlier theoretical paradigms with the purpose of understanding human-environmental interactions, including cultural ecology, evolutionary ecology, human behavioral ecology, and human ecology. Cultural ecology focuses on how humans adapt to environmental conditions, though it does not adequately account for human agency in transforming those environments or the dynamic nature of ecosystems. Because cultural ecology was primarily developed for studying egalitarian societies, it has been difficult to apply to state-level societies (Balée 1998b, 2006; Crumley 1994). Evolutionary ecology has also been important in the development of historical ecology (Winterhalder 1994). However, an historical ecological approach argues for historical and cultural processes being as important in shaping ecosystems and society as evolutionary processes (Balée 1998b, 2006). Human behavioral ecology builds upon evolutionary ecology, though there is more of a focus on adaptive *human* behaviors in response to social and environmental conditions. Human behavioral ecology predicts how people should act in specific environmental conditions and tests these predictions with ethnographic data. By applying evolutionary models to cultural ecology, human behavioral ecology suggests that natural selection guides variation (Kelly 2013). Human ecology has been used effectively in conjunction with a contextual approach that considers interdisciplinary data sets, including archaeological, geological, biological, and climatic, to answer questions about human land relationships and recognizes that humans can cause geomorphological change that can have environmental effects (Butzer 1982; Waters 1992).

Yet, human ecology has been critiqued for lacking “an explicit historical component” (Crumley 1994:4). The contextual approach relies on an ecological systems approach that assumes equilibrium (Waters 1992).

Though historical ecology offers a comprehensive methodology for tracing human-environmental interactions over time, critiques of the approach suggest the need for greater consideration of the role of human decision-making in modifying or adapting to environments. Whitehead (1994:36) wrote “Simply to chart changes in landscape through time once again places phenomena rather than persons at the center of explanation,” and “the history of an ecology is more complex…and must include an account of the synergetic impacts of changing human ideas”. Similarly, Widgren and Håkansson (2014:12) argue that historical ecology has not adequately considered “how different types of social processes are linked to different human-environmental relationships”. Thus, for historical ecology to better address anthropological questions it requires additional explanatory scaffolding to go beyond the data and into the social processes that were occurring over the *longue durée*. Below, I consider theory on common-pool resources, property rights, social institutions, landesque capital, and traditional ecological knowledge among hunter-gatherers and horticulturalists to model how humans may have actively managed past environments in central Kentucky.

Common-Pool Resources

Societies throughout the world have found diverse ways to manage common-pool resources (CPRs) (Acheson 1989; Ostrom 1990; 2000). A CPR is “a natural or man-made resource system that is sufficiently large as to make it costly (but not impossible) to exclude potential beneficiaries from obtaining benefit from its use" (Ostrom 1990:30). In CPR systems (1) the resources must be bound physically/spatially, biologically, or socially, (2) a distinct group of users has free rein over the resources, (3) several users take part in extracting resources, (4) there are understood rules, formal or informal, in regard to the right way to extract resources, (5) all users are entitled to resources that have yet to be extracted, (6) there is competition for resources, and finally, (7) a group of people who have exclusive rights exist, who may or may not be the people using the resource (Stevenson 1991). Individuals must be willing to accept certain costs (Smith and Wishnie 2000) and work with others to construct "a good that helps a community or collectivity achieve a goal" (Acheson 1989:376). Thus, "the management of common pool resources often relies on the existence of sharing systems" (Kagi 2001:5). The benefits of such management must outweigh the costs (Acheson 1989).

Societal conceptions of property rights play a key role in negotiations around resources. Barnard and Woodburn (1988:10) argue that "rights in property, together with other socially recognized links between people and things, are vehicles for the expression of ideals and values and other manifest concerns about the nature of human beings and the way they relate and should relate to others". Bromley (1992:4) writes that "property is a social instrument, and particular property regimes are chosen for particular social purposes". Though generally egalitarian, hunter-gatherer groups do have conceptual understandings of property, and they structure their lives in relation to property. Cashdan (1989:40) notes that "virtually all foragers have systems of land tenure (usually communal) that control access to the land and its resources". In hunter-gatherer societies, there are several types of property rights, including those over (1) landscapes and the resources that can be found upon them, (2) portable property such as tools and other utilitarian wares, weaponry, clothing, and decorative items, (3) food such as meat and harvested vegetables, (4) the labor and capacities of others, and finally (5) knowledge (Barnard and Woodburn 1988:14).

In terms of portable property in hunter gatherer societies, there often are cultural norms in place which do not allow for any one person to accumulate wealth beyond that required for day to day life. Hunter-gatherers must share these items. Food items often belong to those who acquire it, but must be shared if the person has more than they can immediately consume. Types of sharing include giving of gifts in the form of goods or food without expecting anything in return, exchange in which both people or groups get something, redistribution, and demand sharing (Kagi 2001; Peterson 1993). In terms of technological investment, hunter-gatherer groups can expend a great deal of labor gathering materials for production and maintenance of tools (Kelly 2013). Mobility, common in hunter-gatherer societies, is a risk aversion strategy that preserves access to a wide and diverse resource base for water, food, and raw materials for tools. It also allows for social interaction with other groups (Cashdan 1989; Crothers and Bernbeck 2004; Kelly 2013). In general, there are few foraging societies in which people impose control over the rights of the capabilities and labor of other people. However, that does not mean that such tactics do not occur in hunter-gatherer societies (Barnard and Woodburn 1988).

Access to CPRs can range from open to restricted (Kagi 2001; Ostrom 1990). Kagi (2001:6) defines an open-access system as “a situation in which there is no clearly defined group of economic agents, entitled to use the resource, and where there exist no rules or restrictions on resource use”, and a common property system as “a situation in which a clearly defined group of economic agents has sole access to the resource and where rules and restrictions on using the resource exist". In an open-access situation, the concept of ownership does not exist, "only the opportunity to use something" (Bromley 1992:11). If resources in an area are highly variable, patchy, or diffuse, providing limited productivity, groups may decide that it is not worth defending or claiming them (Acheson 1989; Crothers 2008; Eerkens 1999). In this sense, the groups would be employing an open-access system.

In hunter-gatherer societies, it can be expected that people are "naturally endowed" with the right to access and extract resources from the surrounding landscape: "The general principle in use of land is that access to resources in one's home area is automatic and unchallengeable, untrammeled by formalities or gestures of any sort towards one's seniors, the living or the dead, who have used these resources before oneself but who are given no role in handing them on" (Barnard and Woodburn 1988:15). In his discussion of hunter-gatherers during the Archaic period in Kentucky, Crothers (2008:138) suggests that as long as there was low population density and resources were not overused, social networks would remain "intimate, interaction…iterative, and information…freely obtained and given". While open-access systems often are the most effective method of resource maintenance, they do have potential disadvantages, including uncoordinated land use where it "can be life threatening if a group unknowingly enters a region already harvested by another group" (Eerkens 1999:311).

Common property systems may occur in areas where resource patches are defined and highly productive (Acheson 1989). In areas where commonly open-access systems are employed, common property regimes may be enforced in times of uncertainty, ecological catastrophe, or demographic change. Eerkens (1999) suggests three reasons traditional societies might decide to create and enforce common property systems: (1) the cost-benefit of defendability, (2) environmental risk buffering, and (3) social conflict buffering. If an area has only sparse resources or the needed extraction technology for the available resources is too costly then groups will decide that it is not to their benefit to defend. Concerning environmental risk buffering, through CPR systems, harvesting agreements are established to minimize the potential of overharvesting or adversely affecting others. Social conflict buffering is a mechanism that can be used if social relations fail to a point where they cannot be mended. In this way, open areas allow for buffer zones, places to escape, and an area where game and resources can regenerate due to lack of harvesting (Eerkens 1999).

When an area is deemed worth protecting, and rich in resources, there are two mechanisms to attain a necessary balance, those being perimeter defense and social boundary defense. Perimeter defense involves guarding a spatially bounded area with the intent to exclude others from obtaining resources. Social boundary defense involves withholding critical information, thus, preventing others from harvesting resources (Eerkens 1999). Resources that at one time may have been open-access may become more exclusive as common property regimes develop, with groups increasingly controlling access to territories and developing alliances with surrounding groups to maintain these territories (Johnson 1989).

Stevenson (1991) argues that CPRs are not “physical or tangible objects” but rather, social institutions put in place to manage resources. Land management goals can be achieved through enforcement of these social institutions (Ostrom 1990, 2000). North (1990:1) defines institutions as “the rules of the game in a society or, more formally,…the humanly devised constraints that shape human interaction”. For Ostrom (2000:143-144), institutions and social norms can be defined as “shared understandings about actions that are obligatory, permitted, or forbidden”. Berkes and Turner (2006:490) suggest institutions “develop out of the accumulation of knowledge and the elaboration of resource management practices of a group of people capable of making decisions to alter their actions through learning”.

Failure to reproduce or adhere to these norms within small groups will be noticed by others in the group, which is often reason enough not to resist or disregard them (Ostrom 2000). Rules may be enforced through “socially regulated access, management rules governing resource harvests, means of monitoring compliance to these rules, and sanctions to punish those who violate them” (Smith and Wishnie 2000:504). For North (1990:1), “institutional change shapes the ways societies evolve through time and hence is the key to understanding historical change”. The concept of CPRs helps us understand how groups negotiate resources. However, to understand how and why people create anthropogenic environments we must understand how and why humans invest in those resources. Rather than ecosystem resources being static, they are dynamic and can be transformed through active management.

Landesque Capital

Amartya Sen introduced the concept of *landesque capital* for increased land productivity and *laboresque capital* for increased labor productivity in what he deemed ‘underdeveloped countries’ (Widgren and Håkansson 2014). When discussing preindustrial agriculture in the Pacific, Brookfield (1984:16) utilized the concept of landesque capital: “Some innovations create ‘landesque’ capital, which once created persists with the need only of maintenance; other innovations require continued application and leave no lasting mark on the land”.

Blaikie and Brookfield (1987:9) define the concept of landesque capital as “any investment in land with an anticipated life well beyond that of the present crop, or crop cycle”. Investment occurs with the intent to improve the capacity of the landscape for economic benefits. Widgren and Håkansson (2014) expound upon the concept of landesque capital and state that “such investments, although physical, are both an integral part of, and reflection of, social processes” (Widgren and Håkansson 2014:13). There may be social, ritual, or economic incentives for institutions to be enacted and individuals to invest labor and time to alter the environment. Investment in the land is often not temporary, and may lead to land tenure by certain individuals with vested interest in the land, while also sparking innovation (Håkansson and Widgren 2014). In some cases, signatures of landscape modification may be apparent for millennia (Brookfield 1984; Widgren and Håkansson 2014). Landesque capital recognizes that changing property rights over land are central to the creation, maintenance, and even the abandonment of modified environments. A key question that landesque capital asks is: what are the incentives for people to invest labor in land management (Widgren and Håkansson 2014)?

Some researchers have questioned the applicability of landesque capital to small-scale societies such as hunter-gatherers and horticulturalists, most notably due to the use of the term ‘capital’, as in ‘capitalist societies’. Widgren and Håkansson (2014:21) believe that precapitalist anthropogenic alterations such as irrigation, terraces, and enriched soils “qualify as capital (in a Marxist sense) because they are integral parts of economic flows and wealth accumulation". Bayliss-Smith (2014) warns against only considering landscape modification in an economic sense and recommends considerations of both intrinsic (social) value and instrumental (economic) value. Morrison (2014) suggests that the economic leaning concept of capital does not adequately account for social and cultural complexities. Hornborg et al. (2014) offer "symbolic" capital to address monumental nonagricultural constructions such as mounds. For Widgren and Håkansson (2014:23), though, when landesque capital is considered with historical ecology, it allows for a discussion that goes beyond economic choice, into an approach that is "deeply contextual and historically contingent". Morrison (2014) suggests that a contribution of landesque capital is that small-scale societies were capable of altering their surrounding landscape, sometimes improving them in an economic sense.

In some prehistoric precapitalist societies, human labor investment over long periods of time has been demonstrated by agricultural practices that leave lasting impressions including terraces and irrigation canals constructed with stone and earthen materials. However alteration of vegetation structure by hunter-gatherers may leave less obvious traces upon the landscape. Thus, these investments often are not recognized in the archaeological record (Börjeson 2014). Börjeson describes three different types of capital as grey (stone construction), brown (earthen construction), and green (vegetation alteration) and argues we must investigate green capital transformations with innovative and interdisciplinary approaches. It is my contention that subtle human impacts on the forest and its soils can be evaluated through a variety of chemical, magnetic, and microscopic methods, allowing for the recognition of difficult to see landscape modifications by foraging societies. With the concept of investment, landesque capital helps us further understand how and why people might make efforts to alter their surrounding environs.

Immediate vs. Delayed Return Systems

Generally, it has been argued that hunter-gatherer groups operate under immediate-return systems and sometimes delayed-return systems, while horticulturalists and agriculturalists operate under delayed-return systems. Immediate-return groups procure resources with the intent of using them within a short time of initial extraction, while delayed-return groups input labor over time with the expectation of future resource yields (Barnard and Woodburn 1988). Although many hunting and gathering peoples have immediate-return economic systems, it is apparent that they may also make long-term investments in their landscapes. The degree to which hunter-gatherer societies, in particular, played a role as active managers of their surrounding ecosystems has been debated, though more evidence is demonstrating a considerable degree of organization and investment towards those ends (Lightfoot et al. 2013). Therefore, we can no longer assume that hunter-gatherers passively adapted to surrounding environments. Instead we should favor a view that acknowledges and investigates the agency hunter-gatherers had/have in transforming those environs (Lightfoot et al. 2013). If hunter-gatherers were burning the landscape with an expectation of future yields well beyond the act, then we should consider this a delayed-return system and must also rethink how these groups were negotiating relations over land, portable objects, food resources, people, and knowledge. These investments also can be considered in relation to debates about whether human impacts on the environment were purposeful in aim of conservation, or rather indirect results of other activities, and more reminiscent of sustainability.

Conservation and Sustainability in Traditional Societies

As we learn more about the amount of cultural knowledge and degrees of landscape modification by indigenous societies, we begin to realize how successful many groups were in managing and increasing the biodiversity of natural resources. This has led many people to equate human-environment coexistence with conservation. However, others suggest that we should be cautious in our application of the term "conservation" to these practices (Berkes and Turner 2006; Low 1996; Smith and Wishnie 2000). Low (1996:354-355) argues that many have viewed traditional societies as "ecologically aware, and environmentally altruistic" due to "romantic misconceptions". Low (1996:353) argues that "the low ecological impact of many traditional societies results not from conscious conservation efforts, but from various combinations of low population density, inefficient extraction technology, and lack of profitable markets for extracted resources". In other words, small-scale groups are often quite successful at not over-exploiting surrounding resources, though it is based upon demographic and ecological circumstances rather than a conscious strategy or "sacred prohibition" (Low 1996:353).

Additionally, while restraint from depleting resources has been shown to conserve ecosystems, anthropogenic disturbance has been demonstrated to increase resource diversity creating 'habitat mosaics' in novel ways, including prescribed land burning (Smith and Wishnie 2000:514). Alvard (1995:790) defines conservation as "subsistence decisions that are costly to the actor in the short term but aimed at increasing the sustainability of the harvest in the long term." Smith and Wishnie extend this definition arguing that "any action or practice must not only prevent or mitigate resource overharvesting or environmental damage, it must also be designed to do so" (2000:493). One way in which conservation is beneficial for the natural environment is through increasing biological diversity or species richness. The most conducive environments to increasing species richness are early successional habitats created by disturbance, sometimes anthropogenic. Oftentimes, the maintenance of disturbed environments over the long-term enhances biological diversity, as there is a mosaic of habitats created along a spectrum ranging from recently disturbed (early successional) to relatively undisturbed (late successional) (Smith and Wishnie 2000). Thus, according to this definition, propagating or protecting certain plant species through irrigation, seed dispersal, and periodic burning are conservation practices.

Smith and Wishnie (2000) suggest that conservational successes occur when (1) land is controlled or exclusively owned, (2) there are easily distinguishable resources, which (3) rapidly renew themselves in response to disturbance, (4) delayed returns outweigh the immediate returns, and (5) resource using groups are small and stable, accepting institutions governing the use of the resources. They propose that ineffective conservation would result from (1) high demand from groups beyond the resource base (2) rapidly increasing population density, (3) scarcity of resources, (4) availability of alternative resources that are easily substitutable for the scarce resources in question, (5) introduction of novel technologies or ability to move into novel habitats, and (6) ability to relocate loci of production (Smith and Wishnie 2000).

If biodiversity increases as an indirect, nonpurposeful result of human actions, then it can be categorized as sustainability. Switching patches prior to patch depletion would be an example of sustainability, following the marginal value theorem that "predicts that an efficient forager will generally leave a patch well before total exhaustion of resources has occurred" (Smith and Wishnie 2000:512). While the ultimate product may appear as a result of people considering a collective good, Smith and Wishnie (2000:493) suggest that enforcement of institutions hints at the need to diminish the tendencies of self-interested individuals: "Theory thus predicts, and evidence suggests, that voluntary conservation is rare. However, sustainable use and management of resources and habitats by small-scale societies is widespread and may often indirectly result in biodiversity preservation or even enhancement via creation of habitat mosaics".

Adaptive Learning and Traditional Ecological Knowledge

With the explanatory framework outlined above, we can develop models for how humans and the environment interact through feedbacks, as well as how humans approach surrounding landscapes depending on a variety of historical circumstances. Citing ethnographic and ethnohistoric studies, Berkes and Turner (2006) propose three models of how conservation regimes develop in association with cultural knowledge. These include: (1) Depletion Crisis, (2) Ecological Understanding, and (3) Adaptive Co-management. In the Depletion Crisis model humans begin to conserve landscapes as a reaction to resource depletion that adversely affects them. The Ecological Understanding model suggests that humans develop knowledge as part of constant interactions with the surrounding landscape, modifying their approaches as necessary (Turner and Berkes 2006). This requires incremental learning, a distinct amount of social memory, and ecological knowledge. The Adaptive Co-management model combines Depletion Crisis and Ecological Understanding scenarios and "may be defined as a process by which institutional arrangements and ecological knowledge are tested and revised in a dynamic, ongoing, self-organizing process of learning-by-doing" (Berkes and Turner 2006: 486). The authors see the process as related to feedbacks within a system, and conservation is something that is learned. Berkes and Turner (2006:491) write "A communal knowledge base takes a long time to develop, and practices based on such knowledge even longer".

Modelling the Origins of Anthropogenic Environments in Central Kentucky

As indicated by current efforts in restoration ecology, prescribed fire can enhance bio-productivity (more bird species, edge species such as deer, or nut mast), perhaps indirectly or purposefully. Along with the environment, the advent of fire management may transform social institutions through new conceptualizations of property rights, information exchange, and land tenure relations. In Archaic period Kentucky, the Common-Pool Resource may have been land and resources upon that land. If people considered land burning to be a useful economic strategy, there would have been an incentive to continue the activity, social norms governing burning at specific times and places would have been enforced, and more people would have joined in collective action to manage these environments. As groups invested in the land through burning, there may have been a movement from open-access to common-property systems to maintain these enhanced resource locales.

The modification of ecosystems, with expected increased future yield of resources such as nut mast or areas that attracted species such as white-tailed deer, would indicate a movement from immediate-return to delayed-return subsistence economies, even before the advent of horticulture. In fact, this property regime may have been foundational for the origins of agriculture in central Kentucky (see Crothers 2008; North 1990). In his discussion of the origins of plant domestication in the upper and middle Green River region of central Kentucky, Crothers finds the concept of property rights to be a valuable explanatory tool for changing human-plant relationships. He writes that such a "transformation…is fundamentally an institutional change in the way humans perceive resources, negotiate rights of access or ownership, and organize the social relations of production" (Crothers 2008:128).

It is unlikely that this occurred as a slow, uni-directional progression. Rather, these processes occurred in concert with sociopolitical and environmental circumstances, and it is likely that groups were frequently refining their approaches to adapt to and manage surrounding resources. Some groups may have even resisted new adaptations in favor of more familiar methods. Changing strategies may have been in response to resource depletion, greater understanding of existing and newly emerging ecosystem conditions, and/or a combination of the two. Additionally, some strategies of resource management or sharing would have changed depending on the needs of those using the resources. Through changing approaches to the landscape, we may expect that humans gain incremental knowledge of how different approaches to the landscape may influence biodiversity, with their approaches changing depending on the success or failure of ecosystem feedback. We also may expect that activities such as land burning would leave an imprint on the landscape transforming the environment in such a way as to shape future ecosystems in the region. Such ecosystem legacies, combined with land management strategies, could have played a role in early horticultural economies in the region.

As property rights and organizational systems were negotiated around the land and its resources, so were they negotiated around portable items such as tools, food, human labor, and knowledge (Barnard and Woodburn 1988). Tool technologies such as grooved axes and celts can require investment in raw material acquisition, manufacture, and curation, but these tools would have played an important role in forest management. Depending on land clearance needs, these tools might have been re-engineered. Information exchange concerning scheduling of burns and resource access would be critical for resource management and claims to resource patches, perhaps leading to greater efforts toward communication. If a group decided to set a fire over a large area, many people potentially would be affected.

Implications

If Archaic hunters and gatherers in Kentucky were burning to create a forest mosaic of varying resources, the implications are profound. These groups, already successfully adapted to resource availability associated with seasonal changes and flux in population parameters, were actively managing surrounding ecosystems through delayed-return systems that suggest investment strategies more similar to horticultural economies, rather than passively encountering available resources. In horticultural societies, corporate kin groups often control access to territories and develop alliances to maintain these territories and social interaction with surrounding groups. These groups rely more heavily on domesticated plants to supplement their diets (Johnson 1989).

In my view, this does not discount the idea of human adaptation. In fact, I believe that recognition of a need to adapt may provide the impetus for agentive innovations. Much as environmental conditions impact us today, they were an important variable in hunter-gatherer lifeways in Kentucky's past. Some have argued that there has been too much focus on the environment, especially in Archaic period research, and question the explanatory strength of environmental models (see discussion in Emerson and McElrath 2009). Of course, as research on anthropogenic environments has demonstrated, groups make decisions to alter their environments, requiring us to view their social and historical circumstance that affect these decisions. However, environmental data are still important, and we must not divorce environmental models from the social and economic conditions of human interaction. We must find holistic ways to connect the two, and I believe that this chapter has provided a comprehensive framework for such an analysis.

To understand how the creation of anthropogenic environments by fire may have happened over millennia in central Kentucky, and more specifically how an associated property regime would take hold in the Sinkhole Plain, I compare data from archaeology, soil geomorphology, forest ecology, karst hydrogeology, and paleoenvironmental reconstructions. I then use data collected from my excavations at Crumps Sink to show that the archaeological and soil geomorphological record of the site are manifestations of environmental and social conditions that were in place at the time of deposition. Thus, these data can be interpreted to better track human-environmental interactions through time. Finally, I merge the environmental and archaeological record with the theoretical approaches outlined in this chapter to model how humans created anthropogenic environments in central Kentucky. But first, in line with an historical ecological approach, we must consider the landscape.

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CHAPTER 3. ENVIRONMENTAL BACKGROUND

South-Central Kentucky Karst

The karst landscapes of south-central Kentucky are ideal for an historical ecological approach because of well-defined boundaries which allow for a focused and detailed study, the presence of cave and sinkhole contexts with excellent preservation potential for inferring paleoenvironments, and valuable previous studies in archaeology (Carstens 1980; Gardner 1987; Prentice 1996; Watson 1969, 1974), ecology (Baskin et al. 1994; Wilkins et al. 1991), geology, and hydrology (Quinlan et al. 1990; White and White 1989). Located within the Interior Low Plateaus physiographic region that extends across much of the Midcontinental United States, south-central Kentucky is a classic example of a karst terrain. It is characterized by caves, rockshelters, sinkholes, karst valleys, and underground rivers. True karst terrains are primarily formed by dissolution of bedrock by water. Solution, precipitation, subsidence, and collapse are responsible for bedrock weathering and the formation of karst landforms. The most common soluble rocks in karst environments are limestones and dolomites. Limestones generally contain 50 to 90 percent calcium carbonate ($CaCO_3$). Dolomites (present in small amounts in the area) have at least 50 percent and up to 90 percent calcium-magnesium carbonate ($CaMg(CO_3)_2$) (Huggett 2011).

The south-central Kentucky karst can be further subdivided into four physiographic sections: (1) Chester Cuesta, (2) Dripping Springs Escarpment, (3) Sinkhole Plain, and (4) Glasgow Uplands (Quinlan et al. 1990; Wells 1973; Figure 3.1). The Chester Cuesta is characterized by soluble limestone overlain by relatively impermeable sandstones forming the longest mapped cave systems in the world including Mammoth Cave (Palmer 2007).

The Dripping Springs Escarpment marks the boundary between the Chester Cuesta and Sinkhole Plain. The Sinkhole Plain and Glasgow Uplands are within the Pennyroyal Plateau, underlain by highly soluble Upper Mississippian limestones of the Ste. Genevieve and St. Louis formations and prone to extensive sinkhole and cave development (Chester et al. 1997; Dougherty 1985; Quinlan et al. 1990). The Sinkhole Plain is a holokarst landscape, characterized by numerous dolines or sinkholes, and lack of surface drainage (Hess et al. 1989, Wells 1973).

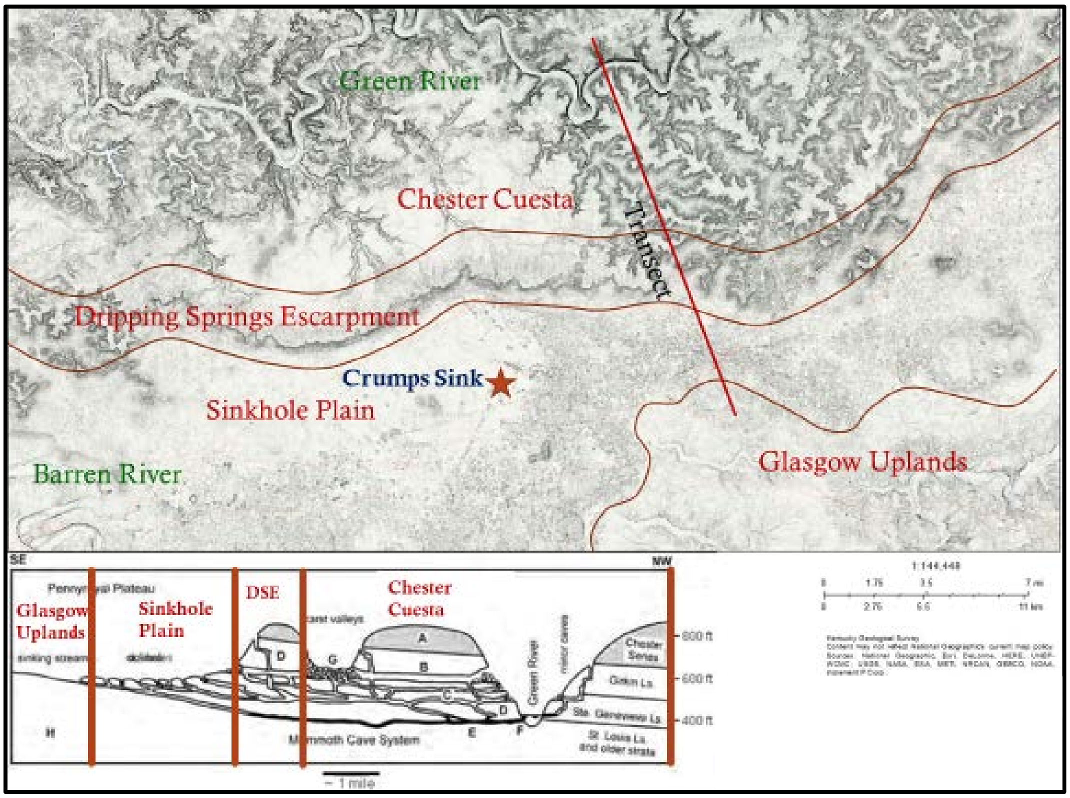

Figure 3.1. Map showing major sections of the south-central Kentucky Karst. Note that Crumps Sink sits at the interface between exposed Ste. Genevieve and St. Louis Limestones, resulting in differential sinkhole development. Map created using online platform KGS LiDAR. Geological profile adapted from Toomey and Olson (2008).

Lithology

The underlying lithology plays a prominent role in the hydrogeology of the region. Marine fossils in the limestone matrices indicate that the earliest sedimentary rocks began forming during the Mississippian and Pennsylvanian Periods of the Paleozoic Era over three hundred million years ago (Mya) when a shallow sea covered southern North America (Palmer 1981). The St. Louis Limestone is the oldest layer and is more than two hundred feet (61 m) thick. It contains many flat nodules of chert and beds of gypsum that seem to have formed due to a high evaporation rate, indicating a dry climate. Overlying the St. Louis Limestone is the Ste. Genevieve Limestone, which is 110-120 feet (33.5-36.5 m) thick. The Ste. Genevieve Formation contains most of the passageways in Mammoth Cave. It comprises light gray limestone and dolomite with isolated nodules of chert. There are no gypsum beds, leading geologists to postulate that the climate was humid at the time of deposition. Overlying the Ste. Genevieve Formation, at 135-140 feet (41-43 m) thick, is the youngest layer of limestone in the region, the Girkin Formation. It also contains light gray limestone and small amounts of dolomite with shale (Palmer 1981). The Big Clifty formation is an insoluble sandstone, at 50-100 feet (15-30.5 m) thick that overlies the limestone formations. At the end of the Mississippian Period either continental uplift or a drop in the sea level caused the region to be periodically at or above sea level. The final deposited sedimentary rocks were conglomerates, sandstones, and shales that formed during the Pennsylvanian Period as near-shore deltaic or beach deposits (Wallace 2003).

Structure and Bedding

The dip of the limestone bedrock plays an integral role in the formation of caves and other landforms in south-central Kentucky. Originally deposited as horizontal beds, the limestone and sandstone formations in the area now gently dip in a northerly direction toward the Green and Barren rivers. This influences the direction of hydrological flow and the dip of lithological formations exposed at the surface (Palmer 1981). For example, the interface between the St. Louis and overlying Ste. Genevieve formations is exposed at the surface, with the northern half of the Sinkhole Plain composed of Ste. Genevieve Limestones at the surface, and the southern half St. Louis Limestones. The more soluble nature of the limestones in the St. Louis formation has led to the extensive development of sinkholes that dot the landscape. It has been hypothesized that the random pattern of sinkhole formation is related to random outcropping of interbedded chert (Hess et al. 1989; Wells 1973). Though rocks of both formations are extremely soluble (Dougherty 1985), there is a much lower incidence of sinkholes in the Ste. Genevieve limestones. In the Chester Cuesta (or Mammoth Cave Plateau), Big Haney Limestones and Big Clifty Sandstones are often exposed at the surface and comprise the caprock protecting the massive cave passages in the underlying limestones.

Hydrology

Hess et al. (1989) have identified five ways water enters the hydrological system of the south-central Kentucky karst. These include (1) sinking streams that enter the Sinkhole Plain from the Glasgow Uplands through swallow holes, (2) sinkholes in the Sinkhole Plain proper that act as conduits for precipitation, recharging below-ground cave systems; (3)

aquifers recharged by precipitation on sandstone ridges of the Chester Cuesta where water enters vertical shafts at the edge of the impermeable sandstone, (4) precipitation entering the water table through karst valleys, and (5) back-flooding by the Green River into underground systems.

As base-level catchments for water from the region, the Green and Barren rivers are important components of the hydrological system of the area (Hess et al. 1989; Quinlan et al. 1990). The Sinkhole Plain is a holokarstic landscape, meaning that there are few to no surficial streams and thus no riverine terrace development (Hess et al. 1989; Huggett 2011; White 1988). Upon reaching the Sinkhole Plain, surficial creeks from the Glasgow Uplands sink into expansive subsurface drainage systems that travel in a northwesterly direction toward the Barren and Green Rivers, following the dip of the underlying limestone formations (Quinlan et al. 1990). Based on extensive dye tracing, hydrologists have delineated three distinct subsurface drainage systems within the Sinkhole Plain. These include the Graham Springs basin that feeds into the Barren River and the Turnhole Springs and Bear Wallow basins that feed into the Green River (Quinlan et al. 1990). Underground streams are often restricted, and they are guided by the interbedded chert formations that are far less soluble than the limestone matrix (Hess et al. 1989).

Chester Cuesta

Sandstones, common in the Chester Cuesta, often contain rocks including quartz that are not as easily weathered by chemical dissolution as limestones. Mechanical processes are much more effective than solutional processes in weathering sandstones (Huggett 2011). Protection of cave passages from roof fall by relatively impermeable sandstone is a major reason for the extensive length of the Mammoth Cave system. It is the longest known cave system in the world, currently more than 400 miles (644 km) in mapped length (Palmer 2007; Wallace 2003). Situated alongside the Green River, Mammoth Cave was formed by a variety of factors. As the upper Green River lowered its base level through downcutting into its current valley, tributary streams, which largely flow underground from the Sinkhole Plain, also cut horizontal passages into the surrounding limestones. There are four levels of passage development in Mammoth Cave, each created when the Green River was at a higher base level than it is at present. Granger et al. (2001) analyzed sediments using cosmogenic radionuclide dating of ^{26}Al and ^{10}Be to date passage development. The upper levels of the cave were formed prior to 2.4 Mya, with sediment being deposited in these levels between 2.3-2.4 Mya. Upon further downcutting followed by stabilization 2 Mya, the second oldest level of cave passages was formed. Significant downcutting was caused by a shift in the course of the Ohio River at 1.5 Mya and again at 1.2 Mya which was caused by glacial advances that reached the Ohio River valley. Over the past 3.5 million years sandstone weathering has been relatively slow (2 to 7 meters per million years), compared to weathering of limestone in the region, which has been incised about 30 meters every million years (Granger et. al 2001).

Creation of cave passages by hydrological processes occurs most commonly at the water table in the lower passages, although dissolution can still occur in all parts of the cave. The upper passages of Mammoth Cave are unsaturated (vadose zone), while the lower levels closer to the water table are saturated and remain hydrologically active (phreatic zone). Vadose zones are more stable, dry environments than phreatic zones. The dry environment in the upper levels of Mammoth Cave has allowed for the preservation of commonly perishable Late Archaic to Early Woodland archaeological materials, including textiles, basketry, and gourd bowls (Crothers and Watson 1993). Ridges and knobs such as Flint Ridge and Indian Hill, respectively, are also prominent in the Chester Cuesta, demonstrating that differential weathering can result during the formation of drainage networks in a landscape containing lithological units with different structural properties. Sinkholes are also present throughout the Chester Cuesta.

Dripping Springs Escarpment

Demarcating the boundary between the Sinkhole Plain and the Chester Cuesta is the Dripping Springs Escarpment. This conspicuous boundary is perceptible as a considerable increase in elevation (approximately 150 feet (45 m)) from south to north. The Dripping Springs Escarpment contains vertical shafts, knobs, rockshelters, and karst valleys. In the knobs and on the escarpment edge, water from precipitation travels through soluble rock and further dissolves joints, creating vertical shafts that eventually reach underground drainages leading to the Barren and Green Rivers. Vertical shafts form when water cuts vertically through the lithological units, regardless of the orientation of bedding planes. Solution chimneys are primarily controlled by the structure of the formation (e.g., bedding planes) and are irregular. Water drains through small passageways at the base of these features (White 1988). Knobs are present in the Dripping Springs Escarpment. Based on models of rockshelter development from other parts of the world, it is likely that limestone and sandstone rockshelters and caves at the edge of the escarpment were initially formed due to differential erosion rates, events of mass wasting, and restricted weathering action (Barton and Clark 1993) caused by base level river or stream scouring, water seepage, processes of freeze-thaw, and wind blasting (Straus 1990), all of which attack weak areas of bedrock.

Sinkhole Plain

The Sinkhole Plain is a holokarst landscape, characterized by numerous dolines or sinkholes, and lack of surface drainage. This seeming lack of available water has resulted in characterizations of the Sinkhole Plain as a marginal environment that would not have supported significant prehistoric occupations (e.g., Fowke 1922). Though the lack of surface drainage creates the illusion that water is unavailable, water can still be accessed at point locations such as springs, sinkholes, and karst windows, and archaeological sites are prominent around these features (Carstens 1980; Gatus and Maynard 1978). Sinkholes like Crumps Sink pockmark the landscape of the Sinkhole Plain, penetrating the soluble Ste. Genevieve and St. Louis limestones (Groves et al. 2013). Other common features of the Sinkhole Plain are uvalas, caves, springs, karst windows, knobs (outliers of the Chester Cuesta), sinking streams, and vertical shafts/solution chimneys (Hess et al. 1989, Wells 1973; White 1988). Uvalas are formed by collapse along an underground drainage network, connecting several sinkholes (White 1988). Karst windows are underground rivers that are exposed after collapse of cave roofs (Hess et al. 1989). Springs are the upwelling of water from the below ground aquifers (White 1988). A complex underground drainage network guides water to the Barren and Green rivers. These caves often have some degree of hydrological flow. For example, Crumps Cave is a large cave passage in the Graham Springs Basin that is the location of an abandoned river passage (Quinlan et al. 1990). Knobs (or residual hills) are remnants of the Chester Cuesta to the north, and often still have caprock, preserving the lower soluble strata, and rising as high as 100 meters above the plain (Hess et al. 1989; White 1988). Vertical shafts often ring the edges of knobs. Prehistorically, some of these shafts were used for interment of the dead (Applegate 2008; Haskins 1988). These knobs are also known to have chert outcrops (Quinlan et al. 1990) and may have been quarried by Native Americans for tool production. Prehistoric groups accessed water at point locations such as springs, sinkholes, and karst windows, which are often located near or within caves and rockshelters. Caves and rockshelters are the primary archaeological site type in the south-central Kentucky karst region (Carstens 1980; Fowke 1922; Gatus and Maynard 1978).

Glasgow Uplands

The Glasgow Uplands have features similar to the Sinkhole Plain. Two key landforms (sinking streams and swallow holes) are apparent in the Glasgow Uplands and Glasgow Upland/Sinkhole Plain boundary. For their surficial extent, sinking streams form valleys as deep as 35 meters below the present surface (Hess et al. 1989). Swallow holes are locations where sinking streams of the Glasgow Uplands go below ground and enter the Sinkhole Plain. The transfer of water from the surface to below ground can be abrupt (White 1988).

Sinkhole Geomorphology

Throughout the world, sinkholes vary significantly in size, ranging from barely noticeable depressions to immense openings hundreds of meters wide and hundreds of meters deep (Hess et al. 1989; White 1988). Sinkholes are closed depressions and water must exit through the base of the depression. They most often are formed through dissolution or collapse. White (1988) notes that all closed depressions have three characteristics: (1) a drain acting as a conduit for water to travel into underground drainage systems, (2) a zone at bedrock that has been altered by solution, and (3) a cover of soil or sedimentary material. Processes such as dissolution (a relatively slow process), soil and sediment transport through piping, sheet wash, and sudden collapse of clastic bedrock can occur.

Two key sinkhole types are solution sinks and collapse depressions. Solution sinks are bowl shaped depressions formed by dissolution of limestone matrices through weak joints and fractures over a long period of time. The drain at the base of these features can be plugged by accumulated sediments and soils. When water is unable to exit the sinkhole through the conduit a pond may form. Similar ponds can also suddenly drain when the plug opens. Collapse depressions are formed when bedrock overlying a cave passage is weakened through solution of joints, causing roof collapse. Over time, constant dissolution makes sinkholes deeper and wider until they reach the edge of another sink. As sinkholes meet each other, they form compound sinks (or uvalas). Valley sinks are those in which surficial drainage has gone underground through sinking streams. Runoff and sinking streams further dissolve these sinks. After formation of these closed depressions, sediments are deposited through alluvial, colluvial, aeolian, and chemical processes (Hess et al. 1989; White 1988). Soils form in place through weathering and biological reworking of deposited sediments (Birkeland 1999). Soils and sediments can also collapse by a process called soil piping, where soils are transported into vertical joints and fractures in the rock that have been dissolved by water. As soils and sediments travel into the subsurface, they leave a void or cavity below the soil surface. Eventually the arch above this cavity collapses (Hess et al. 1989; White 1988).

Sinkholes can act as catchment basins for sediments and can preserve the soil geomorphological and archaeological record providing important paleoenvironmental and archaeological information. However, because sinkholes are dynamic features under continuous, variable dissolution and weathering dependent on a number of conditions, it is difficult to predict which locations will have the most complete sedimentary record. However, knowledge of karst and, in large sinks, hillslope processes, can help us make informed guesses concerning locations with intact deposits. Flat areas (summit and shoulder) on the edges of sinks have thin soils because they contribute sediments to the depression through alluvial, colluvial, and aeolian processes. Changes in vegetation in karst terrains (e.g., from forest to grassland) can lead to significant erosion through sheetwash (Martin 2006). In Kentucky, historic agriculture has eroded soils around the edges of sinkholes. These eroded soils were redeposited within sinkholes, thereby, capping older sediments (Dicken and Brown 1938). Dicken and Brown (1938) note that a major episode of erosion occurred in the karst regions of Kentucky after historical land clearing and cultivation resulting in significant sediment accumulation in sinkholes. Unless undisturbed, it is unlikely that sinkhole margins will contain deep deposits. The mid slope of a sink may be altered through mass and fluid movement of soils (creep, flow, slides, heaves, falls, and subsidence) (Huggett 2011). The footslope of a sinkhole is the location in which many of these erosional debris accumulate and is most likely to contain deeper deposits that have been capped by sediments from the summit, shoulder, and mid slope. However, karst processes such as subsidence and soil piping may compromise the deposits from below, something which may not be noticeable at the surface. The four primary soils found in the Sinkhole Plain are Crider, Pembroke, Nicholson, and Baxter. Soils in the region can be "(1) deep, moderately- to well-drained soils on level to steeply rolling uplands; (2) deep, well- to poorly-drained soils on floodplains, upland flats, and depressions; and (3) shallow to moderately deep, well-drained soils of ridges, knobs and benches that are often associated with limestone outcrops" (Baskin et al. 1994: 233). Parent materials "include loess, residuum weathered from high grade and cherty limestones, old alluvium, and recent alluvium" (Baskin et al. 1994: 233).

Paleoenvironments and Holocene Climate Change

Today the south-central Kentucky karst "has a mild temperate rainy climate without a distinct dry season and with a hot summer" (Baskin et al. 1994:235). Braun (1950) characterized the physiography of the south-central Kentucky karst as the Mississippian Plateau section within the Western Mesophytic Forest region. Kuchler (1964) described the vegetation of the region as oak-hickory forest fragmented by bluestem prairie. According to Baskin et al. (1997:333) the vegetation in the region, "ranges from redcedar-hardwood forests on xeric, rocky upland sites to swamp forests of poorly-drained upland depressions". Early European visitors to south-central Kentucky in the late eighteenth and early nineteenth century noted a prairie-like landscape characterized by expansive grasslands, with herbs, shrubs, and a few trees, calling it the "Big Barrens" (Baskin et al. 1994). In Kentucky, when present, barren and cedar glade ecosystems occur primarily on karstic limestones and dolomites extending throughout the Pennyroyal Plateau of the Mississippian Plateau (Baskin et al. 1994; Chester et al. 1997).

Baskin et al. (1994) developed definitions of specific barrens-like ecosystems including cedar glades, xeric limestone prairies, and deep-soil barrens. Cedar glades occur naturally on very shallow soils or even on limestone bedrock. Xeric limestone prairies develop on sloped landforms that have thin soils due to erosion caused by human influences on the landscape (e.g., historic agriculture). Barrens have deep soils and are more likely to develop woodlands because of these deep soils. However, human modification through fire may have allowed barrens ecosystems to persist in prehistory (Baskin et al. 1994). A variety of prairie species are found in barrens, cedar glade, and xeric limestone prairie ecosystems in the Pennyroyal Plateau, with the most dominant one being little bluestem, a C_4 perennial bunch grass (Baskin et al. 1994; Chester et al. 1997). Some of these ecosystems still remain in the Pennyroyal Plateau (Chester et al. 1997). Initially, it was argued that the barrens in Kentucky and the greater Interior Low Plateaus were an expansion of Midwestern Tallgrass Prairies primarily through climate change (Transeau 1935), though this has more recently been questioned.

Baskin et al. (1994) argue that the Big Barrens should not be considered part of a climate induced extension of the Prairie Peninsula and provide several lines of evidence to make their case: (1) deciduous forest is the climax vegetation for the region, not barrens; (2) soils are forest-developed; (3) forests regrew after burning stopped; (4) similar response (as 3) when agricultural land stops being cultivated; (5) the current regional climate is more favorable for forest than grassland; (6) maps of paleovegetation show no extension of prairies into the area, and a pollen analysis from Jackson Pond and Salts Cave shows that grasslands appear after the Hypsithermal; (7) paleoclimate was more amenable to grassland development in the Midwest than south-central Kentucky; and (8) although there is some overlap in the fauna and flora of the Big Barrens and Tallgrass Prairies, there are also significant differences in them. These lines of evidence led the authors and others to argue that the barrens are anthropogenic in origin, presumably created by land burning by indigenous people (Anderson et al. 2000; Baskin et al. 1994; Chester et al. 1997; Guyette et al. 2003; Heikens and Robertson 1994; Jefferies 2009; Wilkins et al. 1991). More recently, humans have suppressed wild fires, and former barren ecosystems are reverting to forests, further suggesting that fire was a key element in maintaining this early successional habitat (Anderson et al. 2000; Baskin et al. 1994).

However, based on his mapping of twentieth century lightning strike data in Mammoth Cave National Park, Ray (1997:179) suggests that while "most agree that wildfires occurring on flat-lying, streamless terrain were responsible for maintaining this eastern grassland", lightning strikes may have been the key ignition source in the barrens and not only an anthropogenic creation. He suggests that Native Americans likely set fires as a supplement to lightning fires. Ray also questions whether we can accurately say soils originally developed in forests, one of the reasons Baskin and others say that they are not an extension of Midwestern Tallgrass Prairies. Ray notes that grasslands did not expand in the region until after the Middle Holocene Hypsithermal but does not investigate this further. Instead, he opts for lightning strikes as the most important contributor to barrens vegetation in the region.

The past climate in the region was different than that we experience today. To fully assess how the barrens may have originated and the role of climate and humans in their origin, we must consider a wide range of paleoenvironmental data for south-central Kentucky and surrounding states. Below, I consider numerous data sets, including pollen diagrams and charcoal frequencies from pond sediments and soil/sediment profiles, faunal remains, sediment accumulation histories as seen in soil profiles, and stable isotopes (carbon and oxygen) from soil profiles and speleothems (Table 3.1).

Table 3.1. Paleoenvironmental proxy sites discussed in text.

Site Name	**Landform**	**State**	**Dataset**	**Source**
Cliff Palace Pond	Pond	KY	Pollen, Charcoal	Delcourt et al. 1998
Jackson Pond	Pond	KY	Pollen	Wilkins et al. 1991
Salt’s Cave	Cave	KY	Pollen	Schoenwetter 1974
Koster	Colluvial Fan	IL	Soil Profile	Hajic 1990
Napoleon Hollow	Colluvial Fan	IL	Soil Profile	Styles 1985
Modoc Rockshelter	Rockshelter	IL	Sediment Profile	Ahler 1993, 1998
Devil’s Icebox Cave	Cave	MO	Speleothem	Denniston et al. 2007
Patton Bog	Bog	OH	Pollen, Charcoal	Abrams et al. 2014
Anderson Pond	Pond	TN	Micromorphology	Driese et al. 2017
Cheek Bend	Cave	TN	Faunal	Klippel and Parmalee 1982
Savannah Creek	Floodplain	TN	Soil Profile, Isotopes	Driese et al. 2008
Wine Spring	Forest Stand	TN	Charcoal	Fesenmyer and Christensen 2010
Tennessee River	Floodplain	TN/AL	Soil Profile, Isotopes	Kocis 2011
Buckeye Creek Cave	Cave	W. VA	Speleothem, Sediment Profile, Charcoal	White 2007, Springer et al. 2010
Douthard Creek	Floodplain	W. VA	Soil Profile	Driese et al. 2005

Though the data sets differ in type and in the landforms they were collected from, the information they have yielded helps us characterize the climatic history of the Middle and early Late Holocene periods in Kentucky, the greater Interior Low Plateaus and Southern Appalachian Mountains, and the Midwestern United States.

Middle Holocene (ca. 9000 to 4200 cal. BP)

When the Big Barrens first formed is still unclear, but they may have originated during the Middle Holocene Thermal Maximum, (also known as the Hypsithermal or Climatic Optimum between 9000 and 4200 cal. BP). This was a period of generally warmer and drier conditions throughout the Interior Low Plateaus (Delcourt and Delcourt 1979; Walker et al. 2012). During the early Holocene, mesic woodlands were prominent, with oak and hornbeam being dominant species. Spruces, which had been more common during the Pleistocene, were declining (Wilkins et al. 1991). In the Pennyroyal Plateau, this resulted in mesic tree taxa being replaced by oaks, hickories, and chestnuts in upland forests (Wilkins et al. 1991). In the Highland Rim of Tennessee (an extension of the Pennyroyal Plateau), decreased rainfall and increased temperatures allowed for barrens and cedar glades to expand in the region, resulting in an open vegetation structure. At Cheek Bend Cave in middle Tennessee, Stratum V (correlated with the onset of the Middle Holocene Climatic Optimum) contained insectivore remains, suggesting an environment with decreased summer rainfall and/or increased summer heat, which would have allowed cedar glades to expand in the region. Drought tolerant vegetation increased while mesic deciduous species decreased, allowing for a more open vegetation structure (Klippel and Parmalee 1982). Stratum VI, (deposited during the later stage of the Middle Holocene Thermal Maximum), contained insectivore remains that showed the conditions were ameliorating and becoming wetter (Klippel and Parmalee 1982). The degree to which the Middle Holocene Thermal Maximum influenced the development of barrens ecosystems in south-central Kentucky is unclear, and based on pollen diagrams, it seems that grassland expansion occurred during the early Late Holocene, after the onset of the Holocene Climatic Optimum (Wilkins et al. 1991; Schoenwetter 1974).

It has been argued that the more open vegetation structure associated with the Middle Holocene Thermal Maximum caused significant upslope erosion/downhill accumulation at several archaeological sites in the Midwestern United States, where the process has been demonstrated consistently. In Illinois, Hajic's (1990) investigations of colluvial and alluvial contexts at Koster and Styles' (1985) geomorphological investigations of a colluvial fan at nearby Napoleon Hollow show enhanced sedimentation during the Middle Holocene. At Modoc Rockshelter in Illinois, Ahler (1993, 1998) noted that enhanced sedimentation rates had occurred early in the Middle Holocene. Though many attribute erosion in the Midwestern United States to climatic conditions and a transition toward more open vegetation structure associated with the ebbs and flows of the eastern margin of the Prairie, the extent to which climate was responsible for such manifestations has been questioned (Van Nest 1997).

Citing the concept of equifinality, which argues that there are always a number of possible reasons for a final outcome, Van Nest (1997) argues that the climatic model for sediment erosion has been accepted uncritically, without consideration for other possible catalysts for such geomorphological change and offers other explanations for this change. These erosional events preserved in the soil geomorphological record have not been considered sufficiently or documented outside of the Midwestern United States. However, similar manifestations are seen as far east as the Appalachian Mountains and to the south in Tennessee. At Buckeye Creek Cave in West Virginia, sedimentation rates seem to be most rapid between 7000 and 6000 cal. BP, after which these sedimentation rates decrease (Springer et al. 2010). Between 7100 and 5600 cal. BP at Anderson Pond in Tennessee, soil formation along with desiccation was occurring in the pond (Driese et al. 2017). By the beginning of the Late Holocene sedimentation slowed and aggradation had decreased (Hajic 1990).

New techniques are nuancing our understanding of Holocene environmental history in the region and providing more direct indicators of climate and environment. Stable carbon isotopic analyses of soil organic matter (δC^{13}_{som}) have been used to assess late Quaternary paleoenvironments in the Eastern United States. The key focus is on the proportions of C_3 plants, primarily trees, shrubs, and cool-season grasses, and C_4 plants, open grassland species adapted to more arid conditions. Due to differing photosynthetic pathways, C_3 plants discriminate more than C_4 plants against $^{13}CO_2$ in the atmosphere, leading to more negative values, often -21‰ and -35‰, with an average of -27‰ for C_3 plants, -10‰ and -16‰, averaging 13‰ for C_4 plants. These negative values represent the ratio of C_3 vs. C_4 plants. Tracking changes in these ratios (from more negative to less negative; or vice versa) in a vertical column of a soil profile allows for a relative understanding of vegetation dynamics over time as ecosystems ebb and flow in species, structure, temperature, and moisture (Boutton 1996; Holliday 2004; Stinchcomb et al. 2013).

Though only a few stable carbon isotope studies of soil organic matter have been undertaken in the Interior Low Plateaus, they have yielded interesting results. For instance, at Savannah Creek in southeastern Tennessee, Driese et al. (2008) identified four cyclical events during the Middle Holocene over consecutive 300-year time spans, in which δC^{13}_{som} became less negative (interpreted this as shift to warmer and drier conditions) followed by a shift back to more negative values (interpreted as a shift to wetter and cooler conditions). The warmer and drier events appear as a narrow spike, suggesting they were ephemeral in nature. These findings hint that the Middle Holocene was more variable than the simplified explanations of homogenous warming and drying. With data from three research sites along a stretch of the Tennessee River extending from southeastern Tennessee to northeastern Alabama, Kocis (2011), demonstrated similar cyclical episodes to those recognized by Driese et al. (2008).

Early Late Holocene (ca. 4200-3000 cal. BP)

By the early Late Holocene (4200-3000 cal. BP), environmental conditions began trending to a cooler and wetter regime, more similar to the current climate (Walker et al. 2012). The forests of the Interior Low Plateaus became mesic and deciduous, a trend which has continued to the present (Delcourt and Delcourt 1979). However, xeric grassland species became increasingly common, contrary to what should be expected in mesic environments. At Jackson Pond in the Pennyroyal Plateau, grasslands became more prominent, interspersed with deciduous forests, notably after the end of the Middle Holocene Thermal Maximum. The timing of increased grassland development after the Middle Holocene suggests that while the Middle Holocene Thermal Maximum may have influenced the more open forest structure and grassland initially, there may have been other catalysts for maintenance of those communities (Wilkins 1991:236).

Drought or human manipulation of vegetation by fire are among factors that may have contributed to Late Holocene grassland development. At Devil's Icebox Cave in central Missouri, oxygen and carbon isotopes preserved in speleothems demonstrate increasing aridity at 3500-2600 cal. BP. The values found in the speleothems may indicate an increase in the ratio of C_4 vs. C_3 plants associated with expanding grasslands. These drought patterns have been noted throughout the Great Plains, though some areas remained warm and moist, further indicating the variability of climate throughout prehistory

(Denniston et al. 2007). However, it is important to note that Devil's Icebox Cave is along the eastern margin of Midwestern Tallgrass Prairie and may signal ebbs and flows in those ecosystems. In West Virginia, Driese et al. (2005) found increased levels of C_4 plants at 3830 cal. BP, though based on other climatic models, cooler, mesic conditions had arisen (Delcourt and Delcourt 1979; Walker et al. 2012). Another plausible explanation could be that increased C_4 plant representation relates to grassland expansion associated with anthropogenic forest clearance.

Cores from Jackson Pond in Larue County, Kentucky yielded pollen assemblages showing increases in pollen of grassland species such as prairie clover after the Middle Holocene (Wilkins et al. 1991). Pollen records from Salts Cave in Mammoth Cave National Park demonstrate an increase in *Ambrosia* pollen after human occupation of the cave (Schoenwetter 1974) during the Late Archaic and Early Woodland periods (Gardner 1987; Watson 1969, 1974). Further dating of these deposits is discussed in Chapter 4. These examples demonstrate that despite a shift back to mesic conditions in the Interior Low Plateaus, xeric species were becoming increasingly common, suggesting another process either in concert with or other than climate may have been responsible for grassland expansion.

By the Late Archaic period, fire activity also had become more common in the Cumberland Plateau in Kentucky and Southern Appalachian Mountains of Tennessee and North Carolina, changing forest structure from red cedar forests to oak-chestnut forests (Delcourt et al. 1998). Similar changes in vegetation occurred in surrounding regions throughout the Interior Low Plateaus and Southern Appalachian Mountains after at least 4000 cal. BP, coincident with consistent increases in wood charcoal in the sedimentological record (Delcourt et al. 1998; Fesenmyer and Christensen 2010; White 2007; Springer et al. 2010).

Based on pollen records and charcoal deposition at three pond sites in Kentucky, Tennessee, and North Carolina Delcourt and Delcourt (1998) postulated that humans burned the forest to promote the oak-chestnut forests between the Late Archaic and Woodland periods which "increased biological diversity" through creation of a range of habitats from early successional to old-growth (Delcourt and Delcourt 1998). Delcourt et al. (1998) hypothesized that land clearance through prescribed burns also may have played a role in the early domestication of plants in the Cumberland Plateau. Fesenmyer and Christensen (2010) collected charcoal samples from a forest in North Carolina and found that consistent burning occurred at 4000 cal. BP. Deep cave sediments from Buckeye Creek Cave in West Virginia show increased charcoal frequencies after 4000 radiocarbon years BP. Unlike the previous examples which show burning of the landscape by the Late Archaic, observable burning, indicated by an increase in charcoal frequencies, did not occur at Patton Bog until the Middle Woodland period (Abrams et al. 2014).

While more recent studies in the Interior Low Plateaus and Southern Appalachian Mountains have hypothesized the occurrence of prehistoric anthropogenic burning based on wood charcoal abundance, palynology, and sedimentology (Fesenmyer and Christensen Jr. 2010; White 2007), few studies have comprehensively incorporated the archaeological record into their discussions (see Delcourt et al. 1998), and none has speculated about how indigenous populations organized such land management. To distinguish between natural climatic regimes, which humans were taking advantage of, and humans actively manipulating the environment, we must connect fire histories and vegetation changes with human land use over time.

Returning to the south-central Kentucky study area, while Baskin et al. (1994) demonstrated that the origin and maintenance of the barrens does not match expectations based on the climate, more work needs to be done to understand the relationship between humans and environmental variability in the region. One question is: how did these environmental changes manifest in the Sinkhole Plain? If these overall climatic and human impacts models are correct then evidence for them should be present in the soil geomorphological record, including erosion in the Middle Holocene, variability in climate, transition to the early Late Holocene and fires on the landscape. But, first we must integrate paleoecological and fire proxy information with the archaeological record.

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CHAPTER 4. ARCHAEOLOGICAL BACKGROUND

Middle to Late Archaic Human-Environmental Interactions and Social Dynamics in the Lower Ohio River Valley

The Middle and Late Archaic periods in the Midcontinent were witness to considerable transitions in climatic and social developments. Climatically, the lower Ohio River valley experienced the onset of the Middle Holocene Climatic Optimum, which spanned through the entirety of the Middle Archaic period and into the Late Archaic period, followed by the transition toward more temperate early Late Holocene conditions more similar to those of the present. In addition to environmental shifts, major social developments occurred related to settlement-subsistence strategies, social interaction, exchange, demography, and conflict (Jefferies 2008). Considerations of these factors are critical for modeling how and when Native Americans changed their approaches to surrounding ecosystems. The focus of the dissertation is on the late Middle Archaic and Late Archaic periods. I consider developments in the Middle and Late Archaic period that may have had created cultural legacies associated with shifting human-environmental interactions that resulted in the creation of anthropogenic environments.

Below, I highlight previous archaeological interpretations concerning shifting settlement-subsistence strategies, the debate on hunter-gatherer sedentism vs. sustained mobility, and the relationship between humans and ecosystems during the Middle and Late Archaic period in the lower Ohio River valley region. Following a discussion of overall trends and modeling of human behaviors in the larger region, I focus more specifically on the archaeology of the south-central Kentucky region, as outlined in Chapter 3. As outlined in Chapter 2, I view humans and the environment as mutually interdependent and believe that a comprehensive understanding of nature and people is essential to a holistic study. Further, neither environment nor society is unilineal in their trajectory and each are shaped by specific, variable historical contexts.

There has been some debate in the archaeological community concerning how we should approach and theorize the Archaic archaeological record (see Emerson and McElrath 2009). Among the criticisms of previous Archaic studies are that they have been environmentally deterministic, with too great a focus on human responses or adaptations to climatic conditions and minimal scrutiny of social developments and human decision making in cultural process. More recently, archaeologists have considered more social, economic, and political models and evidence for understanding increasing complexity of hunter-gatherer populations in the Midcontinent. Perhaps the most used indicator of increasing complexity during the Middle and Late Archaic are mound sites such as Watson Brake (Middle) and Poverty Point (Late) in the lower Mississippi valley. The presence of such sites so early in North American prehistory has intrigued archaeologists, and some of them have even suggested that shell midden sites further north are purposeful constructions (Emerson and McElrath 2009; Anderson 2002).

Anderson utilized the concept of tribal societies in his discussion of monumentality in the Southeastern United States. He writes "the Middle Archaic appears to have been a time of interrelated environmental stress and population pressure" and restricted mobility (Anderson 2002:257). Emerson and McElrath (2009:33) write that "the systematic construction of monumental forms does require 'formal' conceptions of planning and organization and perceptions of time and space that would seem at a premium among…Middle Archaic" hunter-gatherers. However, human landscape modification need not only be demonstrated by the presence of monumental architecture. Perhaps the origins of such earthen construction has its roots in forest manipulation and the creation of anthropogenic environments. It seems possible that humans had already learned how to organize such events through seasonal activities that were being undertaken toward these ends. I agree that social developments must not be ignored. Yet, I still consider environment to play a significant role in Archaic lifeways in Kentucky. How can we reconcile this?

First, we must recognize the role of human agency and ingenuity in transforming landscapes and that even construction of earthen mounds occurred in a specific topographic setting and left a lasting environmental legacy. It seems possible that hunter-gatherers were practicing silvicultural methods of managing nut trees (Munson 1986). If hunter-gatherers were practicing delayed return methods, then we must reassess the common view of hunter-gatherer societies as passive (Lightfoot et al. 2013). Thus, environmental proxies should not be viewed only as a manifestation of environmental processes but also cultural (Leach 1992). Second, with more recent methodologies from a variety of sciences that provide fine-grained information on the paleoenvironmental record in the Midcontinent over millennia, Archaic archaeology is poised to make significant breakthroughs in charting the interplay between humans and their environment. We cannot ignore such data or models completely in favor of altogether separate or opposing lines of inquiry, but instead we should venture to revise previous models that were developed with more coarse-grained data. I argue that one of the greatest contributions of Archaic period archaeological research over the last century has been its aim at modeling human-environmental history over 9000 years through data-rich climatic and geomorphological studies. With this in mind, we have the capability to trace how humans in the past responded to climatic change and impacted their environments and the consequences of these events. Continuing to nuance this understanding will inform our own circumstances about how we respond to contemporary regional and global climatic events as well as how we impact the environment.

Middle Archaic (ca. 9000-5800 cal. BP)

The Middle Archaic period is best understood when separated into two components: early Middle Archaic (ca. 9000-7000 cal. BP) and late Middle Archaic (ca. 7000-5800 cal. BP) (Jefferies 2008, 2009). Much like previous Early Archaic groups, early Middle Archaic hunter-gatherers were highly mobile (Jefferies 1996), and they had similar subsistence strategies, socioeconomic organization, and material culture (Jefferies 2009). Caldwell (1958) proposed the primary forest efficiency model in which Archaic populations developed a greater knowledge of their surrounding resources and began using them more effectively through the Holocene. However, it is likely that groups had already adapted to their respective regions and become regionalized by the Paleoindian period (Maggard and Stacklebeck 2008). Additionally, ecosystems did not remain static, and, over millennia, indigenous populations negotiated shifting environmental regimes that affected plant and animal communities, hydrological regimes, and landscape geomorphology. These groups would have had to adjust to these conditions as well as changing their conceptions of property rights.

The Middle Holocene Climatic Optimum, beginning at around 9000 cal. BP, allowed for a patchwork of ecological zones to emerge throughout the Midcontinent, and by the early Middle Archaic period Native American populations were responding with new resource extraction strategies (Caldwell 1958; Homsey-Messer 2015; Jefferies 1996). It has been argued that the Holocene Climatic Optimum created an open, patchy forest structure in which nut mast became more important than it previous had been. Through her study of cave and rockshelter sites in Alabama (Dust Cave, Stanfield Worley Bluff Shelter, Russell Cave) and Illinois (Modoc Rockshelter), Homsey-Messer (2015) utilized the concept of foragers vs. collectors (see Binford 1980) as a spectrum and argued that early Middle Archaic groups were launching task-oriented excursions to upland settings with the primary goal of processing nut mast: "This change in function is embedded in the broader shift from high to low residential mobility prompted by warming and drying associated with the Middle Holocene" (Homsey-Messer 2015:349). Thus, the Early Archaic period was characterized by high residential mobility, and the early Middle Archaic period by low residential mobility. Early Middle Archaic low residential mobility seems to have been reworked into a logistical collection strategy by the late Middle Archaic period (Stafford 1994; Stafford et al. 2000).

Another shift in settlement and resource extraction strategies is apparent by the late Middle Archaic period. Stafford (1994; Stafford et al. 2000), also utilizing the concept of foragers vs. collectors employed by Homsey-Messer (2015), argued that hunter-gatherers were establishing base camps from which they could send task groups to acquire different resources (logistical collection strategy) rather than mapping onto resources and moving whole groups as earlier hunter-gatherers had done (residential foraging strategy) as had been seen in the Early and early Middle Archaic periods. While during the Early Archaic and early Middle Archaic periods hunter-gatherer groups appear to be operating as residential foraging groups mapping onto a variety of resources, by the late Middle Archaic period groups were beginning to occupy certain areas such as wetlands more intensively, a trend that continued into the Late Archaic (Jefferies 2008; Stafford 1994; Stafford et al. 2000).

Jefferies (2008) suggested that with rich (primarily aquatic) resources nearby, base camps occupied during multiple seasons and having deep middens, greater diversity in tools and cultural features, and exchange of nonlocal materials at the Black Earth site (southern Illinois), Bluegrass site (southern Indiana), the KYANG (falls of the Ohio), and the Green River shell middens are evidence of increased complexity and sedentism among hunter-gatherer groups. As populations became larger and better established in these locations, territories may have been formed and mobility restricted. Hunter-gatherer groups were no longer as independent as they once were and were forced to consider other groups throughout the region when exploiting resources (Jefferies 2008; Crothers 2008).

Brown and Vierra (1983) considered climate to be the driving force behind the movement to the lowlands. They proposed the push-pull hypothesis in which they surmised that hunter-gatherer groups were either pushed into floodplains during the dry Hypsithermal as uplands became more xeric or were pulled into the floodplains by the attractive array of resources available to them. Fluvial geomorphology studies of major river valleys in the Midwest, Midcontinent, and Southeastern United States suggest that fluvial systems had stabilized by the late Middle Archaic and Late Archaic period (Hajic 1990; Schuldenrein 1996; Stafford 2004). These geomorphological trends were also used to explain why humans increasingly settled in floodplain settings. This stabilization feasibly could have allowed greater access to aquatic resources (Jefferies 2008; Styles and

McMillan 2009). Though the push-pull model provided a feasible explanation for the Middle to Late Archaic archaeological record, later research has demonstrated that groups did not move only to the lowlands nor focus only on aquatic resources. Occupation at the upland Bluegrass site in southern Indiana, suggests continued use of the uplands with a focus on upland terrestrial species (Stafford 1994). Not only this, but more data is needed on how the Middle Holocene Climatic Optimum manifested in the region.

Throughout the Middle Archaic period, humans relied on a variety of plant resources such as hickory nuts, black walnuts, hazelnuts, and acorns. Additionally, grape, persimmon, sumac, and raspberry/blackberry seeds were utilized during the Middle Archaic throughout the Midcontinent (Jefferies 1996). Grape seeds have been found as far north as Michigan, and as far south as Tennessee. However, they are most pronounced in the lower Ohio and Tennessee river valleys. Persimmon distribution in the archaeological record matches the geographic range of the tree, which is south of the Illinois River. Fleshy fruit trees and shrubs would have done well in disturbed environments, meaning that human alteration of the vegetation could make these species more pronounced (Simon 2009). Tubers seem to have been more commonly used in the western portion of the Midcontinent found in contexts in Michigan, Missouri, and Illinois, but one specimen was found in Tennessee. They do not preserve well, contributing to their spotty occurrence at archaeological sites throughout the Midcontinent. Wild bean is found throughout the Midcontinent in Middle Archaic assemblages. Nuts appear to have been very important throughout the Midcontinent, though hickory nut shells are very thick and can preserve better than other plant specimens which may introduce bias in archaeological interpretations of subsistence (Simon 2009).

Among the animal species consumed were small mammals, deer, and turkey. In some river valleys there was an increased focus on shellfish (Jefferies 1996). While considering faunal resource utilization, primarily within and along the margins of the Prairie Peninsula, Styles and McMillan (2009) found that resource availability increased due to the differential nature of the warming and drying episode of the Hypsithermal across the Midcontinent. They suggest that patchy anthropogenic fire would have contributed to variability across the landscape. In xeric prairies such as those in the southern part of the Prairie Peninsula, groups focused more on small mammals than on deer and aquatic animals. Logistical mobility may have allowed for better procurement of deer and aquatic animals such as fish during the Middle Holocene. Highlighting the spatial variability, Styles and McMillan (2009:72) write "where sustainable, high-ranked animal resources were available—bison in the prairies, deer in the deciduous forest, and fish in the large river valleys—hunters and foragers tended to focus their economies on these resources, which interplayed with the settlement and mobility strategies of the respective groups". Although slightly further afield from the lower Ohio River valley, this acknowledgement of ecosystems managed by fire during the Archaic period in the Midwestern prairies is important as we consider advents of such fire management in the central Kentucky study area.

The late Middle Archaic period was marked by the increased importance of ground stone technology such as pestles, mortars, and grooved axes and more intense processing of hickory nuts, acorns, and black walnuts (Jefferies 2008). The higher frequencies of nutshell have been attributed to the ecological success and expansion of oak and hickory forests (Gardner 1997), which could feasibly have been the result of fire activity and the alteration of forests by selective tree-girdling (Delcourt et al. 1998; Munson 1986). The use of ground stone tools such as pestles and axes further suggests changes in how people procured and processed resources from the surrounding environment. These ground stone implements allowed for vegetal foods to be more efficiently exploited and processed (Jefferies 1996).

In addition to these shifts in settlement and subsistence, there is evidence suggesting increased social interaction and integration shown through "decreased group mobility, reorganization of settlement and subsistence strategies, use of formal mortuary areas, elaboration of interregional exchange networks" (Jefferies 2009:648), and the creation of elaborate bone pins and atlatl weights (Burdin 2004). Jefferies (2008:185) found that specific bone pin designs are often found in certain regions, suggesting "a restructuring of inter-group relationships and a more broadly defined cultural identity". Interestingly, bone pins north of the Ohio River differ from those south of the Ohio River, which may mean that the river was a "social boundary demarcating distinctly different regional hunter-gatherer groups" (Jefferies 2008:185). The late Middle Archaic signifies a shift in human approaches to the environment, first affected by the Middle Holocene Climatic Optimum, then followed by new mobility and resource extraction strategies. It seems possible that by this time, people were impacting the environment through fire to affect edge species and nut mast. There were also new tools to process vegetal materials. New forms of social interaction and integration may have forced groups to alter land tenure relations.

Late Archaic (ca. 5800-3200 cal. BP)

The early part of the Late Archaic period was chronologically situated within the Middle Holocene Climatic Optimum, which ended ca. 4200 cal. BP (Walker et al. 2012). However, with the climatic transition from the Middle to early Late Holocene, climatic conditions at the end of the Late Archaic period had become more similar to present conditions (Jefferies 2008). Thus, the beginning of the Late Archaic period is not directly correlated with the Middle to Late Holocene transition, which may be significant, warranting future attention. At the very least, the chronological offset of cultural and environmental epochs suggests some degree of mutual exclusivity in development.

Throughout Kentucky, the number of Late Archaic sites increased as compared to earlier components, suggesting increases in population or changes in settlement strategies. The archaeological record of the Late Archaic period exhibits similarities to the archaeological record of the late Middle Archaic period, including continued focus on floodplain settings, epitomized by the shell middens in a number of regions including the middle Green River valley, where shell was first deposited in the late Middle Archaic or earlier. The substantial size of shell middens along the Green River suggests that these sites were important locations visited by hunter-gatherer groups over a long period of time (Marquardt and Watson 2005). However, these groups continued to utilize upland settings (Jefferies et al. 2005). Though during the Early and Middle Archaic periods, Native American populations occupied rockshelter and cave entrances, it was not until the Late Archaic period that they began exploring dark zones of caves (Watson 1974). Late Archaic settlements were more dispersed than those in the Middle Archaic period and populations steadily increased.

Many archaeologists have pointed to increased settlement in floodplain settings as an example of increased sedentism and complexity (Jefferies 2008). However, Crothers and Bernbeck (2004) suggest that archaeologists should recognize the significance of autonomy in hunter-gatherer social dynamics. They argue that the Green River shell middens could have formed over a long period of time as autonomous foragers frequented sites, rather than as areas that were occupied continuously by related groups. These sites became important locales as people frequented them over thousands of years. Crothers and Bernbeck (2004:406) posit that sites along the Green River can best be explained with the aid of the foraging mode of production model. The authors suggest that "mobility, dynamic forager interaction, and institutional structure are at the core," of the model and propose that complexity can be quantified by considering the interrelationship which occurs between the overlying institutional structure and the individual agents either reproducing or resisting it. The authors "see in a foraging mode of production a set of social relationships – some of them economic, others rather political or ideological in nature" (Crothers and Bernbeck 2004:406). The crux of the model lies in the idea that mobility is the key component, and social institutions are necessary to maintain such patterns of movement. These foragers are also operating under an immediate-return system in which they remain autonomous. As autonomous individuals integrate with and disperse from these mobile groups, these groups continuously change in composition due to the necessity "for any individual to be highly flexible in her/his adaptation to a constantly shuffled environment" (Crothers and Bernbeck 2004:412).

Crothers (2008) has also suggested that a focus on increasing sedentism is limited in explanatory power and disregards the dynamic nature of hunter-gatherer groups. He suggests that a focus on resource access was dependent on agreements between different groups. For example, in the Green River, shell resources seem to have been attractive during the Late Archaic. Those who had access to these resources could allow others to use them. In turn, information and material exchange would have occurred. Crothers does not agree with the idea that the populations that used these sites were sedentary, and among his reasoning is a lack of evidence of structures and the random placement of burials (Crothers 2008).

Late Archaic hunter-gatherers seem to have been impacting the landscape in significant ways, including creating large shell middens in the middle Green River valley through continued reuse of important places, plant domestication of weedy annuals that thrive in disturbed environments, and continued consumption of nut mast resources that were perhaps enhanced by silviculture (Jefferies 2008; Smith 2006; Wagner 2005). While there are few starchy or oily seeds in the assemblage from Late Archaic Carlston Annis in the middle Green River valley, fleshy fruit seeds such as grape, persimmon, and honey locust and seeds such as knotweed have been found (Crawford 2005), suggesting their economic importance. However, domesticated plants are apparent in Early Woodland cave contexts in the Mammoth Cave region. Wagner (2005) argues that botanical remains from Carlston Annis demonstrate that humans were purposefully managing the surrounding landscape. Though there is no evidence of domestication, people appear to have been manipulating the forests, increasing "patch diversity in a vegetation type typified by diversity" (Wagner 2005:238). One of the key pieces of evidence of silviculture is the heavy use of nut mast at Carlston Annis. If people were modifying surrounding forests with fire, this may have affected land tenure relations with other people and also would have required some investment of labor. Thus, the creation of anthropogenic landscapes may be an indicator of increasing social complexity.

In Late Archaic contexts in the Tennessee River valley area, Western Illinois/Iowa, and Western Kentucky, Simon noted differences in frequencies of certain types of nutmeats (Simon 2009: 97). In the Tennessee River valley area, acorn contribution averaged 60 percent, while it averaged less than 20 percent in Western Illinois/Iowa and Western Kentucky. Hickory nut shell frequencies in the archaeological record averaged nearly 90 percent in western Kentucky, slightly over 70 percent in Western Illinois/Iowa, and under 30 percent in the Tennessee River valley area. While black walnut is scarcely represented in Western Kentucky, it is better represented in Western Illinois/Iowa (~7 percent) and the Tennessee River valley area (~15 percent). Simon suggests a relationship between latitude and presence of certain types of nuts and that "nutshell quantities are also closely tied to occupation intensity and site type" (Simon 2009:97). She also suggests that prominence of nut types in areas where the trees are less common may indicate a focus on those resources.

Late Middle and Late Archaic human burial populations have yielded data on life expectancy, pathology, social inequality, and violence. Some people were buried with nonlocal exchange goods, while others were not, suggesting social inequality (Jefferies 2008). The increased evidence of violence among burial populations throughout the Midcontinent, though variable across the landscape, has been offered as evidence of increasing social tension. Mensforth (cited in Crothers 2008) found that there were increases in violence and trophy taking during the Late Archaic in the Green River valley. He interpreted this as relating to exclusive access of some groups to resources during the Late Archaic and conflict related to access to certain resources such as shoals. Such trophy taking is also seen in Indiana (Schmidt and Osterholt 2014). Throughout the lower Ohio River valley evidence for violence includes burials with projectile points piercing bone, scalping, and dismemberment (Jefferies 2008).

In the lower Ohio River valley, late Middle and Late Archaic material culture indicates efforts by hunter-gatherers to communicate group affiliations. Jefferies (1997) and Burdin (2004) identified a number of styles in late Middle Archaic and Late Archaic period bone pins and bannerstones, respectively. For both artifact types, there are patterns in the regional distribution of specific styles. However, during the Late Archaic the bone pins became less elaborate, and atlatl weights became more similar to each other over a large area, perhaps indicating increased social interaction (Burdin 2004; Jefferies 1997). Marine shells and copper artifacts were also found in Green River shell middens suggesting interaction with southern groups along the Gulf and southern Atlantic coasts and with northern groups possibly as far as Michigan (Jefferies 1996, 2008). Similar projectile point styles over large areas have also been considered as evidence for increased social interaction and exchange (Jefferies 2008).

The diet of Late Archaic hunter-gatherers was of a greater variety as well with people exploiting white-tail deer, small mammals, birds, fish, seeds, fruits, nuts and river mussels. Excavations indicate that hunter-gatherers began cultivating plants that had been supplementary during the Middle Archaic period, such as maygrass, goosefoot, squash, and gourds, more intensively (Jefferies 1996). As hunter gatherer groups grew in size and population density increased, the productivity of mussel shoals steeply declined. Increasing violence suggests competition that was plausibly associated with resource stress (Crothers 2008). Increased violence may indicate that while groups were becoming more integrated, they were also becoming more protective of resources as populations surged. The presence of Late Archaic cave art at Adair Glyph Cave (Kentucky) and 3rd Unnamed Cave (Tennessee) suggests that humans were beginning to change their approach to the landscape and to each other. Glyphs include meanders and chevrons either as mud glyphs or incisions in rock (Simek et al. 2001).

When modeling how early agriculture may have begun, Smith (cited in Gremillion 2002) offered the floodplain weed hypothesis in which floodplains stabilized during the mid-Holocene (Schuldenrein 1996), and therefore people aggregated in floodplains, taking advantage of a variety of aquatic animals and plants, and also disturbed the surrounding environment through daily activities. Plants such as chenopodium, sumpweed, and maygrass could thrive in these disturbed areas. Gremillion et al. (2008) proposed that the earliest domestication (at least in the Cumberland Plateau area) occurred in the uplands. Lack of domesticates in Green River shell midden contexts does not corroborate the floodplain weed hypothesis (Crawford 2005).

Advantages of plant domestication include an increased resource base, and the ability to consume more easily processed, larger and edible plants. However, one of the major disadvantages of plant domestication would have been controlling the land upon which the plants are growing. As people invest labor in cultivating certain plants, they must also protect the land that these resources are on. Groups must be less mobile, and interpersonal violence may be more common as others encroach on their territory. Social institutions must be put in place that allow for people to negotiate access to these resources (Crothers 2008). The Terminal Late Archaic period (ca. 3200-2500 cal. BP) (Jefferies

2009) is the cultural period defining the end of the Late Archaic period and marking a transitional stage to the Early Woodland period.

Human-Environmental Interactions in Central Kentucky

To better understand the data behind these interpretations, I consider archaeological investigations in three important regions of Central Kentucky. First, I discuss previous investigations and interpretations related to the Cave Research Foundation Archaeological Project (CRFAP), with a focus on the South-Central Kentucky Karst, in particular the Chester Cuesta and the Sinkhole Plain, and with the goal of summarizing human occupations of karst settings and human-environmental interactions between the Archaic and Woodland periods. Next, I review previous work conducted through the Shell Mound Archaeological Project (SMAP) on Archaic period occupations in the middle Green River valley, located northwest of the South-Central Kentucky Karst region. This is followed by a discussion of interpretations by previous researchers of human-environmental interactions during the Archaic and Woodland periods. Finally, I discuss how it relates to larger trends throughout the Interior Low Plateaus and Midcontinent.

South-central Kentucky has been the subject of interdisciplinary, systematic, archaeological investigation for over a century. However, much of what we know about human use of rockshelters in south-central Kentucky comes from surveys and excavations in the Chester Cuesta, with minimal work in the Sinkhole Plain (Carstens 1980; Prentice 1996; Watson 1974). In the late 1800's, Frederick Putnam from the Peabody Museum of Natural History at Harvard University, visited the Mammoth Cave area (Nelson 1917; Watson 1974). In 1917 Nels C. Nelson published his work on excavation of the historic entrance of Mammoth Cave. He believed that because the caves of Kentucky had been south of the farthest extent of the Pleistocene glaciers they may contain evidence of Pleistocene human occupations. In the cave entrance, Nelson (1917) found midden deposits and many artifacts assignable to the Archaic and Woodland periods. Though less studied, early investigations in the south-central Kentucky karst in the 1920's and 1930's yielded promising archaeological and paleontological sequences associated with sinkholes and caves (e.g., Fowke 1922, Webb and Funkhouser 1934). Gerard Fowke (1922) from the Smithsonian Institution was also interested in the archaeological potential of sinkhole and cave sites in the region. Among the sites he visited was Crumps Cave. Fowke (1922:123) wrote a rather grim assessment of the archaeological potential of the region:

> *It would seem useless to make any further examination of the level limestone region of central or southern Kentucky. Nearly all the minor drainage is underground, and most of the caves have inlets through sink holes or in small crevices. The water supply is scanty except along streams, and in such situations the caves are usually, for various reasons, of such character as to preclude a continuous occupation, or one extending to a very ancient date.*

However, referring to Crumps Cave entrance, he alluded to the presence of archaeological remains: "There is abundant room and a good light near the front and it is reported that quantities of ash were formerly to be seen on the earth a short distance in" (Fowke 1922:118). Patty Jo Watson initiated the ongoing CRFAP in the 1960's. Watson's (1969, 1974) research initially focused on Salts Cave, in Mammoth Cave National Park, and she documented some of the earliest and most extensive cave exploration in Eastern

North America. Between the Late Archaic and Early Woodland periods (ca. 3500 to 2000 cal. BP) Native Americans traversed miles of sinuous passages guided by the light of cane torches in their efforts to collect several cave minerals. These explorers left behind torch debris, gourd bowls, basketry, footwear, paleofeces, and occasionally, human bodies (Crothers 2012; Watson 1969, 1974). In the 1960s and 1970s, Watson and her colleagues launched a multidisciplinary study of the remains in Salts Cave that included archaeology, botany, zoology, geology, chemistry, and medicine (Crothers 2014). Through excavations of Salts Cave and analysis of paleofeces, Watson and paleoethnobotanist Richard Yarnell identified the remains of plants that were in the early stages of domestication, including sunflower and sumpweed, meaning that these cave explorers were horticulturalists (Watson 1969, 1974).

Occupation levels dated to the Late Archaic and Early Woodland periods (between 3,490 RCYBP and 2,200 RCYBP) (Gardner 1987; Watson 1969, 1974). Radiocarbon dates obtained for Test Unit J showed that occupation occurred between 2510 RCYBP and 2340 RCYBP. In Units J and C a layer with a high density of hydrologically deposited disintegrated charcoal was located directly below the primary occupation layers, suggesting a large forest fire had occurred outside of the cave (Watson 1974). It is unclear whether this fire was natural or cultural or how large it was, but in relation to the upper deposits, it is quite intriguing. Artifactual debris found above the layer included woodworking tools such as flaked and ground stone celts, nut processing tools such as pestles, and Turkey-tail type projectile points (Gardner 1987; Watson 1974). In both units, colluvial and alluvial wash from the entrance buried cultural layers between occupations at the site, as demonstrated by sand overlying occupational horizons. Salts Cave is a drain for water entering the sinkhole, and it is still very wet. In addition, fragmentary pollen records from the cave deposits demonstrate an increase in *Ambrosia* pollen after human occupation of the cave, further suggesting changes in vegetation from forest to grasslands outside of the vestibule (Gardner 1987; Schoenwetter 1974; Watson 1974). Notably, this change in vegetation structure was occurring after the Middle Holocene Climatic Optimum.

Though there are dates for the occupational horizons in Unit J, there was a need for dates for the earlier fire episode. Thus, three nut shell samples from Level 20 were submitted by Carlson and Crothers (2015) for analysis. The three AMS dates for that layer are shown in Table 4.1. This fire episode either predates the major occupation of the vestibule and exploration of Salts Cave interior by a small margin or is coeval with the beginning of occupation and exploration of the cave.

Table 4.1. Radiocarbon Dates from Salts Cave.
Ages calibrated using CALIB 7.1 (Stuiver et al. 2018).

Lab No.	**Provenience**	**RCYBP**		**Calibrated Range BP***
		BP	**1σ error**	**Two σ**
ISGS-A3571	JIV-20	2575	15	2750-2730
D-AMS 009910	JIV-20	2618	28	2758-2742
D-AMS 009911	JIV-20	2805	27	2991-2845

Carstens' (1980) investigations of rockshelter sites in the south-central Kentucky karst region collected evidence spanning the Middle Archaic to Late Prehistoric periods, providing information about subsistence and seasonality in the area over several millennia. In Horizon I of Owl Cave, located at the edge of a sinkhole in the Mammoth Cave Plateau, Early Archaic to Middle Archaic inhabitants primarily subsisted on deer and hickory nuts from transitional forest edge environments. There was also a gradual decrease in the hunting of smaller mammals over time (Carstens 1980).

Significant changes in subsistence strategies occurred during the Late Archaic and Early Woodland periods. In Horizons II and III of Owl Cave, an increase in represented floral habitat diversity over time is indicated (Carstens 1980). There was also an increase in the frequency of hickory nut remains, coupled with a decrease in wood charcoal in Horizon II. The documented plant remains led Carstens to argue that plants became more economically significant by the Late Archaic period (Carstens 1980:91). This was further corroborated by the discovery of pestles and nutting stones in the Late Archaic Horizons II and III, but not in Horizon I. However, deer hunting remained very important. To Carstens, the increase in exploited niches during the Late Archaic suggested transformations "in the overall social structure", and "a new mode of cultural adaptation in the Central Kentucky Karst" associated with early horticulture (Carstens 1980:93-94).

At Crumps Cave, Early Woodland period occupants of the cave began exploiting resources from a more diverse array of habitats than during the Late Archaic period. However, at the end of the Early Woodland period, the diversity of habitats exploited decreased. To Carstens this indicated a "return to an apparent focal economy, occurring sometime during the Middle Woodland period", that focused on deer (Carstens 1980:104-105). In the levels that Carstens suggested date to the late Middle Woodland and early Late Woodland periods, a greater diversity of habitats were once again exploited. Carstens noted that the increase in represented ecological niches during the Early Woodland period is similar to subsistence practices occurring at Salts Cave and Owl Cave at a similar time.

Carstens also noted that no domesticates were found at Crumps Cave, suggesting unique differences between it and other cave sites in the Chester Cuesta/Mammoth Cave Plateau.

Crumps Cave Vestibule and Sink

Crumps Cave is a large cave formed by an abandoned river, and it is accessible through a sinkhole (Quinlan et al. 1990). The vestibule and surrounding sinkhole have produced evidence of human occupation dating from the Early Archaic to Late Prehistoric periods. The first systematic excavations at the site were undertaken by Kenneth Carstens (1980). Carstens was investigating human occupations throughout the south-central Kentucky karst, and he excavated multiple cave entrances and rockshelter sites in the Chester Cuesta, in Mammoth Cave National Park, and Crumps Cave entrance, the only site he investigated in the Sinkhole Plain. Carstens excavated one 1x1 meter test unit to a depth of 80 centimeters in the vestibule entrance and identified deposits dating from the Middle Archaic to Late Prehistoric periods. The unit that Carstens excavated had "11 natural and cultural levels of deposition…in the grid-east wall profile…Each stratum contained…ash, charred botanical remains, limestone breakdown, and loamy sands and clays that alternated in bands of thickness" (Carstens 1980:98). Carstens hoped to complete excavations in the unit at a later date, but in his absence, looters pillaged much of the vestibule. Upon his return to the cave, Carstens could no longer identify the original unit and ceased his investigations of the vestibule.

In the late 1980s, mud glyphs were found further in the cave interior and were radiocarbon dated to the early Woodland period. These mud glyphs show a variety of images etched into the mud, including spirals, human figures, animal figures such as a rattlesnake and tools such as an ax (Davis 1996). The rarity of such glyphs throughout the Interior Low Plateaus further attests to the cultural significance of the site (Davis 1996; DiBlasi 1996; Simek et al. 2001). Since the looting in the 1970s, there had been concern about the integrity of deposits in Crumps Cave. In his assessment of the cave vestibule, George Crothers determined that there were intact deposits along the cave walls and also in a location that previously was protected by a large wooden barrel used as a water reservoir.

The question remains: Are periods with greater representation of habitat diversity the result of far ranging procurement strategies or of the purposeful creation of environmental niches with the use of fire? Lack of domesticates at rockshelter sites also suggests that if fires were being set on the landscape, they were not only set to improve gardening plots (Delcourt et al. 1998), but also likely to promote oak-hickory forests through the limiting of litter and opening of canopy (Royse et al. 2010), and promote the exploitation of edge species such as deer and turkey.

The subsistence trends identified by Watson (1974), Carstens (1980), and Prentice (1996) in the Chester Cuesta/Mammoth Cave Plateau and Sinkhole Plain area are seen throughout the Interior Low Plateaus region. The Middle Archaic period was marked by the advent of ground stone technology, such as pestles, pitted stones, and grooved axes, and more intensive processing and consuming of hickory nuts, acorns, and black walnuts, trends that continued through the Late Archaic and Woodland periods (Crawford 2005; Crothers 1999; Gardner 1997; Jefferies 1996; 2008, 2009; Moore and Dekle 2010; Munson 1986; Simon 2009; Stafford 1994; Stafford et al. 2000; Wagner 2005). The higher frequencies of nutshell have been attributed the ecological success and expansion of oak and hickory forests (Gardner 1997), which could feasibly have been the result of fire activity and selective management of habitats by indigenous forms of silviculture.

In both the Chester Cuesta/Mammoth Cave Plateau and the Sinkhole Plain, botanical and faunal data indicate that there was an increase in exploited habitats at multiple rockshelter sites during the Late Archaic and Early Woodland periods, suggesting that plants became more economically significant (Carstens 1980:91). This was corroborated by the discovery of presumed plant processing tools such as pestles and nutting stones in Late Archaic levels of Owl Cave. Deer hunting remained important. The increase in exploited niches during the Late Archaic and Early Woodland coincides with the presence of early domesticated plant species found in the diets of cave explorers in deep cave zones of Mammoth and Salts Caves. However, domesticated plant species are absent in many rockshelter sites, which may be a result of seasonal differences in occupations, different functional uses between caves and rockshelters, or use by horticultural and non-horticultural groups (Carstens 1996).

Middle Green River Valley

After previous work was conducted in cave contexts of south-central Kentucky, Watson, in collaboration with William Marquardt, was curious to see if early domesticates could be identified at the late Middle and Late Archaic shell middens in the middle Green River region (ca. 5500 and 3500 cal. BP), slightly earlier than the use of Mammoth Cave, which came to be known as the Shell Mound Archaeological Project (SMAP) (Marquardt and Watson 2005). The only native cultigen in either their domestic or ruderal forms was squash, though at the time squash was believed to be Mesoamerican in origin. However, paleoethnobotanist, Gail Wagner, identified high frequencies of nut charcoal and suggested that Late Archaic hunter-gatherers were already impacting and diversifying surrounding ecosystems in complex ways. She postulated that through forest management activities such as silviculture, they were already creating anthropogenic environments (Wagner 2005). Further, she stated that "The record of plant remains through time at the Carlston Annis site is significant for revealing the nature of how forest management could eventually lead to the tending of domesticated plants" (Wagner 2005:213). In a discussion of anthropogenic ecology throughout the Eastern Woodlands based on the archaeological record, Wagner also referred to the Big Barrens as a likely anthropogenic ecosystem (Wagner 2003).

Crawford (2005:181) wrote that "Anthropogenic communities are visible, in my view, although they are more forest edge or forest opening types of communities than garden associated communities. The possibility of a local, fire-induced ecology is proposed. The Late Archaic Green River material is consistent with an early stage in a continuum culminating in Early and Middle Woodland husbandry systems". Both argued that the primary goal for these hunter-gatherers was woodland management rather than for agricultural economies. Wagner (2005:237) wrote:

> *We can understand how girdling selected trees or using low-intensity ground fires enhanced mast production and encouraged game by clearing the understory and maintaining an open woods where patches of sunlight could reach the ground. But were these Middle-to-Late Archaic folks actively creating openings in the woods that centered around mast trees, but rather centered around useful weeds and early succession plants? And*

where and how was this ground disturbed or churned? Open, disturbed ground is indicated by a number of plants, some of which were later to become important cultivated foods.

Was the increase in niche exploitation during the Late Archaic and Early Woodland periods associated with longer and more expansive foraging forays or the localized human creation of niches through ecosystem manipulation? Based on the ecological history of the area, human manipulation of vegetation seems a plausible factor. Did it happen even earlier in the Archaic with silviculture as Wagner (2005) has posited from data collected at the Green River Shell Middens? Interestingly, vegetation change and increased fire activity occurred contemporaneously with more diffuse plant exploitation practices, domestication, and changing wood-working technologies (from grooved axes to celts) during the Late Archaic/Early Woodland transition (Applegate 2008). The potential significance of this correlation must be assessed in greater detail. Late Archaic to Early Woodland plant domestication has been documented elsewhere in Kentucky, most prominently in the Cumberland Plateau in eastern Kentucky (Delcourt and Delcourt 1998; Delcourt et al. 1998; Gremillion 1997; Gremillion et al. 2008). In the following chapters, I explore whether another significant cultural development occurred in south-central Kentucky: prescribed fire regimes by humans.

For many hunter-gatherer studies, archaeologists have employed adaptationist models for understanding changes in hunter-gatherer land use and, in turn, social complexity. For example, explanations of increased cultural complexity have relied on population pressure, risk minimization for access to resources, or environmental stress. More recently, there have been critiques against adaptationist models of Archaic societal evolution (see Emerson and McElrath 2009 for an in depth summary of competing models). Among the criticisms is that environment is considered to be too large a factor, and human agency is not taken into account. It is my view that adaptationist models relating to the environment should not be totally disregarded. Instead, they must be nuanced further, with addition of the concept of human agency in impacting environments. It is likely that interplay between humans and their environments is marked by societal successes and failures, but due to the coarse-grained nature of the dataset we cannot see this. Environmentally based models that have fallen out of favor may be reexamined as we encounter environmental changes in the Anthropocene. While the Archaic period spans 9000 years, the extent of our theoretical grounding in Archaic traditions perhaps extends back only a century. There is no doubt that early models of hunter-gatherer environmental interactions are flawed, but they provide important foundations that we can build upon. One of the greatest strengths of the Archaic studies is the fact that many of them have considered a number of environmental variables including vegetation, geomorphology, and climate change in relation to socio-cultural developments.

The richness of the archaeological dataset and environmental models that have been developed through Archaic period research should be considered a strength, not a weakness. As finer-grained environmental data and chronologies of the archaeological record become available, I believe that this will be better recognized. The Archaic period in the Midcontinent witnessed dramatic environmental transitions from the Pleistocene/Holocene transition and Younger Dryas (ca. 11,000 cal. BP), to the cooling episode (ca. 8200 cal. BP), to the Middle Holocene Climatic Optimum (ca. 9000-4200 cal. BP), followed by the Late Holocene conditions we experience today. The effects of those environmental circumstances were variable across the region and no doubt affected cultural developments. With impending climatic changes over the next century, we may encounter increasingly severe environmental conditions, such as temperature fluctuations and shifting fluvial regimes, soil erosion, altered vegetation communities, and many other potentialities. As we search for solutions to these dilemmas, we may reconsider the Holocene environmental record and Archaic hunter-gatherer responses as informative historical examples. Although I believe that social and economic developments and movements towards complexity should be taken into account and that models should be constructed to aid in understanding those developments, environmental studies in conjunction with human dynamics provide an opportunity for holistic studies. The excavations at Crumps Sink provide an opportunity to better integrate archaeological and environmental data sets, trace ebbs and flows in human-environmental interactions, and identify anthropogenic impacts on past ecosystems.

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CHAPTER 5. ARCHAEOLOGICAL INVESTIGATIONS AT CRUMPS SINK

Auger Tests and Excavation Units

As part of assessment of the Crumps Site for the Heritage Land Conservation Fund, in 2009 Crothers cored within Crumps Sink to assess its archaeological potential and identified buried archaeological deposits to a depth of at least 3 meters below the present ground surface. Based only on small diameter auger cores made across the sinkhole, it was not clear whether the anthropogenic soils observed in the auger were a primary deposit or sediments that had been eroded from the rim of the sinkhole and redeposited in the bottom of the sink. Therefore, in July 2015, an excavation unit was placed in Crumps Sink (Figure 5.1).

Figure 5.1. Crumps Sink excavations, looking west.

It was located outside of the cave entrance and corresponded to the deepest core containing buried deposits. The grid from the 2009 investigations was reestablished to geo-reference the unit with the rest of the cores and spot-finds. The 2009 bucket auger locations were still visible and were flagged and then remapped with a total station. Unit 1, measuring 1m east-west by 2 m north-south, was oriented to magnetic north. A second 1x2 m unit (Unit 2), oriented SW-NE was placed in the cave vestibule, with the goal of capturing the apparent orientation of sediment deposition. Excavations were not begun in the vestibule until fall 2016 and because the deposits were secondarily deposited and greatly eroded those investigations are not discussed here.

Collection and Documentation Methodology

From the beginning of the excavation, faunal remains, botanical remains, and artifacts from arbitrary 10 cm levels within natural levels (zones) were collected by dry-screening with quarter-inch (6.35 mm) mesh for each 1x1m subunit. Zones were identified based on changes in sedimentary characteristics during excavation. The south subunit was always excavated first, followed by the north subunit. Generally, the first 8-9 cm of each level were excavated with a shovel, followed by troweling to clean and level the floor for photographs. After photographing each level, a plan map of the level was drawn to show differences in sediment properties and potential features. Diagnostic and other artifacts were piece-plotted on level forms when exposed *in situ*. Prior to excavation, due to expectation of deep deposits and the necessity of only excavating a small area, precautions were taken to ensure safety, and preparations were made to shore the walls of the unit. As excavations progressed, a ladder was used to enter and exit the unit, and with further depth buckets were lifted out of the unit by rope. The unit walls were shored with plywood boards and a combination of foundation jacks and 2x4s buttressing vertically oriented 2x6s with vertical 4x4s in the center (Figure 5.2). Beginning with Level 8, which was 70-80 centimeters below surface (cmbs), culturally unmodified rock (principally limestone) greater than ½ inch (12.7 mm) in greatest dimension was weighed in the field with a Berkeley spring scale and discarded. Also, beginning with Level 8, after obvious artifacts and bone were removed, all residual material retained in the ¼ inch screen was bagged to be washed and further sorted at the field station or archaeology laboratory. Prior to Level 8, artifacts were removed from the ¼ inch screen, but residual material was not collected nor was the unmodified rock weighed before discarding. After washing, all remaining material greater than ¼ inch was sorted and the rock was weighed and discarded.

Figure 5.2. Showing Unit 1, and shoring of walls during excavations, looking north.

The rock weight from the lab sample was added to the field weight to get total weight of rock per level. In addition, the weight of each major artifact type (lithic debitage, bone, and burned sediment) was recorded. This material is discussed in Chapter 6. Beginning with Level 5B, due to its appearance as a midden or a buried soil horizon, flotation samples were collected, but they were from the general matrix, not from a specific location or corner of each level. These samples were approximately 20 cubic liters (l^3) in volume. In Level 8, flotation samples were collected systematically from a column in the NE and SW corners of Unit 1. The float column samples were 30x30x10 cm.

Zone Designations

The original stratigraphic zone distinctions during excavations were assigned Roman numerals I, II, III, and IV based on changes in soil/sediment color and texture seen during excavation. Following documentation of the profile and further consideration of the sediment analyses, several sub-horizons were distinguished. These were designated by adding a suffix in the form of an uppercase letter for each sub-horizon. As shown in Table 5.1, I determined that Zone III contained two similar but slightly different sub-zones and separated them into Zones III A and III B. Likewise, I separated Zone IV into several subzones (IV A through IV I). The deposits at the terminus of cultural horizons, with few to no artifacts and with sediment texture more similar to non-anthropogenic than to anthropogenic deposits, were designated Zone V. Thus, hereafter, I use zone distinctions determined by profile documentation and soil description. The following zones are based on soil/sediment color and texture, not on archaeological material, radiocarbon dates, or soil pedology (Table 5.1). However, archaeological material and soil geomorphological analyses are considered in Chapter 6 for a better understanding of the chronological and site formation history.

Table 5.1. Zone Designations at Crumps Sink.

<table>
<tr><th>Level</th><th>Zones During Excavation</th><th>Revised Zones after Profile Documentation</th></tr>
<tr><td>1</td><td>I</td><td>I</td></tr>
<tr><td>2</td><td rowspan="4">II</td><td rowspan="4">II</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td></tr>
<tr><td>5A</td></tr>
<tr><td>5B</td><td rowspan="4">III</td><td rowspan="3">III A</td></tr>
<tr><td>6</td></tr>
<tr><td>7</td></tr>
<tr><td>8</td><td>III B</td></tr>
<tr><td>9</td><td rowspan="30">IV</td><td>IV A</td></tr>
<tr><td>10</td><td>IV A, IV B</td></tr>
<tr><td>11</td><td rowspan="3">IV B</td></tr>
<tr><td>12</td></tr>
<tr><td>13</td></tr>
<tr><td>14</td><td rowspan="3">IV C</td></tr>
<tr><td>15</td></tr>
<tr><td>16</td></tr>
<tr><td>17</td><td rowspan="2">IV D</td></tr>
<tr><td>18</td></tr>
<tr><td>19</td><td>IV D, IV E</td></tr>
<tr><td>20</td><td rowspan="3">IV E</td></tr>
<tr><td>21</td></tr>
<tr><td>22</td></tr>
<tr><td>23</td><td rowspan="4">IV F</td></tr>
<tr><td>24</td></tr>
<tr><td>25</td></tr>
<tr><td>26</td></tr>
<tr><td>27</td><td>IV F, IV G</td></tr>
<tr><td>28</td><td rowspan="5">IV G</td></tr>
<tr><td>29</td></tr>
<tr><td>30</td></tr>
<tr><td>31</td></tr>
<tr><td>32</td></tr>
<tr><td>33</td><td rowspan="2">IV H</td></tr>
<tr><td>34</td></tr>
<tr><td>35</td><td>IV I</td></tr>
<tr><td>36</td><td>IV I, V</td></tr>
<tr><td>37</td><td rowspan="2">V</td></tr>
<tr><td>38</td></tr>
</table>

Processing of Artifacts

After the residual dry-screen material was washed through window screen, the primary material sorted from each level included rock, lithic debitage, bone, burned sediment, charcoal, mussel shell, and terrestrial gastropods, as well as small lithic, bone, and shell artifacts. Unmodified rock identified in the lab was weighed and added to the field mass of rock of each 1x1m ten-centimeter level. Artifacts and other material were catalogued according to standard University of Kentucky archaeology laboratory protocol (Appendix).

Flotation

Flotation column samples were collected beginning with level 5A. The samples were collected in the northeast and southwest corners of the North and South subunits in 10-cm levels (with the exception being that Level 5B was 5 cm thick). Each sample was approximately 30x30x10cm and on average contained 20 cubic liters (l^3) of sediment. The bags of sediment were transported back to the lab weekly by crews returning to the UK Archaeology Laboratory. Flotation processing has not been completed and is not discussed here. Therefore, the mass of artifacts and rocks in the flotation samples are not included in the coarse fraction masses presented in Chapter 6.

Stratigraphy

Zone I

Zone I is between 0 and 10 cmbs and is a 10YR3/4 dark yellowish brown, silty clay loam. It is slightly darker and contains more organic material than Zone II. Zone I was interpreted as a weakly developed modern A horizon.

Zone II

Zone II is between 10 and 45 cmbs and is a 10YR3/4 dark yellowish brown silt loam flecked with small fragments of charcoal and burned sediment. This zone may be the result of erosion/deposition from historic agricultural activities around the sink. This zone has been truncated, and these areas have been filled in with a mix of darker and lighter sediment. These disturbances may be from tree falls or other recent disturbances in the sink. Zone II was interpreted as the B horizon of the modern soil surface.

Zone III A

Zone III A is between 45 and 70 cmbs and is a 10YR2/2 very dark brown silt loam. There is a layer of well-sorted rock (2-5 cm in diameter) at the top of this horizon. The upper surface of this zone is undulating, and the rock layer is discontinuous. Below the rock layer, sediment is friable with some gravel-sized limestone inclusions and a low contains a low density of charcoal flecking. It was interpreted as buried A horizon Ab1 and midden.

Zone III B

Zone III B is between 70 and 80 cmbs and is a 10YR2/1 black to 10YR2/2 very dark brown silt loam that is friable with white, degraded limestone fragments. Both the surface and basal topography of this layer are undulating, though the basal topography of this stratum undulates to a greater degree than the upper surface of the stratum. This layer is discontinuous throughout the unit. It was interpreted as a continuation of buried A horizon Ab1 and midden. This may be the root zone of Zone III.

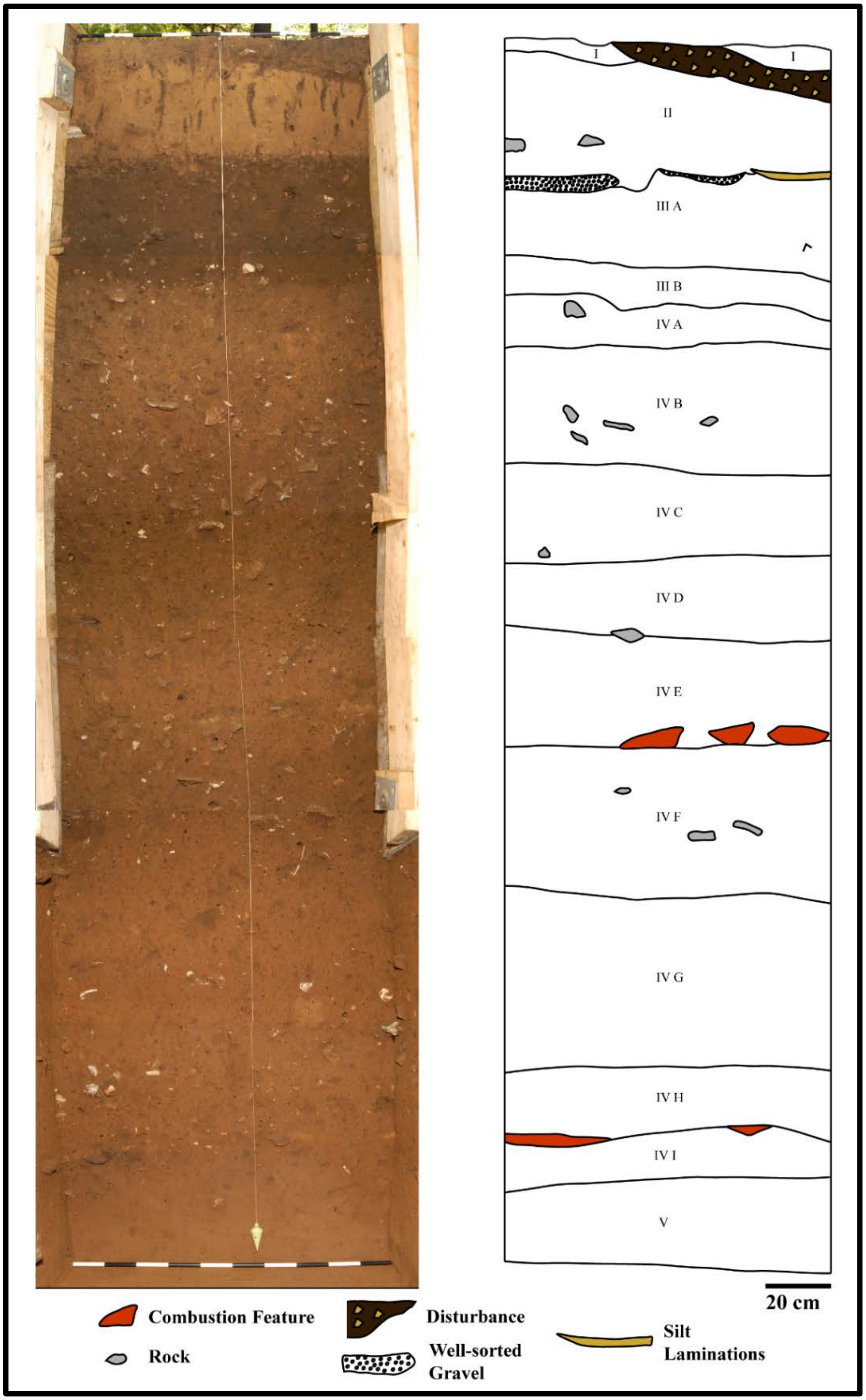

Figure 5.3. North profile photo and drawing.

Zone IV A

Zone IV A is between 80 and 95 cmbs and is a 10YR3/2 very dark grayish brown, (slightly more gray than Zone IV B) silty clay loam that is friable with some limestone inclusions. It has more pore space than previous zones. Surface and basal topography range from planar to wavy. It was interpreted as the B horizon or a transitional AB horizon of buried A horizon Ab1 and it is midden.

Zone IV B

Zone IV B is 95 to 135 cmbs and is a 10YR3/2 very dark grayish brown to 10YR3/3 dark brown silt loam with some clay that is friable and flecked with abundant large pieces of charcoal (>2cm in diameter), poorly sorted angular limestone, burned sediment, and terrestrial gastropod shells. It has significant pore space, and pockets of diffuse silt (10YR5/6 yellowish brown) are apparent. This zone was interpreted as the B horizon and parent material of buried A horizon Ab1 and midden.

Zone IV C

Zone IV C is 135 to 160 cmbs and is a 10YR3/2 very dark grayish brown silt loam that is friable to very friable. It has much pore space and a greater density of subangular-angular, poorly sorted limestone than IV B and IV D. This zone is flecked with charcoal, burned sediment, terrestrial gastropod shells, and some mussel shell, and it was interpreted as buried A horizon Ab2 and midden.

Zone IV D

Zone IV D is 160 to 185 cmbs and is a 10YR3/2 very dark grayish brown to 10YR3/3 dark brown silty clay loam and friable to very friable. It has much pore space and a lower density of charcoal flecking, burned sediment, and sub-angular limestone than Zone IV C. It is slightly more gray than Zone IV E. Zone IV D was interpreted as midden and this zone may represent the transitional AB horizon of buried A horizon Ab2.

Zone IV E

Zone IV E is 185 to 220 cmbs and is a 10YR3/3 dark brown friable silt loam flecked with charcoal. It contains subangular to angular limestone inclusions and has much pore space. Zone IV E has a lower density of limestone compared to the above Zone IV D and lower Zone IV F. It is interpreted as midden and the B horizon of buried A horizon Ab2.

Zone IV F

Zone IV F is 220 to 265 cmbs and is a 10YR3/2 very dark grayish brown friable silt loam with dense charcoal flecking throughout. It contains more poorly sorted, subangular-angular limestone than Zone IV E. Limestone fragments range in size from small to large gravels that often are oriented horizontally. Zone IV F is less porous than any of the Zone IV zones that rest above Zone IV F. The upper and lower boundaries are clear to gradual. Zone IV F is interpreted as buried A horizon Ab3 and midden.

Zone IV G

Zone IV G is 265 to 320 cmbs and is a 10YR3/3 dark brown silt loam. It is less friable and porous than Zone IV F (porosity is very low) and also has a lower density of charcoal flecking and subangular to angular limestone than IV F. Limestone fragments range in size from small to medium gravel. Zone IV G was interpreted as midden and the B horizon of buried A horizon Ab3.

Zone IV H

Zone IV H is 320 to 340 cmbs and is a 7.5YR3/3 dark brown silty clay loam. It has a similar amount of charcoal to Zone IV G. In addition to color difference, it is distinguished from IV G by the presence of moderately sorted gravel-sized reddish limestone. Zone IV H was interpreted as part of the B horizon of buried A horizon Ab3.

Zone IV I

Zone IV I is 340 to 355 cmbs and is a 7.5YR3/3 dark brown silty clay loam, flecked with some charcoal and limestone. Feature 5 (a combustion feature) and an ash layer that may have been associated with the feature are evident at the interface between IV H and IV I. Zone IV I was interpreted as a faint buried A horizon (Ab4).

Zone V

Zone V is 355 to 380 cmbs and is a 7.5YR3/4 dark brown silty clay loam. It has few inclusions and very little charcoal, which is only apparent toward the upper boundary. No charcoal is apparent near the lower boundary of this zone. Zone V marks the beginning of archaeologically sterile deposits and its matrix may be primarily or secondarily deposited loess.

Archaeologically Sterile Deposits

Archaeologically sterile deposits were reached at 380 cmbs. A bucket auger was used to collect systematic sediment samples below this depth. The use of the bucket auger was terminated upon reaching impenetrable rock at 517 cmbs. In general, all samples are 7.5YR brown silt loams to silty clay loams with some very small gravel-sized inclusions. Small gravel sized inclusions present between 380 and 460 cmbs were absent at depths below 460 cmbs. At 517 cmbs rock was encountered. It is possible that this rock is the top of the roof-fall from the collapsed sink. The deposits between 380 and 517 cmbs are considered to be a continuation of Zone V.

Features

Pit and hearth features were also encountered, suggesting humans were directly occupying or performing activities within the sinkhole, aside from trash disposal. Five features were encountered during excavation. Feature 1 appears to be a result of undulating topography of the base of Zone III B interface with Zone IV, rather than cultural in origin, and is not considered here. The remaining features were one rock cluster (Feature 2; Figure 5.4) and three apparent surface hearths (Features 3-5; Figures 5.5-5.8).

Figure 5.4. Feature 2 looking west, a cluster of limestone in a shallow pit feature.

Figure 5.5. Feature 3, diffuse oxidized sediment and ash in the center of north half from *in situ* burning.

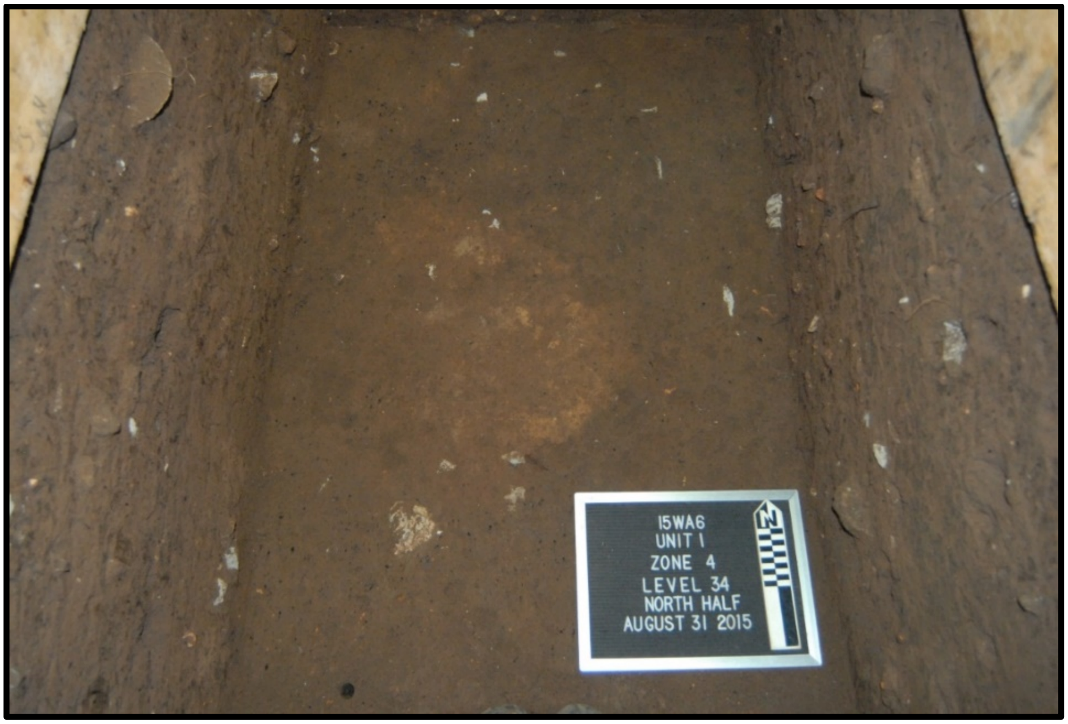

Figure 5.6. Feature 4, distinctly oxidized sediment and ash from *in situ* fire.

Figure 5.7. Feature 5, pedestalled in the northwest corner of the north half.

Figure 5.8. Feature 5 profile, facing west.

Radiocarbon Dating

Twelve samples of nut charcoal were submitted to DirectAMS (Bothell, WA) for radiocarbon dating. Archaeological deposits at Crumps Sink spanned the Middle Archaic to Late Archaic periods (7200-2900 cal. BP) (Table 5.2).

Table 5.2. Radiocarbon dates from Crumps Sink.
Ages calibrated using CALIB 7.1 (Stuiver et al. 2018).

Lab No.	Sample ID	Level	Depth Below Surface (m)	RCYBP		Calibrated BP
				BP	1σ error	Two σ
D-AMS 024358	CS6N	6	0.50-0.60	2866	28	2882-3070
D-AMS 013555	CS8N-1	8	0.70-0.80	3005	26	3078-3326
D-AMS 024359	CS12N	12	1.1-1.2	4232	30	4650-4857
D-AMS 013556	CS16N-1	16	1.5-1.6	3562	38	3722-3971
D-AMS 024360	CS18N	18	1.7-1.8	4081	27	4446-4803
D-AMS 024361	CS20N	20	1.9-2.0	4118	31	4527-4815
D-AMS 013557	CS25N-1	25	2.4-2.5	4880	28	5588-5652
D-AMS 024362	CS28N	28	2.7-2.8	4999	28	5653-5884
D-AMS 024363	CS32N	32	3.1-3.2	6092	29	6860-7153
D-AMS 024364	CS34N	34	3.3-3.4	6033	31	6788-6957
D-AMS 013558	CS37N-1	37	3.65	6106	38	6887-7156
D-AMS 024365	CS38N	38	3.7-3.8	6206	33	7003-7241

Based on radiocarbon dating and projectile point types, I correlated deposits to specific environmental and cultural periods, which is discussed below. The radiocarbon dates are further discussed along with projectile point typologies from Crumps Sink.

Artifacts

Artifacts recovered consisted of flaked stone projectile points, flaked/ground stone hoes, ground stone pestles, a grooved axe fragment, bone awls and needles, and shell beads. Refuse representing hunter-gatherer food preparation over a 4300-year time span includes thousands of fragments of animal bone, mussel shell, and charred nutshell. Diagnostic projectile points (n=19) were analyzed, and correlated with the nearest associated radiocarbon dates to develop a chronology for projectile point technologies at Crumps Sink and to compare this chronology with previously accepted age ranges throughout the Midcontinental and Eastern United States (Table 5.3).

Table 5.3. Diagnostic projectile points from Crumps Sink, Unit 1, North half.

Field Specimen #	**Level**	**Zone**	**Depth below surface (m)**	**Type**
18-7	5B	III A	0.43	Motley
18-8	5B	III A	0.43-0.50	Saratoga Broad Bladed
18-9	5B	III A	0.43-0.50	Raddatz Side Notched
44-6	10	IV A, B	0.9-1.0	Motley
63-7	13	IV B	1.2-1.3	Motley
69-16	14	IV C	1.3-1.4	Merom
71-10	15	IV C	1.4-1.5	McWhinney Heavy Stemmed
71-11	15	IV C	1.4-1.5	Table Rock Cluster
73-18	16	IV C	1.5-1.6	Late Archaic Stemmed
126-7	22	IV E	2.1-2.2	Raddatz Side Notched
126-8	22	IV E	2.1-2.2	Stanly Stemmed
170-18	25	IV F	2.4-2.5	Helton
150-10	26	IV F	2.5-2.6	Raddatz Side Notched
150-11	26	IV F	2.5-2.6	Raddatz Side Notched
173-20	27	IV F, G	2.6-2.7	Raddatz Side Notched
176-8	29	IV G	2.8-2.9	Raddatz Side Notched
178-10	30	IV G	2.9-3.0	Raddatz Side Notched
181-11	31	IV G	3.0-3.1	Raddatz Side Notched
181-10	31	IV G	3.0-3.1	Raddatz Side Notched

The results of the projectile point analysis are summarized below. I then summarize the types, depths, and age ranges for formalized groundstone tools recovered from Crumps Sink.

Motley Cluster

The North subunit sample yielded three Motley Cluster projectile points. Field Specimen #44-6 was recovered from Zone IVA/B, Level 10 and Field Specimen #63-7 was recovered from Zone IV B, Level 13 (Figure 5.9). One radiocarbon date was acquired from Zone IV B, Level 12, placing it between the two mentioned projectile points in depth. Projectile points from this cluster have been assigned to the Late Archaic through Early Woodland periods, with an age range of 3400-2600 RCYBP (Justice 1987). The nearest radiocarbon date at Crumps Sink was 4232±30 RCYBP (4650-4857 cal. BP) making it inconsistent with previously reported ranges. For the Motley cluster this date is too early (Justice 1987).

In the stratigraphic sequence, this date is out of place in comparison to other radiocarbon dates. The date suggests that charcoal was exhumed from older deposits (possibly Zone IV E) and redeposited. Field specimen #18-7 was located in Zone IIIA, Level 5B (Figure 5.10). Charcoal from Zone IIIA, Level 6 yielded a radiocarbon date of 2866±28 RCYBP (2882-3070 cal. BP). This date is consistent with the expected range of the Motley projectile points from throughout the Midcontinent (Justice 1987).

Figure 5.9. Motley Cluster.
a) FS #44-6, Zone IV A/B, Level 10; b) FS #63-7, Zone IV B, Level 13.

Figure 5.10. Motley Cluster.
FS #18-7: Zone III A, Level 5B.

Saratoga Broad Bladed

One Saratoga Broad Bladed projectile point (FS#18-8; Figure 5.11) was recovered from Zone III A, Level 5B. Charcoal from Zone IIIA, Level 6 yielded a radiocarbon date of 2866±28 RCYBP (2882-3070 cal. BP). Saratoga Cluster projectile points have been recovered from contexts dating to between 4000 and 2600 RCYBP (Justice 1987). Thus, this date is consistent with the expected range of Saratoga projectile points from throughout the Midcontinent (Justice 1987).

Figure 5.11. Saratoga Broad Bladed.
FS# 18-8, Zone III A, Level 5B.

Merom Cluster

The North subunit yielded one projectile point from the Merom projectile cluster (FS#69-16; Figure 5.12). This point was recovered from Zone IV C, Level 14. One sample was submitted for radiocarbon dating from Zone IV C, Level 16 and yielded a date of 3562±38 RCYBP (3722-3971 cal. BP). Merom cluster projectile points have been assigned to the Late Archaic period, ranging in age from 3600 to 3000 RCYBP (Justice 1987). Thus, the date is consistent with age ranges of projectile points from the Merom cluster throughout the Midcontinental and Eastern United States.

Figure 5.12. Merom Cluster.
FS#69-16, Zone IV C, Level 14.

McWhinney Heavy Stemmed

The North subunit at Crumps Sink yielded one McWhinney Heavy Stemmed projectile point, which is classified within the Late Archaic Stemmed cluster (Figure 5.13). The example recovered from Crumps Sink was found in Zone IV C, Level 15. The nearest associated date was Zone IV C, Level 16 at 3562±38 RCYBP (3722-3971) cal. BP.

McWhinney projectile points have been assigned to the Late Archaic period with dates ranging from 6000 to 3000 RCYBP (Justice 1987). This date is consistent with date ranges for this point type in the Midcontinental and Eastern United States.

Figure 5.13. McWhinney Heavy Stemmed.
FS#71-10, Zone IV C, Level 15.

Table Rock Cluster

One Table Rock Cluster projectile point was recovered from the North half of Unit 1 at Crumps Sink (Figure 5.14). Field Specimen #71-11 was recovered from Zone IV C, Level 15. The nearest associated date was Zone IV C, Level 16 at 3562±38 RCYBP (3722-3971) cal. BP. Table Rock Cluster projectile points were manufactured during the Late Archaic period with dates ranging from 5000 to 3000 RCYBP (Justice 1987). Thus, this radiocarbon date is consistent with accepted radiocarbon date ranges for Table Rock Cluster projectile points in the Midcontinental and Eastern United States.

Figure 5.14. Table Rock Cluster.
FS#71-11: Zone IV C, Level 15.

Late Archaic Stemmed Cluster

One Late Archaic Stemmed Cluster projectile point (FS#73-18) was found in Zone IV C, Level 16 (Figure 5.15). A radiocarbon date from Zone IV C, Level 16 was 3562±38 RCYBP (3722-3971 cal. BP). Late Archaic Stemmed Cluster projectile points were manufactured during the Late Archaic period with dates ranging from 6000 to 3000 RCYBP (Justice 1987). Thus, the radiocarbon date associated with the projectile point from Crumps Sink is consistent with date ranges for this point type in the Midcontinental and Eastern United States.

Figure 5.15. Late Archaic Stemmed Cluster.
FS#73-18, Zone IV C, Level 16.

Helton

One corner notched projectile point was classified as a Helton due to similarities to corner notched Helton projectile points identified at Modoc Rock Shelter in southwest Illinois (Ahler and Koldehoff 2009) and the Lone Wolf site in east-central Missouri (Harl 2009). Field Specimen #170-18 (Figure 5.16) was recovered from Zone IV F, Level 25. A charcoal sample from the same level as this projectile point yielded a radiocarbon date of 4880±28 RCYBP (5588-5652 cal. BP). Helton phase deposits at Modoc have a date range of 5500-5000 RCYBP, and Helton phase deposits at Lone Wolf have a date range of approximately 5650-4850 RCYBP (Ahler and Koldehoff 2009; Harl 2009). The radiocarbon date associated with the Helton projectile point at Crumps Sink is at the later portion of this accepted range, but there is overlap, demonstrating contemporaneity. The presence of this projectile point style this far to the east may be significant and warrants further attention.

Figure 5.16. Helton.
FS#170-18, Zone IV F, Level 25.

Stanly Stemmed

One projectile point assignable to the Stanly Stemmed Cluster was recovered in the north half of Unit 1. It was FS# 126-8 (Zone IV E, Level 22) (Figure 5.17). Stanly Stemmed projectile points were manufactured during the Middle Archaic period between approximately 8000 and 7000 RCYBP. The nearest radiocarbon date was from Zone IV E, Level 20 and had an age of 4118$\pm$31 RCYBP (4527-4815 cal. BP), inconsistent with the accepted age range of Stanly Stemmed projectile points in the Midcontinental and Eastern United States. A charcoal sample collected from below this Stanly Stemmed projectile point, in Zone IV F, Level 25 yielded an age of 4880±28 RCYBP (5588-5652 cal. BP), also inconsistent with the accepted range for the Stanly Stemmed Cluster. As was noted earlier in this chapter, Zone IV E is interpreted as the B horizon of buried A horizon Ab2. This horizon seems to have formed during a period of enhanced sediment accumulation in the sink, and may indicate an erosional episode. Thus, the chronological inconsistency may be related to this projectile point being redeposited during this period of upslope erosion/downhill accumulation.

Figure 5.17. Stanly Stemmed.
FS#126-8, Zone IV E, Level 22.

Raddatz Side Notched

Nine Raddatz Side Notched projectile points were recovered from Crumps Sink (Figures 5.18-5.20). Seven examples (Figure 5.18) were recovered from deposits with accepted age ranges for this projectile point type (FS#'s 150-11, 173-20, 176-8, 178-10, 181-10, and 181-11).

Figure 5.18. Raddatz Side Notched.
a) FS#150-11, Zone IV F, Level 26; b) FS#150-10, Zone IV F, Level 26; c) FS#173-20, Zone IV F/G, Level 27; d) FS#176-8, Zone IV G, Level 29; e) FS#178-10, Zone IV G, Level 30; f) FS#181-10, Zone IV G, Level 31; g) FS#181-11, Zone IV G, Level 31.

These seven projectile points were found in Zone IV F, Level 26 (n=2), Zone IV F/G, Level 27 (n=1), Zone IV G, Level 29 (n=1), Zone IV G, Level 30 (n=1), and Zone IV G, Level 31 (n=2). The dates that encompass the span of these projectile points were Zone IV F, Level 25 at 4880±28 RCYBP (5588-5652 cal. BP), Zone IV G, Level 28 at 4999±28 RCYBP (5653-5884 cal. BP) and Zone IV G, Level 32 at 6092±29 RCYBP (6860-7153 cal. BP). Raddatz Side Notched projectile points have distinct U-shaped side notches with prominent squared basal ears and a straight to concave basal edge. These points were often bifacially resharpened. Additionally, if the distal end of the blade was broken these projectile points were often repurposed into hafted endscrapers with the repurposed edge being steeply angled and sharply incurvate (Jefferies 1990; Justice 1987).

Two of these seven specimens were repurposed into hafted endscrapers. Raddatz projectile points have a general geographic range within the lower Ohio River valley, though similar side notched variants are evident for the Middle Archaic period in other parts of the Midcontinent (see Emerson and McElrath 2009). They have been assigned to the Middle Archaic period with dates ranging from 8000 to 5000 RCYBP (Justice 1987). Stafford and Cantin (2009) note that these points need better dating, but based on dates from 15Pe925 in southern Indiana, they have assigned them to an age range of 5500-6300 RCYBP in Southern Indiana. At the Knob Creek site a deep side notched point was associated with a radiocarbon date of 5830±90 RCYBP. McBride noted a number of Large Side Notched Specimens assignable to the Raddatz or Brannon Side Notched cluster at the late Middle Archaic Baker site in the middle Green River valley (McBride 2000). The specimens at Crumps Sink were recovered between Levels 26 and 31. Radiocarbon dates from the same deposits suggest that the projectile points date ranges are between 4850 and 6100 RCYBP (5600-7150 cal. BP), consistent with the previously reported ranges.

The remaining two Raddatz Side Notched projectile points were recovered from shallower deposits. Field Specimen #126-7 (Figure 5.19) was recovered in Zone IV E, Level 22. The closest radiocarbon date is from Zone IV E, Level 20 with an age of 4118±31 RCYBP (4527-4815 cal. BP). This is inconsistent with the accepted age range for this type. This projectile point was recovered from the accumulated sediment horizon Zone IV E along with the previously described Stanly Stemmed projectile point. As with the Stanly Stemmed projectile point, it is plausible that this Raddatz Side Notched projectile point was redeposited during a period of uphill erosion/downhill accumulation.

Figure 5.19. Raddatz Side Notched.
FS#126-7: Zone IV, Level 22.

Field Specimen #18-9 is a heavily resharpened projectile point that was recovered in a very shallow stratum in Zone IIIA, Level 5B (Figure 5.20). Charcoal from Zone IIIA, Level 6 yielded the closest associated radiocarbon date of 2866±28 RCYBP (2882-3070 cal. BP). Again, this date is inconsistent with the expected range of Raddatz Side Notched points in the Midcontinental and Eastern United States (Justice 1987). Zone IIIA, Level 5B is at the surface of buried A horizon Ab1. This buried A horizon appears to have been stable for over 2000 years until it was capped by Zone II, which may be the result of erosion/deposition from historic agricultural activities around the sink. The most likely explanation for the stratigraphic placement of this projectile point is that it was redeposited at the time that buried A horizon Ab1 was at the surface.

Figure 5.20. Raddatz Side Notched.
FS#18-9: Zone III A, Level 5B.

Formalized Groundstone Tools

Though many groundstone objects were recovered from the North half of Unit 1 of Crumps Sink, not all could be classified as a specific formalized tool. However, the objects that could be classified included pestle and flaked limestone hoe fragments. Six objects identified as fragments of pestles were found in the North half deposits of Unit 1. These were FS#'s 73-17, 141-7, 170-20, and 150-9. For FS#150-9 three pestle fragments were cataloged as a group. Five of the pestles fragments were found in Zone IV F, Levels 24-26, with an associated radiocarbon date from Level 25 of 4880+28 RCYBP (5588-5652 cal. BP). One pestle fragment (FS #73-17) was recovered from Zone IV C, Level 16, with an associated radiocarbon date in Level 16 of 3562±38 RCYBP (3722-3971 cal. BP). One flaked limestone hoe fragment (FS#27-8) was recovered from the North half and was in Zone IIIB, Level 8 and had an associated radiocarbon date in Level 8 of 3005±26 RCYBP (3078-3326 cal. BP)

Conclusions

Archaeological investigations at Crumps Sink revealed that it has exceptional stratigraphic integrity. Evidence for this can be seen in minimal mixing of nut charcoal revealed by radiocarbon dates, the fact that projectile points and associated radiocarbon dates are consistent with accepted date ranges throughout the Midcontinental and Eastern United States with few exceptions, and the presence of primary features. Projectile point types represented in the north half of Unit 1 at Crumps Sink are Motley (n=3), Saratoga Broad Bladed (n=1), Merom (n=1), McWhinney Heavy Stemmed (n=1), Late Archaic Stemmed (n=1), Table Rock Cluster (n=1), Stanly Stemmed (n=1), Helton (n=1) and Raddatz Side Notched (n=9). The presence of these projectile points suggests cultural use of the site extending from the late Middle Archaic to Early Woodland periods. With depth, radiocarbon dates range from 2870-6100 RCYBP (2900-7200 cal. BP) suggesting cultural occupation between late Middle Archaic and Terminal Late Archaic periods. Thus, projectile point typologies and radiocarbon dates complement each other well. Examples such as an outlier radiocarbon date in Zone IV B, and the three redeposited projectile points are informative about site formation processes, especially when considered in conjunction with descriptions of stratigraphic zones. These zones and the site formation processes that created them will be considered in greater detail in Chapter 6.

Table 5.4. Inferred cultural periods for deposits at Crumps Sink.
Ages calibrated using CALIB 7.1 (Stuiver et al. 2018).

Level	**Zones**	**Calib. BP* Two σ**	**Projectile Points (North Half)**	**Formalized Ground Stone**	**Assigned Cultural Period**
1	I				Historic-Modern
2-5A	II				
5B-7	III A	2882-3070	Motley (n=1) Saratoga Broad Bladed (n=1) Raddatz Side Notched (n=1)		Terminal Archaic- Early Woodland
8	III B	3078-3326		Limestone Hoe Fragment (n=1)	
9	IV A				Late Archaic- Terminal Archaic
10	IV A, IV B		Motley (n=1)		
11-13	IV B	4650-4857	Motley (n=1)		
14-16	IV C	3722-3971	Merom (n=1) McWhinney Heavy Stemmed (n=1) Table Rock Cluster (n=1) Late Archaic Stemmed (n=1)	Pestle Fragment (n=1)	Late Archaic
17-18	IV D	4446-4803			
19	IV D, IV E				
20	IV E	4527-4815			
21-22			Raddatz Side Notched (n=1) Stanly Stemmed (n=1)		
23-24	IV F			Pestle Fragment (n=1)	
25-26		5588-5652	Helton (n=1) Raddatz Side Notched (n=2)	Pestle Fragment (n=4)	Late Middle Archaic
27	IV F, IV G		Raddatz Side Notched (n=1)		
28-32	IV G	5653-5884 6860-7153	Raddatz Side Notched (n=1) Raddatz Side Notched (n=1) Raddatz Side Notched (n=2)		
33-34	IV H	6788-6957			
35	IV I				
36	IV I, V				
37-38	V	6887-7156 7003-7241			

Also of note is the where formalized ground stone tools are present in the deposit (Table 5.4). Pestle fragments were found in Level 16, and Levels 24-26, placing the appearance of such formalized tools at the end of the late Middle Archaic and into the Late Archaic period. In fact, with five of the six pestle fragments recovered in deposits dating to 4880±28 RCYBP (5588-5652 cal. BP), it suggests that at the site the greatest use of pestles was during late Middle to Late Archaic transition or the very early part of the Late Archaic period. This corresponds in age with intensive nut processing, likely associated with silviculture, identified in the middle Green River region (Wagner 2005). The single flaked limestone hoe fragment was recovered from Zone III B, Level 8 which had an associated Terminal Late Archaic period radiocarbon date. This corresponds in age with early plant domestication seen in the region and also cave exploration seen at Mammoth Cave. The changes in formalized ground stone tools present between the late Middle/Late Archaic and Terminal Late Archaic periods seems significant and could be another indicator of the shift from silvicultural to horticultural economies in the region.

The presence of discernable, horizontally laid stratigraphic zones further suggests integrity of the deposits at Crumps Sink. In Chapter 6, I summarize the magnetic, chemical, trace elemental, and soil micromorphological characteristics of these layers and consider the results to understand site formation processes at Crumps Sink. With these data, I reconstruct environmental conditions and human activities throughout the site's history and evaluate the timing and nature of anthropogenic land burning in the region.

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CHAPTER 6. SITE FORMATION PROCESSES AT CRUMPS SINK

Geoarchaeology

Waters (1992:3-4) defines geoarchaeology as the "application of concepts and methods of the geosciences to archaeological research", utilizing "techniques and approaches from geomorphology (the study of landform origin and morphology), sedimentology (the study of the characteristics and formation of deposits), pedology (the study of soil formation and morphology), and geochronology (the study of time in a stratigraphic sequence) to investigate and interpret the sediments, soils, and landforms at archaeological sites". Geoarchaeological investigations are multiscalar in their scope, considering space and time (Stein 1993). Through the contextual or human ecological approach, archaeologists must consider a variety of datasets including archaeological, geological, biological, and climatic (Butzer 1982). Stein (2005:121) utilizes concepts from sedimentology for interpreting site formation processes of archaeological deposits, writing "principles state that a sediment deposit of a solid material on the earth's surface is the result of four factors: (1) source, (2) transport mechanism, (3) environment of deposition, and (4) post-depositional changes that alter the original character of the sediment." One of the most common post-depositional changes is soil formation (Birkeland 1999; Holliday 2004; Stein 2005).

Soil Geomorphology

Birkeland (1999:1) defines soil geomorphology as "the study of soils and their use in evaluating landform evolution and age, landform stability, surface processes, and past climates". In 1941, Hans Jenny (cited in Barnes et al. 1998 and in Holliday 2004) proposed that five factors are involved in soil formation: climate, organisms, topography, parent material, and time. As soils form, a variety of processes can occur, including eluviation (or transfer of particles out of a horizon) illuviation (transfer of particles into a horizon), leaching, erosion, calcification/ decalcification, salinization/desalinization, decomposition, humification, ferrugination (where iron is released and soils become more red), and gleization (graying as iron is reduced in anaerobic soils) (Holliday 2004). Periods of soil formation versus sediment deposition can indicate the relative stability of the local landscape over time (Holliday 2004). I utilize concepts from soil geomorphology to reconstruct paleoenvironmental conditions at Crumps Sink and test the hypothesis by Baskin et al. (1994) that barrens ecosystems in the Sinkhole Plain were created and maintained by indigenous land burning.

Anthropogenic Impacts

Leach (1992:409) views "the geological environment of human beings as being culturally defined". Humans have the ability to cause geomorphological change (Butzer 1982). If shown to have been created by humans, the processes that have occurred on a landscape are manifestations of specific socioeconomic conditions, and their effects on the landscape can be traced back to these specific historical conditions (Widgren and Håkansson 2014). Thus, many site formation processes at archaeological sites are not fully explainable by environmental conditions. Anthropogenic inputs can be used as a measure of human activities and occupation intensity. Human alteration of vegetation structure and agricultural activity can lead to rapid erosion and sediment deposition through sheet-wash in sensitive karst terrains (Dicken and Brown 1938; Martin 2006; White 1988). Here, I utilize the concept of anthropogenic inputs to understand the degree to which humans altered the landscape at Crumps Sink.

Geoarchaeological Investigations at Crumps Sink

Identifying the fingerprints of prehistoric forest management can prove to be difficult, requiring interdisciplinary approaches (Börjeson 2014). Using various datasets collected from Crumps Sink, I describe sediment deposition and soil formation in a karst landform to understand landscape responses to climatic processes and human activities over four millennia. To understand human and environmental impacts on the landform I utilized concepts and methods from soil geomorphology. I ask, how do events, such as (1) Middle Holocene warming and drying, (2) wetter and cooler conditions favoring forest development in the Late Holocene, and (3) human impacts on the environment, manifest in the sedimentological record?

Recognizing that the depositional processes are localized, I still consider the phases of sediment accumulation and soil formation in relation to environmental conditions documented throughout the Interior Low Plateaus. I utilize observations from macroscopic field description, loss-on-ignition analysis, magnetic susceptibility analysis, and plant available phosphorous readings, soil micromorphology, and artifacts and ecofacts recovered, to identify buried soils and anthropogenic impacts in deposits. I use charcoal samples for radiocarbon dating to develop a chronology of these histories. Along with the archaeological record, I use soil geomorphology to reconstruct the paleoenvironmental history and evolution of a landscape (Birkeland 1999; Holliday 2004). The analyses summarized in this chapter were used to distinguish between climatic and human induced impacts on the Crumps Sink landform and, ultimately, to determine whether increased forest burning occurred in the region during the Late Holocene, or even earlier.

Landform Context of Crumps Sink

Crumps Sink is a sinkhole with a surficial catchment area of 2.56 ha, and thus provides an opportunity to focus on localized site formation processes without complicating factors such as alluvial deposition from distant sources. The following analysis focuses on characterizing the Crumps Sink deposits site formation processes between 7200 and 2900 cal. BP. The underlying geology of Crumps Sink is the interface between Ste. Genevieve and St. Louis limestones. Crumps Cave was formed by an underground river, and the sink may have opened up with collapse of the cave before 7200 years ago, which is the oldest radiocarbon date we have from the sink deposits. Based on the modified Köppen-Geiger world climate classification system, the Central Kentucky Karst is within a humid subtropical to temperate oceanic climate. The mean annual precipitation within an area of a radius of 35km surrounding Crumps Sink is 1300 mm per year, and the average annual temperature of 14.7℃ (Groves et al. 2013).

Crumps Sink is located in the area of the Hammack-Baxter and Baxter-Nicholson soil associations. The landform surrounding the sinkhole is a Crider silt loam with 2-6 percent slopes, while within the sinkhole, it is a Baxter gravelly silt loam with 12-20 percent slopes (Mitchell 2004). Crider silt loams are generally found on undulating ridges and have a parent material of loess and residuum from limestone. They are well-drained and usually have a depth to bedrock exceeding 60 inches (152 cm). Baxter gravelly silt loams are generally found on hillsides and side slopes of depressions and form from limestone residuum. They are well-drained and the depth to bedrock exceeds 60 inches (152 cm) (Mitchell 2004).

Stratigraphy

Field descriptions of the profile yielded important information that allowed for preliminary interpretations of the stratigraphic history of the site. Fourteen stratigraphic zones were identified (Table 6.1; Figure 6.2). Based on the field descriptions and the following lab analyses, I have separated the deposits conceptually into 5 soil/sediment units that will aid in reconstructing the depositional sequence at the site (Table 6.1).

Table 6.1. Zone descriptions and soil designations.

Soil horizon	Date Range (cal. BP)	Zone	Depth (mbs)	Soil/Sediment Description
A	**Modern**	**I**	0-0.10	10YR3/4, dark yellowish brown, silty clay loam, friable.
B	**Historic**	**II**	0.10-0.45	10YR3/4, dark yellowish brown, silty loam, flecked with small fragments of charcoal and burned sediment.
Ab1	**2880-3700**	**III A**	0.45-0.70	10YR2/2, very dark brown silt loam. There is a layer of well sorted rock (2-5 cm in diameter) at the top of this horizon. The upper topography of this zone is undulating and the rock layer is discontinuous. Below rock layer, matrix is friable, with some gravel-sized limestone inclusions, and a low density of charcoal flecking.
		III B	0.70-0.80	10YR2/1 black to 10YR2/2 very dark brown, silt loam, friable, with white, degraded limestone fragments. The surface and basal topography is undulating, though the basal topography undulates more. This layer is discontinuous throughout the unit.
B1		**IV A**	0.80-0.95	10YR3/2 very dark grayish brown, silty clay loam, friable with some limestone inclusions. Zone IV A has much pore space. Surface and basal topography range from planar to wavy. Zone IV A is slightly more gray than Zone IV B.
		IV B	0.95-1.35	10YR3/2 very dark grayish brown to 10YR 3/3 dark brown, silt loam with some clay, friable, flecked with high density of large pieces of charcoal ($\geq$ 2 cm in diameter), poorly sorted angular limestone, burned sediment, and terrestrial gastropod shells. Zone IV B has much pore space. Pockets of diffuse silt (10YR 5/6 yellowish brown) are evident in matrix.
Ab2	**3720-5590**	**IV C**	1.35-1.60	10YR3/2 very dark grayish brown, silt loam, friable to very friable, much pore space, higher density of subangular-angular poorly sorted limestone than the above Zone IV B and the lower Zone IV D. Flecked with a high density of charcoal, burned sediment, terrestrial gastropods, and some mussel shell.
		IV D	1.60-1.85	10YR3/2 very dark grayish brown to 10YR 3/3 dark brown, silty clay loam, friable to very friable. Zone IV D has much pore space. In relation to Zone IV C it has a lower density of charcoal flecking, burned sediment, and sub-angular limestone. Zone IV D is slightly grayer than IV E.
B2		**IV E**	1.85-2.20	10YR3/3 dark brown silt loam, friable, flecked with charcoal, and subangular-angular limestone. Zone IV E has much pore space. Lower density of limestone compared to the above Zone IV D and below Zone IV F.
Ab3	**5590-6950**	**IV F**	2.20-2.65	10YR3/2 very dark grayish brown silt loam, friable with dense charcoal flecking throughout. There is an increase in poorly sorted, subangular-angular limestone compared to IV E. Limestone ranges in size from small to large gravels, often oriented horizontally. Zone IV F is less porous than any of the Zone IV zones that rest above Zone IV F. The upper and lower boundaries are clear to gradual.
B3		**IV G**	2.65-3.20	10YR3/3 dark brown silt loam. Zone IV G is less friable and porous (low porosity) than Zone IV F. Zone IV G has a lower density of charcoal flecking and subangular-angular limestone than Zone IV F. Limestone ranges in size from small to medium gravel.
		IV H	3.20-3.40	7.5YR3/3 dark brown silty clay loam. Zone IV H contains a similar amount of charcoal to previous layer. Zone IV H is distinguished from Zone IV G by the presence of moderately sorted gravel sized reddish limestone. Zone IV G has low porosity.
Ab4	**6880-7240**	**IV I**	3.40-3.55	7.5YR3/3 dark brown silty clay loam, flecked with some charcoal and limestone. Zone IV I is less friable than friable than the above zones within Zone IV, but it is still easily broken. Feature 5 and an ash layer are evident at the interface between IV H and IV I.
B4		**V**	3.55-3.80	7.5YR3/4 dark brown silty clay loam, with few inclusions. Very little charcoal is apparent and this charcoal is found towards the upper boundary of this zone. No charcoal is apparent at the base of the excavation. This zone continues beyond the final depth of hand excavations.

Following excavation of cultural deposits, a bucket auger was used to core the lower archaeologically sterile deposits. With depth, retrieved loose sediment samples from these tests were described (Table 6.2), with half of the sample screened in the field, and the remainder collected for bulk sediment analyses.

Table 6.2. Sediment descriptions from archaeologically sterile deposits.

Soil horizon	Date Range	Zone	Depth (mbs)	Soil/Sediment Description
-	-	-	3.8-3.94	7.5YR3/3 dark brown silty clay loam
-	-	-	3.94-4.05	7.5YR3/3 dark brown silty clay loam
-	-	-	4.05-4.16	7.5YR4/2 brown silt clay loam small gravel
-	-	-	4.16-4.28	7.5YR4/2 brown silt clay loam small gravel
-	-	-	4.28-4.40	7.5YR5/3 brown silt clay loam small gravel
-	-	-	4.40-4.51	7.5YR5/3 brown silt clay loam small gravel (pockets of grey silt) much smaller pebbles <.5 cm (Sieved 1/2/17 No charcoal found)
-	-	-	4.51-4.60	7.5YR/5(2 or 3) brown silt loam, very fine, cement-like
-	-	-	4.60-4.71	7.5YR5/3 brown silt loam, very fine, cement-like, inclusions absent
-	-	-	4.71-4.81	7.5YR5/3 brown silt loam, very fine, cement-like, inclusions absent
-	-	-	4.81-4.91	7.5YR5/3 brown silt loam, very fine, cement-like, inclusions absent
-	-	-	4.91-5.01	7.5YR5/3 brown silt loam, very fine, cement-like, inclusions absent (possible charcoal) (sieved 1/2/17, No charcoal found)
-	-	-	5.01-5.12	7.5YR5/3 brown silt loam, very fine, cement-like, inclusions absent
-	-	-	5.12-5.17	7.5YR5/3 brown silt loam, very fine, cement-like, small inclusions (began hitting rock layer). Resting atop bedrock at base of sinkhole or collapsed roof-fall of Crumps Cave.

Field Methods

Soil Profiles and Sampling

Each exposed profile in the test unit was documented with scale drawings and high-resolution photography. Loose, unconsolidated sediments were collected systematically in a vertical column every five centimeters as one cup volume (500 gram) samples from the South profile to capture the entire vertical extent of the profile (Figure 6.2). The first 3.8 meters samples were collected every 5cm (0-5, 5-10, 10-15…..). The cmbs captures the midpoint of the sample (e.g., if 0-5 cmbs, then here documented as 2.5 cmbs). This is to allow creation of line graphs documenting change over time. After 3.8 meters samples were collected with a bucket auger with thickness of each sample ranging from 10-14 cm. Midpoints for these samples are also displayed here.

Figure 6.1. Collection of soil micromorphology samples from North profile.

Forty-six *in situ* soil samples were collected from the North profile in overlapping sections of burlap inundated with plaster, as outlined in Goldberg and MacPhail (2003), capturing nearly the entire vertical extent of the profile. After sample locations were determined, blocks were carved into the wall, and strips of burlap were dipped in fast-setting plaster and placed directly on these blocks to encapsulate them. They were left to dry overnight (Figure 6.1). Each sample was assigned a numeric identification based on location in the wall and labelled with an arrow to clarify orientation. Labels were written on the side of the sample that was once the profile face. Photographs were taken, and their location on the profile was documented.

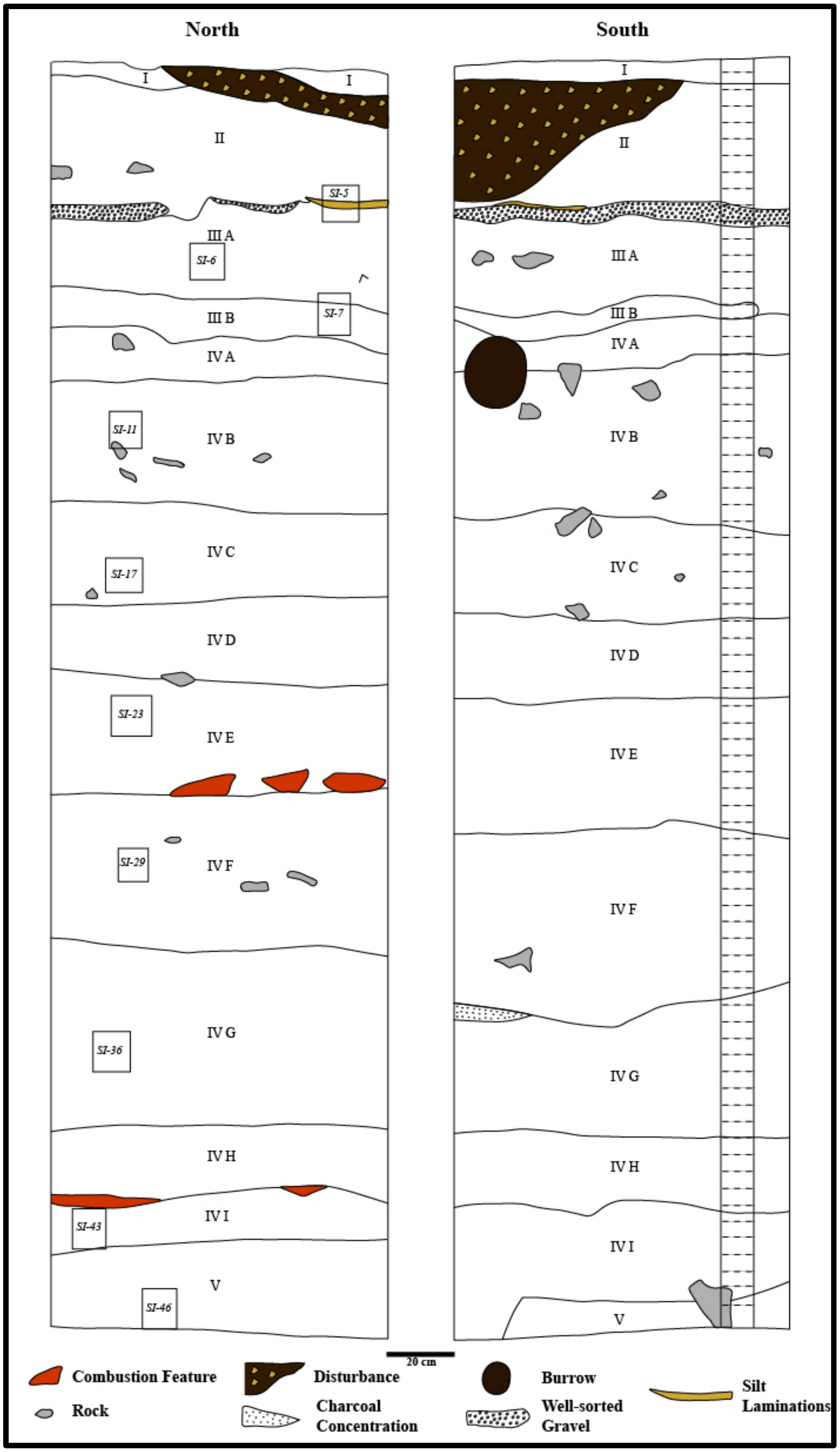

Figure 6.2. North and South Profile walls and locations of analyzed soil samples.

Upon collection, samples were sealed and transported to the UK Archaeology Laboratory in Lexington, and ten selected samples (Figure 6.2) were commercially prepared as thin-sections by Applied Petrographic Services, Inc. (Greensburg, PA) for micromorphological analyses with a petrographic microscope.

Laboratory Methods

I performed magnetic susceptibility and loss-on-ignition analyses in the Geoarchaeology Laboratory at Washington University in St. Louis.

Magnetic Susceptibility

Soil formation and exposure to fire will alter the magnetic signatures of the soils, forming secondary ferromagnetic oxides that make soils redder and elevate the magnetic susceptibility (Holliday 2004; Teixeira et al. 2002). Therefore, magnetic susceptibility analysis is useful for identifying periods of landform stability and also for providing evidence of human land burning that may have caused erosion. I conducted magnetic susceptibility analysis using a Bartington MS2B sensor as outlined by Dearing (1999). For the analysis, approximately 10 grams of sample in a sealed polystyrene bottle was placed in the sample sensor and measured for magnetic susceptibility. The higher the presence of ultrafine magnetic grains in a sedimentary matrix, the higher the frequency dependence. Zones that exhibit both higher magnetic susceptibility readings and frequency dependence readings may be interpreted as the result of soil formation (Dalan 2006).

Magnetic susceptibility results are reported in high field and percent frequency dependence. Table 6.3 shows the low field values and frequency dependence measurements. Magnetic susceptibility demonstrates the presence of five soil horizons at Crumps Sink, including one modern soil and four buried soils (Figure 6.3).

Loss-on-Ignition

Loss-on-ignition was determined by weighing of the sample before and after being burned in an oven at 550℃ and 1000℃ resulting in measurement of the percentage of organic matter (OM) and calcium carbonate (CaCo3) content, respectively. Spikes in calcium carbonate may indicate environmental dynamics such as arid environments or soil formation such as a calcium enriched B horizon. Increased calcium carbonate may also result from inputs such as plant ash, a possibility that is explored for Crumps Sink with soil micromorphology. Spikes in soil organic matter may indicate buried A horizons and/or periods of increase in addition of organic material, such as charcoal (Holliday 2004).

Loss-on-ignition was performed following the procedures outlined by Rosenmeier and Abbott (2005). I first weighed the samples in a crucible (4-6 grams per crucible) and then placed them in a Model 30 GC Lab Oven (Quincy Lab, Inc., Chicago IL) overnight at 200℃ to remove all moisture. Upon removal from the oven, the sample material was transferred to smaller (pre-weighed) crucibles. All measurements of mass were made on a Sartorius analytical balance (Goettingen, Germany) that measured mass to one thousandth of a gram. Then, each crucible with sample was weighed before being placed in a Vulcan oven at 550℃ for the organic content measurement. After burning, the samples were allowed to cool, and then reweighed to record the change from pre-ignition to post-ignition. Then, they were again placed in the oven at a temperature of 1000℃ for the calcium carbonate content measurement. After cooling, the samples were weighed to record the post-ignition weight.

Table 6.3. Data from bulk sediment analyses.
(Table continues on following page)

		Magnetic Susceptibility		Loss-on-Ignition		Phosphorous
cmbs	**Zone**	**LF (x)**	**% fd**	**% OM**	**% CaCO3**	**PPM**
2.5	I	1.98E-02	11.8710	7.7	19.2	94.04
7.5		1.78E-02	12.0036	4.9	12.2	85.97
12.5	II	1.77E-02	11.8903	3.7	9.2	87.28
17.5		1.74E-02	11.7923	3.4	8.6	89.90
22.5		1.85E-02	11.8781	3.5	8.8	98.19
27.5		1.86E-02	11.6439	3.6	9.2	101.46
32.5		1.89E-02	12.1587	4.0	10.0	99.94
37.5		2.01E-02	12.4845	4.5	11.2	101.46
42.5		2.36E-02	12.5108	5.2	13.2	120.88
47.5	III A	3.26E-02	12.8682	7.4	18.3	128.74
52.5		3.64E-02	13.2003	8.6	21.2	125.47
57.5		3.82E-02	12.7594	8.3	20.6	126.56
62.5		3.76E-02	12.6768	7.9	20.0	137.68
67.5		3.63E-02	12.3035	8.1	20.6	159.94
72.5	III B	3.65E-02	12.3394	8.3	24.2	195.29
77.5		3.24E-02	12.3943	6.8	36.3	163.43
82.5	IV A	2.66E-02	12.3671	5.7	47.3	133.32
87.5		2.48E-02	12.5922	5.7	45.6	128.30
92.5	IV A, IV B	2.46E-02	12.2197	5.1	43.6	126.99
97.5		2.38E-02	12.4182	4.9	44.7	130.48
102.5	IV B	2.34E-02	12.2631	5.3	44.0	125.90
107.5		2.27E-02	12.2795	5.2	42.4	129.61
112.5		2.38E-02	11.8507	5.5	43.0	132.23
117.5		2.50E-02	12.2262	5.7	38.3	132.45
122.5		2.68E-02	12.3761	5.1	37.3	132.67
127.5		2.71E-02	12.1987	5.6	36.9	125.03
132.5	IV C	2.71E-02	12.0520	5.4	38.7	125.47
137.5		2.83E-02	12.0302	5.6	39.0	117.83
142.5		2.84E-02	12.1267	5.9	39.0	114.12
147.5		3.15E-02	12.5585	6.0	37.2	113.68
152.5		3.35E-02	12.3258	5.9	36.2	114.77
157.5		3.45E-02	12.5683	6.1	33.4	107.14
162.5	IV D	3.67E-02	12.6904	6.5	33.1	101.03
167.5		3.59E-02	12.6851	6.0	32.4	96.44
172.5		3.54E-02	12.4700	5.4	30.9	87.28
177.5		3.21E-02	12.2968	5.1	30.7	90.55
182.5	IV D, IV E	3.06E-02	12.3563	4.6	30.6	88.59
187.5		2.79E-02	12.7285	3.9	29.4	90.55
192.5	IV E	2.54E-02	12.6677	3.8	31.9	87.50
197.5		2.44E-02	12.4438	4.0	36.6	88.15
202.5		2.29E-02	12.6279	3.8	30.0	84.23
207.5		2.31E-02	12.5790	3.5	27.7	84.88
212.5		2.33E-02	12.4561	3.6	32.6	89.03

		Magnetic Susceptibility		Loss-on-Ignition		Phosphorous
cmbs	**Zone**	**LF (x)**	**% fd**	**% OM**	**% CaCO3**	**PPM**
217.5		2.38E-02	12.2404	4.3	35.2	85.75
222.5	IV F	2.34E-02	12.4643	3.8	35.4	87.93
227.5		2.74E-02	12.3313	3.7	30.5	86.41
232.5		2.65E-02	12.5036	3.9	26.3	84.23
237.5		2.62E-02	12.6721	3.9	24.4	78.77
242.5		2.69E-02	12.5586	4.1	20.3	77.46
247.5		2.89E-02	12.4685	4.4	18.1	82.92
252.5		2.91E-02	12.5926	4.7	17.8	109.54
257.5		2.94E-02	12.5545	4.5	17.0	84.44
262.5	IV F, IV G	2.97E-02	12.9896	4.6	15.9	85.10
267.5		2.78E-02	12.6283	4.1	14.0	80.30
272.5	IV G	2.70E-02	12.8203	4.3	14.3	75.72
277.5		2.63E-02	12.7597	4.1	13.6	75.06
282.5		2.58E-02	12.7631	3.7	14.5	65.46
287.5		2.59E-02	12.9232	3.8	15.2	61.97
292.5		2.42E-02	12.7400	3.5	13.3	59.57
297.5		2.47E-02	12.6616	3.7	13.1	62.84
302.5		2.39E-02	12.6410	3.6	11.3	65.46
307.5		2.33E-02	12.5106	3.7	10.1	71.57
312.5		2.17E-02	12.8015	3.5	9.8	83.57
317.5		1.99E-02	12.4964	3.3	9.3	85.97
322.5	IV H	1.82E-02	12.3944	3.1	8.6	86.41
327.5		1.82E-02	12.7130	3.2	8.9	82.48
332.5		1.85E-02	12.3267	3.3	9.3	87.06
337.5		1.91E-02	11.8734	3.3	9.6	90.55
342.5	IV I	2.06E-02	11.7979	3.3	9.5	102.34
347.5		2.21E-02	12.0023	3.2	9.4	97.10
352.5	IV I, V	2.26E-02	12.6920	3.2	9.7	87.06
357.5		2.14E-02	11.9690	3.0	10.3	73.97
362.5	V	1.95E-02	12.1560	3.1	9.3	69.17
367.5		1.86E-02	12.6464	3.2	9.7	58.91
372.5		1.77E-02	12.0726	2.5	8.9	56.08
377.5		1.73E-02	11.9790	2.5	8.4	63.93
387	-	1.20E-02	11.9572	2.2	7.0	49.31
410.5	-	1.01E-02	11.3786	1.9	6.3	45.39
422	-	8.44E-03	10.5555	1.8	6.0	43.86
434	-	8.65E-03	10.9176	1.9	6.3	38.84
445.5	-	8.77E-03	10.7577	2.2	6.8	39.71
455.5	-	8.73E-03	10.6326	2.0	6.4	38.84
465.5	-	8.90E-03	10.6299	2.0	6.6	40.15
476	-	8.72E-03	10.5836	2.0	6.4	40.80
486	-	8.73E-03	10.4568	2.1	6.6	41.02
496	-	9.71E-03	10.4346	2.2	6.9	42.11
506.5	-	9.21E-03	10.5392	2.2	6.7	41.68
514.5	-	8.08E-03	10.0828	2.2	6.9	41.24

Plant Available Phosphorous

Phosphorous concentrations in soils are an indicator of human occupation intensity. Anthropogenic soil phosphorous is added to soil as human waste, food refuse, and animal manure. Phosphorous fixes to soil particles and is geochemically stable (Holliday 2004). This analysis was undertaken to identify periods when humans were intensively using the sink, with the goal of relating these periods with soil geomorphological histories and to understand to what degree human activities left a signature on the landscape and also whether there were periods when humans influenced landform stability and instability. Phosphorous analyses were undertaken by the University of Kentucky's Regulatory Services Soils Laboratory. The analysis is part of a routine soil test in which nutrients are extracted through Mehlich III and analyzed by inductively coupled plasma spectroscopy (http://soils.rs.uky.edu/tests/methods.php#Detailed). The analyses are reported as pounds per acre, which I have converted to parts per million (ppm) in Table 6.3.

Bulk Sediment Results

The magnetic susceptibility signature elevates when late Middle Archaic hunter-gatherers begin using the sink and this signature remains evident for the extent the archaeological sequence (Table 6.4; Figure 6.3). This likely relates to the use of combustion features such as hearths at the site. However, magnetic susceptibility signatures correlate most dramatically with soil horizons. For example, magnetic susceptibility signatures are lower in correlation with B horizons and greater in correlation with A horizons. Though soil formation occurred in the Middle Holocene, the most pronounced soil horizons occur during the early Late Holocene which may relate to increasingly forested conditions in the sinkhole. Buried A horizons Ab1 and Ab2 have the most distinct elevated magnetic signatures, and Ab3 and Ab4 have the least distinct, but still apparent, spikes in magnetic susceptibility (Figure 6.3). The most clear correlative spike between magnetic susceptibility and frequency dependence is in Ab1. The modern A horizon has very weak soil development and is indicated by slightly heightened magnetic susceptibility readings at ground surface. Below Ab1, frequency dependence percentages remain consistent until dropping relatively significantly to their lowest values in archaeologically sterile deposits. These data suggest that soil development played a role in magnetic signatures at the site. This soil formation may have occurred during periods of decreased sediment accumulation allowing for organic buildup. Buried soils Ab1, Ab2, Ab3, and Ab4 may be interpreted as formed during periods of landform stability, though the degree of landform stability is differential. For example, Ab4 may have been formed during a brief episode of decreased sediment accumulation, as it was faint during field documentation and in the signatures from lab analyses.

Table 6.4. Means for soil stratigraphic units from Crumps Sink.

Soil Stratigraphic Unit	**Pedon Distinction**	**Xlf (mean)**	**Xfd (mean)**	**% OM (mean)**	**% CaCO3 (mean)**	**Plant Available Phosphorous (ppm)**
1	**A**	1.88E-02	11.94	6.30	15.70	90.01
	B	1.93E-02	12.05	3.99	10.03	99.87
2	**Ab1**	3.57E-02	12.65	7.91	23.03	148.16
	B1	2.49E-02	12.28	5.38	42.31	129.70
3	**Ab2**	3.23E-02	12.38	5.79	31.16	106.83
	B2	2.38E-02	12.50	3.83	32.34	86.59
4	**Ab3**	2.69E-02	12.52	4.13	23.73	86.46
	B3	2.26E-02	12.60	3.58	10.06	75.26
5	**Ab4**	2.13E-02	12.33	3.25	9.45	99.72
	B4	1.83E-02	12.21	2.83	9.08	62.02
Culturally Sterile	**B4 continued**	9.16E-03	10.74	2.06	6.58	41.91

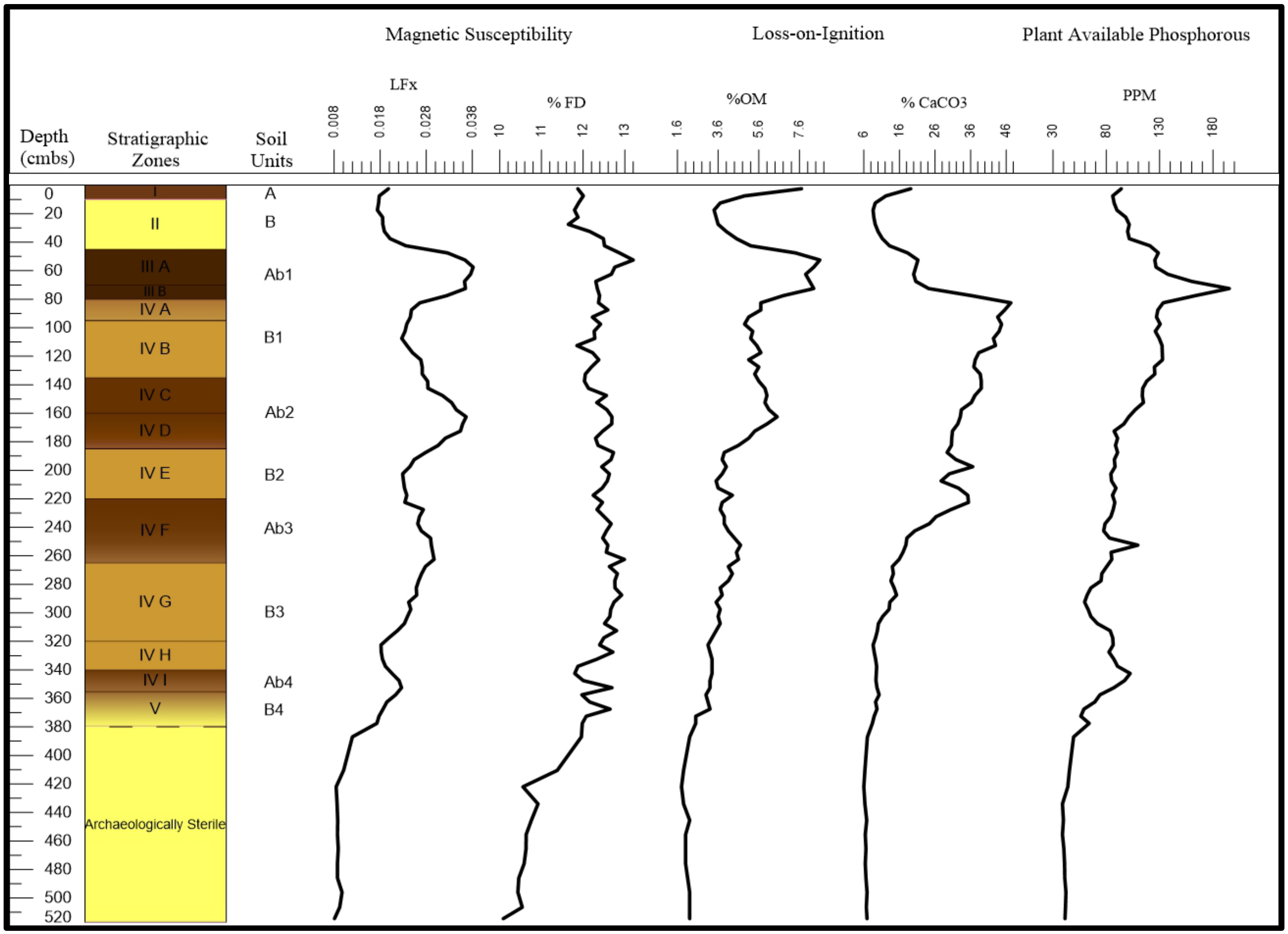

Figure 6.3. Line graph showing trends in bulk sediment analysis.

Soil Ab3 was more pronounced than Ab4. This pattern of more pronounced soils in younger deposits is also exhibited when comparing Ab3 to Ab2, and Ab2 to Ab1, which could suggest leaching in the profile over time, or what I argue to be the more plausible explanation, periods of landform stability became longer as climates trended from warmer and drier to wetter and cooler between the Middle and Late Holocene. That Ab1 had the highest magnetic susceptibility in conjunction with a higher frequency dependence suggests that this soil formed during an extensive period of landform stability, perhaps lasting over two millennia. However, despite this seeming movement toward more prominent soil development, it is evident that these buried soils are capped by lighter sediments.

Lower magnetic susceptibility readings correspond with these buried B horizons (B, B1, B2, B3, B4). These zones likely formed during periods of enhanced sediment accumulation and suppressed biological activity and organic buildup. Thus, the soil geomorphological model proposed for Crumps Sink is that periods of enhanced sedimentation occurred, suggesting landform instability. After, sediment accumulation, soil development occurred at the ground surface within these sediments. Eventually, soil surfaces were capped by another episode of enhanced sedimentation. Whether climate or humans influenced periods of landform stability vs. periods of landform instability must be considered for each horizon. When comparing archaeological deposits with archaeologically sterile deposits, magnetic susceptibility values are higher after human occupation in the sink, even during periods of enhanced sediment accumulation. This indicates that human activities left an identifiable signature in soils throughout human history at the site, starting in the late Middle Archaic period.

The percent organic matter (%OM) values are greatest in the modern A horizon and buried A horizon Ab1. Buried A horizon Ab2 has a higher %OM than B horizons B1 and B2. Though minor blips, soil horizons Ab3 and Ab4 are exhibited in the %OM at the site. Comparing the archaeological and archaeologically sterile deposits, it is apparent that %OM is higher in archaeological deposits than in archaeologically sterile deposits from prior to 7200 cal. BP. Also of note is that average %OM increases at approximately 180 cmbs and remains relatively high to around 45 cmbs, encompassing horizons Ab2, B1, and Ab1. Percent calcium carbonate (%$CaCO_3$) values increase slightly after human occupation of the sink, though they are increasingly pronounced between 240 and 50 cmbs, beginning in the upper portion of Ab3, and elevating through B2, Ab2, B1, and the lower portion of Ab1, which is correlated with Zone III B. More prominent spikes in this range trend with horizons B1 and B2. Concentrations of calcium carbonate in Late Holocenen B horizons suggest downward movement of calcium carbonate precipitates, a process associated with soil formation. The very high levels of calcium carbonate in these soil levels relative to the rest of the profile may be due to specific anthropogenic inputs and environmental trends at the time of their formation. Possible anthropogenic and environmental contributions of calcium carbonate will be discussed in the soil micromorphology section of this chapter.

Plant available phosphorous levels are enhanced throughout human occupation in the sinkhole, suggesting human impacts on soil chemistry through various camp activities as early as the late Middle Archaic. Spikes are exhibited in correlation with soil horizons

Ab4, Ab3, and Ab1. The general values are increasingly more pronounced between 160 and 40 cmbs, encompassing horizons Ab1, B1, and Ab2. The results indicate that by the Late Holocene or Late Archaic/Terminal Late Archaic phosphorous levels steadily increased. Higher values may relate to the more intensive use of the sink. If environmental conditions were wetter during this time then heightened phosphorous levels may also be related to weathering of bone and plant ash incorporated into the soil/sediment matrix.

For all bulk sediment analyses, the data show consistent, though subtle, background traces during human occupation at the site, suggesting that human activities left discernable chemical, magnetic, and mineral signatures. Certain datasets trend with specific site formation processes. Magnetic susceptibility and organic matter spikes correspond with periods of soil formation, with the most prominent spikes being in the Late Holocene buried A horizons. The lowest values of magnetic susceptibility are correlated with B horizons. Higher percentages of calcium carbonate are correlated with Late Holocene B horizons. One very distinct occurrence is that of the increasing organic matter, calcium carbonate, and plant available phosphorous signatures starting at 160-180 cmbs and trending upward. These increased levels may indicate increased human impacts on the landform by additions of charcoal and plant ash through burning and other activities. Increased precipitation during the Late Holocene may have resulted in dissolution of phosphorous rich archaeological components such as animal bone. These possibilities are explored further in the soil micromorphological analysis.

Coarse Fraction (≥6.35mm)

The mass of three artifact/ecofact classes (lithic debitage, bone, and burned sediment measured in grams per excavation level) is used as a proxy to understand general trends in human occupation intensity in the sinkhole. Due to its ubiquitous nature in archaeological sites, lithic debitage is a good indicator of human occupation intensity over time. For this study, utilized flakes, retouched flakes, and formal tools are not included in this quantity. For this study, bone fragments are used as a proxy for intensity of hunting and food processing. Bone tools are not included in this quantity.

The third indicator of human activity that is considered is burned sediment. During camp activities, such as the use of hearths, the heating of sediments can cause sediments to become reddened from an increase in ferromagnetic oxides. Many of the burned sediment nodules recovered from Crumps Sink have nutshell impressions, suggesting that these nodules were created by burning nut shell after the processing of nut mast. The mass of burned sediment by level may indicate when humans increased the use of combustion features, which presumably are related to processing of nut mast. In addition to these artifact classes, I quantify kg of rock recovered per level. This rock may have been deposited during erosion and exposure of bedrock around the rim of the sink or it could have been deposited in the sink from the gathering rock by hunter-gatherers for hearths, hot-rock cooking techniques, and other camp activities.

Table 6.5. Mass of recovered materials (0.25 inch/6.35 mm mesh).
Note different collection methodology was implemented in Levels 1-7 vs. 8-38.

		Anthropogenic			**Geogenic**
Level	**Zone**	**Flakes (g)**	**Bone (g)**	**Burned Sediment (g)**	**Rock (kg)**
1	I	*103.30*	*4.80*	-	-
2	II	*54.60*	*11.90*	-	-
3		*22.00*	*4.40*	-	-
4		*2.70*	*0.00*	-	-
5A		*137.40*	*1.00*	-	-
5B	III A	*138.20*	*11.80*	-	-
6		*155.70*	*23.10*	-	-
7		*123.00*	*60.00*	-	-
8	III B	141.20	200.00	7.30	32.87
9	IV A	258.17	169.57	1.78	14.78
10	IV A, B	112.80	161.70	14.00	21.90
11	IV B	184.80	193.40	18.80	24.41
12		142.00	163.90	4.70	21.69
13		152.40	250.00	7.30	20.07
14	IV C	161.20	254.80	1.60	19.51
15		106.80	276.30	22.10	23.01
16		179.20	576.50	43.70	26.59
17	IV D	171.20	454.50	23.90	21.91
18		68.93	206.29	28.12	10.87
19	IVD, E	110.10	222.90	15.60	10.60
20	IV E	82.60	277.10	39.20	17.59
21		69.20	134.80	17.20	6.65
22		105.90	114.40	10.40	12.01
23	IV F	132.20	162.20	3.60	11.57
24		143.50	138.40	18.50	16.81
25		108.10	114.70	12.90	15.68
26		177.40	189.40	10.80	17.70
27	IV F, G	76.60	233.84	8.38	16.45
28	IV G	121.56	122.29	3.59	16.16
29		107.70	247.00	16.70	12.43
30		76.30	138.60	11.90	9.46
31		66.00	54.50	2.40	9.64
32		135.20	83.90	1.60	15.34
33	IV H	98.00	83.20	0.00	20.49
34		150.50	104.90	4.50	25.05
35	IV I	35.90	72.10	0.00	13.82
36	IV I, V	33.10	21.50	0.00	8.62
37	V	1.50	0.20	0.00	6.50
38		0.00	0.20	0.00	0.47

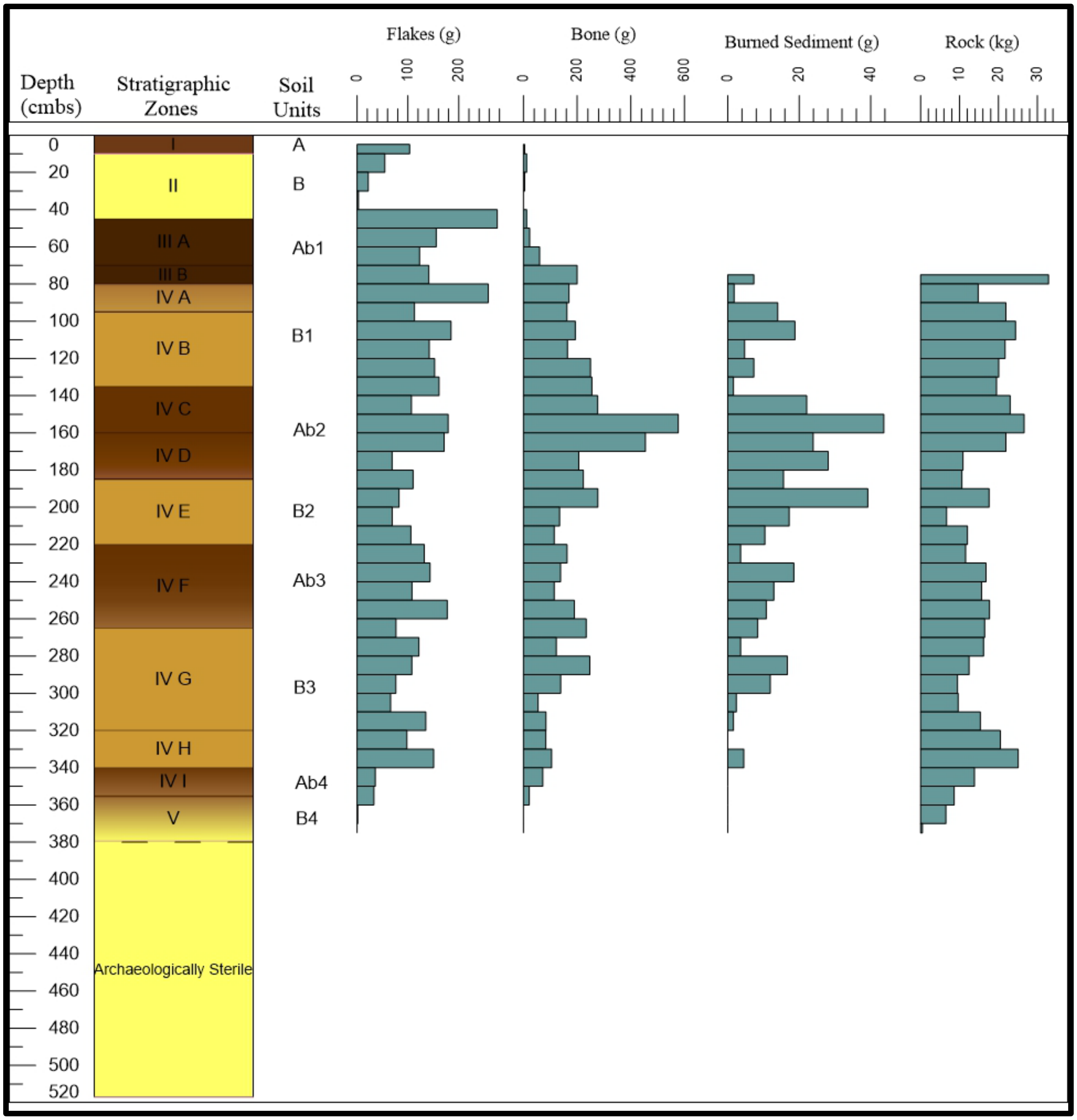

Figure 6.4. Showing actual masses of coarse fraction.

Coarse Fraction Results

The results of coarse fraction analysis are presented as a bar graph and the significance of the presence of different artifact classes is assess using Chi-Squared Goodness of Fit statistical analysis (Zar 1984), where I compared the expected g/m^3 values with the observed g/m^3 values for lithic debitage, bone, burned sediment, and expected versus observed kg/m^3 values for rock from each ten-cm-level at Crumps Sink (Figure 6.4; Table 6.6). The null hypothesis is that material would be distributed evenly throughout the deposit. However, trends emerge that show periods of significantly greater than or lower than expected levels of these materials.

Table 6.6. Chi-Square goodness of fit for coarse fraction.

Soil	Lithic Debitage g/m^3			Bone g/m^3			Burned Sediment g/m^3			Rock kg/m^3		
	Exp.	**Obs.**	**χ2**	**Exp.**	**Obs.**	**χ2**	**Exp.**	**Obs.**	**χ2**	**Exp.**	**Obs.**	**χ2**
Ab1	1083.65	1594.57	**240.89**	1464.03	842.57	**263.80**	39.80	7.3	**26.54**	150.57	94.50	**20.88**
B1	1238.58	1843.43	**295.37**	1673.34	1942.18	**43.19**	45.48	32.6	**3.65**	172.09	257.13	**42.02**
Ab2	1547.59	1374.66	**19.32**	2090.81	3536.78	**1000.01**	56.83	119.42	**68.93**	215.03	203.78	**0.59**
B2	928.72	859.00	**5.23**	1254.72	1754.33	**198.94**	34.11	66.8	**31.33**	129.04	156.17	**5.70**
Ab3	1238.58	1403.00	**21.83**	1673.34	1511.75	**15.60**	45.48	45.8	**0.00**	172.09	154.4	**1.82**
B3	2166.46	1078.94	**545.91**	2926.90	1191.99	**1028.36**	79.56	40.69	**18.99**	301.02	178.6	**49.79**
Ab4	309.86	359	**7.79**	418.62	721	**218.42**	11.38	0	**11.38**	43.05	138.2	**210.30**

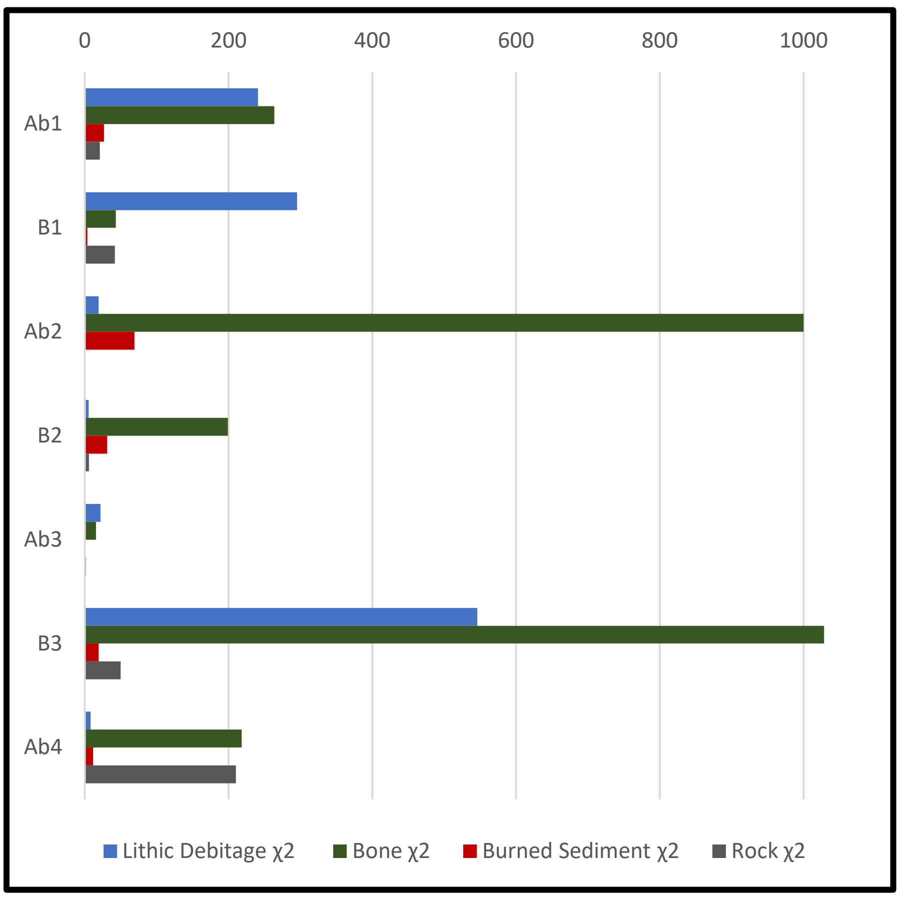

Figure 6.5. Chi-square goodness of fit for coarse fraction.

Lithic debitage is present throughout the deposits, but greater than expected quantities are exhibited in buried horizons Ab1 and B1 (Figure 6.4). Much lower than expected quantities are seen in B3. The greater amount of lithic debitage in B1 may indicate increased human occupation on the landform. The greater levels of lithic debitage in Ab1 may be related to it being a former surface on the landform that accumulated a much lower amount of sediment over a long period of time, with more flakes accumulating from visits to the site for perhaps over two millennia. The much lower amount of lithic debitage in B3 may be a result of a higher ratio of sedimentation than deposition of lithic debitage or less prominent use of the site at this time. Bone quantities are much higher than expected in Ab2. This may relate to increased processing of faunal remains in the sink at this time. As seen with lithic debitage, bone quantities are much lower than expected in B3, which also may relate to more rapid sedimentation or less processing of faunal resources at the site during this time (Table 6.6, Figure 6.5).

Burned sediment nodules are increasingly represented from B3 to Ab3 to B2 and reach their highest quantities in Ab2. This may be due to increased use of *in situ* combustion features at the site for daily camp activities during the Late Archaic period. Burned sediment nodules may have first formed as part of larger, intact combustion features that were later broken up by trampling and soil formation. Lower than expected levels of burned sediment were observed in Ab4 (initial human occupation) and Ab1. For Ab4, the low representation of burned sediment nodules may be due to minimal human activity in this early period. However, a combustion feature (Feature 5) is evident on top of this buried A horizon. For Ab1, Native Americans may have been involved in different activities at the site. For example, it seems that there was increased use of cave entrances and deep cave zones (including at Crumps Cave) during the time of formation of Ab1, which based on radiocarbon dates and projectile points, was first formed during the Terminal Late Archaic and Early Woodland periods. Another potential reason for the low amount of burned sediment in Ab1 is that this buried horizon was once at the surface for at least two millennia. Weathering activities may have obliterated the traces of this artifact class over time. Also of note is the significant decrease in burned sediment in horizon B1. As will be discussed in the soil micromorphology section, this is a period of increased plant ash deposition. Charcoal was also prominent in this zone. With the high amounts of plant ash and charcoal, it is odd that burned sediment nodule quantities are lower in this zone. One explanation could be that the burning exhibited in this horizon occurred elsewhere on the landform, rather than in place as would be suggested by burned sediment nodules.

Rock levels are higher than expected in Ab4, Ab1, and B1 and lower than expected in B3 (Table 6.6, Figure 6.5). Based on the bar graph, rock levels seem to trend higher with buried A horizons (Figure 6.4). Rock levels are consistently high between 170 and 70 cmbs, with the greatest mass at 70 to 80 cmbs. Increased rock quantities may indicate exposure of bedrock around the sinkhole rim or humans actively bringing rock into the site. That larger amounts of rock generally trend with buried soils, which may relate to a higher rock to sediment deposition ratio or to no sediment uphill to be redeposited. Low levels of rock in B3 may relate to secondarily deposited loess.

Overall, the data suggests lower than expected values of artifact classes in B3. This may relate to increased sedimentation associated with erosion during the Middle Holocene, diluting the archaeological record. There are increased levels of lithic debitage, bone, burned sediment, and rock in Ab2. This may be related to increased human activity or more intensive processing activities at the site during this time. Bone and burned sediment levels decrease fairly significantly in B1, though lithic debitage increases. Increasing phosphorous at this time may indicate that bone was dissolved and redeposited during the wetter Late Holocene.

Soil Micromorphology

Soil micromorphology is the study of *in situ* soils and sediments that have been collected as naturally oriented samples. Soil micromorphology has been used in soil science to identify the factors responsible for soil development or alteration. The technique has been useful for classifying soils and interpreting soil formation (Stoops 2003). The benefits of the approach for soil geomorphology are that with the use of a petrographic microscope one can identify and assess soil fabric, mineralogy, organic features, and processes such as translocation of clays (Courty et al. 1989). Though the method has been employed in soil sciences since the early twentieth century (Kubiena 1938), more recently soil micromorphology has been advocated as a viable technique for archaeological investigations (Goldberg 1983). Micromorphology can also aid in identifying microscopic organic components such as bone, grass, or charcoal in archaeological deposits (Goldberg and Sherwood 2006). It also is a complementary technique when combined with bulk sediment analyses (Goldberg and Sherwood 2006). Micromorphology has been used in conjunction with geochemical analyses to infer the function and post-depositional processes of specific anthropogenic features at Dust Cave in Alabama (Homsey and Capo 2006). In archaeology, micromorphology has been used most often outside the United States (Courty et al. 1989), though the technique has become more common in the United

States over the last twenty years (Josephs 2000; Homsey and Capo 2006; Sherwood 2001; Sherwood and Goldberg 2001).

Soil micromorphology may detect thin lenses of water-deposited silts caused by disturbance to the matrix from water percolation in temperate climates (Teixeira et al. 2002), and/or soil aggregates that were broken from soil matrices by mechanical disturbances and redeposited through colluvial processes (Courty et al. 1989; Holliday 2004). Courty et al. (1989) used micromorphological analysis to understand the intensity of occupation and land management in Chalcolithic, Late Bronze Age, and Iron Age deposits in Genoa, (Liguria) Italy. They found evidence of increased deforestation, colluvial erosion, and cultivation. Courty et al. (1989:298) interpreted "the inclusion of organic matter and charcoal, rounded soil relics and nodules, including papules of translocated clay and…differing brown soil materials" in Layer 6 (Chalcolithic) as evidence for colluvial origin likely related to erosion. In a younger layer from the Iron Age, they were able to identify charred grass (Courty et al. 1989).

Cruise et al. (2009) used micromorphology in conjunction with palynology, magnetic susceptibility, and chemistry in a peat site in Liguria, Italy to identify periods of deforestation and grassland expansion between the Iron Age and Roman period. Micromorphology showed evidence of increased soil erosion and burning through the presence of fine charred fragments, though there was an absence of coarser charcoal. They interpreted this as evidence of "light, controlled burning" of lower lying weedy, herbaceous plants rather than clearance of forests. At a site in southwestern Norway, Sageidet (2009) suggested that "coarse to micro fine charcoal particles…and…dusty clay coatings and infillings may indicate clearance by burning" during the Early Bronze Age. In the Rio

Puerco Basin of New Mexico, French et al. (2009) found macroscopic charcoal (identified in soil profile description) and microscopic charcoal (identified with micromorphology as lenses of mixed microcharcoal and alluvial sediment). With these studies in mind, and questions about soil development in relation to environmental change, as well as Native American forest management during the Archaic period in Kentucky, I looked for similar features at Crumps Sink.

Of the 47 *in situ* blocks collected from the profile, ten samples were selected for analysis based on specific questions that were raised during excavations, profile documentation, and loose sediment analysis. Excluding the modern A horizon, these samples capture each A horizon and associated B horizon exhibited in the profile. I began my analysis at University of Tübingen’s Geoarchaeology Laboratory. I continued and completed my analysis and photographed analyzed micromorphological features at Murray State University’s Stinchcomb Laboratory. Descriptions of thin-section slides were made with the aid of manuals (Bullock 1985; Stoops 2003). Other references I considered to aid in identification of specific minerals and features include Courty et al. (1989), Macphail and Goldberg (2017), Stoops et al. (2010), and Nicosia and Stoops (2017).

For the following soil micromorphology framework, I use definitions from Bullock et al. (1985) and Stoops (2003). The microstructure describes how the soil/sediment matrix is arranged, considering aggregates and voids (Bullock et al. 1985), and it can often inform about the degree of soil formation at a site. To determine the microstructure, various optical analyses were undertaken, including description of peds, degree of ped separation, degree of accommodation, pedality, and types of voids. The course/fine (c/f) related distribution is the comparison of coarse and fine components in the soil/sediment matrix. For this study, 60µm marked the separation between silt and very fine sand particles (Bullock et al. 1985; Stoops 2003).

Pedofeatures identified in the thin-section are the result of post-depositional processes associated with soil formation and may be evidence of depletion or accumulation of certain minerals. They can include mineral precipitates, such as calcium carbonate, or clay-sized particles mechanically transported downward through the solum. Calcium carbonate hypocoatings are deposited along void walls as water that is rich in calcium carbonate travels through preferential pathways in the soil until evaporating and allowing the mineral to recrystallize in place. Pedogenic carbonate nodules are impregnative features in the sediment matrix that are created when minerals such as calcium carbonate are deposited in the same place consistently. These nodules can incorporate or displace the surrounding matrix. When calcium carbonate is redeposited in microcrystalline form that is infused with the soil matrix, creating a calcitic crystallitic b-fabric that can be identified in thin-section under cross polarized light.

When considering anthropogenic/archaeological components, I used Nicosia and Stoops (2017) as a reference. Ash pseudomorphs form during the burning of plant tissue such as wood or leaves, and they generally have a rhomboidal or spherical shape (Canti and Brochier 2017). These ash pseudomorphs are first mineralized as calcium oxalates. During soil formation they are quickly weathered and become calcium carbonates (Durand et al. 2010). Calcium carbonate features, including calcitic crystallitic b-fabric and weathered ash pseudomorphs, were identified in the Crumps Sink thin-sections. These features are discussed and further considered in relation to $CaCO_3$ percentages from loss-on-ignition analyses. These features provide valuable information concerning anthropogenic impacts, fire histories, and changing Holocene environmental conditions at Crumps Sink.

Soil Micromorphology Results

In soil stratigraphic units 5 and 4 (see Table 6.7), the b-fabric ranges from undifferentiated in B horizons B4 and B3 to undifferentiated with minimal calcitic crystallitic b-fabric in A horizons Ab4 and Ab3. The minimal calcitic crystallitic b-fabric may be expected in the A horizons and is likely in association with soil formation and minor dissolution and redeposition of calcium carbonate in these buried soils. However, for soil stratigraphic units 4 and 5 the amount of calcitic crystallitic b-fabric is relatively low, when compared to shallower deposits. These horizons are Middle Holocene in age and correspond with the late Middle Archaic cultural period. In soil stratigraphic unit 3 (B2 and Ab2) and the B horizon in soil stratigraphic unit 2 (B2) the b-fabric is calcitic crystallitic, meaning that this mineralization covers a majority of the surface area when viewed in thin-section.

These deposits date to the Late Archaic period and possibly the early part of the Terminal Archaic period. High percentages of calcium carbonate indicated by the loss-on-ignition analyses in these horizons corroborate the soil micromorphological findings. However, what contributed these high amounts of calcium carbonate in a deposit that has otherwise much lower levels of calcium carbonate is investigated further by assessing plant ash levels in these deposits. The other important question is: what environmental conditions caused the increasing hydrological activity that dissolved and redeposited this calcium carbonate within the matrix in microcrystalline form? This deposit is early Late Holocene in age, so these processes could relate to increased precipitation in the region. In the A horizon of soil stratigraphic unit 2 (Ab1) and the B horizon for soil stratigraphic unit 1 the b-fabric is fully undifferentiated.

The peds are angular blocky to subangular blocky and granular in B4. From Ab4 and upward through Ab2 the peds are subangular blocky and granular. In Ab1 and B2 the granular matrix becomes more dominant. In B the ped structure is angular blocky. The ped separation is generally weak to moderate between B4, Ab4, B3, and Ab3. The separation becomes greater between B2, Ab2, B1, and Ab1. The ped separation is again weak in B. The accommodation generally ranges from accommodated to partially accommodated between B4, Ab4, B3, at least in B horizons. The pedality is weak throughout, which suggests consistent sedimentation over time. Thus, the buried soils at the site may best be described as cumulic. Voids seen throughout the profile include channels, planes, vughs, and compound packing voids. In Ab2 and B1, voids present include large compound packing voids within a granular microstructure of large aggregates suggesting that these zones were mixed through disturbance. The c/f related distribution is well sorted between B4, Ab4, and B3, trending towards moderately sorted in Ab3, and is moderately sorted in B2, Ab2, B1, and Ab1. Again it is well-sorted in B. Plant ash is evident though very sporadic in Ab4. It does not appear again until Ab3, B2, and Ab2, B1, and it was observed at increasingly greater amounts between Ab3, B2, Ab2, and B1. Notably, plant ash is present in large amounts in Ab2 and B1. Note that the amounts of plant ash have not been quantified and frequencies are only discussed based on qualitative observations. In Ab1 no plant ash was observed. though the amount was not quantified. The presence of plant ash trends with the presence of calcitic crystallitic b-fabric.

These data show that soil stratigraphic units 5 and 4 are similar to each other with generally a channel vughy microstructure. Soil stratigraphic unit 3 transitions from a vughy, subangular microstructure with granular infillings to a granular subangular blocky microstructure. The B1 microstructure is only granular and this deposit appears to have experienced much disturbance. Ab1, which seems to be a soil horizon that was at the surface ofr at least two millennia, has a granular, subangular blocky, and to some degree channel microstructure. Generally these microstructure features are smaller than seen in the lower horizons, which suggests different factors in the formation of this horizon than the soils below. The B1 horizon is also the deposit with the highest levels of plant ash and little evidence of *in situ* burning which suggests that this burning was not local to the immediate area, but rather occurred on the surrounding landform. Increased rock quantities were seen in horizons Ab2 and B1, also suggesting erosion of bedrock on the surrounding landform, and also increased camp activities at the site. This zone also has calcitic crystallitic b-fabric. The original zone designations for this level are Zones IV A and IV B and it has been radiocarbon dated to the Late Archaic to Terminal Archaic periods. The presence of calcitic crystallitic b-fabric in horizons B1, Ab2, and B2 relates to the high levels of plant ash and the process of hydrological dissolution and recrystallization of this plant ash.

Table 6.7. Soil micromorphological analysis of thin-sections.

Soil Strat. Unit	Pedon	Zone	Sample ID	Peds	Ped Separ.	Accommodation	Pedality	Voids	Microstructure	c/f related distribution c/f 60μm	Micromass/ b-fabric	Plant Ash
1 Historic to Modern	**A**	**I**	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
	B	**II**	SI-5 37-47 cmbs	Angular blocky	Weak	Accommodated-partially accommodated	Weak	Plane, vugh, compound packing (granular), lenticular	Subangular blocky	Open porphyric, well sorted	Undifferentiated	No
2 2880-3700 cal BP	**Ab1**	**III A**	SI-5 37-47 cmbs	Granular and subangular blocky	High	Unaccommodated	Weak	Plane, compound packing (granular), channel	Granular, subangular blocky	Open porphyric, moderately sorted	Undifferentiated	No
		III A	SI-6 54-65 cmbs	Angular blocky and granular	High	Partially accommodated-Unaccommodated	Weak-Moderate	Many micro-planar, also large channel, and vugh, very small granular infills	Subangular blocky channel	Open porphyric, moderately sorted	Undifferentiated	No
		III B	SI-7 69-82 cmbs	Granular and subangular blocky	High	Partially accommodated-unaccommodated	Weak	Compound packing (granular), many plane, few channel, vugh	Granular, subangular blocky	Open porphyric, moderately sorted	Undifferentiated	No
	B1	**IV B**	SI-11 105-116 cmbs	Granular and subangular blocky	High	Unaccommodated	Weak	Compound packing (granular), few plane, channel, and vugh	Granular	Open-double spaced porphyric, moderately sorted	Calcitic crystallitic	Yes
3 3700-5590 cal BP	**Ab2**	**IV C**	SI-17 149-159 cmbs	Subangular blocky and granular	High	Partially accommodated-unaccommodated	Weak	Compound packing (granular), plane, few channel, few vugh	Granular subangular blocky microstructure	Open porphyric, moderately sorted	Calcitic crystallitic	Yes
	B2	**IV E**	SI-23 190-202 cmbs	Subangular blocky and granular	Mod.-High	Partially accommodated-unaccommodated	Weak	Vugh, planes, few channel, compound packing (granular)	Vughy, subangular with granular infillings	Double-spaced porphyric, moderately sorted	Calcitic crystallitic	Yes
4 5590-6950 cal BP	**Ab3**	**IV F**	SI-29 236-246 cmbs	Subangular blocky and granular	Mod.	Partially accommodated-unaccommodated	Weak	Plane, channel, vugh, compound packing	Subangular, channel, vughy, with granular infillings	Open porphyric, well-moderately sorted	Undifferentiated and minimal calcitic crystallitic	Yes
	B3	**IV G**	SI-36 291-303 cmbs	Subangular blocky and granular	Weak	Accommodated-partially accommodated	Weak	Channel, planes, vughs, and compound packing voids	Channel vughy, subangular, with bioturbated areas that are granular	Open porphyric, well sorted	Undifferentiated	No
5 6880-7240 cal BP	**Ab4**	**IV I**	SI-43 344-356 cmbs	Subangular blocky and granular	Mod.	Partially accommodated-unaccommodated	Weak	Channel, planes, vughs, granular in infilled voids	Channel to vughy, with granular infillings	Open-porphyric, well sorted	Undifferentiated and minimal calcitic crystallitic	Yes
	B4	**V**	SI-46 367-380 cmbs	Angular blocky-subangular blocky and granular	Weak-Mod.	Accommodated-unaccommodated	Weak	Channel, planes, vughs, with compound packing voids in granular microstructure	Channel to vughy	Open porphyric, perfectly-well sorted	Undifferentiated	No

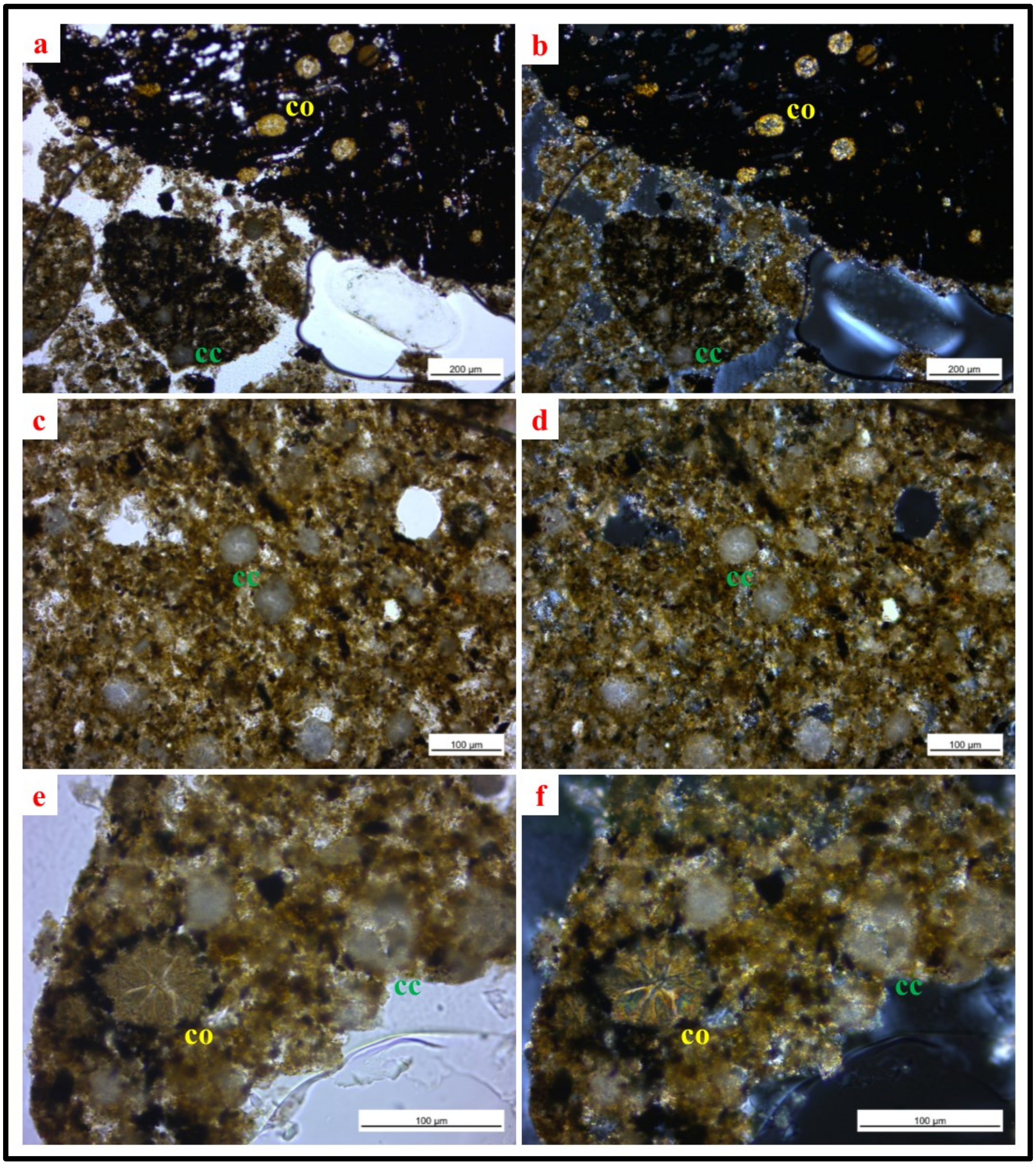

Figure 6.6. Plant ash from Crumps Sink deposits Zone IVB, Sample ID SI 11. a, 10x calcium oxalates (co) within cell structure of wood charcoal and calcium carbonate (cc) in highly organic matrix, possibly degraded charcoal plane polarize light (PPL); b, same as a cross polarize light (XPL); c and d, 20x calcium carbonate nodules in calcitic crystallitic soil/sediment matrix, PPL and XPL, respectively; e and f, 40x.

Sedimentation Histories

Using zone depths and radiocarbon dates it was possible to statistically model sediment accumulation rates over time at Crumps Sink (see Blaauw and Christen 2011). A sedimentation curve based on this model was created by Gary Stinchcomb (see Figure 6.7). The results show a fairly consistent sediment accumulation, with slightly enhanced sediment accumulation during the Middle Holocene (Figure 6.7).

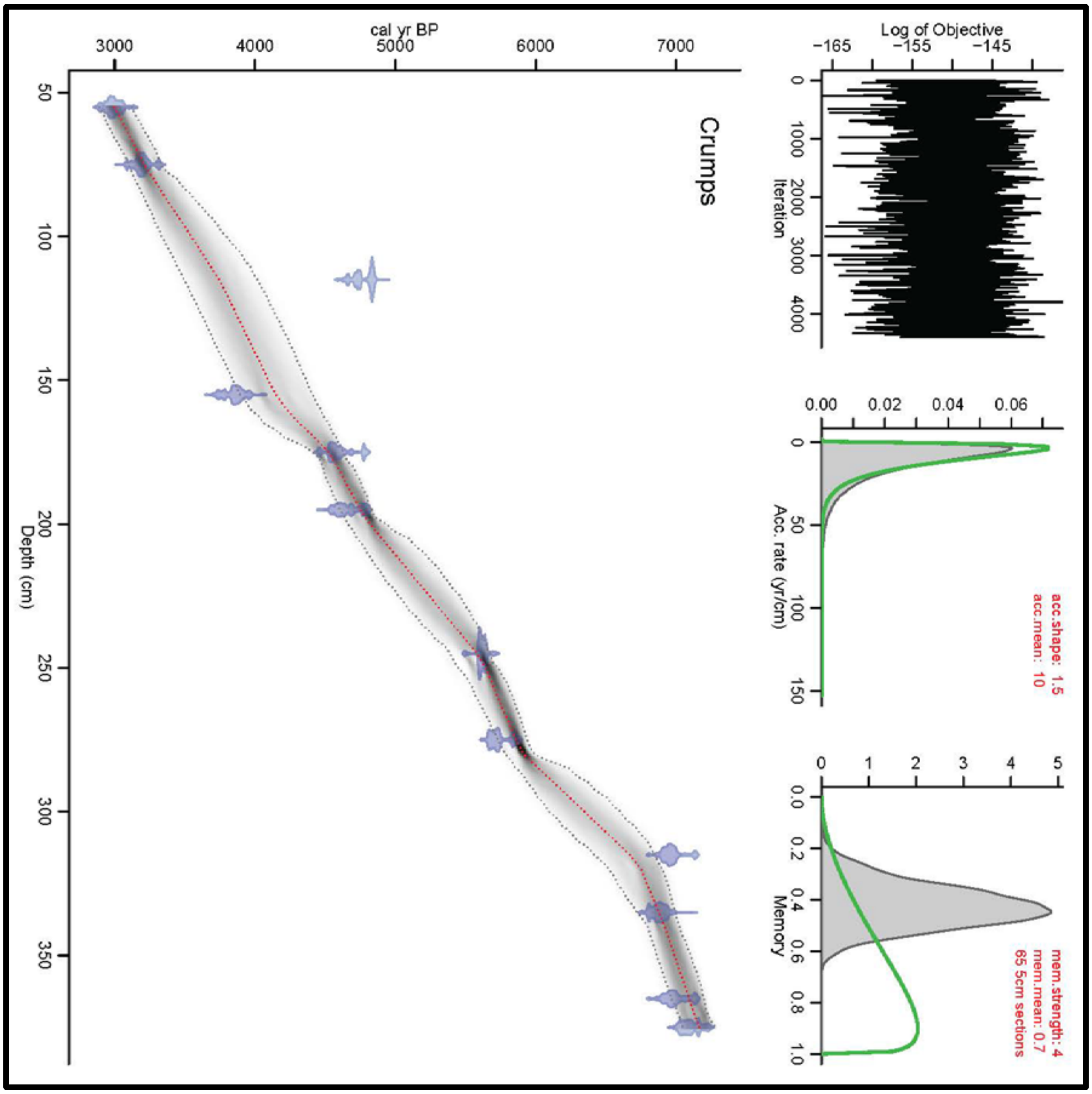

Figure 6.7. Sediment accumulation rates at Crumps Sink.

There is one major outlier seen in Zone IV B, Level 12, that dates to 4232+30 RCYBP (4650-4857 cal. BP) (Table 5.2). This outlier is in the deposit with much plant ash and a period of steady erosion (Horizon B1 or Zones IV A and IV B). It is possible that the charcoal fragment was exhumed by erosion around the sink and then redeposited within the sink. It is important to recognize that sediment deposition did not cease altogether. Rather, there were periods during which soil formation outpaced sediment accumulation to a degree that left a signature. Thus, with the possible exception of Ab1, the soil horizons at Crumps Sink may be best described as cumulic (Buol et al. 2011). Ab1 may not be a cumulic soil, but rather it may have been a stable land surface for 2000-2500 years.

Environmental History and Human Activities at Crumps Sink

The deposits spanning the Middle to Late Holocene transition and late Middle Archaic to Terminal Late Archaic periods (7200-2900 cal. BP) provide a dataset that addresses specific questions of human behavior, landform stability, and climate change throughout the Holocene. These deposits are significant due to the relatively rapid deposition of sediment, preserving the archaeological and paleoenvironmental record. During the Middle Holocene Thermal Maximum, Crumps Sink experienced consistent sediment accumulation. Crumps Sink contains a deep, well preserved soil profile, representing four thousand years of climatic and human impacts on the landform. Excavation and bucket augering revealed five horizons of sediment deposition (B4, B3, B2, B1, B) indicating landform instability resulting in uphill erosion/downhill accumulation. Each of these B horizons is the parent material for one of five soil horizons (Ab4, Ab3, Ab2, Ab1, A) which formed during periods of decreased uphill erosion/downhill accumulation and some degree of landform stability. Because Crumps Sink is a catchment basin that continually received sediment, these soils (with the possible exception of Ab1) were generally cumulic, meaning that sediment deposition did not cease altogether when these soils were forming (see Buol et al. 2011 for discussion of cumulization). Today, sediment movement, likely through sheetwash, is evident on the ground surface. With a very organic matrix, high magnetic susceptibility coupled with an elevated frequency dependence, and highly weathered limestone rock, it is clear that this surface received relatively little sedimentation for very long period of time, allowing much time for soil formation activities. This will be discussed more in the Late Holocene environmental summary.

The magnetic susceptibility signature elevates when late Middle Archaic hunter-gatherers begin using the sink and this signature remains elevated through the Late Archaic, Terminal Archaic, and potentially and Early Woodland component in the sink. This likely relates to the use of combustion features burning sediments during a variety of camp activities.

Middle Holocene (ca. 7200-4200 cal. BP)

Humans began frequenting the sink around 7200-7000 cal. BP during the late Middle Archaic period and Middle Holocene Thermal Maximum or Hypsithermal. Prior to this, there does not seem to have been a prominent activity location for hunter-gatherers, although the cave entrance may have been frequented. The first archaeological materials are associated with a weakly developed soil that overlies 1.4 meters of colluvium. Between 7200 and 5600 cal. BP Crumps Sink experienced slow but consistent sediment accumulation, presumably secondarily deposited loess that may have been in flux due to erosion during the Middle Holocene. Holocene deposits remain light, compact and apparently colluvial. Erosion and desiccation have been seen in the geomorphological record throughout the Midcontinental United States during the Middle Holocene Thermal Maximum (Butzer 1978; Hajic 1990; Styles 1985; Ahler 1993, 1998; Springer et al. 2010; Driese et al. 2017).

At 5500 cal. BP, sediment accumulation slowed, allowing enough animal and root activity, and buildup of organic matter to result in soil formation. Between 5500 and 4800 cal. BP, another erosional event occurred, although less pronounced and shorter in time than that prior to 5500 cal. BP. This was at roughly the same time as an episode of decreased precipitation in the middle Green River valley reflected in terrestrial gastropod species at Carlston Annis (Baerreis 2005). This was followed by soil formation between 4800 and 3800 cal. BP. These 3 episodes of Middle Holocene soil formation (Ab4: ~7200-7000 cal. BP; Ab3 5500 cal. BP; and Ab2: 4800-3800 cal. BP) interposed with periods of sediment accumulation may relate to recently documented trends of cyclical wet/dry cycles observed in oxygen and carbon isotopes in Middle Holocene soil profiles in West Virginia, Tennessee, and Pennsylvania (Driese et al. 2005; Driese et al. 2008; Kocis 2011; Stinchcomb et al. 2013). The periods of soil formation may reflect wetter conditions with more closed or forested vegetation structure, and the periods of sediment accumulation may be associated with warmer conditions leading to more open vegetation structure.

Late Holocene (ca. 4200 cal. BP-present)

Geoarchaeological analyses suggest more prominent soil formation, bioturbation, and addition of organic material occurring during the early Late Holocene and multiple buried A horizons are apparent throughout the Late Holocene. Greater addition of organics in buried A horizons may relate to shifting environmental regimes toward wetter, more forested conditions at the end of the Holocene Thermal Maximum (ca. 4200 cal. BP). An alternative explanation is that the greater addition of organic matter to the matrix due to a lack of source sediment around the rim of the sinkhole.

The most rapid sediment deposition occurred between 3900 and 3000 cal BP. At the same time, stable carbon isotope values from a cave speleothem in Missouri suggest an increase C_4 vs. C_3 species between 3500 to 2600 cal BP, and in a soil profile an increased level of C_4 plants in West Virginia at around 3800 cal BP. (Denniston et al. 2007; Driese et al. 2005). This may lead to a similar interpretation for the cause of sedimentation at Crumps Sink. However, one thing that may suggest human influence is the highest levels of plant ash occurring at this time. It is possible that C_4 species showing up in Missouri and West Virginia may relate to grassland expansion, as seen in pollen profiles from Jackson Pond and Salts Cave in central Kentucky. The high levels of plant ash between 3900 and 3000 cal. BP may suggest that humans were burning the surrounding environment, something that will be explored later in this chapter. Based on radiocarbon dating, with one date being errant, and geoarchaeological analyses, the most rapidly deposited and mixed layer is Zones IV A and IV B. Humans seem to be occupying the site more intensively in the Late Archaic/early Late Holocene period and may be causing erosion.

The b-fabric in the thin-sections is calcitic crystallitic, which is only the case in minor instances during times of soil formation in Middle Holocene deposits. Also, calcium carbonate levels are at their highest in the Late Holocene between 4500 and 3000 cal BP. Increased plant ash deposited in these levels contributed a source of calcium carbonate that could be dissolved and recrystallized in the matrix. After 3000 cal. BP soil formation persisted for over two millennia, suggesting landform stability until burial by erosion associated by what has been interpreted as historic agriculture. This occured during the Terminal Late Archaic and Woodland periods, after the expansion of grasslands at Jackson Pond, and at the same time as early horticulture and cave exploration at nearby Mammoth Cave. Preliminary micromorphological analyses suggest a different structure of soil fabric than seen in the deeper horizons which may suggest different factors in its development than those responsible for deeper horizons. This soil first formed after grassland expansion was first documented for the region (Wilkins et al. 1991; Schoenwetter 1974).

Anthropogenic Impacts at Crumps Sink

Late Middle Archaic (7200-5600 cal. BP)

In late Middle Archaic deposits lithic debitage, bone, and burned sediment are all evident at low to moderate, but consistent quantities over time. After hunter-gatherers began using the sink, magnetic susceptibility, organic matter, plant available phosphorous, and calcium carbonate (though to a lesser degree) all elevate, demonstrating that camp activities left an identifiable human signature in the soils at the site.

Late Archaic (5600-3900 cal. BP)

Plant ash is sparsely present in Late Archaic deposits starting at around 5600 cal. BP, and is likely a result of use of hearth features, but also could be associated with early minimal land burning. Burned sediment nodules steadily rise to their highest levels between 4800 and 3900 cal. BP, during the Late Archaic period, indicating *in situ* hearth activity. Plant ash levels increase in Ab2, suggesting an increase in burning. Ab2 is dated to between 4400-4800 cal. BP. Ab2 also has the highest level of animal bone and a high amount of lithic debitage. Burned sediment shows a spike between 4800 and 3900 years ago, which falls within the range of the sparse ash rhombs. Rock levels also rise in these deposits. Bone and lithic debitage quantities are generally consistent during prehistoric occupation of the site. The burned sediment with nutshell impressions and high levels of animal bone suggest that combustion features were being used for more intensive processing of nut mast and faunal resources. Maybe increased use of sink, population may be higher, at least looks like intensive processing of nut mast, high bone in second soil. This evidence may suggest silvicultural activities at the site, and it is contemporaneous with the data suggesting woodland management in the middle Green River region (Crawford 2005; Wagner 2005).

Late Archaic-Terminal Late Archaic (3900-2900 cal. BP)

Plant ash is most prominent in B1 (Zones IVA and IV B) suggesting this is the period of the greatest amount of combustion in the sink. However, burned sediment quantities drop in this deposit, suggesting that the burning occurred elsewhere on the landform, and may have been from different activities rather than surface hearths. Rock increases dramatically during this time and is sustained suggesting erosion and also possibly increased camp activities or use of rock for camp activities. The %OM is relatively high and much charcoal flecking was evident during field descriptions of sediments at the site. Calcium carbonate levels are also highest in these deposits, with plant ash plausibly being the primary contributor. In thin-section these zones have a calcitic crystallitic b-fabric. Also evident is that phosphorous levels increase in these deposits. This may relate to increased precipitation dissolving animal bone in the matrix. This deposit appears to have accumulated fairly rapidly, based on radiocarbon dates, and may indicate a period of erosion as indicated by an outlier radiocarbon date that is earlier than would be expected. Remember, that the early Late Holocene was a time when we should expect increasingly forested conditions creating stable soils. I argue that this deposit was created by increased indigenous forest burning and disturbance on the surrounding landform, causing enhanced uphill erosion/downhill accumulation in the sink.

By 3000 cal. BP the landform stabilized, and no plant ash is evident in thin-sections from soil horizon Ab1 (Zones III A and III B). This is at the same time as Native Americans began frequenting Crumps Cave with greater intensity (Carstens 1980), suggesting that there were changing preferences in landform use. This is also contemporaneous with cave exploration seen in Mammoth Cave. This surface may have remained stable for over two millennia, before it was capped by an apparent historic horizon (B; Zone II) possibly from erosion during historic agriculture in the region (see Dicken and Brown 1938). A weakly developed A horizon (A; Zone I) is now forming at ground surface.

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CHAPTER 7. SUMMARY AND CONCLUSIONS

Baskin et al. (1994) made the case that the Big Barrens of Kentucky is anthropogenic in origin, the result of land burning by Native American populations. Charcoal data from forest stands, pond sediments, and deep cave sediments throughout the Interior Low Plateaus and Southern Appalachian Mountains show increased forest fires by at least 4000 years ago (Delcourt et al. 1998; Fesenmyer and Christensen 2010; White 2007). Pollen records from central Kentucky demonstrate expansion of grassland ecosystems by the end of the Middle Holocene Thermal Maximum and into the Late Holocene despite environmental conditions that should favor forest development (Delcourt and Delcourt 1979; Schoenwetter 1974; Walker et al. 2012; Wilkins et al. 1991). Formalized groundstone tool technologies associated with land clearance (grooved axes) and processing of nut mast (pestles) appear in the archaeological record by the late Middle Archaic period (Jefferies 2008). Late Archaic period data from the middle Green River region suggest that Native Americans were creating anthropogenic ecosystems through disturbance, perhaps related to silviculture (Wagner 2005). Plant domestication occurred in Central Kentucky, including at Mammoth Cave, between the Late Archaic and Early Woodland periods (Smith 2006; Watson 1985). When considered together, these data suggest a major shift in human-environmental interactions during and after the Middle Holocene/Late Holocene transition, and between the late Middle Archaic and Early Woodland periods. However, heretofore, a multidisciplinary study was still needed to link Holocene environmental proxy data with the Archaic archaeological record at a single site to understand how these developments correlate over time. Here, I consider paleoenvironmental and archaeological data collected during my dissertation excavations at Crumps Sink in the Sinkhole Plain. With these data, I test the hypothesis that Archaic hunter-gatherers played a role in creating and maintaining Big Barrens ecosystems in Kentucky through land burning. The data from Crumps Sink suggest that hunters and gatherers were burning to create a forest mosaic of varying resources. These groups were actively managing surrounding ecosystems through delayed-return systems that suggest investment strategies more similar to horticultural economies.

Archaeological Investigations in the Sinkhole Plain

The unique geological, topographic, and ecological nature of the Sinkhole Plain, characterized by thin soils, few hydrological obstacles, and xeric ecosystems, may have made it especially conducive to fire ecology. Karst features such as sinkholes and caves are prevalent throughout this region. These closed catchments accumulate sediment and have the potential for containing important paleoenvironmental and archaeological information. As access points to water from underground drainages, these sites became important points on the landscape for human occupation. However, until this study, the archaeological significance of sinkholes in the region was not recognized to the same degree as cave entrances and deep cave contexts. I directed archaeological excavations in the summer of 2015 at Crumps Sink to assess the chronology of occupation, range of prehistoric activities, and geomorphological history of the site. Stratified archaeological deposits spanning the Middle to Late Holocene transition and the late Middle Archaic to Terminal Late Archaic periods (7200-2900 cal. BP) were excavated to a depth of 3.8 m below ground surface. Projectile points were analyzed to provide information on cultural periods represented at the site. Geoarchaeological analyses, including magnetic susceptibility, loss-on-ignition, plant available phosphorous, soil micromorphology, and anthropogenic inputs measured by artifact mass were considered to examine landform dynamics in relation to environmental change during the Middle-Late Holocene transition and human activities that include silviculture, plant domestication, and potential use of fire for land clearance.

Archaeological Site Formation Processes at Crumps Sink

With the exception of a faint buried soil indicating slightly suppressed sedimentation between 7200 and 7000 cal. BP, sediment accumulation was consistent and apparently accelerated between 7200 and 5600 cal. BP, corresponding with the generally warmer and drier conditions of the Middle Holocene Thermal Maximum. After humans began occupying the sinkhole, background magnetic and chemical signatures became greater than they were at pre-occupation levels. During the transition from the Middle Holocene to the Late Holocene between 5600 and 3900 cal. BP, data show horizons of more prominent soil development, possibly reflecting shifting environmental regimes toward wetter climate and more densely forested conditions at the end of the Holocene Thermal Maximum (ca. 4200 cal. BP). However, also between 5600 and 3900 cal. BP, there are overlapping episodes of soil formation and sediment accumulation, suggesting cyclical episodes of drier conditions (enhanced sedimentation) and wetter conditions (decreased sedimentation allowing soil development) during the Middle to Late Holocene transition. Similar cyclical wet/dry cycles have been observed from oxygen and carbon isotope studies in Middle Holocene soil profiles in West Virginia, Tennessee, and Pennsylvania (Driese et al. 2005; Driese et al. 2008; Kocis 2011; Stinchcomb et al. 2013). Thus, the soil horizons at Crumps Sink may reflect larger Holocene climatic trends.

Scattered ash pseudomorphs in Late Archaic deposits from 5600 to 3900 cal. BP may be remnants of combustion features associated with increased use of the site and focused processing of nut mast and/or the beginnings of forest management by fire. Burned sediment nodules with nut shell impressions are at the highest masses between 4800 and 3900 cal. BP. Ground stone pestle fragments are present between 5600 and 3900 cal. BP. The trends in plant ash, burned sediment nodules, pestle fragments, and animal bone data combined suggest that hunter-gatherers were using the site to process nut mast and fauna with *in situ* combustion features. The combination of burned sediment and faunal remains suggests that humans were increasingly using combustion features at the site, perhaps for more intensive resource extraction of nut mast and animals such as deer. Although it does not point directly toward human land burning, it certainly suggests that hunter-gatherers were more intensively processing nut mast and this is occurring at the same time that Wagner suggests the creation of anthropogenic environments at the Green River Shell Middens. During this period of enhanced sedimentation and peaking at the end of this period, burned sediment increases dramatically continuing into a period of soil formation that may suggest another episode of wetter conditions favoring forest development between 4800 and 4000 years ago. This is occurring at the same time as major population increases in the middle Green River valley. These features may have been disturbed and disaggregated through bioturbation and trampling. These activities may be associated with early silviculture in the region, and are contemporary with postulated anthropogenic ecology in the middle Green River region (Wagner 2005). The greatest density of plant ash is found in deposits, which appear to have been deposited relatively rapidly, dating between 3900 and 3000 cal. BP spanning the Late Archaic to Terminal Late Archaic periods. From the Late Archaic to Terminal Late Archaic periods (ca. 4000-3000 cal. BP), archaeological deposits contain the highest amounts of plant ash seen in the sink, evidence of increased sediment accumulation, and high quantities of rock accumulation, landscape burning may have disturbed vegetation to a degree that caused extensive erosion and exposure of bedrock. Burned sediment nodule masses drop dramatically suggesting few *in situ* combustion features and rather burning coming from around the landform. A single radiocarbon date from this deposit is older than expected and out of date in the sequence. This suggests that this deposit was create by erosion from the surrounding landform and accumulation in the sink.

The data from 5600 to 3900 cal. BP at Crumps Sink suggest a focus on faunal remains and intensive processing of nutmast, perhaps associated with silvicultural activities, such as woodland management. The data from 3900 to 3000 cal. BP at Crumps Sink suggest that there was increased burning on the landform of Crumps Sink, which may relate to regional trends of increased forest fires in Kentucky and the greater Interior Low Plateaus. The timing of this proposed land burning sequence fits with larger trends seen in charcoal frequencies by at least 4000 cal. BP throughout the Interior Low Plateaus and Southern Appalachian Mountains (Delcourt et al. 1998; Fesenmyer and Christensen Jr. 2010; White 2007), potential silviculture seen in the middle Green River region (ca. 5600-3900 cal. BP) (Wagner 2005), and early horticulture (ca. 4000-2500 cal. BP) (Crothers 2008; Smith 2006; Watson 1985), grassland expansion (after ca. 4500 cal. BP) (Wilkins 1991; Schoenwetter

1974), and the transition from the Middle to Late Holocene (ca. 4200 cal. BP) (Walker 2012).

The most prominent soil development at the site over the past 7200 years begins at approximately 3000 cal. BP. This soil may have been the interior ground surface of the sinkhole for at least two millennia. This was also at a time when humans were exploring major caves in the region and experimenting with plant domestication. In the north half of Unit 1, a flaked limestone hoe fragment was found within this soil, which may suggest cultivation activities at the site. At this time, Native Americans began using the cave entrance more frequently (Carstens 1980), and though there is a high quantity lithic debitage in this soil, there are no diagnostics lithic artifacts from periods later than the Early Woodland period and no radiocarbon dates later than the Terminal Late Archaic period. Plant ash was not evident in this level and the calcium carbonate percentages are relatively low. This may be a result of processes of weathering during soil formation that would have dissolved calcium carbonate and redeposited it in the B horizon during translocation. This soil was eventually capped by a yellow silt deposit, potentially deposited during erosion from historic agriculture in the region (see Dicken and Brown 1938). A weak soil horizon is currently forming at the present ground surface. However, starting 3000 years ago during the Terminal Late Archaic period, and for at least two millennia, likely until the historic period, the landform was at its most stable during the last 7000 years.

Distinguishing between Human and Climate Induced Fires

Though Baskin et al. (1994) suggested that the Big Barrens grasslands were formed by anthropogenic burning, Ray (1997) argued that these fires may be the result of lightning strikes. We must consider both possibilities. Therefore, if these fires are forest fires, then how can we distinguish between them as created by humans or by changes in climate? Bowman et al. (2011:224) argue that there are three key factors in distinguishing human activities from climatic processes:

> *(1) temporal or spatial changes in fire activity and vegetation apparent from palaeoecological proxies, (2) a demonstration that these changes are not predicted by climate-fuels-fire relationships and paleoclimate reconstructions for the period of fire regime change, and (3) a demonstration that fire regime changes coincide in space and time with changes in human history (e.g., technological, economic, political, or demographic changes, including colonization of new lands) known from archaeology, anthropology and historical sources.*

Aside from very sparse ash rhombs in soil Ab4 at 7200-7000 cal. BP from which the micromorphological sample was collected just beneath a hearth, no plant ash was evident between 7000 and 5600 cal. BP. Plant ash begins being deposited consistently, and based on calcium carbonate percentages, likely in increasing quantities, between 5600 and 3900 cal. BP. Burned sediment with nut impressions and animal bone masses indicate this may be related to *in situ* combustion features for cooking. Climatically, this is a time of environmental transition from the Middle Holocene Thermal Maximum to the early Late Holocene. Plant ash becomes much more pronounced in a sediment accumulation layer dating between 3900 and 3000 years ago, at the beginning of the early Late Holocene. Increased burning is also seen in the Interior Low Plateaus and Southern Appalachian Mountains in other studies by at least 4000 years ago.

For the second factor, this was at a time when forested conditions should have become more common during the transition to a wetter and cooler period during the early Late Holocene (Delcourt and Delcourt 1979; Walker et al. 2012). However, grasslands expand in central Kentucky (Schoenwetter 1974; Wilkins et al. 1991). There is also greater C_4 plant representation in West Virginia (Driese et al. 2005) and Missouri (Denniston et al. 2007), though the Missouri example is along the edge of the prairie peninsula. At Crumps Sink, there is more prominent soil development, or at least decreased sedimentation allowing for increased organic accumulation and pronounced bioturbation. However, there is a period of erosion associated with the highest amount of plant ash. Either there was a drought at this time or greater C_4 representation relates to landscape burning promoting grassland species. However, in the Interior Low Plateaus, climatically, it seems that forest development was favored.

For the third factor, there are significant changes in human history in the lower Ohio River valley during the late Middle Archaic and Late Archaic periods, contemporaneous with increases in plant ash seen at Crumps Sink. In the middle Green River valley, there is population increase, increased interregional exchange, the manufacture of formalized groundstone tools (possibly associated with silviculture) such as pestles, grooved axes, and celts, and evidence of land clearing. Perhaps the most significant change is the beginning of agriculture in the region. Crothers (2008) has identified changing property rights associated with early horticultural economies in the region. This study adds time-depth and an understanding of the socioecological legacies that led into early agriculture and builds upon Crothers' recognition of changing property rights.

Modelling the Origins of Anthropogenic Environments in Central Kentucky

Generally, models of human-environmental interactions during the Archaic period strongly emphasize humans adapting to their environments. However, my dissertation study demonstrates that Archaic hunter-gatherers also impacted their surrounding environments, possibly as early as the Middle Archaic period and certainly by the Late Archaic period. In fact, Archaic hunter-gatherers at Crumps Sink impacted the landform in ways that left signatures in the soils and potentially transformed the surrounding ecosystem. The strength of this study is that it demonstrates these impacts, even on a microscopic scale, and should set a precedent for future studies at Archaic period sites.

Human actions through disturbance may create ecosystem legacies (sensu Winterhalder 1994) that are the impetus for future ecological developments. For example, the transitions seen in settlement-subsistence strategies: Early Archaic high residential mobility → early Middle Archaic low residential mobility → late Middle Archaic logistical collecting (see Homsey-Messer 2015; Stafford 1994; Stafford et al. 2000; Jefferies 2008) may indicate incremental learning associated with adaptations to environmental conditions and likely social conditions perhaps associated with population increases. For example, proponents of the push-pull hypothesis argued that xeric conditions during the Middle Holocene may have influenced Native American settlement and subsistence strategies such as the movement toward base camps in river valleys (Brown and Vierra 1983). By the late Middle Archaic and Late Archaic periods, increased sedentism and social complexity may have led to the constriction of resource bases, thus requiring new approaches to maintain and perhaps increase the biodiversity of resource yields. Ecosystem disturbance by humans to create and/or maintain diverse resource patches, perhaps associated with silviculture, beginning during the Middle Archaic and reaching prominence in the Late Archaic (Wagner 2005). Nut mast increased in importance throughout the Holocene, and beyond the Archaic, though perhaps its greatest importance was during the Archaic period. If such changes are demonstrated, we can argue that Late Archaic hunter-gatherers were *adapting* to environmental conditions favoring forest development in *active* ways. By the Late Holocene (Delcourt and Delcourt 1979), and seemingly in cyclical episodes during the Middle Holocene (Driese et al. 2005, 2008; Kocis 2011; Stinchcomb 2013), wetter environmental conditions favoring forest development prevailed throughout the Midcontinent. This may have required new strategies to maintain open vegetation structure. Finally, major cultural developments played a significant role in human-environmental interactions. These include increasing population size, interaction, and trade.

During the late Middle Archaic period, which correlated with the Middle Holocene Thermal Maximum, hunter-gatherers may have been focusing more intensively on reliable locations with access to water such as Crumps Sink. This may explain why the first observable use of the sink by hunter-gatherers was during this period. By the Late Archaic period, they may have burned the landscape to intensively process nut mast at levels not seen in previous time periods. To manage nut trees with high yields, especially in times when conditions were trending wetter during the early Late Holocene, creating a closed canopy structure not beneficial for growth and germination of saplings, people were burning the surrounding landscape. Thus, hunter-gatherers were active managers of their surrounding ecosystems, while also adapting to environmental conditions. Thus, rather than merely altering collection strategies by passively responding to “where the resources are”, they were creating resource bases that could be exploited on demand. This would have required investment, or landesque capital and perhaps institutional land tenure systems.

By the late Middle Archaic period (at the same time as logistical collection strategies) there seems to be increased social interaction, complexity, and sedentism. In the Late Archaic period this continues and leads to increased interpersonal violence, suggesting ranges are being contested. Thus, a common-pool resource model for management of resources in the Sinkhole Plain may have developed: Early Archaic (open access), early Middle Archaic (open access, but with greater importance of point locations such as caves), late Middle Archaic (open access, but large base camps suggesting conceptions of land tenure), Late Archaic (a shift towards common-property regimes where resources are defended, associated with increased investment at sites through fire), Terminal Late Archaic (continued shift toward common-property regimes, but population increases and interactions with land increasingly destructive), Terminal Late Archaic to Woodland (common-property system in place) and land tenure relations established. My assumption is that the barrens were an open access area during much of the Archaic, though changes in environmental conditions such as the Hypsithermal may have affected how people gathered on the land. There was likely open-access to resources, especially during the Early and Middle Archaic periods. Information on resources was likely freely and openly disseminated, which would have been necessary due to the fact that permanent water could only be accessed by way of karst windows and caves. However, in times of resource depletion it is likely that groups reformulated institutions, practicing regulated common property systems, in which information was withheld from incoming groups in order for more localized groups to conserve water and other resources found in such microenvironments.

As populations increased during the Late Archaic and Early Woodland period, and shellfish resources potentially declined, there may have been a need to access new, lower ranked resources (Crothers 2008). Corporate groups may have been responsible for prescribed fire regimes, with specific groups having access to such systems. If the Sinkhole Plain was a cultural buffer zone, or only visited for specific logistical tasks during the Middle Archaic through Middle Woodland periods, then it would be an ideal place to establish prescribed fire regimes with delayed benefits since few settlements would be adversely affected. Changes in social structure surrounding resource acquisition may indicate incremental learning of ecological knowledge (sensu Turner and Berkes 2006), as well as adjustments to shifting resource bases and environmental conditions.

The degree of access to common-pool resources is historically contingent. Therefore, it would have been difficult to control, and the dispersed nature of sinkhole resources may have meant that it was too costly to defend. However, the unique geological, topographic, and ecological nature of the Sinkhole Plain may have made it especially conducive to fire ecology. In the karst terrain, with thin soils, few hydrological obstacles, and species which thrive in disturbed conditions, it also may have had increasing value to prehistoric groups for hunting, weedy plants, and expansive open areas. Over time there may have been fluctuations between open access and common property systems. During periods where human use of fire was important, the Sinkhole Plain may have also been a coveted land resource which was controlled communally among many different local groups interested in resources such as game.

Though it seems that an active management strategy is undertaken by the Late Archaic period, it would not be surprising (especially as seen in squash domestication by the Middle Archaic period) if humans are actively managing their environments much earlier. Thus, this model can be built upon and will likely be altered once we begin to recognize traditional societies as ecosystem managers. I believe that this can open up valuable new investigations of human-environmental interactions by considering humans and environment as mutually responding to and acting upon each other, as advocated in historical ecology (sensu Balée 2006). No doubt, we may consider altering settlement-subsistence strategies as an active strategy, though perhaps passive in its impacts on the environment. Additionally, principles of long-term investment would have already been quite well understood, as resources such as nut trees have different time frames or cycles in which they are productive (Turner and Berkes 2006).

It seems that burning on the landscape may have initially resulted from silviculture and management of land to increase important game animals. If this is the case, it may be the precursor for early horticulture. Chronologically, an increase in plant ash is demonstrated during the Middle to Late Holocene transition and during the early Late Holocene. If conditions were wetter during this time, this may have been an adaptation to maintain more open forest structure or promote nut-bearing trees. A firm understanding of human-environmental interactions during the Archaic period is important for understanding the domestication of native cultigens in eastern North America.

Future Directions

The geoarchaeological work in this dissertation provides an important paleoenvironmental foundation for exploring human-environmental interactions in the region. However, more work needs to be done. It will be essential to find a non-site context to obtain another stratified paleoenvironmental record. To avoid archaeological deposits overshadowing natural deposits, features such as sinkholes, cave entrances, talus slopes or deep caves that have little evidence of human habitation must be identified. A systematic coring program throughout the Sinkhole Plain will aid in this endeavor. Also, throughout the Interior Low Plateaus and Southern Appalachian Mountains, efforts have been made to chart charcoal frequencies over time with success. My study suggests the presence of a previously unrecognized feature that may indicate large-scale land burning: plant ash in micro-geomorphological thin-sections. Future work on botanical and faunal remains from Crumps Sink will also reflect the immediate environment and the species selected by hunter-gatherers that may relate to fire ecology. In addition, analysis of the archaeobotanical record will better quantify changes in nut mast and whether any domesticates are present at the site and whether they correlate with the fire history and human activities at the site.

Future comparison of sites among the Mammoth Cave Plateau, Dripping Springs Escarpment, and Sinkhole Plain can provide more detail about the aforementioned environmental and cultural changes. Site location in distinct physiographic regions will allow a greater assessment of differences in land use among regions. I hypothesize that the unique geological, topographic, and ecological nature of the Sinkhole Plain characterized by thin soils, few hydrological obstacles, and more xeric ecosystems may have made it especially conducive to fire ecology and suggest that it was the first region to be affected by fire management in central Kentucky.

Implications and Significance

This research is significant for a variety of reasons: (1) the implications of changing human-land interactions in relation to the origins of agriculture in the Eastern U.S.; (2) further assessment of recent research suggesting that prehistoric small-scale societies were more active agents in transforming their landscapes than previously believed; (3) developing a model of how hunter-gatherers and horticulturalists occupy and utilize holokarst landscapes; (4) determining the catalysts for prehistoric origins of grasslands in the Interior Low Plateaus; (5) contributing to contemporary dialogue concerning barren grassland management in the Midwestern United States; (6) elucidating the Holocene history of geogenic, biogenic, and anthropogenic sediment deposition in a karst setting; and (7) offering a framework for distinguishing between human activities and environmental processes over time. My investigations began with the Big Barrens grasslands and have brought us through a variety of interweaving datasets, models, and patterns. Such is the strength of an historical ecological approach that recognizes all things are interconnected, and minor changes can ricochet across lithospheric, biospheric, atmospheric, and human dimensions. Such a consideration of long-term human dynamics, especially intertwining impacts of environmental change on landforms and people, as well as human impacts of landforms and environments, can be useful in our own solutions for current and future environmental dilemmas.

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APPENDIX

Artifact Catalog, Unit 1, North Half.

Unit 1, North ½, Level 1, Zone I, 0-10 cmbs, Field Specimen No. 2			
Catalogue No.	**Material**	**Count**	**Weight (g)**
2-1	Bone	-	4.8
2-2	Debitage	-	103.3
2-3	Coal	-	2.8
Unit 1, North ½, Level 2, Zone II,10-20 cmbs, Field Specimen No. 5			
5-1	Bone	-	11.9
5-2	Shell	-	0.2
5-3	Charcoal	-	2.1
5-4	Debitage	-	54.6
5-5	Modified Bone-Awl	1	1.0
5-6	Glass	4	3.7
5-7	Groundstone	1	106.1
5-8	PPK Fragment-Proximal	1	1.9
5-9	Retouched Flake	1	0.4
5-10	Retouched Flake	1	7.0
5-11	Utilized Flake	1	3.0
Unit 1, North ½, Level 3, Zone II, 20-30 cmbs, Field Specimen No. 9			
9-1	Bone	8	4.4
9-2	Debitage	-	22.0
9-3	Mussell Shell	-	1.6
9-4	Historic Ceramic-Rim	1	0.2
9-5	PPK Fragment	1	1.6
9-6	Charcoal	-	1.6
Unit 1, North ½, Level 4, Zone II, 30-40 cmbs, Field Specimen No. 11			
11-1	Bone	-	<0.1
11-2	Debitage	-	2.7
11-3	Charcoal	-	1.2
11-4	Glass	1	0.7
Unit 1, North ½, Level 5A, Zone II, 40-44 cmbs, Field Specimen No. 16			
16-1	Bone	-	1.0
16-2	Debitage	-	137.4
16-3	PPK Fragment	1	2.9
16-4	Graver/Multitool	1	3.5
16-5	Thick Biface Fragment	1	6.3
16-6	Repurposed PPK-Burin?	1	1.5
16-7	Utilized Flake	1	1.7
16-8	Retouched Flake	1	7.6
Unit 1, North ½, Level 5B, Zone III A, 43-50 cmbs, Field Specimen No. 18			
18-1	Bone	-	11.8
18-2	Debitage	-	138.2
18-3	Charcoal	2	0.3
18-4	PPK Fragment-Distal	1	3.4

18-5	Biface Fragment	1	1.6
18-6	Utilized Flake	1	1.8
18-7	PPK B-See Plan Map	1	8.0
18-8	PPK C- See Plan Map	1	14.6
18-9	PPK D-See Plan Map	1	8.9
Unit 1, North ½, Level 6, Zone III A, 50-60 cmbs, Field Specimen No. 23			
23-1	Bone	-	23.1
23-2	Debitage	-	155.7
23-3	Charcoal	-	0.9
23-4	Utilized Flake	1	38.9
23-5	Utilized Flake	1	1.0
23-6	Utilized Flake	1	2.6
23-7	Utilized Flake	1	0.7
23-8	Utilized Flake	1	1.6
23-9	Utilized Flake	1	3.2
23-10	Utilized Flake	1	3.9
23-11	Utilized Flake	1	5.0
23-12	Utilized Flake	1	2.6
23-13	PPK/Drill Fragment	1	2.0
23-14	Biface Fragment	1	0.8
23-15	PPK Fragment	1	3.6
23-16	PPK Fragment	1	3.2
Unit 1, North ½, Level 7, Zone III A, 60-70 cmbs, Field Specimen No. 33			
33-1	Bone	-	60.0
33-2	Debitage	-	123.0
33-3	Charcoal	-	1.1
Unit 1, North ½, Level 8, Zone III B, 70-80 cmbs, Field Specimen No. 27			
27-1	Bone	-	200.0
27-2	Debitage	-	141.2
27-3	Charcoal	-	10.6
27-4	Burned Sediment	-	7.3
27-5	Mussel Shell	-	0.9
27-6	Bone Awl	1	1.9
27-7	Cannel Coal/Coal	3	2.1
27-8	Hoe Fragment	1	80.8
27-9	Gorget Fragment	1	19.6
27-10	Utilized Flake	1	3.6
27-11	Utilized Flake	1	1
27-12	Utilized Flake	1	3.6
27-13	Utilized Flake	1	2.6
27-14	Utilized Flake	1	2.1
27-15	Utilized Flake	1	1.3
27-16	Utilized Flake	1	3.6
27-17	Land Snail	1	0.2
27-18	Biface Fragment	1	0.4
27-19	Biface Fragment	1	0.5
27-20	Biface Fragment	1	0.8
27-21	Biface Fragment	1	10.8

Unit 1, North ½, Level 9, Zone IV A, 80-90 cmbs, Field Specimen No. 43			
43-1	Bone	-	169.6
43-2	Shell	-	5.8
43-3	Debitage	-	258.2
43-4	Charcoal	-	4.3
43-5	Burned Sediment	3	1.8
43-6	Modified Antler	1	5.4
43-7	Groundstone	1	210.8
43-8	Retouched Flake	1	0.3
43-9	Retouched Flake	1	1.5
43-10	Retouched Flake	1	1.2
43-11	Utilized Flake	1	2.8
43-12	Scraper Fragment	1	1.3
Unit 1, North ½, Level 10, Zones IV A & B, 90-100 cmbs, Field Specimen No. 44			
44-1	Bone	-	161.7
44-2	Debitage	-	112.8
44-3	Charcoal	-	7.3
44-4	Land Snail	-	22.9
44-5	Burned Sediment	-	14.0
44-6	PPK Base (diagnostic)	1	7.9
44-7	Biface Fragment (distal)	1	7.5
44-8	PPK Fragment (distal)	1	0.4
44-9	PPK Fragment (distal)	1	0.2
44-10	Endscraper?	1	2.5
44-11	Utilized Flake	1	1.4
44-12	Utilized Flake	1	11.7
44-13	Drilled Ground Stone Fragment- Bannerstone?	1	6.6
Unit 1, North ½, Level 11, Zone IV B, 100-110 cmbs, Field Specimen No. 47			
47-1	Bone	-	193.4
47-2	Debitage	-	184.8
47-3	Land Snail	-	31.2
47-4	Charcoal	-	8.8
47-5	Mussel Shell	1	0.2
47-6	Burned Sediment	-	18.8
47-7	Worked Bone-Turtle Shell	1	1.2
47-8	Groundstone Fragments	4	7.8
47-9	PPK Fragment (distal)	1	1.1
47-10	PPK Fragment (distal)	1	3.1
47-11	PPK Fragment (distal)	1	2.6
47-12	Utilized Flake	1	0.3
47-13	Quartz Pebble	1	4.5
Unit 1, North ½, Level 12, Zone IV B, 110-120 cmbs, Field Specimen No. 56			
56-1	Bone	-	163.9
56-2	Shell	-	38.5
56-3	Debitage	-	142.0
56-4	Charcoal	-	33.0
56-5	Burned Sediment	-	4.7
56-6	Bone Awl	1	3.3

56-7	Utilized Flake	1	9.6
56-8	Biface Fragment	1	7.5
56-9	Hafted Drill	1	3.4
56-10	Biface Fragment	1	7.6
56-11	Retouched Flake	1	1.2
Unit 1, North ½, Zone IV B, Level 13, 120-130 cmbs, Field Specimen No. 63			
63-1	Bone	-	250.0
63-2	Debitage	-	152.4
63-3	Shell	-	40.8
63-4	Charcoal	-	26.3
63-5	Burned Sediment	-	7.3
63-6	Utilized Flake	1	1.6
63-7	PPK Fragment	1	6.3
63-8	Groundstone	1	209.4
Unit 1, North ½, Level 14, Zone IV C, 130-140 cmbs, Field Specimen No. 69			
69-1	Bone	-	254.8
69-2	Debitage	-	161.2
69-3	Shell	-	54.5
69-4	Charcoal	-	17.4
69-5	Burned Sediment	-	1.6
69-6	Scraper	1	2.4
69-7	Utilized Flake	1	12.5
69-8	Utilized Flake	1	3.6
69-9	Utilized Flake	1	7.5
69-10	Utilized Flake	1	2.3
69-11	Utilized Flake	1	1.7
69-12	Thick Biface	1	26.9
69-13	PPK	1	3.7
69-14	PPK	1	3.2
69-15	PPK	1	0.8
69-16	PPK	1	2.6
69-17	PPK	1	10.0
69-18	PPK	1	0.5
Unit 1, North ½, Level 15, Zone IV C, 140-150 cmbs, Field Specimen No. 71			
71-1	Bone	-	276.3
71-2	Shell	-	77.7
71-3	Debitage	-	106.8
71-4	Charcoal	-	35.6
71-5	Burned Sediment	-	22.1
71-6	Polished Bone	1	0.3
71-7	Drill Fragment	1	1.4
71-8	PPK Fragment	1	5.7
71-9	PPK Fragment	1	5.2
71-10	PPK	1	19.2
71-11	PPK	1	4.3
71-12	Retouched Flake	1	17.8
Unit 1, North ½, Level 16, Zone IV C, 150-160 cmbs, Field Specimen No. 73			
73-1	Bone	-	576.5

73-2	Debitage	-	179.2
73-3	Charcoal	-	14.3
73-4	Burned Sediment	-	43.7
73-5	Land Snail	-	84.8
73-6	Mussel Shell	-	1.0
73-7	Groundstone Fragment (pestle?)	1	237.8
73-8	Worked Bone	1	4.2
73-9	Worked Bone	1	1.1
73-10	Utilized Flake	1	0.4
73-11	Utilized Flake	1	3.2
73-12	Utilized Flake	1	1.0
73-13	Biface Fragment	1	0.3
73-14	Biface Fragment	1	1.1
73-15	Biface Fragment (medial)	1	5.1
73-16	Biface Fragment	1	0.8
73-17	Groundstone Pestle Fragment	1	64.4
73-18	PPK	1	14.2
73-19	PPK Base	1	1.8
Unit 1, North ½, Level 17, Zone IV D, 160-170 cmbs, Field Specimen No. 84			
84-1	Bone	-	454.5
84-2	Debitage	-	171.2
84-3	Shell	-	151.3
84-4	Charcoal	-	22.8
84-5	Burned Sediment	-	23.9
84-6	Pedogenic Carbonate Sample	-	1.5
84-7	Biface Fragment	1	15.5
84-8	Utilized Flake	1	3.5
84-9	Modified Bone	1	1.1
84-10	Groundstone	1	287.4
84-11	Groundstone	1	16.4
Unit 1, North ½, Level 18, Zone IV D, 170-180 cmbs, Field Specimen No. 89			
89-1	Bone	-	206.3
89-2	Debitage	-	69.0
89-3	Land Snail	-	138.9
89-4	Charcoal	-	11
89-5	Mussel Shell	-	12.9
89-6	Burned Sediment	-	28.1
89-7	Groundstone Tool Fragment?	1	1.3
89-8	Bone Awl	2	18.2
89-9	Bone Projectile Point	1	2.2
89-10	Projectile Point	1	8.3
89-11	Projectile Point Fragment (distal)	1	6.1
89-12	Projectile Point Fragment (medial)	1	8.8
89-13	Projectile Point Fragment (medial)	1	0.8
89-14	Biface Fragment	1	0.3
89-15	Bannerstone Fragment (quartz)	1	2.2
89-16	Utilized Flake	1	5.1
89-17	Utilized Flake	1	31.3

89-18	Utilized Flake	1	46.8
89-19	Utilized Flake	1	4.3
89-20	Pedogenic Carbonate Sample	-	2.6
Unit 1, North ½, Level 19, Zones IV E & D, 180-190 cmbs, Field Specimen No. 94			
94-1	Bone	-	223.0
94-2	Shell	-	278.5
94-3	Debitage	-	110.1
94-4	Charcoal	-	14.2
94-5	Burned Sediment	-	15.6
94-6	Pedogenic Carbonate Sample	-	2.9
94-7	Bone Tool	1	1.7
94-8	Utilized Flake	1	2.2
94-9	Rough Biface Fragment	1	14.7
94-10	Groundstone	1	18.8
Unit 1, North ½, Level 20, Zone IV E, 190-200 cmbs, Field Specimen No. 100			
100-1	Bone	-	277.1
100-2	Debitage	-	82.6
100-3	Shell	-	307.7
100-4	Charcoal	-	13.3
100-5	Burned Sediment	-	39.2
100-6	Groundstone	1	108.0
100-7	Retouched Flake	1	23.0
100-8	Retouched Flake	1	11.7
100-9	PPK	1	11.8
100-10	Modified Bone	2	8.1
100-11	Modified Rock?	1	10.0
Unit 1, North ½, Level 21, Zone IV E, 200-210 cmbs, Field Specimen No. 119			
119-1	Bone	-	134.8
119-2	Shell	-	175.2
119-3	Charcoal	-	23.1
119-4	Debitage	-	69.2
119-5	Burned Sediment	-	17.2
119-6	Pedogenic Carbonate Sample	-	2.2
119-7	Antler Tine	1	61.1
119-8	Modified Bone	8	14.3
119-9	Groundstone?	1	202.5
Unit 1, North ½, Level 22, Zone IV E, 210-220 cmbs, Field Specimen No. 126			
126-1	Bone	-	114.4
126-2	Shell	-	72.1
126-3	Debitage	-	105.9
126-4	Charcoal	-	22.8
126-5	Burned Sediment	-	4.7
126-6	Modified Bone	3	3.2
126-7	PPK	1	13.3
126-8	PPK	1	5.2
126-9	Groundstone	2	85.8
126-10	Groundstone	1	750.0
Unit 1, North ½, Level 23, Zone IV F, 220-230 cmbs, Field Specimen No. 127			

127-1	Bone	-	162.2
127-2	Debitage	-	132.2
127-3	Shell	-	39.4
127-4	Charcoal	-	7.7
127-5	Burned Sediment	-	3.6
127-6	Bifacial Tool	2	36.0
127-7	Bifacial Tool	1	30.9
127-8	PPK Fragment	1	3.1
127-9	Modified Bone	1	0.8
Unit 1, North ½, Level 24, Zone IV F, 230-240 cmbs, Field Specimen No. 141			
141-1	Bone	-	138.4
141-2	Debitage	-	143.5
141-3	Charcoal	-	3.9
141-4	Mussel Shell	-	12.6
141-5	Land Snail	-	45.6
141-6	Burned Sediment	-	18.5
141-7	Pestle Fragment	1	11.7
141-8	Hammerstone	1	134.8
141-9	Worked Bone	1	1.5
141-10	Worked Bone	1	1.4
141-11	Utilized Flake	1	2.3
141-12	Utilized Flake	1	1.3
141-13	Biface Fragment	1	0.9
141-14	Biface Fragment	1	0.7
141-15	Biface Fragment	1	0.6
141-16	Biface Fragment	1	0.9
141-17	Biface Fragment	1	1.4
141-18	Drill Fragment	1	2.2
Unit 1, North ½, Level 25, Zone IV F, 240-250 cmbs, Field Specimen No. 170			
170-1	Bone	-	114.7
170-2	Debitage	-	108.1
170-3	Land Snail	-	23.9
170-4	Mussel Shell	-	2.3
170-5	Burned Sediment	-	12.9
170-6	Charcoal	-	10.3
170-7	Pedogenic Carbonate Sample	3	0.8
170-8	Biface Fragment	1	6.2
170-9	Utilized Flake	1	5.1
170-10	Utilized Flake	1	1.8
170-11	Utilized Flake	1	3.2
170-12	Utilized Flake	1	1.1
170-13	Utilized Flake	1	1.4
170-14	Biface Fragment	1	11.8
170-15	Worked Bone	1	0.7
170-16	Utilized Flake	1	9.4
170-17	PPK Fragment (base)	1	1.0
170-18	PPK Fragment (base)	1	4.6
170-19	Groundstone Fragment	1	166.6

170-20	Pestle Fragment	1	174.6
Unit 1, North ½, Level 26, Zone IV F, 250-260 cmbs, Field Specimen No. 150			
150-1	Bone	-	189.4
150-2	Shell	-	31.4
150-3	Debitage	-	177.4
150-4	Charcoal	-	21.0
150-5	Burned Sediment	-	10.8
150-6	Pedogenic Carbonate Sample	-	3.8
150-7	Groundstone Fragments	2	28.1
150-8	Modified Bone Fragments	6	6.1
150-9	Pestle Fragments	3	302.9
150-10	PPK	1	7.5
150-11	PPK Fragment	1	5.9
Unit 1, North ½, Level 27, Zones IV F & G, 260-270 cmbs, Field Specimen No. 173			
173-1	Bone	-	233.8
173-2	Debitage	-	76.6
173-3	Shell	-	11.8
173-4	Charcoal	-	11.0
173-5	Burned Sediment	-	8.4
173-6	Ash	-	1.3
173-7	Pedogenic Carbonate Sample	-	8.6
173-8	Utilized Flake	1	7.1
173-9	Utilized Flake	1	2.4
173-10	Utilized Flake	1	2.6
173-11	Utilized Flake	1	3.7
173-12	Utilized Flake	1	1.9
173-13	Utilized Flake	1	0.7
173-14	Utilized Flake	1	0.6
173-15	Utilized Flake	1	0.2
173-16	Groundstone Fragment	2	5.7
173-17	Bone Tool Refit	2	1.8
173-18	PPK Fragment	1	3.5
173-19	PPK Fragment	1	5.7
173-20	PPK Fragment	1	4.5
Unit 1, North ½, Level 28, Zone IV G, 270-280 cmbs, Field Specimen No. 174			
174-1	Bone	-	122.3
174-2	Debitage	-	121.6
174-3	Land Snail	-	1.5
174-4	Charcoal	-	7.3
174-5	Mussel Shell	-	0.7
174-6	Burned Sediment	-	3.6
174-7	Worked Bone Fragment (medial)	1	0.9
174-8	Biface Fragment (medial)	1	3.5
174-9	Biface Fragment	1	4.1
174-10	Pedogenic Carbonate Sample	-	5.7
174-11	Groundstone Tool Fragment	1	2.4
174-12	Utilized Flake	1	11.3
174-13	Utilized Flake	1	1.2

174-14	Utilized Flake	1	0.9
174-15	Utilized Flake	1	1.0
174-16	Utilized Flake	1	0.7
174-17	Utilized Flake	1	1.5
174-18	Utilized Flake	1	0.6
Unit 1, North ½, Level 29, Zone IV G, 280-290 cmbs, Field Specimen No. 176			
176-1	Bone	-	247.0
176-2	Shell	-	2.2
176-3	Charcoal	-	5.3
176-4	Debitage	-	107.7
176-5	Burned Sediment	-	16.7
176-6	Pedogenic Carbonate Sample	-	1.4
176-7	Retouched Flake	1	8.2
176-8	PPK Fragment	1	5.2
176-9	PPK Fragment	1	1.5
176-10	PPK Fragment	1	4.1
Unit 1, North ½, Level 30, Zone IV G, 290-300 cmbs, Field Specimen No. 178			
178-1	Bone	1	138.6
178-2	Debitage	1	76.3
178-3	Shell	1	<0.1
178-4	Charcoal	-	22.1
178-5	Burned Sediment	-	11.9
178-6	Core	1	82.2
178-7	Utilized Flake	1	6.0
178-8	Biface Fragment	1	2.7
178-9	Biface Fragment	1	12.1
178-10	PPK	1	7.7
178-11	Modified Bone, Antler Tine Fragments	2	0.6
Unit 1, North ½, Level 31, Zone IV G, 300-310 cmbs, Field Specimen No. 181			
181-1	Bone	-	54.5
181-2	Debitage	-	66.0
181-3	Charcoal	-	2.7
181-4	Burned Sediment	-	2.4
181-5	Chunk of Wood Charcoal	-	-
181-6	Biface Fragment	1	4.4
181-7	Utilized Flake	1	3.9
181-8	Biface Fragment-PPK?	1	1.1
181-9	Land Snail	1	0.1
181-10	PPK	1	2.9
181-11	PPK	1	4.5
181-12	Pedogenic Carbonate Sample	8	4.7
Unit 1, North ½, Level 32, Zone IV G, 310-320 cmbs, Field Specimen No. 182			
182-1	Bone	-	83.9
182-2	Debitage	-	135.2
182-3	Charcoal	-	5.0
182-4	Land Snail	1	0.3
182-5	Burned Sediment	2	1.6
182-6	Worked Bone?	1	0.7

182-7	Scraper?	1	34.9
182-8	Utilized Flake	1	1.6
Unit 1, North ½, Level 33, Zone IV H, 320-330 cmbs, Field Specimen No. 185			
185-1	Bone	-	83.2
185-2	Debitage	-	98.0
185-3	Charcoal	-	11.3
185-4	Biface Fragment	1	1.7
185-5	Drilled Bone-Needle Fragment?	1	0.7
185-6	Worked Bone	1	0.7
Unit 1, North ½, Level 34, Zone IV H, 330-340 cmbs, Field Specimen No. 187			
187-1	Debitage	-	150.5
187-2	Bone	-	104.9
187-3	Charcoal	-	2.5
187-4	Burned Sediment	2	4.5
187-5	Utilized Flake	1	4.8
187-6	Utilized Flake	1	0.8
187-7	Worked Bone?	1	<0.1
187-8	Pedogenic Carbonate Sample	5	0.8
Unit 1, North ½, Level 35, Zone IV I, 340-350 cmbs, Field Specimen No. 189			
189-1	Bone	-	72.1
189-2	Debitage	-	35.9
189-3	Charcoal	-	1.2
Unit 1, North ½, Level 36, Zones IV I & V, 350-360 cmbs, Field Specimen No. 191			
191-1	Bone	-	21.5
191-2	Debitage	-	33.1
191-3	Piece-Plot Charcoal (358.5 cmbs, 5 cm E, 56 cm S)	-	-
191-4	Piece-Plot Charcoal (358 cmbs, 41 cm S, 20 cm E)	-	-
191-5	Piece-Plot Charcoal (359 cmbs, 83 cm S, 21 cm W)	-	-
191-6	Charcoal (general matrix)	-	1.0
191-7	PPK Fragment	1	4.3
191-8	Drilled Bone Fragment	1	1.7
191-9	Pedogenic Carbonate Sample	5	0.4
Unit 1, North ½, Level 37, Zone V, 360-370 cmbs, Field Specimen No. 194			
194-1	Debitage	2	1.5
194-2	Retouched Flake	1	1.7
194-3	Bone	1	0.2
194-4	Charcoal (general matrix)	-	0.2
194-5	Piece-Plot Charcoal (366 cmbs, 4 cm E, 57 cm S)	-	-
194-6	Piece-Plot Charcoal (365 cmbs, 70 cm S, 1 cm E)	-	-
194-7	Piece-Plot Charcoal (368.5 cmbs, 26 cm S, 13 cm E)	-	-
194-8	Pedogenic Carbonate Sample	5	0.5
Unit 1, North ½, Level 38, Zone V, 370-380 cmbs, Field Specimen No. 196			
196-1	Bone	-	0.2
196-2	Charcoal	-	0.2
196-3	Pedogenic Carbonate Sample	-	31.4

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Summer 2013	Teaching Assistant and Field Instructor: UK Archaeology Field School (University of Kentucky ANTH 583)
Spring 2013	Teaching Assistant: Archaeology-Myths and Controversies (University of Kentucky ANTH 102)
Fall 2012	Teaching Assistant: Origins of New World Civilizations (University of Kentucky ANTH 242)
Summer 2012	Field Technician: Kentucky Archaeological Survey University of Kentucky

Fall 2011- Spring 2012	Research Assistant: William S. Webb Museum University of Kentucky Archaeology Laboratory
Fall 2010- Spring 2011	Docent: Mace Brown Museum of Natural History College of Charleston
Spring 2010	Teaching Assistant: Archaeology (College of Charleston ANTH202)
Spring 2010	Intern: Brockington and Associates Cultural Resource Management, Mount Pleasant, SC

Academic Honors, Awards, Fellowships

2018	University of Kentucky Department of Anthropology Travel Funding Travel to Southeastern Archaeological Conference, Augusta, GA
2018	Legacy Fund Dissertation Writing Fellowship Department of Anthropology, University of Kentucky
2018	Anthropology Excellence Dissertation Fellowship Department of Anthropology, University of Kentucky
2017	Frontiers in Archaeological Sciences Conference Travel Funding Travel to Rutgers University to present dissertation research
2017	University of Kentucky Travel Funding Travel to Society for American Archaeology Meeting Vancouver, British Columbia, Canada
2017	Douglas C. Kellogg Fellowship Award for Geoarchaeological Research Society for American Archaeology
2016	Felburn Foundation Grant, for dissertation excavations and analysis
2016	National Science Foundation Graduate Student Supplemental Research Grant For courses in archaeological soil micromorphology at the University of Tübingen in Germany in summer 2017
2016	University of Kentucky Travel Funding Travel to Society for American Archaeology Meeting Orlando, Florida

2015	Kentucky Organization of Professional Archaeologists Research Grant
2015	Phillip M. Smith Graduate Student Research Grant for Cave and Karst Research, Cave Research Foundation, for dissertation excavations and analysis
2015	University of Kentucky Travel Funding Travel to Society for American Archaeology Meeting San Francisco, California
2013	Susan Abbott Jamieson Pre-Dissertation Research Fund Award University of Kentucky Anthropology Department
2012	Nick Crawford Karst Education Scholarship Western Kentucky University Center for Cave and Karst Studies for Cave Archaeology course at Mammoth Cave National Park, Kentucky
2011	Outstanding Anthropology Student, College of Charleston
2010	Archaeology Program Fellowship, College of Charleston For archaeological field work at El Purgatorio, Casma, Peru
2010	Jon Morter Fellowship for Archaeological Research, College of Charleston For archaeological field work at El Purgatorio, Casma, Peru
2009-2010	Puddin' Hill Award, Polk County Community Foundation
2009	Thomas Jefferson Foundation Scholarship, Monticello Department of Archaeology for archaeological field work at Monticello, Charlottesville, Virginia
2008-2009	John A. Albertson Education Award, Polk County Community Foundation
2007-2011	Presidential Community Enhancement Grant, College of Charleston
2007-2011	Watson-Brown Foundation Scholarship, Watson-Brown Foundation
2007-2010	Former Agents of the FBI Foundation Scholarship, Society of Former Special Agents of the FBI
2007-2008	Kirby Endowment Scholarship for First Year Students, Polk County Community Foundation
2007	Athletic Alumni Scholarship, Polk County High School

Articles

- **Carlson, Justin N.**
  2017 Assessing Human Activities, Sediment Deposition, and Pedogenesis at Crumps Cave Vestibule and Sink, Warren County, Kentucky, *Cave Research Foundation Annual Report 2014-15*: 97-99.

- Douglas, Joseph C., Alan Cressler, George Crothers, Marion O. Smith, Kristen Bobo, and **Justin N. Carlson**
  2016 Recent Investigations at 15 Ed23: Historic and Cultural Resources in a Disturbed Cave Environment, *Mammoth Cave Research Symposia*, 11th Research Symposium.

- Visonà, Paolo, with George M. Crothers, **Justin N. Carlson**, Donald Handshoe, Silvana Lora, P. Allegra Rasia, Luanao Toniolo
  2014 A Forgotten Roman Settlement in the Veneto. University of Kentucky Geoarchaeological Investigations at Tezze di Arzignano (Vicenza, Italy) in 2012. http://www.fastionline.org/docs/FOLDER-it-2014-314.pdf

Technical Reports

- **Carlson, Justin N.** and David Pollack
  2018 *Eight Thousand Years of History: Archaeological Investigation of the Renox Site (15Cu110), Cumberland County, Kentucky*. Kentucky Archaeological Survey, Research Report No. 19. University of Kentucky, Lexington.

- David Pollack and **Justin N. Carlson**
  2018 *Archaeological Investigation of the Late Middle Archaic Judd Site (15Cu111), Cumberland County, Kentucky*, Kentucky Archaeological Survey, Research Report No. 18. University of Kentucky, Lexington.

- **Carlson, Justin N.** and Claiborne Daniel Sea
  2018 Chipped Stone. In *Archaeological Investigation of the Late Middle Archaic Judd Site (15Cu111), Cumberland County, Kentucky*, by David Pollack and Justin N. Carlson. Kentucky Archaeological Survey, Research Report No. 18. University of Kentucky, Lexington.

- **Carlson, Justin N.**
  2016 *An Archaeological Assessment of Two Areas within the Active Heroes Organization Property, Bullitt County, Kentucky*. Kentucky Archaeological Survey Report No. 282.

- **Carlson, Justin N**., Jonas Yates, and Bruce Manzano
  2014 *Phase 1 Archaeological Survey of the Big Rock Stream Restoration Tract Mason County, Kentucky*. UK-PAR Project No. 14-7.

- **Carlson, Justin N.**, Jonas Yates, and Claiborne Daniel Sea
  2014 *Phase 1 Archaeological Survey of a Proposed Construction/Demolition Debris Landfill in Boyd County, Kentucky*. UK-PAR Project No. 14-11.

<u>Blog Entry</u>

2017 (fall)

- **Justin N. Carlson,** *What can we learn from "Dirt"? Geoarchaeology at a Sinkhole in Kentucky*. Kentucky Archaeology Month Blog Series.

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