GEOARCHAEOLOGY IN THE CURRENT RIVER VALLEY, OZARK NATIONAL SCENIC RIVERWAYS, SOUTHEAST MISSOURI

By

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ABSTRACT

On the Ozark Plateau, human occupation spanning the last 11,500 ^{14}C yr B.P. is well documented in the archaeological record. Recently, geoarchaeological investigations have been conducted in the reach of the Current River valley contained within Ozark National Scenic Riverways (NSR). The current study was conducted in an effort to establish a geoarchaeological model for Ozark NSR. Alluvial stratigraphy, particle-size distribution data, and optically stimulated luminescence ages were used to investigate late-Quaternary landscape evolution and model the geologic preservation potential for cultural deposits. Stable carbon isotope data were used to reconstruct paleoenvironmental change during the late Pleistocene and Holocene.

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TABLE OF CONTENTS

ABSTRACT………………………………………………………………………………… iii

ACKNOWLEDGEMENTS…………………………………………………………………… iv

TABLE OF CONTENTS……………………………………………………………………. v

LIST OF TABLES…………………………………………………………………………...viii

LIST OF FIGURES…………………………………………………………………………. ix

1. INTRODUCTION………………………………………………………………... 1
Statement of Problem and Research Objectives……………………………………….. 1
Selecting the Study Area……………………………………………………………….. 2
Significance of Research……………………………………………………………….. 3
Dissertation Structure………………………………………………………………….... 4

2. ENVIRONMENTAL SETTING OF THE OZARK PLATEAU……………………… 5
Alluvial Landforms in River Valleys…………………………………………………... 6
Modern Setting…………………………………………………………………………. 7
Climate………………………………………………………………………………... 7
Vegetation…………………………………………………………………………….. 8
Soils…………………………………………………………………………………... 9
Quaternary Geology…………………………………………………………………… 10
Late-Quaternary Paleoenvironment…………………………………………………… 16
Late-Quaternary Landscape Evolution in the Current River Valley…………………... 22
Terrace Classification and Sequencing……………………………………………….. 23
Landform-Archaeological Site Relationships………………………………………… 30
Effects of Historic Logging on the Current River Valley……………………….…..... 33
Remodeling Late-Quaternary Landscape Evolution in the Current River Valley……... 34
Summary……………………………………………………………………………….. 36

3. ARCHAEOLOGICAL HISTORY OF THE OZARK PLATEAU………..................... 37
History of Human Occupation on the Ozark Plateau………………………………….. 38
Pre-Clovis…………………………………………………………………………….. 38
Paleoindian……………………………………………………………………………. 47
Early Paleoindian (Clovis)…………………………………………………… 47
Middle Paleoindian (Folsom)………………………………………………… 54
Late Paleoindian (Dalton)…………………………………………………….. 54
Archaic………………………………………………………………………………... 58
Early Archaic………………………………………………………………… 59
Middle Archaic……………………………………………………………….. 59
Late Archaic………………………………………………………………….... 60
Woodland……………………………………………………………………………... 63

Early Woodland…… 64
Middle Woodland…… 65
Late Woodland…… 67
Mississippian…… 68
Emergent/Early Mississippian…… 70
Middle and Late Mississippian…… 72
Oneota…… 73
Historic Period…… 74
Historic Native Americans…… 74
Historic Euroamericans…… 75
Summary…… 76

4. METHODS…… 78
Field Methods…… 78
Laboratory Methods…… 79
Horizon Development Indices…… 79
Stable Carbon Isotope ($\delta^{13}C$) Analysis…… 80
Particle Size Analysis…… 82
Optically Stimulated Luminescence Dating…… 82
Radiocarbon Dating…… 83

5. ALLUVIAL STRATIGRAPHY, CHEMOSTRATIGRAPHY, AND GEOCHRONOLOGY OF VALLEY FILLS IN THE CURRENT RIVER VALLEY…… 84
Alluvial Stratigraphy…… 84
Stable Carbon Isotopes…… 86
Geochronology…… 89
T-1 Terraces…… 92
Round Spring…… 92
T-2 Terraces…… 99
Akers Ferry…… 99
Pulltite…… 107
Round Spring…… 113
T-3 Terraces…… 119
Ramsey Field…… 119
Pin Oak…… 127
Alluvial Fans…… 134
Chubb Hollow…… 134
Creek Fills…… 141
Gladden Creek…… 141
Summary…… 147

6. LATE-QUATERNARY LANDSCAPE EVOLUTION AND GEOLOGIC POTENTIAL FOR CULTURAL DEPOSITS IN THE CURRENT RIVER VALLEY…… 148
Late-Quaternary Landscape Evolution in the Current River Valley…… 148
Alluvial Stratigraphy and Chronology…… 148

Stable Carbon Isotopes………………………………………………………….. 155
Geoarchaeology in the Current River Valley……………………………………...156
T-1 Fill……………………………………………………………………... 156
T-2 Fill……………………………………………………………………... 157
T-3 Fill……………………………………………………………………... 159
Alluvial Fan Deposit……………………………………………………….. 160
Geologic Preservation Potentials for Cultural Deposits…...……………………..... 161
Summary…………………………………………………………………….. 163

7. CONCLUSION……………………………………………………………….....165
Landscape Evolution and Pre-Clovis Potential in the Ozarks…………………………. 165
Contributions and Relevancy……………………………………………………... 167
Recommendations for Future Work……………………………………………….169

REFERENCES CITED……………………………………………………………….171

APPENDIX A. SOIL CORE DESCRIPTIONS……………………………………………..202
Akers Ferry Locality………………………………………………………………203
Gladden Creek Locality…………………………………………………………... 204
Pulltite Locality…………………………………………………………………205
Round Spring T-1 Locality……………………………………………………….. 206
Round Spring T-2 Locality……………………………………………………….. 207
Ramsey Field Locality……………………………………………………………208
Pin Oak Locality………………………………………………………………….. 210
Chubb Hollow Locality…………………………………………………………212

APPENDIX B. PARTICLE-SIZE DISRIBUTION RESULTS……………………………..214

APPENDIX C. STABLE CARBON ISOTOPE RESULTS………………………………...218

APPENDIX D. OPTICALLY STIMULATED LUMINESCENCE RESULTS…………….234

LIST OF TABLES

Table

2.1 Radiocarbon, optically stimulated luminescence (OSL), and archaeological age comparison for Current River valley landform sediment assemblage…………………. 24

3.1 Pre-Clovis sites and their ages, issues with acceptance, and references……………….. 44

4.1 Quantification of horizon properties for calculating horizon morphology index (HDI) values………………………………………………………………... 80

5.1 Radiocarbon age for the buried paleosol at the Round Spring T-1 locality……………. 93

6.1 Geologic preservation potentials for buried archaeological sites in the Current River valley……………………………………………………………………..161

LIST OF FIGURES

Figure

2.1 Location of Current River and Ozark National Scenic Riverways, southeast Missouri.. 5

2.2 Physiographic Regions of North America…………………………………………... 11

2.3 Physiographic subdivisions of the Ozark Plateau……………………………………… 14

2.4 Geologic map of Missouri……………………………………………………………... 15

2.5 Reconstruction of dominant paleo air masses in eastern North America………....... 17

2.6 Selected cross sections of landforms in the Current River valley……………………... 26

2.7 Model of terrace formation…………………………………………………………….. 28

2.8 Quaternary climate, vegetation, and cultural sequences for the Current River valley…………………………………………………………………………………... 29

2.9 Landform-archaeological site occurrences…………………………………………….. 31

2.10 Cross-section of the Current River valley at the 23CT351 archaeological site location……………………………………………………………………………….. 34

3.1a Hypothesized migration route through the Ice-Free Corridor…………………………. 41

3.1b Hypothesized coastal migration route…………………………………………………. 42

3.2 Pre-Clovis sites mentioned in the text…………………………………………………. 43

3.3 Artifacts of the Buttermilk Creek complex from the Debra L. Friedkin site in southeast Texas……………………………………………………………………. 46

3.4 Number of Clovis projectile points known from Ozark NSR………………………….. 53

3.5 Archaeological sites in Ozark NSR with a Dalton component………………………… 57

3.6 Archaeological sites in Ozark NSR with a Late Archaic component………………….. 62

5.1 Map of the study localities……………………………………………………………... 85

5.2 Topographic map of the Round Spring T-1 locality…………………………………… 94

5.3a Round Spring T-1 locality. View southeast………………………………………… 95

5.3b Round Spring T-1 locality. View east………………………………………………. 95

5.4 Round Spring T-1 soil profile……………………………………………………….. 96

5.5 Round Spring T-1 HDI……………………………………………………………… 97

5.6 δ^{13}C and PSD depth functions from the T-1 at Round Spring…………………………. 98

5.7 Topographic map of the Akers Ferry locality…………………………………………..102

5.8 Akers Ferry T-2 locality. View west…………………………………………………...103

5.9 Akers Ferry T-2 soil profile………………………………………………………… 104

5.10 Akers Ferry T-2 HDI……………………………………………………………... 105

5.11 δ^{13}C and PSD depth functions from the T-2 at Akers Ferry…………………………… 106

5.12 Topographic map of the Pulltite locality………………………………………………. 108

5.13 Pulltite T-2 locality. View west…………………………………………………….. 109

5.14 Pulltite T-2 soil profile…………………………………………………………………110

5.15 Pulltite T-2 HDI……………………………………………………………………….. 111

5.16 δ^{13}C depth function from the T-2 at Pulltite…………………………………………… 112

5.17 Topographic map of the Round Spring T-2 locality…………………………………… 114

5.18a Round Spring T-2 locality. View south……………………………………………….. 115

5.18b Round Spring T-2 locality. View north……………………………………………….. 115

5.19 Round Spring T-2 soil profile………………………………………………………….. 116

5.20 Round Spring T-2 HDI……………………………………………………………… 117

5.21 δ^{13}C depth function from the T-2 at Round Spring……………………………………. 118

5.22 Topographic map of the Ramsey Field locality………………………………………...122

5.23 Ramsey T-3 locality……………………………………………………………………123

5.24 Ramsey T-3 soil profile………………………………………………………………... 124

5.25 Ramsey T-3 HDI…………………………………………………………………..125

5.26 $\delta^{13}C$ and PSD depth functions from the T-3 at Ramsey Field…………………………. 126

5.27 Topographic map of the Pin Oak locality……………………………………………… 129

5.28 Pin Oak T-3 locality. View is northeast……………………………………………..130

5.29 Pin Oak T-3 soil profile………………………………………………………………... 131

5.30 Pin Oak T-3 HDI…………………………………………………………………..132

5.31 $\delta^{13}C$ and PSD depth functions from the T-3 at Pin Oak……………………………….. 133

5.32 Topographic map of the Chubb Hollow locality………………………………………. 136

5.33a Chubb Hollow alluvial fan locality. View southwest…………………………………. 137

5.33b Chubb Hollow alluvial fan locality. View southwest…………………………………. 137

5.34 Chubb Hollow alluvial fan soil profile………………………………………………… 138

5.35 Chubb Hollow alluvial fan HDI……………………………………………………...139

5.36 $\delta^{13}C$ and PSD depth functions from the alluvial fan at Chubb Hollow………………... 140

5.37 Topographic map of the Gladden Creek locality……………………………………….142

5.38 Gladden Creek fill locality. View is northeast…………………………………………143

5.39 Gladden Creek soil profile……………………………………………………………... 144

5.40 Gladden Creek HDI……………………………………………………………………. 145

5.41 $\delta^{13}C$ depth function from Gladden Creek……………………………………………… 146

6.1 Locality stratigraphy and OSL ages organized by landform…………………………... 150

6.2 Conceptualization of terrace sequence with T-2 at Akers Ferry as fill strath terrace…. 151

CHAPTER 1

INTRODUCTION

Archaeological work on the Ozark Plateau has revealed a rich record of Paleoindian through historic human occupation (Banks 1978; Chapman 1975, 1980; Fowke 1922, 1928; Lynott et al. 2006; Morse and Morse 1983; O'Brien and Wood 1998; Wood and McMillan 1976), and at least one site may have a pre-Clovis component (Ray et al. 2000). In the last few years, the University of Kansas, ODYSSEY Archaeological Research Fund has supported geoarchaeological investigations at a site in the Current River valley with the goal of locating pre-Clovis deposits (Mandel 2009; Ray and Mandel 2010). The research presented in this dissertation was designed to supplement ODYSSEY's work.

In this dissertation, I determined the geologic potential for cultural deposits in alluvial landform sediment assemblages (LSA) throughout the Current River valley. My study is limited to the segment of the river valley contained within Ozark National Scenic Riverways (NSR), a unit of the National Park Service. I focused on landscape evolution during the late Pleistocene through Holocene, expanding on Roger Saucier's (n.d., 1983, 1987, 1996) work on this topic. My study involved determining the alluvial stratigraphy, chemostratigraphy, and geochronology of late-Quaternary terrace fills and alluvial fan deposits. In combination, these quantitative datasets indicate where cultural deposits may occur in the river valley.

Statement of Problem and Research Objectives

As stated above, the primary goal of this investigation was to identify the geologic potential for archaeological deposits in alluvial LSAs in the Current River valley. I used alluvial stratigraphy and particle-size distribution data to investigate late-Quaternary landscape evolution.

I also reevaluated the terrace sequence and model of landscape evolution proposed by Saucier (1987). Using optically stimulated luminescence (OSL) dating, I determined the numerical ages of late-Quaternary valley fills.

Selecting the Study Area

The Ozark Plateau is one of the oldest exposed landmasses in the world and has been left relatively undisturbed during the multiple glaciation events that covered portions of North America. Paleoenvironmental and paleontological studies conducted in the Central Mississippi Valley and on the Ozark Plateau have shed light on the bioclimatic history of the region (Delcourt and Delcourt 1984, 1994, 1999; Denniston et al. 2000; Haj 2007; Haynes 1985; Jones 2010; Kay 1982; King 1973, 1981; McMillan and Klippel 1981; Mehringer et al. 1968, 1970; Parmalee et al. 1969; Parmalee and Oesch 1972; Saunders 1977; Wood 1976) and archaeological investigations have proved the Plateau has supported human occupation for at least the last 11,000 ^{14}C yr B.P. years, and perhaps longer (Cannon et al. 2010; Lynott et al. 2006; Ray et al. 2000; O'Brien and Wood 1998). Data collected from these investigations provides the basis for development of a regional culture-historical framework that spans the prehistoric and historic past.

In the Current River valley, previous archaeological investigations suggest that springs, terrace fills in stream valleys, alluvial and co-alluvial fans at the mouths of tributary streams, colluvial aprons on footslopes and toeslopes, and the areas in front of caves and rockshelters are perhaps the best localities to look for archaeological materials. The potential for cultural deposits is greatest near perennial water sources, the confluences of rivers, places where the uplands can be easily accessed, and at other localities important to the continent's early occupants such as lithic resources.

My dissertation focused on identifying the geologic potential for cultural deposits in stream terraces and alluvial fan deposits. While it is important to consider the distance between these deposits and the landscape features mentioned above, I did not factor these data into my analysis. They may, however, aid future archaeological research to identify patterns in land use and human behavior.

Significance of Research

The research presented in this dissertation is significant for at least four reasons. First, it refines and clarifies landscape evolution investigations conducted by Roger Saucier in the 1980s and 1990s. Saucier devised a model for late-Quaternary landscape evolution based on macro-scale observations of terrace fills. My dissertation presents spatio-temporal patterns of landscape evolution, a numerical chronology for terrace fills and alluvial fan deposits, and characterizes the physical properties of those fills. Second, it characterizes alluvial stratigraphy and chronology in the study area. Third, it is only the second study of its kind conducted in the Current River valley and the first to use multiple proxies to assess landscape evolution and extrapolate these data to shed light on the archaeological record. Fourth, and most important toward answering the main question posed in this dissertation, it presents a model of geologic potential for cultural deposits in the Current River valley. The data presented in this dissertation add significantly to archaeological investigations on the Ozark Plateau.

Dissertation Structure

An environmental history of the Ozark Plateau including Quaternary geology, climate, and vegetation change, is presented in Chapter 2. Chapter 3 includes a review of the history of human occupation on the Ozark Plateau. Chapter 4 is an overview of field and laboratory methods used in the study, including stable carbon isotope analysis, particle-size analysis, horizon development indices, optically stimulated luminescence dating, and radiocarbon dating.

Background on the analytical techniques and the results of alluvial stratigraphy, chemostratigraphy, and geochronology analyses at each study site is presented in Chapter 5. In Chapter 6, I consider how the data presented in Chapter 5 allow me to revise previous models of landscape evolution in the Current River valley. I discuss the geologic potential for cultural deposits in LSAs and correlate these data with information from previous archaeological investigations. Chapter 7 is a review of the findings presented in Chapter 6 and discussion of the contributions and relevancy of the dissertation and recommendations for future work.

Appendix A contains soil descriptions from each of the eight localities included in this study. Appendix B presents the results of particle-size distribution analysis. The results of stable carbon isotope analysis are presented in Appendix C. Optically stimulated luminescence ages are provided in Appendix D.

CHAPTER 2

ENVIRONMENTAL SETTING OF THE OZARK PLATEAU

The Ozark Plateau is a complex landscape with a rich and diverse environment (Figure 2.1). Because the goal of this dissertation is to understand late-Quaternary landscape evolution in the Current River valley and to determine the potential for cultural deposits in Ozark NSR, understanding the valley's physical environment is important. The environmental and archaeological records detail physical and social changes in the study area throughout the late Quaternary and together illustrate the Current River valley's history.

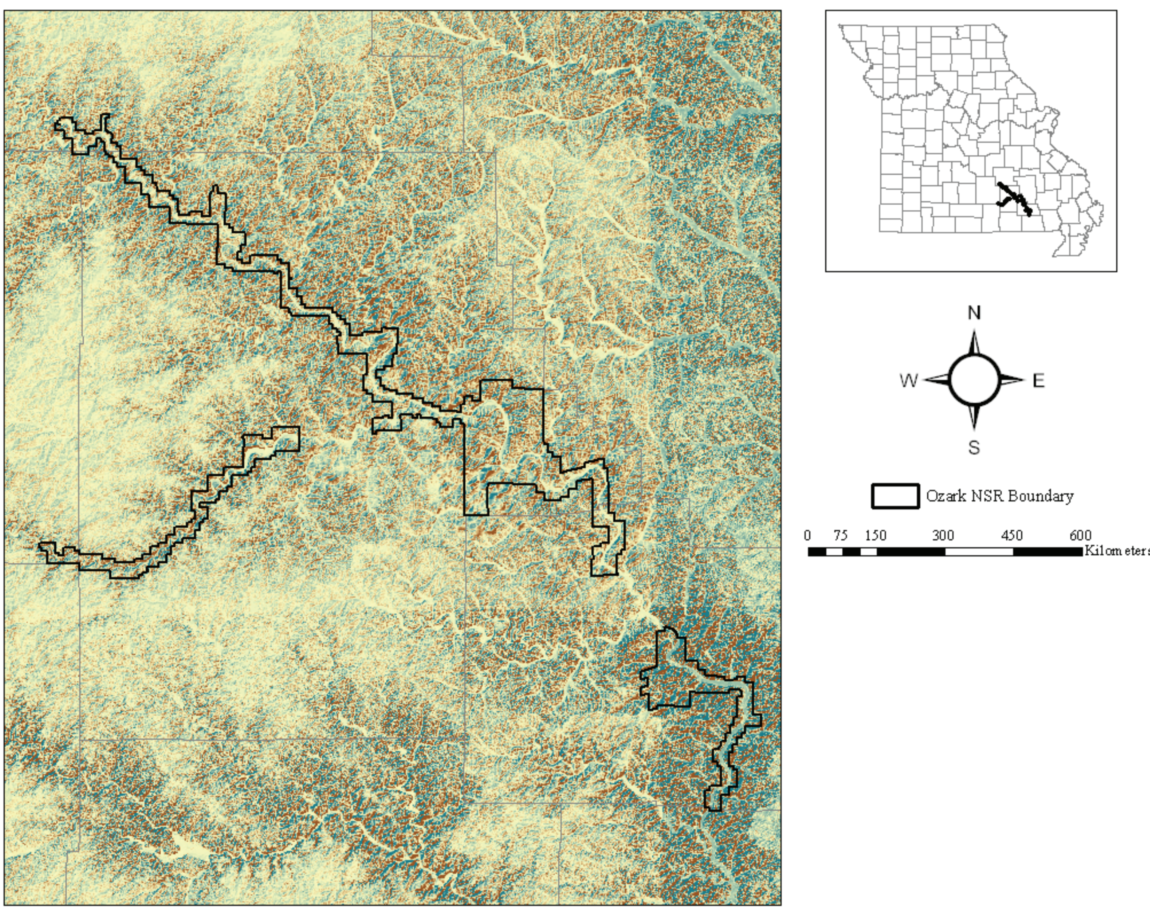

Figure 2.1. Location of Current River and Ozark National Scenic Riverways, southeast Missouri.

In this chapter, I first describe alluvial landforms in the Current River valley. Then, I review the valley's physiography and geology. Next, I describe the climate and vegetation patterns from the late Pleistocene through the Holocene. I also examine the terrace sequence and model of late-Quaternary landscape evolution proposed by the late Dr. Roger Saucier, a geomorphologist who spent many years working in southeast Missouri. A thorough study of the Current River valley's physical history is necessary to update its geomorphological history and understand how and why prehistoric and historic populations occupied the region.

Alluvial Landforms in River Valleys

An alluvial terrace is a former floodplain, a bench of fluvial deposits located between the stream channel and valley wall (Selby 1985:286). Floodplains are formed as streams deposit sediment near the edges of the channel. Eventually, a stream downcuts or moves laterally, leaving the floodplain elevated and subject to aggradation only occasionally when the stream floods. Cycles of cutting and filling, or incision and infilling, occur due to changes in stream load, discharge, stream base level, and climate change. A larger sediment load than the stream can transport, due to upland erosion for example, results in terrace aggradation (Selby 1985). Conversely, terrace incision occurs when stream compentency—its ability to transport sediment—is improved. Terraces may be either paired or unpaired. Paired terraces are formed when downcutting is the predominant method of incision (Selby 1985). Lateral cutting results in unpaired terraces, as is the case in the Current River valley. In some river valleys, terraces converge downstream.

Terrace surfaces are usually flat and scarps separate different terraces. Terraces may be either continuous or discontinuous in a river valley. Younger terraces are usually continuous and older terraces are often more eroded and therefore discontinuous. Often, terrace sequences are incomplete due to variability in cutting and filling (Selby 1985).

Alluvial fans are features shaped like partial cones that radiate away from a single point (Ritter et al. 2002). They form at the mouths of tributary streams and are comprised of sediments eroded from the uplands. Sediments in alluvial fans are well-sorted, fine upwards, and stratified. Paticles are often well-rounded. Fanhead entrenchment reduces sedimentation on fans, ceasing aggradation. This can be caused by an internal geomorphic control, climate change, base-level change, or reduction in the volume of sediment from the source.

Modern Setting

The Current River is located in southeast Missouri. It is a seventh-order stream where it joins the Black River, which flows into the White River, one of the largest drainage systems in the region (Vogele 1990). The White River than drains into the Mississippi River. The headwaters of the Current River occur at the northern end of Ozark NSR. Tributaries and perennial spring activity contribute a significant amount of water to the system. Even so, seasonal effective precipitation causes the water level to fluctuate dramatically, especially during the summer months.

Climate

The Current River valley, like the rest of the Ozark Plateau, has a continental climate with hot, relatively wet summers and mild, dry winters. According to Sauer (1968), the region's topographic relief is not enough to influence climatic conditions. Therefore, the climate is controlled by the region's position in the mid-latitudes. The region is classified as a warm-summer subtype of the temperate humid climate (Trewartha and Horn 1980). The mean annual rainfall at Van Buren, Missouri is 122 cm (High Plains Regional Climate Center 2012). Most precipitation occurs between April and September. The average January and July temperatures at Van Buren are -0.7˚C and 25˚C, respectively (High Plains Regional Climate Center 2012).

Prevailing winds are from the south and/or southeast. Wind activity is mostly cyclonic, creating variable weather (Sauer 1968). Modern droughts are driven by La Nina conditions, which lower tropical SST temperatures in the eastern Pacific Ocean (Seager 2007) and tend to last approximately a decade (Cook et al. 2007). Late Holocene droughts were multi-decadal (Cook et al. 2007).

In south-central North America, mima mounds indicate multi-decadal megadroughts during the middle and late Holocene (Siefert et al. 2009) and are correlated with droughts in the Great Plains. Given the spatial extent of these mounds, mid-late Holocene droughts were stronger and lasted longer than historic droughts. Middle Holocene droughts have also been recorded on the Ozark Plateau (Delcourt et al. 1997; King and Allen 1977; McMillan 1976; Smith 1984).

Vegetation

Modern vegetation on the Ozark Plateau is quite diverse. Microenvironments determine the specific vegetation types that occur within various topographic settings (Huber and Rapp 1983). The primary vegetation regime is oak-hickory forest interrupted by prairies, cedar glades, and oak savanna. It is part of the oak-hickory climax association of the Carolinian biotic province in eastern North America (Dice 1943). This climax association represents trees with low moisture needs. Prior to historic logging, oak species were co-dominant with shortleaf pine

(Braun 1950). Steyermark (1940) divides the oak-hickory forest into five edaphic associations: 1) sugar maple – bitternut hickory, 2) sugar maple – white oak, 3) oak – hickory, 4) oak – pine, and 5) white oak – red maple.

Upland and lowland hardwood deciduous forests are markedly different from one another. Upland forests are almost solely comprised of oak (*Quercus*), including white (*Q. alba*), black (*Q. velutina*), and blackjack (*Q. marilandica*) subspecies. Sauer (1968) notes that this region constitutes one of the largest unmixed oak forests in North America. Lowland forests are more mixed, containing bur oak (*Q. macrocarpa*), butternut (*Juglans cinerea*), cottonwood (*Populus deltoides*), hackberry (*Celtis occidentalis*), tulip tree (*Liriodendron tulipifera*), sugar maple (*Acer saccharum*), sycamore (*Plantanus occidentalis*), water maple (*Acer saccharinum*), walnut (*Juglans nigra*), and many other varieties (Sauer 1968:58).

Increased regional settlement and the cessation of logging had a dramatic effect on the region's ecology. As timber stands grew back, they were more dense and had thicker undergrowth. A focus on cultivation on stream terraces decreased the extent of lowland forests. In general, species that easily propagate, such as oak (*Quercus*), elm (*Ulmus*), sycamore (*Plantanus*), and cottonwood (*Populus*), spread across the region.

<u>Soils</u>

Surface soils in the Current River valley are derived primarily from residual gravels or bedrock, alluvial, and colluvial parent materials. Residual soils are usually formed from weathered dolomites and other bedrock material, on upland ridges and hillslopes. As such, upland soils tend to be cherty and shallow with clay or clay loam textures (Sauer 1968). Deposits of interbedded sand and gravel line the trunk and tributary streambeds (Bridge 1930).

These soils tend to be thick and organic rich, making them especially good for agricultural purposes.

Soil temperature is generally mesic and soil moisture is either udic, aquic, ustic, or xeric. Ultisols tend to form in forested environments and are the most prevalent soil order in the Current River valley. Alfisols, Entisols, and Inceptisols are also present in the study area. These orders form in stream valleys and on hillslopes. Mollisols, formed on floodplains and stream terraces, comprise a small percentage of mapped soil orders in the study area. In this dissertation, individual soil series representing alluvial soils will not be considered. Mapping units presented in the soil surveys for Dent, Shannon, and Carter counties are generalized and do not accurately reflect the soils developed at individual localities. For example, soils at Gladden Creek, a creek floodplain locality, and Pin Oak, a T-3 locality, are both mapped as Wideman although these are distinctly different landforms with different soil morphologies.

Quaternary Geology

The Ozark Plateau is a large physiographic region that extends across Illinois, Missouri, Arkansas, Oklahoma, and Kansas. The only highland region between the Appalachian and Rocky mountain ranges, the Ozarks, along with the Ouachita Mountains to the southwest, comprise the Interior Highlands (Madole et al. 1991; Thornbury 1965) (Figure 2.2). Fenneman (1938) describes the Ozarks as an elongated dome stretching northeast-southwest from the Mississippi River, west to northern Arkansas and into northwestern Oklahoma. The dome is formed by uplifted igneous rocks that dip away from the apex toward the edges of the formation (Sauer 1968). Rocks of progressively younger age outcrop toward the dome's flanks (Klinger and Kandare 1987). During at least the last two million years, episodic uplift and erosion, along with attendant river entrenchment to equalize base level, have dissected the dome and created two strath terraces in the river valleys (Bretz 1965). These successive uplifts and subsequent erosion have shaped the province, creating a cuesta environment.

Running east-west across the Ozark Plateau is the Ozarks Divide. Rivers on the north side of the divide flow into the Missouri River. Rivers on the south side flow into the White and Arkansas rivers.

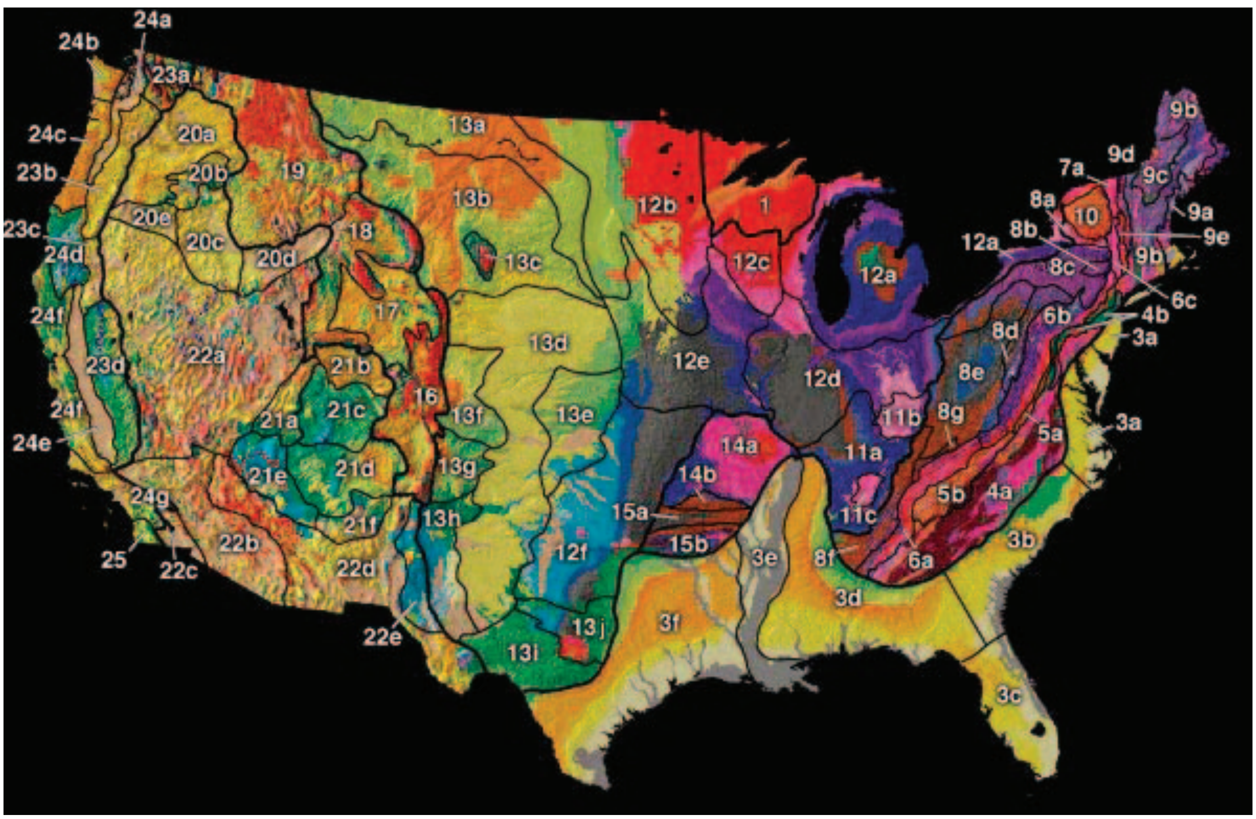

Figure 2.2. Physiographic Regions of North America. Area 14a includes the Springfield and Salem plateaus and area 14b is the Boston Mountains. (USGS, http://tapestry.usgs.gov/physiogr/physio.html, after Fenneman (1946)).

The exact age of the Ozark Plateau's geology and its evolutionary history is uncertain. According to Madole et al. (1991), Thornbury (1965), and McCracken (1971), regional uplift did not begin until approximately 65 million years ago, at the beginning of the Tertiary Period.

Others believe that the region was uplifted and exposed to erosion and weathering since the end of the Pennsylvanian Period, 300-280 million years ago, forming a peneplain (Bretz 1965; Unklesbay and Vineyard (1992). With peneplanation, a concept devised by Davis (1899), surficial erosion wears down a landscape to base level. This is a controversial concept (Phillips 2002) and King (1953) and Tarr (1898) argue that 1) modern peneplains have not been identified in the geologic record, and 2) extant erosion surfaces were created by processes other than base level equifinality (see Phillips 2002 for a discussion of the peneplain debate and possible explanations for the absence of peneplains). Rhoads and Thorn (1996) maintain that peneplanation is only a theoretical concept with little application to the physical environment. For the purposes of this dissertation, I consider the Ozark Dome simply an erosional surface.

The Current River valley is situated in the Salem Plateau physiographic subregion (Figure 2.3). The Salem Plateau has a heavily dissected surface, due partly to the steep slope of the southern side of the Ozark dome, where the stream channels have incised and migrated sufficiently to form deep, bedrock-lined valleys (Klinger and Kandare 1987). Given its steep, narrow ridges, the Salem Plateau is less navigable than the rest of the Ozarks, especially in the vicinity of the Current River valley (Sauer 1968).

Several other physiographic subregions are present on the Plateau. The St. Francois Mountains are the area's highest elevation and are located at the center of the Ozark Plateau. Three topographic highs—the Salem and Springfield plateaus and Boston Mountains—emanate away from the St. Francois Mountains. The Shawneetown ridge is located toward the southwestern edge of the region, where it merges with the Ouachita Mountains of northwestern Arkansas.

The Salem Plateau is underlain by dolomite and limestone bedrock that is Ordovician and older in age (Thornbury 1965) (Figure 2.4). These rock units contain quartz and chert and outcrop sporadically across the research area, providing a source of lithic material for stone tool production. Some outcrops of Precambrian rhyolite are also exposed (Vineyard 1967; Klinger and Kandare 1987; Price 1983). The geomorphology of the Salem Plateau is strongly controlled by the Cambrian-age Potosi and Eminence dolomites (Anderson 1979). The Potosi formation, found across the Salem Plateau, is a limestone consisting of chert-rich dolomite (Sauer 1968). Sauer noted that the area underlain by Potosi limestone has extremely steep slopes that are not seen elsewhere on the Ozark Plateau. The proximity of the various bedrock formations to the surface affects soil formation as well as the distribution of biological communities and provides excellent raw material sources for lithic manufacture (Klinger and Kandare 1987). A sizeable outcrop of Cambrian-age dolomite exists near the center of the Current River valley (Missouri Department of Conservation 2010).

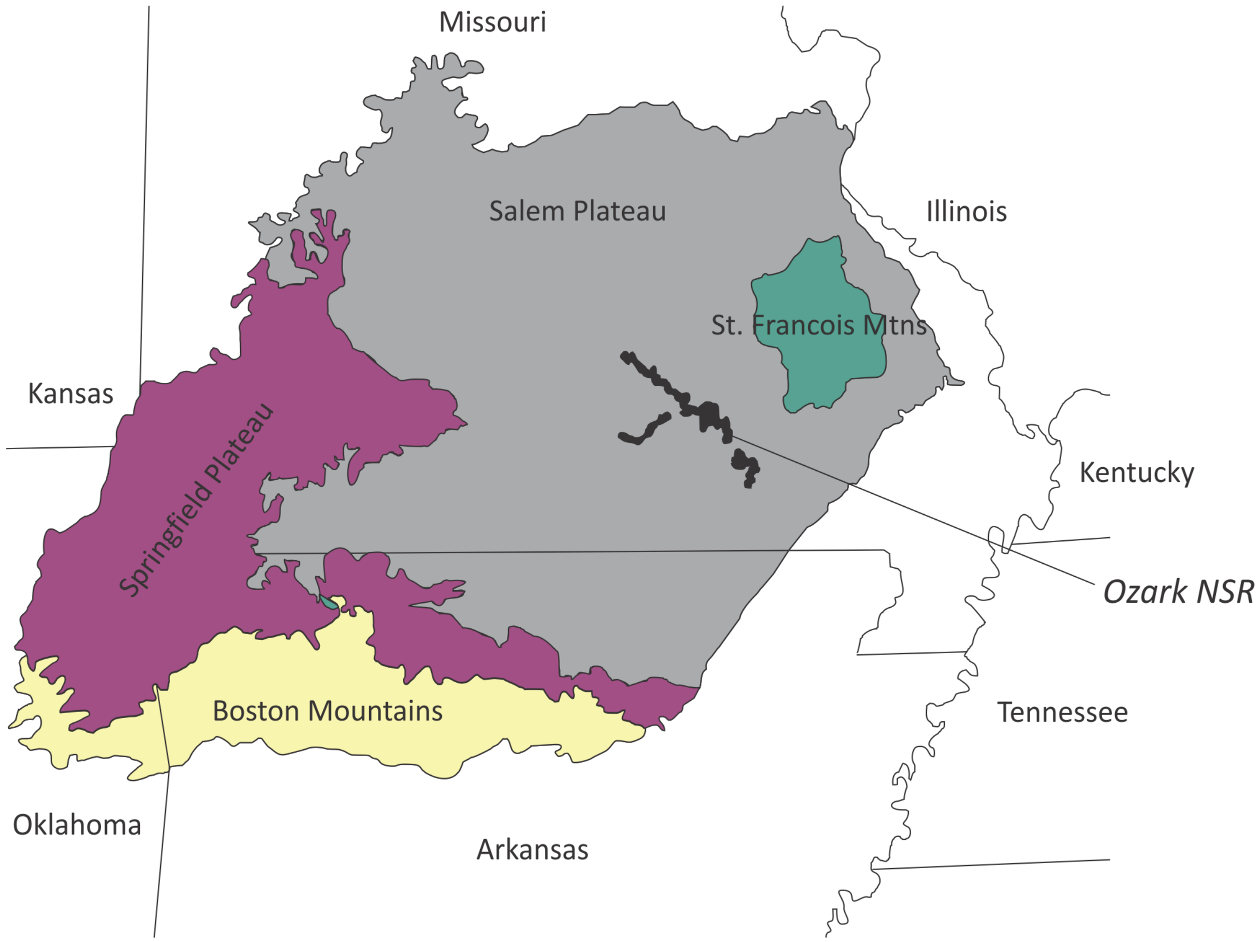

Figure 2.3. Physiographic subdivisions of the Ozark Plateau. The boundary of Ozark NSR is delineated in black.

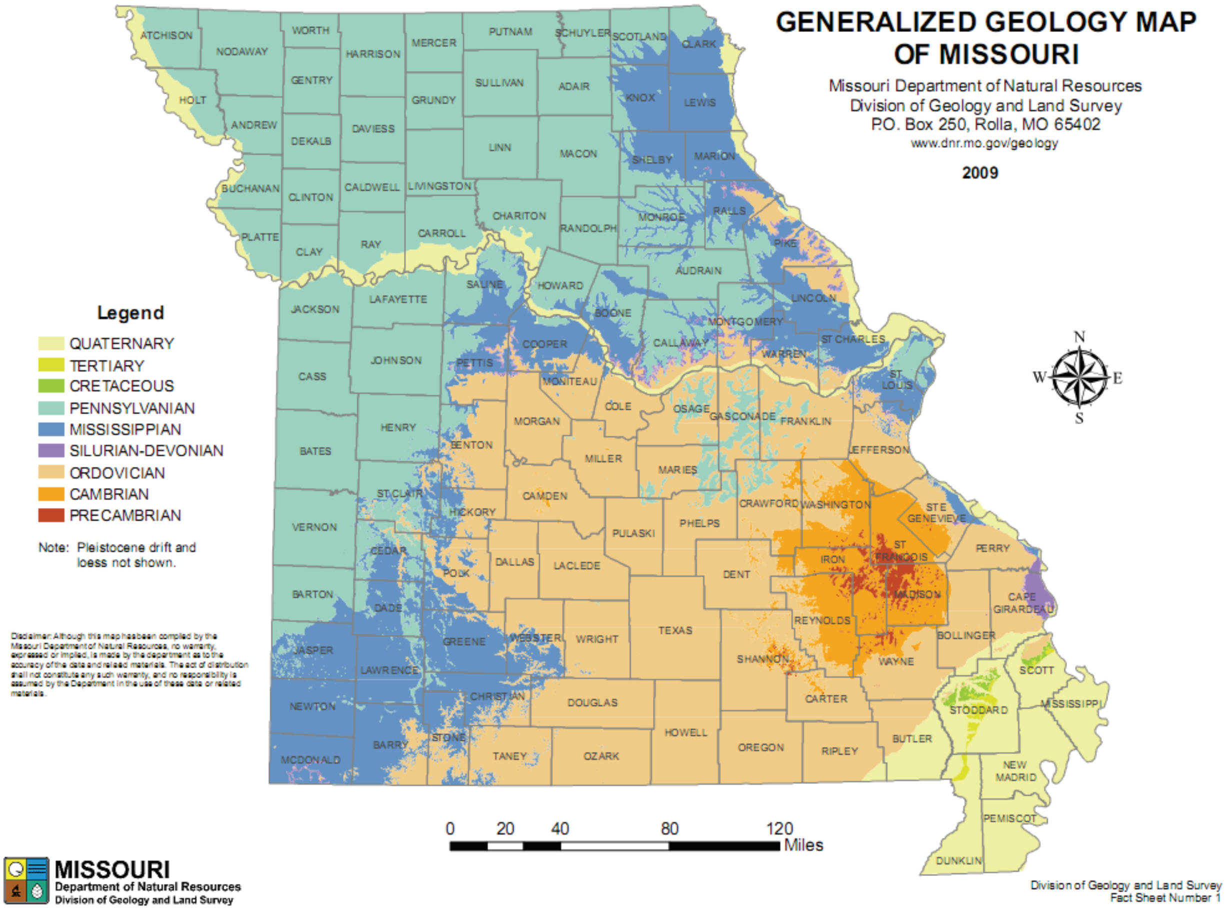

Figure 2.4. Geologic map of Missouri (Missouri DNR, http://dnr.mo.gov/geology/adm/publications/gen_info.htm).

Soils on the Plateau are exceptionally cherty, which had a profound effect on the stream channels:

> The Ozarks contain probably more chert…than any other similar area. Over nine-tenths of the surface, chert is so abundant that it covers the roads, chokes the stream beds, and in many places all but obliterates the soil [Sauer 1968:16].

Erosion of limestone bluffs on outside stream bends has left residual chert exposed on upland slopes (Rafferty 1980). Chert is transported downslope by alluvial and colluvial processes, where it collects in stream valleys. Nodules left in residual upland soils are often angular, given natural breakage patterns, and can be resistant to both mechanical and chemical weathering.

Chert nodules trap and allow sediments to accumulate and in effect armor the soil surface, particularly on steep slopes. Differential erosion on these bedrock materials by water, weather, and mechanical processes affects physiographic relief on the Ozark Plateau.

Karst topography is common on the Salem Plateau. Soluble dolomites and limestones, in combination with a shallow groundwater table and significant quantities of surface water, have contributed to the development of the karstic landscape, including surficial water recharge/discharge features. The dissolution and collapse of bedrock has created aboveground features such as sinkholes and caves of various sizes. These features, in combination with karsts, remove water from stream channels—forming 'losing streams'—and create underground river networks. Water discharge at the surface usually occurs through springs. One of the largest double-orifice springs in the western hemisphere, Big Spring, is contained in Ozark NSR. On the Salem Plateau, karst topography and bedrock solubility strongly influence the evolution of stream valleys (Sauer 1968).

Late-Quaternary Paleoenvironment

Climate and biotic communities changed significantly during the late Pleistocene and early Holocene. Several paleoenvironmental studies specific to the Missouri Ozarks have been conducted (e.g., Delcourt et al. 1997, 1999; Denniston 2000; King and Lindsey 1976; King 1973, 1981; Mehringer et al. 1968, 1970; Parmalee et al. 1969; Royall et al. 1991; Saunders 1977; Smith 1984). Smith (1984) and Jones (2010) reconstructed late-Quaternary climate change from the pollen record at Cupola Pond in Ripley County, Missouri, just south of Ozark NSR. Delcourt and Delcourt (1984) examined late-Quaternary palynological records across eastern North America, including pollen spectra from Boney Springs in west central Missouri. Also, broad patterns of bioclimatic response to changes in airmass position have been established for eastern North America in the late glacial and deglacial periods (e.g., Bartlein et al. 1998; COHMAP Members 1988; Delcourt and Delcourt 1981, 1984; Overpeck et al. 1992; Prentice et al. 1991; Smith 1984).

Boreal forests mostly consisting of spruce and jack/red pine dominated much of eastern North America during the Last Glacial Maximum (LGM) (Delcourt and Delcourt 1981). At that time, with the Arctic Airmass blocked by the Laurentide ice sheet, the Polar Frontal Zone separated the Pacific and Maritime Tropical airmasses. The Polar Frontal Zone extended east-west across lower North America and merged with the Gulf Stream (Delcourt and Delcourt 1984) (Figure 2.5a). The Polar Frontal Zone controlled the position of a mixed deciduous-conifer forest ecotone that separated the more northern boreal forest from the southern temperate deciduous forests.

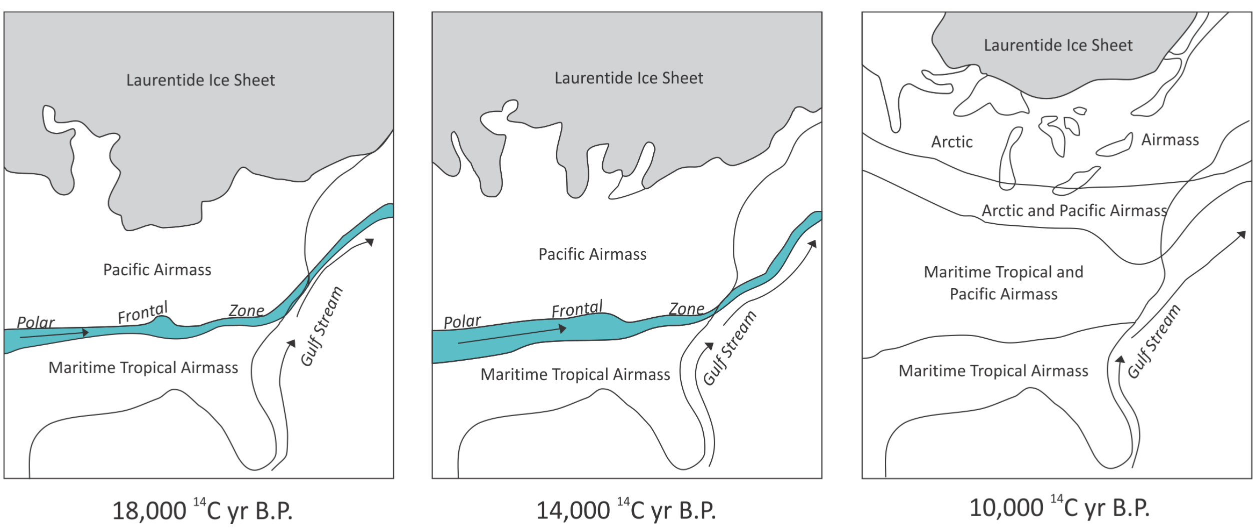

Figure 2.5. Reconstruction of dominant paleo air masses in eastern North America (redrawn from Delcourt and Delcourt 1984:277; with permission of Elsevier).

According to Delcourt et al. (1997, 1999), a boreal forest of spruce (*Picea*) and jack (*Pinus banksiana*) and/or red pine also (*Pinus resinosa*) occupied the Ozark Plateau during the LGM (approximately 24,000 ^{14}C yr B.P.). Heather voles (*Phenacomys Intermedius*) inhabited northern Arkansas and Tennessee at that time (Parmalee et al. 1969; Guilday and Parmalee 1972). The modern southern limit of these small mammals' habitat is the northern border of the United States. At Trolinger, Jones, Kirby, Koch, and Boney springs in western Missouri, King (1973) found that the uppermost portion of middle-Wisconsinan deposits contained a mixed spruce (*Picea*) and deciduous tree pollen assemblage. Mastodon (*Mammut*) dominates the Pleistocene faunal assemblages at these sites, with some musk ox (*Ovibos moschatus*) and horse (*Equus*) represented.

Grüger (1972) interprets the mid-Wisconsinan pollen record from southern Illinois as prairie with stands of oak-hickory (*Quercus-Carya)* forest, indicating a warmer and/or drier climate than suggested by the pollen records at springs on the Ozark Plateau. Northern Illinois, however, was dominated by pine (*Pinus*) and spruce (*Picea*) forest with few deciduous trees. King (1973) argues that the spruce (Picea)/deciduous tree pollen spectra should be interpreted as parkland rather than prairie given the presence of musk ox (*Ovibos moschatus*) in Ozarks springs deposits. Mehringer et al. (1970) encountered an assemblage at Trolinger Spring that contained numerous small boreal mammals like the snowshoe hare (*Lepus americanus*), dating between 32,000 and 25,000 ^{14}C yr B.P. In addition, they recorded a mastodon (*Mammut*)/ground sloth (*Mylodontinae*)/giant beaver (*Castoroides*) assemblage at Boney Spring that dated to 16,500-13,500 ^{14}C yr B.P.

Between 17,000 and 16,000 ^{14}C yr B.P., increased solar radiation weakened zonal atmospheric flow and intensified the Bermuda High Pressure System, which was in place over the central Atlantic Ocean. Subsequently, the Maritime Tropical Airmass shifted northward (Delcourt and Delcourt 1984). Higher temperatures and increased precipitation during the summer months, brought northward by the Maritime Tropical Airmass, activated melting on the southern edge of the Laurentide ice sheet and brought the continent into late glacial conditions (Dremanis 1977). At approximately 16,500 ^{14}C yr B.P., the northern boreal forests were edged out by cool-temperate deciduous species like oak (*Quercus*), ash (*Fraxinus*), and hickory (*Carya*) (Delcourt and Delcourt 1984; Smith 1984). By the time the Laurentide ice sheet started its final retreat at 14,000 ^{14}C yr B.P., the boreal forest began to contract.

By 12,000 ^{14}C yr B.P., the spruce-dominated (*Picea*) forest of the full glacial episode was replaced by a cool-temperate forest of oak (*Quercus*) and ironwood (*Carpinius caroliniana*) trees (Delcourt et al. 1999; Royall et al. 1991). Late glacial vegetation responses in most of eastern North America were immediate and a direct result of the shifting Polar Frontal Zone (Delcourt and Delcourt 1984) (Figure 2.5b). On the western Plateau, a forest-edge environment was in its initial stages of development (King and Lindsey 1976). However, at Trolinger and Boney Springs, King (1973) identified a slight expansion in the spruce (*Picea*) forest at the very end of the Wisconsin, an indication of cooler and wetter conditions, which resulted in a mixed spruce (*Picea*)/deciduous tree pollen profile. This scenario is not replicated in the pollen profile at Muscotah Marsh in northeast Kansas, which has a predominantly spruce (*Picea*) pollen assemblage at the end of the Pleistocene (Grüger 1973). Additionally, Grüger (1972) recorded the presence of a deciduous forest and prairie in southern Illinois at that time. It may be that the presence of a mixed spruce (*Picea*)-deciduous tree forest on the Ozark Plateau during the late Wisconsin is a local phenomenon (King 1973).

At 10,000 ^{14}C yr B.P., the Laurentide ice sheet had continued its northward retreat and the boreal tree taxa migrated with it. The Arctic Airmass descended across the mid-continent of North America, just south of the ice sheet and mixed with the Pacific Airmass (Figure 2.5c). In the midcontinent, where a mesic climate prevailed, the Pacific Airmass controlled deciduous forest distribution in the summer months and the Maritime Tropical Airmass in the winter months (Delcourt and Delcourt 1984; King 1973). The Maritime Tropical Airmass continued to be the sole climatic control on the distribution of warm-temperate tree species in the southeast.

All of eastern North America experienced increased seasonality during the early Holocene. Major changes occurred in the vegetation communities across the Ozark Plateau at that time (Delcourt et al. 1997; 1999). Speleothem records show an increase in C_3 vegetation, which Denniston et al. (2000) attribute to precipitation changes caused by meltwater pulses from glacial Lake Agassiz that lowered sea surface temperatures in the Gulf of Mexico. The oak-ironwood (*Quercus-Carpinus caroliniana*) forests of the Plateau opened up and became an oak-hickory (*Quercus-Carya*) savanna slightly before the onset of the Altithermal (Delcourt et al. 1997, 1999; King and Lindsey 1976; McMillan 1976). Denniston et al. (2000) recorded a negative excursion in speleothem $\delta^{13}C$ values during the early Holocene, which they attribute to the displacement of deciduous forests by oak savanna on the upland slopes above the caves in their sample.

The Altithermal, a dry and warm period that lasted from 9,000-5,000 ^{14}C yr B.P., was caused by a shift to westerly prevailing winds that brought warm, dry air across the Great Plains and into the Eastern Woodlands (Dean et al. 1996; Wright 1976). The Prairie Peninsula, a zone of prairie grasses and forbs, expanded eastward, edging out drought-vulnerable tree species in the area of northern Missouri, Illinois, and Iowa (Delcourt and Delcourt 1984; King 1981; King and Allen 1977; Van Zant 1979). Speleothem records from the Plateau show an increase in steppe environment indicators between 7,500-3,500 ^{14}C yr B.P. (Denniston et al. 2000). Pollen data from Rodgers Shelter (McMillan 1976), Old Field Swamp (King and Allen 1977), Cupola Pond (Smith 1984), and Modoc Rock Shelter (Denniston et al. 1999) support the speleothem records.

The shift toward a savanna community reduced vegetative cover on soils. As aridity increased and uplands and hillsides were denuded of vegetation, erosion occurred. Though effective precipitation decreased considerably during the Altithermal, the frequency and severity of storm systems increased, causing further erosion (Brackenridge 1981; Haynes 1995; Knox 1983; Mandel 2008; McMillan and Klippel 1981). Sediment eroded off the uplands was transported into streams where it accumulated on floodplains and the surfaces of low terraces during high-magnitude floods.

The Ozark climate ameliorated between 6,000 and 4,000 ^{14}C yr B.P. as the Altithermal ended. Effective precipitation increased while mean annual temperatures decreased slightly, allowing mesic conditions and a forest-edge environment to return to the Plateau. Vegetation on the Plateau shifted to an oak-shortleaf pine (*Quercus-Pinus echinata*) forest in the east and an oak-hickory (*Quercus-Carya*) forest in the west (Delcourt et al. 1999). A return to mesic conditions in the last 5,000 years caused the Prairie Peninsula to contract and retreat westward and cool-temperate forests of beech (*Fagus*), white pine (*Pinus strobus*), shortleaf pine (*Pinus echinata),* and tupelo gum (*Nyssa*) became established on the Plateau (Smith 1984). Modern climate zones driven by meridional airflow have been in position since the mid-Holocene (Delcourt and Delcourt 1984).

During the Holocene, the primary control on spring discharge was available water, affected by cycles of climatically-induced precipitation. Though the largest springs likely never experienced appreciable changes in their net discharge, Saucier (n.d.) postulates that small springs and streams went completely dry during warm periods. These smaller features likely reactivated whenever precipitation in the region increased. The periodic cessation of discharge would have affected the distribution of perennial and intermittent stream and, subsequently, prehistoric Native American settlement patterns.

Late-Quaternary Landscape Evolution in the Current River Valley

Prior to Saucier's geomorphological investigations in the Current River valley, researchers had only a limited understanding of the history and evolution of landforms in this portion of the Ozarks. Saucier (1987) noted a paucity of literature on the soils and sediments of the river valley. Hence, his work was among the earliest and most influential geomorphological investigations conducted in the Current River valley. Through multiple studies that have incorporated archaeological data, Saucier constructed a model of landscape evolution. His seminal work is the basis for this dissertation.

In 1987, Saucier contributed to a final report of investigations undertaken between 1984 and 1986 (Price et al. 1987). In this document, Saucier provided a summary of his investigations in the Current River valley, which took place between 1982 and 1986. He also made clear that understanding the geologic and geomorphologic history of the area was integral to understanding the archaeological record. Saucier was the first researcher to call for multidisciplinary investigations in archaeological research in this part of the Plateau. In his view, the Current

River valley's physical and cultural histories could not be understood separately given the close relationship between natural resources and their exploitation by prehistoric people.

Saucier's first task was to identify alluvial landforms and their distribution in the river valley by examining 1:24,000 USGS topographic maps, aerial photographs, historic photographs, sub-surface data from water well boring logs, and cross-valley profile drawings (Saucier 1987). From these sources, he was able to describe a terrace formation sequence and chronology. Saucier also evaluated the relationship between archaeological sites and geomorphic landforms in the context of large-scale water and sediment mobility processes in the river valley. He modeled past stream channel movement, the effects of springs and intermittent streams on the larger river valley, and the effects of nineteenth and twentieth century logging on sediments in the river valley. Although his investigations focused on the portion of the Current River within Ozark NSR, Saucier extended the reach of his study to the Lower Mississippi Valley in order to capture the geomorphology of the entire Current River valley.

Terrace Classification and Sequencing

Saucier identified four terrace surfaces in the Current River valley. While establishing a chronology of terrace fills, he found that radiocarbon and optically stimulated luminescence ages did not corroborate archaeological data. OSL was in its infancy as a dating technique in the mid-1980s and radiocarbon dating of sediments is difficult in the strong leaching environment of the forested Ozark Plateau. Instead, Saucier relied on relative dating from archaeological materials to determine the chronology (Saucier 1987:138) (Table 2.1). Importantly, terraces are unpaired, meaning they do not occur uniformly on both sides of the stream channel. Because the river runs over bedrock, the Current River is not a truly meandering stream; instead, it shifts from side to side within the valley, removing and redepositing whole sediment packages in the process (Saucier 1987).

Table 2.1. Radiocarbon, optically stimulated luminescence (OSL), and archaeological age comparison for Current River valley landform sediment assemblages (after Saucier 1987:139).

Landform	Radiocarbon Ages	OSL Ages	Archaeological Ages
T-2 Terrace	Modern	4,000±700 B.P.	> 10,000 B.P.
	Modern		
	590±140 ^{14}C yr B.P.		
T-3 Terrace	2,175±165 ^{14}C yr B.P.	5,500±900 B.P.	> 12,000 B.P.
	3,415±185 ^{14}C yr B.P.		
	3,510±90 ^{14}C yr B.P.		

The Current River's floodplain is a constantly aggrading surface that sits between 3 and 6 m above the water level (Saucier 1987:110) (Figure 2.6). Floodplain aggradation occurs when the river exceeds its banks and fine sediments are deposited next to the stream channel. Scouring or erosion of the floodplain occurs when floodwaters achieve a high velocity and remove sediments from the stream channel or when the stream channel migrates laterally, removing sediments from the cutbank. Saucier (1987) noted that depositional processes form a natural levee on the floodplain, immediately adjacent the stream channel.

Saucier (1983, 1987) divided the floodplain into two discrete landforms, T-1 and T-0 (Figure 2.6). Because they have similar elevations and morphologies, he considered both the T-1 and T-0 terrace surfaces the modern floodplain. He divided them into separate units to indicate that the T-0 fills are slightly younger than the T-1 fills. The T-0 fills have been aggrading since the mid-nineteenth century, while the T-1 fills began aggrading sometime prior to the Historic period (Saucier 1987:110). The T-1 terraces often contain chutes and swales that formed during flooding, stream channel migration, and bend cutoffs. Saucier (1983:4) identified two distinct floodplains only as a temporal designation to indicate changes in stream sediment load from prehistoric to historic times when vegetation removal caused severe upland erosion. However, including the T-1 terrace in the floodplain has caused confusion in identifying and/or correlating the landform positions of some archaeological sites.

The T-2 terrace makes up approximately 20% of the valley floor and is 3-6 m above the water level (Saucier 1987) (Figure 2.6). Radiocarbon ages indicate that the T-2 terrace fills aggraded during the late Pleistocene and early Holocene, from 15,000-7,000 ^{14}C yr B.P. The upper stratum of the terrace fill is fine-grained, gray-brown silty and sandy clays (Saucier 1983). As the Current River approaches the Lower Mississippi Valley alluvial plain, the T-2 terrace becomes more areally extensive and contains abandoned meander belts. Saucier (1987:113) noted that abandoned channel segments are representative of changes in paleohydrology.

The T-3 terrace fills aggraded between 23,000 and 35,000 ^{14}C yr B.P. during the middle Wisconsin glacial episode (Farmdalian Stage) (Figure 2.6). This terrace often occurs at the mouths of tributary streams and comprises only a small portion of the valley floor (Finney 2006). The T-3 surface is 6-12 m above the water level and is flatter than the other surfaces in the Current River valley (Saucier 1983, 1987). Less overbank deposition has occurred on the T-3 terrace surface because of its position high above the stream channel, but ≥50 year floods inundate the landform. Sediments in the upper stratum of the terrace fill are reddish-brown and lithologically similar to those comprising the T-2 terrace fill. Historically, the T-3 terrace was cultivated and the most intensively used landform in the river valley.

The T-4 terrace is the highest and oldest terrace in the Current River valley (Figure 2.6). The T-4 fills aggraded during the Sangamon Interglacial Stage, prior to 75,000 ^{14}C yr B.P. These terrace fills occur discontinuously throughout the river valley, usually at the mouths of tributary streams. Saucier (1987) identified T-4 at only a few locations between Van Buren and

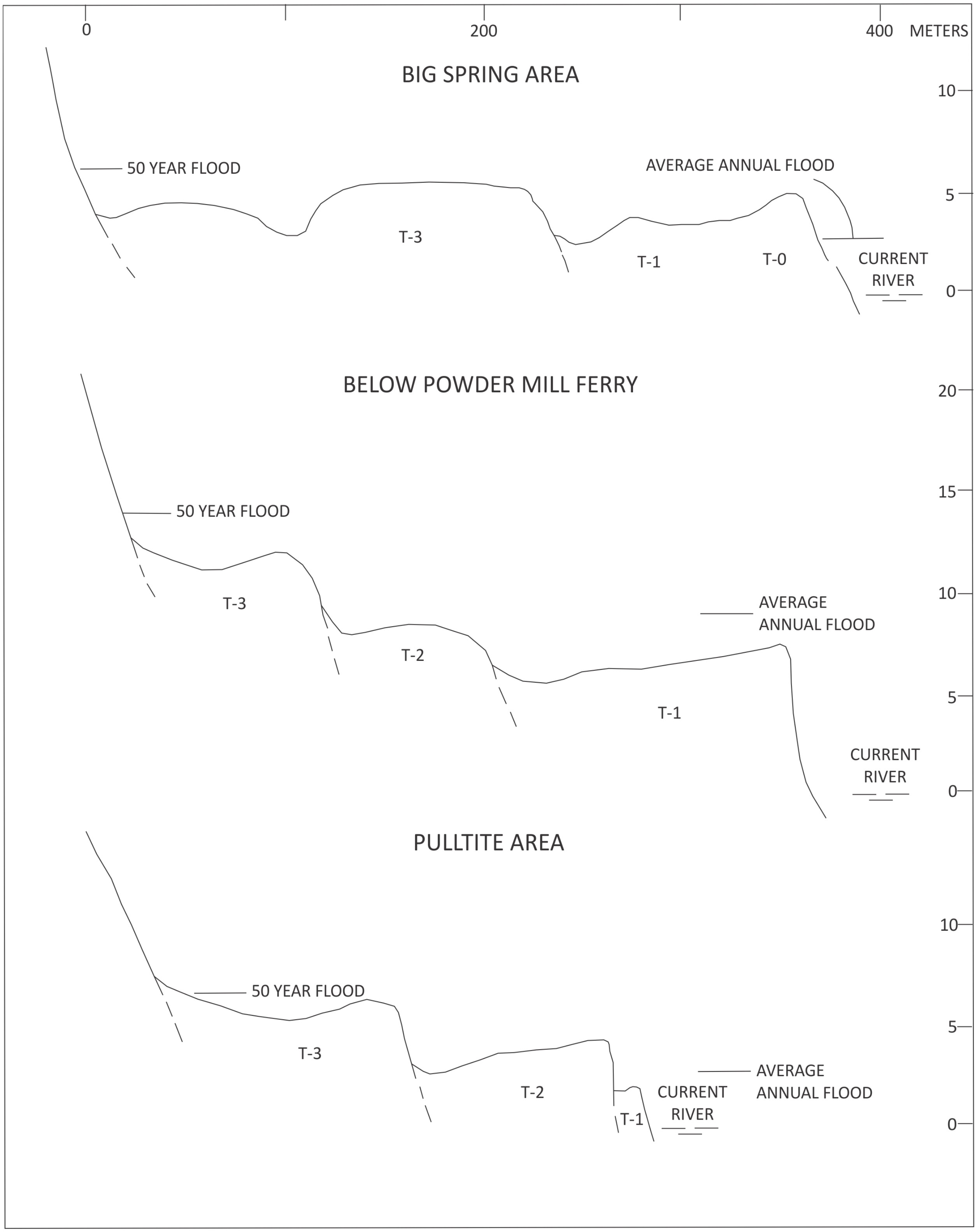

Figure 2.6. Selected cross sections of landforms in the Current River valley (redrawn from Saucier 1987:111).

Doniphan, Missouri. At those localities, the terrace surface is approximately 18 m above the water level. Saucier (1987) combined his landform classification with known late Pleistocene and Holocene climatic events to develop a five-stage model of terrace formation for the Current River. He argued that traditional models of terrace formation, wherein terraces are built during periods of stream channel instability as the result of changes in stream discharge, do not apply to the Current River valley (Saucier 1987:134). Instead, terrace formation here was the result of cycles of increased storminess and flooding.

According to Saucier, T-4 terrace fills aggraded against the valley wall during Stage A (Figure 2.7a). During Stage B, channel instability—the result of elevated precipitation levels and flooding—allowed the floodplain to widen and the channel to cut into older fills, forming a T-3 terrace on Stage A fills Figure 2.7b). Stage C is marked by a return to channel stability, during which the stream downcut, forming a new floodplain and leaving the Stage C floodplain as the T-2 terrace (Figure 2.7c). Another period of channel instability caused Stage D when flood frequency increased and portions of the T-2 and T-3 terrace fills were removed (Figure 2.7d). The onset of modern stream channel conditions signifies Stage E (Figure 2.7e). The stream channel is stable and the T-2 and T-3 terrace surfaces aggrade during major flood events. The T-1 and T-0 terraces tend to be scoured during flooding because of a lack of vegetative cover.

A tenet of Saucier's terrace formation model is that glacial and interglacial cycles cause climatic changes that affect stream channel stability (Figure 2.8). Periods of glacial advance are correlated with periods of stream channel instability and interglacial periods are correlated with stream channel stability. According to Saucier (1987:136),

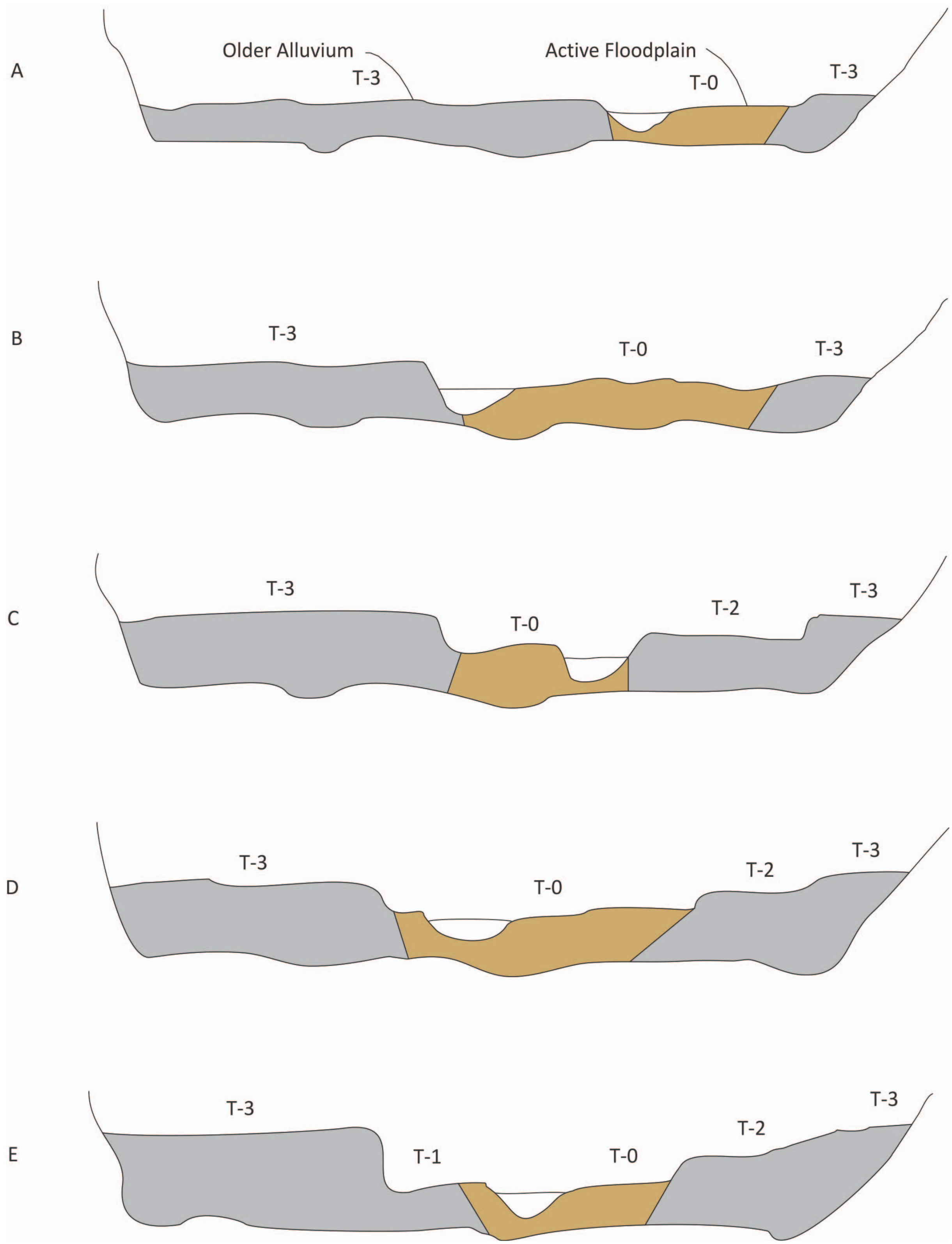

Figure 2.7. Model of terrace formation (redrawn from Saucier 1987:133): A, early stage of landform development; E, last stage of landform development.

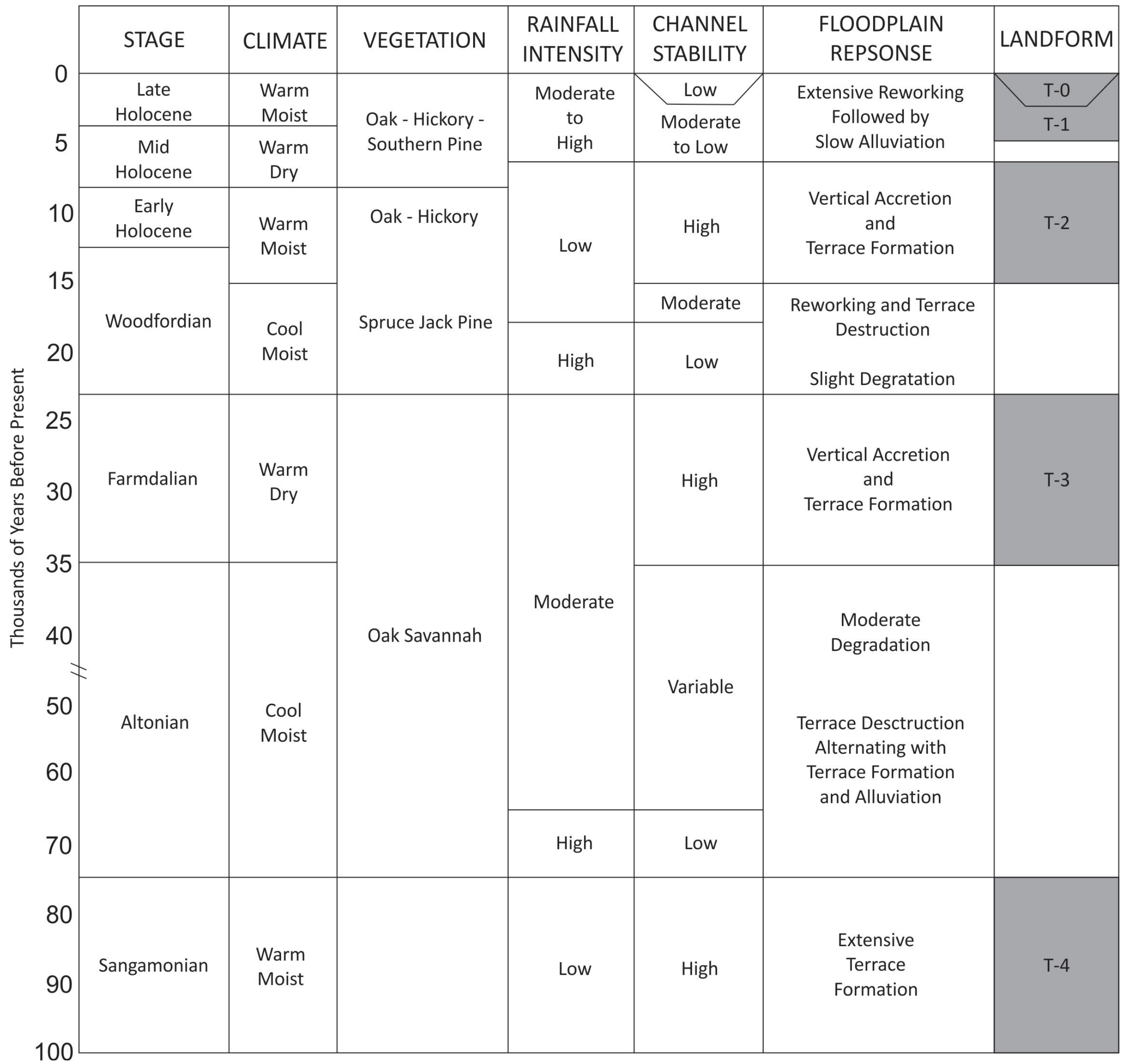

Figure 2.8. Quaternary climate, vegetation, and cultural sequences for the Current River valley (redrawn from Saucier 1987:144).

> “[i]f the periods of stream channel stability and instability are assumed to be caused by climatic changes attributable to glacial/interglacial cycles, it could be argued that there should be remnants of a much larger number of terraces in the valley than there are. The explanation is offered that the stability/instability cycles are correlated with climatic fluctuations within a single glacial/interglacial cycle and that during each glacial interval, the terraces in the valley are completely destroyed.”

Saucier concluded that terraces older than the late Quaternary are not preserved in the active river valley because they were removed during the last glacial advance. Since the Holocene is part of an interglacial period, terraces are in a cycle of upbuilding in the Current River valley.

Regardless of their position in the formation sequence, terrace fills in the river valley are lithologically similar. The lower strata of the fills are composed of coarse sediments, primarily sand and gravel deposited as bars when the river was laterally accreting. Overlying the coarse fills are deposits of fine-grained overbank sediments resulting from vertical accretion. The upper strata of the T-0 and T-1 terrace fills are composed of silty and sandy loams that are immediately underlain by point bar and mid-channel deposits.

Landform-Archaeological Site Relationships

Alluvial terrace surfaces were ideal locations for human habitation because they provided close proximity to water and a variety of food resources. These were the first landforms to be occupied since uplands and ridges did not offer such a wide range of amenities (Figure 2.9). Saucier (1987) observed that, regardless of their age, the majority of prehistoric archaeological sites occur on T-3 terraces. It appears, though, that prehistoric landform use was fairly diverse and sites occur on T-2 and T-3 terraces, in the uplands, and along tributary streams.

Analysis of recorded prehistoric site locations reveals that Paleoindian sites tend to be located on T-3 terraces, along tributary streams, and on the uplands, while Late Paleoindian (Dalton), Archaic, Woodland, and Mississippian sites occur on both T-2 and T-3 terraces. Middle Archaic people almost exclusively occupied the T-3 terrace. This is most likely due to the onset of the Altithermal, which decreased the frequency of flooding on T-3 and reduced habitability and resource availability on the uplands. Later, the T-3 terrace was also the focus of Mississippian-age groups that needed large tracts of flat land for horticulture and to support an increasingly large and nucleated population.

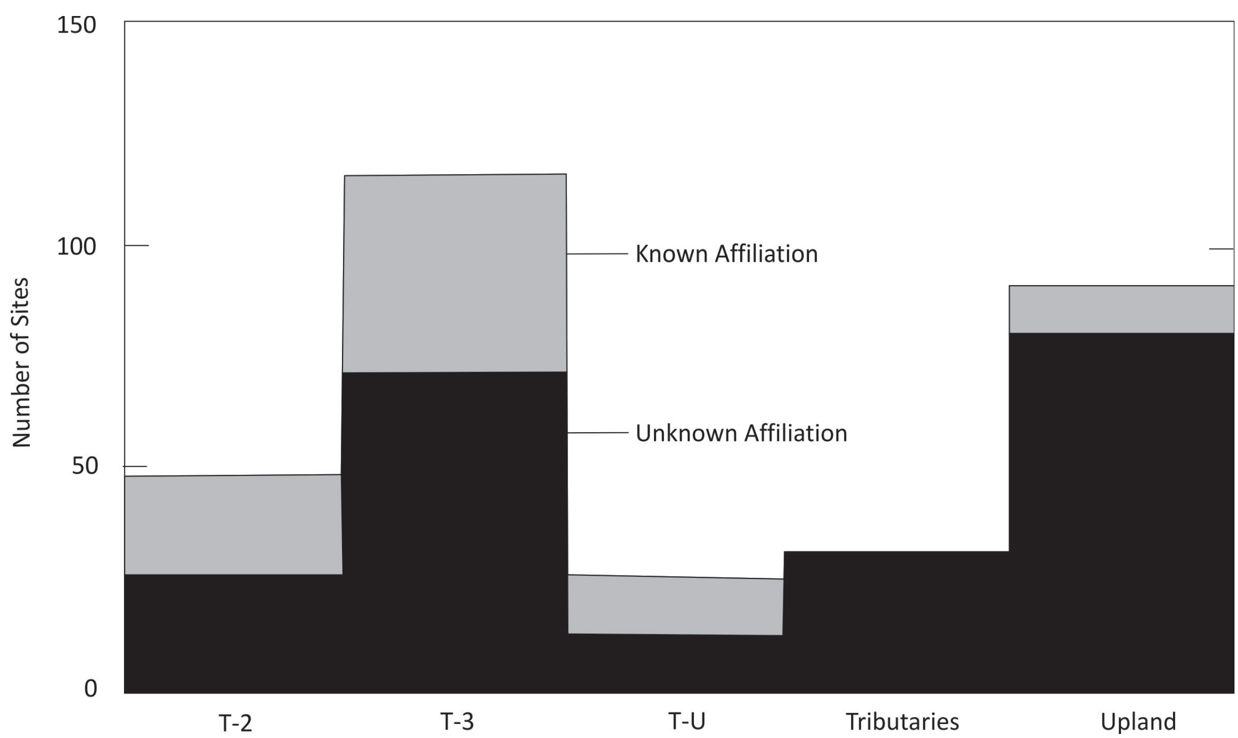

Figure 2.9. Landform-archaeological site occurrences (redrawn from Saucier 1987:158). T-U represents undifferentiated terraces.

Lynott et al. (2006) note that bias in archaeological research toward the Current River and Jack's Fork's floodplains and alluvial terraces, as well as exposures in small stream valleys, has skewed site-landform data. Their research at the Alley Mill site (23SH159), which is situated in colluvium and alluvium at the base of a steep bluff along the Jack's Fork valley wall, proved that rather than focusing occupation on particular terraces, prehistoric populations chose to live at the valley margins, often at the mouths of tributary streams. These deposits have since been covered by slopewash or colluvium, have no surface expression, and are often forested or commercially developed, making them difficult to target for archaeological investigation.

Saucier (1987) determined that archaeological data was the most reliable indicator of the ages of terrace fills. He demonstrated this by comparing temporally-diagnostic archaeological materials from good stratigraphic context with radiocarbon and TL ages. His archaeological evidence consisted of nine Early Archaic sites buried in T-2 terrace fills and 22 Early Archaic sites in T-3 terrace fills, one of which may actually be Paleoindian in age. Within these fills, deposits rich in clay and organic matter were sampled for radiocarbon and TL dating. These strata, composed of fibric materials, are located below the fine-grained alluvial deposits and were probably laid down when chutes or swales formed during increased stream activity.

Two radiocarbon ages obtained from T-2 terrace fills were essentially modern in age. A third sample yielded an age of 540 ± 140 ^{14}C yr B.P. From the T-3 terrace fills, Saucier acquired radiocarbon ages of 2,175 ± 165 ^{14}C, 4,145 ± 185 ^{14}C, and 3,510 ± 90 ^{14}C yr B.P. Because these ages were significantly younger than the archaeological materials suggested, TL samples were taken to either corroborate or refute the radiocarbon ages. The TL samples returned ages of 4,000 ± 700 B.P. in the T-2 terrace fills and 5,500 ± 900 B.P. in the T-3 terrace fills. In the end, both radiocarbon and TL ages were significantly younger than associated temporally diagnostic archaeological deposits. To shed additional light on the dating issue, Saucier examined a suite of fossil pollen samples to better constrain and test the validity of the radiocarbon ages. Unfortunately, the sediments only yielded pollen from species specific to a temperate riverine/floodplain environment, which corresponds with a number of periods during the Quaternary.

Effects of Historic Logging on the Current River Valley

Between the late nineteenth century and the early twentieth century, logging denuded the Ozark uplands of vegetation. Without protective cover, the thin veneer of upland soil composed of fine-grained sediment as well as gravel-sized clasts, eroded downslope and into the river channels. In the Current River valley, the fine-grained sediment has since moved through the system. Gravels, however, have moved downstream at a much slower rate and continue to clog channels throughout the drainage basin as point and mid-channel bars. Historically, livestock grazing kept vegetation from colonizing gravel bars. Recently, the bars have stabilized and become vegetated, keeping gravels from moving farther downstream.

Removing timber from the uplands caused significant changes in natural stream channel processes (Saucier 1987). The initial influx of upland sediments obstructed the stream channel by increasing its suspended and bed loads, which in turn increased the frequency and severity of flood events. These changes resulted in flood chute formation, floodplain reworking, overbank scouring and deposition, and the alteration of bars and islands.

Gravels have significantly altered stream channel sinuosity. In areas where the gravel supply is low, the channel tends to be straight or retain its existing curvature. Where the gravel supply is high, the stream channel curvature is usually amplified. Saucier estimated that 15% of the T-0 floodplain has been reworked in the last 100-150 years. Had logging not occurred and gravel not subsequently been introduced to the stream channel, the magnitude of floodplain alteration observed over the past 150 years would have taken 5,000-10,000 years. Additionally, the average height of flood events has increased since logging occurred. Saucier noted that the increase in flood height is related to either climate change or the influx of gravel blocking flood chutes and smaller channels.

Remodeling Late-Quaternary Landscape Evolution in the Current River Valley

In the mid 1990s, an NPS development project provided Saucier (1996) the opportunity to investigate stratigraphy at the Gnat Alley Woods site (23CT351). The site is associated with the T-3 terrace above the confluence of a small stream that joins the Current River (Figure 2.10). This stretch of the river valley is not particularly wide, only about 300 m across, and the mouth of the hollow is 40 m wide. Terrace fills in both valleys consist of coarse basal material that fines upward to silty and sandy clays and loams (Saucier 1996:4).

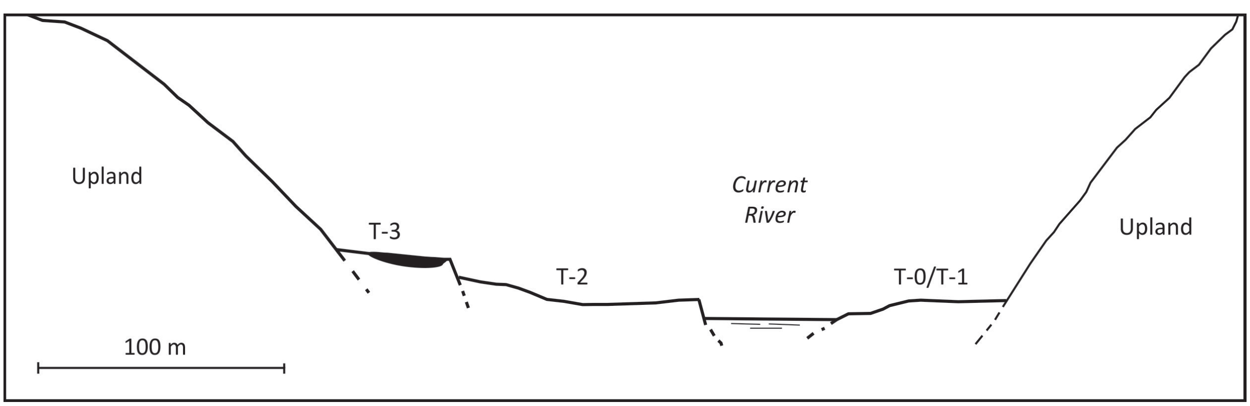

Figure 2.10. Cross-section of the Current River valley at the 23CT351 archaeological site location (redrawn from Saucier 1996:23).

At Gnat Alley Woods, Saucier found that in addition to vertical accretion on the modern floodplain surfaces, the T-2 and T-3 currently are aggrading because their surfaces are below the elevations of high-magnitude floods. Because the Current River flows over resistant dolomite bedrock, the channel is incising slowly. However, lateral migration of the channel is an ongoing process that erodes the floodplain and terrace fills along the stream channel. Therefore, terrace fills have not formed through cut-and-fill episodes initiated by a change in the river's base level. Given continuous aggradation and the slow pace of downcutting, one might expect that all terrace surfaces would eventually have the same elevation. However, because the various terrace surfaces occur at different elevations, Saucier postulated that a significant erosional process must be at work. He determined that periodic increases in lateral stream channel movement and floodplain instability, the result of more frequent and intense storms and flooding (Knox 1983), remove substantial portions of the floodplain. After a section of floodplain is removed, vertical accretion begins again. Only portions of floodplain alluvium are removed at any one time, resulting in multiple terrace elevations that aggrade with each high magnitude flood. Saucier noted that denuded vegetation, caused by major floods, could have been a major contributor to erosion.

Radiocarbon ages were not obtained from Gnat Alley Woods. However, indirect dating from archaeological evidence at the site revealed a different chronology of T-3 terrace aggradation than Saucier had originally devised. Elsewhere in the Current River valley, Paleoindian sites sit on the T-3 terrace surface. At Gnat Alley Woods, however, archaeological materials in the fill indicate that it aggraded between 9,000-3,000 ^{14}C yr B.P. Saucier attributed this difference to the cycles of erosion caused by lateral channel migration and to the previously described floodplain instability. He concluded that LSAs in the Current River valley are only lithostratigraphic and morphostratigraphic units, not chronostratigraphic units (Saucier 1996:18). Because aggradation was diachronous in the Current River valley, Saucier did not develop a temporal model for the drainage network. Per his assessment, the data from Gnat Alley Woods indicate that archaeological site-landform relationships must be constructed at individual locations since the age of a terrace fill cannot be accurately inferred from a landform of comparable topographic position.

Summary

The late-Quaternary period in Ozarks history was exceptionally dynamic. Paleoenvironmental and geological research has proven that bioclimatic change has affected late-Quaternary landscape evolution in this region. In this chapter, I described the Current River valley's physical characteristics (geology and geomorphology) as well as its history of paleoenvironmental change from the late Pleistocene through the Holocene. This information is critical to my dissertation for two reasons. First, because my project is designed to assess the potential for cultural deposits in the valley, it is important to understand the spatio-temporal pattern of LSAs. Second, environmental data provides an important context for understanding archaeological data in terms of human-landscape interaction and the settlement and subsistence strategies of past populations.

CHAPTER 3

ARCHAEOLOGICAL HISTORY OF THE OZARK PLATEAU

People have lived on the Ozark Plateau for thousands of years. The record of occupation here is unique to North America and reflects ever-changing environmental conditions. Importantly, the region's archaeological history provides a framework with which to view paleoenvironmental change and landscape evolution and consider how these factors affect people. Establishing patterns in past human behavior using site data in the Current River valley is difficult. Sites attributed to any given archaeological tradition occur in a variety of geologic contexts (i.e., T-1, T-2, and T-3 terrace fills, alluvial fan deposits, upland settings, and near springs). For example, Clovis deposits occur in T-2 and T-3 terrace fills as well as creek fills. As such, there is no real predictability in the archaeological record. This makes the data presented in chapters 5 and 6, wherein I present a model of the geologic potential for cultural deposits for the Current River valley, all the more important.

In this chapter, I use a culture-historical approach to describe the sequence of human occupation from pre-Clovis to Historic times, with reference to sites in Ozark NSR. This discussion contextualizes modern archaeological investigations and reveals the nature of the archaeological record. It is important to note that there is a difference between cultural technologies and their expressions (e.g., Clovis fluted points, Mississippian triangular points, Mississippian sand-tempered ceramics) and archaeological traditions (e.g., Hopewell, Dalton, Clovis). The terms 'technology' and 'culture' are not synonymous and one should not necessarily be used to describe the other. In this dissertation, I use technologies or expressions of technologies in the archaeological record to describe a particular archaeological tradition because it is these data that have been employed historically to describe groups of people.

History of Human Occupation on the Ozark Plateau

The Ozark Plateau has been occupied since the Pleistocene/Holocene transition, likely before. Except for a short period during the Late Mississippian Powers Phase when the Ozarks may have been abandoned (Lynott 1991a), people lived on the river terraces and in the uplands of the stream valleys across the region during the late Pleistocene and throughout the Holocene. While there are stretches of time to which little material culture and few subsurface features have been attributed, some time periods are very well represented on the Plateau.

In the following section, I examine the history of human occupation in the Ozarks. I use established culture-historical terms, and refer to the artifacts, subsistence strategies, and settlement patterns most prevalent in the region during these periods. Each period is static, though this is a function of organization rather than a true cultural phenomenon. I also provide information on archaeological sites in Ozark NSR that are attributed to each particular period. All dates are in radiocarbon years before present, unless otherwise noted.

Pre-Clovis (11,500+ ^{14}C yr B.P.)

Finding and identifying pre-Clovis cultural deposits is a difficult endeavor because, compared to later sites, archaeologists are unsure of what pre-Clovis sites and cultural material look like (Goebel et al. 2008). And, given the paucity of recorded pre-Clovis cultural deposits, it is difficult to understand pre-Clovis landscape use. It may be prudent, however, to use data from Clovis sites and information on Clovis settlement and/or colonization strategies to find and interpret pre-Clovis sites (Hofman 1996). Those sites containing both Clovis and pre-Clovis components, such as the Debra L. Friedkin site and Meadowcroft Rockshelter, are of particular use in this quest. Meltzer (2009:211) notes that by using the principle of uniformitarianism, generalizations can be made from Clovis data about how earlier people adapted to life in the New World. These generalizations can then be tested against the archaeological record.

Using Clovis sites to infer the location of pre-Clovis sites across regions is made difficult by differences between North American bioclimates. Bioclimatic conditions on the Great Plains (Johnson and Willey 2000; Musgrove et al. 2001), southeast (H. Delcourt 1979; P. Delcourt 1980), and southwest (Haynes 1995), where multiple Early Paleoindian sites are recorded, are dissimilar from the predominantly deciduous forest conditions Early Paleoindians and pre-Clovis people encountered on the Ozark Plateau and Eastern Woodlands. As an additional complication, microenvironments within bioclimatic zones were varied and locally distinct (Anderson et al. 1996; Graham 1986; E. Grüger 1972; King 1973).

In southeastern North America at the Pleistocene-Holocene transition, bioclimate controlled group size, technology, and mobility patterns (Anderson and Hanson 1988; Anderson et al. 1996:6; Cable 1982). Anderson et al. (1996) argued the effect of bioclimate on Paleoindians could have varied even between drainages. In the northern part of the region, forests were patchy and Paleoindians practiced collector adaptations based on resource distribution. These Paleoindians operated from a central base camp and collected resources at strategically-placed short-term use camps. They employed a formalized and highly curated tool kit like that utilized by earlier Paleoindian populations to the north and west. Conversely, in the southern part of the Southeast, a continuous hardwood canopy prevailed and Paleoindians engaged in residentially-mobile foraging. The more homogeneous environment allowed people to forage across the region using short-term camps, moving on when a particular area was exhausted. These Paleoindians maintained tool kits comprised of expedient tools. As the ice sheet retreated and southern hardwood trees expanded northward, all Paleoindians in the southeast adopted foraging subsistence strategies.

Assumptions about pre-Clovis sites and pre-Clovis adaptive strategies could easily be affected by this problem of variable bioclimates. Webb and Rindos (1997) argued that people colonize new territories more quickly when they do not adapt to foreign environments, thus lowering their carrying capacity and forcing forward progression. In their view, limiting adaptation allows humans to move rapidly across the landscape. Kelly (2003:54), however, asserted that as people encountered new environments, they chose to adapt or not based on the perceived difficulty or risk associated with doing so. These decisions were at least partially influenced by the ease with which people made "cognitive maps." Adaptation based on ease would have been entirely dependent on the population's original adaptive strategy. Neither scenario requires prior knowledge of an environment but both could affect our understanding of how people occupied or moved through previously unknown areas, which could in turn affect any inferences made from Clovis and pre-Clovis site distributions.

Recent research in the fields of archaeology, skeletal biology, genetics, and linguistics has provided valuable information on the peopling of the New World. Contrary to the Clovis-First theory, these data indicate that humans inhabited the Americas prior to 11,500 ^{14}C yr B.P. Though the definitive number of migrations and their pattern and origination are not yet established, we do know that humans first set foot in the New World well before the Pleistocene-Holocene transition, most likely utilizing a coastal route (Figures 3.1a and 3.1b) (Surovell 2003). This conclusion is based on artifactual evidence and radiocarbon ages from camps and lithic workshops along the southern coast of Alaska and the coast of the Pacific Northwest (Fladmark 1979). Another popular migration theory, the Solutrean hypothesis, argues that pre-Clovis people migrated across the north Atlantic from the Iberian Peninsula (Bradley and Stanford 2004; Stanford and Bradley 2012).

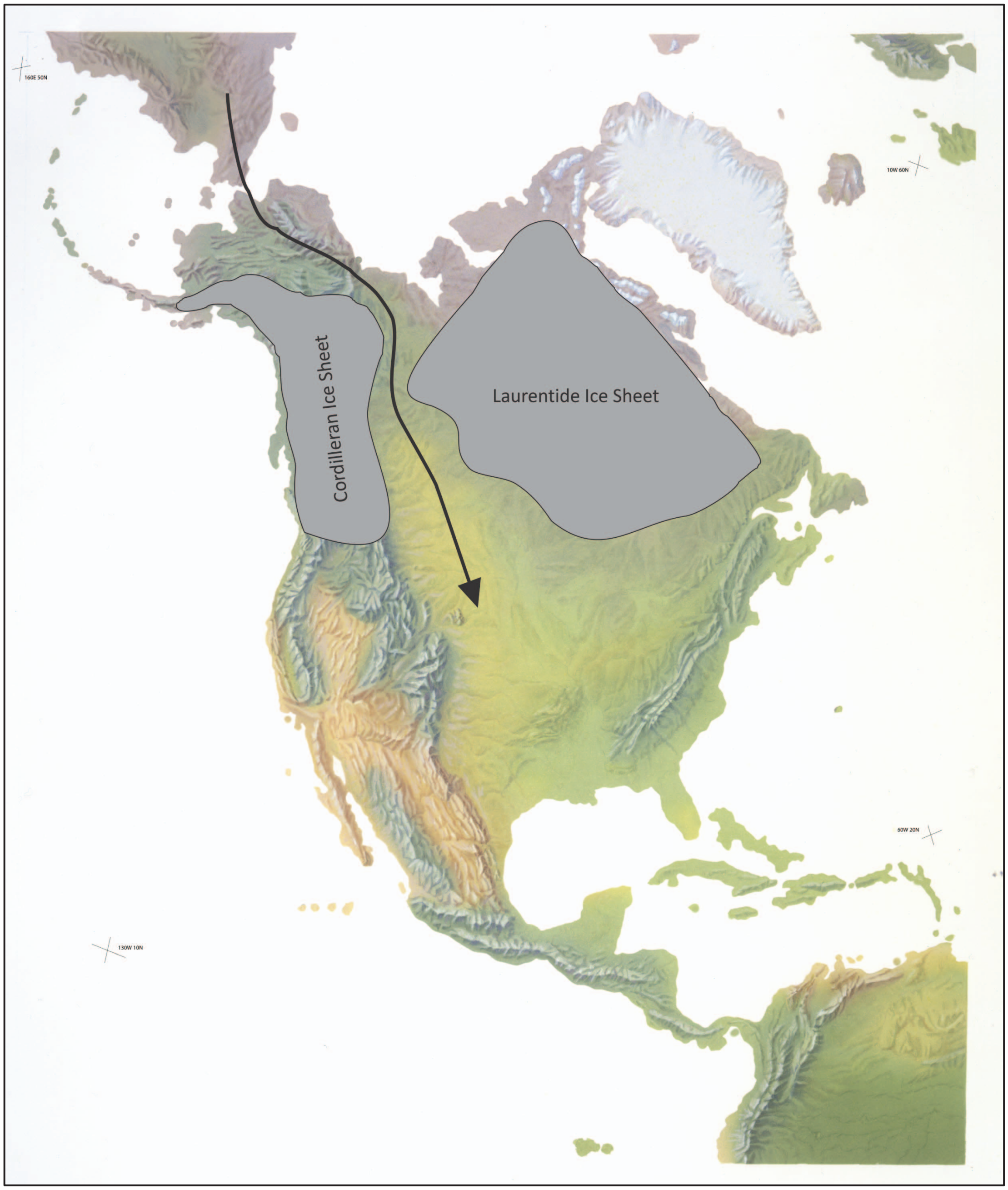

Figure 3.1a. Hypothesized migration route through the Ice-Free Corridor at approximately 11,500 ^{14}C yr B.P. (relief map by Kenneth Townsend).

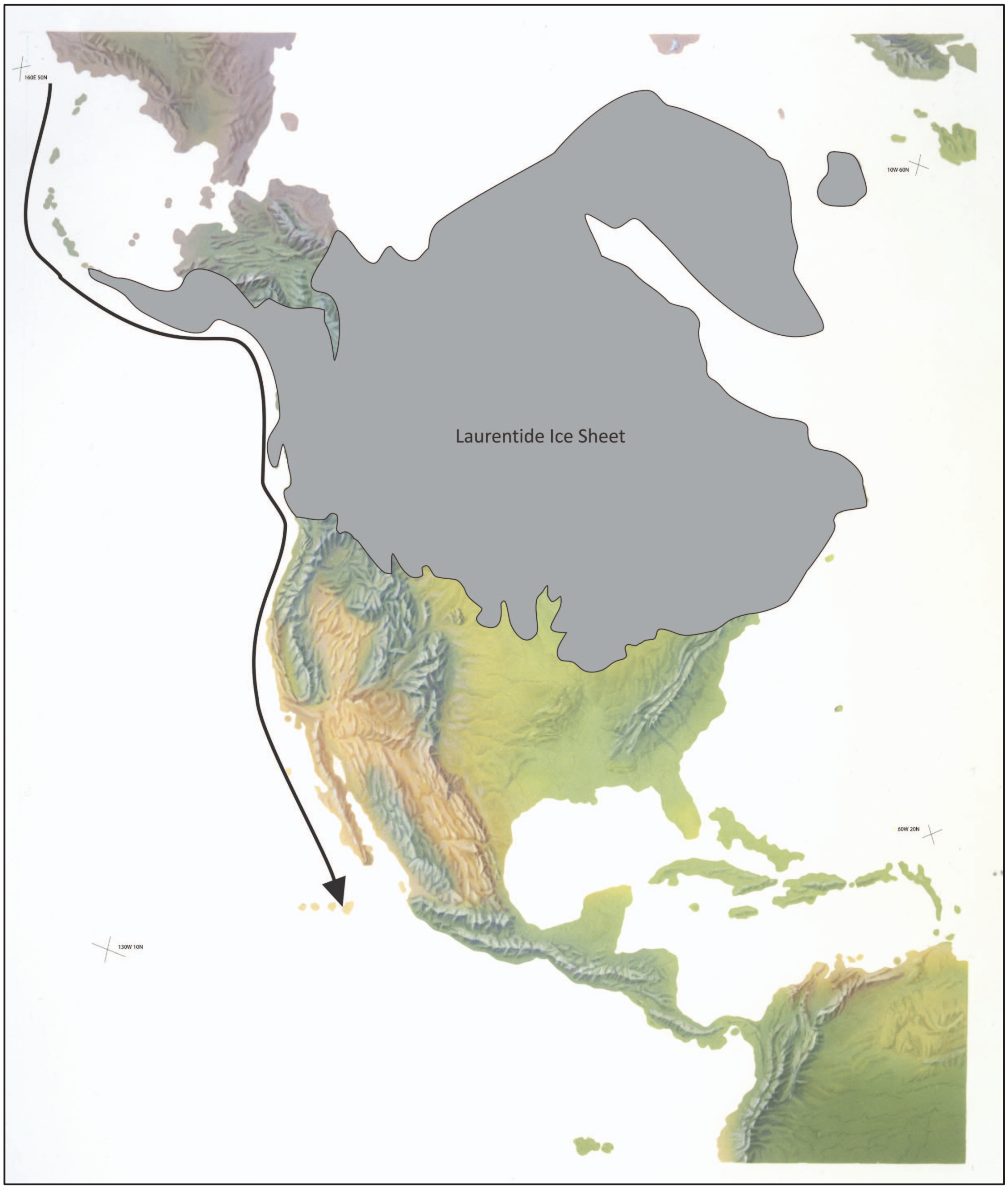

Figure 3.1b. Hypothesized coastal migration route at approximately 15,000 ^{14}C yr B.P. (relief map by Kenneth Townsend).

Figure 3.2 is a map of pre-Clovis sites mentioned in this text. Several archaeological sites in North America have yielded evidence that suggests occupation prior to 11,500 ^{14}C yr B.P. These include Paisley Cave in Oregon (Jenkins 2010; Smith 2009), Meadowcroft Rockshelter in Virginia (Adovasio, Donahue, and Stuckenrath 1990; Adovasio and Pedler 2005), Hebior and Schaefer in Wisconsin (Overstreet and Kolb 2003; Overstreet 2005), Page-Ladson in Florida (Dunbar et al. 1988), La Sena in Kansas (Holen 2006), Cactus Hill in Virginia (McAvoy and McAvoy 1997), Lovewell in Nebraska (Holen 2006), and the Manis mastodon site in Washington (Waters, Stafford, et al. 2011). Some researchers question the validity of dates, artifacts, and geomorphic contexts of these sites. Table 3.1 provides an overview of archaeological sites with pre-Clovis components including the age of the pre-Clovis component, issues that have been raised in regard to that component, and the pertinent references.

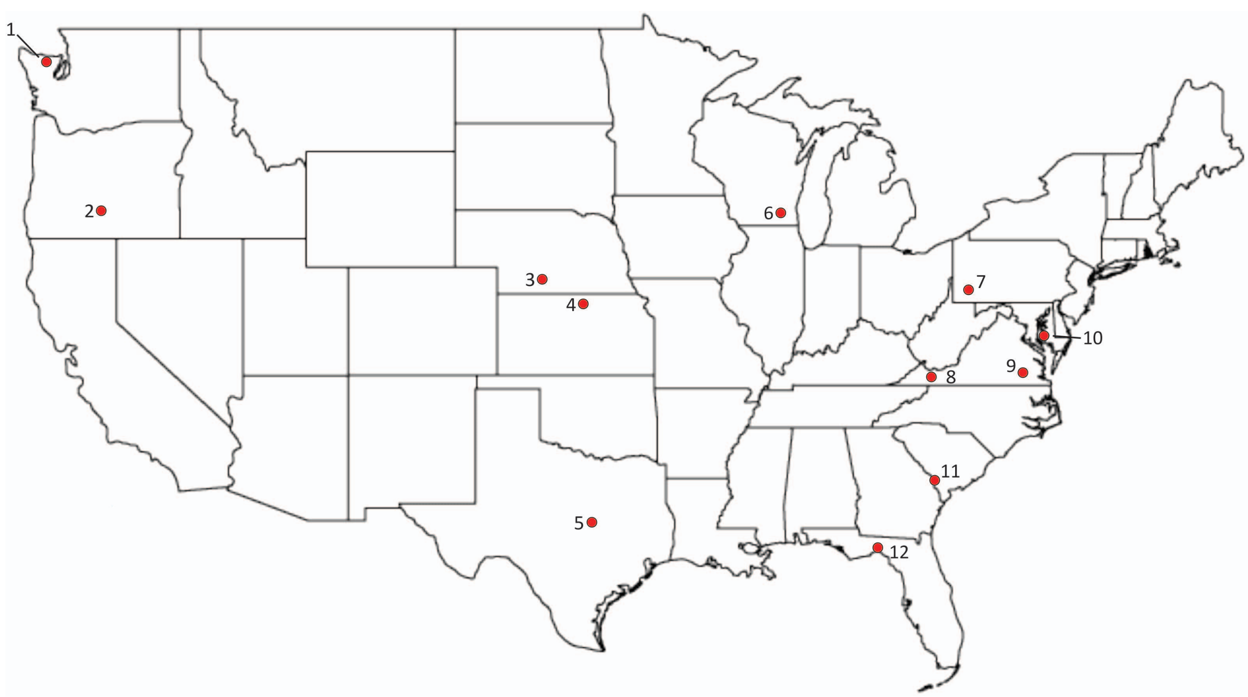

Figure 3.2. Pre-Clovis sites mentioned in the text: 1, Manis; 2, Paisley Cave; 3, La Sena; 4, Lovewell; 5, Debra L. Friedkin; 6, Hebior/Schaefer; 7, Meadowcroft Rockshelter; 8, Saltville; 9, Cactus Hill; 10, Miles Point; 11, Topper; 12, Page-Ladson.

Table 3.1. Pre-Clovis sites and their ages, issues with acceptance, and references.

Site	Location	Date	Problems and Issues	References
Paisley Cave	Oregon	12,300 cal B.P. (coprolites); 16,000-13,000 ^{14}C yr B.P. (obsidian hydration)	Coprolites may belong to herbivores, not humans (Goldberg et al. 2009).	Gilbert et al. 2009; Jenkins 2007, 2010; Smith 2009
Meadowcroft Rockshelter	Pennsylvania	14,555-13,955 ^{14}C yr B.P.	Potential lignite coal contamination of radiocarbon ages (Dincauze 1989; Haynes 1980, 2005).	Adovasio and Pedler 2005; Adovasio et al. 1990
Hebior and Schaefer	Wisconsin	12,570-12,290 ^{14}C yr B.P. (mammoth bones)		Joyce 2006; Overstreet and Kolb 2003; Overstreet 2005
Page-Ladson	Florida	14,400 calendar years B.P.	Stratigraphy	Dunbar et al. 1988
La Sena	Nebraska	19,000-18,000 ^{14}C yr B.P.	Are bone tools ecofact?	Holen 2006
Lovewell	Kansas	19,000-18,000 ^{14}C yr B.P.	Are bone tools ecofact?	Holen 2006, 2007
Cactus Hill	Virginia	15,070 ± 70 ^{14}C yr B.P. (hearth); 16,670 ± 730 ^{14}C yr B.P. (under artifact cluster)	Artifacts may be geofacts, not cultural.	McAvoy and McAvoy 1997; Wagner and McAvoy 2004
Manis	Washington	13,800 calendar years B.P.		Waters, Stafford, et al. 2011
Debra L. Friedkin	Texas	15,500 calendar years B.P.	Only OSL ages are available; have large standard deviation of 900-1,000 years. No provenience for OSL samples provided.	Waters, Forman, et al. 2011
Saltville	Virginia	15,000 ^{14}C yr B.P.		McDonald 2000; Wisner 1996
Miles Point	Maryland	41,000-13,000 calendar years B.P. (sediments)		Lowery et al. 2010
Topper	South Carolina	>15,000 calendar years B.P. (OSL)	Pre-Clovis artifacts in colluvium and alluvium and not paleosol. Artifacts appear to be geofacts. Bioturbation makes obtaining good 14C ages difficult (Waters et al. 2009).	Goodyear 1999, 2000, 2005; Waters et al. 2009
Monte Verde	Chile	13,000-12,500 ^{14}C yr B.P.	Dickinson (2011) questions the feasibility of travelling along the narrow paleoshoreline of the Pacific continental shelf and argues the periglacial paleoenvironment at the time of pre-Clovis colonization would have been difficult to navigate. Lynch (1990, 2001) argues that the artifacts are not cultural and people would not have inhabited the wet, boggy locality of Monte Verde in the late Pleistocene.	Dickinson 2011; Dillehay 1989, 1997; Lynch 1990, 2001
Taima Taima	Venezuela	14,000-12,000 ^{14}C yr B.P.	Projectile points next to megafauna remains from later occupations and sank through wet sediments?	Gruhn 2005; Meltzer 2009; Tamers 1971

Identifying exactly what kind of archaeological record pre-Clovis people may have left behind is extremely difficult. Site type and character is highly dependent on the size of the pre-Clovis population and their adaptive strategies for subsistence and settlement. Currently, the artifacts from pre-Clovis sites indicate a lithic tool technology of blades, bifaces, and bladelets was employed across the continent at the Pleistocene-Holocene transition and earlier. The Buttermilk Creek complex, dated to 15,500 calendar years B.P. and identified by Waters, Forman, et al. (2011) at the Debra L. Friedkin site, contains small tools indicative of a highly mobile population (Figure 3.3). Bifacial tools include preforms, chopper/adzes, and discoidal cores. The majority of these tools are late-stage. Small lithic tools from this site include one bifacially worked tool, one graver, four notches, and 17 "straight-to-convex edged tools" (Waters, Forman, et al. 2011). Use wear suggests tools were applied to both hard and soft (organic) materials.

Blade-like flakes were found associated with mammoth remains at the Hebior and Schaefer sites (Joyce 2006). The mammoth bones, dated to 12,290-12,570 ^{14}C yr B.P., exhibited cut and butchering marks, indicating the animal was either hunted or scavenged.

There is evidence of a mammoth kill at Mud Lake in Wisconsin dating to 16,000 calendar years B.P., but no stone tools were recovered in direct association with the faunal remains (Overstreet 2005). Diagnostic Chesrow complex artifacts, which Adovasio and Pedler (2004) argue may be ancestral to Clovis, were found at Mud Lake and in the southern Lake Michigan basin (Overstreet 1993). At Meadowcroft Rockshelter in Virginia, a lanceolate biface was recovered from sediments dating to 15,200 calendar years B.P. (Adovasio 1992, 1993; Adovasio, Gunn, et al. 1980; Adovasio, Donahue, and Stuckenrath 1990; Adovasio and Pedler 2005). In Florida, Page-Ladson also may contain evidence of pre-Clovis tools. Several pieces of chert debitage, a unifacial flake tool, and a hammerstone were found with mastodon remains in a sinkhole in the Aucilla River. The pre-Clovis component at Page-Ladson dates to 14,400 calendar years B.P. (Dunbar et al. 1988).

Figure 3.3. Artifacts of the Buttermilk Creek complex from the Debra L. Friedkin site in southeast Texas (Waters, Forman, et al. 2011:1602; with permission of The American Association for the Advancement of Science).

Holen (2006, 2007) argues that mammoth bone breakage at the La Sena site in Nebraska and Lovewell site in Kansas demonstrates pre-Clovis manufactured bone tools. In addition, bone and ivory tools have been recovered from Saltville (McDonald 2000; Goodyear 2005). Perhaps, bone was a common material for pre-Clovis tools and the majority of these artifacts have not survived in the archaeological record.

The Ozark Plateau is home to two potential pre-Clovis sites. The Big Eddy site (23CE426) is located in southwest Missouri, in T-1 fill along the banks of the Sac River. A well-stratified site, Big Eddy contains a suite of prehistoric components spanning the Early Paleoindian through Mississippian cultural periods. The pre-Clovis component is represented by debitage and a possible manuport excavated from 390 cm below the floodplain's surface (Ray et al. 2000). At the Shriver site (23DV12), located on an upland ridge in northwest Missouri in Daviess County, stone tool debris was excavated from strata beneath a Folsom-age component (Reagan et al. 1978; Rowlett 1981). Paleoindian and potential pre-Clovis artifacts were recovered between 30 and 40 cmbs. Rowlett obtained a date of 13,000 B.P. through thermoluminescence dating and geochronological investigations, though the legitimacy of this date has been questioned (Mark Lynott, personal communication, 2011).

Paleoindian (11,200-10,000 ^{14}C yr B.P.)

Early Paleoindian (Clovis, 11,600-10,900 ^{14}C yr B.P.). As mentioned above, it may be that our best option for exploring pre-Clovis is, in fact, Clovis (Hofman 1996). A good understanding of Clovis technology and of the late Pleistocene paleoenvironment may better elucidate the origins and lifeways of Clovis progenitors. It is important to note that all pre-11,500 ^{14}C yr B.P. evidence is not necessarily directly related to Clovis. Multiple Paleoindian groups, likely with different sets of adaptive strategies, were almost certainly present in North America during the late Pleistocene (Hofman 1996).

The Clovis archaeological tradition was discovered when a fluted projectile point, the diagnostic artifact of this culture, was found in association with extinct megafauna in 1933 at the Blackwater Draw site in New Mexico (Cotter 1937). The issue of who first set foot in the New World aside, people with Clovis technology occupied all of the western hemisphere, colonizing it at a rather rapid rate (Haynes 1964). Waters and Stafford (2007) reevaluated Clovis radiocarbon ages and determined that the archaeological tradition flourished between 11,050 and 10,800 ^{14}C yr B.P. Goebel et al. (2008) argue that archaeological sites containing Clovis deposits are tightly dated to between 11,200 and 10,900 ^{14}C yr B.P. Ferring (2001), however, reported an age of 11,600 ^{14}C yr B.P. from the Clovis component at the Aubrey site in Texas, making it the oldest recorded Clovis site in North America.

Proposed colonization tactics contend that Clovis entered the New World through the Ice-Free Corridor or from the Pacific coast sometime around 11,500 ^{14}C yr B.P. If Clovis migrated along the coast, the date of proposed entry could be pushed back one to several thousand years earlier depending on glacial cycles. Watercraft almost certainly played an important role in New World colonization, both along the Pacific coast and inland North America (Dixon 1999, 2001; Erlandson et al. 2002; Erlandson 2008; Erlandson and Moss 1996; Fladmark 1979; Jodry 2005; Mandryk et al. 2001; Stanford and Bradley 2002). Information from archaeological sites in Australia suggests that humans had developed maritime voyaging by 40,000 calendar years B.P. (Bowler and Magee 2000; Gamble 1994; Mulvaney and Kamminga 1999). People used watercraft to traverse the waters between the Japanese mainland and Izu Islands by 30,000 calendar years B.P. and the Jomon culture developed specialized seafaring and hunting craft no later than 9,000-8,000 calendar years B.P. (Oda 1990). Evidence from California's Channel Islands provides some of the earliest evidence of boat use in North America at 10,400 and 10,970 ± 80 ^{14}C yr B.P. (Jodry 2005). Lithic raw material distribution between mainland British Columbia and nearby islands demonstrates boat usage by 9,500 calendar years B.P. (Carlson 1994).

Clovis sites occur across North America and into Central and South America (Barton et al. 2004). In North America, Clovis sites are concentrated in the southeast (Mason 1962) and southwest (Haynes 1966). These apparent concentrations may be an effect of sampling bias.

Clovis were the first people to practice fluting in their projectile point manufacture strategy and this attribute is a typological and temporal indicator of the Early Paleoindian period. Chapman (1975) noted that Clovis fluted projectile points took on a variety of forms and did not always resemble the type points found in the Southern High Plains and Southwest. O'Brien and Wood (1998) point out that variation among projectile points throughout the Paleoindian period often leads to confusion between Clovis and Late Paleoindian Dalton points. Kelly and Todd (1988) argue that Clovis projectile points, though diverse in morphology, did not exhibit regional stylization. Differences in Clovis projectile point forms often reflected the type and quality of the raw material. Regardless of morphology, almost all Clovis points were made from high quality cryptocrystalline rock (Goodyear 1979; Meltzer 1993; O'Brien and Wood 1998). Other lithic tools, such as bifaces, cores, preforms, knives, scrapers, and other unifacial tools, comprise the Clovis toolkit. Dincauze (1993) argued that the most drastic differences in Clovis toolkits—specifically, the discarded portions of toolkits—occur between sites of varying distances from the lithic source. Cores and core reduction debris are commonplace at or near the quarry.

Farther away from the source, toolkits contain mostly bifaces, bifacial thinning flakes, and bipolar cores.

Several Clovis—and Paleoindian in general—habitation patterns have been proposed. In most cases, Clovis sites are either large or small habitations. Large habitation sites, such as Shoop in Pennsylvania (Witthof 1952), Gainey in Michigan (Simons et al. 1984), and Bull Brook in New Hampshire (Byers 1954), include several distinct artifact clusters that resemble the small habitation sites. These artifact clusters appear to be the remains of family activities, centered on a hearth (Dincauze 1993). Dincauze suggested that this indicates the use of temporary and/or portable shelters. Large sites have been variously interpreted as created by several families gathering together for a purpose (e.g., hunting) or aggregates of several site visits by different families.

Flora and fauna of ecotones changed during the Pleistocene-Holocene transition, but people were never without access to resources for subsistence, travel, trade, and tool making. For many years, archaeologists believed Clovis people were solely big game hunters, but some now argue they were generalists rather than specialists (Cannon and Meltzer 2004; Meltzer 1993; Meltzer and Smith 1986). There is an effort to understand the degree to which big game contributed to the Paleoindian diet and Clovis' overall impact on fauna (see Anderson et al. 1996).

In the Eastern Woodlands, Paleoindians developed a foraging subsistence strategy rather quickly (Meltzer and Smith 1986). Such a subsistence strategy would have been aided by a settlement strategy that focused on small-range mobility rather than long-distance movement (Anderson 1990, 1991). Paleoindian populations grew at these staging areas, allowing the development of information and reproductive networks (Anderson 1990, 1991, 1996). This model of settlement is different from Kelly and Todd's (1988) vision of early Paleoindians as high-technology foragers, wherein people were extremely mobile, moved swiftly in order to exploit terrestrial fauna with a technology-based hunting strategy, and focused more on animal behavior than familiarizing themselves with the landscape. Anderson argued that the major routes into the Eastern Woodlands from the Mississippi Valley were the Ohio, Cumberland, and Tennessee rivers. It happens that these three river valleys contain some of the highest concentrations of Paleoindian projectile points in North America. Anderson (1990) asserted these concentrations are evidence of a less mobile population and population nucleation around staging areas.

Archaeological evidence from across the Ozark Plateau indicates that people occupied the region during the Pleistocene-Holocene transition. Several Clovis-age archaeological sites have been documented on the Plateau (e.g., Graham et al. 1981; Hajic et al. 2007; Klinger et al. 1989; Lopinot et al. 1998, 2000; Ray et al. 2000). At least one Clovis-age buried feature has been recorded in the Current River valley (Klinger et al. 1989). Data on the Clovis culture are outlined in Chapter 3.

Chapman (1975) notes that in Missouri, Clovis points tend to be concentrated in terrace fills and on uplands along the main branches and confluence of the Missouri and Mississippi rivers. This inference is valid even though private collecting, point type identification, and significant Mississippi River channel migration during the Holocene may bias the distribution of recorded Clovis points (O'Brien and Wood 1998). In Missouri, Clovis artifacts are often found on the surface as isolated finds near particular landscape features, including bogs, stream valleys, lake margins, and other wetlands like backwater areas (Chapman 1975; Finney 2006).

Excavations at the Kimmswick site (Graham et al. 1981; Graham and Kay 1988; Koch 1841) yielded Clovis-age cultural deposits, including two projectile points, found in association with Pleistocene-age mastodon remains. Graham and colleagues also found the remains of Pleistocene faunal species adapted to mixed forest/grassland environments in the Clovis-age deposits. The researchers collected pollen data from the surrounding area, which indicated that the transitional Pleistocene-Holocene vegetation community contained a large number of grass species. Because mastodons are typically associated with boreal forest and spruce-dominated environments, it is clear they were capable of adapting to a variety of habitats, as were humans. Elsewhere in Missouri, megafauna-human associations occur at the Miami mastodon in Saline County where a flake was found between mastodon long bones and the Grundel mastodon in Holt County that exhibited spiral fracturing. It appears that areas devoid of Clovis points in Chapman's study are also areas where Mehl (1962) identified an absence of Pleistocene megafauna.

Recent investigations at the Big Eddy site on the Sac River in western Missouri exposed a stratified sequence of site occupation from Clovis/Gainey to Mississippian with a potential pre-Clovis occupation at the very base of the terrace fill (Hajic et al. 2007; Lopinot et al. 1998, 2000; Ray et al. 2000). Radiocarbon ages from the alluvium containing the Early Paleoindian materials indicate the stratum aggraded from 11,380-10,180 ^{14}C yr B.P. Below the Clovis/Gainey level, large cobbles and a possible flake were encountered. Ray and colleagues believe these cobbles are anvils or manuports and possibly associated with a pre-Clovis component (Ray et al. 2000). These sediments aggraded between 12,950-11,380 ^{14}C yr B.P.

In Ozark NSR, Clovis components have been identified at four sites (Figure 3.4). Leo Anderson's private collection from the Partney Farm site (23CT2) (Chapman 1960) and Alan

Banks' (1978) private collection from the Sinking Creek site (23SH97) each contain a fluted projectile point. A third Clovis point fragment was recovered during excavations at the Two Rivers site (23SH101), on a T-3 terrace above the confluence of the Jacks Fork and Current River (Klinger et al. 1989). The Two Rivers locality was, and continues to be, a particularly rich archaeological site. The mid-section and base of a fluted point were also discovered at Alley Mill (23SH159) (Lynott et al. 2006).

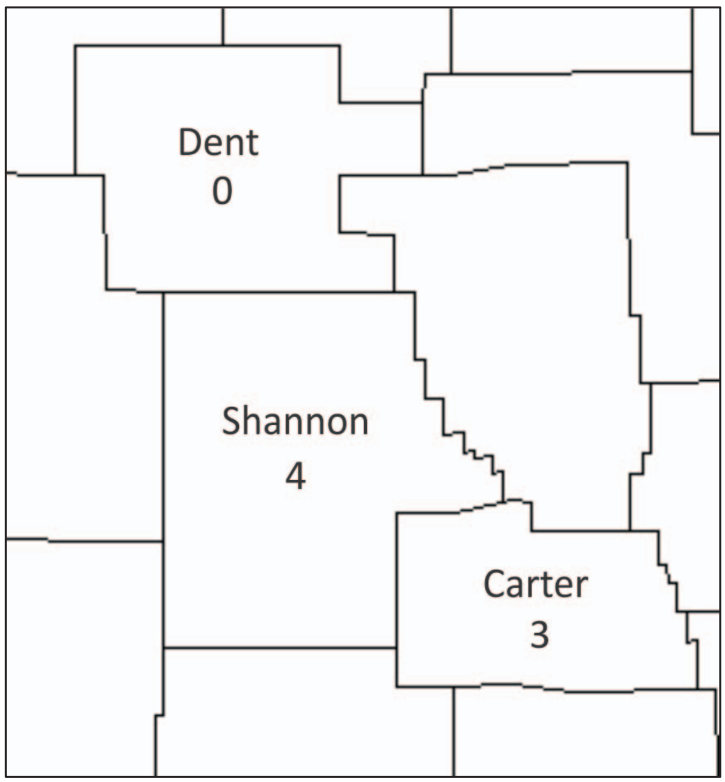

Figure 3.4. Number of Clovis projectile points recorded in Ozark NSR by county. Carter County projectile point count from Chapman 1975.

The Current River valley was an attractive environment to early Paleoindians. Palynological investigations at Cupola and Big Wolf ponds by Smith (1984) and Delcourt and Delcourt (1984) indicate that at the end of the Pleistocene (approximately 18,000 ^{14}C yr B.P.), the Laurentide ice sheet blocked cold air from Canada and the Plateau became a refuge for a number of cool-temperate deciduous tree species like oak, ash, maple, birch and willow (Smith

1984; Lynott et al. 1996). During the early Holocene, these hardwood tree species migrated northward as glacial ice retreated as a result of increased temperatures and annual precipitation and the subsequent disappearance of coniferous tree species like as pine, spruce, and fir (Delcourt and Delcourt 1994; Lynott et al. 1996; Smith 1984).

Middle Paleoindian (Folsom, 10,900-10,200 ^{14}C yr B.P.). Folsom people lived in central North America, slightly overlapping with Clovis. Because they were centralized in the Great Plains, Great Basin, and Rocky Mountains, few Folsom sites are found east of the Central Plains. After megafauna extinctions at the end of the Pleistocene, Folsom developed a subsistence strategy focused on smaller mammals, like the *Bison antiquus*, an extinct form of bison that provided materials beyond meat, such as hides for clothing and large, sturdy bones for tool manufacture (Frison 1978).

Though both are fluted, Folsom projectile points differ morphologically from Clovis points in several ways (Bradley 1991, 1993). Though Folsom and Folsom-like projectile points have been have been recorded in Missouri (Chapman 1975; Delling 1966; Smail 1951) and Illinois (Perino 1985) and occur throughout the eastern United States, none have been identified in Ozark NSR or the Current River valley.

Late Paleoindian (Dalton, 10,500-10,000 ^{14}C yr B.P.). Dalton technologies appear in southeastern North America at a time when the climate returned to semi-glacial conditions with cold temperatures and increased precipitation. Though their tools resemble that of earlier Paleoindians, Dalton practiced a broad, diverse subsistence similar to their Archaic descendents (Walker et al. 2001). They focused on large and small mammals, as well as some birds, turtle, and fish, adapting their strategy to individual ecotones (Ballenger 1998; Morse 1971a, 1971b, 1977). Dalton also appear to have buried their dead in cemeteries (Morse 1997).

On the western edge of the Plateau, the archaeological record at Rodgers Shelter indicates established populations of Dalton people on the Plateau by 10,500 ^{14}C yr B.P. (Kay 1982; McMillan and Klippel 1981; Wood and McMillan 1976). The Dalton component at Rodgers Shelter demonstrates that people survived in a forest edge environment primarily by hunting deer and other game and collecting nuts. A number of projectile points (n=85) and hafted cutting tools (n=627) suggest the occupation was specialized and geared toward hunting. In addition, the assemblage yielded specialized scraping tools and woodworking tools (adzes). An established Dalton population, demonstrated by sites like Rodgers Shelter, indicates a long period of human presence in the western Ozarks, possibly having begun in Early Paleoindian or pre-Clovis times.

Three theories on Dalton settlement patterns are available, all involving territories with a seasonal base camp around which population movement was based on resource access. Morse (1973) argues these resource territories were situated on river valleys or drainage basins. Schiffer (1975) views Dalton operating in hexagonal territories that allowed them to access multiple resource types. Others theorize that from the base camp, Dalton alternated use of satellite camps in different resource areas such as the Mississippi Alluvial Valley and the Ozark Escarpment (Price and Krakker 1975). These theories may all be accurate as they are based on analyses of archaeological sites within different geographic zones.

Dalton projectile points are often lanceolate with concave bases, more finely manufactured than Clovis or Folsom points, and though not fluted, exhibit grinding at the haft (Chapman 1975). Unlike the fluted points of earlier archaeological traditions, Dalton points are manufactured by knapping long parallel flakes from the lateral margin to the mid-line of the tool. Dalton points usually exhibit slightly different morphological characteristics, some being beveled and/or serrated, leading Walthall and Holley (1997) to argue that Dalton manufactured easily transportable tools that were designed for specific tasks. Other stone tools in Dalton assemblages include adzes for the working vegetal material, scrapers, engravers, and grinding stones, as well as bone and antler tools.

Dalton is well documented on the Ozark Plateau at sites like Rodgers Shelter (Wood and McMillan 1976), Graham Cave (Logan 1952), and the Arnold Research Cave (Shippee 1966). In some areas of the Plateau, Dalton is contemporaneous with Folsom and/or Early Archaic groups (O'Brien and Wood 1998). Within Ozark NSR, Dalton components exist at several sites, frequently found buried deep in alluvial sediment packages. Figure 3.5 shows the distribution of known Dalton components in Ozark NSR. These sites include, but are not limited to, Alley Mill (23SH159) (Lynott et al. 2006), Round Spring (23SH19), and Akers Ferry (23SH23) (Lynott 1989b).

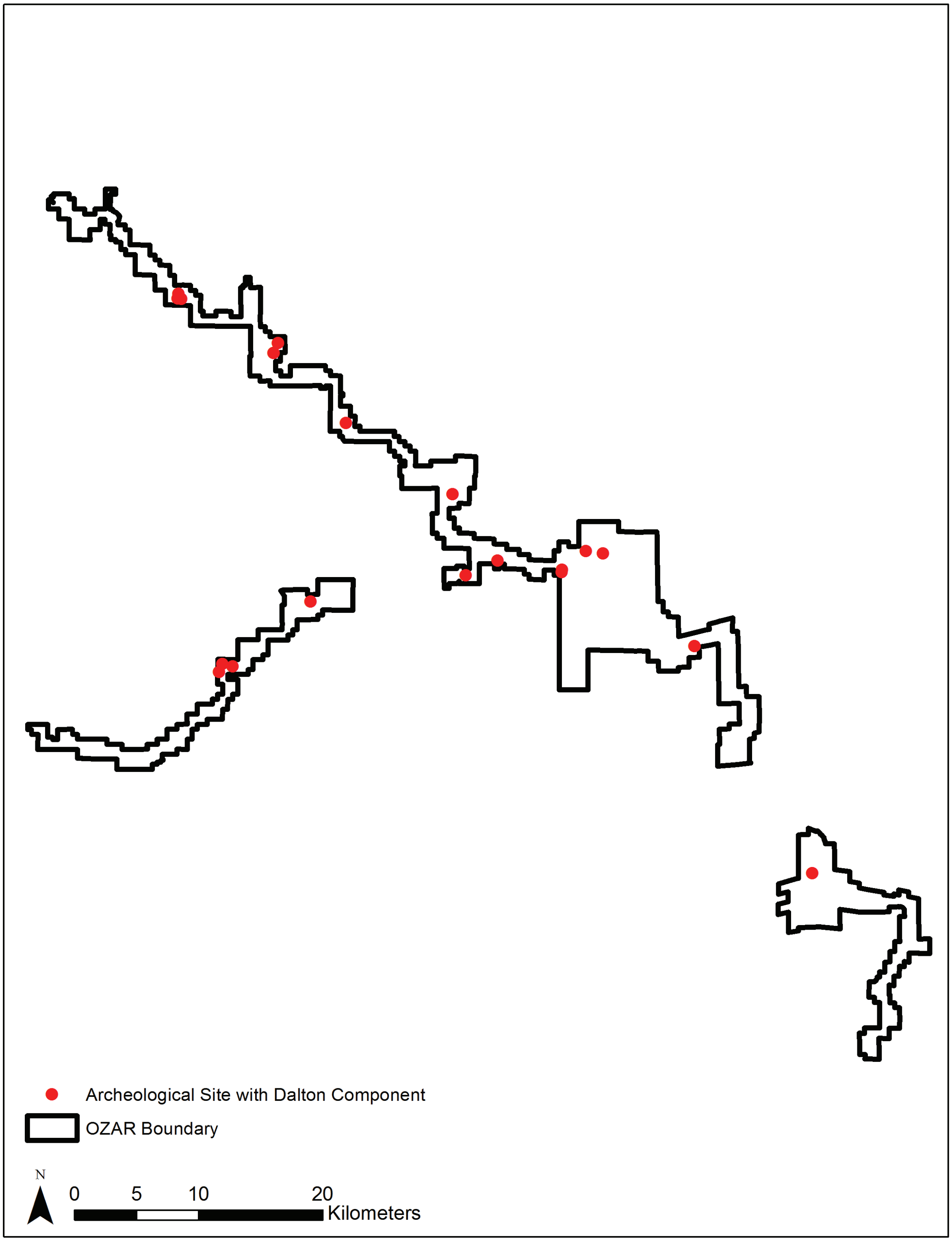

Figure 3.5. Archaeological sites in Ozark NSR that contain a Dalton component. Map by Amanda Davey, National Park Service, Midwest Archeological Center.

Archaic (10,000-3,000 ^{14}C yr B.P.)

Major environmental changes occurred during the Archaic, which forced humans to develop new subsistence and settlement strategies. The onset of the Altithermal, a return to warm temperatures and decreased precipitation, resulted from a shift in the air masses over the North American continent (O'Brien and Wood 1998; Smith 1984). As the Laurentide ice sheet retreated, the Arctic air mass, previously kept at bay by glacial ice, spread over the Great Plains, where it met with the Pacific air mass and established an easterly directional gradient at 10,000 ^{14}C yr B.P. The dominant vegetation type on the Ozark Plateau shifted from forests to prairies and parklands, thereby establishing the Prairie Peninsula (Delcourt and Delcourt 1984; Smith 1984; McMillan 1976).

To be successful in a new environment, Archaic people diversified their food sources and hunted a myriad of animals like white tailed deer, rabbit, small mammals, fish, birds, turtle, and other marine life, much as their Dalton predecessors had. They incorporated a variety of plants in their diets and the early stages of plant domestication were in place by the later part of this period. Archaic people implemented a specialized, more diverse tool kit than had previously been employed that included a variety of projectile points and stone tools for working wood and other vegetal materials. Projectile point forms are lanceolate, stemmed, and notched (side, corner, and basal). The atlatl was a tremendous technological advance in the Archaic hunters' tool kit, which aided spear propulsion (Webb 1981). Importantly, changes in subsistence and technology regionalized Archaic groups; distinct cultural entities, centered on specific resources or sets of resources, appeared during this period. Given the number and types of subsurface features and artifact types, Archaic period site function was specialized (O'Brien and Wood 1998, Raab et al. 1979).

Early Archaic (10,000-7,500 ^{14}C yr *B.P.).* Early Archaic life on the Ozark Plateau resembles that of Dalton. People migrated seasonally and practiced a mobile foraging economy (Anderson and Hanson 1988; O'Brien and Wood 1998). They moved between base and resource acquisition camps depending on the seasons and resource availability, mostly occupying lowland features such as low river terraces and floodplains. Early Archaic subsistence was as diverse as Dalton and they exploited a variety of terrestrial mammals—elsewhere in North America, Early Archaic people hunted marine mammals as well. Projectile point forms include Rice Lobed, Rice Contracting Stemmed, Rice Lanceolate, Hidden Valley Stemmed, and Graham Cave Notched (Chapman 1975). Price (1991) and Price and Hastings (1996) found evidence at Gnat Alley Woods (23CT351) that Rice Lobed points, thought to be temporally contemporaneous, were actually in use sequentially. They appeared during the Late Paleoindian period, replacing Dalton points, and became the predominant point type of the Early Archaic. Chapman (1975) refers to Early Archaic assemblages as belonging to the "Rice Complex."

Early Archaic occupations in Ozark NSR are identified at several sites, including Gnat Alley Woods (23CT351), Two Rivers (23SH101) (Klinger and Kandare 1987), Alley Mill (23SH159) (Lynott et al. 2006), and Big Goose Bay (23SH50) (Price et al. 1985). Like Dalton, Early Archaic assemblages are often buried deep in alluvium or colluvium, which limits their visibility. As such, Early Archaic sites are not particularly well documented in the Current River valley.

Middle Archaic (7,500-5,000 ^{14}C yr *B.P.).* During the latter part of the Altithermal, grasslands continued to expand on the Plateau (McMillan and Klippel 1981; Wood and McMillan 1976). This allowed Middle Archaic people to exploit parkland/savannah-adapted animals such as antelope, prairie chickens, bison, and deer (McMillan 1976). Information from the Salt River valley and other localities in the Midwest indicate hickory nut processing was of particular value in the Middle Archaic subsistence strategy (Dering 1999; Stafford et al. 2000; Yarnell and Black 1985d). Jakie Stemmed projectile points, smaller, side-notched points found across the Ozarks, and other artifact types were introduced during this time including groundstone celts, axes, bone and antler tools, and some textiles.

Periodic droughts on the Plateau contributed to vegetation destabilization and soil erosion in the uplands and sediment washed into stream channels with lowered water tables (Wood and McMillan 1976). Sabo et al. (1990) believe slope erosion may have exposed mineral deposits not previously available to the region's inhabitants. In the western Ozarks, drought-resistant tree species colonized floodplains but were areally limited (Wolverton 2002, 2005). During his excavations in the Salt River valley, Warren (1982) found evidence that the human population grew during the Middle Archaic. Because typically forest-dwelling animals were forced to congregate in stream valleys, population expansion was likely the result of easy resource access (Morse and Morse 1983; Price and Hastings 1996; Sabo et al. 1990).

In Ozark NSR, Middle Archaic deposits have been identified at Akers Ferry (23SH106), Gnat Alley Woods (23CT351), Two Rivers (23SH101), and Culpepper Cemetery (23SH168) among others. Middle Archaic sites are often found under alluvial or colluvial sediment packages.

Late Archaic (5,000-3,000 ^{14}C yr *B.P.).* As the Altithermal ended, forests expanded and subsistence resources were plentiful. Late Archaic archaeological deposits indicate an increase in population, site size, the number of features (particularly hearth features) and artifacts, as well as defined occupations surfaces (O'Brien and Wood 1998). The distribution of sites shows Late Archaic people settled on a wider range of landforms, occupying uplands and ridge tops in addition to floodplains and river terraces. In the Current River valley, Late Archaic sites are known from upland surface scatters, the plowzones of alluvial terraces, and in shallow buried alluvial contexts.

Late Archaic people moved between base and seasonal camps, though they were increasingly sedentary. The shift toward sedentism and settling a variety of geographic locations may be attributed to focus on *collecting* food sources, rather than *foraging* (Brown 1985). The number of site types increased during Late Archaic with the addition of lithic procurement and workshop locations and burial mound sites. Eventually, in combination with the effects of regionalization, Late Archaic people lived semi-permanently at central locations, travelling seasonally to the uplands and floodplains in order to exploit the resources available in those ecotones (Emerson et al. 2009).

Technological changes during the Late Archaic include a substantial increase in quartzite usage for stone tool manufacture (Price and Hastings 1996). Though projectile points like the Table Rock Stemmed, Stone Square stemmed, and Sedalia Lanceolate, remained in use, ground stone tools like manos, bannerstones, axes, gorgets, and beads, are found in the archaeological record of the Late Archaic. In addition, plant processing and utilization became more important, evidenced by the introduction of the Sedalia Digger (Chapman 1975). Long-distance trade networks were established during the Late Archaic and goods such as copper, galena, animal teeth, and shells were shuttled across the eastern Midwest (Yerkes 1987). In areas outside the Ozarks, people undertook earthen construction projects (e.g., Poverty Point (Ford and Webb 1956)).

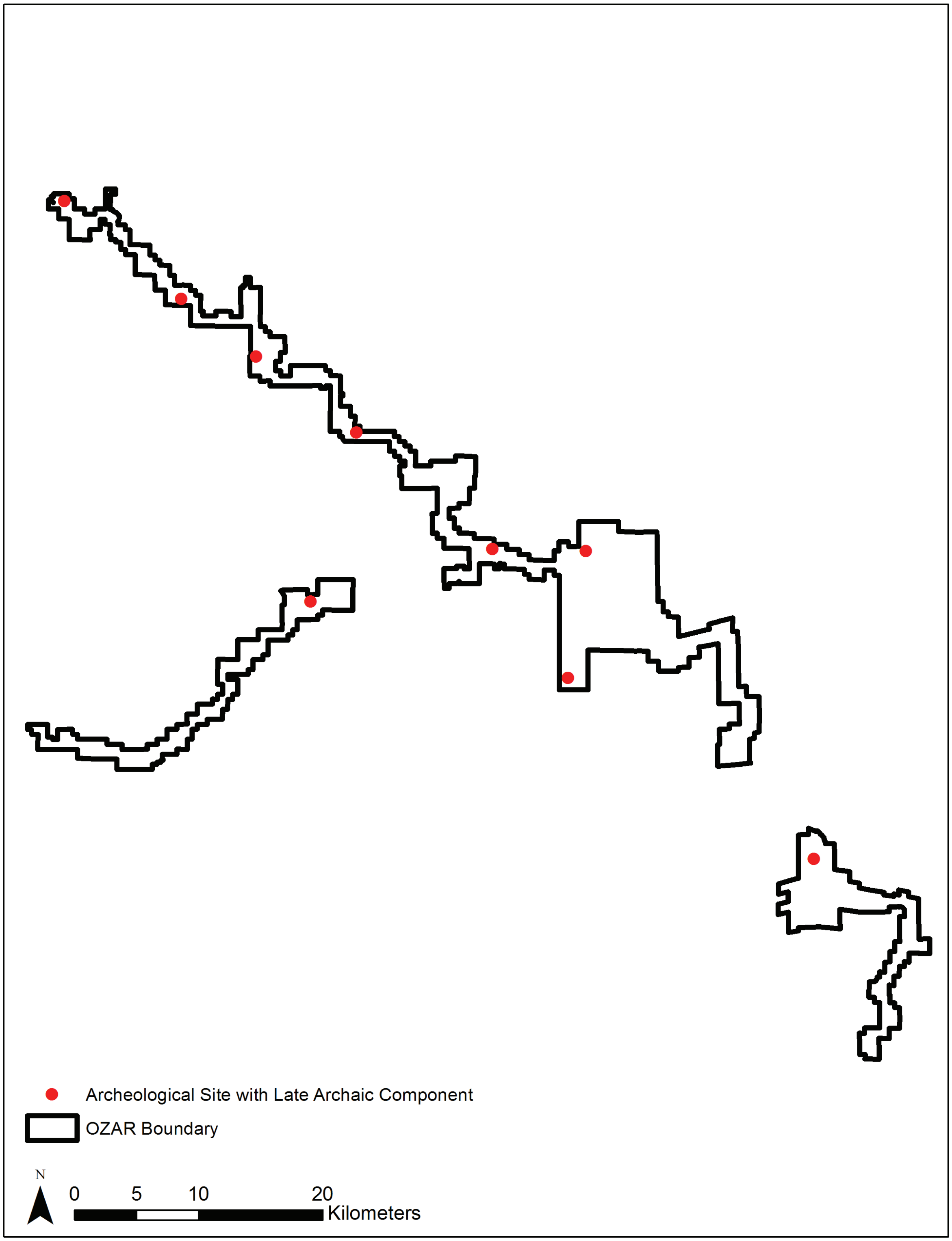

Figure 3.6 Archaeological sites in Ozark NSR with a Late Archaic component. Map by Amanda Davey, National Park Service, Midwest Archeological Center.

Late Archaic occupations within Ozark NSR are often defined by the presence of quartzite. These sites include Owls Bend (23SH81), Akers Ferry (23SH106), Old Eminence (23SH104), Two Rivers (23SH101), Alley Mill (23SH159), and Pulltite (23SH94). Figure 3.6 shows the distribution of Late Archaic sites in Ozark NSR.

Woodland (3,000-1,000 ^{14}C yr B.P.)

The transition from the Archaic to the Woodland periods was a particularly dry interval in the climate record (Wendland 1978). Termed the Sub-Atlantic climatic episode, the drought lasted from 2,850-1,750 ^{14}C yr B.P. and was followed by the Scandic episode, a period of even warmer temperatures and less precipitation, which occurred between 1,750 and 1,350 ^{14}C yr B.P. (Wendland 1978). Ceramic vessels, ideal for cooking and storing food and serving as ceremonial or symbolic pieces, became mainstream during the Woodland period. In fact, ceramic and projectile point types define Woodland period chronology. As O'Brien and Wood (1998:180) note, pottery is an exceptionally good chronological indicator because of the "change and the rapidity with which that change occurred—both in the way pottery was manufactured and in how it was decorated."

Though Archaic-style hunting and gathering made an important contribution to the diet, Woodland people shifted to plant domestication and horticulturalism. They also exploited seeds and some evidence of seed consumption is available from Ozark NSR (Lynott 1989a). With the change in subsistence strategy, Woodland people practiced an increasingly sedentary lifestyle while continuing to occupy river floodplains because of the rich resource base provided by this ecotone (O'Brien 1987). Woodland people extracted as many resources from the forests as they could (O'Brien and Wood 1998). Referring to this as "primary forest efficiency," Caldwell

(1958:ix) described the period as a time when the "East was economically on a plateau, continuing and developing an exploitive pattern which had been formulated during Archaic times."

The Woodland period set the stage for complex social changes active on local and regional scales. As early as the Early Woodland period in some regions, people built mounds and earthworks, prominently altering the cultural and physical. During the Middle Woodland period, a cross-continental exchange of sacred, ceremonial goods took place (Spielmann 2002). Tool technologies changed and by the Late Woodland period, the bow and arrow was in widespread use (Nassaney and Pyle 1999). By the end of the Woodland period, people practiced garden-plot horticulture, preparing subsequent people for full-scale agriculture.

Though the iconic symbols of the Woodland period—mounds and earthworks—are rare in the Ozarks, the occupation sites of a mostly sedentary population mark this present. Woodland people in the Ozarks participated in long-distance trade networks and split their subsistence efforts between hunting and gathering and plant cultivation.

Early Woodland (3,000-2,500 ^{14}C yr B.P.). Based on settlement patterns and subsistence strategies, the Early Woodland period was a continuation of the Late Archaic. People lived a semi-sedentary lifestyle, rotating between seasonal camps, and practiced hunting and gathering. Elsewhere in North America, people manufactured large-scale earthen monuments as part of mortuary and/or ceremonial practices, though evidence of these activities is not seen in the Ozarks.

Ceramics first came into use during the Early Woodland. In southeast Missouri, the diagnostic ceramic type of this time period is Tchula, a fine, sand-tempered pottery. The type site is in northeast Arkansas in the Eastern Lowlands. Tchula ceramics were in use from 2,500-

1,200 ^{14}C yr B.P. and are seen in the archaeological record across the region (Price 1986). Price (1986) argues that Tchula pottery is contemporaneous with and reminiscent of Early Woodland ceramics from the Mississippi Alluvial Valley. Sand-tempered pottery is present on the Ozark Plateau until approximately 1,000 ^{14}C yr B.P.

Early Woodland sites are difficult to identify and at Ozark NSR, only four are attributed to this time period. Because the Early Woodland was relatively short and many sites do not contain ceramic artifacts, many sites assigned to the Early Woodland period may actually be attributable to other time periods (i.e., Late Archaic-Early Woodland, Early Woodland-Middle Woodland) (Finney 2006). Possible Early Woodland sites at Ozark NSR are Torrential Rains (23DE41), Rocky Falls Cabin (23SH328), and unnamed sites 23SH70 and 23CT105.

Middle Woodland (2,500-1,600 ^{14}C yr B.P.). Middle Woodland people lived semi-sedentary lives and practiced an increasingly horticultural subsistence strategy. The number of ceramic styles in production surged during the Middle Woodland, which represent specific time periods. In and along the flanks of the Mississippi River Valley, Havana-style pottery was predominant, taking on myriad forms in terms of vessel shape, size, and temper and a variety of decorative motifs involving stamping, incising, and zoning (O'Brien and Wood 1998). These types are divided into Early, Middle, and Late Havana, based on their appearance in the archaeological record. In western Missouri, Havana sites are often termed Kansas City Hopewell, though O'Brien and Wood (1998) argue this terminology was used only because of its similarity to Havana pottery from Illinois, which was once considered Hopewell in association. Non-Havana pottery was also manufactured throughout Missouri, particularly in the southeastern floodplain counties. Undecorated pottery in this area is usually called Baytown (O'Brien and Wood 1998). It is important to note that Middle Woodland pottery has not been identified in the

Current River valley and this archaeological tradition is generally identified by projectile point style (Mark Lynott, personal communication, 2012).

Changes in manufacture and decorative style were concurrent with, and likely the result of, changes in subsistence focus during the Middle Woodland (O'Brien and Wood 1998). While faunal assemblages in Illinois show increased exploitation of aquatic resources, those in eastern Missouri demonstrate focus on upland faunal resources like deer until well into the Late Woodland. Middle Woodland sites in Illinois contain large amounts of seeds, particularly those that were oily and/or starchy. This trend is seen throughout the American Bottom and in the Mississippi Alluvial Valley.

In the Eastern Woodlands and parts of the Midwest, the Middle Woodland is marked by an increase in social complexity associated with monument building and activities related to ceremonialism. People engaged in elaborate burial practices, participated in long-distance trading or questing to obtain rare and sacred materials, and spent considerable time and energy moving sediment for the construction of earthen mounds and embankments walls. In the archaeological record, Middle Woodland-age earthen monuments and their associated assemblages of impressive sacred artifacts are attributed to the Hopewell Culture, whose epicenter spanned the Ohio, Illinois, and Mississippi river valleys (Dancey 2005; Pacheco 1996). Hopewell material culture exhibits complexity that suggests social and cultural dynamics were more multifaceted at this time than in previous periods of time. Importantly, earthworks served as landmarks for the remembering and acting out of cultural traditions, allowing the Hopewell to live across a wide geographic region while maintaining their cultural cohesiveness.

It is unsurprising that Middle Woodland sites in the Ozarks look vastly unlike their eastern counterparts given the strikingly different physical environment of the Ozarks from the wide, broad floodplains of the major river systems to the east. Finney (2006) believes environmental parameters may have kept people in the Ozarks from participating in the Hopewell Interaction Sphere and barred the transfer of that cultural information into the region. Near Ozark NSR, traditional Middle Woodland influences are limited to dentate-stamped ceramics, Snyders projectile points, burial mounds, and the presence of Eastern Agricultural Complex plants in floral assemblages (Finney 2006). Two sites within Ozark NSR are attributed to the Middle Woodland, 23SH114 and Pulltite (23SH122). Two sites (23CT105 and 23SH70) belong to both the Early Woodland/Middle Woodland periods and one (23SH73) can be attributed to the Middle Woodland/Late Woodland periods.

Late Woodland (1,600-1,000 ^{14}C yr B.P.). By the Late Woodland, the massive earthen monument projects, long distance movement of raw materials, and elaborate artifacts of the Middle Woodland had faded away. Often attributed to the so-called collapse of the Hopewell Interaction Sphere, social changes in the Late Woodland were likely caused when large, territorial settlement units were established (Seeman and Dancey 2000). Artifact manufacture was mostly homogenous across the Midwest and Eastern Woodlands, which Chapman (1980) argues was the result of regional stabilization. As O'Brien and Wood (1998:223) state,

> compared to Middle Woodland artifacts, those made during the Late Woodland period are rather unexciting. Gone are the fancy stamped and incised pottery designs, as are the items made of exotic raw materials that made their way across the Midwest between ca. A.D. 1 and A.D. 100. Even the projectile points made after A.D. 450 are less interesting from a visual standpoint than those made during the Middle Woodland period.

Due to an ever-increasing focus on horticulturalism, Late Woodland people occupied large sedentary villages, exploiting local resources to supplement their diet. Chapman (1980), however, believes an overall shift away from horticulturalism occurred with the advent of the bow and arrow and subsequent trend toward generalized hunting and gathering.

Diagnostic ceramics from the Late Woodland period include a sand-tempered pottery attributed to the Barnes tradition. Though found in Ozark NSR, Barnes tradition ceramics occur more often to the south and east of the Current River valley. The Maramec Spring phase, slightly later in time that the Barnes tradition, introduced limestone-tempered pottery to the region (Reeder 2000). Maramec Springs ceramics are often found in associated with Emergent Mississippian and Mississippian artifacts (Lynott 1991b; Lynott and Price 1994). There are seven Maramec Spring sites in Ozark NSR: Owls Bend (23SH10), Heartbreak Shelter (23DE7), Mouth of Rocky (23SH141), 23SH75, Shawnee Creek (23SH11), Limekiln Cave (23SH109), and Round Spring Grotto (23SH96). Other Late Woodland sites include Culpepper (23CT7), Chubb Hollow (23CT104), Gnat Alley Woods (23CT351), Two Rivers (23SH101), Pulltite (23SH122), and Alley Mill (23SH159).

Mississippian (1,250-400 ^{14}C yr B.P.)

Increased regional diversity lead to incredible cultural changes during the Mississippian period. After 1,200 ^{14}C yr B.P., shell replaced sand and limestone as the primary temper for ceramics and was the sole temper type using during the Mississippian. Ceramic vessel morphology shifted from conical jars, in use during the Woodland period, to globular jars in the early part of the Mississippian (O'Brien and Wood 1998). Projectile point morphology shifted toward small tools used principally as arrows or darts rather than spear points. Large permanent villages were established and occupied year-round, many surrounding civic centers where platform mounds and other earthworks were constructed (Chapman 1980).

During the Mississippian, climate change occurred with the end of the Scandic (1,750-1,350 ^{14}C yr B.P.), the Neo-Atlantic (1,350-850 ^{14}C yr B.P.), and the Pacific (850-450 ^{14}C yr B.P.) climatic episodes. Climate amelioration happened during the Neo-Atlantic episode, between the dry Scandic episode and even drier Pacific episode. These fluctuations in temperature and precipitation likely affected Mississippian horticulture and/or agriculture practices.

Mississippian people cultivated several plants belonging to the Eastern Agricultural Complex in addition to exploiting riverine resources by hunting and gathering. Maize agriculture became a major focus of subsistence activities during this period. Some researchers (Henning 1970) believe the onset of the Pacific episode during the Late Mississippian period caused large populations centers to break apart as prairie vegetation expanded east, took over agricultural fields, and became unmanageable for prehistoric farmers.

Most of the information currently available about the Mississippian period is derived from excavations in the Mississippi Alluvial Valley. Thus, a geographic bias is inherent in any discussion of the Mississippian. That said, two important differences exist between Mississippian people living in the Ozarks and those living farther east. First, in the Ozarks Mississippian people did not build the large platform mounds that are so often found at sites belonging to this period. A platform mound has been identified on the Eleven Point River in Eleven Point National Forest (Mark Lynott, personal communication, 2010), but its time of construction is unknown. Second, Mississippian people living in the Ozarks did not practice maize agriculture.

It is probable that Mississippian people living in the river valleys of the eastern Ozarks were under Cahokian influence to some degree. Emerson and Hughes (2001) argue that certain material types used to make wares like ceramic vessels and effigy pipes at Cahokia were sourced from the Ozarks. These materials include clay, hematite, limonite, galena, and chert. While Cahokia may have acquired raw materials from the Ozarks, Lynott (2003) notes that this does not necessarily mean Cahokia exerted control over the region in such a way as to leave the eastern Ozarks a "cultural backwater."

Emergent/Early Mississippian (1,250-800 ^{14}C yr B.P.). The Emergent Mississippian period, or as some researchers prefer, the Terminal Late Woodland period (Fortier and McElrath 2002), is marked by the introduction of shell-tempered pottery. Shell-tempered pottery was historically believed to have come into use between 1,000 and 900 ^{14}C yr B.P.. It has since been identified in archaeological contexts as early as 1,300 ^{14}C yr B.P., granting it the label of "Emergent" Mississippian (Lynott 1986; Lynott and Price 1989; Lynott, Monk, and Price 1984; Lynott et al. 1985; Lynott et al. 1986). Small triangular projectile points, platform mounds, and maize farming have also been identified in Emergent Mississippian contexts.

Incipient Mississippian cultural traits occur across the Mississippi Alluvial Valley and onto the Ozark Plateau. In addition to shell-tempered pottery, the Emergent Mississippian archaeological record in the Ozarks contains corner-notched projectile points and Scallorn points, which are small triangular points with expanding stems. Lynott (1991c) believes the shift to smaller projectile points is due to a change in economic focus, from a strictly hunting and gathering subsistence strategy to one that focused on horticulture and, outside the Ozarks, corn agriculture. On the Plateau, people lived semi-sedentary lives, inhabiting small river terrace settlements that were focused on hunting, gathering, and cultivating plants belonging to the Eastern Agricultural Complex (Lynott 1988, 1991c; Lynott et al. 1986). Maize was present on the Plateau at this time, but a study of stable carbon isotopes in human bones conducted by

Thomas Boutton concluded that it did not comprise a significant portion of the diet until 1,050-950 ^{14}C yr B.P. (Boutton et al. 1991; Lynott et al. 1986; Lynott et al. 1996).

Lynott et al. (2000) discovered through INAA that clays used to make various types of pottery from Akers Ferry (23SH23) and Two Rivers (23SH101) came from a variety of locations. They also discovered that a variety of Emergent Mississippian pottery types, once thought to be chronologically distinct, are contemporaneous (Barnes, Baytown, Maramec Spring, Owls Bend, and Varney). Lynott et al. also found that for much of the Late Woodland and Early Mississippian periods, there was major movement of ceramics and ceramic materials between the Western Lowlands and the Eastern Ozarks. The authors note, "some Varney ceramics are being made from Eastern Ozark hill clays and used at sites in the Eastern Ozarks, while other Varney ceramics are being made from Western Lowland clays and imported into the Eastern Ozarks" (Lynott et al. 2000:121).

Lynott et al.'s findings demonstrate that while people living in the Ozarks did not manufacture the same artifact types or earthen architecture as Mississippians farther east, they did operate within the larger Emergent Mississippian cultural system. During the Varney Tradition, the Naylor pottery style was prevalent. Its distribution in the archaeological record indicates people moved between the Mississippi Alluvial Valley and the Ozark Plateau. In fact, Early Mississippian sites in the Ozarks may represent temporary campsites utilized by people traveling from the Mississippi Alluvial Valley (Finney 2006). Naylor ceramics take many forms: ovoid or circular disks, pipes, jars, bowls, and pans (Lynott 1989a). Another ceramic type, Owls Bend flat-bottomed jars, indicates an influx of Coles Creek culture ceramic wares into the Ozarks from the Plum Bayou complex of northeastern Arkansas (Finney 2006; Morse and Morse 1996).

Many sites at Ozark NSR contain Emergent Mississippian components but excavations have only been conducted at Akers Ferry (23SH106), Chubb Hollow (23CT104), Gooseneck (23CT54), Isaac Kelly (23CT111), Owls Bends (23SH10), Shawnee Creek (23SH11), and Two Rivers (23SH101). Shawnee Creek (23SH11) contains earthen architecture in the form of a wall trench structure and other pit features and represents a small farmstead (Lynott and Price 1989). Bozell (1987) analyzed the faunal remains from Shawnee Creek and found the occupants exploited the same resources as Emergent Mississippian people (deer, turkey, squirrel, beaver, and raccoon as well as riverine resources like turtle).

Middle (800-600 ^{14}C yr B.P.) and Late (600 ^{14}C yr B.P.-Contact) Mississippian. During the Middle and Late Mississippian periods, the population boomed and civic-ceremonial centers gained considerable social and political control (Chapman 1980). The Powers Phase erupted in the Mississippi Alluvial valley between 750 and 700 ^{14}C yr B.P., lasting only 1-2 generations. During this period, people lived within a four-tiered settlement hierarchy that included mound centers, villages, hamlets, farmsteads, and specialized activity centers, many of which were palisaded. At the end of the Powers Phase, approximately 600 ^{14}C yr B.P., Mississippian communities in the eastern Ozarks and large portions of the Mississippi Alluvial Valley were effectively abandoned. In the areas not abandoned, significant increases in population occurred at civic centers, evidence of population nucleation (Morse and Morse 1983:271).

After the Powers Phase, pottery styles change from relatively plain to highly artistic with obvious Mississippian symbolism (Lynott 2012, personal communication). Ceramic vessel forms expanded to include jars, bowls, and bottles and were decorated with incising, punctuating, noding, embossing, slipping, engraving, appliquéing, and painting (O’Brien and Wood 1998). A wide variety of projectile point types were utilized during this period. The

Nodena projectile point, whose manufacture began around 600 ^{14}C yr B.P., was produced throughout the Middle and Late Mississippian periods and the Madison projectile point, common in the vicinity of Cahokia, was manufactured for a number of years after 1,100 ^{14}C yr B.P. and (O'Brien and Wood 1998). Other diagnostic artifacts include shaft straighteners, pottery trowels, chert blades, celts, hoes, and ceramic effigy figurines.

Middle-Late Mississippian subsurface sites have not been identified in the eastern Ozarks. Some isolated surface finds can be attributed to the Late Mississippian and Protohistoric periods (Lafferty and Price 1996).

Oneota (1,000-350 ^{14}C yr B.P.)

Though not found in the eastern Ozarks, the cultural remains of the Oneota Tradition have been found elsewhere on the Ozark Plateau. Oneota originated in the Upper Midwest and is roughly contemporaneous with the Mississippian period. During the Pacific climatic episode, Oneota people migrated south and west, perhaps because drier conditions shortened the growing season and pushed the threshold of the Prairie Peninsula further east and north (Gibbon 1972). This move may also have been catalyzed by dwindling Mississippian power and influence (Gibbon 1972). As they spread across the Midwest, Oneota sites became smaller and increasingly homogeneous, probably as a result of these environmental and social conditions. Because similar pottery types occur across the Midwest, it seems that Oneota people interacted with one another across the Midwest, probably as part of the catlinite trade.

Oneota people practiced agriculture (mostly maize, squash, and beans) and some hunting and gathering. Diagnostic Oneota artifacts include catlinite pipes and tablets, small triangular projectile points (Madison Type), groundstone tools (e.g., sandstone shaft smoothers celts, and manos), bone and antler tools, as well as shell-tempered ceramics with incised or thumb-imprint decorations. Of particular popularity were ceramic globular jars, which were decorated with a variety of motifs. As mentioned above, the distribution of Oneota cultural material across the Midwest and into the Central Plains is indicative of a well-established trade network (Tiffany 2000).

<u>Historic Period</u>

Historic Native Americans. The Historic period in the Ozarks began at approximately AD 1700. Chapman (1980) believes the dispersal of large population centers during the Late Mississippian was the catalyst that broke the Oneota into the Missouri and Osage tribes. See O'Brien and Wood (1998:347) for a discussion on the origin and movements of early Historic Native American groups in Missouri.

The first recorded interaction between the Osage and Europeans probably occurred in 1719. According to Finney (2006), the Osage sold the parcel of land containing what is now Ozark NSR to the United States government on November 10, 1808 during a transaction that took place at Fort Clark. By 1825, the Osage had ceded the rest of their lands in Missouri, moving into Oklahoma and Kansas.

In 1784, the Shawnee and Delaware tribes were forcefully removed to southeast Missouri, the Shawnee from southern Ohio, Tennessee, and Kentucky and the Delaware from Pennsylvania and New Jersey. This occurred after the United States government failed to honor treaties created with these and other Native American groups. The Spanish government provided the Shawnee and Delaware with lands in the area of Cape Girardeau (Lynott 1981). These tribes later ceded their land to the U.S. government in treaties signed in 1815 and 1825 and moved west, settling for a few years in the Jacks Fork and Current River valleys (Price et al. 1983).

Other Native American groups who occupied the area include the Kickapoo and Cherokee (Finney 2006). After the War of 1812, the Kickapoo took a land offer in the western Ozarks. In 1828, during the Trail of Tears, members of the Cherokee Tribe moved through the area en route to Oklahoma and Kansas. A number of other Native and Euroamerican groups had made their way to the Missouri Ozarks by this time, making temporary or semi-permanent settlements and subsisting through hunting and agriculture. Because the material culture of the time was largely European, it is often difficult to distinguish the cultural origin of these transient occupations in the archaeological record.

Historic Euroamericans. The Euroamerican occupation of the Ozarks was not documented until after the Louisiana Purchase in 1803, when miners moved to the region. Successful copper mining occurred to the northeast of the Current River valley, in Carter and Shannon counties, although a copper mine operation was undertaken on Big Shawnee Creek as well (Finney 2006). Lead mining took place in Washington County to the northeast.

The majority of early settlers in the Ozarks were of Scots-Irish descent. Prior to the Civil War, people from Kentucky, Tennessee, Virginia, and North Carolina settled in the Ozarks in small towns and farmsteads where they cultivated commercial crops (Finney 2006). Grist, powder, and saw mills operated along the Current River and some of its larger tributaries (Lynott et al. 2006). During the Civil War, part of the population moved out of the Ozarks because of a lack of law enforcement. After the war ended, people slowly returned to the Ozarks, many of them from surrounding Midwestern states like Illinois and Indiana and as far east as New York (Finney 2006).

Large-scale logging of short-leaf pine and hardwood tree species began in the 1880s and continued until the 1920s (Finney 2006). Subsequently, railroads were built in the region. Once the hillsides had been clear-cut and the timber industry failed, massive depopulation occurred as the number of available jobs dropped. In the 1920s, government programs like the Works Progress Administration and Civilian Conservation Corps brought in jobs for young men, which alleviated the economic vacuum left by the logging industry. After World War II, improved roadways, telephones, and radios became commonplace throughout the Ozarks. By the 1960s, the population was on the rise.

Many of the Euroamerican sites in Ozark NSR are farmsteads or mills. Old Eminence (23SH104) was excavated by James and Cynthia Price in the early 1980s (Price et al. 1983)—the original town of Eminence burned down during the Civil War and was rebuilt on its current site in 1867. Farmsteads include the Nichols farm (23DE73), Klepzig-Brandt farm (23SH148), and Chilton-Williams farm complex (23SH152). The Alley Spring Roller Mill (23SH159) and the Phillips Bay Mill (23CT235) are both listed on the National Register of Historic Places.

Summary

Decades of archaeological research at Ozark NSR, and in the Ozarks in general, has provided a substantial foundation for present and future investigations. Through the work of a number of researchers, we know the subsistence and settlement strategies people used in their occupation of the region from the Pleistocene/Holocene transition to historic times. We also have available a vast collection of cultural material that demonstrates technological and morphological artifact change through time, which occurred alongside broad environmental and cultural change.

In this chapter, I provided the archaeological history of human occupation in the Current River valley. This information is critical to exploration of the river valley's evolution in a variety of ways. Environmental research provides context for archaeological research and vice versa. In this case, archaeology has provided us an understanding of where people were living and at what time and, possibly, why they were living there. In this dissertation, as I explore the landform sediment packages that have geologic potential for cultural deposits, the archaeological background allows for a better understanding of landform use in particular, as well as post-depositional processes that affected and continue to affect archaeological sites and their preservation.

CHAPTER 4

METHODS

Data collection at Ozark NSR was driven primarily by the need to understand past environmental conditions and determine the age of buried surfaces in terrace fills in order to reach this dissertation's broader goals and objectives. Field methodology was dependent upon access to terraces, the nature of archaeological sites previously recorded at each locality, and general logistical considerations. A variety of laboratory analyses were performed on samples from cores collected at Ozark NSR in order to assess alluvial stratigraphy, chemostratigraphy, and geochronology at each locality.

Field Methods

The initial phase of the field investigation involved reconnaissance of the Current River valley. During a boat-based survey, 1:24,000 7.5" USGS topographic quadrangles and terrace maps drawn by Roger Saucier were used to field check landforms and record cutbanks. Following the reconnaissance, it was determined that cutbanks exposed only T-1 fills and many were dangerous due to undercutting by a recent flood. Therefore, all soil-stratigraphic data was obtained from 6.5 cm-diameter cores collected with a Giddings hydraulic soil probe. Coring locations were chosen based on ease of access with the coring rig. Additionally, site selection was influenced by the results of previous archaeological work at nearby sites. Sampling depth was controlled by buried gravel deposits and ranged from 2-6 m below surface. Each core was briefly described before it was wrapped in cellophane and aluminum foil and boxed. Core locations were recorded using Geographic Positioning Systems (GPS) coordinates. A total of 12 cores were collected from seven localities, eight for geomorphological analysis and four for OSL dating.

Laboratory Methods

Detailed pedological descriptions were made for each core utilizing a standard methodology and nomenclature (Soil Survey Division Staff 1993; Birkeland 1999). Soils were incorporated in the stratigraphic framework of each core described. According to Birkeland (1999), soils comprise an important element of Quaternary landscape evolution. Buried soils are key when searching for past human habitation sites. Soils were numbered consecutively from the top down, Soil 1 being the modern surface soil.

Two sample sets were collected down the length of each core, one for stable carbon isotope analysis and another for particle-size distribution (PSD) analysis. Stable carbon isotope samples of approximately 10 g were obtained at 5 cm intervals from the surface to the bottom of each core. PSD samples of 30-50 g were taken from every horizon and homogenized. Those portions of the core that were in contact with the core barrel were avoided during sampling.

<u>Horizon Development Indices</u>

Five properties from Appendix B were used to quantify horizon development, including rubification, color lightening, texture (clay %), structure, and clay films in the pedon described at each study locality. These properties were combined into a Horizon Development Index (HDI) in order to relate soil development to the geomorphic position of each LSA. To calculate the indices, a procedure similar to that developed by Harden and Taylor (1983) for profile development indices was used. Table 4.1 outlines the scoring system for each property. Each property was scored and then normalized to the highest possible score for that property. Then, the average of the four properties was calculated for each horizon, resulting in an HDI value. The HDI values were then plotted with depth, using the midpoint of each horizon. Texture was included in the HDI only for those localities where horizons were sampled for PSD (Akers Ferry, the T-1 at Round Spring, Ramsey Field, Pin Oak, Chubb Hollow).

Table 4.1. Quantification of horizon properties for calculating horizon morphology index (HDI) values.

Property	Quantification†				
Rubification					
Points	10	20			
Color	10YR	7.5YR			
Highest Possible Score	20				
Color Lightening					
Points	0	10	20	30	40
Value	2	3	4	5	6
Highest Possible Score	40				
Texture (Clay %)					
Highest Possible Score	24				
Stucture					
Points	0	10	20	30	
Grade	sg	wk	mod		
Type		gr	sbk	pr	
Highest Possible Score	50				
Clay Films					
Points	0	10	20	30	
Amount	none	few	common	many	
Distinctness		faint	distinct		
Highest Possible Score	60				

†sg = single grain; wk = weak; mod = moderate; gr = granular; sbk = subangular blocky; pr = prismatic

Stable Carbon Isotope ($\delta^{13}C$) Analysis

Sample preparation for stable carbon isotope analysis of organic carbon was conducted at the Kansas Geological Survey using a procedure adapted by Haj (2007). Samples were dried at 46°C and ground and homogenized using a ceramic mortar and pestle. When necessary, samples were ground with a Fritsch Pulverisette. During the decarbonation process, approximately 1g of sample was weighed out into plastic centrifuge tubes. Ten milliliters of 0.5N hydrochloric acid solution were added to each sample. When the reaction was complete, acidity was confirmed with pH strips. No sample required more than one acidification before being centrifuged and the waste liquid decanted. After acidification, samples were rinsed with 40 mL of distilled water, centrifuged, and the waste liquid decanted.

The rinse process was repeated three additional times. After drying at 46°C, samples were removed from the centrifuge tubes, pulverized with a ruby mortar and pestle, and transferred to glass vials. The above process of decarbonation has no effect on the $\delta^{13}C$ values of the samples (Midwood and Boutton 1998).

After decarbonation, stable carbon isotope analysis was conducted at the Keck Paleoenvironmental and Environmental Stable Isotope Laboratory at the University of Kansas. Carbon content was estimated based on sample color. The amount of sample used in the analysis, ranging from 3-20 mg, was determined by carbon content before being weighed out into a tin capsule. Each capsule was combusted in a Costech ECS4010 elemental analyzer together with a ThermoFinnigan MAT253 isotope ratio mass spectrometer. In each set of analyses, National Institute of Standards and Testing standards were used to calibrate $\delta^{13}C$ values. These standards include USGS-24 (graphite) #8541, IAEA-600 (Caffeine), and ANU (sucrose) #8542. In addition, DORM-2 (dogfish muscle) was used as a pre-calibrated internal standard. The precision of reported $\delta^{13}C$ values is usually greater than 0.2%.

Particle-Size Distribution Analysis

PSD analysis was completed at the Geoarchaeology and Paleoenvironment Laboratory at the Kansas Geological Survey through the pipet method, following Soil Survey Laboratory Methods Manual (2004). Samples were dried at 46°C, homogenized using a ceramic mortar and pestle, and passed through a < 2 mm sieve. Ten grams of sample were oven dried and weighed. Samples with organic carbon content of > 1.72% were pretreated to remove organic matter. A sodium hexametaphosphate solution dispersed the sample, which was then mechanically shaken. Wet sieving removed the sand fraction from the suspension, which was then fractionated through dry sieving. Twenty-five milliliter silt and clay aliquots were removed from the remaining suspension with a pipet, oven dried, and weighed. The results are presented as weight percentages, totaling 100% of the <2 mm fraction.

Optically Stimulated Luminescence Dating

Small aliquot OSL dating was conducted at the Luminescence Geochronology Laboratory at the University of Nebraska-Lincoln using the procedure outlined in Werner et al. (2011). Separate cores were collected from four localities for this analysis: Akers Ferry, Round Spring (T-1 terrace), Ramsey Field, and Chubb Hollow. From within these cores, samples were selected from particular depths to ensure sand content and target buried surfaces. The outer several millimeters of core were removed from each sample to eliminate sediments exposed to light during coring. After moisture content was determined, samples were wet sieved to obtain the 150+ μm and 90-150 μm fractions, mixed with hydrochloric acid to remove carbonates, and then dried. Heavy minerals were removed by floting each sample in sodium polytungstate. A subsequent hydrofluoric acid treatment removed feldspars. Samples were sieved again to obtain the 90-125 μm fraction. Silicon spray was used to adhere grains to aluminum discs within a 5 mm mask. A Risø DA-15 TL/OSL reader was used to obtain preheat plateau temperatures and then analyze the aliquots for optical age. OSL ages are reported in years before AD 2002, designated as B.P.

Radiocarbon Dating

One radiocarbon age was determined on charcoal by the Isotope Geochemistry Section at the Illinois State Geological Survey. The sample was decalcified and assayed using atomic mass spectrometry. The ^{14}C age was $\delta^{13}C$ corrected and is reported in radiocarbon years before present (^{14}C yr B.P.).

CHAPTER 5

ALLUVIAL STRATIGRAPHY, CHEMOSTRATIGRAPHY, AND GEOCHRONOLOGY OF VALLEY FILLS IN THE CURRENT RIVER VALLEY

In this chapter, I present the results of investigations at the eight study localities, grouped according to LSA. I begin by providing background on each analytical technique. Then, for each locality, I describe its geographic location, geomorphic setting, and archaeological context (Figure 5.1). Next, I review the alluvial stratigraphy, chemostratigraphy, and geochronology. Soil profile descriptions and particle-size data are presented in appendices A and B, respectively. Stable carbon isotope data are presented in Appendix C, and OSL ages are provided in Appendix D.

Alluvial Stratigraphy and Chronology

Soil stratigraphy is key to understanding the site formation processes of archaeological sites (Birkeland 1999; Ferring 1992; Holliday 1992). Stratigraphy can be used to construct soil chronosequences, which are sets of genetically related soils that evolved under similar vegetative, topographic, and climatic conditions through time (Harden 1982). Hence, chronosequences are indicators of time, stability, and climate (Huggett 1998).

Soils are products of diagenesis and require time to develop. Therefore, soils factor into chronosequence studies (Harden 1982; Harden and Taylor 1983; Harden 1990). Quantitative soil development indices, like those developed in this study, reflect the magnitude of soil development (i.e., the presence of a Bt horizon vs. a Bw horizon, evidence for clay illuviation, etc.).

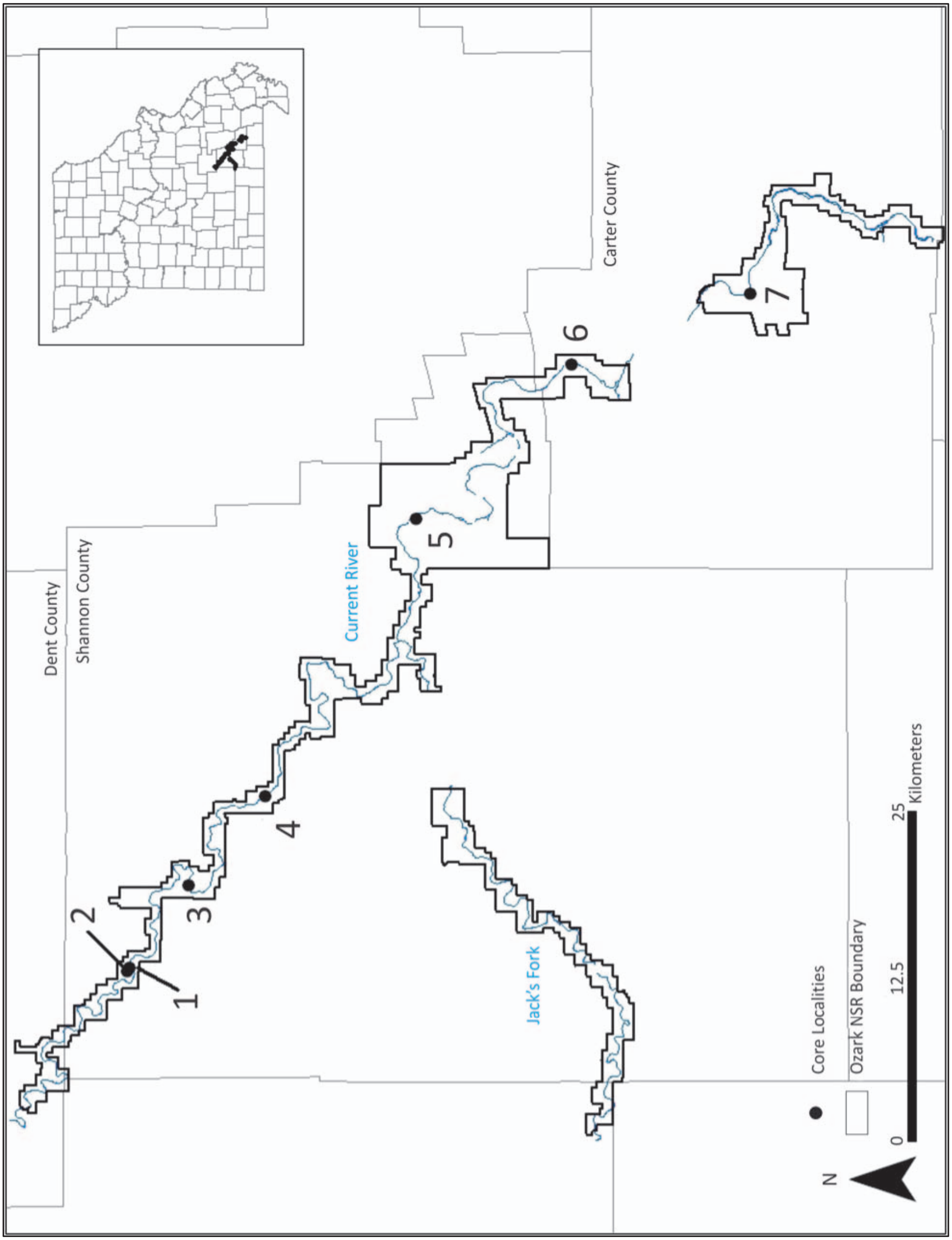

Figure 5.1. Map of the study localities: 1, Akers Ferry; 2, Gladden Creek; 3, Pulltite; 4, Round Spring; 5, Ramsey Field; 6, Pin Oak; 7, Chubb Hollow.

PSD analysis was conducted on cores from Akers Ferry, Round Spring (T-1), Ramsey Field, Pin Oak, and Chubb Hollow to 1) characterize the lithology of LSAs, and 2) determine of the magnitude of soil development, particularly illuviation based on clay content. Lithostratigraphic units have not been identified in the eastern Ozarks. Haj (2007) argues that a lithostratigraphic nomenclature developed for late-Quaternary alluvium in the western Ozarks most likely can be applied to the entire Ozark Plateau. He observed three lithostratigraphic units in the Bear Creek valley, which have also been documented in the Pomme de Terre River valley: the Boney Spring Formation, the Pippins Cemetery Member, and the Rogers Shelter Member (originally identified by Brackenridge [1981]). The late-Quaternary alluvial deposits in the Current River valley are sandier than the lithostratigraphic units in the Pomme de Terre river valley, but there are some similarities. Additional research is needed to correlate lithostratigraphic units across the Ozark Plateau.

Also of importance, in the 1980s, Saucier produced detailed, hand-drawn maps of terrace fills in Ozark NSR that are overlain on 1:24,000 7.5" USGS topographic quadrangles. His maps are helpful to park managers and researchers for easy identification of terraces. During my study, however, I determined that Saucier's designations are not always correct. His maps were used to guide the search for suitable landforms to include in the analysis, but in two cases—the T-2 at Round Spring and T-3 at Pin Oak, which are described below—I was able to refine his map and redefine those landforms.

Stable Carbon Isotopes

Stable carbon isotope (^{13}C) values determined on soil organic matter (SOM) from stratigraphic sequences provide information about past environments (e.g., Cyr et al. 2011; Haj

2007; Hajic et al. 2007; Nordt 2001). These values indicate vegetation change through time and, therefore, climatic fluctuations (Boutton 1996; Boutton et al. 1998). All plants discriminate $^{13}CO_2$ from the atmosphere. Depending on their photosynthetic pathways, however, plants differentially fractionate ^{13}C and ^{12}C carbon isotopes (Boutton 1996; Boutton et al. 1998; O'Leary 1988; Vogel 1980). C_3 plants, such as trees, shrubs, herbs, and cool season prairie grasses, discriminate the heavier isotope, ^{13}C. These plants fix carbon from the atmosphere through a process of enzyme ribulose biphosphate carboxylase (O'Leary 1988). C_4 plants, including warm season prairie grasses and other plants adapted to warm and arid environments, discriminate the lighter ^{12}C isotope. With C_4 plants, carbon is fixed from the atmosphere via carboxylation of phosphoenolpyruvate (O'Leary 1988). Crassulacean acid metabolism (CAM) plants (succulents) fix carbon in the same way as C_4 plants. Stable carbon isotope ratios measure the contribution of C_3, C_4, and CAM plants to community net primary productivity (Boutton 1996; Boutton et al. 1998; Farquhar et al. 1989).

The stable carbon isotope ratio of $^{13}C/^{12}C$ in SOM compared with a known standard is expressed in parts per million (‰) as a $\delta^{13}C$ value (Vogel 1980). SOM from plant communities dominated by C_3 plants generally produce $\delta^{13}C$ values between -32‰ and -22‰. By contrast, SOM from C_4-dominant communities produce $\delta^{13}C$ values between -17‰ to -9‰. CAM plants produce $\delta^{13}C$ values similar to C_4 plants.

Shifts in species composition within a vegetation community alter the isotopic composition of SOM, which serves as a proxy for climate change. Over time, the $\delta^{13}C$ value of SOM decreases as organic carbon (OC) from the previous vegetation regime decays and is replaced by OC from the new plant community. The duration of this process is determined by the soil turnover rate (Boutton 1996; Boutton et al. 1998). As such, changes in dominant plant communities can be measured by assessing shifts in $\delta^{13}C$ values through the soil profile. The biological structure of C_4 plants provides them high water-use efficiency, thereby increasing their productivity in arid, warm environments (Haj 2007; O'Leary 1988). Changes in the contribution of C_4 plants to SOM provide strong indications of climatic change as warmer and/or drier conditions support the propagation of C_4 species in the plant community (Boutton et al. 1998).

While changes in the influence of C_3 and C_4 plants are most often used to explain variation in the isotopic composition of SOM with depth and/or between buried soils, other processes can explain the range of values presented by $\delta^{13}C$ data (Cyr et al. 2011). Krull and Skjemstad (2003) list these as:

1) the Suess effect, by which atmospheric ^{13}C has decreased by 1.3‰ since the Industrial Revolution (mid-1700s),
2) ^{13}C fractionation and addition caused by soil microorganisms as SOM decomposes,
3) changes in environmental conditions and associated stress, and
4) the downward movement of intact soluble carbon fractions.

Changes of up to 1‰ may be the product of environmental stress (Ehleringer et al. 2000). According to Krull and Skjemstad (2003) and Krull et al. (2005), natural soil processes are responsible for $\delta^{13}C$ value ranges within the magnitude of 1-3‰. Ranges of greater than 3‰ are attributable to actual change in C_3 and C_4 vegetation communities.

Incursions of the prairie-forest ecotone occur in the western Ozarks as early as 12,000 ^{14}C yr B.P. (King and Lindsey 1976) and again in the early and middle Holocene (Haj 2007). Fluctuations of the eastern and southern limits of the prairie-forest ecotone are uncertain for the late Quaternary (Denniston et al. 1999; McMillan and Klippel 1981; Williams et al. 2009). In the eastern Ozarks, pollen records from Cupola Pond suggest an oak-hickory savanna was in place by 10,000 ^{14}C yr B.P., just before the onset of the Altithermal (Delcourt et al. 1997, 1999; Jones 2010; Smith 1984). Cave speleothem records also indicate oak-hickory savanna at 10,000 ^{14}C yr B.P. (Denniston et al. 2000). As the Altithermal strengthened, savanna continued to spread east until climate amelioration at approximately 6,000 ^{14}C yr B.P. followed by a shift to oak-shortleaf pine forest.

Prior to my study, a stable carbon isotope record derived from SOM had not yet been established for late-Quaternary alluvial soils in the eastern Ozarks. Concerns have been raised about how much information this analysis could provide because Ozark NSR is in the core of the forested Ozark Plateau. Vegetation may not have opened up enough during the period of record to be seen in the $\delta^{13}C$ record. This concern, however, had not been tested. Therefore, $\delta^{13}C$ values were determined on SOM in stratigraphic sequences at all of my study sites.

Geochronology

OSL dating of sediments, a technique developed by Huntley et al. (1985), directly dates the luminescence signal of mineral grains by providing an estimate of burial time. When mineral grains in sediments are exposed to sunlight, their luminescence signals are zeroed or bleached. Bleaching occurs when light attenuating through the water column exposes suspended sediments to solar radiation. After burial, the luminescence signal in these grains builds again with exposure to atmospheric radiation (Huntley 1985; Rittenour 2008; Wallinga 2002). The longer grains stay buried, the stronger and more easily measured the signal becomes. OSL ages are derived by dividing the amount of radiation present in the sample by the annual radiation dose in the environment surrounding the sample (Rittenour 2008; Wallinga 2002). The sample's radiation content is called the equivalent dose (D_e). Sample size can be either large- (> 100 grains) or small-aliquot (< 100 grains) or single grain.

Three problems may compromise OSL dating: incomplete bleaching, post-depositional mixing, and dose-rate heterogeneity (Rittenour 2008; Wallinga 2002). Partial zeroing of the luminescence signal in sediments during water transport is perhaps the biggest problem facing OSL dating, particularly in alluvium. OSL ages on partially bleached sediments are older than the actual age of sediment burial. Environmental factors contributing to partial bleaching include large concentrations of suspended sediment, water depth, transport distance, and transportation mode (suspension, saltation, bedload) (Rittenour 2008). Methods exist to identify the amount of bleaching and control for its influence on D_e values and associated age estimates. They include utilizing components of the quartz OSL signal to date the most light sensitive OSL traps (Rittenour 2008; Jain et al. 2005) and single grain dating techniques (Duller et al. 1999; Duller 2000, 2008). Single grain analysis results in a large distribution of D_e values, and statistical methods have been developed to isolate the grains representing true burial age. Rittenour (2008) described several of these methods, which involve calculating the mean of the lowest 5% of the D_e values (Olley et al. 1998), fitting a Gaussian distribution to the youngest D_e values in a histogram (Lepper et al. 2000), and the central age, minimum age, and finite mixture models (Galbraith et al. 1999).

In alluvial settings, older sediments are often more completely bleached than modern or late Holocene sediments (Jain et al. 2004; Rittenour 2008). Older sediments like those in Pleistocene terrace fills have been in the river system for a long period. As such, they likely underwent multiple transportation and deposition cycles prior to final deposition than those sediments found in modern channel and floodplain deposits. Similarly, large grains (sand and gravel) are better bleached than small grains (fine sand, silt, and clay) because they move through the system at a slower rate, allowing more sun exposure.

Bleaching studies have been conducted on alluvium in several regions of the United States. For example, OSL analysis on Pleistocene alluvium conducted by Rittenour et al. (2003, 2005, 2007) and Holbrook et al. (2006) in the lower Mississippi River valley indicate that even under the high suspended load and meltwater discharge conditions of the late Pleistocene, sediments were well bleached and partial exposure only minimally influenced results. Also, DeJong et al. (2006, 2007) and Rittenour et al. (2006) found that sediments in the Colorado River valley were better bleached and yielded more reliable OSL ages than sediments from tributary catchments. Sediments in the trunk stream experience a longer transport period than sediments in small tributary streams. The shorter transport time in tributary streams increases the incidence of partial bleaching in those sediments. Studies from archaeological sites in fluvial environments around the world indicate that alluvial deposits yield good age estimates (e.g., DeLong and Arnold 2007; Feathers 2003; Feathers et al. 2006; Fuchs and Lang 2001; Rich and Stokes 2001)

Using radiocarbon ages determined on soil organic matter in humid woodland environments is problematic because modern carbon is eluviated from surface horizons and illuviated deep in the subsoil, causing contamination (Rolfe Mandel, personal communication, 2011). Also, large pore space in Ozark NSR's sandy alluvium allows modern carbon to travel down the soil column more readily than in finer-grained sediments. Bioturbation by animals and plants contribute to this problem. Though ^{14}C dating of charcoal has been accomplished at Ozark NSR with good results, obtaining charcoal from soil cores proved challenging. In fact, only one core from the T-1 terrace at the Round Spring locality yielded charcoal.

To establish the time of alluviation, small-aliquot OSL ages were determined on sediments from cores at the Akers Ferry, Round Spring (T-1), Ramsey, and Chubb Hollow localities. OSL ages are expressed as years B.P. to 1 σ.

T-1 Terrace

The T-1 terrace in the Current River valley is a gently sloping (0-3%) often unpaired surface 1-4 m above the modern floodplain. Flood frequency on T-1 varies depending on the elevation of the terrace above the channel. T-1 fills are comprised of fine-grained alluvium overlying coarse bedload deposits. One T-1 terrace locality, Round Spring, was studied.

Round Spring

The T-1 terrace at Round Spring is currently maintained as an NPS campground (Figures 5.2, 5.3a, and 5.3b). It is mostly open, covered with grass and a few deciduous trees. The T-0 surface is approximately 2 m below the T-1 surface and is a large gravel bar. The surface soil on the T-1 is mapped as Huzzah sandy loam, a coarse-loamy, siliceous, superactive, mesic Cumulic Hapludoll (USDA 2005). Archaeological investigations have been not been conducted on the T-1 surface or in the underlying fill at Round Spring and no archaeological materials have been observed on the surface of this landform. However, archaeological sites attributed to the Archaic through Historic periods have been recorded on the adjacent T-2 and T-3 fills at this locality.

Two strata occur in the sandy fill at the Round Spring T-1 locality (Figure 5.4). The soil (Soil 1) developed in the top stratum is 120 cm thick and has a weak A-C profile. The A horizon is a 19 cm-thick loamy sand. The C horizon is 101 cm thick and consists of loamy sand. An abrupt boundary separates the C horizon from the bottom stratum. In the top stratum, sand content ranges from 75.8% to 81.6% (Figure 5.4 and Appendix C).

The soil (Soil 2) developed in the bottom stratum is 120 cm thick and has a well expressed A-Bt profile. The Ab horizon is 20 cm thick and consists of sandy loam. The underlying argillic horizon (Bt1b and Bt2b) also consists of loam and is 80 cm thick. A radiocarbon age of 1,810 ± 15 ^{14}C yr B.P. was determined on wood charcoal from the Bt1b horizon of Soil 2 (ISGS-A1992) (Table 5.1). The HDI (Figure 5.5) shows that Soil 2 is more developed than Soil 1.

Also, two OSL ages were obtained from Soil 2, one of 1,700 ± 200 B.P. from the top Bt1b horizon and one of 3,000 ± 400 B.P. from the bottom Bt1b horizon. Silt and clay peak in the Bt1b horizon before decreasing slightly in the Bt2b horizon (Figure 5.6). The period of landscape stability represented by Soil 2 was long enough for a prominent clay bulge to form in the Bt1b horizon.

Table 5.1. Radiocarbon age for the buried paleosol at the Round Spring T-1 locality.

Locality	Material	Sample Horizon	Sample Depth (cmbs)	$\delta^{13}C$	^{14}C age (yr B.P.)	Cal Age (yr B.P.)	Median Cal Age (yr B.P.)	Lab No.
Round Spring T-1	charcoal	Bt1b	165	-24.5	1810 ± 15	1707-1815	1754	ISGS-A1992

$\delta^{13}C$ values determined on SOM at the Round Spring T-1 locality range from -24.8‰ to -21.4‰, indicating a C_3 plant community for the period of record (Figure 5.6). The lightest value, -24.8‰, occurs in the A horizon of the top stratum. The heaviest value, -21.4‰, occurs in the Ab horizon of the bottom stratum. The difference between the lightest and heaviest $\delta^{13}C$ values is 3.4‰. That difference is large enough that it may be the result of increased C_4 plant contributions to SOM (see Krull and Skjemstad 2003). A 1.5‰ excursion toward heavier $\delta^{13}C$ values occurs at the boundary between the two strata, which may be attributed to natural soil processes. Based on the OSL ages, the bottom stratum aggraded between 3,000 B.P. and 1,700 B.P. Heavier $\delta^{13}C$ values recorded in the bottom stratum may, therefore, reflect greater contributions to SOM from C_4 plants during the late Holocene.

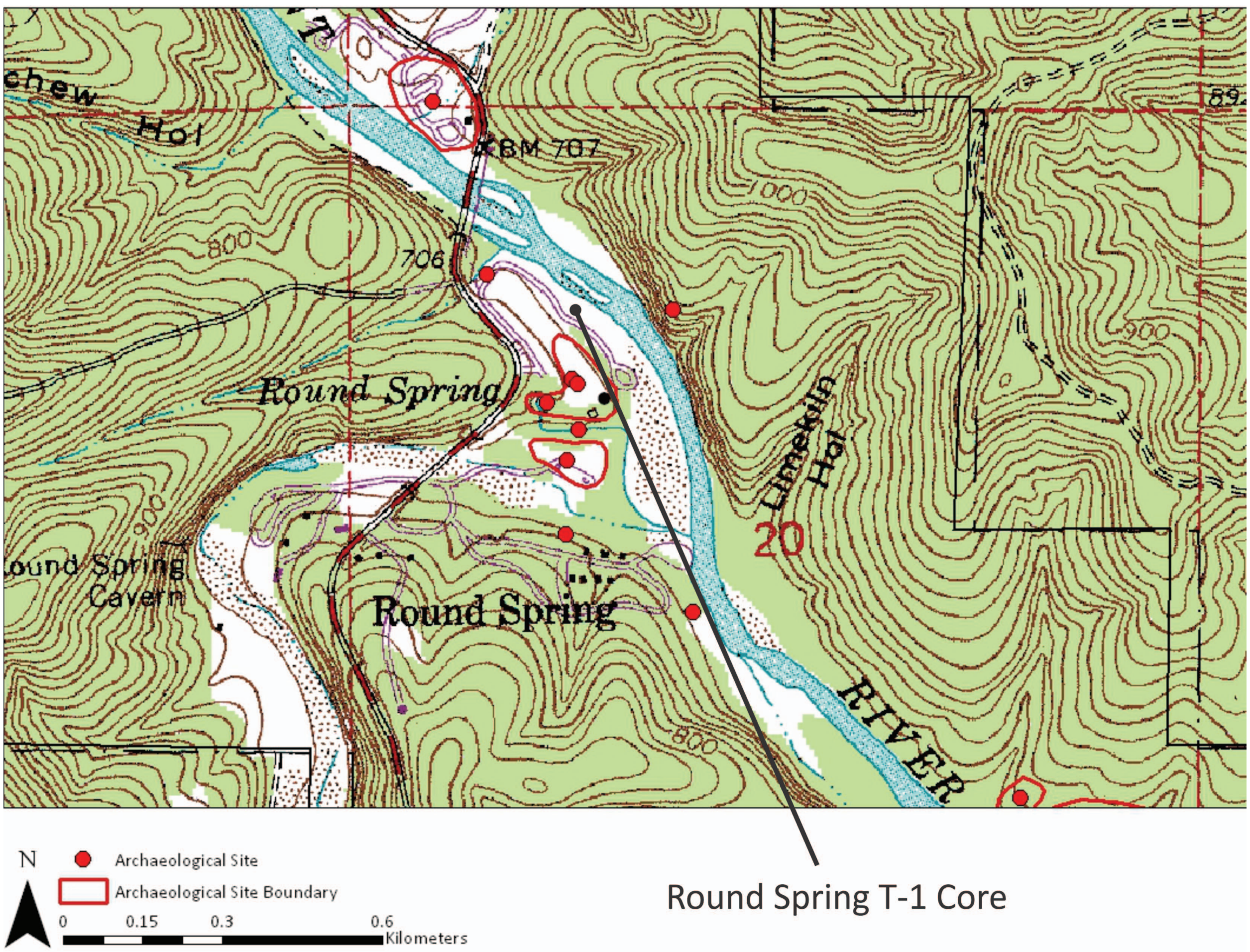

Figure 5.2. Topographic map of the Round Spring T-1 locality.

Figure 5.3a. Round Spring T-1 locality. View southeast. River runs south, behind the trees.

Figure 5.3b. Round Spring T-1 locality. View southwest, toward scarp of T-3 terrace. River is to the east.

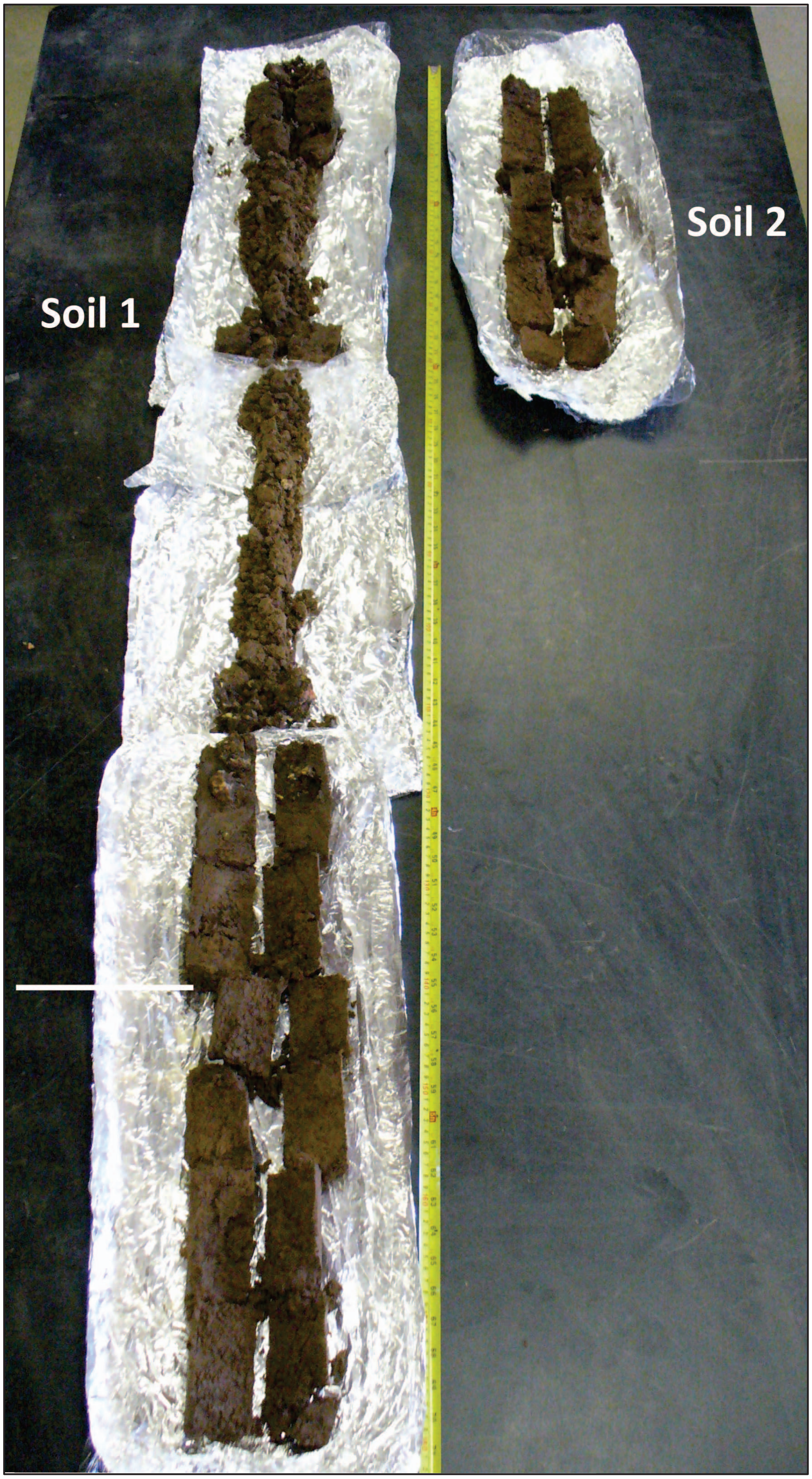

Figure 5.4. Round Spring T-1 soil profile.

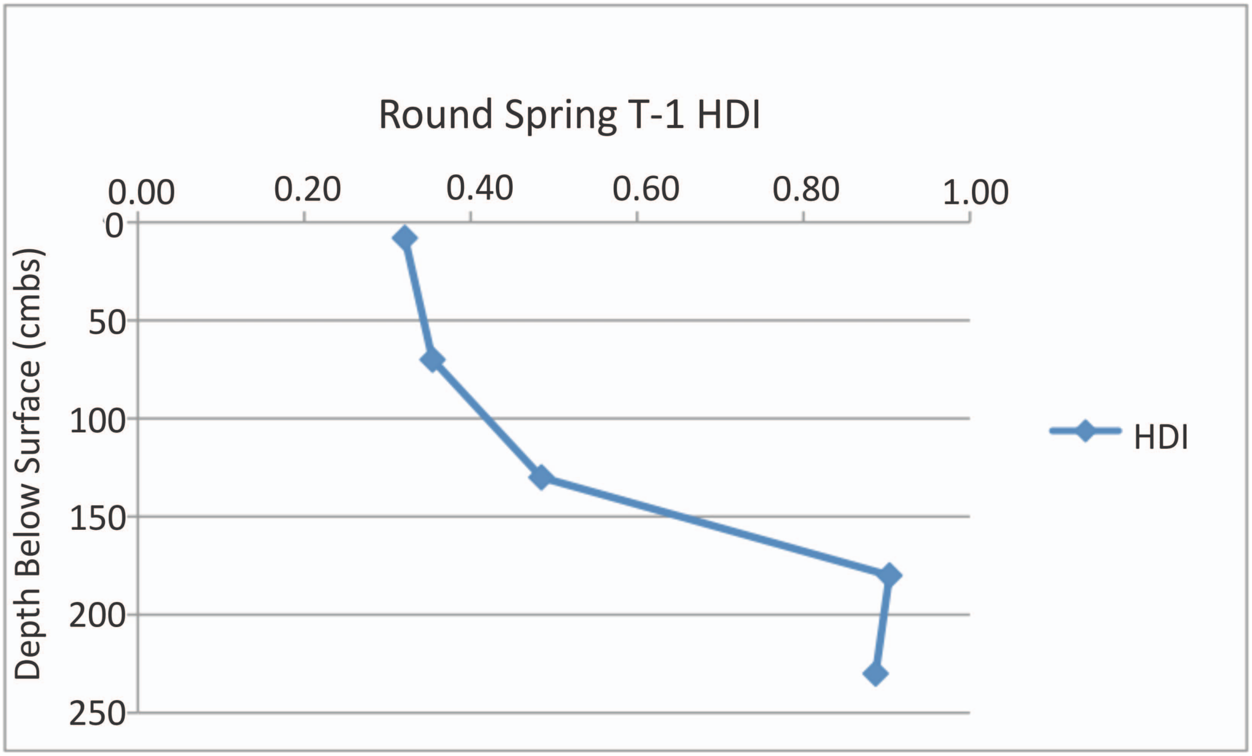

Figure 5.5. Round Spring T-1 HDI.

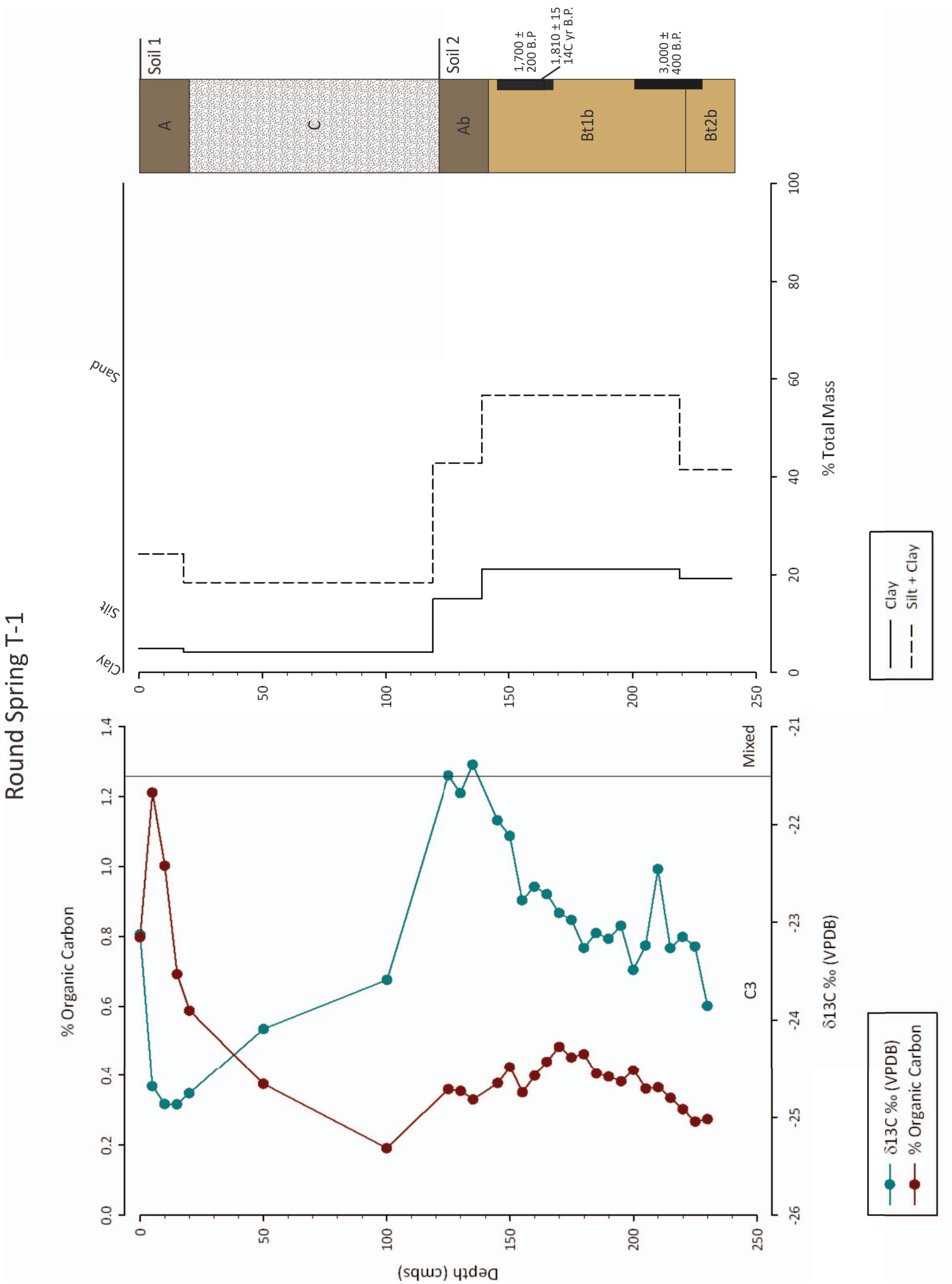

Figure 5.6. δ13C and PSD depth functions from the T-1 at Round Spring.

T-2 Terraces

In the Current River valley, the T-2 terrace surface has a 0-3% slope and is 1 to 3 m above the T-1 surface. The T-2 is rarely flooded and largely unpaired in the study area, though sometimes nested with T-1 or T-0 fills. T-2 fill is comprised of fine-grained alluvium overlying coarse bedload deposits. Three T-2 localities were analyzed for this study: Akers Ferry, Pulltite, and Round Spring.

<u>Akers Ferry</u>

The T-2 terrace at Akers Ferry is maintained as a parking area for Ozark NSR concessioners and visitors (Figure 5.7 and 5.8). An NPS visitor center and privately owned river outfitter are located on the landform, several hundred meters west-southwest of the coring location. Vegetation cover is grass with a few deciduous trees. The T-2 surface is 1.0-1.5 m higher than the T-1 surface at this locality. The surface soil on T-2 is mapped as Bearthicket silt loam, a fine-silty, mixed, active, mesic Ultic Hapludalf derived from silty alluvium (USDA 2005).

Excavations conducted in 1980 and 1987 in the T-2 fill at Akers Ferry (23SH23) yielded Dalton and younger cultural deposits (Lynott 1989b). These excavations included 106 shovel tests and eight 1x1 m and seven 1x2m test units. Shovel tests were excavated to a depth of 30-40 cmbs and test units were excavated to 120 cmbs. Dalton cultural material was encountered between 50 and 60 cmbs. Archaic artifacts occurred between 40 and 50 cmbs and Woodland cultural material occurred between 20 and 50 cmbs. In 2006 and 2007, excavations on the colluvial fan on the distal end of the T-2 terrace yielded Dalton artifacts at 61 cmbs (Cannon et al. 2010). During the current study, two flakes were recovered from the core, one at 5 cmbs and one at 90 cmbs.

Two strata comprise the fine-grained T-2 fill at Akers Ferry (Figure 5.9). The soil (Soil 1) developed in the top stratum is 86 cm thick and has a well expressed Ap-A-Bw-Bt profile. The A and Bw horizons are 22 cm and 25 cm thick, respectively, and both are silt loams. The Bt horizon is 29 cm thick and consists of silt loam. Distinct, discontinuous clay films occur on ped faces in the Bt horizon. An abrupt boundary separates the Bt horizon from the bottom stratum. The age of the top stratum is unknown. The HDI (Figure 5.10) shows that the Bt horizon is the most developed horizon in the profile.

A soil (Soil 2) with a well expressed Bt-BCt profile is developed in the upper 121 cm of the bottom stratum. The argillic horizon (Bt1b and Bt2b) is 45 cm thick. The Bt1b consists of silt loam and the Bt2b consists of loam. The BCt1b and BCtb2 horizons consist of stratified sandy loam. Distinct, discontinuous clay films occur on ped faces in the Bt and BCt horizons of Soil 2. The Cb horizon is 46 cm thick and consists of loose sand and gravel. The HDI (Figure 5.10) indicates that the Bt1b and Bt2b horizons are well developed.

Four OSL ages were determined on sediment samples from the bottom stratum. The lower sample, which was from the Cb horizon of Soil 2, yielded an age of 45,400 ± 3,900 B.P. The upper sample, also from the Cb horizon, yielded an age of 34,400 ± 3,100 B.P. Two OSL ages were determined on sediment samples from the BCt2b horizon. The lower and upper samples yielded ages of 33,600 ± 2,900 B.P. and 29,800 ± 2,900 B.P., respectively. These ages are much older than expected. As noted in Chapter 2, Saucier (1987) believed T-2 terrace fills aggraded between 15,000-7,000 B.P. Therefore, the T-2 surface at Akers Ferry is a fill strath terrace cut across T-3 fill. Sometime during the late Pleistocene, the stream channel migrated east as it incised, cutting an erosion surface (strath) across the T-3 fill. The stream channel subsequently migrated west, perhaps during the Pleistocene-Holocene transition, leaving what were formerly deep T-3 deposits exposed at and near the surface. The strath was mantled by a thin veneer of early-Holocene alluvium. The contact between the eroded late-Wisconsinan and early-Holocene sediments forms the boundary between the top and bottom strata.

The $\delta^{13}C$ values determined from SOM at Akers Ferry range from -25.9‰ to -20.2‰ (Figure 5.11), indicating a C_3/C_4 plant community for the period of record. The lightest $\delta^{13}C$ value of -25.9‰ occurs in the Ap horizon of the modern soil. The heaviest $\delta^{13}C$ value of -20.2‰ occurs in the Bt1b horizon. The difference between the lightest and heaviest $\delta^{13}C$ values is 5.7‰, which may reflect an increase in C_4 vegetation contributions to SOM. Overall, $\delta^{13}C$ values trend from lighter to heavier between the A and Bt1b horizons. Below the Bt1b horizon, a slight trend toward lighter $\delta^{13}C$ values occurs.

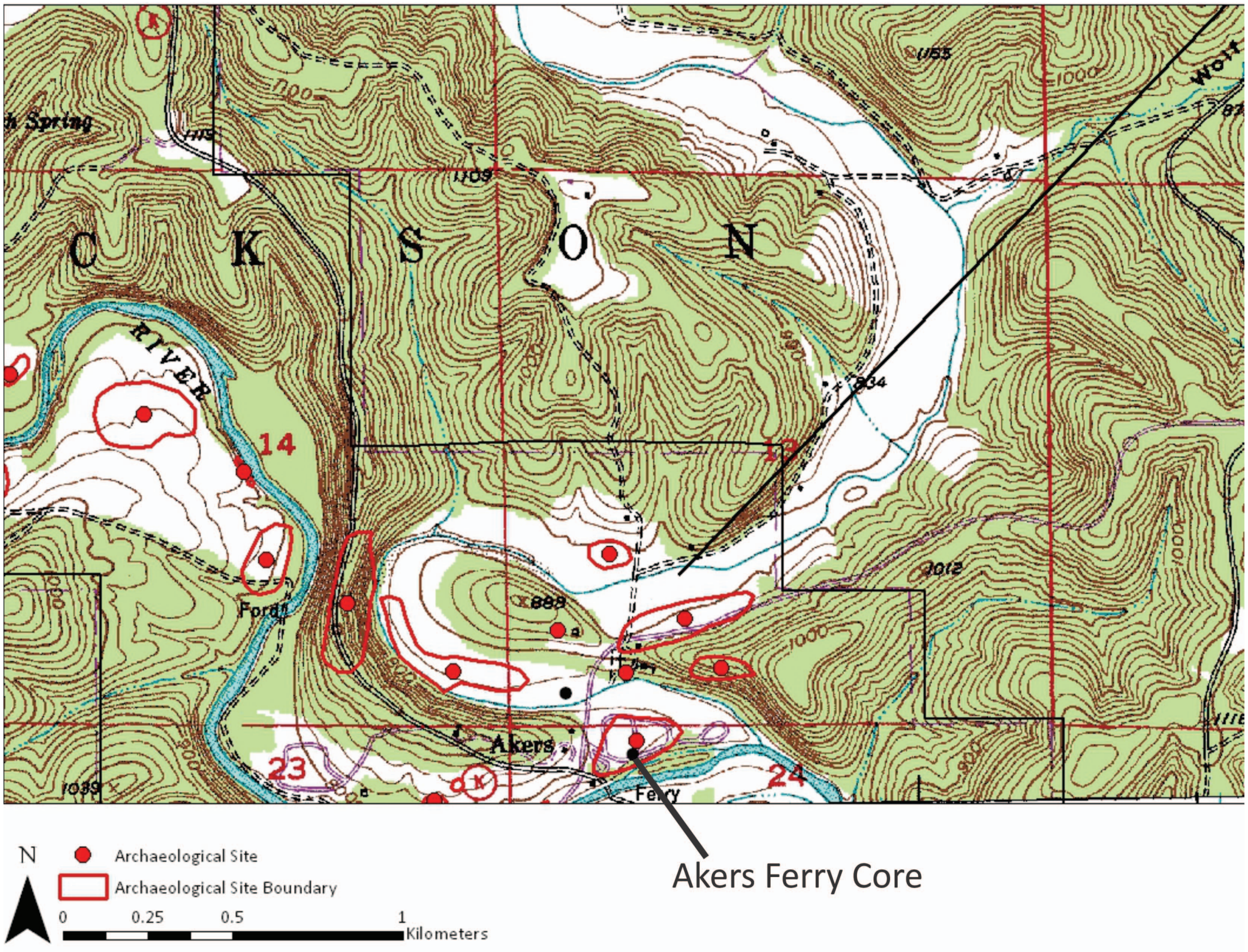

Figure 5.7. Topographic map of the Akers Ferry locality.

Figure 5.8. Akers Ferry T-2 locality. View west. River is to the south.

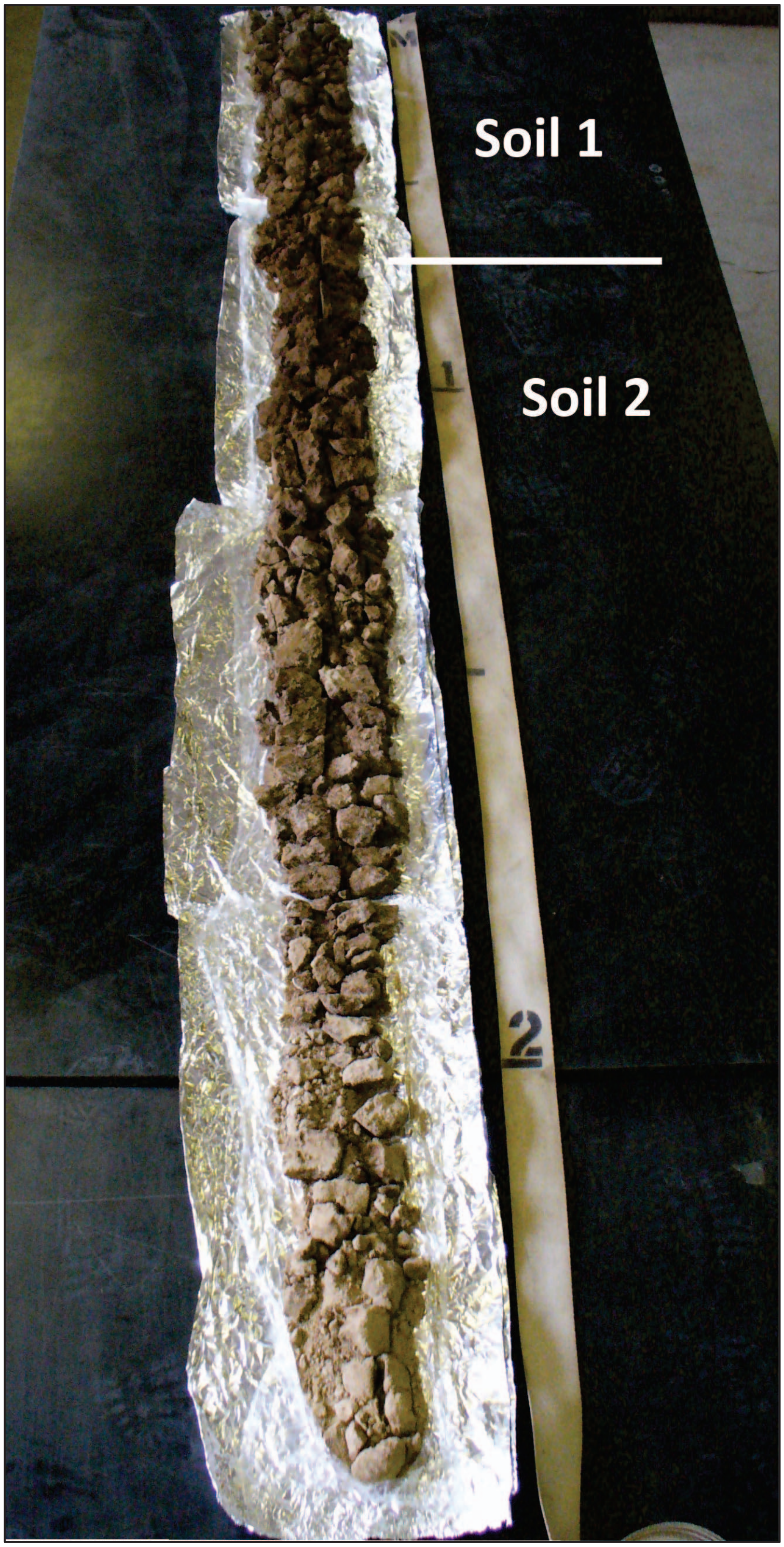

Figure 5.9. Akers Ferry T-2 soil profile.

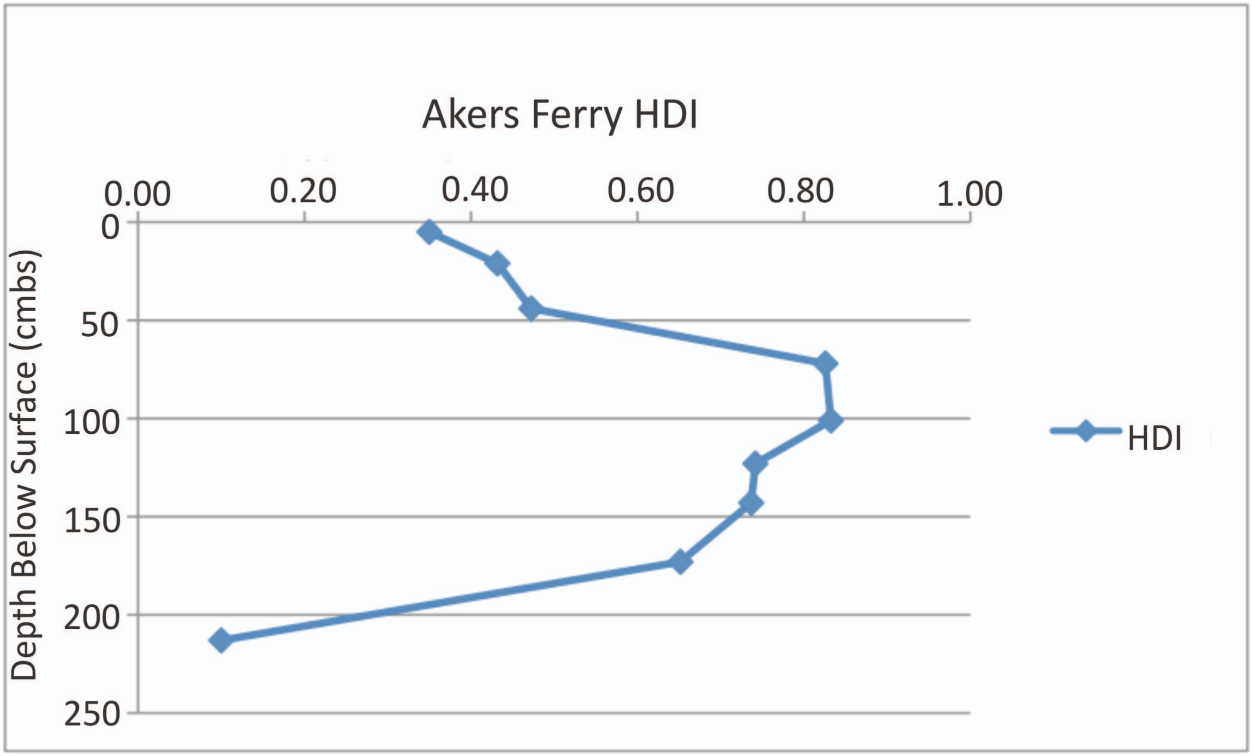

Figure 5.10. Akers Ferry T-2 HDI.

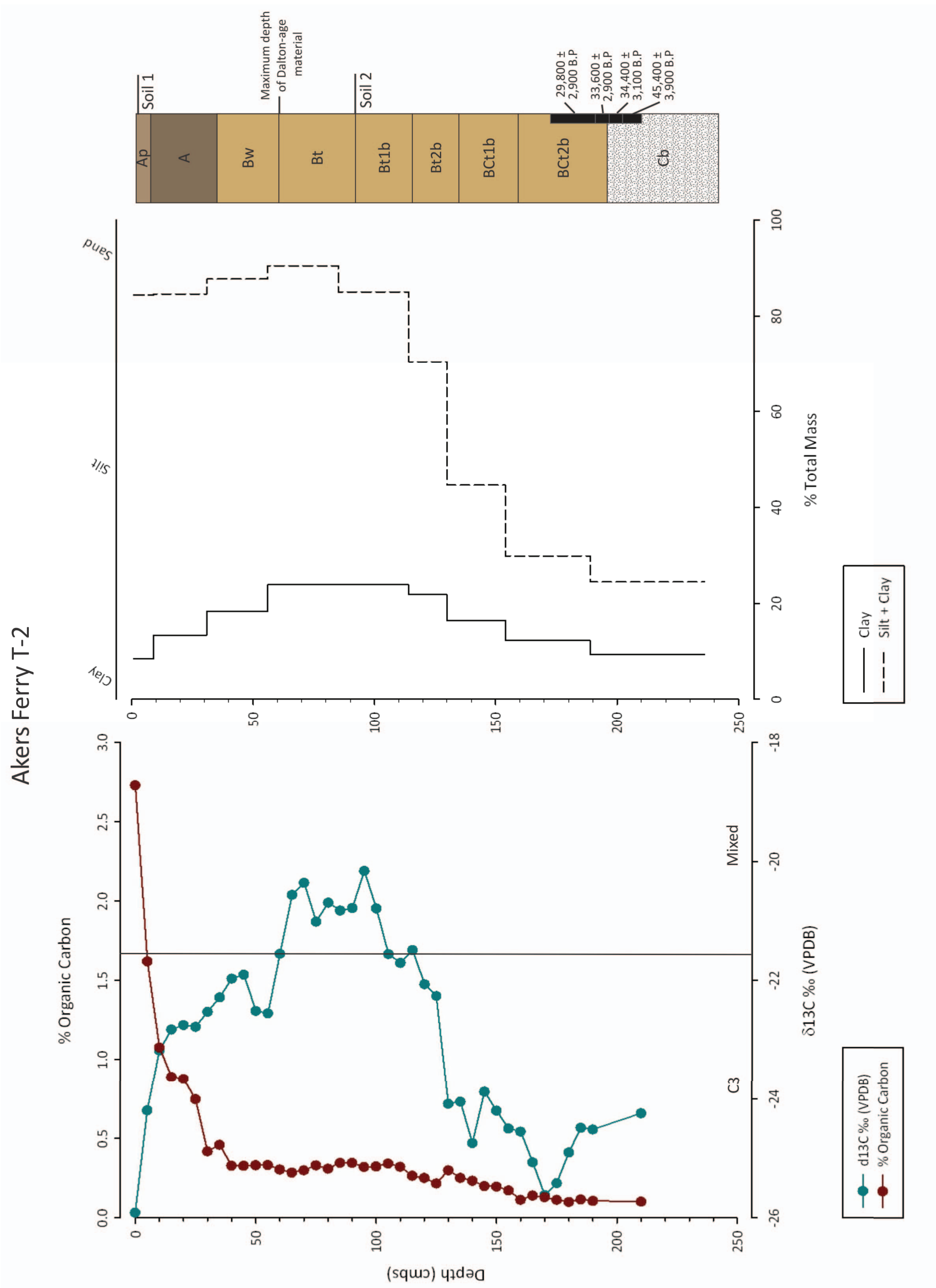

Figure 5.11. $\delta^{13}C$ and PSD depth functions from the T-2 at Akers Ferry.

Pulltite

A remnant of the T-2 terrace occurs at the Pulltite locality where a large group campsite is maintained (Figure 5.12 and 5.13). The vegetation is mostly grass, though deciduous trees stand along the 2.5 m-high scarp above the river channel and cover the hillslope adjacent the landform. The USDA (2005) incorrectly maps the surface soil as Clarksville-Scholten complex, a hillslope soil.

Shovel test excavations at the Pulltite locality (23SH94 and the surrounding area) have yielded Late Archaic, Middle Woodland, and Late Woodland cultural materials (Lynott 1982; Vawser 1999). During Lynott's 1982 work at 23SH94, excavated 29 shovel tests to depths of 30 cmbs. In 1999, Vawser excavated 18 shovel tests and three test units near two buildings on the campground loop drive in advance of Park maintenance. Cultural materials were recovered from the upper 30 cm of fill. During the current study, one flake was collected from the core at 20 cmbs.

The soil developed in the T-2 fill at Pulltite is 157 cm thick with a well expressed A-AB-Bt-BC-C profile (Figure 5.14). The argillic horizon (Bt1, Bt2, and Bt3) is 80 cm thick, consists of silty clay loam, and has distinct, discontinuous clay films. The thickness of the argillic horizon may indicate a long period of pedogenesis in the T-2 fill. The HDI (Figure 5.15) indicates the argillic horizon is the most developed horizon in the profile.

The $\delta^{13}C$ values derived from SOM at Pulltite range from -27.6‰ to -21.7‰, indicating a C_3 plant community for the period of record (Figure 5.16). The lightest $\delta^{13}C$ value, -27.6‰, was recorded in the A horizon. The heaviest $\delta^{13}C$ value, -21.7‰, occurred in the BC horizon. The difference between the lightest and heaviest $\delta^{13}C$ values is 6‰, reflecting an increase in C_4 vegetation contributions to SOM with depth. Two small $\delta^{13}C$ excursions are evident. The first excursion occurs between the A and AB horizons with a shift of 2.2‰ toward heavier $\delta^{13}C$ values. The second excursion occurs between the Bt2 and Bt3 horizons and is represented by another shift of 2‰ toward heavier $\delta^{13}C$ values. A shift of 2‰ back toward lighter $\delta^{13}C$ values occurs between the BC and C horizons. These shifts fall within the 1-3‰ $\delta^{13}C$ change that could be the result of natural soil processes.

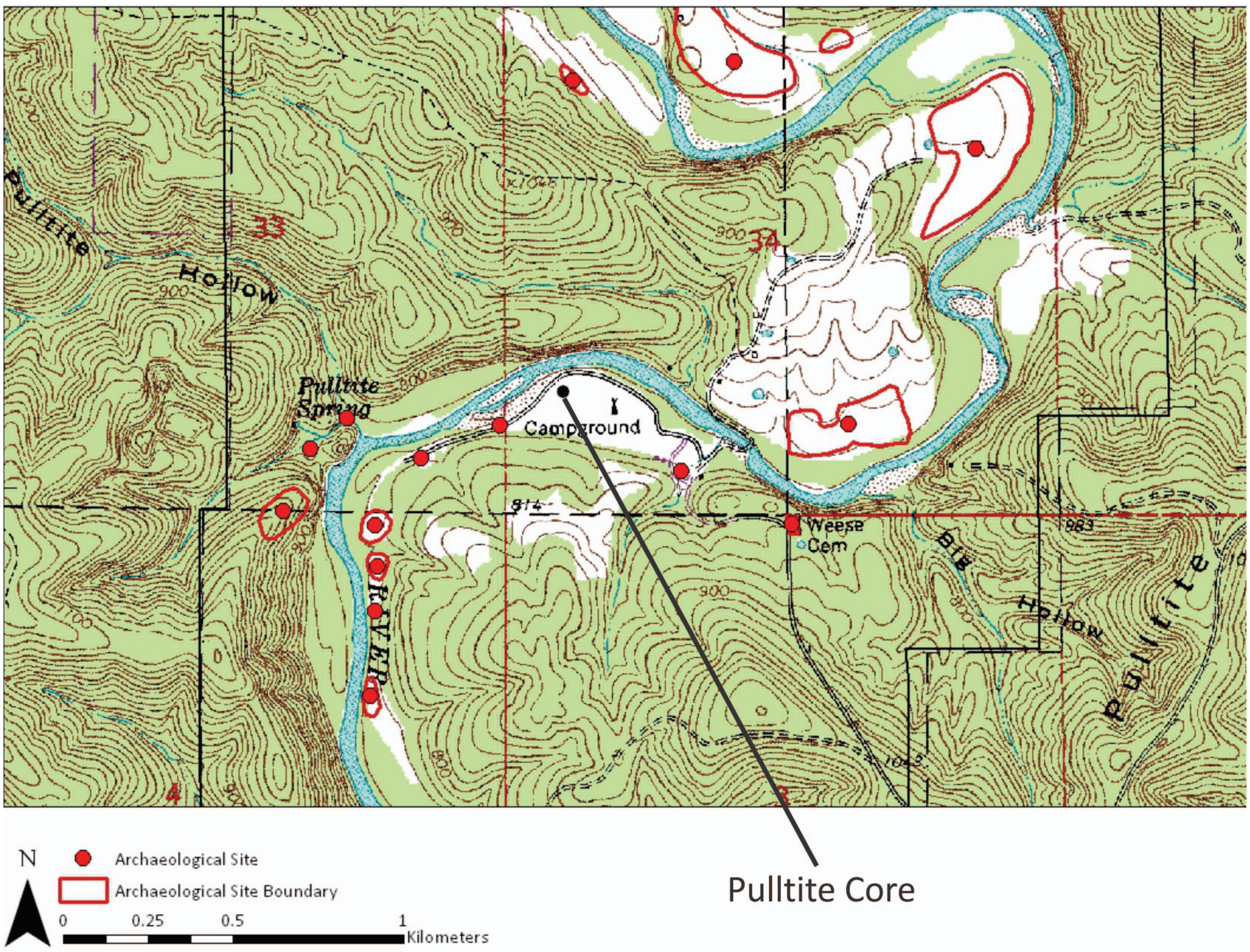

Figure 5.12. Topographic map of the Pulltite locality.

Figure 5.13. Pulltite T-2 locality. View west. River flows to the south, behind the trees.

Figure 5.14. Pulltite T-2 soil profile.

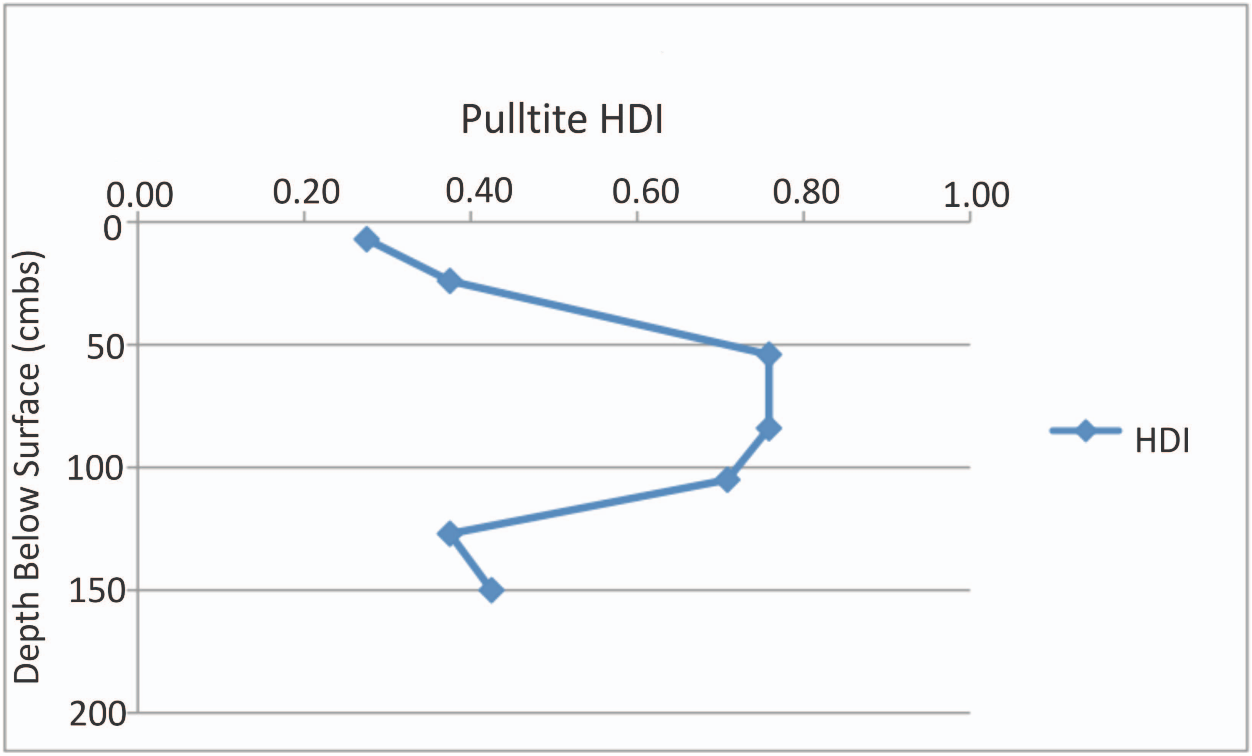

Figure 5.15. Pulltite T-2 HDI.

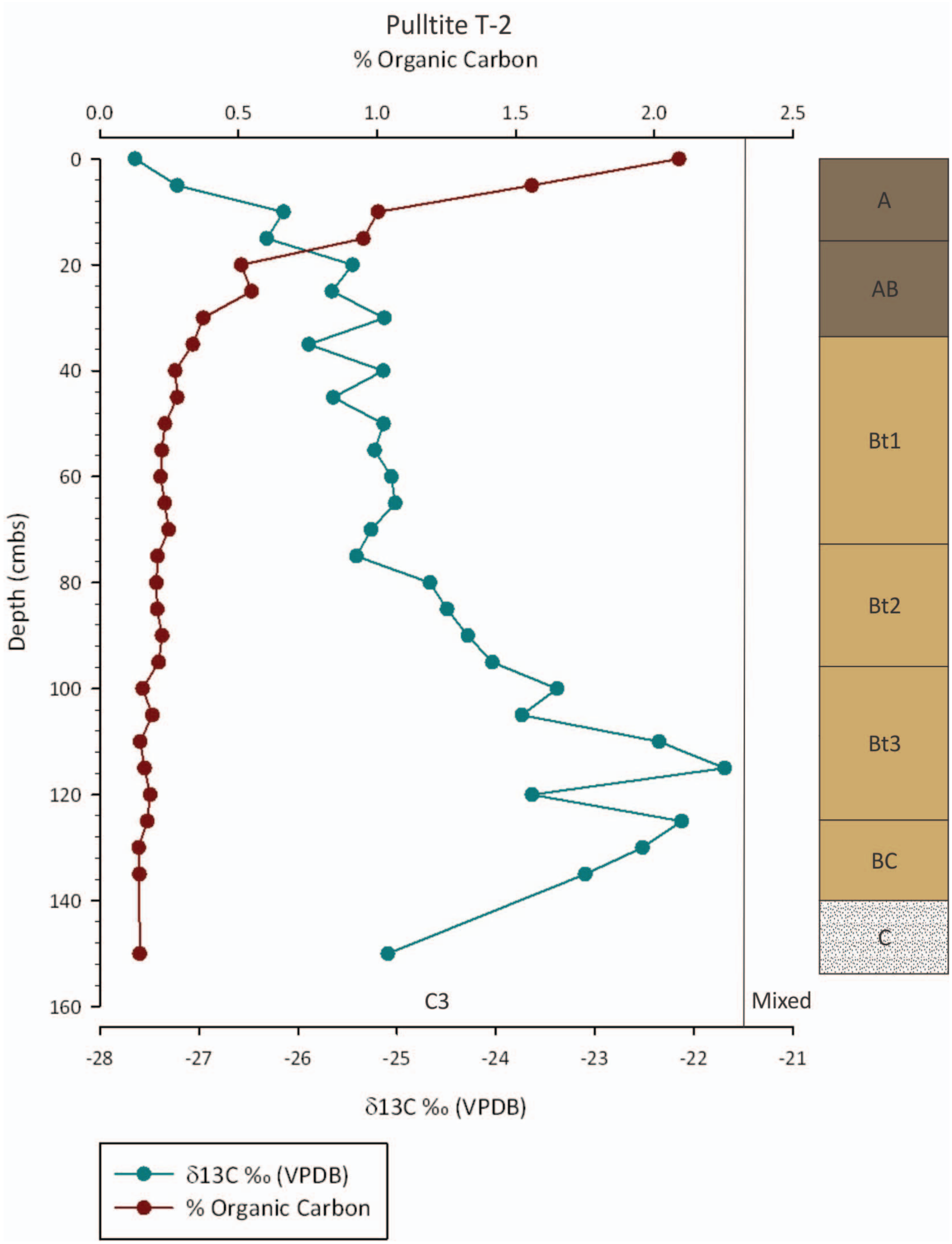

Figure 5.16. $\delta^{13}C$ depth function from the T-2 at Pulltite.

Round Spring

The T-2 at Round Spring, which Saucier originally mapped as a T-3, is an open grassy area (Figures 5.17, 5.18a, and 5.18b). Deciduous trees cover the 1.5 m-high scarp between the T-2 surface and the T-1 surface. Immediately south of the coring location, the Round Spring branch flows into the Current River. The surface soil at this locality is mapped as Secesh silt loam, a fine-loamy, siliceous, active, mesic Ultic Hapludalf (USAD 2005).

Dalton, Late Archaic, Woodland, Mississippian, and Historic archaeological materials have been recovered during excavations on the T-2 (23SH19) (Lynott 1991b). The 1981 investigations included the excavation of eight test units to an approximate depth of 50 cmbs and five shovel test transects. Shovel tests were excavated to 30 cmbs. During the current study, three flakes were collected from the core at 50, 90, and 100 cmbs.

Two strata comprise the fine-grained T-2 fill at Round Spring (Figure 5.19). The soil (Soil 1) developed in the top stratum is 180 cm thick and has a well expressed A-Bw-Bt-BCt profile. A clear boundary separates the BCt horizon of Soil 1 from Soil 2 developed in the bottom stratum.

Soil 2 is represented by a strongly expressed argillic horizon (Bt1b and Bt2b) that is 40 cm thick; the A horizon was stripped off by erosion prior to burial. The Bt1b and Bt2b horizons consist of sandy loam. The HDI (Figure 5.20) shows an overall increase in soil development with depth.

The $\delta^{13}C$ values determined on SOM from the T-2 at Round Spring range from -25‰ to -22.4‰ (Figure 5.21), indicating a C_3 plant community for the period of record. The lightest $\delta^{13}C$ value of -25‰ occurs in the BCt horizon. The heaviest $\delta^{13}C$ value of -22.4 occurs in the Bt horizon. The difference between the lightest and heaviest $\delta^{13}C$ values is 2.6‰, suggesting that changes in isotopic composition throughout in the T-2 are the result of natural soil. The $\delta^{13}C$ values in the top stratum are slightly heavier overall, while $\delta^{13}C$ 3C values in the bottom stratum are slightly lighter. This difference is not large enough to be considered the result of a bioclimatic change.

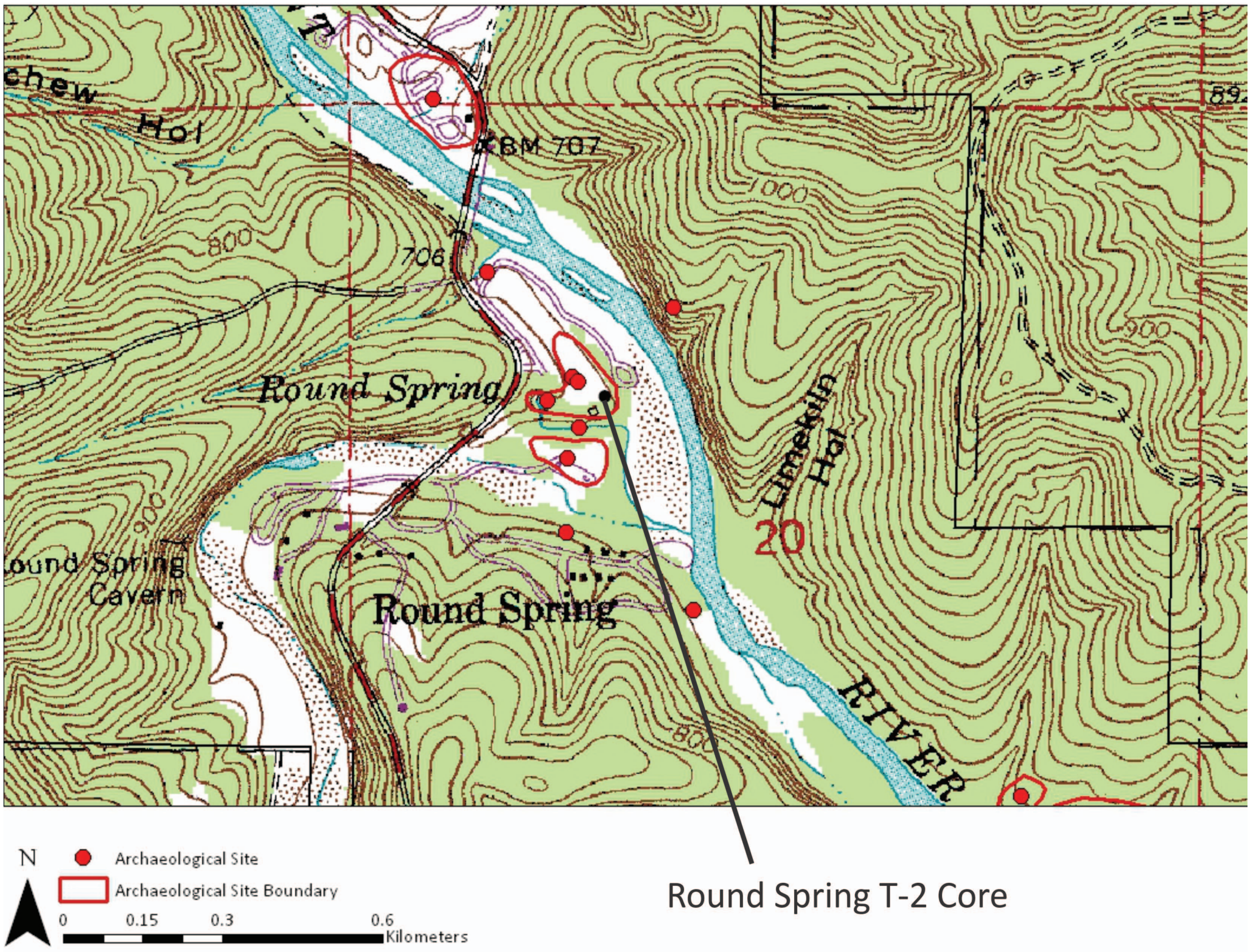

Figure 5.17. Topographic map of the Round Spring T-2 locality.

Figure 5.18a. Round Spring T-2 locality. View south. River is to the west, Round Spring branch is in background, behind the trees.

Figure 5.18b. Round Spring T-2 locality. View north. River is to the east. Open grassy area is location of the septic field.

Figure 5.19. Round Spring T-2 soil profile.

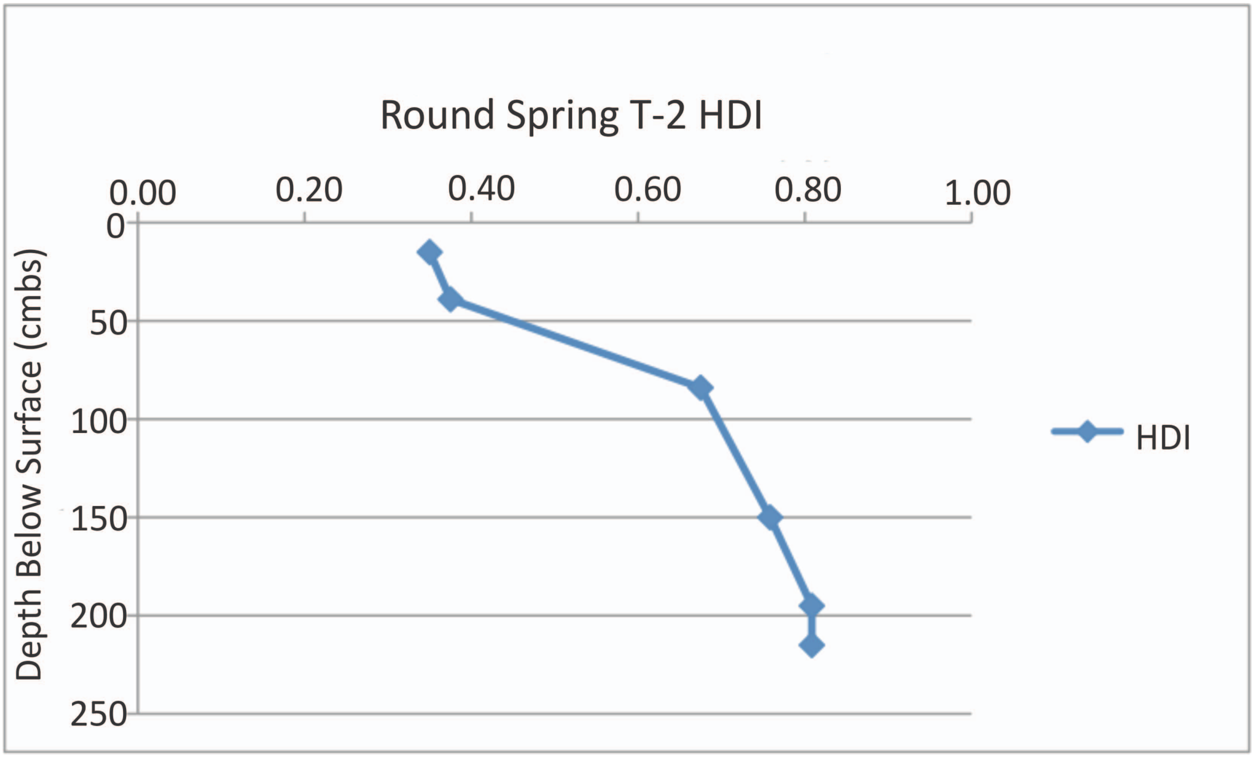

Figure 5.20. Round Spring T-2 HDI.

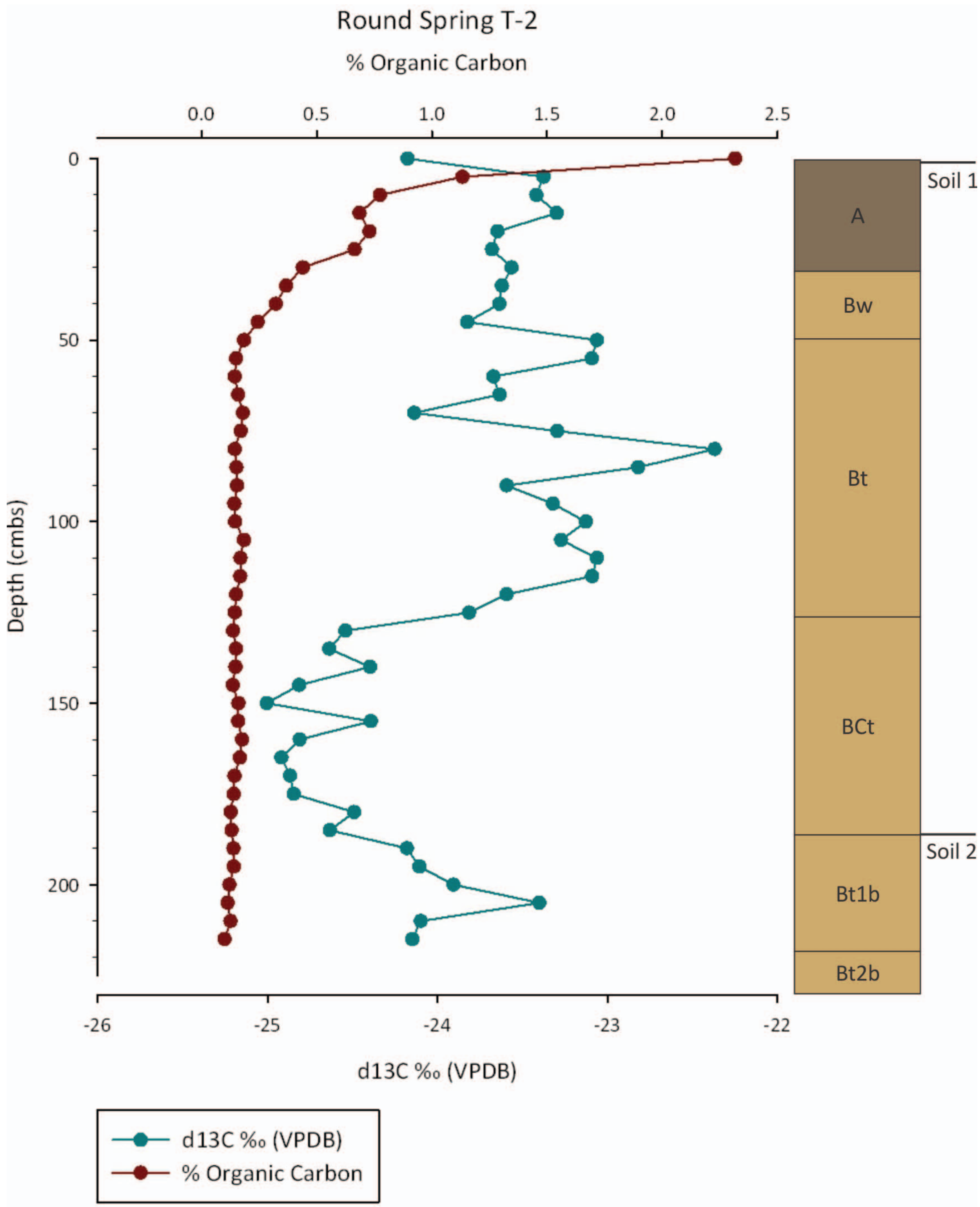

Figure 5.21. $\delta^{13}C$ depth function from the T-2 at Round Spring.

T-3 Terrace

T-3 is the highest alluvial terrace in Ozark NSR; Saucier (1987) mapped T-4 terraces elsewhere in the Current River valley, but none have been identified in the study area. The T-3 surface has 0-3% slopes and is 3-4 m above the T-2 surface. Like T-1 and T-2, T-3 is typically unpaired, but often nested with younger fills. T-3 fills consist of fine-grained deposits overlying coarse gravel deposits. Two T-3 terraces were studied, Ramsey Field and Pin Oak.

Ramsey Field

The T-3 at Ramsey Field is approximately 200 m wide and almost one mile long. The coring location is in an open field that is hayed periodically (Figure 5.22 and 5.23). Deciduous trees and low brush surround the field, growing along the scarp to the east and a road to the west. At this locality, the T-3 surface is approximately 4 m above the T-2 surface. Zanoni fine sandy loam, a coarse-loamy, siliceous, active, mesic Ultic Hapludalf, is mapped on T-3 at Ramsey (USDA 2005).

A large prehistoric site (23SH77) is recorded on the landform and has yielded non-diagnostic lithic materials (Garrison et al. 1976; Lynott 1981).

Three strata comprise the upper 6 m of the T-3 fill at Ramsey (Figure 5.24). The surface soil (Soil 1) developed in the top stratum is 203 cm thick and has a well expressed A-E-Bt/E-BCt profile. The A and E horizons are 34 cm and 21 cm thick, respectively, and consist of sandy loam. Below the E horizon are two Bt/E horizons consisting of sandy loam. Distinct, discontinuous to nearly continuous clay films are common on ped faces and in macropores in the Bt/E horizons. The BCt horizon consists of sandy loam and is 39 cm thick. A sediment sample from the Bt/E2 horizon yielded an OSL age of 9,300 ± 1,000 B.P.

The soil (Soil 2) developed in the middle stratum is 64 cm thick and is represented by a truncated argillic horizon (Bt1b1 and Bt2b1) consisting of loam. Depletion zones of very pale brown (10YR 7/4, dry) sandy loam occur on ped faces in Soil 2. Also, strong brown (7.5YR 5/6, dry) clay films are present on ped faces and in macropores. An abrupt boundary separates the Bt2b1 horizon the Soil 3 developed in the bottom stratum.

Soil 3 has a well expressed Bt-BC-C profile and is 323 cm thick. The argillic horizon (Bt1b2, Bt2b2, Bt3b2, and Bt4b2) has a total thickness of 178 cm. The Bt1b2 consists of loam, the Bt2b2 consists of sandy loam, and the Bt3b2 and Bt4b2 horizons consist of loam. Clay films occur on ped faces and in macropores in the Bt horizons of Soil 3. An OSL age of 9,800 ± 1,200 B.P. was determined on sediment from the Bt1b2 horizon. Two OSL ages were determined on sediment samples from the Bt4b2 horizon. The lower sample (430-445 cmbs) yielded an age of 12,500 ± 1,600 B.P., and the upper sample (410-424 cmbs) yielded an age of 12,000 ± 1,500 B.P. The BCb2 horizon consists of loamy sand and a sediment sample from this horizon yielded an OSL age of 11,200 ± 1.5 B.P. The Cb2 horizon consists of fine sand interbedded with flood drapes. The HDI (Figure 5.25) shows that the magnitude of soil development is similar across soils 1, 2, and 3.

In the T-3 fill at Ramsey Field, the top stratum shows evidence of leaching, indicated by E horizon formation. Slight clay and silt bulges occur in the top stratum, but distinct bulges occur in the middle stratum and extend into the bottom stratum (Figure 5.26). This suggests that while soil development has not crossed the boundary between the top and middle strata, diagenesis has blurred the contact between the middle and bottom strata.

The $\delta^{13}C$ values derived from SOM at Ramsey Field range from -25.1‰ to -19.3‰ (Figure 5.26), indicating a mixed C_3/C_4 plant community during the period of record. The lightest $\delta^{13}C$ value, -25.1‰, occurs in the BCt horizon and the heaviest $\delta^{13}C$ value, -19.2‰, occurs in the Bt/E1 horizon. The difference between the lightest and heaviest $\delta^{13}C$ values is 5.9‰. While C_3 plants were the primary contributors to $\delta^{13}C$ values, slightly heavier $\delta^{13}C$ values between the A and Bt/E2 horizons may be the result of increased SOM contributions from C_4 plants. Three $\delta^{13}C$ excursions are recorded in the Ramsey Field fill, one in the Bt/E1 horizon and another in the Bt/E2 horizon. A shift from -23‰ to -19.9‰ toward heavier values occurs in the Bt/E1 horizon, immediate followed by a shift from -19.3‰ to -22.9‰ toward lighter values. These excursions in $\delta^{13}C$ values reflect an increase in C_4 vegetation contributions to SOM, followed by a shift back to a C_3 signature. In the Bt/E2 horizon, a shift of -24.9‰ to -19.8‰ is recorded. This excursion of 5.1‰ toward heavier $\delta^{13}C$ values occurred around 9,300 B.P. and indicates an increase in C_4 vegetation contributions to SOM at the onset of the Altithermal.

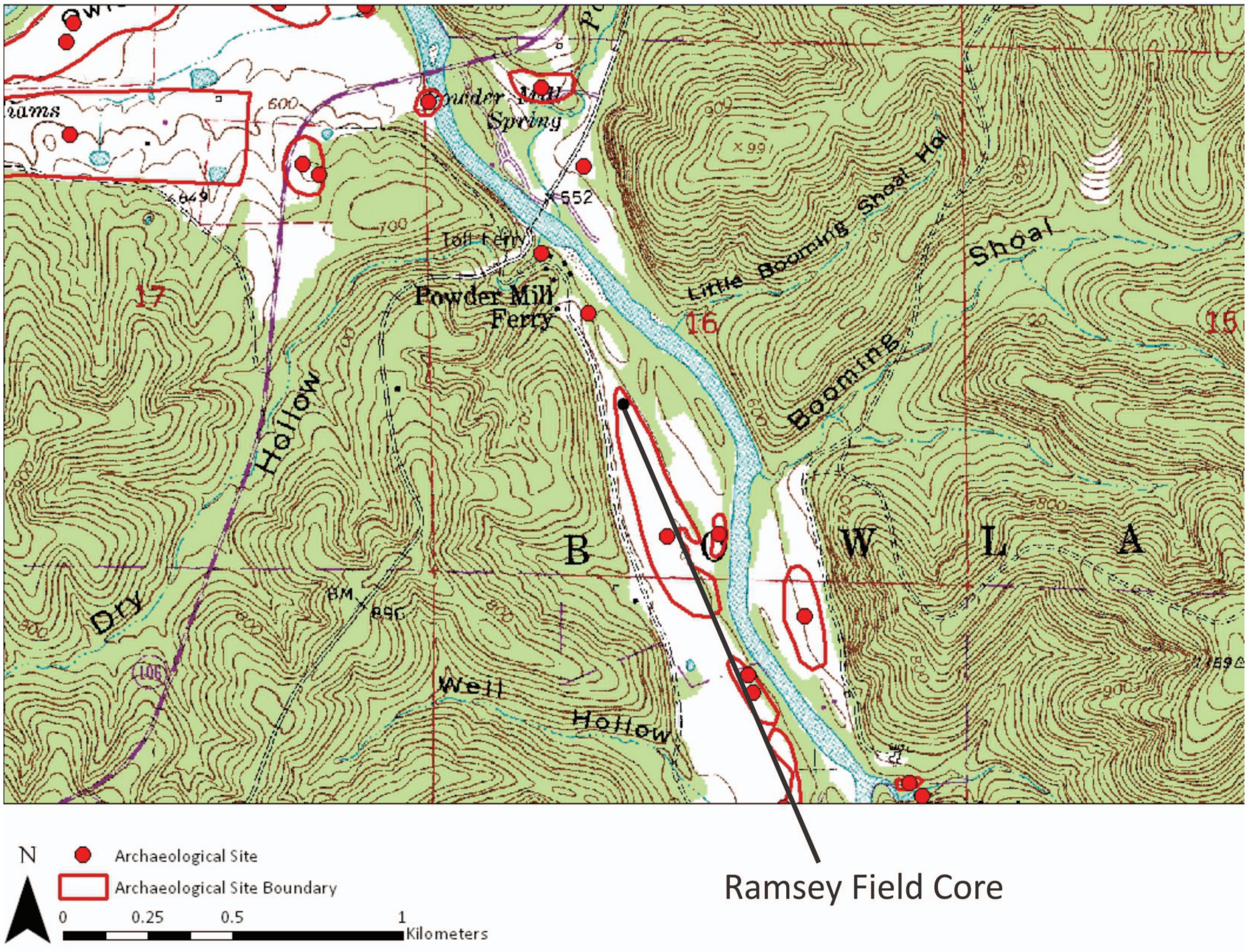

Figure 5.22. Topographic map of the Ramsey Field locality.

Figure 5.23. Ramsey T-3 locality. View south. River is to the west.

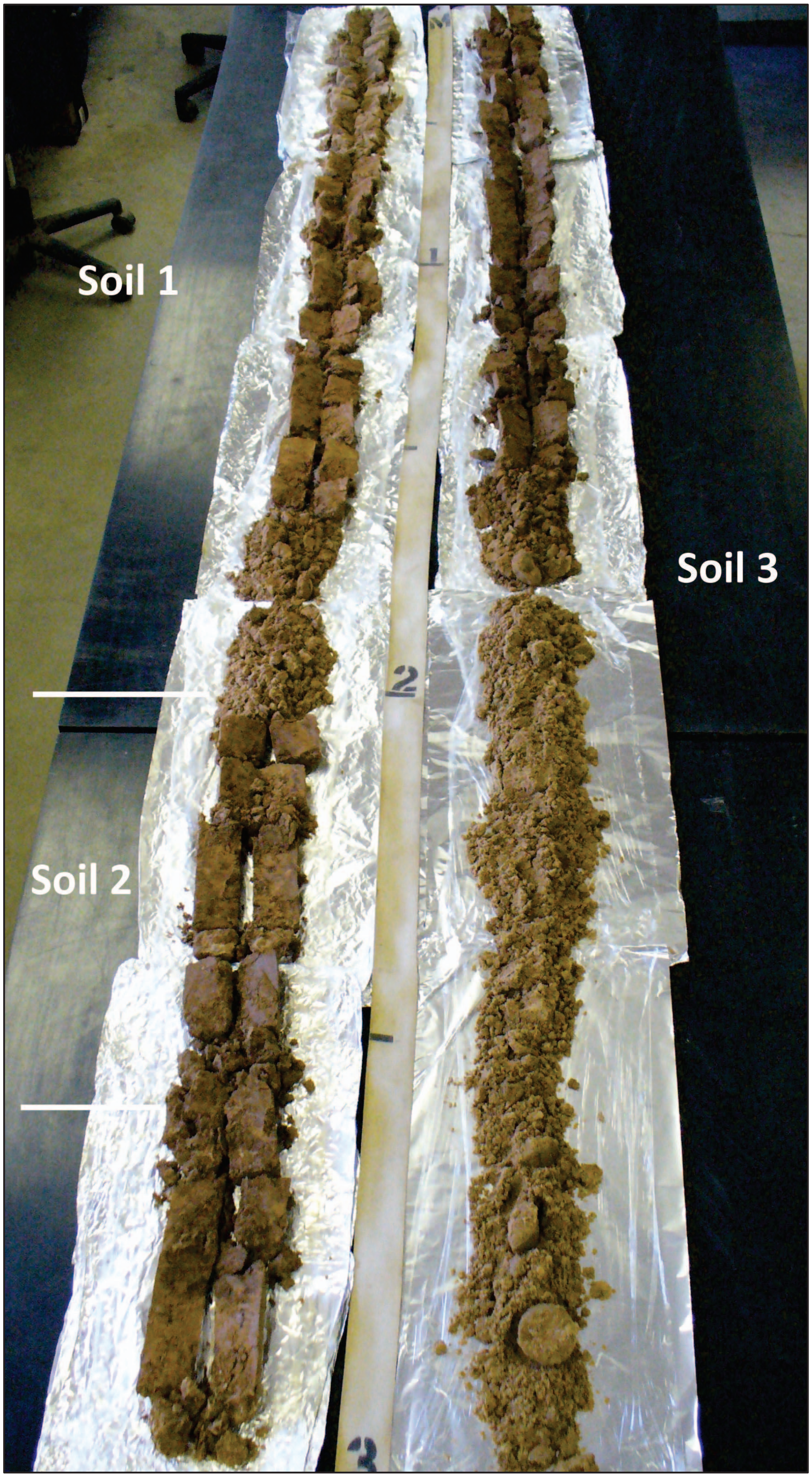

Figure 5.24. Ramsey T-3 soil profile.

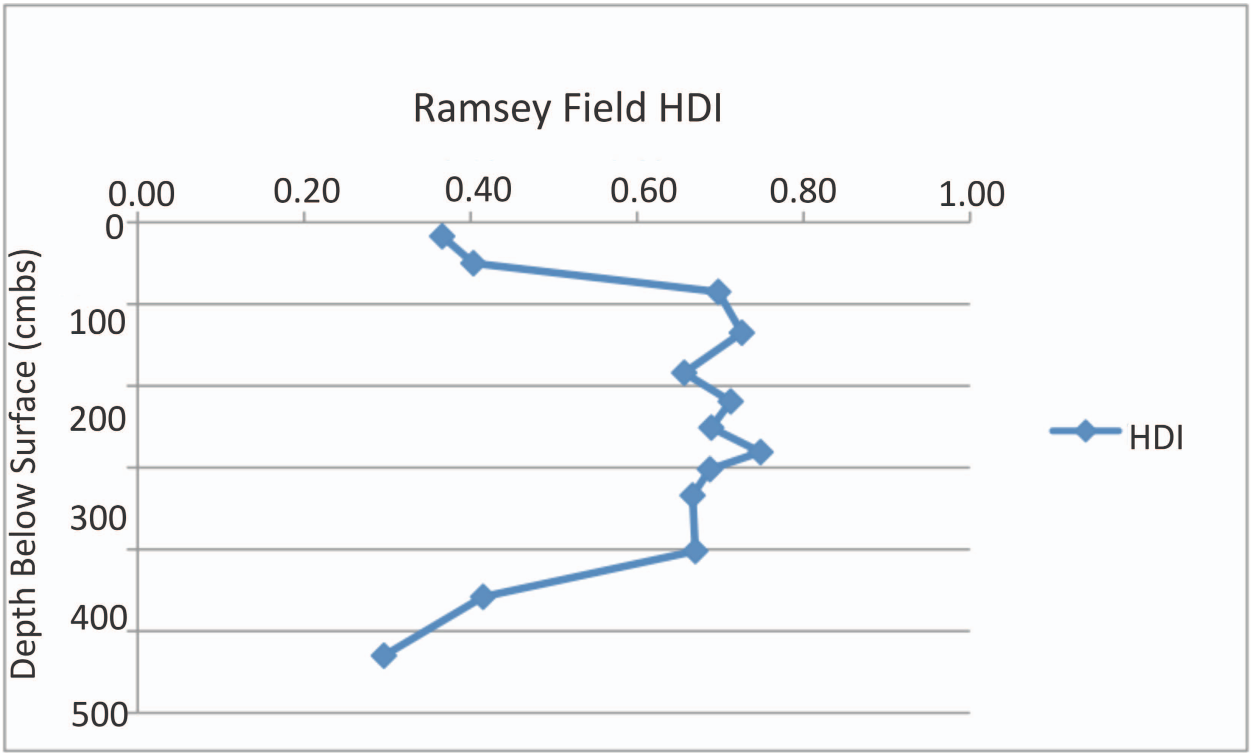

Figure 5.25. Ramsey Field T-3 HDI.

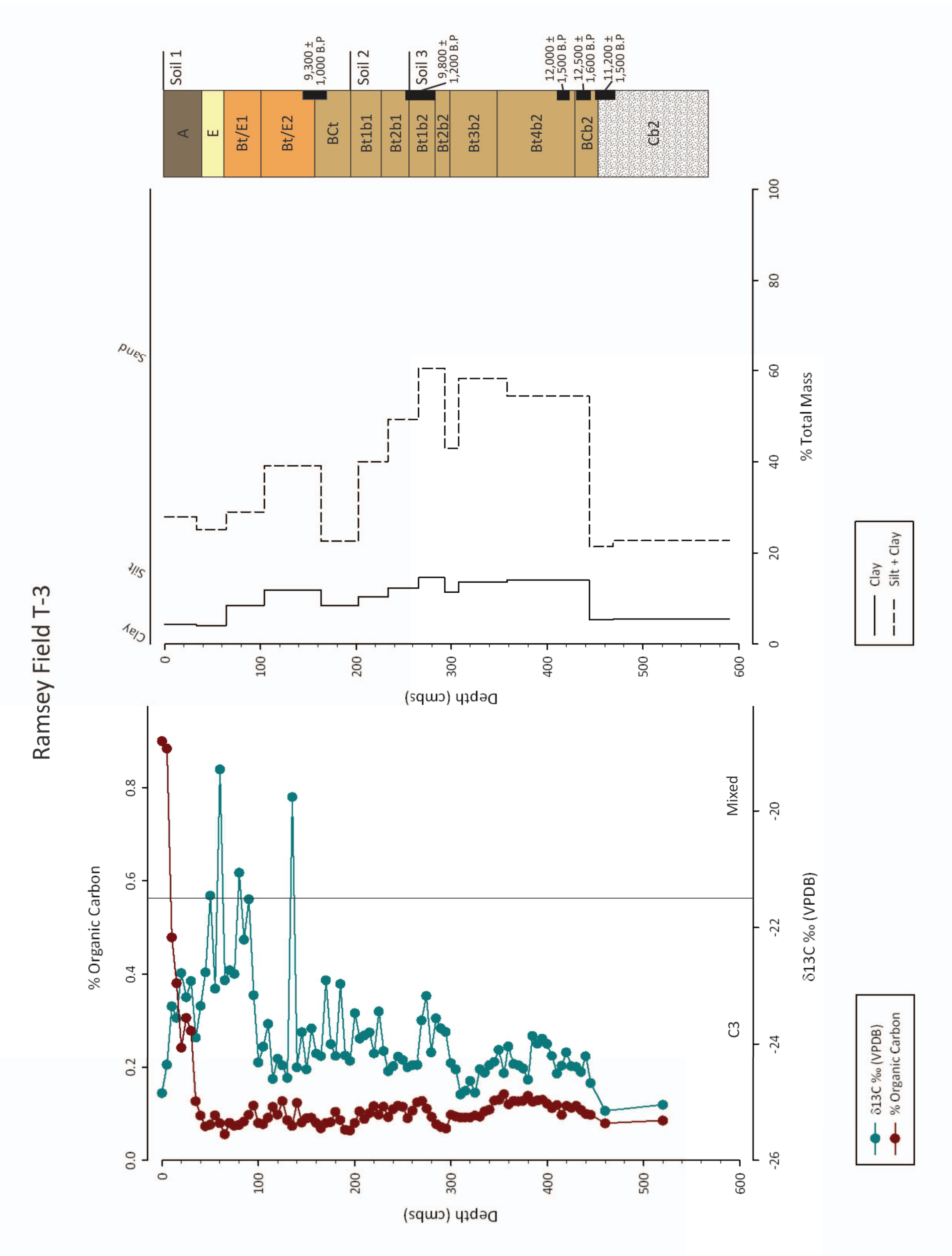

Figure 5.26. $\delta^{13}C$ and PSD depth functions from the T-3 at Ramsey Field.

Pin Oak

Saucier originally mapped the landform at Pin Oak as a T-2 terrace. However, the alluvial stratigraphy suggests it is a T-3 terrace. The landform is a large, grassy field with deciduous trees on the terrace scarp and on the adjacent hillslope (Figure 5.27 and 5.28). The T-3 surface is 0.5-1.0 m above the T-1 surface at Pin Oak. The surface soil is incorrectly mapped as Wideman fine sandy loam, a sandy, siliceous, mesic Typic Udifluvent (USDA 1990).

No sub-surface archaeological investigations have been conducted at Pin Oak (23CT198). NPS archaeologists have collected miscellaneous lithic materials from the surface 23CT198 at Pin Oak. Private collectors have also located Mississippian-age projectile points on the surface (Price et al. 1983).

The core obtained from Pin Oak is 444 cm long, but the fill likely extends much deeper. Problems with the coring rig made it necessary to stop before reaching bedload deposits. Three strata were recorded in the upper 444 cm of the T-3 fill at Pin Oak (Figure 5.29). The soil (Soil 1) developed in the top stratum is 306 cm thick and has a well expressed A-E-BE-Bt-BC profile. The A and E horizons are 15 cm and 26 cm thick, respectively, and consist of sandy loam. The BE horizon is 24 cm thick and consists of sandy loam. The argillic horizon (Bt1, Bt2, Bt3, Bt4) is 218 cm thick and consists of sandy loam to loam. The Bt1 and Bt2 horizons have distinct, discontinuous clay films on ped faces and in macropores. The Bt3 and Bt4 horizons have thin, discontinuous clay films on ped faces and in macropores. Depletion zones of very pale brown (10YR 7/4, dry) sandy loam are present on ped faces in the Bt3 and Bt4 horizons. The BC horizon is 28 cm thick and consists of sandy loam. An abrupt boundary separates the BC horizon from Soil 2 developed in the middle stratum.

Soil 2 is 122 cm thick and has a well expressed AB-Bt-BC profile. The ABb horizon is 46 cm thick and consists of loam. The argillic horizon (Btb) is 53 cm thick and consists of loam. Common depletion zones of very pale brown (10YR 7/3, dry) sandy loam are present on ped faces throughout the middle stratum. An abrupt boundary separates the BCb horizon, which consists of sandy clay loam, of Soil 2 from Soil 3 developed in the bottom stratum.

Only the upper 16 cm of Soil 3 was recovered in the core. Soil 3 is represented by a truncated Bt horizon with sandy clay loam texture. Depletion zones of very pale brown (10YR 7/4) sandy loam are present in macropores and distinct, discontinuous clay films are evident on ped faces and in macropores.

The HDI (Figure 5.30) shows an increase in soil development in soils 1, 2, and 3. Soil 3 appears to be the most developed.

The $\delta^{13}C$ values determined on SOM from the T-3 at Pin Oak range from -25.7‰ to -21.4‰ (Figure 5.31). These values indicate a C_3 plant community for the period of record. The lightest $\delta^{13}C$ value of -21.4 occurs in both the BC and Btb horizons of Soil 1. The heaviest $\delta^{13}C$ value, -25.7‰, occurs in the A horizon. The difference between the lightest and heaviest $\delta^{13}C$ values is 4.3‰, which may indicate increased contributions to SOM from C_4 vegetation.

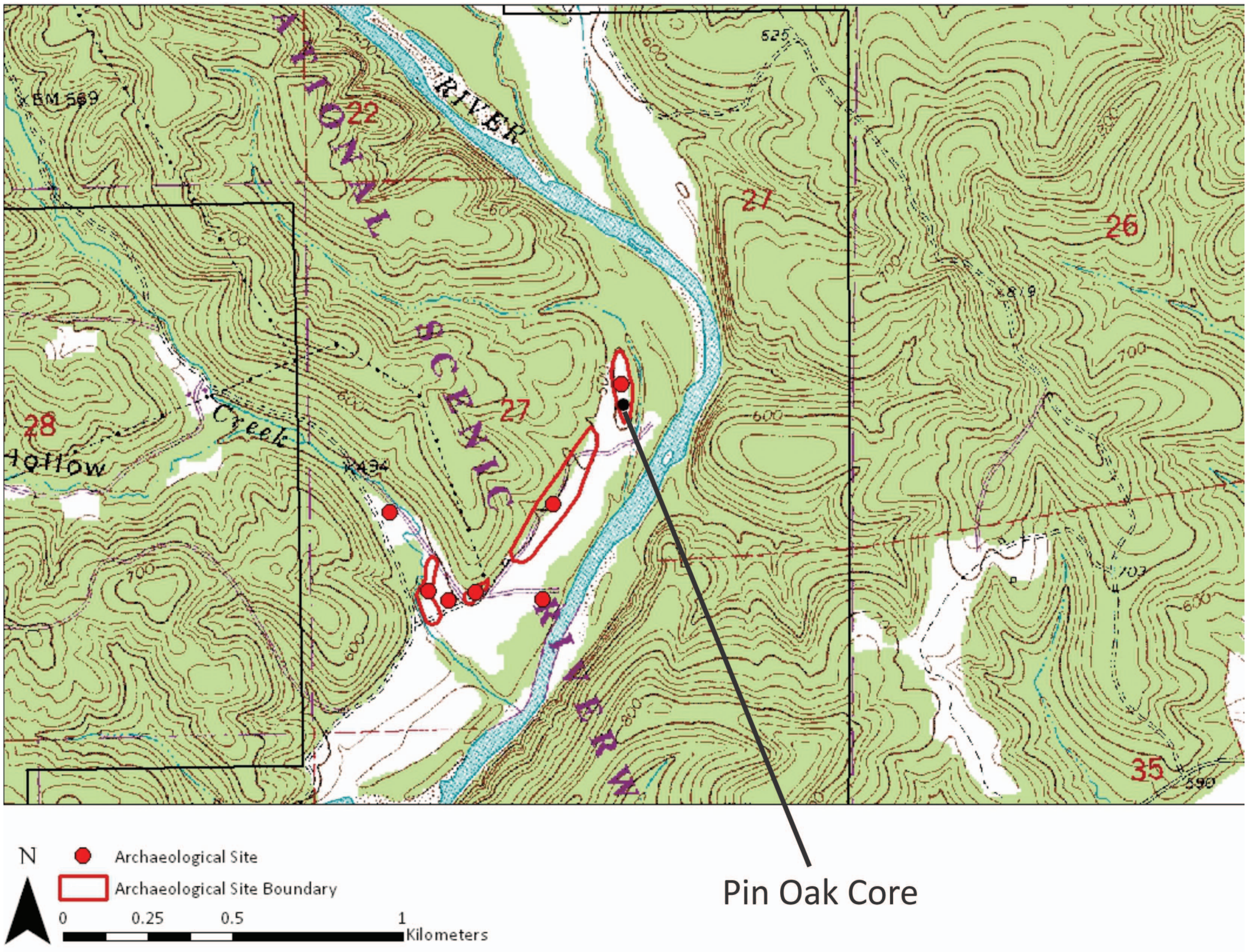

Figure 5.27. Topographic map of the Pin Oak locality.

Figure 5.28. Pin Oak T-3 locality. View is northeast. River is to the east.

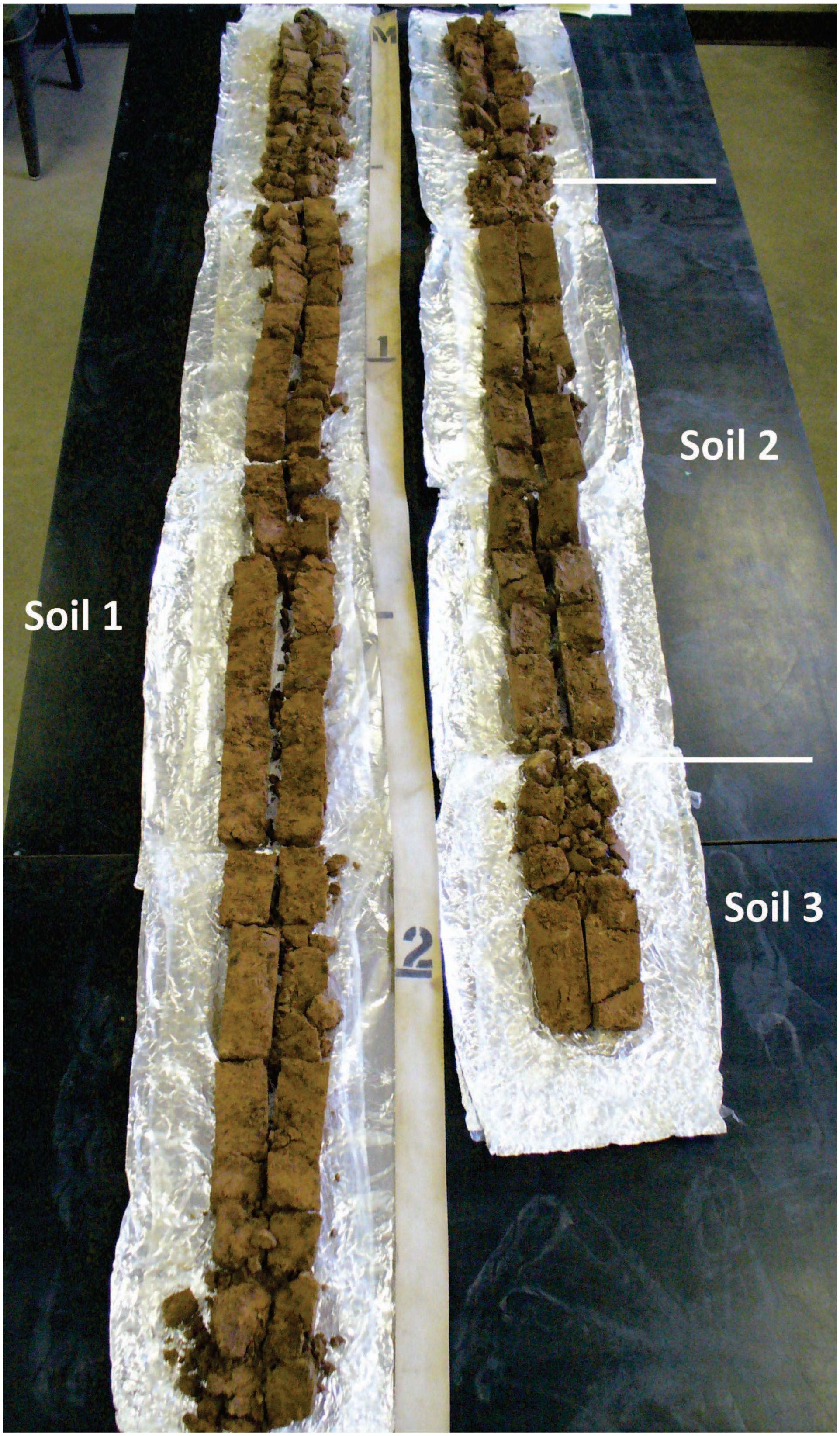

Figure 5.29. Pin Oak T-3 soil profile.

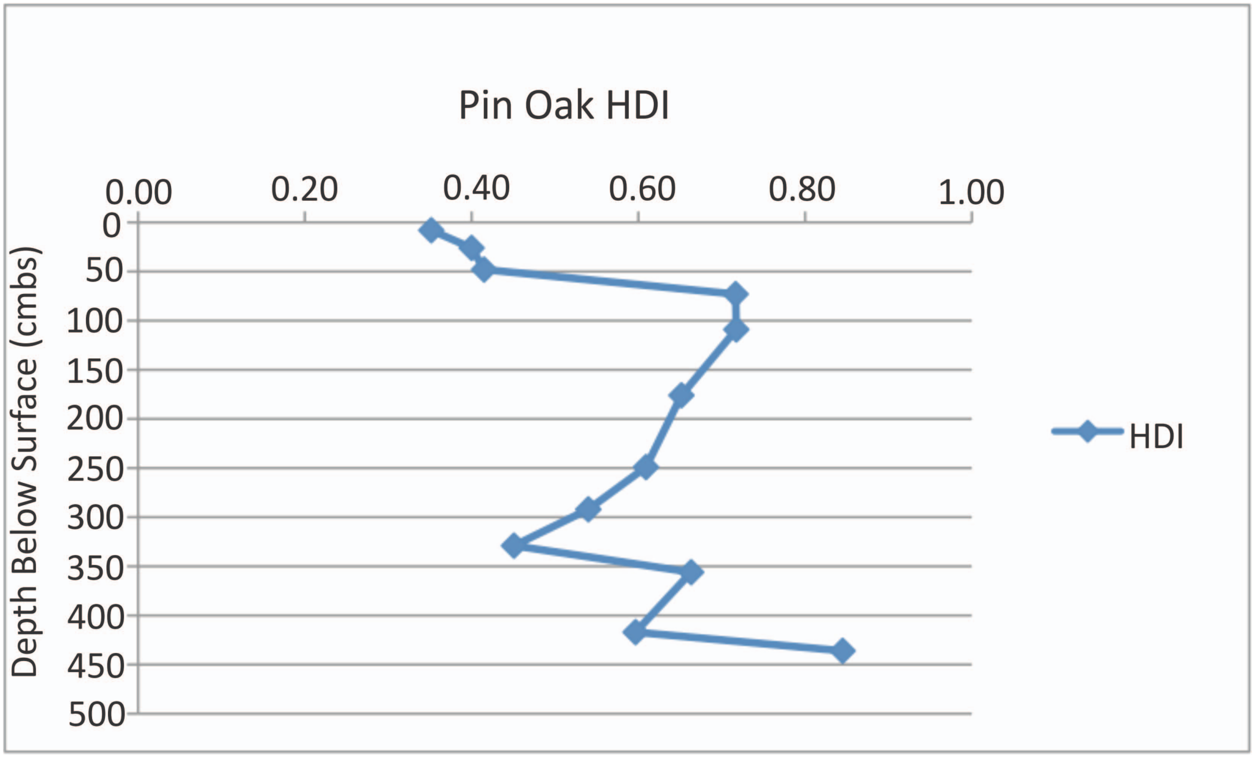

Figure 5.30. Pin Oak T-3 HDI.

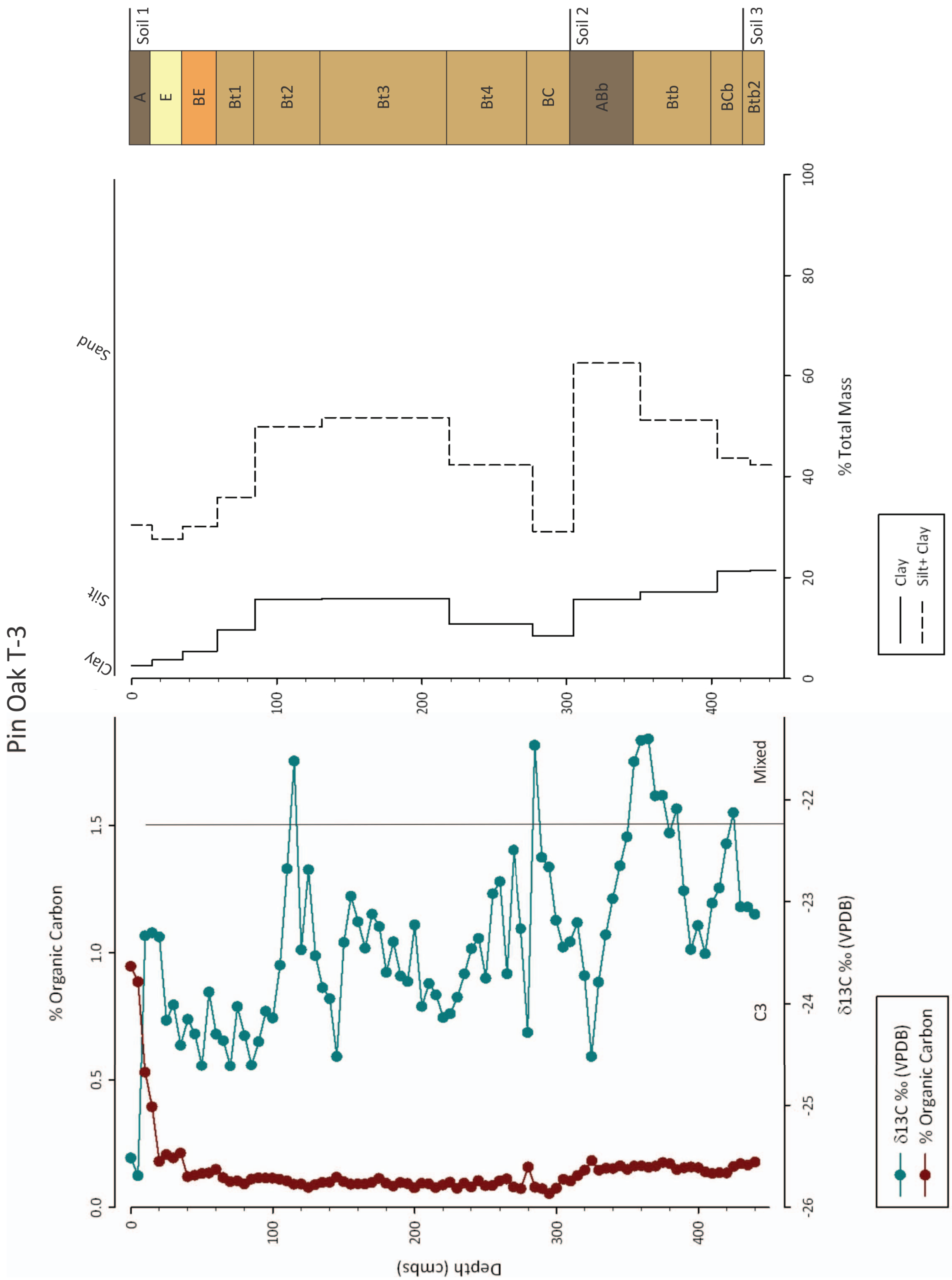

Figure 5.31. $\delta^{13}C$ and PSD depth functions from the T-3 at Pin Oak.

Alluvial Fan

<u>Chubb Hollow</u>

The alluvial fan at Chubb Hollow formed at the mouth of a small, unnamed intermittent stream. A Civilian Conservation Corps picnic shelter is situated on the landform, which is covered with grass (Figures 5.32, 5.33a, and 5.33b). Several deciduous trees stand on the edges of the fan. The surface soil is mapped as an Alred-Rueter complex hillslope soil (USDA 1990).

Archaeological investigations yielded artifacts from Late Archaic through Historic time periods in the alluvial fan fill and in toe slope deposits at Chubb Hollow (23CT104) (De Vore 1986; Garrison et al. 1976; Lynott 1981; Vawser 1999). Garrison et al. (1976) excavated five test units to between 50 and 70 cmbs both north and south of the Chubb Hollow stream. De Vore (1986) excavated four 1x1 m and one 1x1.5 m test units in the area of the parking lot that sits north of the alluvial fan and Chubb Hollow stream. Vawser (1999) excavated one test unit in the alluvial fan deposits and 29 shovel tests in multiple locations at 23CT104.

Two strata comprise the alluvial fan at Chubb Hollow (Figure 5.34). The soil (Soil 1) developed in the top stratum has a well expressed A-AB-Bw-Bt profile and is 143 cm thick. The A horizon is 7 cm thick and consists of silt loam. The cambic horizon (Bw) is 108 cm thick and consists of loam. The argillic horizon (Bt1 and Bt2) is 108 cm thick and consists of silt loam. Faint, nearly continuous clay films occur on ped faces and in macropores in the Bt horizons. Also, the Bt2 horizon has few (5%) light yellowish brown (10YR 6/4, dry) depletion zones of sandy loam in macropores. The Bt2 horizon is welded to Soil 2 developed in the bottom stratum.

Soil 2 is 137 cm thick and has a Bt-BC profile. The argillic horizon (Bt1b and Bt2b) is 117 cm thick and consists of silt loam. Distinct, discontinuous clay films and common (40%) light yellowish brown (10YR 6/4, dry) depletion zones of sandy loam occur on ped faces and in macropores in the Bt1b and Bt2b horizons. An OSL age of 11,400 ± 1,400 B.P was determined on sand grains from the Bt1b horizon, and sediment samples collected from the Bt2b horizon at depths of 163-183 cmbs and 197-225 cmbs yielded OSL ages of 11,900 ± 1,500 B.P. and 18,200 ± 2,100 B.P., respectively. Quartz grains from the deepest sample were partially bleached, so that age does not accurately reflect the time at which they were buried. The BC horizon consists of loam. The HDI (Figure 5.35) shows an overall increase in soil development through the argillic horizon of Soil 1 and into Soil 2 before decreasing in the bottom of Soil 2.

The $\delta^{13}C$ values determined on SOM from the alluvial fan deposits at Chubb Hollow range from -27.2‰ to -22‰, indicating a C_3 vegetation community for the period of record (Figure 5.36). The lightest $\delta^{13}C$ value, -27.2‰, occurs in the A horizon. The heaviest $\delta^{13}C$ value, -22‰, occurs in the Bt1b horizon. The difference between the lightest and heaviest $\delta^{13}C$ values is 5.2‰, suggesting C_4 vegetation had some influence on SOM through time. A 3.8‰ excursion toward heavier $\delta^{13}C$ values occurs between the A and Bw horizons, which could be the result of an increase in C_4 vegetation. Below the Bw horizon, $\delta^{13}C$ values remain fairly constant, varying between -23‰ and -22‰. No significant change in $\delta^{13}C$ values occurs across the boundary between the top and bottom strata.

In the alluvial fan deposits at Chubb Hollow, illuviated clay to a depth of 260 cmbs suggests diagenesis has been in progress for a long time. Overall, the fan fill is less sandy than the other localities in the study, the result of deposition in a low-energy environment.

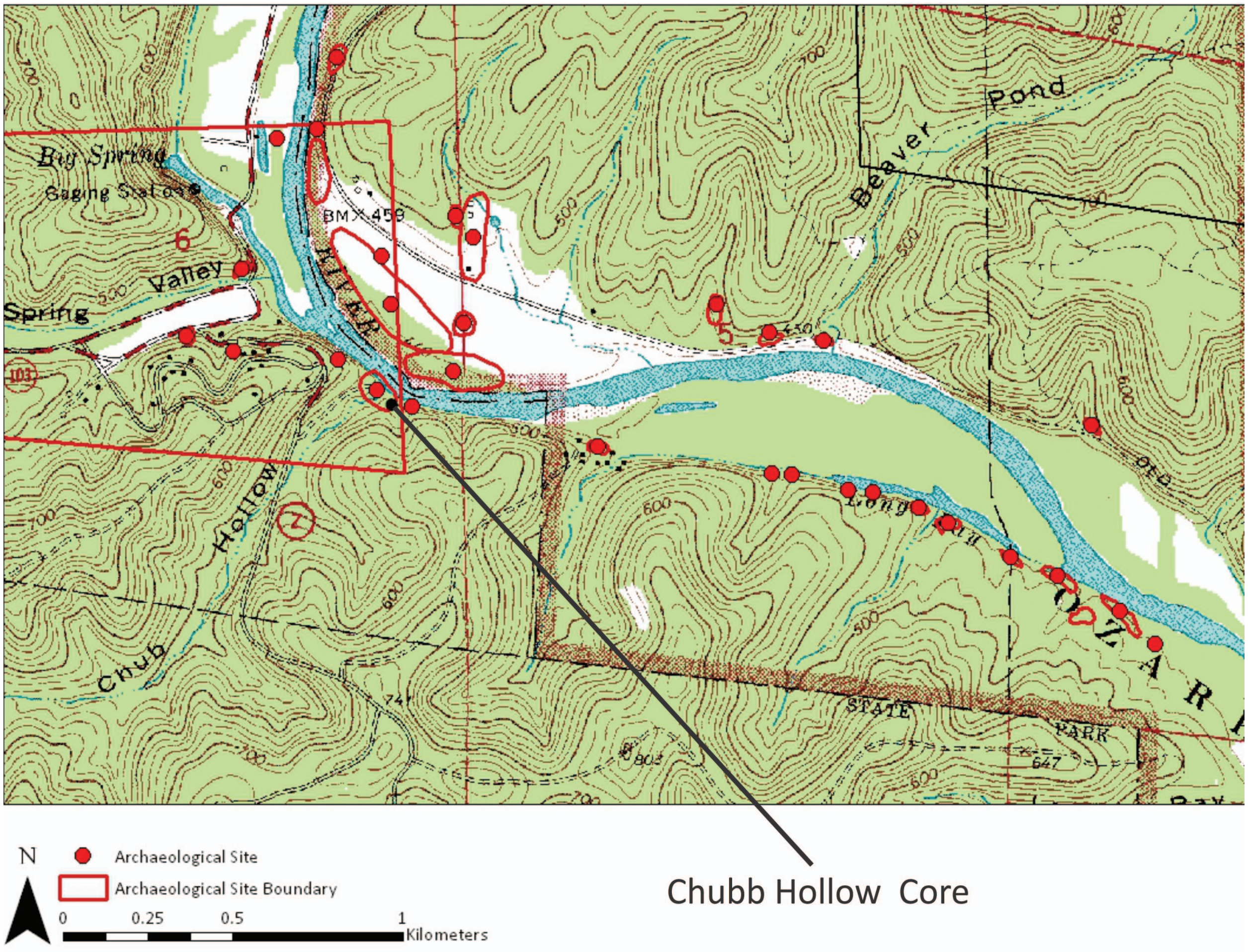

Figure 5.32. Topographic map of the Chubb Hollow locality.

Figure 5.33a. Chubb Hollow alluvial fan locality. View southwest. Truck is sitting on the surface of the fan. River is to the east.

Figure 5.33b. Chubb Hollow alluvial fan locality. View southwest. CCC picnic shelter in pictured in the right side of the frame. River is to the east.

Figure 5.34. Chubb Hollow alluvial fan soil profile.

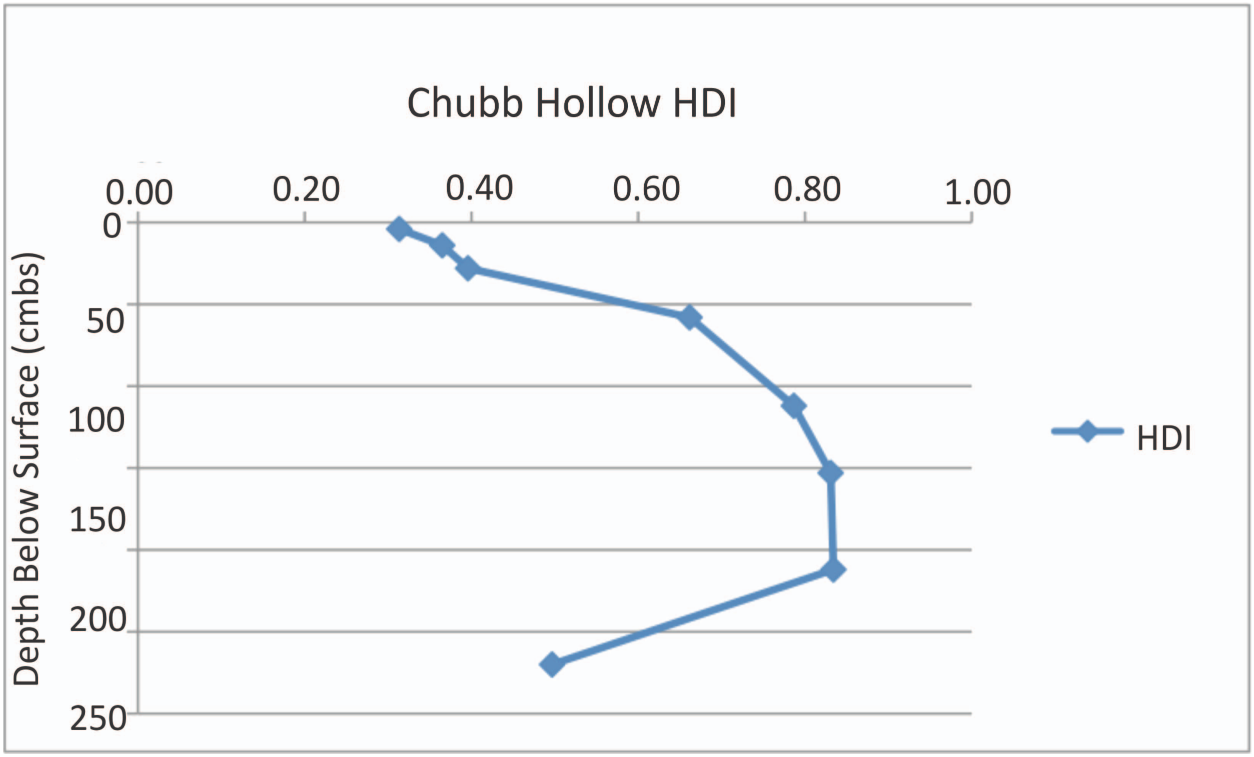

Figure 5.35. Chubb Hollow alluvial fan HDI.

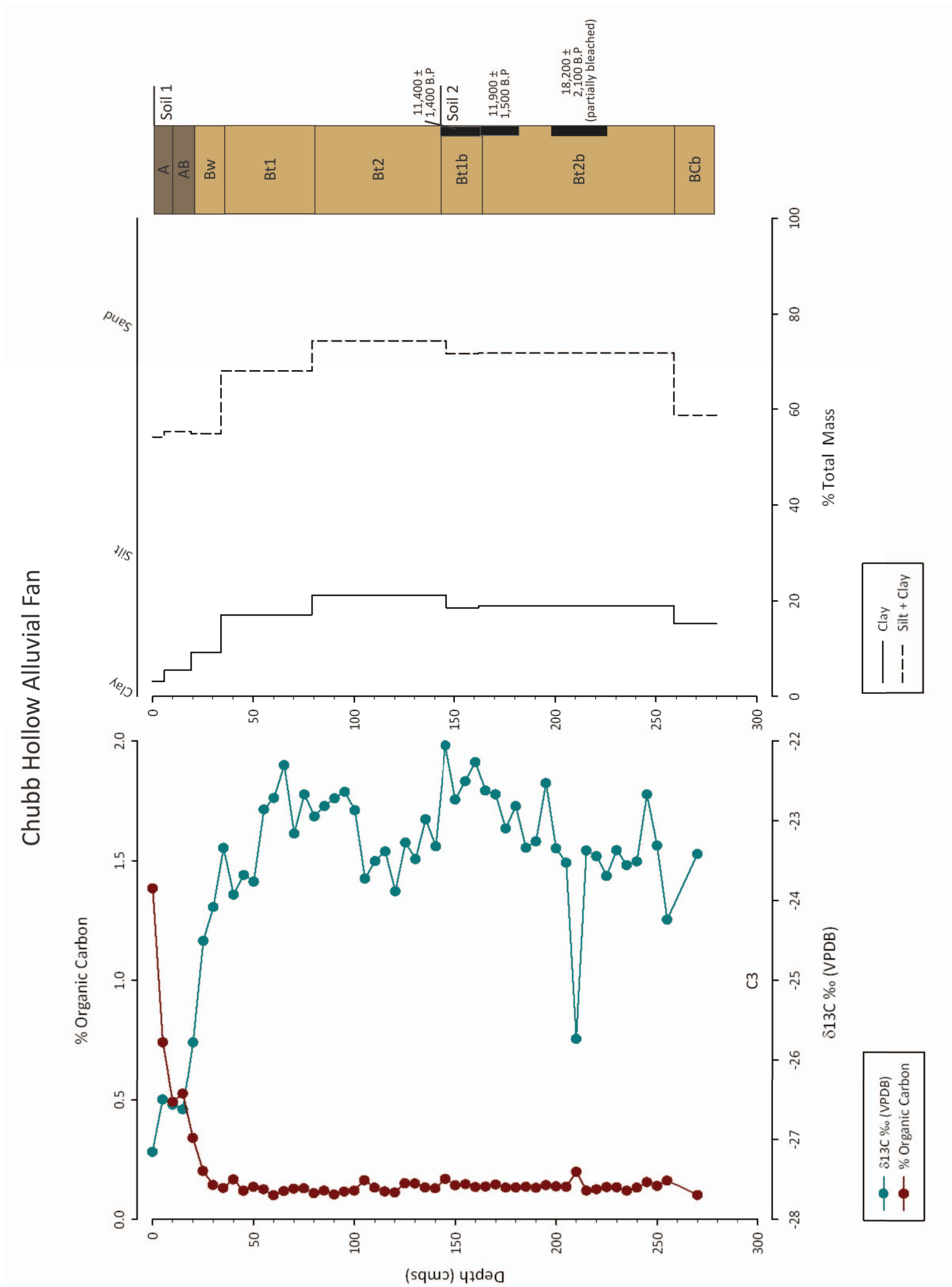

Figure 5.36. $\delta^{13}C$ and PSD depth functions from the alluvial fan at Chubb Hollow.

Creek Fill

Gladden Creek

The Gladden Creek locality is located northwest of the Akers Ferry locality, in an open field that is hayed periodically (Figure 5.37 and 5.38). The LSA consists of fine-grained alluvium overlying bedload deposits of fine, medium, and coarse gravel. The surface soil is mapped as Wideman fine sandy loam, sandy, siliceous, mesic Typic Udifluvent (USDA 2005).

No archaeological investigations have been conducted at the Gladden Creek locality, though the Dances with Grasshoppers site (23SH177) is situated 350 m upstream. Site 23SH177 yielded Dalton, Early, Middle, and Late Archaic, Early Woodland, and Emergent Mississippian artifacts (Price et al. 1983; Price 1992; Price 1996). The Akers Gap site (23SH22) is a multi-component prehistoric and Euro-American site to the east of the Gladden Creek locality (Price 1996). A pedestrian survey and shovel test inventory were conducted on the ridgetop north of the Gladden Creek locality, but did not yield any cultural material (Price 1992).

Two strata comprise the fill beneath the valley floor at Gladden Creek (Figure 5.39). The soil (Soil 1) developed in the top stratum is 46 cm thick and has a well expressed Ap-Bw-Bt profile. Soil 2, developed in the bottom stratum, is 161 cm thick and has a well expressed A-Bt-BC-C profile. The HDI (Figure 5.40) shows a decrease in soil development in the Ap, Bw, and Ab horizons and an increase in soil development in the argillic horizons. Development decreases with depth in the BCB and Cb horizons.

The $\delta^{13}C$ values determined on SOM from the creek fill at Gladden Creek range from -25‰ to -20.8‰, indicating a mixed C_3/C_4 plant community for the period of record (Figure 5.41). The lightest $\delta^{13}C$ value, -25‰, occurs in the Ap horizon. The heaviest $\delta^{13}C$ value, -20.8‰, occurs in the both the Ab and Btb horizons. The difference between the lightest and heaviest $\delta^{13}C$ values is 4.2‰, suggesting that C_4 plants contributed to SOM. Between the A and Btb horizons, $\delta^{13}C$ values become heavier, a trend that continues into the Ab horizon. The $\delta^{13}C$ values shift back to lighter values between the Btb horizon and the base of the core.

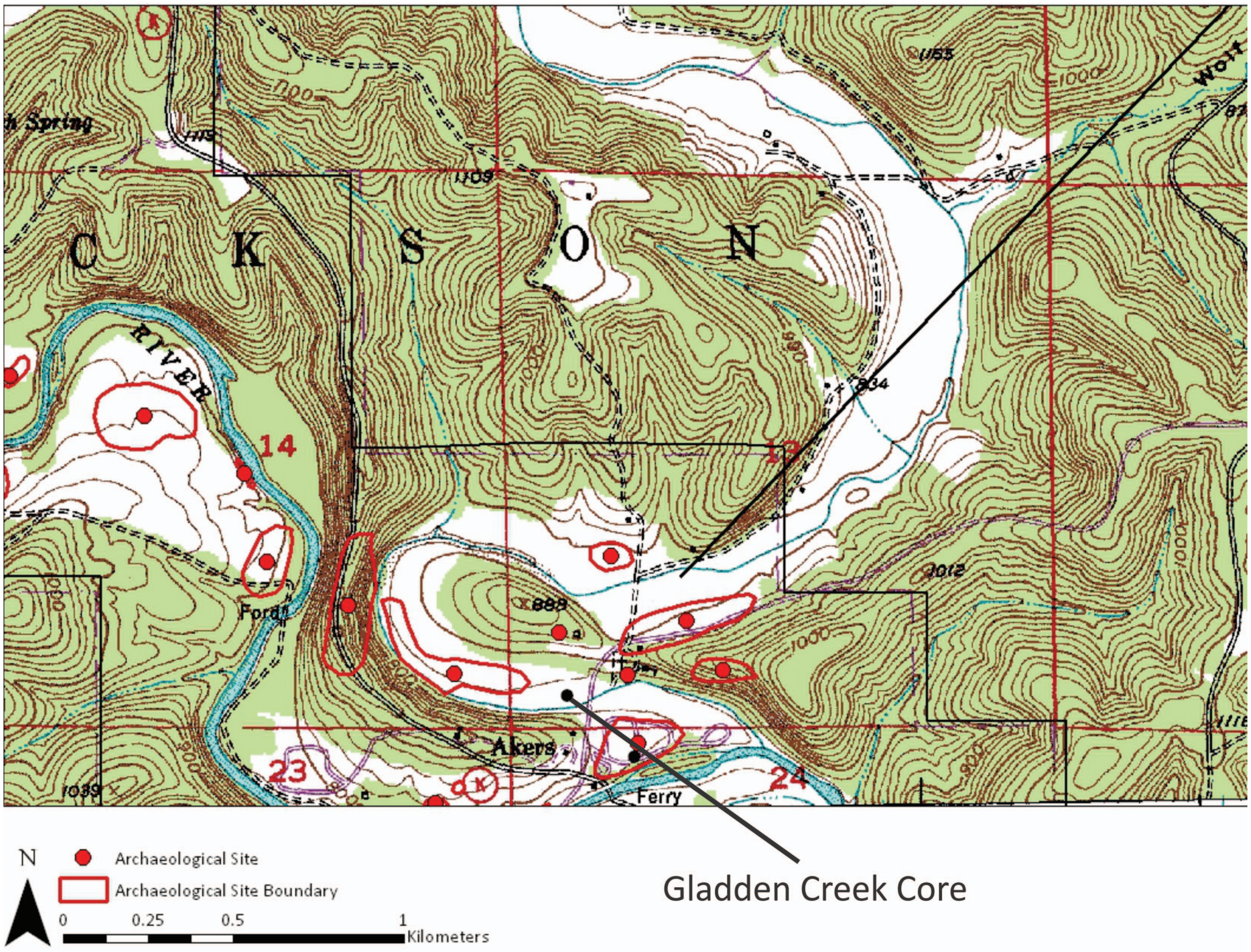

Figure 5.37. Topographic map of the Gladden Creek locality.

Figure 5.38. Gladden Creek fill locality. View is northeast. Gladden Creek runs south and is behind the trees on the left side of the frame.

Figure 5.39. Gladden Creek soil profile.

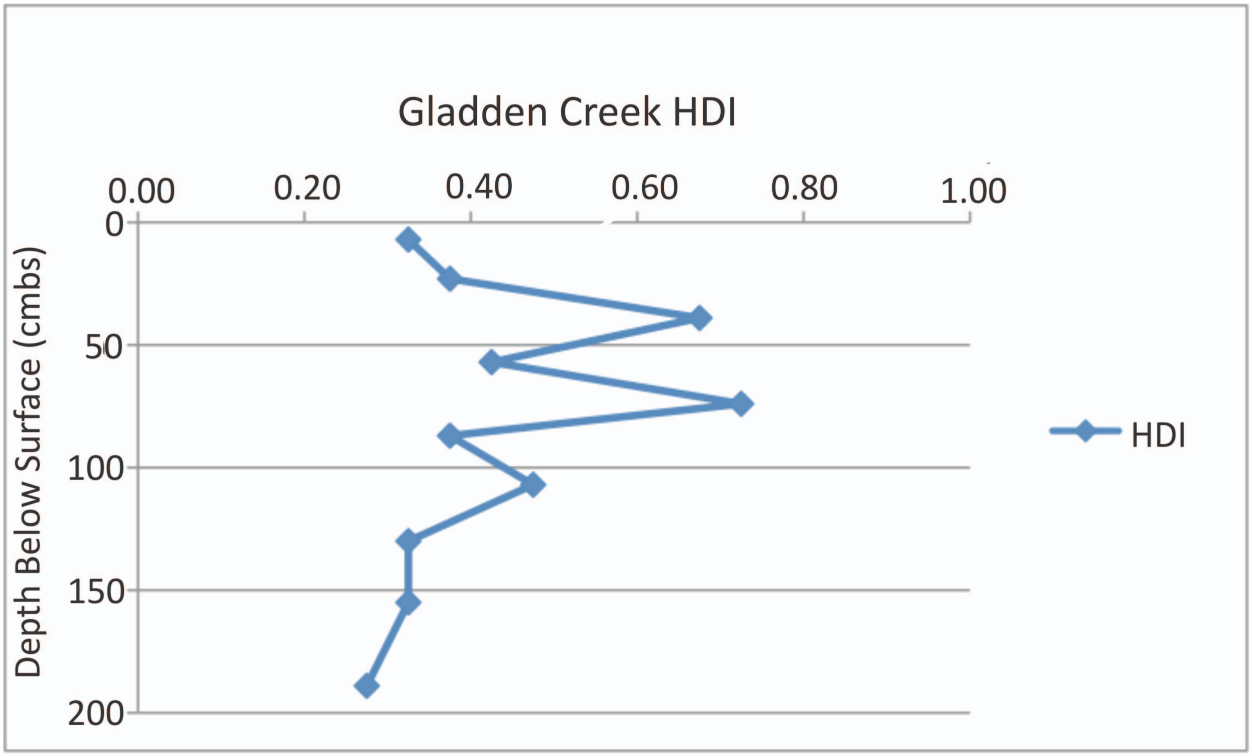

Figure 5.40. Gladden Creek HDI.

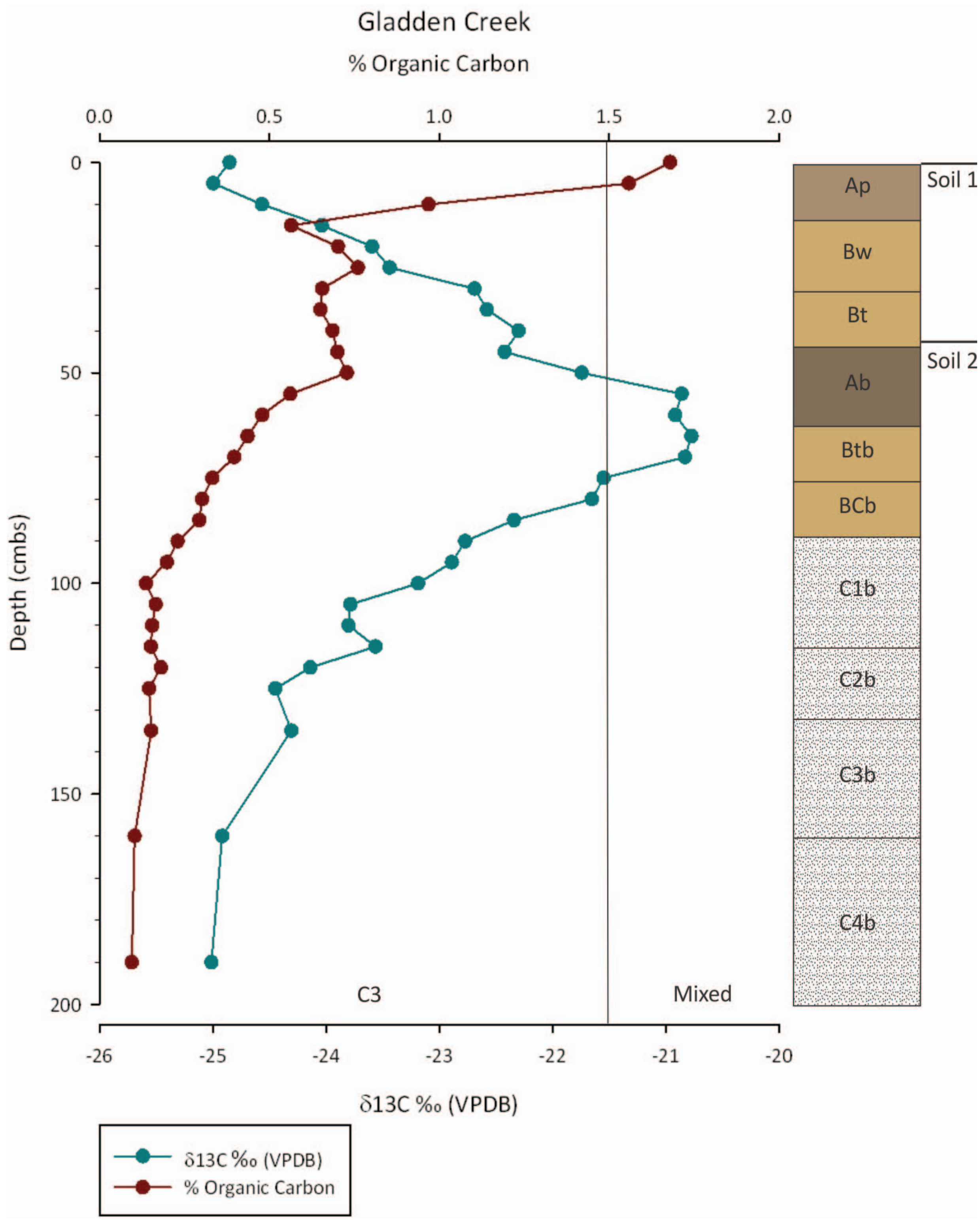

Figure 5.41. $\delta^{13}C$ depth function from Gladden Creek.

Summary

In this chapter, I reviewed the results of alluvial stratigraphy, chemostratigraphy, and geochronology from eight study localities. Using these data, I characterized alluvial LSAs, identified continuity in the late-Quaternary paleoenvironmental record based on stable carbon isotope values, and established an alluvial chronology for the Current River valley. The implications of these data for late-Quaternary landscape evolution and the geologic potential for cultural deposits in the study area are further discussed in Chapter 6.

CHAPTER 6

LATE-QUATERNARY LANDSCAPE EVOLUTION AND GEOLOGIC POTENTIAL FOR CUTURAL DEPOSITS IN THE CURRENT RIVER VALLEY

Previous archaeological research in the Current River valley indicated that cultural deposits were confined to the upper 0.5 m of alluvial fill. However, the data presented in Chapter 5 indicate that there is good geologic potential for archaeological deposits to occur much deeper in alluvial fills, perhaps as much as 5 m below surface. Additionally, while buried archaeological deposits were thought to be limited to T-3 terrace fills, alluvial fan deposits, and creek fills, my data indicates that T-2 and T-1 terrace fills also have potential to yield buried prehistoric deposits. A study of site distribution data from Ozark NSR make clear that establishing patterns in site locations from particular archaeological traditions is difficult. This problem is further affected by the landscape complexity my study has revealed.

To begin this chapter, I review the data presented in Chapter 5 and discuss how it affects our understanding of late-Quaternary landscape evolution in the Current River valley. I then compare my findings with the conclusions Saucier drew from his work in the Current River valley. Finally, I evaluate the geological potential for cultural deposits in the Current River valley.

Late-Quaternary Landscape Evolution in the Current River Valley

Alluvial Stratigraphy and Chronology

Saucier (1987, 1996) developed a terrace sequence and model of late-Quaternary landscape evolution for the Current River valley. For my dissertation, alluvial stratigraphy, stable carbon isotope values of SOM, and numerical ages were determined at eight localities in the river valley to refine Saucier's findings. The OSL ages indicate that terrace fills are younger than Saucier's estimates (Figure 6.1). This finding was unexpected, but given the valley floor is narrow and bedrock valley walls confine the channel, the Current River is constantly migrating laterally and recycling alluvium.

The T-1 fill at Round Spring is comprised of two strata: Historic flood deposits overlying late-Holocene alluvium (Figure 6.1). The timing of aggradation is uncertain, but an OSL age of 3,000 B.P. obtained from 2 m below surface provides a minimum age of alluviation. Between ca. 3,000 B.P. and ca. 1,700 B.P., 1.5 m of alluvium accumulated on the T-1. Alluviation was interrupted by a period of stability shortly after ca. 1,700 B.P and a soil (Soil 2) with a well expressed A-Bt profile developed on T-1. Soil 2 is developed in the bottom stratum, which is 120 cm thick and consists of sandy loam fining upward to loam. Following the period of stability represented by Soil 2, alluviation resumed and a soil (Soil 1) with a weakly expressed A-C profile formed in the top stratum. The top stratum consists of loamy sand and is 120 cm thick. Historic logging removed vegetation from the uplands and probably caused the last period of erosion on uplands and concomitant alluviation on the valley floor.

At Akers Ferry, the T-2 is a strath cut across the T-3 fill (Figures 6.1 and 6.2). Based on OSL ages, the T-3 fill beneath the T-2 strath was aggrading before ca. 45,500 B.P. Between ca. 45,500 B.P. and 29,800 B.P., it is likely that part of the T-3 fill was removed by erosion, as only 30 cm of alluvium separates the samples that yielded these two OSL ages. After ca. 29,800 B.P., approximately 1 m of alluvium aggraded before a period of stability allowed a soil (Soil 2) with a well expressed Bt-BC profile to develop. The top of Soil 2 is an erosional surface; the A horizon was removed when the strath formed. Soil 2 is formed in the bottom stratum, which is 150 cm thick and consists of sandy loam fining upward to silt loam. Climate change during the

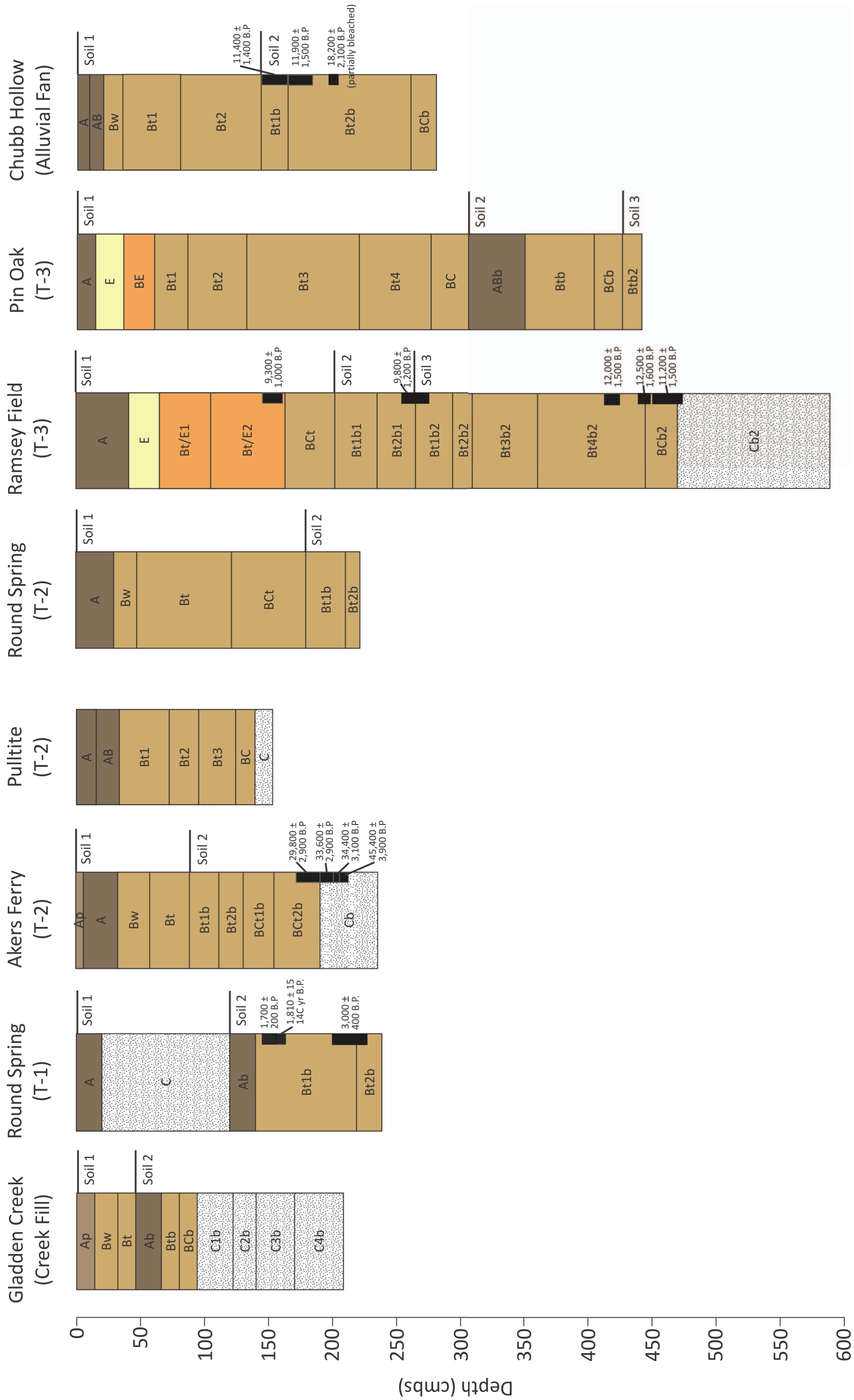

Figure 6.1. Locality stratigraphy and OSL ages organized by landform.

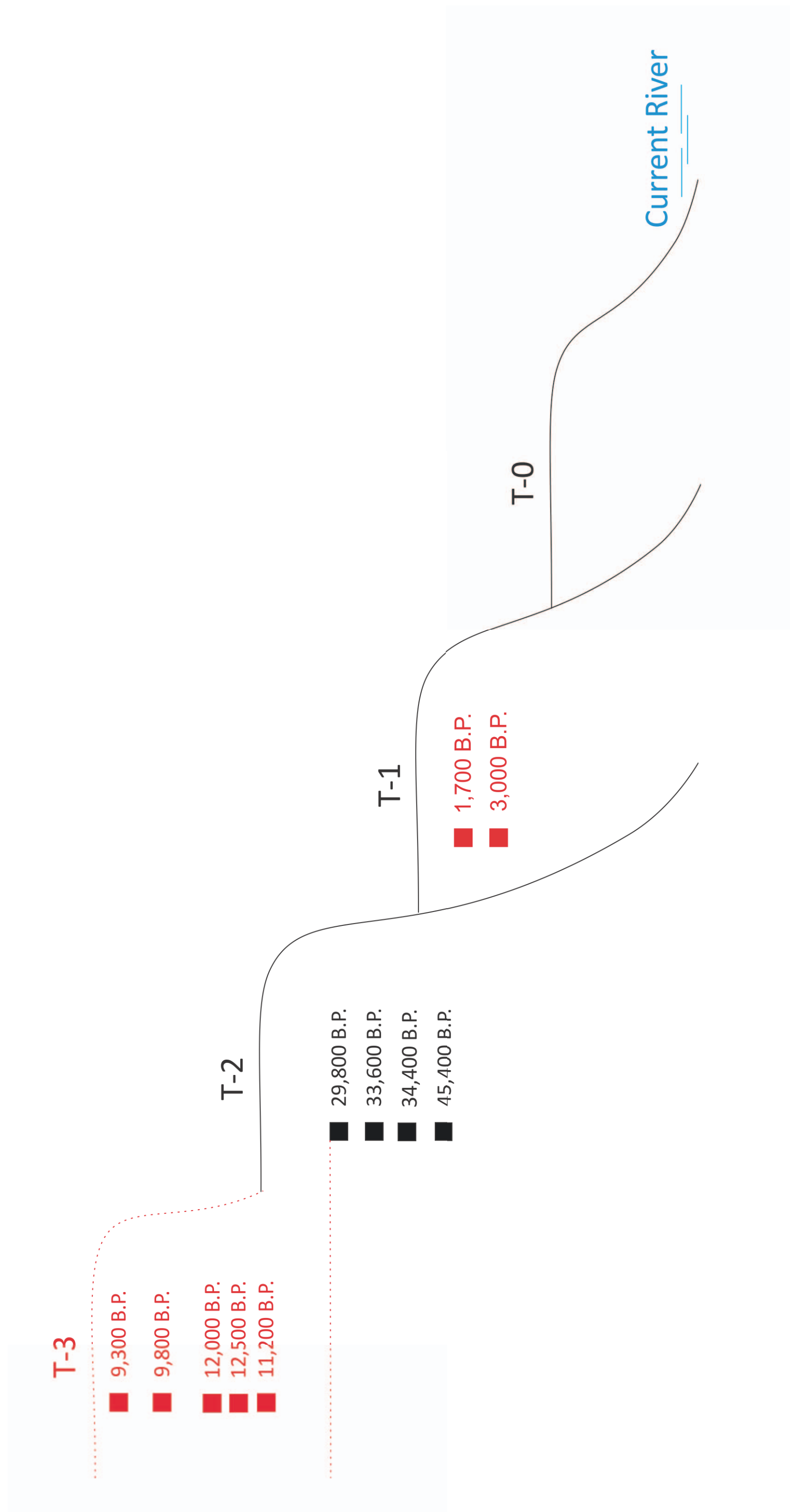

Figure 6.2. Conceptualization of terrace sequence at Akers Ferry with T-2 as a fill strath terrace. The red portions of the diagram indicate hypothetical fills and ages.

late Pleistocene and early Holocene may have triggered downcutting and lateral channel migration that created the strath, though this is not recorded in the $\delta^{13}C$ results. Soil 2 was eventually buried by 86 cm of alluvium before another period of stability allowed the modern surface soil (Soil 1) with a well expressed Ap-A-Bw-Bt profile to develop in the top stratum. The top stratum is 86 cm thick and consists of silt loam.

Two strata comprise the T-2 fill at Round Spring (Figure 6.1). The top stratum is 180 cm thick and consists of silt loam. A surface soil (Soil 1) with a well expressed A-Bw-Bt-BCt profile developed in the top stratum. The bottom stratum is 40 cm thick and consists of sandy loam fining upward to silt loam. A paleosol represented by Bt horizons is developed in the bottom stratum; the A horizon was stripped off by erosion prior to burial. Numerical ages are needed to determine the time of aggradation of the T-2 fill at Round Spring.

One stratum comprises the T-2 fill at Pulltite (Figure 6.1). The surface soil at this locality has a well expressed A-AB-Bt-BC-C profile consisting of silt loam. Without numerical ages it is uncertain when T-2 fill at Pulltite aggraded. However, a major creek joins the Current River immediately upstream from Pulltite and may have influenced alluvial stratigraphy and chronology at this locality.

Three strata comprise the upper 6 m of T-3 fill at Ramsey Field. When T-3 aggradation began is uncertain, but alluviation was underway by ca. 12,500 B.P. At ca. 9,800 B.P., a period of stability occurred, allowing a soil (Soil 3) with a well expressed Bt-BC profile to develop in the bottom stratum. The bottom stratum is 323 cm thick and consists of loamy sand fining upward to loam. Aggradation resumed shortly after ca. 9,800 B.P., burying Soil 3 beneath 31 cm of alluvium. Another period of stability allowed Soil 2, which consists of two Bt horizons, to form in the middle stratum. The middle stratum is 64 cm thick and consists of sandy loam.

Renewed aggradation prior to ca. 9,300 B.P. resulted in the burial of Soil 2 beneath 203 cm of alluvium. Soil 1 is formed in the top stratum and has a well expressed A-E-Bt/E-BC profile. The 203 cm-thick top stratum consists of sandy loam.

Three strata consisting of fine-grained alluvium comprise the T-3 fill at Pin Oak (Figure 6.1). The top stratum is 306 cm thick and consists primarily of sandy loam. The surface soil (Soil 1) developed in the top stratum has a well expressed A-E-BE-Bt-BC profile. Soil 2 has developed in the middle stratum with a well expressed AB-Bt-BC profile. Soil 2 is 122 cm thick and consists of sandy clay loam fining upward to loam. The bottom stratum is 16 cm thick and consists of sandy clay loam. Soil 3 developed in the bottom stratum is represented by a Bt horizon. Numerical ages are needed to determine when T-3 fill aggraded at Pin Oak. However, the alluvial stratigraphy is similar to that observed at Ramsey Field. T-3 fills at these two localities may have aggraded during the same period.

Two strata were recorded in the upper 2.7 m of the alluvial fan at Chubb Hollow (Figure 6.1). It is uncertain when the fan began aggrading; an OSL age of 18,200 B.P. was determined from a sediment sample at 2 m below surface but is problematic because of partial bleaching. The bottom stratum began aggrading before ca. 11,900 B.P., during which time one meter of alluvium was deposited on the fan. Between ca. 11,900 B.P. and 11,400 B.P., an additional 20 cm of alluvium was deposited on the fan surface. A period of stability occurred at ca. 11,400 B.P., allowing a soil (Soil 2) with a well expressed Bt-BC profile to develop in the bottom stratum. The bottom stratum, which is 137 cm thick, consists of loam fining upward to silt loam. Soil 2 was eventually buried by alluvium and Soil 1 formed in the top stratum with a well expressed A-AB-Bw-Bt profile. Soil 1 is 143 cm thick and consists primarily of silt loam.

Two strata were recorded in the fill at Gladden Creek (Figure 6.1). The top stratum is 46 cm thick and consists of silt loam. A surface soil (Soil 1) with a moderately expressed A-Bw profile is developed in the top stratum. The presence of a cambic horizon suggests Soil 1 is relatively young. The bottom stratum is 161 cm thick and consists of loose sand and gravel fining upward to silt loam. A soil (Soil 2) with a well expressed A-Bt-C profile is developed in the bottom stratum.

My findings allow me to refine Saucier's terrace sequence and landscape-evolution model. He proposed that T-1 terrace fills aggraded during the Proto/Historic period, T-2 terrace fills aggraded between 15,000 and 7,000 B.P, T-3 terrace fills aggraded between 35,000 and 23,000 B.P., T-4 terrace fills aggraded sometime before 75,000 B.P. The OSL ages presented in my dissertation indicate that T-1 terrace fill aggraded from 3,000 B.P. to present. Most of the T-3 fill beneath the T-2 strath aggraded between ca. 45,500 and 29,800 B.P. The upper 6 m of the fill beneath the T-3 surface aggraded between ca. 12,500 and 9,300 B.P. At Chubb Hollow, an alluvial fan began aggrading before ca. 11,900 B.P. The time when aggradation ceased on the fan is unknown. However, the magnitude of soil development suggests that the fan has been stable for at least 3,000 years.

After his work at Gnat Alley Woods, Saucier (1996) suggested that the alluvial stratigraphy and chronology of terrace fills are difficult to characterize valley-wide. I present a preliminary alluvial stratigraphic and chronologic framework for the Current River valley, but agree with Saucier that alluvial stratigraphy may vary beneath the same terrace from one locality to the next. For example, I found that a strath formed across T-3 fill at Akers Ferry and perhaps at Round Spring, but not at Pulltite. If straths formed only at certain localities, the alluvial stratigraphy and chronology of T-2 will vary throughout the valley. Hence, it should not be assumed that a particular terrace occurs at the same elevation, or that alluvial deposits beneath the same surface are of the same age throughout the river valley. Therefore, archaeological site-landform relationships can be generalized valley-wide, but should be investigated and described at individual localities.

The alluvial stratigraphy and chronology of the Current River also may be strongly affected by spring outlets and tributary streams. The Current River valley contains some of the largest springs in the western hemisphere. Where spring outlets and major tributary streams join the Current River, influxes of water and sediment may affect erosion and sedimentation, respectively. As such, alluvial stratigraphy and chronology may differ above and below these confluences. The Pulltite locality may be an example of water and sediment influxes from a tributary stream influencing alluvial stratigraphy and chronology.

My data suggest that sediment contribution from the Jack's Fork affects alluviation below its confluence with the Current River. Saucier mapped few T-3 terraces above the Jack's Fork confluence. However, these terraces are more common below the Jack's Fork, where they occur as remnants occur on the margins of the valley floor.

Saucier's terrace sequence and model of late-Quaternary landscape evolution was qualitative. My data, including alluvial stratigraphy, stable carbon isotope values, and OSL ages, refine and quantify Saucier's model. However, more data are needed before the results of my study are applied to the entire length of the Current River.

Stable Carbon Isotopes

The $\delta^{13}C$ values from the eight study sites indicate mostly C_3 vegetation contributions to soil carbon for the period of record. At Akers Ferry, Ramsey Field, and Gladden Creek, $\delta^{13}C$

values indicate that C_3 plants contributed most of the organic carbon to the soils for the period of record. However, excursions toward heavier $\delta^{13}C$ values occur that reflect both C_3 and C_4 vegetation influences on soil carbon. Excursions in the $\delta^{13}C$ values at all localities except the T-2 at Round Spring are large enough (> 3‰) to reflect increased contributions of organic carbon by C_4 vegetation, but the exact timing of those shifts is unknown. One shift of -24.9‰ to -19.8‰ occurs in the Bt/E1 horizon in the Ramsey Field fill. This 5.1‰ excursion toward heavier values at 9,300 B.P. may reflect the onset of the Altithermal.

Geoarchaeology in the Current River Valley

<u>T-1 Fill</u>

According to Saucier (1987), the T-1 fill throughout the Current River valley aggraded during the modern period. However, the data presented in my dissertation indicate that T-1 fill at Round Spring began aggrading during the late Holocene. This is a significant finding because archaeologists can now investigate Archaic and perhaps Woodland cultural deposits in a buried context.

Specifically, Archaic and Woodland cultural deposits may occur in the bottom stratum. Previous archaeological investigations in the study area recorded Late Archaic cultural deposits only in the plowzone. For example, at the Akers Ferry T-2 locality, Archaic deposits were excavated between 30 and 50 cmbs (Lynott 1989b). At Chubb Hollow (23CT104), Late Archaic materials were recovered at a depth of 60 cmbs (Garrison et al. 1976; Vawser 1999). The upper 50 cm of fill at Pulltite (23SH94 and the surrounding area) yielded both Late Archaic and Middle to Late Woodland cultural deposits (Lynott 1982; Vawser 1999). At site 23SH177 above the

Gladden Creek locality, Late Archaic and Woodland materials were recorded in the surface soil (Price et al. 1983; Price 1996).

The period of stability during which Soil 2 developed in the bottom stratum of the T-1 fill likely persisted for several hundred years; hence both Late Archaic and Woodland people could have lived on the stable surface represented by that soil. Paleoenvironmental conditions during the early to middle Holocene were similar to the modern environment and so the T-1 and higher terraces were forested. Archaic and Woodland people may have occupied the T-1 surface to exploit both river and forest resources.

Dalton, Late Archaic, Woodland, Mississippian, and Historic archaeological deposits have been recorded in the T-2 fill at Round Spring and are considered part of site 23SH19 (Lynott 1991b). The archaeological components in this fill suggest that the Round Spring area was occupied before and during T-1 aggradation. During the Late Archaic and Woodland periods, people could have occupied both the T-1 and T-2 surfaces, though archaeological testing of the T-1 fill is necessary to determine if it was actually occupied.

T-2 Fill

At Akers Ferry (23SH23), archaeological investigations recovered Dalton artifacts between 50 and 60 cmbs (Cannon et al. 2010; Lynott 1989b). Therefore, the top stratum began aggrading sometime before 10,000 ^{14}C yr B.P. Above the Dalton component, Archaic and Woodland cultural deposits were recovered. Depending on when the erosional event that formed the T-2 strath terrace occurred, there might be high geologic potential for Early Paleoindian and/or pre-Clovis cultural deposits in the top stratum, between the base of the Dalton component (60 cmbs) and the erosional surface (~1 m below surface).

The $\delta^{13}C$ values in Soil 2 at Akers Ferry indicate that after ca. 29,800 B.P., a mixed community of C_3 and C_4 plants was in place. If Soil 2 developed during the late Pleistocene, Akers Ferry may have been an ecotone where humans found access to a wide variety of resources. This microenvironment may have briefly occurred in the late-Pleistocene environment of the Current River valley. An overall trend in $\delta^{13}C$ values away from mixed C_3/C_4 vegetation and toward a C_3-dominated community is evident in Soil 1, above the Dalton occupation. Dalton people may have initially occupied the landform to exploit a variety of resources. Later in time, if the landform became more forested than during the Dalton occupation, people may have been interested in other amenities the location provided. Perhaps the river ran low during the Altithermal and Akers Ferry was a good place to ford the river, as was its use during the Historic period.

Based on my findings and the results of previous investigations, the stratigraphy of the T-2 fill at Akers Ferry is extremely complex. Archaeological investigations recorded vastly different stratigraphy across the site (e.g., Lynott 1989b; Mandel 2010). Lynott (1989b) encountered Dalton-age materials in a package of sediment 10 cm thick. Immediately above the Dalton component, a small number of Archaic materials were recovered from a 10 cm-thick component. Hence, during the Archaic period, which lasted for about 7,000 years, sedimentation on the T-2 surface was either slow or coupled with episodes of erosion. If erosion periodically occurred during early and middle Holocene, Archaic occupation of Akers Ferry may have been more extensive than is suggested by the archaeological record.

Mandel (2010) and Cannon et al. (2010) recorded a colluvial apron on a toeslope at Akers Ferry. The apron merges with the T-2 fill. Two buried soils were identified in the apron, one at a depth of 60 cm and another between 1.5 and 2.0+ m below surface (Mandel 2010). Also, archaeological deposits were recorded in the apron to a depth of 61 cmbs. Those deposits were correlated with the Dalton component identified at 60 cmbs in the T-2 fill.

T-3 Fill

At the Ramsey Field locality, where archaeological site 23SH77 has been recorded, there is high geologic potential for pre-Clovis through Archaic cultural deposits in the T-3 fill. Aggradation of the upper 6 m of T-3 fill was underway at ca. 12,500 B.P. A period of stability occurred at ca. 9,800 B.P. that allowed Soil 3 to develop in the bottom stratum. Pre-Clovis and Paleoindian deposits may occur in the bottom stratum.

Formation of Soil 3 was followed by an episode of alluviation. Aggradation was interrupted by a period of landscape stability prior to ca. 9,300 B.P., which allowed Soil 2 to develop in the middle stratum. There is high geologic potential for Late Paleoindian cultural deposits in the middle stratum.

Renewed alluviation after ca. 9,300 B.P. resulted in burial of Soil 2 and aggradation of the top stratum. There is high geologic potential for Late Paleoindian, Archaic, and Woodland cultural deposits in the top stratum, and Mississippian and Historic deposits may occur at shallow depths.

The $\delta^{13}C$ record at Ramsey Field does not indicate any major climate changes for the period of record. However, there is an excursion toward heavier values (increased C_4 plant contributions to SOM) at 9,300 B.P. The T-3 terrace was forested for much of the period of human occupation, but would have provided access to the river-edge ecotone while simultaneously keeping people above the more frequently flooded terrace surfaces.

An effort was made to determine the alluvial stratigraphy and chronology of T-3 at Two Rivers, but the only unforested area on the landform is a campground. The campground surface has been hardened with chat, and coring proved impossible. Additional work in the form of backhoe trenching and/or test unit excavation should be conducted at Two Rivers in order to understand the nature of the T-3 fill at this locality.

Alluvial Fan Deposit

The alluvial fan at Chubb Hollow began aggrading before ca. 11,900 B.P. and continued to aggrade until a period of stability occurred at ca. 11,400 B.P. and allowed Soil 2 to develop in the bottom stratum. There is high geologic potential for pre-Clovis and Paleoindian cultural deposits in the bottom stratum. Renewed aggradation on the fan after ca. 11,400 B.P. buried Soil 2 beneath 1.5 m of alluvium. In Soil 1, which developed in the top stratum, archaeological investigations recovered Late Archaic through Historic cultural deposits. The Late Archaic deposits occur near the surface, between 50 and 60 cmbs (Garrison et al. 1976; Vawser 1999), indicating that the top stratum has been stable for approximately 3,000 years. Between the Late Archaic deposits and the boundary between Soil 1 and Soil 2, there is high geologic potential for Dalton cultural deposits.

$\delta^{13}C$ values remain constant throughout most of the period of record at Chubb Hollow. A shift toward lighter (C_3) values occurs in the upper portion of Soil 1, between the A and Bw horizons, and may indicate a shift in vegetation composition near the end of the Altithermal.

Geologic Preservation Potentials for Cultural Deposits

Late Quaternary alluvial deposits are differentially preserved in the Current River valley. This finding should be considered in any attempt to predict the locations of archaeological sites. In my dissertation, I used alluvial stratigraphy and chronology to determine where buried cultural deposits may occur in the river valley (Table 6.1). Two criteria were used to assess the geologic potential for buried cultural deposits: (1) the presence or absence of late Pleistocene and Holocene alluvial deposits, and (2) the presence or absence of buried soils (after Bettis and Benn 1984:22).

The presence or absence of buried soils is an important factor when evaluating the geologic potential for cultural deposits in alluvial deposits (Mandel 1992; Mandel and Bettis 2001). Buried soils indicate periods of stability and are good targets for finding cultural deposits (Holliday 1989, 1992; Ferring 1992). Prehistoric people, however, sometimes occupied aggrading alluvial surfaces; hence archaeological materials may be found in sediment that has not been modified by soil development (Hoyer 1980).

Table 6.1. Geologic preservation potentials for buried cultural deposits in the Current River valley.

Cultural Periods	Current River Valley			
	T-1	T-2	T-3	Alluvial Fan
Pre-Clovis	--	+	+++	+++
Paleoindian	--	+++	+++	+++
Early Archaic	?	+++	+++	+++
Middle Archaic	?	+++	?	+++
Late Archaic	+++	+++	?	+++
Woodland	+++	+++	?	?
Mississippian	--	?	?	?

Note: Graph modeled after Mandel (1992). -- = impossible; ? = unknown; + = low potential; ++ = moderate potential; +++ = high potential

Based on the OSL ages and archaeological evidence, there is high potential for buried Late Archaic and Woodland period cultural deposits in the bottom stratum of the T-1 fill. This finding is significant given that the T-1 fill was previously thought to have aggraded during the Proto-Historic and Historic periods (Saucier 1987). Weak soil formation in the top stratum suggests that the upper 1.2 m of T-1 fill aggraded during the Historic period and, therefore, has no potential for containing prehistoric cultural deposits. Historic artifacts may occur on and within the top stratum.

At Akers Ferry, archaeological evidence indicates alluvial deposits beneath the T-2 surface, which mantle a strath terrace cut across T-3 fill, contain Dalton, Archaic, and Woodland cultural material. The Dalton component occurs 0.5-0.6 m below surface. Additional OSL ages are needed to determine the geologic potential for Early Paleoindian and pre-Clovis cultural deposits below the Dalton component, between 0.6 and 0.8 m below surface. Additional OSL ages also are needed to determine when the strath terrace formed to better assess the geologic potential for cultural deposits in the T-3 fill. However, an OSL age of ca. 29,800 B.P. determined on a sediment sample from 1.7 m below surface indicates there is at least low potential for pre-Clovis and Paleoindian cultural deposits in the upper 0.9 m of the T-3 fill. Given the Historic use of Akers Ferry, archaeological remains dating to the 19th century and later are likely to occur on the T-2 surface.

Alluvial deposits and buried soils comprising the upper 6 m of T-3 fill are likely to contain archaeological deposits dating to the pre-Clovis, Paleoindian, and Early Archaic periods. Pre-Clovis and Paleoindian cultural deposits may occur in the bottoms tratum. Late Paleoindian materials are likely to occur in the top stratum, at approximately 1.6 m below surface, where a sediment sample yielded an OSL age of ca. 9,300 B.P. Archaeological evidence from the Pin

Oak locality indicates that Mississippian cultural material may occur on T-3 surfaces. Historic deposits almost certainly occur on these surfaces as well.

Alluvial fans in the Current River valley have high potential for buried cultural deposits. The alluvial fan at Chubb Hollow is comprised of late-Pleistocene and Holocene deposits and contains at least one buried soil. Pre-Clovis and Paleoindian cultural deposits may occur in the bottom stratum. There is also high potential for Paleoindian and Early and Middle Archaic deposits to occur in the top stratum as archaeological investigations at the locality recovered Late Archaic artifacts between 0.5 and 0.6 m below surface. Historic archaeological deposits likely occur on the alluvial fan surface at Chubb Hollow, particularly deposits left during the Civilian Conservation Corps work in the area in the 1930s and 1940s.

A number of factors may affect archaeological site distribution. First, cycles of erosion and sedimentation may have differentially preserved alluvial deposits containing archaeological materials in the Current River valley. Second, flood frequency likely controlled the habitability of alluvial landform surfaces during the prehistoric and Historic occupation of the Current River valley, subsequently affecting site distribution. Third, site distribution may be closely linked to the landscape features such as springs, river portages, and river confluences. Future research that considers site distribution should take these factors into consideration.

Summary

In this chapter, I first reviewed the data presented in Chapter 5 and discussed their implications for late-Quaternary landscape evolution in the Current River valley. Then, I compared my model of late-Quaternary landscape evolution with that proposed by Saucier (1987, 1996). Finally, I described the geoarchaeology of the Current River valley. My goal was to (1) identify the geologic potential for cultural deposits in LSAs using alluvial stratigraphy and chronology, and (2) use archaeological evidence to compare the geologic potential for cultural deposits among LSAs. Importantly, I was able to identify high geologic potential for Archaic and Woodland cultural deposits in the buried soil at T-1. The T-1 fill was previously thought to have aggraded during the Proto-Historic and Historic periods.

CHAPTER 7

CONCLUSION

My dissertation marks the first attempt to systematically identify the geologic potential for cultural deposits in the Current River valley in Ozark National Scenic Riverways. Saucier's work in the 1980s and 1990s and that of the ODYSSEY Archaeological Research Fund in recent years have investigated alluvial LSAs in the river valley, but neither established a valley-wide geoarchaeological model. By combining stable carbon isotope analysis and OSL dating with a detailed alluvial stratigraphic investigation, I sought to revise Saucier's model of landscape evolution. I used these data to determine the geologic potential for cultural deposits in the Current River valley.

In this final chapter I review the data presented in my dissertation and consider the geologic potential for cultural deposits in the Current River valley. I discuss how my study contributes to our understanding of archaeology, as well as late-Quaternary landscape evolution and bioclimatic change in the Ozarks. I end the dissertation by making recommendations for future work in the Current River valley and the larger region.

Landscape Evolution and Geoarchaeology in the Ozarks

When Saucier (1997, 1996) developed a terrace sequence and model of late-Quaternary landscape evolution for the Current River, he did not have a suite of radiocarbon or OSL ages to rely on. In fact, the few OSL ages Saucier did obtain for his studies indicated alluvial fills were considerably younger than the archaeological deposits they contained. However, OSL was in its infancy as a dating technique in the mid-1980s and these results were likely inaccurate. Instead, Saucier relied on relative dating via temporally diagnostic artifacts. He concluded that terrace aggradation occurred diachronously in the Current River valley and an alluvial chronology could not be established for the valley as a whole.

In my study, OSL ages were obtained from four LSAs in order to quantify and refine Saucier's model. Based on those ages, T-1 fill began aggrading sometime prior to ca. 3,000 B.P. and was interrupted by a period of soil development after ca. 1,700 B.P. A thin veneer of Historic alluvium caps the T-1 surface. This finding is particularly significant as all T-1 fill was previously thought to have aggraded in the last 200 years. The T-3 fill began aggrading before ca. 45,000 B.P. and continued to aggrade until ca. 9300 B.P. Two buried soils were recorded in the T-3 fill, indicating that aggradation was interrupted by two episodes of landscape stability before the T-3 surface finally stabilized. Also, in some reaches of the valley, as the Current River was downcutting, it migrated laterally and cut across the T-3 fill, thereby forming a fill strath terrace (T-2). The strath was subsequently mantled by alluvium and the modern surface soil formed in the stratum above the erosion surface.

Evidence from Chubb Hollow indicates that alluvial fans began aggrading on the margins of the valley floor prior to ca. 11,900 B.P. Aggradation at Chubb Hallow continued until at least ca. 11,400 B.P. and was interrupted by an episode of landscape stability and soil formation. Renewed aggradation after 11,400 B.P. resulted in burial of the soil, but the entire chronology of alluvial fan development has not been determined.

Based on the results of my investigation, I was able to identify the geologic preservation potentials for cultural deposits in the Current River valley. Pre-Clovis, Paleoindian, and Archaic cultural deposits are likely to occur in the T-3 fill and in alluvial fans in the Current River valley. Mississippian deposits may occur on the T-3 surface. Based on archaeological investigations at

Akers Ferry, the top stratum of the T-2 fill has potential to yield Dalton, Archaic, and Woodland cultural deposits. Archaic and Woodland archaeological materials may occur in the T-1 fill.

Contributions and Relevancy

There are a number of ways in which my dissertation adds to the geomorphological and archaeological records of the Current River valley and Ozark Plateau. The work presented in my dissertation

- better refines, clarifies, and characterizes Saucier's description of terrace sequences and late-Quaternary landscape evolution in the Current River valley, particularly through the application of OSL dating,
- presents the first stable carbon isotope record on SOM in the eastern Ozarks. This dataset did not reveal an encroachment of the Prairie Peninsula during the Altithermal. Instead, it indicates that a stable, predominantly C_3 vegetation community was in place in the Current River valley for much of the late Pleistocene and Holocene,
- provides information that can be used to develop a lithostratigraphic nomenclature for late-Quaternary alluvium in the eastern Ozarks,
- presents a predictive model for cultural deposits in alluvial landforms in the Current River valley,
- facilitates our understanding of geomorphological processes in the Current River valley and their affect on the archaeological record,
- lays the foundation for more specific archaeological studies, such as systematically searching for pre-Clovis-age deposits in terrace fills and alluvial fan deposits,

understanding how and when the Ozark Plateau's role in early human colonization of North America began, and identifying dynamics affecting site distribution through time,

- identifies the potential geologic context of cultural deposits.

My study also altered our view of archaeology and geomorphology in the eastern Ozarks and Current River valley. From the data presented in my dissertation, several important contributions can be recognized.

- Archaeological deposits from different time periods may be present in multiple geologic contexts (e.g., terrace fills of various elevations and alluvial fan deposits). Site distribution data from the Current River valley indicate that sites attributed to various archaeological traditions occur on a variety of landforms. The majority of sites occur in alluvial contexts, but sites from one particular tradition do not necessarily occur in the same fills throughout the river valley. It appears that sites attributed to each archaeological tradition occur in T-2 terrace, T-3 terrace, upland, and spring contexts.
- The archaeological and geomorphological records in the Current River valley are not as patterned and predictable as they are elsewhere in North America. As such, it is important to build an overall, generalized model of geologic potential for cultural deposits in the Current River valley. While Saucier alluded to this problem, he did not have the geochronological and paleoenvironmental data to support this idea. My dissertation documents the complexity of landform development in the Current River valley and the subsequent difficulty of predicting archaeological site locations.
- Archaeological sites in alluvial contexts are multi-component, indicating that alluvial landforms were occupied repeatedly through time. This finding strengthens my model

for the geologic potential for cultural deposits for two reasons. First, the model is based in part on the presence of archaeological components at the study localities and the alluvial stratigraphy and chronology were correlated with the archaeological record at each locality. Second, we can assume continuity in the occupation sequence of particular landforms and use stratigraphy and chronology to determine which additional archaeological traditions may be present in alluvial deposits.

- Previously, archaeologists working in the Current River valley believed archaeological deposits to occur only within the upper 0.5 m of alluvial fills. My study indicates that there is geologic potential for archaeological deposits to occur much deeper in alluvial fills, as much as 5 m below surface in T-3 fills. Archaeologists must then be willing to excavate much deeper than they originally thought was necessary. Relatedly, my dissertation greatly expands the localities and geomorphic contexts where buried archaeological sites may occur. We now know that alluvial fans and higher terraces along valley walls have the potential to yield deeply buried archaeological deposits.

Recommendations for Future Work

The work presented in my dissertation determined the geologic potential for cultural deposits in the Current River valley, thereby identifying the surfaces on which people could have lived, made tools, hunted, gathered, and processed food, and carried out other cultural traditions. Those buried landscapes can now be targeted for archaeological research. Systematic deep testing should be undertaken to study potential pre-Clovis and Paleoindian cultural deposits, as those deposits would be deeply buried in alluvial fills. Near-surface deposits can be investigated through traditional archaeological excavation.

As mentioned earlier, a lithostratigraphic nomenclature has not been developed for late-Quaternary alluvium in the eastern Ozark Plateau. The results of my study may be used towards developing such a nomenclature. A soil characteristic guide could be developed from the data presented herein. Such a guide should summarize HDI and other pedological characteristics for use by archaeologists.

Within Ozark NSR, other localities should be investigated in order to refine the alluvial chronology. In particular, localities below Big Spring, as well as T-1 and T-2 terraces below the Jack's Fork, should be evaluated. Obtaining numerical ages from those localities and landforms would shed more light on the timing of alluviation in the Current River valley. OSL ages determined on sediment from terrace fills below the Jack's Fork would indicate whether two separate chronosequences occur: one above and one below the Jack's Fork. Finally, it would be useful to study landforms immediately below major springs. Spring flow may affect landscape evolution, which could prove important in understanding the archaeological record.

The peopling of the New World is an interesting research avenue for archaeologists. Steps should be taken to further research pre-Clovis and understand the nature and context of a pre-11,500 14C yr B.P. occupation of North America. Models of pre-Clovis' initial entry into North America have been proposed but none postulated for their colonization of that continent. Allowing what we know about Dalton and Clovis people to guide the search for pre-Clovis sites may prove extremely useful. Because of its geographic position, the Ozark Plateau, specifically the Current River valley, may be an excellent place to test hypotheses of pre-Clovis settlement, subsistence, and colonization derived from Dalton and Clovis data.

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APPENDIX A.

SOIL CORE DESCRIPTIONS

Akers Ferry Locality
Date Collected: July 27, 2011
Date Described: August 16, 2011
Slope: 0-3%
Soil Series: Bearthicket silt loam
Land Cover: Grass with few deciduous trees

Depth (cm)	Horizon	Description
0-10	Ap	Brown (10YR 4/3, dry) silt loam; weak fine granular structure; friable; many fine and very fine roots; few worm casts and few open ant and worm burrows; cultural deposits in lower 5 cm of core; abrupt boundary.
10-32	A	Brown (10YR 4/3, dry) to dark yellowish brown (10YR 4/4, dry) silt loam; weak medium subangular blocky parting to weak fine subangular blocky structure; firm; many fine and very fine roots; few worm casts and few open ant and worm burrows; gradual boundary.
32-57	Bw	Dark yellowish brown (10YR 4/4, dry) silt loam; weak medium subangular blocky parting to weak fine subangular blocky structure; firm; common fine and very fine roots; few worm casts and few open ant and worm burrows; common fine and very fine pores and few fine irregular pores; gradual boundary.
57-86	Bt	Brown (7.5YR 4/4, dry) silt loam; moderate fine subangular blocky; few fine and very fine roots; few worm casts and few open ant and worm burrows; common fine and very fine pores and few irregular pores; common fine distinct discontinuous dark brown (7.5YR 3/2, dry) clay films on ped faces; abrupt boundary.
86-115	Bt1b	Brown (7.5YR 4/3, dry) silt loam; moderate medium prismatic parting to moderate medium and fine subangular blocky; hard; few very fine roots; few fine and very fine pores; few medium distinct discontinuous dark brown (7.5YR 3/2, dry) clay films on ped faces; few flecks of charcoal in the core; cultural deposits in upper 5 cm of core; gradual boundary.
115-131	Bt2b	Dark yellowish brown (10YR 4/4, dry) loam; weak fine prismatic parting to weak fine subangular blocky structure; hard; few fine pores; common distinct discontinuous dark brown (7.5YR 3/2, dry) clay films on ped faces; clear boundary.
131-155	BCt1b	Brown (10YR 4/3, dry) and sandy loam; moderate medium prismatic parting to moderate medium and fine subangular blocky;

		firm; few fine and very fine pores; parts along bedding planes; common distinct discontinuous dark brown (7.5YR 3/2, dry) clay films on ped faces; clear boundary.
155-190	BCt2b	Light brownish gray (10YR 6/2, dry, 40%), dark yellowish brown (10YR 4/6, dry, 40%), dark yellowish brown (10YR 3/6, dry, 20%) sandy loam; weak fine subangular blocky; friable; few coarse gravel; few fine and very fine pores; parts along bedding planes; common distinct discontinuous dark brown (7.5YR 3/2, dry) clay films on ped faces; gradual boundary.
190-236	Cb	Loose sand and gravel; single grain structure.

Gladden Creek Locality
Date Collected: July 27, 2011
Date Described: August 17, 2011
Slope: 0-3%
Soil Series: Wideman fine sandy loam
Land Cover: Hayed field

Depth (cm)	Horizon	Description
0-13	Ap	Brown (10YR 4/3, dry) silt loam; weak fine granular structure; hard; many fine and very fine and few medium roots; many worm casts and few open ant and worm burrows; abrupt boundary.
13-32	Bw	Dark yellowish brown (10YR 4/4, dry) silt loam; weak fine subangular blocky structure; friable; common fine and very fine roots; many worm casts and many open worm and few open ant burrows; common fine and very fine pores; gradual boundary.
32-46	Bt	Dark brown (10YR 3/3, moist) silt loam; weak medium subangular blocky parting to weak fine subangular blocky structure; common fine and very fine roots; common worm casts and open ant and worm burrows; many distinct nearly continuous very dark grayish brown (10YR 3/2, moist) clay films on ped faces; many fine and very fine pores; clear boundary.
46-67	Ab	Very dark brown (10YR 2/2, moist) silt loam; moderate medium granular parting to weak fine granular; firm; few very fine roots; common worm casts and open worm burrows; few fine and very fine pores; gradual boundary.
67-80	Btb	Very dark grayish brown (10YR 3/2, moist) – dark brown (10YR 3/3, moist) silt loam; moderate medium subangular blocky parting

		to weak fine subangular blocky; firm; few very fine roots; few worm casts and open worm burrows; common fine and very fine pores; many distinct nearly continuous very dark grayish brown (10YR 3/2, moist) clay films on ped faces; gradual boundary.
80-94	BCb	Brown (10YR 4/3, dry) – dark brown (10YR 3/3, dry) silt loam; weak fine subangular blocky; friable; few fine and very fine pores; gradual boundary.
94-120	C1b	Dark yellowish brown (10YR 4/4, moist) sandy loam; weak fine subangular blocky; friable; few coarse gravel; clear boundary.
120-140	C2b	Brown (10YR 4/3, moist) – dark brown (10YR 3/3, moist) loose sand and few fine gravel; single grain; gradual boundary.
140-170	C3b	Dark yellowish brown (10YR 4/4, moist) loose sand and many fine, medium, and coarse gravel; single grain; gradual boundary.
170-207	C4b	Dark yellowish brown (10YR 3/4, moist) loose sand and many fine, medium, and coarse gravel; single grain.

Pulltite Locality
Date Collected: July 27, 2011
Date Described: August 18, 2011
Slope: 0-3%
Soil Series: Clarksville-Scholten complex (incorrect)
Land Cover: Grass and deciduous trees

Depth (cm)	Horizon	Description
0-14	A	Very dark grayish brown (10YR 3/2, dry) silt loam; weak fine granular structure; friable; common medium, fine, and very fine and few coarse roots; many worm casts and common open worm burrows; gradual smooth boundary.
14-34	AB	Dark yellowish brown (10YR 4/4, dry) silt loam; weak fine subangular blocky parting to weak fine granular structure; friable; common fine and very fine roots; common worm casts and few open worm burrows; common fine and very fine pores; organic coats on ped faces; one debitage at 20 cmbs; gradual smooth boundary.
34-73	Bt1	Brown (7.5YR 4/4, dry) – strong brown (7.5YR 4/6, dry) silt loam; moderate medium subangular blocky parting to moderate fine subangular blocky; firm; few fine and very fine roots; common worm casts and few open worm burrows; common fine and very

		fine pores; common distinct discontinuous brown (7.5YR 4/4, dry) clay films on ped faces and in macropores; gradual smooth boundary.
73-95	Bt2	Strong brown (7.5YR 4/6, dry) silt loam; moderate medium subangular blocky parting to moderate fine subangular blocky; firm; few fine and very fine roots; few worm casts and open worm burrows; common fine and very fine pores; common distinct discontinuous brown (7.5YR 4/4, dry) clay films on ped faces and in macropores; gradual smooth boundary.
95-114	Bt3	Brown (7.5YR 4/4, dry) – strong brown (7.5YR 4/6, dry) silt loam; weak medium subangular blocky parting to weak fine subangular blocky structure; firm; common fine and very fine pores; common distinct discontinuous brown (7.5YR 4/4, dry) clay films on ped faces and in macropores; gradual smooth boundary.
114-140	BC	Dark yellowish brown (10YR 4/4, dry) – yellowish brown (10YR 5/4, dry) silt loam; weak fine subangular blocky structure; friable; common fine gravel; common fine and very fine pores; parts along bedding planes; clear smooth boundary.
140-157	C	Yellowish brown (10YR 5/4, dry) sandy loam; weak fine subangular blocky structure; many fine, medium, coarse gravel.

Round Spring T-1 Locality
Date Collected: November 1, 2011
Date Described: November 15, 2011
Slope: 0-3%
Soil Series: Huzzah sandy loam
Land Cover: Grass with few deciduous trees

Depth (cm)	Horizon	Description
0-19	A	Black (10YR 2/1, moist) loamy sand; weak fine granular; common fine and very fine roots; common worm casts and open worm burrows; abrupt boundary.
19-120	C	Black (10YR 2/1, moist) loamy sand; weak fine subangular blocky; loose sand and many fine, medium, and coarse gravel; abrupt boundary.
120-140	Ab	Very dark brown (10YR 2/2, moist) sandy loam; moderate medium subangular blocky parting to weak fine subangular blocky; firm; common fine and very fine pores; gradual boundary.

140-220	Bt1b	Brown (7.5YR 4/4, moist) loam; moderate medium subangular blocky parting to weak fine subangular blocky; firm; common fine and very fine pores; common distinct very dark brown (7.5YR 2.5/2, moist) clay films on ped faces and in macropores; few fragments of charcoal was recovered at 165 cmbs; gradual boundary.
220-240	Bt2b	Brown (7.5YR 4/4, moist) sandy loam; moderate medium subangular blocky parting to weak fine subangular blocky; firm; common fine and very fine pores; common distinct very dark brown (7.5YR 2.5/2, moist) clay films on ped faces and in macropores; gradual boundary.

Round Spring T-2 Locality
Date Collected: July 27, 2011
Date Described: August 18, 2011
Slope: 0-3%
Soil Series: Secesh silt loam
Land Cover: Grass with few deciduous trees

Depth (cm)	Horizon	Description
0-30	A	Brown (10YR 4/3, dry) silt loam; weak fine granular structure; friable; many fine and very fine roots; common worm casts and open worm burrows; one debitage at 12 cmbs; gradual boundary.
30-47	Bw	Brown (10YR 4/3, dry) sandy silt loam; weak fine subangular blocky; common fine and very fine roots; common worm casts and open worm burrows; common fine and very fine pores; organic coats on ped faces; gradual boundary.
47-120	Bt	Brown (7.5YR 4/4, dry) silt loam; weak medium prismatic parting to weak medium and fine subangular blocky; firm; very few fine roots; common worm casts and open worm burrows; common fine and very fine pores; common faint nearly continuous brown (7.5YR 4/3, dry) clay films on ped faces and in macropores; three debitage were collected from 50, 90, and 100; gradual boundary.
120-180	BCt	Brown (7.5YR 4/4, dry) silt loam; moderate medium subangular blocky; firm; few worm casts and open worm burrows; common fine and very fine pores; common distinct nearly continuous brown (7.5YR 4/4, dry) clay films on ped faces and in macropores; common fine gravel; clear boundary.

180-210	Bt1b	Brown (7.5YR 4/4, dry) sandy loam; moderate medium prismatic parting to moderate medium and fine subangular blocky; firm; common fine and very fine pores; common distinct discontinuous reddish brown (5YR 4/4, dry) clay films on ped faces and in macropores; common fine gravel; gradual boundary.
210-220	Bt2b	Strong brown (7.5YR 4/6, dry) sandy loam; moderate medium prismatic parting to moderate medium and fine subangular blocky; firm; common fine and very fine pores; common distinct discontinuous yellowish red (5YR 4/6, dry) clay films on ped faces and in macropores; many fine gravel.

Ramsey Field Locality
Date Collected: July 28, 2011
Date Described: August 19, 2011
Slope: 1-3%
Soil Series: Zanoni fine sandy loam
Land Cover: Hayed field

Depth (cm)	Horizon	Description
0-34	A	Brown (10YR 5/3, dry) sandy loam; weak medium granular parting to weak fine granular; friable; many fine and very fine roots; common worm casts and open worm burrows; clear boundary.
34-65	E	Yellowish brown (10YR 5/4, dry) sandy loam; weak fine subangular blocky; friable; few very fine roots; few worm casts and open worm burrows; few fine and very fine pores; few organic coats on ped faces; clear boundary.
65-105	Bt/E1	Brown (7.5YR 4/4, dry) sandy loam; moderate medium subangular blocky parting to moderate fine subangular blocky; firm; few very fine roots; common worm casts and open worm burrows; common fine and very fine pores; common distinct discontinuous yellowish red (5YR 4/6, dry) and very dark brown (7.5YR 2.5/3, dry) clay films on ped faces and in macropores; common depletion zones of light yellowish brown (10YR 6/4, dry) sandy loam; gradual boundary.
105-164	Bt/E2	Brown (7.5YR 4/4, dry) sandy loam; moderate medium subangular blocky parting to moderate fine subangular blocky; firm; few very fine roots; common worm casts and open worm burrows; common fine and very fine pores; common distinct nearly continuous to

		continuous yellowish red (5YR 4/6, dry) and very dark brown (7.5YR 2.5/3, dry) clay films on ped faces and in macropores; common depletion zones of light yellowish brown (10YR 6/4, dry) sandy loam; abrupt boundary.
164-203	BCt	Brown (7.5YR 4/4, dry) sandy loam; weak medium and fine subangular blocky; friable; very few very fine roots; common fine and very fine pores; common distinct discontinuous yellowish red (5YR 4/6, dry) clay films on ped faces and in macropores; common depletion zones of light yellowish brown (10YR 6/4, dry) sandy loam; abrupt boundary.
203-234	Bt1b1	Strong brown (7.5YR 4/6, dry) sandy loam; moderate medium subangular blocky parting to moderate fine subangular blocky; firm; very few very fine roots; common fine and very fine pores; common distinct discontinuous strong brown (7.5YR 5/6, dry) clay films on ped faces and in macropores; many depletion zones of very pale brown (10YR 7/4, dry) sandy loam; gradual boundary.
234-267	Bt2b1	Brown (7.5YR 4/4, dry) – dark brown (7.5YR 3/4, dry) loam; weak medium subangular blocky parting to weak fine subangular blocky; firm; very few very fine roots; common fine and very fine and few medium pores; common distinct discontinuous strong brown (7.5YR 5/6, dry) clay films on ped faces and in macropores; many depletion zones of very pale brown (10YR 7/4, dry) sandy loam; abrupt boundary.
267-294	Bt1b2	Strong brown (7.5YR 4/6, dry) loam; moderate medium subangular blocky parting to moderate fine subangular blocky; firm; common fine and very fine pores; few manganese inclusions; common distinct discontinuous brown (7.5YR 4/4, dry) clay films on ped faces and in macropores; many depletion zones of very pale brown (10YR 7/4, dry) sandy loam; gradual boundary.
294-309	Bt2b2	Strong brown (7.5YR 4/6, dry) sandy loam; moderate medium subangular blocky parting to moderate fine subangular blocky; firm; common fine and very fine pores; many faint nearly continuous brown (7.5YR 4/4, dry) clay films on ped faces and in macropores; many depletion zones of very pale brown (10YR 7/4, dry) sandy loam; gradual boundary.
309-359	Bt3b2	Strong brown (7.5YR 4/6, dry) loam; weak medium subangular blocky parting to weak fine subangular blocky; soft; common fine and very fine pores; many faint nearly continuous brown (7.5YR 4/4, dry) clay films on ped faces and in macropores; common

		depletion zones of very pale brown (10YR 7/4, dry) sandy loam in macropores only; gradual boundary.
359-445	Bt4b2	Brown (7.5YR 4/4, dry) – strong brown (7.5YR 4/6, dry) loam; weak medium subangular blocky parting to weak fine subangular blocky; soft; common fine and very fine pores; many faint nearly continuous brown (7.5YR 4/4, dry) clay films on ped faces and in macropores; few depletion zones of very pale brown (10YR 7/4, dry) sandy loam in macropores only; clear boundary.
445-470	BCb2	Yellowish brown (10YR 5/4, dry) – yellowish brown (10YR 5/6, dry) loamy sand; weak medium and fine subangular blocky; friable; few fine and very fine pores; gradual boundary.
470-590	Cb2	Yellowish brown (10YR 5/4, dry) fine sand; single grain; periodic flood drapes of brown (7.5YR 4/4, dry) sandy loam, weak fine subangular blocky.

Pin Oak Locality
Date Collected: July 29, 2011
Date Described: August 19, 2011
Slope: 0-3%
Soil Series: Wideman fine sandy loam (incorrect)
Land Cover: Mowed field

Depth (cm)	Horizon	Description
0-15	A	Brown (10YR 5/3, dry) sandy loam; weak fine granular; friable; common fine and very fine roots; many worm casts and open worm burrows; gradual boundary.
15-36	E	Yellowish brown (10YR 5/4, dry) sandy loam; weak fine subangular blocky; common fine and very fine roots; common worm casts and open worm burrows; common fine and very fine pores; common organic coats on ped faces; gradual boundary.
36-60	BE	Yellowish brown (10YR 5/4, dry) – yellowish brown (10YR 5/6, dry) sandy loam; weak fine subangular blocky, friable, few very fine roots; common worm casts and open worm burrows; common organic coats on ped faces; few fine and very fine pores; clear boundary.
60-86	Bt1	Strong brown (7.5YR 5/6, dry) sandy loam; weak medium subangular blocky parting to weak fine subangular blocky; friable; few very fine roots; few worm casts and open worm burrows; common fine and very fine pores; common distinct discontinuous

		brown (7.5YR 4/4, dry) clay films on ped faces and in macropores; gradual boundary.
86-132	Bt2	Strong brown (7.5YR 4/6, dry) loam; weak medium subangular blocky parting to weak fine subangular blocky; firm; few very fine roots; few worm casts and open worm burrows; common fine and very fine pores; common distinct discontinuous reddish brown (5YR 4/4, dry) clay films on ped faces and in macropores; many manganese inclusions; gradual boundary.
132-220	Bt3	Strong brown (7.5YR 4/6, dry) loam; weak medium subangular blocky parting to weak fine subangular blocky; firm; few very fine roots; few worm casts and open worm burrows; common fine and very fine pores; common faint discontinuous reddish brown (5YR 4/4, dry) clay films on ped faces and in macropores; few depletion zones of very pale brown (10YR 7/3, dry) sandy loam on ped faces; common manganese inclusions; gradual boundary.
220-278	Bt4	Strong brown (7.5YR 4/6, dry) sandy loam; weak medium subangular blocky parting to weak fine subangular blocky; firm; few very fine roots; few worm casts and open worm burrows; common fine and very fine pores; common faint discontinuous reddish brown (5YR 4/4, dry) clay films on ped faces and in macropores; few depletion zones of very pale brown (10YR 7/4) sandy loam on ped faces; gradual boundary.
278-306	BC	Brown (7.5YR 5/4, dry) sandy loam; weak fine subangular blocky; friable; common fine and very fine pores; few depletion zones of light gray (10YR 7/1, dry) sandy loam on ped faces; abrupt boundary.
306-352	ABb	Dark yellowish brown (10YR 4/4, dry) loam; weak fine subangular blocky parting to weak medium and fine granular; firm; common very fine roots; few worm casts; common fine and very fine and few medium pores; common depletion zones of very pale brown (10YR 7/3, dry) sandy loam on ped faces and in macropores; gradual boundary.
352-405	Btb	Brown (7.5YR 4/4, dry) loam; weak fine subangular blocky; firm; common fine and very fine and few medium pores; common thin discontinuous dark brown (7.5YR 3/4, dry) clay films on ped faces and in macropores; common depletion zones of very pale brown (10YR 7/3, dry) sandy loam on ped faces and in macropores; clear boundary.
405-428	BCb	Strong brown (7.5YR 4/6, dry) sandy clay loam; weak fine subangular blocky; common fine and very fine pores; common

		depletion zones of very pale brown (10YR 7/3, dry) sandy loam on ped faces and in macropores; abrupt boundary.
428-444	Btb2	Strong brown (7.5YR 4/6, dry) sandy clay loam; moderate medium prismatic parting to moderate medium and fine subangular blocky; firm; common fine and very fine pores; common distinct discontinuous yellowish red (5YR 4/6, dry) clay films on ped faces and in macropores; few depletion zones of very pale brown (10YR 7/4, dry) sandy loam in macropores.

Chubb Hollow Locality
Date Collected: November 2, 2011
Date Described: November 15, 2011
Slope: 0-3%
Soil Series: Alred-Rueter complex (incorrect)
Land Cover: Grass and deciduous trees

Depth (cm)	Horizon	Description
0-7	A	Brown (10YR 4/3, dry) silt loam; weak fine granular; friable; common fine and very fine roots; many worm casts and open worm and ant burrows; one debitage at 5cmbs; gradual boundary.
7-20	AB	Dark grayish brown (10YR 4/2, dry) – brown (10YR 4/3, dry) loam; weak fine subangular blocky parting to weak fine granular; friable; common fine and very fine roots; many worm casts and open worm and ant burrows; common fine and very fine pores; common organic coats on ped faces; gradual boundary.
20-35	Bw	Dark yellowish brown (10YR 4/4, dry) silt loam; weak fine subangular blocky; friable; few fine and very fine roots; common worm casts and open worm burrows and few ant burrows; common organic coats on ped faces; clear boundary.
35-80	Bt1	Strong brown (7.5YR 4/6, dry) silt loam; weak medium subangular blocky parting to weak fine subangular blocky; friable; few fine and common very fine roots; common worm casts and open worm burrows; common fine and very fine pores; common faint nearly continuous brown (7.5YR 4/4, dry) clay films on ped faces and in macropores; common black (10YR 2/1, dry) manganese films on ped faces; gradual boundary.
80-143	Bt2	Strong brown (7.5YR 5/6, dry) silt loam; moderate medium subangular blocky parting to weak fine subangular blocky; firm; few fine and very fine roots; common worm casts and few open

		worm burrows; common fine and very fine pores; common faint nearly continuous brown (7.5YR 4/4, dry) – strong brown (7.5YR 4/6, dry) clay films on ped faces and in macropores; few (5%) depletion zones of light yellowish brown (10YR 6/4, dry) sandy loam in macropores; many black (10YR 2/1, dry) manganese films on ped faces; clear boundary.
143-163	Bt1b	Strong brown (7.5YR 5/6, dry) silt loam; moderate medium subangular blocky parting to moderate fine subangular blocky; firm; few very fine roots; common fine and very fine pores; common distinct discontinuous brown (7.5YR 4/4, dry) – (7.5YR strong brown 4/6, dry) clay films on ped faces and in macropores; common (40%) depletion zones of light yellowish brown (10YR 6/4, dry) sandy loam on ped faces and in macropores, gradual boundary.
163-260	Bt2b	Strong brown (7.5YR 5/6, dry) silt loam; moderate medium subangular blocky parting to moderate fine subangular blocky; firm; few very fine roots; common fine and very fine pores; common distinct discontinuous brown (7.5YR 4/4, dry) clay films on ped faces and in macropores; many (80%) depletion zones of light yellowish brown (10YR 6/4, dry) sandy loam on ped faces and in macropores, gradual boundary.
260-280	BCb	Yellowish brown (10YR 5/4, dry) loam; weak medium subangular blocky; friable; few fine and very fine pores; common fine and few coarse gravel.

Note: When the term “micropore” is used, it refers to biopores.

APPENDIX B.

PARTICLE-SIZE DISTRIBUTION RESULTS

Particle-Size Distribution Analysis
Pipet Method
Laboratory: Kansas Geological Survey, Geoarchaeology and Paleoenvironment Laboratory
Technicians: Celeste McCoy, Laura Murphy, Bridget Sanderson
Date: December 2011

Locality	*Depth (cmbs)*	***Total Sand*** **2000-50 μm**	*Coarse Silt 50-20 μm*	*Medium Silt 20-5 μm*	*Fine Silt 5-2 μm*	***Total Silt*** **50-2 μm**	*Coarse Clay 2-0.2 μm*	*Fine Clay <0.2 μm*	***Total Clay*** **<2 μm**
Akers Ferry	0-10	15.6	22.8	43.3	9.8	75.9	6.8	1.7	8.4
Akers Ferry	10-32	15.4	21.8	39.3	10.1	71.2	10.4	3.0	13.4
Akers Ferry	32-57	12.3	21.9	38.8	8.6	69.4	10.9	7.4	18.3
Akers Ferry	57-86	9.5	19.4	37.0	10.2	66.6	12.1	11.8	23.9
Akers Ferry	86-115	15.0	16.3	37.3	7.6	61.2	12.2	11.6	23.9
Akers Ferry	115-131	29.5	11.3	29.2	8.2	48.6	12.0	9.8	21.8
Akers Ferry	131-155	55.3	7.4	15.5	5.3	28.2	7.6	8.8	16.4
Akers Ferry	155-190	70.1	5.2	8.1	4.3	17.6	4.9	7.4	12.2
Akers Ferry	190-236	75.5	5.1	6.2	3.8	15.1	4.1	5.2	9.3
Ramsey Field	0-34	72.1	9.5	11.3	2.8	23.7	3.4	0.9	4.3
Ramsey Field	34-65	74.9	8.6	10.0	2.4	21.0	2.8	1.2	4.0
Ramsey Field	65-105	71.0	8.8	9.5	2.2	20.5	4.2	4.3	8.5
Ramsey Field	105-164	60.9	11.2	13.5	2.5	27.2	5.7	6.2	11.9
Ramsey Field	164-203	77.4	5.5	7.0	1.8	14.2	3.3	5.1	8.4
Ramsey Field	203-234	60.0	11.5	14.8	3.4	29.7	5.1	5.2	10.3
Ramsey Field	234-267	50.7	14.5	18.5	4.0	37.0	6.4	5.9	12.3
Ramsey Field	267-294	39.5	17.6	24.0	4.3	45.9	7.2	7.4	14.6
Ramsey Field	294-309	57.1	13.1	15.1	3.3	31.5	5.8	5.6	11.3
Ramsey Field	309-359	41.7	16.6	23.4	4.7	44.7	6.5	7.2	13.6
Ramsey Field	359-445	45.6	14.3	20.3	5.9	40.4	7.5	6.5	14.0
Ramsey Field	445-470	78.6	7.6	6.7	1.7	16.0	3.1	2.2	5.4
Ramsey Field	470-590	77.3	8.3	7.5	1.3	17.2	3.3	2.2	5.5
Chubb Hollow	7-20	44.6	18.6	25.6	5.8	50.0	4.8	0.6	5.4
Chubb Hollow	20-35	45.1	17.5	22.2	6.1	45.7	6.3	2.9	9.1

Locality	*Depth (cmbs)*	***Total Sand***	*Coarse Silt*	*Medium Silt*	*Fine Silt*	***Total Silt***	*Coarse Clay*	*Fine Clay*	***Total Clay***
		2000-50 µm	*50-20 µm*	*20-5 µm*	*5-2 µm*	**50-2 µm**	*2-0.2 µm*	*<0.2 µm*	**<2 µm**
Chubb Hollow	35-80	32.0	19.7	25.6	5.6	50.9	7.5	9.5	17.0
Chubb Hollow	80-143	25.6	19.9	27.8	5.5	53.2	9.5	11.7	21.2
Chubb Hollow	143-163	28.3	20.2	28.0	5.1	53.2	9.0	9.5	18.5
Chubb Hollow	163-260	28.2	15.4	31.1	6.4	52.9	10.3	8.6	18.9
Chubb Hollow	260-280	41.2	13.3	25.3	5.1	43.6	8.8	6.3	15.2
Round Spring T-1	0-19	75.8	6.8	9.6	2.9	19.2	3.8	1.2	4.9
Round Spring T-1	19-120	81.6	4.9	7.7	1.7	14.3	3.1	1.0	4.1
Round Spring T-1	120-140	57.2	9.4	14.5	3.8	27.7	6.8	8.2	15.0
Round Spring T-1	140-220	43.3	10.8	19.8	4.9	35.5	9.3	11.9	21.2
Round Spring T-1	220-240	58.6	5.8	13.0	3.3	22.2	8.3	10.9	19.2
Pin Oak	0-15	69.6	10.9	13.8	3.2	27.9	2.4	0.1	2.6
Pin Oak	15-36	72.4	9.5	11.6	2.9	24.0	3.3	0.3	3.6
Pin Oak	36-60	69.9	9.8	12.0	2.9	24.7	4.0	1.3	5.4
Pin Oak	60-86	64.1	10.4	12.8	3.1	26.3	5.4	4.2	9.6
Pin Oak	86-132	50.1	13.2	17.1	3.9	34.3	7.1	8.6	15.7
Pin Oak	132-220	48.3	13.7	18.9	3.3	35.9	7.7	8.1	15.8
Pin Oak	220-278	57.7	13.3	15.0	3.3	31.5	5.6	5.1	10.7
Pin Oak	278-306	70.9	8.4	9.7	2.6	20.7	4.2	4.2	8.4
Pin Oak	306-352	37.5	13.0	27.6	6.2	46.8	8.7	7.0	15.7
Pin Oak	352-405	48.8	9.4	18.8	5.8	34.0	9.3	7.9	17.2
Pin Oak	405-428	56.3	9.2	9.9	3.4	22.5	9.2	12.0	21.2
Pin Oak	428-444	57.7	8.7	8.2	4.0	20.9	9.3	12.2	21.4

RoTap Analysis
*Conducted on samples containing greater than 50% sand.
Laboratory: Kansas Geological Survey, Geoarchaeology and Paleoenvironment Laboratory
Technicians: Celeste McCoy, Laura Murphy, Bridget Sanderson
Date: December 2011

		Percent of Total Mass							
Locality	*Depth (cmbs)*	*Very Coarse*	*Coarse*	*Medium Coarse*	*Medium*	*Fine*	*Very Fine*	*Pan*	*Loss*
Akers	155-190	0.21	2.20	35.27	34.74	24.99	1.22	0.21	1.16
Akers	190-236	0.30	2.74	37.14	34.97	23.13	1.12	0.19	0.39
Ramsey	0-34	0.02	0.21	5.60	27.10	61.53	3.89	1.12	0.53
Ramsey	34-65	0.01	0.16	5.36	27.25	61.69	3.88	0.88	0.77
Ramsey	65-105	0.10	0.20	7.93	27.69	59.00	3.54	0.69	0.85
Ramsey	105-164	0.00	0.09	2.68	17.83	70.31	6.41	1.50	1.18
Ramsey	164-203	0.00	0.09	4.22	26.64	65.02	2.48	0.50	1.05
Ramsey	203-234	0.01	0.06	3.24	21.02	68.80	4.87	1.08	0.92
Ramsey	294-309	0.00	0.01	0.53	8.01	80.18	8.15	2.06	1.06
Ramsey	445-470	0.00	0.06	2.99	21.30	70.62	3.51	0.74	0.77
Ramsey	470-590	0.02	0.30	5.55	23.72	64.64	3.92	0.79	1.05
Pin Oak	0-15	1.52	2.21	13.49	24.30	51.49	4.11	1.84	1.03
Pin Oak	15-36	0.09	1.18	13.18	24.41	54.23	4.61	1.28	1.04
Pin Oak	36-60	0.02	1.23	12.90	24.93	54.44	4.20	1.17	1.10
Pin Oak	60-86	0.06	1.42	10.65	23.71	57.29	4.21	1.06	1.60
Pin Oak	220-278	0.09	0.49	4.45	16.62	68.75	6.62	1.57	1.40
Pin Oak	278-306	0.00	0.08	7.07	30.93	56.93	2.89	0.64	1.44
Pin Oak	405-428	0.10	0.80	4.84	18.08	66.26	7.02	1.72	1.17
Pin Oak	428-444	0.08	0.48	5.33	18.94	64.62	7.22	1.88	1.45
Round Spring T-1	0-19	1.99	2.62	15.40	26.62	49.00	2.55	0.82	1.00
Round Spring T-1	19-120	3.69	2.71	19.55	32.31	38.79	1.18	0.33	1.45
Round Spring T-1	120-140	0.02	0.31	8.88	26.56	57.88	3.98	0.83	1.54
Round Spring T-1	220-240	2.78	1.51	15.03	28.67	47.90	2.73	0.49	0.89

APPENDIX C.

STABLE CARBON ISOTOPE RESULTS

Stable Carbon Isotope Analysis

Laboratory: Keck Paleoenvironmental and Environmental Stable Isotope Laboratory, University of Kansas

Technician: Greg Cane Date: 2/1/2012 Tray: 1

Analysis #	Depth (cmbs)	Locality	Amount (mg)	Ampl 44 (mV)	Area 44 (Vs)	$d^{13}C$ VPDB	C%	Comments
73973	0	Round Spring T-2	6.259	26568	652.93	-24.18	2.32	
73974	5	Round Spring T-2	6.070	12763	309.35	-23.38	1.13	
73975	10	Round Spring T-2	6.137	8948	214.59	-23.42	0.78	
73976	15	Round Spring T-2	8.473	10844	262.11	-23.30	0.69	
73977	20	Round Spring T-2	7.683	10628	252.54	-23.65	0.73	
73978	25	Round Spring T-2	7.874	9903	236.27	-23.68	0.66	
73979	30	Round Spring T-2	7.350	6132	145.70	-23.56	0.44	
73980	35	Round Spring T-2	7.026	4920	116.91	-23.62	0.37	
73983	40	Round Spring T-2	7.130	4384	104.29	-23.64	0.32	
73984	45	Round Spring T-2	8.680	4067	96.13	-23.83	0.24	
73985	50	Round Spring T-2	15.529	5445	129.76	-23.06	0.18	
73986	55	Round Spring T-2	15.104	4349	103.07	-23.09	0.15	
73988	60	Round Spring T-2	15.002	4184	98.46	-23.67	0.14	
73989	65	Round Spring T-2	15.421	4721	111.36	-23.64	0.16	
73990	70	Round Spring T-2	16.117	5514	130.97	-24.14	0.18	
73991	75	Round Spring T-2	15.837	5132	121.64	-23.30	0.17	
73994	80	Round Spring T-2	15.579	4289	101.70	-22.37	0.14	
73995	85	Round Spring T-2	15.707	4521	107.36	-22.82	0.15	
73996	90	Round Spring T-2	15.650	4635	109.24	-23.59	0.15	
73997	95	Round Spring T-2	15.365	4200	99.44	-23.32	0.14	
73998	100	Round Spring T-2	15.509	4323	102.18	-23.13	0.15	
73999	105	Round Spring T-2	15.145	5358	126.39	-23.27	0.18	
74000	110	Round Spring T-2	16.588	5359	126.88	-23.06	0.17	
74001	115	Round Spring T-2	16.083	5163	122.49	-23.09	0.17	
74004	120	Round Spring T-2	15.137	4362	103.00	-23.59	0.15	
74005	125	Round Spring T-2	18.588	5134	121.43	-23.82	0.15	
74006	130	Round Spring T-2	16.052	4246	99.66	-24.54	0.14	
74007	135	Round Spring T-2	16.600	4716	113.10	-24.64	0.15	
74008	140	Round Spring T-2	16.412	4631	109.55	-24.40	0.15	
73987	Montana Soil	QQ Std	2.004	6611	155.50	-17.35	1.72	True $d^{13}C$= -17.20
74009	Peach Leaves	QQ Std	0.111	9725	225.66	-26.19	45.15	True $d^{13}C$= -26.20
73969	DORM	Std	0.203	17140	403.97	-17.23	44.39	True $d^{13}C$= -17.22

Analysis Note: $d^{13}C_{VPDB}$ values corrected for mass dependency. Average correction is +0.02‰

Stable Carbon Isotope Analysis

Laboratory: Keck Paleoenvironmental and Environmental Stable Isotope Laboratory, University of Kansas

Technician: Greg Cane Date: 2/9/2012 Tray: 2

Analysis #	Depth (cmbs)	Locality	Amount (mg)	Ampl 44 (mV)	Area 44 (Vs)	$d^{13}C$ VPDB	C%	Comments
74615	145	Round Spring T-2	16.779	4321	106.16	-24.81	0.14	
74616	150	Round Spring T-2	17.252	5147	128.12	-25.01	0.16	
74617	155	Round Spring T-2	20.234	6071	149.93	-24.39	0.16	
74618	160	Round Spring T-2	16.660	5481	136.19	-24.81	0.18	
74619	165	Round Spring T-2	17.238	5308	133.17	-24.92	0.17	
74620	170	Round Spring T-2	17.266	4576	114.96	-24.87	0.14	
74621	175	Round Spring T-2	19.820	5091	128.91	-24.85	0.14	
74622	180	Round Spring T-2	20.989	4975	123.85	-24.49	0.13	
74625	185	Round Spring T-2	16.631	3998	101.58	-24.63	0.13	
74626	190	Round Spring T-2	18.547	4874	119.63	-24.18	0.14	
74627	195	Round Spring T-2	19.487	5141	126.79	-24.11	0.14	
74628	200	Round Spring T-2	19.423	4471	110.26	-23.91	0.12	
74630	205	Round Spring T-2	18.578	3962	98.36	-23.40	0.11	
74631	210	Round Spring T-2	18.955	4568	111.25	-24.10	0.13	
74632	215	Round Spring T-2	19.326	3695	89.96	-24.15	0.10	
74633	0	Pulltite	6.898	26412	663.09	-27.65	2.09	
74636	5	Pulltite	6.868	19806	492.64	-27.22	1.56	
74637	10	Pulltite	5.877	10996	271.91	-26.14	1.00	
74638	15	Pulltite	8.483	14917	371.90	-26.32	0.95	
74639	20	Pulltite	7.957	7417	186.99	-25.45	0.51	
74640	25	Pulltite	8.317	8440	210.16	-25.66	0.55	
74641	30	Pulltite	10.101	6874	173.79	-25.13	0.37	
74642	35	Pulltite	10.555	6466	163.42	-25.89	0.33	
74643	40	Pulltite	6.674	3376	84.32	-25.14	0.27	
74646	45	Pulltite	8.779	4485	113.43	-25.64	0.28	
74647	50	Pulltite	6.455	2856	70.72	-25.13	0.24	
74648	55	Pulltite	10.045	4113	103.90	-25.23	0.22	
74649	60	Pulltite	7.009	2838	71.30	-25.06	0.22	
74650	65	Pulltite	8.454	3628	91.68	-25.02	0.23	
74629	Montana Soil	QQ Std	2.065	6466	157.98	-17.06	1.65	True $d^{13}C$= -17.20
74651	Peach Leaves	QQ Std	0.105	9104	220.38	-26.36	45.55	True $d^{13}C$= -26.20
74609	DORM	Std	0.018	1614	38.94	-17.24	45.73	True $d^{13}C$= -17.22

Analysis Note: $d^{13}C_{VPDB}$ values corrected for mass dependency. Average correction is +0.02‰

Stable Carbon Isotope Analysis

Laboratory: Keck Paleoenvironmental and Environmental Stable Isotope Laboratory, University of Kansas

Technician: Greg Cane Date: 2/1/2012 Tray: 3

Analysis #	Depth (cmbs)	Locality	Amount (mg)	Ampl 44 (mV)	Area 44 (Vs)	$d^{13}C$ VPDB	C%	Comments
74022	70	Pulltite	6.653	3243	76.52	-25.26	0.25	
74023	75	Pulltite	5.941	2450	58.11	-25.41	0.21	
74024	80	Pulltite	10.358	4146	97.37	-24.67	0.20	
74025	85	Pulltite	8.999	3649	85.95	-24.49	0.21	
74026	90	Pulltite	6.061	2714	63.85	-24.28	0.22	
74027	95	Pulltite	8.056	3382	79.49	-24.04	0.21	
74028	100	Pulltite	8.521	2625	61.72	-23.38	0.15	
74029	105	Pulltite	7.253	2720	64.16	-23.74	0.19	
74032	110	Pulltite	20.792	5841	138.69	-22.35	0.15	
74033	115	Pulltite	19.534	6070	143.80	-21.69	0.16	
74034	120	Pulltite	16.459	5782	136.80	-23.63	0.18	
74035	125	Pulltite	19.594	6407	152.26	-22.12	0.17	
74037	130	Pulltite	18.692	5052	120.18	-22.52	0.14	
74038	135	Pulltite	19.187	5305	125.16	-23.10	0.14	
74039	150	Pulltite	19.905	5551	130.82	-25.09	0.14	
74040	0	Akers Ferry	4.559	23441	560.66	-25.91	2.73	may want to reweigh
74043	5	Akers Ferry	4.933	15090	361.25	-24.19	1.62	may want to reweigh
74044	10	Akers Ferry	7.108	14685	346.02	-23.18	1.08	may want to reweigh
74045	15	Akers Ferry	5.126	8884	207.55	-22.83	0.89	may want to reweigh
74046	20	Akers Ferry	3.738	6437	149.83	-22.75	0.88	may want to reweigh
74047	25	Akers Ferry	4.535	6571	154.80	-22.78	0.75	may want to reweigh
74048	30	Akers Ferry	5.970	4903	115.00	-22.53	0.42	may want to reweigh
74049	35	Akers Ferry	7.111	6449	149.53	-22.29	0.46	may want to reweigh
74050	40	Akers Ferry	4.121	2704	63.45	-21.97	0.33	may want to reweigh
74053	45	Akers Ferry	3.250	2073	48.33	-21.91	0.33	may want to reweigh
74054	50	Akers Ferry	4.400	2926	68.18	-22.51	0.33	may want to reweigh
74055	55	Akers Ferry	4.348	2889	67.75	-22.56	0.33	may want to reweigh
74056	60	Akers Ferry	4.051	2480	58.23	-21.55	0.30	may want to reweigh
74057	65	Akers Ferry	6.676	3752	88.36	-20.56	0.28	may want to reweigh
74036	Montana Soil	QQ Std	2.030	8594	203.92	-19.21	2.21	True $d^{13}C$= -17.20
74058	Peach Leaves	QQ Std	0.105	9293	216.55	-26.32	45.25	True $d^{13}C$= -26.20
74016	DORM	Std	0.018	1679	38.85	-17.34	44.84	True $d^{13}C$= -17.22

Analysis Note: $d^{13}C_{VPDB}$ values corrected for mass dependency. Average correction is -0.08‰

Stable Carbon Isotope Analysis

Laboratory: Keck Paleoenvironmental and Environmental Stable Isotope Laboratory, University of Kansas

Technician: Greg Cane Date: 2/2/2012 Tray: 4

Analysis #	Depth (cmbs)	Locality	Amount (mg)	Ampl 44 (mV)	Area 44 (Vs)	$d^{13}C$ VPDB	C%	Comments
74076	70	Akers Ferry	5.349	3028	75.76	-20.36	0.30	
74077	75	Akers Ferry	5.702	3496	88.35	-21.01	0.33	
74078	80	Akers Ferry	8.037	4534	115.41	-20.69	0.31	
74079	85	Akers Ferry	5.552	3578	89.97	-20.83	0.35	
74080	90	Akers Ferry	6.716	4310	108.16	-20.78	0.35	
74081	95	Akers Ferry	8.909	5134	131.74	-20.16	0.32	
74082	100	Akers Ferry	7.649	4493	114.39	-20.79	0.32	
74083	105	Akers Ferry	6.940	4380	109.95	-21.56	0.34	
74086	110	Akers Ferry	6.908	4120	103.56	-21.71	0.32	
74087	115	Akers Ferry	6.865	3338	85.48	-21.49	0.26	
74088	120	Akers Ferry	9.172	4209	107.20	-22.06	0.25	
74089	125	Akers Ferry	11.760	4654	118.43	-22.26	0.22	
74091	130	Akers Ferry	8.533	4651	118.76	-24.08	0.30	
74092	135	Akers Ferry	7.445	3448	87.82	-24.05	0.25	
74093	140	Akers Ferry	9.253	3895	101.02	-24.75	0.23	
74094	145	Akers Ferry	17.083	6153	157.81	-23.88	0.20	
74097	150	Akers Ferry	17.225	6143	156.43	-24.20	0.20	
74098	155	Akers Ferry	16.385	5276	131.60	-24.50	0.17	
74099	160	Akers Ferry	19.363	4096	102.74	-24.55	0.11	
74100	165	Akers Ferry	19.120	4958	124.70	-25.07	0.14	
74101	170	Akers Ferry	20.974	5048	126.72	-25.62	0.13	
74102	175	Akers Ferry	20.581	4370	108.83	-25.42	0.11	
74103	180	Akers Ferry	19.786	3715	92.19	-24.90	0.10	
74104	185	Akers Ferry	17.689	3900	95.73	-24.49	0.12	
74107	190	Akers Ferry	21.642	4263	107.26	-24.52	0.11	
74108	210	Akers Ferry	16.404	3226	79.37	-24.25	0.10	
74109	0	Gladden	3.806	11763	291.56	-24.85	1.68	
74110	5	Gladden	5.408	15542	384.01	-25.00	1.56	
74111	10	Gladden	4.454	8105	197.93	-24.57	0.97	
74090	Montana Soil	QQ Std	2.004	7139	175.24	-18.38	1.90	True $d^{13}C$= -17.20
74112	Peach Leaves	QQ Std	0.105	8669	211.02	-26.41	43.77	True $d^{13}C$= -26.20
74105	DORM	Std	0.021	1805	43.61	-17.46	42.50	True $d^{13}C$= -17.22

Analysis Note: $d^{13}C_{VPDB}$ values corrected for mass dependency. Average correction is -0.12‰

Stable Carbon Isotope Analysis

Laboratory: Keck Paleoenvironmental and Environmental Stable Isotope Laboratory, University of Kansas

Technician: Greg Cane Date: 2/7/2012 Tray: 5

Analysis #	Depth (cmbs)	Locality	Amount (mg)	Ampl 44 (mV)	Area 44 (Vs)	$d^{13}C$ VPDB	C%	Comments
74419	15	Gladden	3.692	4158	101.24	-24.04	0.56	
74420	20	Gladden	4.234	5771	141.66	-23.60	0.70	
74421	25	Gladden	3.929	5810	142.28	-23.44	0.76	
74422	30	Gladden	5.675	7170	175.45	-22.69	0.65	
74423	35	Gladden	4.720	6029	145.96	-22.58	0.65	
74424	40	Gladden	4.965	6666	161.56	-22.30	0.69	
74425	45	Gladden	4.661	6343	154.80	-22.42	0.70	
74426	50	Gladden	5.090	7225	174.87	-21.74	0.73	
74429	55	Gladden	4.186	4672	113.80	-20.86	0.56	
74430	60	Gladden	7.317	6746	165.78	-20.92	0.48	
74431	65	Gladden	11.085	9271	226.05	-20.78	0.44	
74432	70	Gladden	7.409	5788	140.28	-20.83	0.40	
74434	75	Gladden	6.640	4403	106.97	-21.55	0.33	
74435	80	Gladden	9.420	5608	136.32	-21.65	0.30	
74436	85	Gladden	6.041	3607	87.36	-22.34	0.29	
74437	90	Gladden	7.955	3728	89.94	-22.77	0.23	
74440	95	Gladden	7.203	2913	71.73	-22.89	0.20	
74441	100	Gladden	10.814	3047	74.34	-23.19	0.14	
74442	105	Gladden	16.936	5545	133.89	-23.79	0.17	
74443	110	Gladden	17.785	5452	131.73	-23.80	0.15	
74444	115	Gladden	20.525	6125	148.11	-23.56	0.15	
74445	120	Gladden	18.355	6531	157.53	-24.14	0.18	
74446	125	Gladden	16.520	4808	116.30	-24.45	0.15	
74447	135	Gladden	18.922	5692	137.43	-24.31	0.15	
74450	160	Gladden	18.298	3849	92.89	-24.92	0.10	
74451	190	Gladden	18.349	3559	85.98	-25.01	0.09	
74452	0	Ramsey	9.484	16136	393.96	-24.85	0.90	
74453	5	Ramsey	12.760	21012	518.71	-24.36	0.88	
74454	10	Ramsey	12.833	11711	286.09	-23.35	0.48	
74433	Montana Soil	QQ Std	1.262	3955	97.50	-17.00	1.58	True $d^{13}C$= -17.20
74455	Peach Leaves	QQ Std	0.109	9434	229.67	-26.35	45.02	True $d^{13}C$= -26.20
74413	DORM	Std	0.018	1624	39.58	-17.39	39.78	True $d^{13}C$= -17.22

Analysis Note: $d^{13}C_{VPDB}$ values corrected for mass dependency. Average correction is +0.01‰

Stable Carbon Isotope Analysis

Laboratory: Keck Paleoenvironmental and Environmental Stable Isotope Laboratory, University of Kansas

Technician: Paula Richter Date: 2/3/2012 Tray: 6

Analysis #	Depth (cmbs)	Locality	Amount (mg)	Ampl 44 (mV)	Area 44 (Vs)	$d^{13}C$ VPDB	C%	Comments
74125	15	Ramsey Field	5.521	3921	97.14	-23.55	0.38	
74126	20	Ramsey Field	7.467	3419	83.63	-22.78	0.24	
74127	25	Ramsey Field	8.739	5011	123.40	-23.20	0.31	
74128	30	Ramsey Field	7.227	3793	93.06	-22.92	0.28	
74129	35	Ramsey Field	8.775	2109	51.65	-23.89	0.13	
74130	40	Ramsey Field	14.825	2679	65.68	-23.34	0.10	
74131	45	Ramsey Field	8.770	1331	32.62	-23.53	0.08	Ampl 44<min threshold
74132	50	Ramsey Field	9.148	1245	30.58	-23.92	0.07	Ampl 44<min threshold
74135	55	Ramsey Field	9.565	1752	42.81	-23.45	0.10	Ampl 44<min threshold
74136	60	Ramsey Field	13.055	1573	38.46	-23.87	0.06	Ampl 44<min threshold
74137	65	Ramsey Field	10.536	2126	51.87	-24.14	0.11	
74138	70	Ramsey Field	11.009	1524	37.26	-24.88	0.07	Ampl 44<min threshold
74140	75	Ramsey Field	9.415	1546	38.13	-23.72	0.09	Ampl 44<min threshold
74141	80	Ramsey Field	8.520	1458	35.40	-24.41	0.09	Ampl 44<min threshold
74142	85	Ramsey Field	7.873	1252	30.62	-24.26	0.08	Ampl 44<min threshold
74143	90	Ramsey Field	7.386	1790	43.90	-24.40	0.13	Ampl 44<min threshold
74146	95	Ramsey Field	7.777	1723	42.54	-23.16	0.12	Ampl 44<min threshold
74147	100	Ramsey Field	14.742	2252	54.70	-24.32	0.08	
74148	105	Ramsey Field	12.419	1828	44.71	-24.04	0.08	
74149	110	Ramsey Field	13.449	2336	56.83	-23.65	0.09	
74150	115	Ramsey Field	11.493	2483	60.91	-24.60	0.11	
74151	120	Ramsey Field	15.212	2818	69.09	-24.25	0.10	
74152	125	Ramsey Field	13.144	3170	77.11	-24.37	0.13	
74153	130	Ramsey Field	11.835	1946	47.31	-24.59	0.09	
74156	135	Ramsey Field	12.860	1639	39.99	-24.18	0.07	Ampl 44<min threshold
74157	140	Ramsey Field	18.349	4283	104.24	-24.41	0.12	
74158	145	Ramsey Field	14.685	2258	55.12	-23.80	0.08	
74159	150	Ramsey Field	13.415	2291	55.71	-24.44	0.09	
74160	155	Ramsey Field	13.348	2307	56.19	-23.73	0.09	
74139	Montana Soil	QQ Std	2.019	6722	165.15	-17.84	1.78	True $d^{13}C$= -17.20
74161	Peach Leaves	QQ Std	0.100	8808	213.78	-26.35	46.84	True $d^{13}C$= -26.20
65635	DORM	Std	0.020	1886	44.12	-17.69	47.48	True $d^{13}C$= -17.22

Analysis Note: $d^{13}C_{VPDB}$ values corrected for mass dependency. Average correction is -0.25‰

Stable Carbon Isotope Analysis

Laboratory: Keck Paleoenvironmental and Environmental Stable Isotope Laboratory, University of Kansas

Technician: Greg Cane Date: 2/3/2012 Tray: 7

Analysis #	Depth (cmbs)	Locality	Amount (mg)	Ampl 44 (mV)	Area 44 (Vs)	$d^{13}C$ VPDB	C%	Comments
74174	160	Ramsey Field	12.696	1992	48.43	-24.16	0.08	
74175	165	Ramsey Field	23.813	3161	76.66	-24.21	0.07	
74176	170	Ramsey Field	19.873	3059	74.08	-22.91	0.08	
74177	175	Ramsey Field	20.759	3285	79.60	-24.00	0.08	
74178	180	Ramsey Field	16.717	3331	81.20	-24.21	0.10	
74179	185	Ramsey Field	15.840	2623	64.15	-22.97	0.09	
74180	190	Ramsey Field	19.566	2465	60.27	-24.20	0.07	
74181	195	Ramsey Field	18.554	2297	55.81	-24.29	0.06	
74184	200	Ramsey Field	17.364	2646	65.16	-23.47	0.08	
74185	205	Ramsey Field	20.000	3955	97.60	-23.91	0.10	
74186	210	Ramsey Field	21.158	3519	87.02	-23.85	0.09	
74187	215	Ramsey Field	16.260	3103	76.71	-23.80	0.10	
74189	220	Ramsey Field	19.665	4309	105.70	-24.16	0.12	
74190	225	Ramsey Field	22.157	4094	100.71	-23.44	0.10	
74191	230	Ramsey Field	22.577	4867	120.02	-24.12	0.11	
74192	235	Ramsey Field	20.935	3665	90.13	-24.47	0.09	
74195	240	Ramsey Field	18.457	3820	94.28	-24.39	0.11	
74196	245	Ramsey Field	20.634	4522	111.53	-24.22	0.12	
74197	250	Ramsey Field	16.960	3678	90.50	-24.28	0.11	
74198	255	Ramsey Field	18.181	3099	76.50	-24.40	0.09	
74199	260	Ramsey Field	18.880	3762	93.29	-24.37	0.11	
74200	265	Ramsey Field	15.642	3665	90.38	-24.36	0.12	
74201	270	Ramsey Field	22.245	5307	131.07	-23.59	0.13	
74202	275	Ramsey Field	19.306	3990	99.21	-23.17	0.11	
74205	280	Ramsey Field	21.647	3763	93.33	-24.14	0.09	
74206	285	Ramsey Field	18.750	2728	67.82	-23.56	0.08	
74207	290	Ramsey Field	19.075	2587	63.46	-23.73	0.07	
74208	295	Ramsey Field	18.571	2401	59.40	-23.79	0.07	
74209	300	Ramsey Field	16.870	3136	76.87	-24.33	0.10	
74188	Montana Soil	QQ Std	2.005	6709	165.93	-18.15	1.80	True $d^{13}C$= -17.20
74210	Peach Leaves	QQ Std	0.106	8965	219.30	-26.49	45.17	True $d^{13}C$= -26.20
74168	DORM	Std	0.016	1467	35.33	-17.38	46.08	True $d^{13}C$= -17.22

Analysis Note: $d^{13}C_{VPDB}$ values corrected for mass dependency. Average correction is -0.17‰

Stable Carbon Isotope Analysis

Laboratory: Keck Paleoenvironmental and Environmental Stable Isotope Laboratory, University of Kansas

Technician: Paula Richter Date: 2/4/2012 Tray: 8

Analysis #	Depth (cmbs)	Locality	Amount (mg)	Ampl 44 (mV)	Area 44 (Vs)	$d^{13}C$ VPDB	C%	Comments
74223	305	Ramsey Field	15.054	2689	66.42	-24.44	0.09	
74224	310	Ramsey Field	21.434	3703	91.02	-24.87	0.09	
74225	315	Ramsey Field	20.528	3574	87.92	-24.81	0.09	
74226	320	Ramsey Field	17.502	3038	74.68	-24.64	0.09	
74227	325	Ramsey Field	20.509	3680	91.11	-24.84	0.10	
74228	330	Ramsey Field	19.960	3533	86.67	-24.43	0.09	
74229	335	Ramsey Field	18.519	3665	89.91	-24.50	0.11	
74230	340	Ramsey Field	20.414	4127	102.35	-24.37	0.11	
74233	345	Ramsey Field	21.808	5226	128.38	-24.31	0.13	
74234	350	Ramsey Field	21.793	5287	129.82	-24.10	0.13	
74235	355	Ramsey Field	21.316	5626	138.65	-24.50	0.14	
74236	360	Ramsey Field	20.995	4713	116.11	-24.04	0.12	
74238	365	Ramsey Field	20.274	4818	118.79	-24.35	0.13	
74239	370	Ramsey Field	17.817	4226	104.10	-24.37	0.13	
74240	375	Ramsey Field	16.659	3992	98.31	-24.42	0.13	
74241	380	Ramsey Field	19.758	5094	125.40	-24.62	0.14	
74244	385	Ramsey Field	18.759	4113	108.65	-23.86	0.13	
74245	390	Ramsey Field	18.471	4178	109.50	-23.99	0.13	
74246	395	Ramsey Field	17.604	3977	105.41	-23.90	0.13	
74247	400	Ramsey Field	16.873	3546	94.58	-24.00	0.12	
74248	405	Ramsey Field	17.872	3473	92.46	-24.21	0.11	
74249	410	Ramsey Field	15.274	3120	83.60	-24.51	0.12	
74250	415	Ramsey Field	16.753	2822	75.73	-24.38	0.10	
74251	420	Ramsey Field	22.309	4417	120.04	-24.14	0.12	
74254	425	Ramsey Field	21.390	3865	111.29	-24.39	0.11	
74255	430	Ramsey Field	17.167	3207	92.73	-24.40	0.12	
74256	435	Ramsey Field	22.924	3842	113.98	-24.48	0.11	
74257	440	Ramsey Field	18.426	2850	84.78	-24.21	0.10	
74258	445	Ramsey Field	18.604	2860	84.61	-24.67	0.10	
74237	Montana Soil	QQ Std	2.007	6760	167.18	-17.98	1.81	True $d^{13}C$= -17.20
74259	Peach Leaves	QQ Std	0.105	7340	217.25	-26.21	44.77	True $d^{13}C$= -26.20
74217	DORM	Std	0.020	1724	42.14	-17.32	43.88	True $d^{13}C$= -17.22

Analysis Note: $d^{13}C_{VPDB}$ values corrected for mass dependency. Average correction is -0.13‰

Stable Carbon Isotope Analysis

Laboratory: Keck Paleoenvironmental and Environmental Stable Isotope Laboratory, University of Kansas

Technician: Greg Cane Date: 2/8/2012 Tray: 9

Analysis #	**Depth (cmbs)**	**Locality**	**Amount (mg)**	**Ampl 44 (mV)**	**Area 44 (Vs)**	**$d^{13}C$ VPDB**	**C%**	**Comments**
74468	460	Ramsey Field	16.463	2569	62.64	-25.15	0.08	
74469	520	Ramsey Field	17.318	2920	70.48	-25.05	0.09	
74470	0	Pin Oak	9.901	17601	438.42	-25.52	0.95	
74471	5	Pin Oak	9.349	15802	388.78	-25.69	0.89	
74472	10	Pin Oak	11.529	11687	286.50	-23.33	0.53	
74473	15	Pin Oak	10.083	7666	186.73	-23.30	0.39	
74474	20	Pin Oak	8.216	2870	70.42	-23.34	0.18	
74475	25	Pin Oak	10.618	4276	104.04	-24.16	0.21	
74478	30	Pin Oak	11.238	4247	103.00	-24.01	0.19	
74479	35	Pin Oak	10.875	4430	109.28	-24.41	0.21	
74480	40	Pin Oak	11.327	2650	64.94	-24.15	0.12	
74481	45	Pin Oak	11.385	2809	68.25	-24.29	0.13	
74483	50	Pin Oak	11.298	2910	71.37	-24.61	0.13	
74484	55	Pin Oak	10.265	2687	65.81	-23.88	0.13	
74485	60	Pin Oak	11.667	3389	82.25	-24.30	0.15	
74486	65	Pin Oak	9.882	2271	55.21	-24.36	0.12	
74489	70	Pin Oak	12.134	2373	58.63	-24.61	0.10	
74490	75	Pin Oak	11.535	2364	57.56	-24.03	0.10	
74491	80	Pin Oak	11.477	2076	50.59	-24.31	0.09	
74492	85	Pin Oak	8.288	1818	44.34	-24.60	0.11	
74493	90	Pin Oak	9.676	2184	53.42	-24.37	0.12	
74494	95	Pin Oak	10.449	2327	57.37	-24.07	0.12	
74495	100	Pin Oak	17.374	3807	93.53	-24.14	0.11	
74496	105	Pin Oak	17.691	3717	91.83	-23.62	0.11	
74499	110	Pin Oak	17.321	3463	84.99	-22.68	0.10	
74500	115	Pin Oak	14.589	2559	62.89	-21.62	0.09	
74501	120	Pin Oak	15.880	2822	68.45	-23.47	0.09	
74502	125	Pin Oak	18.742	2828	69.64	-22.68	0.08	
74503	130	Pin Oak	16.664	2893	70.44	-23.53	0.09	
74482	Montana Soil	QQ Std	1.418	4482	109.69	-17.10	1.64	True $d^{13}C$= -17.20
74504	Peach Leaves	QQ Std	0.100	8823	212.94	-26.25	45.74	True $d^{13}C$= -26.20
74462	DORM	Std	0.020	1929	46.36	-17.40	47.84	True $d^{13}C$= -17.22

Analysis Note: $d^{13}C_{VPDB}$ values corrected for mass dependency. Average correction is -0.16‰

Stable Carbon Isotope Analysis

Laboratory: Keck Paleoenvironmental and Environmental Stable Isotope Laboratory, University of Kansas

Technician: Greg Cane Date: 2/8/2012 Tray: 10

Analysis #	**Depth (cmbs)**	**Locality**	**Amount (mg)**	**Ampl 44 (mV)**	**Area 44 (Vs)**	**$d^{13}C$ VPDB**	**C%**	**Comments**
74517	135	Pin Oak	15.821	3010	73.43	-23.84	0.10	
74518	140	Pin Oak	16.474	3140	76.86	-23.95	0.10	
74519	145	Pin Oak	15.358	3483	85.57	-24.52	0.12	
74520	150	Pin Oak	15.216	2953	72.40	-23.40	0.10	
74521	155	Pin Oak	19.738	3446	84.51	-22.94	0.09	
74522	160	Pin Oak	17.082	3045	74.39	-23.19	0.09	
74523	165	Pin Oak	20.658	3634	88.57	-23.45	0.09	
74524	170	Pin Oak	16.636	3114	76.47	-23.12	0.10	
74527	175	Pin Oak	19.557	4239	104.32	-23.24	0.11	
74528	180	Pin Oak	21.711	3885	95.74	-23.69	0.09	
74529	185	Pin Oak	21.045	3341	82.75	-23.39	0.08	
74530	190	Pin Oak	22.887	4192	104.05	-23.73	0.10	
74532	195	Pin Oak	19.639	3500	86.24	-23.78	0.09	
74533	200	Pin Oak	18.909	2779	68.55	-23.22	0.08	
74534	205	Pin Oak	17.311	3134	76.68	-24.03	0.09	
74535	210	Pin Oak	17.633	3143	77.07	-23.80	0.09	
74538	215	Pin Oak	15.164	2296	56.34	-23.91	0.08	
74539	220	Pin Oak	20.440	3445	84.63	-24.14	0.09	
74540	225	Pin Oak	18.364	3480	84.95	-24.10	0.10	
74541	230	Pin Oak	22.216	3187	78.38	-23.94	0.08	
74542	235	Pin Oak	23.807	4323	105.45	-23.71	0.10	
74543	240	Pin Oak	21.644	3333	81.57	-23.46	0.08	
74544	245	Pin Oak	20.533	4093	100.39	-23.36	0.10	
74545	250	Pin Oak	17.049	2820	68.91	-23.75	0.09	
74548	255	Pin Oak	22.375	3700	90.15	-22.92	0.09	
74549	260	Pin Oak	16.616	3310	80.91	-22.80	0.10	
74550	265	Pin Oak	18.304	3879	95.31	-23.71	0.11	
74551	270	Pin Oak	20.943	3230	78.71	-22.49	0.08	
74552	275	Pin Oak	21.689	3060	74.83	-23.26	0.07	
74531	Montana Soil	QQ Std	2.148	6728	165.91	-17.04	1.67	True $d^{13}C$= -17.20
74553	Peach Leaves	QQ Std	0.106	9121	222.80	-26.43	45.82	True $d^{13}C$= -26.20
74511	DORM	Std	0.015	1303	31.15	-17.38	41.73	True $d^{13}C$= -17.22

Analysis Note: $d^{13}C_{VPDB}$ values corrected for mass dependency. Average correction is -0.18‰

Stable Carbon Isotope Analysis

Laboratory: Keck Paleoenvironmental and Environmental Stable Isotope Laboratory, University of Kansas

Technician: Greg Cane Date: 2/9/2012 Tray: 11

Analysis #	Depth (cmbs)	Locality	Amount (mg)	Ampl 44 (mV)	Area 44 (Vs)	$d^{13}C$ VPDB	C%	Comments
74566	280	Pin Oak	17.106	5207	127.60	-24.28	0.16	
74567	285	Pin Oak	21.907	3408	83.09	-21.47	0.08	
74568	290	Pin Oak	19.431	2823	69.11	-22.56	0.07	
74569	295	Pin Oak	21.922	2410	58.63	-22.66	0.05	
74570	300	Pin Oak	20.939	3111	76.17	-23.18	0.08	
74571	305	Pin Oak	20.332	4395	106.97	-23.44	0.11	
74572	310	Pin Oak	19.739	3956	96.96	-23.39	0.10	
74573	315	Pin Oak	20.080	4888	118.96	-23.20	0.13	
74576	320	Pin Oak	15.231	4254	105.30	-23.72	0.15	
74577	325	Pin Oak	16.832	5859	144.53	-24.51	0.18	
74578	330	Pin Oak	21.712	6128	148.98	-23.79	0.15	
74579	335	Pin Oak	20.061	5875	144.17	-23.32	0.15	
74581	340	Pin Oak	19.800	5817	141.97	-22.97	0.15	
74582	345	Pin Oak	18.725	5849	143.22	-22.65	0.16	
74583	350	Pin Oak	18.166	5163	126.90	-22.36	0.15	
74584	355	Pin Oak	16.570	5167	125.54	-21.63	0.16	
74587	360	Pin Oak	17.631	5501	134.51	-21.42	0.16	
74588	365	Pin Oak	16.208	4877	118.89	-21.41	0.16	
74589	370	Pin Oak	17.244	5313	130.37	-21.96	0.16	
74590	375	Pin Oak	16.590	5605	136.48	-21.96	0.18	
74591	380	Pin Oak	20.047	6512	159.40	-22.33	0.17	
74592	385	Pin Oak	15.485	4427	107.90	-22.09	0.15	
74593	390	Pin Oak	15.291	4589	111.61	-22.89	0.16	
74594	395	Pin Oak	22.894	6864	168.13	-23.47	0.16	
74597	400	Pin Oak	18.480	5515	134.04	-23.23	0.16	
74598	405	Pin Oak	23.230	6117	150.08	-23.51	0.14	
74599	410	Pin Oak	19.801	5035	123.06	-23.01	0.13	
74600	415	Pin Oak	19.663	5132	124.84	-22.86	0.14	
74601	420	Pin Oak	21.934	5651	137.51	-22.43	0.13	
74580	Montana Soil	QQ Std	2.010	6430	157.17	-17.06	1.67	True $d^{13}C$= -17.20
74602	Peach Leaves	QQ Std	0.110	9375	226.55	-26.47	44.60	True $d^{13}C$= -26.20
74560	DORM	Std	0.015	1447	35.05	-17.30	45.46	True $d^{13}C$= -17.22

Analysis Note: $d^{13}C_{VPDB}$ values corrected for mass dependency. Average correction is -0.06‰

Stable Carbon Isotope Analysis

Laboratory: Keck Paleoenvironmental and Environmental Stable Isotope Laboratory, University of Kansas

Technician: Greg Cane Date: 2/6/2012 Tray: 12

Analysis #	Depth (cmbs)	Locality	Amount (mg)	Ampl 44 (mV)	Area 44 (Vs)	$d^{13}C$ VPDB	C%	Comments
74272	425	Pin Oak	18.258	5528	134.68	-22.12	0.16	
74273	430	Pin Oak	17.655	5643	138.79	-23.05	0.17	
74274	435	Pin Oak	17.057	5285	129.58	-23.05	0.17	
74275	440	Pin Oak	16.036	5306	130.58	-23.12	0.18	
74276	0	Chubb Hollow	5.096	13044	323.53	-27.15	1.38	
74277	5	Chubb Hollow	5.229	7275	178.14	-26.50	0.74	
74278	10	Chubb Hollow	7.852	7181	177.69	-26.56	0.49	
74279	15	Chubb Hollow	5.423	5369	131.19	-26.62	0.53	
74282	20	Chubb Hollow	6.372	4056	100.47	-25.78	0.34	
74283	25	Chubb Hollow	6.328	2414	59.35	-24.50	0.20	
74284	30	Chubb Hollow	7.785	2126	51.93	-24.08	0.14	
74285	35	Chubb Hollow	4.850	1194	29.57	-23.34	0.13	Ampl 44<min Threshold
74287	40	Chubb Hollow	24.717	7727	190.38	-23.92	0.17	
74288	45	Chubb Hollow	23.629	5327	130.84	-23.68	0.12	
74289	50	Chubb Hollow	24.079	6109	150.88	-23.76	0.14	
74290	55	Chubb Hollow	24.300	5788	141.53	-22.86	0.13	
74293	60	Chubb Hollow	24.027	4537	111.52	-22.71	0.10	
74294	65	Chubb Hollow	24.616	5400	134.14	-22.30	0.12	
74295	70	Chubb Hollow	26.457	6362	156.27	-23.16	0.13	
74296	75	Chubb Hollow	23.105	5612	138.41	-22.67	0.13	
74297	80	Chubb Hollow	26.374	5411	132.80	-22.94	0.11	
74298	85	Chubb Hollow	26.611	5949	147.03	-22.82	0.12	
74299	90	Chubb Hollow	27.115	5280	130.28	-22.72	0.10	
74300	95	Chubb Hollow	23.720	5140	126.72	-22.64	0.12	
74303	100	Chubb Hollow	23.986	5372	132.35	-22.87	0.12	
74304	105	Chubb Hollow	26.550	8150	198.77	-23.72	0.16	
74305	110	Chubb Hollow	25.755	6360	156.99	-23.50	0.13	
74306	115	Chubb Hollow	24.422	5335	130.89	-23.38	0.12	
74307	120	Chubb Hollow	25.421	5253	130.49	-23.88	0.11	
74286	Montana Soil	QQ Std	2.035	7280	178.33	-18.51	1.90	True $d^{13}C$= -17.20
74309	Peach Leaves	QQ Std	0.062	9306	226.07	-26.35	79.74	True $d^{13}C$= -26.20
74266	DORM	Std	0.017	1376	33.20	-17.39	42.24	True $d^{13}C$= -17.22

Analysis Note: $d^{13}C_{VPDB}$ values corrected for mass dependency. Average correction is -0.02‰

Stable Carbon Isotope Analysis

Laboratory: Keck Paleoenvironmental and Environmental Stable Isotope Laboratory, University of Kansas

Technician: Greg Cane Date: 2/6/2012 Tray: 13

Analysis #	Depth (cmbs)	Locality	Amount (mg)	Ampl 44 (mV)	Area 44 (Vs)	$d^{13}C$ VPDB	C%	Comments
74356	0	Round Spring T-1	7.499	11387	279.74	-23.12	0.80	
74321	125	Chubb Hollow	24.680	7136	175.63	-23.27	0.15	
74322	130	Chubb Hollow	22.298	6473	158.59	-23.48	0.15	
74323	135	Chubb Hollow	20.597	5310	131.25	-22.98	0.13	
74324	140	Chubb Hollow	22.624	5677	139.94	-23.32	0.13	
74325	145	Chubb Hollow	21.912	7135	174.79	-22.05	0.17	
74326	150	Chubb Hollow	20.829	5740	141.27	-22.73	0.14	
74327	155	Chubb Hollow	20.262	5799	141.76	-22.50	0.15	
74328	160	Chubb Hollow	21.470	5670	138.28	-22.26	0.14	
74331	165	Chubb Hollow	19.239	5066	126.07	-22.62	0.14	
74332	170	Chubb Hollow	22.827	6312	157.50	-22.67	0.15	
74333	175	Chubb Hollow	21.842	5601	138.11	-23.10	0.13	
74334	180	Chubb Hollow	19.551	5085	125.03	-22.81	0.13	
74336	185	Chubb Hollow	19.776	5214	128.46	-23.34	0.14	
74337	190	Chubb Hollow	20.178	5169	127.31	-23.26	0.13	
74338	195	Chubb Hollow	19.784	5474	135.02	-22.53	0.14	
74339	200	Chubb Hollow	20.852	5530	136.66	-23.34	0.14	
74342	205	Chubb Hollow	20.749	5467	134.40	-23.52	0.14	
74343	210	Chubb Hollow	19.919	7469	186.98	-25.73	0.20	
74344	215	Chubb Hollow	22.686	5309	130.18	-23.37	0.12	
74345	220	Chubb Hollow	19.740	4845	118.90	-23.44	0.13	
74346	225	Chubb Hollow	21.781	5685	139.93	-23.69	0.13	
74347	230	Chubb Hollow	19.084	4982	122.01	-23.37	0.13	
74348	235	Chubb Hollow	20.544	4824	118.40	-23.55	0.12	
74349	240	Chubb Hollow	21.063	5417	133.29	-23.51	0.13	
74352	245	Chubb Hollow	18.953	5694	140.17	-22.67	0.16	
74353	250	Chubb Hollow	18.795	5148	125.93	-23.31	0.14	
74354	255	Chubb Hollow	18.735	5904	144.41	-24.24	0.16	
74355	270	Chubb Hollow	21.921	4408	107.84	-23.42	0.10	
74313	Montana Soil	QQ Std	1.221	3801	93.43	-16.96	1.59	True $d^{13}C$= -17.20
74335	Montana Soil	QQ Std	2.256	7034	173.98	-16.99	1.63	True $d^{13}C$= -17.20
74357	Peach Leaves	QQ Std	0.106	9337	228.05	-26.39	45.77	True $d^{13}C$= -26.20

Analysis Note: $d^{13}C_{VPDB}$ values corrected for mass dependency. Average correction is 0.00‰

Stable Carbon Isotope Analysis

Laboratory: Keck Paleoenvironmental and Environmental Stable Isotope Laboratory, University of Kansas

Technician: Greg Cane Date: 2/7/2012 Tray: 14

Analysis #	**Depth (cmbs)**	**Locality**	**Amount (mg)**	**Ampl 44 (mV)**	**Area 44 (Vs)**	**$d^{13}C$ VPDB**	**C%**	**Comments**
74370	5	Round Spring T-1	5.398	12315	300.80	-24.68	1.21	
74371	10	Round Spring T-1	3.252	6264	151.96	-24.87	1.00	
74372	15	Round Spring T-1	9.362	12379	301.14	-24.87	0.69	
74373	20	Round Spring T-1	5.181	5935	143.22	-24.76	0.59	
74374	50	Round Spring T-1	8.058	5881	142.58	-24.09	0.38	
74375	100	Round Spring T-1	9.072	3447	82.99	-23.59	0.19	
74376	125	Round Spring T-1	8.223	5775	139.81	-21.50	0.36	
74377	130	Round Spring T-1	8.056	5599	135.07	-21.68	0.36	
74380	135	Round Spring T-1	8.182	5278	128.28	-21.39	0.33	
74381	145	Round Spring T-1	8.386	6111	149.45	-21.96	0.38	
74382	150	Round Spring T-1	8.900	7369	177.79	-22.12	0.42	
74383	155	Round Spring T-1	9.798	6695	162.39	-22.77	0.35	
74385	160	Round Spring T-1	10.472	8094	196.33	-22.63	0.40	
74386	165	Round Spring T-1	8.078	6958	167.57	-22.71	0.44	
74387	170	Round Spring T-1	7.978	7529	181.48	-22.90	0.48	
74388	175	Round Spring T-1	10.300	9098	219.22	-22.97	0.45	
74391	180	Round Spring T-1	8.463	7628	183.71	-23.26	0.46	
74392	185	Round Spring T-1	9.209	7292	175.99	-23.11	0.41	
74393	190	Round Spring T-1	10.862	8347	201.85	-23.17	0.40	
74394	195	Round Spring T-1	9.117	6783	164.06	-23.03	0.38	
74395	200	Round Spring T-1	9.879	7976	192.85	-23.49	0.42	
74396	205	Round Spring T-1	11.534	8116	195.99	-23.24	0.36	
74397	210	Round Spring T-1	10.114	7169	174.20	-22.46	0.37	
74398	215	Round Spring T-1	8.849	5797	140.63	-23.26	0.34	
74401	220	Round Spring T-1	9.537	5665	136.69	-23.15	0.30	
74402	225	Round Spring T-1	11.422	5997	144.12	-23.25	0.27	
74403	230	Round Spring T-1	10.022	5363	129.92	-23.85	0.27	
74384	Montana Soil	QQ Std	2.000	6422	156.46	-17.10	1.66	True $d^{13}C$= -17.20
74404	Montana Soil	QQ Std new vial	1.230	4033	97.42	-17.22	1.66	True $d^{13}C$= -17.20
74405	Montana Soil	QQ Std new vial	1.324	4148	102.09	-17.23	1.62	True $d^{13}C$= -17.20
74406	Peach Leaves	QQ Std	0.105	9231	223.98	-26.36	45.59	True $d^{13}C$= -26.20
74364	DORM	Std	0.015	1360	33.08	-17.42	44.10	True $d^{13}C$= -17.22

Analysis Note: $d^{13}C_{VPDB}$ values corrected for mass dependency. Average correction is +0.05‰

Stable Carbon Isotope Analysis

Laboratory: Keck Paleoenvironmental and Environmental Stable Isotope Laboratory, University of Kansas

Technician: Greg Cane   Date: 2/10/2012   Tray: Ramsey Field Reruns

Analysis #	Depth (cmbs)	Locality	Amount (mg)	Ampl 44 (mV)	Area 44 (Vs)	$d^{13}C$ VPDB	C%	Comments
74664	45	Ramsey Field	42.541	5535	134.40	-22.77	0.07	
74665	50	Ramsey Field	28.790	3987	96.91	-21.45	0.08	
74666	55	Ramsey Field	30.661	5316	128.29	-23.05	0.10	
74667	60	Ramsey Field	35.864	5087	123.62	-19.29	0.08	
74668	70	Ramsey Field	33.842	3474	83.94	-22.91	0.06	
74669	75	Ramsey Field	32.319	4641	112.90	-22.73	0.08	
74670	80	Ramsey Field	29.153	3955	95.40	-22.80	0.07	
74671	85	Ramsey Field	29.805	4112	99.43	-21.06	0.08	
74674	90	Ramsey Field	31.387	4639	113.09	-22.21	0.08	
74675	95	Ramsey Field	37.985	6482	157.49	-21.51	0.10	
74676	135	Ramsey Field	26.981	3629	88.24	-19.76	0.07	
74678	Montana Soil	QQ Std	2.000	6199	150.47	-17.14	1.77	True $d^{13}C$= -17.20
74684	Peach Leaves	QQ Std	0.100	8458	204.32	-26.53	48.95	True $d^{13}C$= -26.20
74658	DORM	Std	0.018	1636	39.23	-17.28	43.72	True $d^{13}C$= -17.22

Analysis Note: $d^{13}C_{VPDB}$ values corrected for mass dependency. Average correction is -0.05‰

APPENDIX D.

OPTICALLY STIMULATED LUMINESCENCE RESULTS

Equivalent Dose, Dose Rate Data, and Optical Age Estimates
Laboratory: Luminescence Geochronology Laboratory, University of Nebraska-Lincoln
Date: Winter 2011-2012

Locality	**Depth (cmbs)**	**Field #**	**UNL Lab #**	**Depth (m)**	**U (ppm)**	**Th (ppm)**	**K_20 (wt %)**	**In Situ H_20 (%)[a]**	**Dose Rate (Gy/ka)**	**D_e (Gy)[b] ± 1 Std. Err.**	**Aliquots (n)[c]**	**Over-dispersion**	**Optical Age ± 1 σ**
Akers Ferry	172-191	AF T-2	UNL-3419	1.8	2.1	4.9	0.7	10.8	1.41 ± 0.12	42.0 ± 1.2	26/27	15	29.8 ± 2.9
Akers Ferry	191-197	AF T-2	UNL-3420	2.0	1.4	3.9	0.4	9.0	1.04 ± 0.07	34.8 ± 1.0	26/27	15	33.6 ± 2.9
Akers Ferry	197-203	AF T-2	UNL-3417	2.0	1.4	3.4	0.4	8.5	0.99 ± 0.07	34.0 ± 1.4	27/27	21	34.4 ± 3.1
Akers Ferry	203-210	AF T-2	UNL-3418	2.1	1.2	2.6	0.3	8.4	0.82 ± 0.05	37.2 ± 1.4	26/27	20	45.4 ± 3.9
Round Spring T-1	145-165	RS T-1	UNL-3421	1.6	1.9	4.9	0.6	18.9	1.22 ± 0.15	2.1 ± 0.1	23/25	10	1.7 ± 0.2
Round Spring T-1	200-228	RS T-1	UNL-3422	2.1	2.7	7.1	0.8	16.2	1.63 ± 0.18	4.9 ± 0.1	26/27	11.5	3.0 ± 0.4
Ramsey Field	145-168	RA T-3	UNL-3423	1.6	2.0	5.7	0.6	13.6	1.35 ± 0.13	12.6 ± 0.3	31/32	12.3	9.3 ± 1.0
Ramsey Field	253-278	RA T-3	UNL-3424	2.6	2.3	6.7	1.0	15.5	1.69 ± 0.19	16.5 ± 0.3	26/27	9.1	9.8 ± 1.2
Ramsey Field	410-424	RA T-3	UNL-3431	4.2	2.0	6.0	0.9	15.9	1.45 ± 0.17	17.5 ± 0.4	27/27	10.3	12.0 ± 1.5
Ramsey Field	430-445	RA T-3	UNL-3429	4.4	2.2	5.7	0.9	17.1	1.46 ± 0.18	18.3 ± 0.4	27/27	10.3	12.5 ± 1.6
Ramsey Field	450-470	RA T-3	UNL-3430	4.6	2.4	6.8	0.9	17.4	1.58 ± 0.20	17.7 ± 0.4	27/27	11.7	11.2 ± 1.5
Chubb Hollow	143-163	CH All Fan	UNL-3426	1.5	3.5	10.1	1.4	16.0	2.44 ± 0.28	27.8 ± 0.8	25/27	14	11.4 ± 1.4
Chubb Hollow	163-183	CH All Fan	UNL-3427	1.7	3.8	8.8	1.5	15.7	2.49 ± 0.29	29.7 ± 0.7	25/27	10	11.9 ± 1.5
Chubb Hollow	197-225	CH All Fan	UNL-3428	2.1	2.9	6.8	1.2	12.7	2.02 ± 0.20	38.0 ± 2.0	26/27	27	18.2 ± 2.1 (partially bleached)

[a]assumes 100% error in measurement

[b]Central Age Model

[c]accepted disks/all disks