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Archaeological and Dendrochronological Investigations at Cagle Saltpetre Cave, Van Buren County, Tennessee

Sarah Anne Blankenship
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Sarah Anne Blankenship entitled "Archaeological and Dendrochronological Investigations at Cagle Saltpetre Cave, Van Buren County, Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

Charles H. Faulkner, Major Professor

We have read this thesis and recommend its acceptance:

Joseph C. Douglas, Jan F. Simek

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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ARCHAEOLOGICAL AND DENDROCHRONOLOGICAL INVESTIGATIONS AT CAGLE SALTPETRE CAVE, VAN BUREN COUNTY, TENNESSEE

A Thesis
Presented for the
Master of the Arts
Degree
The University of Tennessee, Knoxville

Sarah Anne Blankenship
May 2007

DEDICATION

This thesis is dedicated to my parents, Michael and Bo Blankenship, and the rest of my family, for instilling in me the character to work hard and achieve my goals, and for always encouraging me to follow my heart.

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ABSTRACT

During the 19th century, the increasing demand for saltpeter, a vital ingredient in gunpowder, led to both large- and small-scale saltpeter-mining operations in caves throughout Tennessee. Although the general procedures in the historic processing of saltpeter are fairly well understood, very little archaeological research has been undertaken on specific saltpeter-mining sites. Historic documentation of mining activities within these caves is scarce, thus systematic studies of these sites are integral to a greater understanding of this early extractive industry. The research presented in this thesis is the first in the region in which archaeological and dendrochronological investigations were used in conjunction in an attempt to remedy this absence of formal study.

The dry environment of deep caves allows for excellent preservation of the material record, thus many saltpeter-mining sites still contain the equipment used in the mining operations, much of it still in context. The subject of this study, Cagle Saltpetre Cave, in Van Buren County, Tennessee, is one such site. My research design was focused on outlining the social history of the site, examining specific mining activities and saltpeter processing technologies employed, establishing specific temporal parameters for when the mining activities took place, and delineating changes in processing technology over time. Both archaeological and dendrochronological principles were employed to address these questions.

The archaeological investigation of Cagle Saltpetre Cave consisted of archival research, a comprehensive survey and mapping project, and Geographical Information Systems (GIS)-based data management and analyses. Archival research was conducted in an attempt to locate historic documentation of the mining operations at Cagle Saltpetre Cave. The cave was comprehensively surveyed and mapped in detail in order to document the location of prehistoric and historic cultural remains. The data generated from the mapping project were then examined for spatial patterns using GIS software. By documenting the spatial relationships of extant artifacts and features, information was gleaned to account for specific activities that took place at the site. In addition, these analyses allowed the reconstruction of other important aspects of the mining operations.

During the mining episodes at Cagle Saltpetre Cave, wooden leaching vats needed for the lixiviation of saltpeter, or calcium nitrate, from mined sediment were constructed and used within the cave. When mining operations ceased, these artifacts were abandoned and preserved *in situ*, some remaining virtually intact. Their remarkable preservation enabled tree-ring dating of timbers associated with these artifacts. The results of these analyses indicate that saltpeter was mined and processed at the site during three discrete episodes throughout the 19th century. Additionally, saltpeter-processing technology changed throughout the course of the mining operations.

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CHAPTER I
INTRODUCTION

Saltpeter mining, one of the early historic industries of the Southeast, involved extracting and processing nitrates, referred to as “saltpeter” or “saltpetre”, found in caves and rockshelters for the production of gunpowder. Throughout the 19th century, increasing demand for saltpeter led to both large- and small-scale saltpeter-mining operations in caves throughout the region. Despite the importance of the saltpeter industry to both our country’s military history and early industrial development, surprisingly little is known about the details of mining operations within these caves. This problem has been recognized by the historian Marion Smith who stated, “Mining was often literally out of site when it was done, and consequently was later out of mind…Although early deeds mention saltpeter caves, rarely is anything of consequence revealed about actual mining operations” (1990: 1). Much of what is known about the social history of the saltpeter industry can be attributed to the exhaustive efforts of cave historians (e.g., DePaepe 1985; Douglas 2001a; Faust 1967, George 2001; Smith 1990). Most contemporaneous accounts of saltpeter mining pertain to the few large-scale operations, such as Great Saltpetre Cave and Mammoth Cave in Kentucky, and they are rare. Because the majority of the operations were small, documentation of mining activities is often non-existent; therefore, we must rely on the archaeological evidence in order to understand the mining and production processes.

Research Goals and Organization of Thesis

This thesis seeks to expand our current understanding of 19^{th} century saltpeter mining in the Midsouth through the systematic, scientific study of a specific mining site, Cagle Saltpetre Cave (40VB125) in Van Buren County, Tennessee. In Tennessee, small-scale saltpeter production began in the late 1770s and continued approximately 85 years, ending only with the collapse of Confederate control of the state in the Civil War. Geographically, by the early 1800s saltpeter mining had spread from east Tennessee into middle Tennessee, where there were large numbers of caves with rich nitrate deposits in their sediments. In all, some 250 caves, and an unknown number of rockshelters, were mined for saltpeter in Tennessee (Plemons 1995).

Cagle Saltpetre Cave is currently located within the boundaries of Fall Creek Falls State Park and is managed by the Park. One of hundreds of caves in the Cumberland Plateau mined for saltpeter, Cagle Saltpetre Cave is unique in that it still contains many well-preserved extant artifacts and features related to the historic mining activities, the majority of which remain *in situ*. My primary research focus is to examine specific mining activities and saltpeter processing technologies employed at the site, to establish specific temporal parameters for when the mining activities took place, and to delineate changes in processing technology over time. In order to address these goals, the investigation of Cagle Saltpetre Cave consisted of archival research, a systematic survey and Geographical Information Systems (GIS)-based analyses, and dendrochronological analyses of the preserved material record. This research and the culmination of my analyses are presented according to the following outline.

Chapter II provides a brief overview of cave archaeology in the Midsouth. This includes a summary of archaeological inquiry concerning human utilization of cave environments, beginning with the Late Archaic period (ca. 3000 BC - 1000 BC) and ending with the historic period (ca. AD 1600 – AD 1900).

In Chapter III, a historical overview of saltpeter mining in the southeastern United States is presented. This chapter begins with a summary of the general procedures for mining and processing saltpeter and includes the chemistry behind the conversion of cave saltpeter, primarily calcium nitrate ($Ca(NO_3)_2 \bullet 4H_2O$), to gunpowder niter, or potassium nitrate (KNO_3). This chapter also outlines the development of the saltpeter industry in the Southeast, beginning during the 18th century and ending with the close of the Civil War in the late 19th century. The remainder of this chapter summarizes previous archaeological research on saltpeter mining. It is important to reiterate that archaeological inquiry into saltpeter mining has been minimal, as the majority of southeastern cave archaeology has focused on pre-Columbian (i.e., Native American) cave use. Nonetheless, the few archaeological investigations on the historic saltpeter mining industry are discussed, beginning with De Jean's (1997) identification of saltpeter mining sites throughout the Big South Fork of the Cumberland River and Coy et al.'s (1984) and Fig and Knudson's (1984) studies of saltpeter mining in eastern Kentucky. The previous archaeological investigations of Mammoth Cave, Kentucky and Duncan's (1993, 1995, and 1997) analyses of Saltpeter Cave (15Cr99), Kentucky are then discussed.

In Chapter IV, the environmental setting of Cagle Saltpetre Cave is presented. First, the history of the current archaeological investigations of the site is briefly summarized. Next, the physiography and geology of the site are presented.

The archaeological investigations of Cagle Saltpetre Cave are presented in Chapter V. First, the results of archival research concerning the historic saltpeter mining episodes at Cagle Saltpetre Cave are discussed. The archaeological record at Cagle Saltpetre Cave consists of well-preserved extant artifacts and features resulting from both prehistoric and historic activity. A detailed survey and mapping project of this material was undertaken using a Nikon total station, which allowed accurate documentation of their provenance. In particular, artifacts and features related to saltpeter mining and processing were recorded to identify any intrasite patterning that may exist among the *in situ* material record, allowing the author to reconstruct the historic industrial activities within the cave. The analytical methods used to examine the spatial relationships among the historic material record consisted of a Geographical Information Systems (GIS) -based approach. The ArcGIS® integrated GIS software program was used to both manage the spatial data collected during the mapping project and produce a map of each point (i.e., an *x*, *y*, *z* Cartesian [spatial] coordinate). This allowed the identification of spatial patterns among the extant artifacts and features.

Chapter VI presents the dendrochronological investigations at Cagle Saltpetre Cave. This line of research involved tree-ring dating of wood samples from four saltpeter vats that remain in the cave. Each of these samples was mapped using a Trimble total station, which allowed accurate documentation of their provenance. Both the laboratory methods used in the dendrochronological analyses and the results of these investigations are discussed in detail. Utilizing these results, a chronological framework for the historic mining activities is introduced, indicating that the site was exploited at various times throughout the 19th century. Possible construction dates for each of the vats were determined, demonstrating that the saltpeter processing technology employed at Cagle Saltpetre Cave changed over time. Interpretations are also made concerning the affect that both the political and economic climate of the United States during the 19th century may have had on the saltpeter operations at Cagle Saltpetre Cave.

Finally, in Chapter VII, the results of this research are summarized. In addition, recommendations for future archaeological research concerning saltpeter mining are presented.

CHAPTER II
CAVE ARCHAEOLOGY IN THE MIDSOUTH: AN OVERVIEW

A myriad of limestone caves can be found throughout the vast karst regions of the Appalachian Highlands and Appalachian Plateau provinces of the eastern United States, extending from northern Alabama into Tennessee, Kentucky, West Virginia, and Virginia (Fenneman 1938). Caves, natural subterranean pits, passages, and/or chambers formed in bedrock, have long been exploited, for a variety of purposes, by both the prehistoric and historic occupants of these regions.

In some instances, environmental conditions within caves (i.e., relatively dry, with stable temperatures and humidity) are such that highly perishable materials left by earlier visitors remain well preserved. This phenomenon allows the examination of an archaeological record that would otherwise be absent in an above-ground context. Focusing primarily on investigations within the dark zone (areas beyond the reach of daylight) of cave interiors, the following overview provides a brief summary of cave archaeology in the Midsouth.

LATE ARCHAIC PERIOD (CA. 3000 BC TO 1000 BC)

"Between 4500 and 3000 B.P., there were at least four categories of activity in the caves and deep pits of the Midsouth," (Crothers et al. 2002: 510). These include "simple exploration, exploration plus ritual or ceremony, chert quarrying (sometimes accompanied by creation of graffiti, petroglyphs or mud glyphs), and use of subterranean locales for mortuary purposes" (Crothers et al. 2002: 510). The earliest evidence thus far for dark-zone cave exploration in the Midsouth comes from Jaguar Cave in north-central Tennessee (Robbins et al. 1981; Watson et al. 2005). Radiocarbon assays of river cane (*Arundinaria sp.*) charcoal, used as prehistoric torch material, indicate that during the Late Archaic (ca. 4500 B.P.), prehistoric visitors traveled more than a kilometer through the cave to the end of a passage now referred to as "Aborigine Avenue." Throughout this ca. 400-meter passage are 274 footprints preserved in the soft floor sediment. During the 1970s, archaeologists affiliated with the Cave Research Foundation undertook careful documentation and analysis of the footprints. Their observations suggest that at least nine individuals, possibly representing two separate episodes of visitation, made the arduous trip through Jaguar Cave between 4500 – 4700 B.P. (Watson et al. 2005).

Isolated Late Archaic exploratory episodes have also been documented in other caves in the Midsouth (Crothers et al. 2002), including Lee Cave, (Freeman et al. 1973), Mammoth Cave (Watson 1983, 1996; Watson [ed.] 1969, 1974), Lower Salts Cave (Watson [ed.] 1969, 1974), and Fisher Ridge Cave (Watson 1983) in Kentucky; Wyandotte Cave in Indiana (Munson and Munson 1990); and 3rd Unnamed Cave in Tennessee (Crothers et al. 2002; Franklin 1999; Simek et al. 1998).

Archaic Ceremonial Caves

By the end of the Late Archaic period, people began to leave other evidence for dark-zone cave visitation: geometric markings, or glyphs, on cave walls, floors, and/or ceilings. In the late 1980s, cross-hatching, zig-zags, and other geometric motifs were found incised into the mud-covered floor of a remote passage within Adair Glyph Cave, Kentucky (DiBlasi 1996). A single radiocarbon assay of 3560 ± 110 B.P. was obtained on cane charcoal from this passage, which makes it the earliest site of this type of ceremonial activity in the Midsouth presently known.

Third Unnamed Cave (Franklin 1999; Simek et al. 1998) in northern Tennessee is another early dark-zone cave art site. Prehistoric visitors to the cave left an elaborate assemblage of petroglyphs engraved in the limestone ceilings and breakdown of a remote passage. The motifs include concentric ovals, chevron patterns, and rayed circles, among others. The petroglyphs are thought (Simek et al. 1998) to be associated with extensive chert mining that took place in this passage during the Terminal Archaic (ca. 3000 B.P.). As Crothers et al. (2002: 510) note, the archaeological record of 3rd Unnamed Cave "reflect[s] a complex range of dark-zone activities, possibly including ceremony as well as exploration and mining, by Terminal Archaic foragers."

Archaic Mortuary Caves

Archaic period use of cave interiors for mortuary purposes has been documented in at least one middle Tennessee Cave, Meadows Hill Saltpeter

Cave (Crothers et al. 2002; Owens 1958). In the 1950s, an amateur collector uncovered three flexed burials associated with artifacts such as projectile points and bannerstones, which are diagnostic of the Archaic period.

WOODLAND PERIOD (CA. 1000 BC – AD 1000)

Woodland Cave Mineral Extraction

During the Early Woodland period (ca. 1000 B.C. – 300 B.C.), prehistoric extractive activities within Midsouth caves intensified, with the advent of mining of sulfate minerals such as gypsum ($CaSO_4 \cdot 2H_2O$), mirabilite ($Na_2SO_4 \cdot 10H_2O$), and epsomite ($MgSO_4 \cdot 7H_2O$). Gypsum, hydrated calcium sulfate, occurs as crusts or in fibrous form (satin spar) on cave walls and ceilings and as needle-like speleothems (selenite) in cave sediments (Hill and Forti 1997: 193-194). Mirabilite and epsomite, sulfates of sodium and magnesium respectively, form as crystals, crusts, or "cotton" on cave floors, walls, and ceilings (Hill and Forti 1997: 196-197). Exactly why these substances were removed from cave interiors by prehistoric miners is not known. Crothers et al. (2002: 512) suggest that gypsum powder may have been used in the manufacture of white paint. Selenite and satin spar crystals may have functioned as ceremonial objects or trade items. Both epsomite and mirabilite have laxative properties and thus may have served a medicinal purpose.

Salts Cave and Mammoth Cave in the Mammoth Cave System, Kentucky (Kennedy and Watson 1997; Munsen et al. 1989; Watson [ed.] 1969, 1974) contain the earliest evidence thus far for subterranean sulfate mining; beginning ca. 3000 years ago, gypsum, mirabilite, and possibly epsomite were intensively sought. The techniques for obtaining such minerals were relatively ubiquitous and included "digging into floor sediments for selenite crystals, breaking off natural speleothem features such as gypsum crust and gypsum flowers, brushing or scraping mirabilite and epsomite from walls and breakdown blocks, and battering satin spar…from crevices in walls and ceilings" (Crothers et al. 2002: 512). Big Bone Cave (Crothers 1987, 2001; Faulkner 1991) and Hubbards Cave (Douglas [ed.] 1997; Pritchard 2001), both in middle Tennessee, also contain evidence of Woodland-period gypsum mining. In Big Bone Cave, selenite crystals within the cave floor sediments, rather than gypsum crust from the walls and ceilings, appear to have been of primary interest to the prehistoric miners (Crothers 1987, 2001). Eight radiocarbon determinations from a variety of material remains found within Big Bone Cave (e.g., river cane, plant fibers, and human paleofecal specimens) suggest that the mining activity was most intensive during the Early Woodland period (a calibrated age range of 2850 – 1900 B.P.) (Crothers 1987, 2001; Crothers et al. 2002; Faulkner 1991). Similar to Mammoth and Salts Cave, prehistoric gypsum mining in Hubbards Cave consisted of battering gypsum crust from passage walls with the aid of river cobble hammerstones, which can still be found throughout the cave. Four radiocarbon dates obtained from cane torch fragments indicate that gypsum mining took place at Hubbards Cave during the Early Middle Woodland and Late Middle Woodland periods (2730 – 1280 B.P.) (Pritchard 2001).

Pritchard (2001) has examined the relationship among these major gypsum-mining sites in the Midsouth, proposing that mining activity in Mammoth, Salts, and Big Bone caves all preceded that at Hubbards. Using the BCal® on-line Bayesian radiocarbon calibration program, Pritchard analyzed uncalibrated radiocarbon dates from the aforementioned sites and conducted probability tests of the proposed temporal model. The resulting calibrated chronology of prehistoric activity at these sites is as follows (Pritchard 2001: 89): Mammoth Cave, 2871 BC – AD 179 (Late Archaic to Middle Woodland); Salts Cave, 1201 BC – AD 62 (Terminal Archaic to Middle Woodland); Big Bone Cave, 1401 BC – AD 609 (Late Archaic to Late Woodland); Hubbards Cave, 1001 BC – AD 889 (Woodland). Results of the analyses "indicate a significant amount of elapsed time between the earliest known dates from Mammoth and those from Hubbards" (Pritchard 2001: 100). In addition, probability tests confirmed that "the gypsum mining phenomenon began further north [Kentucky] and spread southward to Big Bone Cave and then Hubbards Cave [middle Tennessee]" (Pritchard 2001: 100). Based on these results, Pritchard argues that prehistoric subterranean mining activity at Hubbards Cave may reflect the expanding interaction sphere of middle Tennessee's inhabitants at that time (2001: 100). Thus, gypsum mining may have been linked to other phenomena such as inter-group trade and increasing social complexity during the Woodland period.

Woodland Mortuary Caves

A number of burial pit caves have been documented in the Southeast and Midsouth (Crothers et al. 2002) though few have been systematically studied. Establishing a chronological sequence for this phenomenon can be quite difficult;

dateable materials associated with prehistoric human remains are often incorporated and obscured in complex deposits of talus, organic debris, animal remains, and modern trash, which accumulate at the bottom of vertical shafts. The few in-depth investigations of mortuary pit caves, one in northern Alabama (Oakley 1971) and several in central Kentucky (Haskins 1987), have indicated Woodland use of these particular sites. These studies lend support to the current consensus that use of pit caves as repositories for human remains occurred primarily during the Woodland period, between ca. 500 – 1000 B.P. (Crothers et al. 2002: 517).

A distinctive regional expression of mortuary cave use, the Copena burial caves of the lower Tennessee River basin, appeared during the Middle Woodland (Walthall and DeJarnette 1974). These caves were a component of the Copena culture burial complex (ca. AD 100 – AD 500) of northwest Georgia and northern Alabama that include above-ground mounds (Anderson and Mainfort 2001; Crothers et al. 2002; Walthall 1973; Walthall and DeJarnette 1974). The Copena "tradition" is distinguishable from other contemporaneous southeastern Woodland groups due to specific burial practices and a distinctive assemblage of mortuary artifacts. In both caves and in-mound contexts, exotic materials such as galena and mica, along with artifacts made from imported greenstone, steatite, and copper are typically associated with Copena interments (Crothers et al. 2002; Walthall 1973; Walthall and DeJarnette 1974). Copena mortuary caves exhibit both fleshed extended burials on prepared surfaces–

similar to mound interments–and cremations (Beck 1995; Walthall and DeJarnette 1974).

The shared characteristic burial ceremonialism and material culture of the Copena (Beck 1995), the Marksville culture of the Lower Mississippi Valley (Mainfort 1996; Seltzer 1933, 1934), and the Santa Rosa-Swift Creek (Blitz 1986) and Swift Creek (Willey 1949; Williams and Elliott [ed.] 1998) cultures of the Gulf Coastal Plain have been viewed as possible southern manefestations of the Ohio River valley Hopewellian horizon (ca. 200 BC to AD 400) (e.g., Anderson and Mainfort 2001; Beck 1995), which were partly shaped from extensive long-distance trade networks that developed during the Middle Woodland.

Woodland Ceremonial Caves

More than 50 prehistoric ceremonial caves (i.e., caves that exhibit ritual expression in the form of petroglyphs, pictographs, and/or mud glyphs) have been identified in the Southeast (e.g., Faulkner 1988, 1992, 1997; Faulkner [ed.] 1986; Simek, Franklin, and Sherwood 1998; Simek et al. 1997; Simek et al. 2001; Simek et al. 2006). Few, however, contain associated artifacts that have yielded only Woodland age radiocarbon determinations, as the majority indicate both Woodland and Mississippian-period use (Crothers et al. 2002). Nonetheless, current evidence suggests that the production of cave art during the Woodland period was more common than earlier periods in southeastern prehistory (Crothers et al. 2002).

At present, 5th Unnamed Cave in middle Tennessee is the earliest definitive Woodland cave art site in the Midsouth (Crothers et al. 2002; Simek, Cressler, and Pope 2004). Two petroglyphs are found on the limestone wall within the cave; an anthropomorph with a square torso and a "toothy mouth" with no associated representation of a head or body. A single accelerator mass spectrometry (AMS) radiocarbon determination on a fragment of bone from the cave yielded a date of 2030 ± 50 B.P. (calibrated age range of 180 BC – AD 70), indicating use of the cave during the Middle Woodland (Crothers et al. 2002: 519; Simek, Cressler, and Pope 2004: Table 10.1). Although deposits within the cave have been badly disturbed by looting, the remains of at least two individuals were recovered from the talus below the petroglyphs and were likely interred by dropping the remains through a vertical shaft entrance (Simek, Cressler, and Pope 2004). This pattern of burial, as previously discussed, was most typical throughout the Woodland period.

The toothy mouth, "an oval with multiple vertical lines filling the interior," has been observed in several other southeastern caves (Simek, Cressler, and Pope 2004: 172). In all instances, the caves also contain multiple human burials. Thus, although the exact meaning of this motif is uncertain, there appears to be a relationship between the presence of this particular motif and the occurrence of multiple human interments within cave interiors (Simek, Cressler, and Pope 2004). The majority of these sites are later in age, dating to the Mississippian period (ca. AD 1000 - AD 1600). Fifth Unnamed Cave may therefore indicate that this phenomenon had its beginnings in the Middle Woodland and extended into the subsequent Mississippian period (Simek, Cressler, and Pope 2004: 172-173).

Another Woodland ceremonial cave, Crumps Cave in Kentucky, contains an elaborate assemblage of glyphs incised into the alluvial mud banks of the cave interior. These mud glyphs consist of abstract patterns and lines and both anthropomorphic and zoomorphic figures (Crothers et al. 2002; Davis and Haskins 1993). A radiocarbon assay obtained from a cane torch fragment, found impacted in an incised line of a glyph, yielded an age of 1980 ± 60 B.P. (Crothers et al. 2002; Davis and Haskins 1993). A sample of charcoal removed from the cave wall above the glyphs provided a radiocarbon determination of 1840 ± 80 B.P. (Crothers et al. 2002). Thus both dates are indicative of the Woodland period.

The prehistoric art found within the dark zone of 19th Unnamed Cave, located in northern Alabama, is similar in subject matter to that of Crumps Cave, Kentucky. The images consist of hundreds of mud glyphs, which include abstract motifs, as well as anthropomorphic and zoomorphic figures (Cressler et al. 1999; Crothers et al. 2002). Compared to other southeastern cave art sites, the glyphs are quite large, with some more than 3 meters in size (Crothers et al. 2002). Each of the glyphs was apparently produced by the prehistoric artists' bare fingers, which were used to incise the mud-covered ceilings of the cave; a manner of execution Faulkner and Simek (2001) have termed "digital tracing." Two radiocarbon determinations obtained on wood charcoal found within 19th Unnamed Cave yielded Woodland dates of 1760 ± 60 and 1240 ± 60 BP

(Cressler et al. 1999; Crothers et al. 2002). In addition, two chronologically diagnostic sherds indicative of Early and Middle Woodland manufacture were recovered from the floor of one of the glyph passages (Cressler et al. 1999; Crothers et al. 2002). Nineteenth Unnamed Cave is one of eleven mud glyph sites known in the Southeast (Faulkner [ed.] 1986; Faulkner and Simek 2001) and, as noted by Crothers et al. (2002: 521), is the southernmost manifestation of this particular cave art tradition.

MISSISSIPPIAN PERIOD (CA. AD 1000 - AD 1600)

Mississippian Ceremonial/Ritual Caves

Current evidence suggests that the production of dark zone parietal art in Midsouth caves was most common during the late prehistoric Mississippian period (e.g. Faulkner 1988, 1996, 1997; Faulkner [ed.] 1986; Simek, Frankenberg, and Faulkner 2001; Simek et al. 1997; Simek et al. 2006). The Mississippian period was characterized by socially complex, stratified societies in which religion, cosmology, and their associated symbolism and/or iconography played an important role (Galloway [ed.] 1989; Waring and Holder 1945). This relationship is demonstrable in the mobiliary objects that bear such icons, which are often found in ceremonial contexts (e.g., Brain and Phillips 1999; Kneberg 1959). Both naturalistic and stylistic representations of this iconography, in the form of petroglyphs, pictographs, and/or mud glyphs, have been found in caves throughout the karst regions of the Eastern Woodlands, including Williams Cave (Bunnell 1979; Faulkner 1988) and Little Mountain Cave (Faulkner 1988) in

Virginia, and 1st Unnamed (Simek et al. 1997), 11th Unnamed (Simek et al. 2001), 12th Unnamed (Faulkner 1988), and Mud Glyph (Faulkner [ed.] 1986; Faulkner, Deane, and Earnest 1984) caves in Tennessee.

The meaning behind this subterranean artistic expression is uncertain, and will likely remain so. "Almost certainly, Mississippian cave art had a religious import," state Simek, Frankenberg, and Faulkner, however, "[t]he meaning of southeastern cave art is certainly more complex than a simple 'religious' interpretation might imply" (2001: 62). Nonetheless, the ceremonial iconography does indicate that these motifs and the caves in which they were produced, likely served a ritual function. They may have been part of private ceremonies or rituals not intended for the general public (Faulkner 1996: 117).

HISTORIC PERIOD (CA. AD 1600 – AD 1900)

The few in-depth studies concerning historic use of Midsouth caves (e.g., Douglas 2001a; Duncan 1993; Faust 1964; George 2005; Smith 1981), have focused primarily on Euro-American relationships and interactions with the underground environment. Furthermore, systematic research on the subject has almost entirely been undertaken by historians, as archaeologists have, for the most part, concerned themselves with pre-Columbian cave usage. A historic archaeological record does indeed exist in caves and certainly deserves the attention of the archaeological community. The few archaeological investigations of Euro-American cave use (e.g., Borreson 1942; Coy et al. 1984; Des Jean 1997; Duncan 1993; Fig and Knudson 1983) have focused on the mining of cave saltpeter, which was used to make gunpowder prior to the development of nitrogen fixation technologies in the early 20th century. Chapter III presents a summary of previous archaeological research on historic saltpeter mining.

CHAPTER III
HISTORICAL OVERVIEW:
SALTPETER MINING IN THE SOUTHEASTERN UNITED STATES

Saltpeter Mining and Processing Operations

For centuries, the recipe for gunpowder consisted of the following ingredients (often in varying quantities): seven parts saltpeter, five parts sulfur, and five parts charcoal. Of the three ingredients, saltpeter (derived from the Latin *sal petrae*, meaning “salt of rock”), or niter as it is often called, is arguably the most vital, as it gives gunpowder its explosive properties. In comparison to sulphur and charcoal, saltpeter has also required the most effort to obtain. Composed of potassium nitrate (KNO_3), “true” saltpeter occurs naturally in certain soils, though few deposits on the earth’s surface contain the quantities needed for large-scale gunpowder manufacture. In the southeastern United States, the nitrate-rich sediments within dry caves became important, reliable sources for the mineral.

In addition to potassium nitrate, a variety of other nitrate minerals, sometimes called “false saltpeter,” have been identified in cave deposits (Hill 1977: 127): nitromagnesite ($Mg(NO_3)_2 \cdot 6H_20$), soda-niter ($NaNO_3$), ammonia-niter (NH_4NO_3), darapskite ($Na(NO_3)(SO_4 \cdot H2O)$), and calcium nitrate ($Ca(NO_3)_2 \cdot 4H_2O$). In the humid environment of the Southeast, the hygroscopic nature of the latter nitrate minerals required their conversion to potassium nitrate, which is more repellent to moisture. Therefore certain procedures were followed when mining and processing cave saltpeter (Eller 1981; Smith 1990):

1. Leaching vats or hoppers were constructed near a water source either inside or outside of the cave.
2. The leaching vats were filled with mined cave sediments.
3. To lixiviate the water-soluble nitrates, water was poured onto the vats one or more times and the resulting nitrate-rich leachate was collected in troughs.
4. The leachate was combined with potash (wood ash) lye to chemically convert the "false" saltpeter solution to a potassium nitrate solution.

   The chemical conversion involves the removal of calcium and magnesium from the solution by the potash lye (potassium hydroxide (KOH)) through the precipitation of the soluble hydroxides of Ca and Mg (Eller 1981: 106):

$$[Ca^{+}, Mg^{+}, NH_4^{+}]\,(NO_3)\ \text{solution}$$

$$\text{KOH} \downarrow$$

$$K^{+} + NH_4^{+} + [NO_3]^{-} + Ca(OH)_2, Mg(OH)_2$$

5. The leachate was then filtered to remove impurities such as lime or sulfates and boiled in order to evaporate the water and form potassium nitrate crystals.
6. The nitrate crystals were then collected, dried, packed, and sent to the powder mills.

The environmental conditions of a particular cave (i.e., the size and shape of passages and/or interior chambers) and the availability of raw materials ultimately determined the types of tools and other equipment used for the mining and processing operations. First and foremost, working within cave interiors required a light source. Presumably, the most common materials used for illumination were pine torches coated in animal fat (which served as a fuel source) (Faust 1955). However, torches fashioned from other organic materials were used. Concerning other possible light sources employed, historian Burton Faust (1955: 9) reports, “It was known practice to soak dried cat-tail [*Typha latifolia*] heads in animal fat or pine pitch for use as torches.”

Due to the scarcity (and thus, high cost) of metal, saltpeter miners often used tools fashioned from local hardwoods, such as hickory or dogwood. These basic tools were ubiquitous throughout the saltpeter industry and included wooden paddles for shoveling loose sediment, and wooden picks, mattocks, and digging sticks, used to remove packed sediment from the cave floors and walls (De Paepe 1981; Faust 1955).

A variety of methods were employed for transporting the mined sediment to the processing equipment, and the types selected depended upon the size and accessibility of the cave. In smaller caves, sediment was often collected in bags, similar to present-day burlap or gunny sacks, and brought to the processing areas (whether inside or outside of the cave) via manual labor (Faust 1955). Within the larger saltpeter caves such as Mammoth and Great Saltpetre in Kentucky, mined during the War of 1812, oxen were used to pull cart-loads of mined earth (Faust 1955, 1967; George 2001, 2005; Hill and De Paepe 1979). A more elaborate system at Sauta Cave, Alabama, mined throughout the 19th century, consisted of a tram on which mule-drawn carts hauled sediment to the cave entrance (Faust 1955; Smith 1983).

In order to process the sediments, it was necessary to have a sufficient supply of water. Where possible, leaching vats were constructed adjacent to a water source, allowing workers to transport buckets of water for the processing needs; for example, Faust (1967: 32) reports that at Meredith Cave, Tennessee, vats were located by a creek some distance outside the cave. Subterranean streams or rivers also supplied fresh water, as in Buchanan Cave, Virginia (Faust 1955: 32). At a number of sites, vats were built well within the cave in proximity to the sediment deposits, despite the lack of a sufficient supply of water; at such operations, it was more efficient to convey water to the sediment deposits rather than moving sediments to an outside water source. Thus, a water conduit system had to be constructed. One such system at Sauta Cave used wooden troughs to convey water from a spring located a quarter mile above the cave entrance (Smith 1983: 301). The larger-scale operations of Great Saltpetre (George 2001), Mammoth (Borreson 1942; De Paepe 1979, 1985; Faust 1967), and Big Bone (Matthews 1967) caves employed an elaborate system of wooden water pipes. These installations consisted of two pipelines, one to supply fresh water to the leaching vats within the cave and another to convey the resulting leachate to boiling kettles, which were typically located near the cave entrance (Faust 1967: 42; George 2001: 50). The flow of water or leachate was forced either by gravity, or, as was the case at Great Saltpetre (George 2001: 47-50) and Mammoth (Borreson 1942: 11-13; De Paepe 1979: 12-14, 1985: 15; Faust 1967: 33, 52), by a series of hand-powered, hydraulic pump stations. Portions of these pipe lines still remain at Mammoth and Big Bone and were constructed in a manner similar to the following description (Faust 1967: 38 - 42):

1. “Straight-grained” logs “about 6 to 9 inches in diameter” were selected.
2. A machine auger was used to “bore a hole about three inches in diameter…from end to end along [the log’s] longitudinal axis…”
3. In order to “join the conduits end-to-end and thus form a continuous pipe line….one end of the bored conduit was beveled like the wood in a pencil point and the opposite end of the conduit was beveled in the opposite direction or from the bore outwardly.”
4. A ring of wrought iron was then heat-fitted around the end of the outer joint log “to prevent any splitting which might result from driving the joint too tight or by water causing the wood to swell.”
5. The inter-fitting log joints were then driven together to form “a water tight spigot and socket type of joint.”

As previously discussed, to extract nitrates it was necessary to lixiviate the cave sediment within leaching vats (also referred to as “hoppers”). Although several vat types were employed throughout the saltpeter industry, the V-shaped and the square-type (also referred to as box-style) forms were the most common. Examples of both are shown in Figures 1 and 2. While the manner of their

Figure 1. Example of a V-shaped vat type in Calfkiller Saltpeter Cave, Tennessee (Matthews 1971: 6).

Figure 2. Example of a square-type vat in Big Bone Cave, Tennessee (Matthews 1971: 4.)

construction certainly varied among sites, Faust (1955: 14-16; 1967: 48-49) provides the general methods used to make both the V-shaped and box-style types.

To construct the V-shaped vats, a rectangular log frame was first constructed. The frame base consisted of two squared logs that were placed on the ground parallel to one another. Holes were augured into the four outer ends of each of the squared base timbers and a log post was set erect into each of the holes. The frame's side timbers were then secured to each corner post by mortise and tenon (also called peg-and-hole) joints.

Next, a straight-grained log was split lengthways into halves. The halves were grooved along the center from end-to-end, forming a trough, and rested perpendicular atop the frame base timbers. A pillar of stacked rocks served as additional support underneath each grooved log. Wooden boards were then placed with their lower ends within the grooves of the trough while their upper ends were allowed to lean against the top rail of the rectangular frame. Thus, a V-shaped vat was formed with a drain at the bottom. A large wooden trough was usually placed adjacent to the vat frame to collect leachate from the log drains.

The frame for a box-style vat was constructed in a manner similar to that of the V-shaped type. However, they were generally much larger and thus able to hold several hundred cubic feet of sediment. To construct the floor of the vat, smaller logs were split into halves, hollowed into troughs, and laid across the bottom frame timbers, concave-side facing upward. A second layer of log troughs was then placed convex-side upward so that they would cover any space between logs in the lower layer. A mat of organic materials, such as twigs or cane, was placed in the bottom of the vats to prevent the leached sediment from clogging the lower layer drainage troughs. The saltpeter-bearing solution would then flow down the middle of the bottom layer of logs and into wooden collection troughs located beside each vat.

The final steps in the production of gunpowder-quality niter involved chemically converting cave saltpeter to potassium nitrate. Because the basic chemistry behind the conversion process has already been described, it will not be reiterated. Rather, the general equipment and procedures used to obtain the potassium nitrate will be discussed.

After the leachate was combined with wood ash (and the chemical conversion completed), the solution was boiled in a large iron kettle in order to evaporate the water and form potassium nitrate crystals (Faust 1955: 17; Rains 1862: 12-13). The crystals were then collected and subjected to further refinement. In 1862, Major George W. Rains, head of the Gunpowder Department of the Confederate States of America (C.S.A.), published detailed instructions on the manufacture of saltpeter, which provided a meticulous description of both the refining process and the equipment used:

> Weigh out two hundred and twenty-five pounds of Saltpetre and put it into the kettle or boiler, with sixteen gallons of water; light a fire under the kettle and let it boil—not too briskly, however—for about two and a half hours, removing the scum that rises to the surface, which should be thrown into an empty barrel. Cold water must be thrown in occasionally to keep the liquor to the same height in the kettle, for it must not be allowed to boil away. After the boiling is finished, allow the fire to die out, and dip out the liquor—not allowing it to cool—into the cloth on the top of the straining barrel, whence it is allowed to run

into the long cooling trough; here it is constantly agitated by raking it forwards and backwards by means of the wooden rake, until it has cooled down to about blood heat, which will take probably two hours or more. During the time of cooling, large quantities of fine needle-shaped crystals of nitre will form in the liquor, which are to be taken out by means of the long-handled spade, and thrown into the draining trough… (1862: 12).

> The crystals of nitre in the draining trough will now commence looking white as snow, and are to be left to drain until next day, when the nitre is removed to the washing barrel…(1862: 13).

> This barrel is then gently filled with cold water to the top, and allowed to remain one hour, when the plug is taken out, and the liquor which is nearly saturated with nitre—holding in solution all that remained of the mother liquor—is allowed to drain off onto the cask kept for that purpose. The nitre thus made is nearly pure, sufficiently so for nearly all purposes, and can be made into gunpowder (1862: 13).

However to make the highest quality gunpowder, Raines further advised:

> …the crystals must be TWICE WASHED [sic] before being taken from the washing barrel, cold water being poured in each time until the barrel is full, and after remaining one hour each time, is to be drawn off as before, and the nitre well drained and then dried; the crystals are now entirely pure and can be used for the best quality of gunpowder (1862: 13).

The Development of the Saltpeter Industry in the Southeast

Prior to the development of modern gunpowder manufacturing technologies in the early 20th century, the American colonies—and later, United States—relied heavily on the importation of saltpeter from British India. However, fluctuations in the overseas market, due in large part to European military campaigns and the often unstable relations among the United States and European powers, often interrupted the supply of imported saltpeter for munitions. Additionally, the onset of the U.S. Civil War also stressed the domestic saltpeter supply, especially in the Confederate States. Sustainable American domestic production of saltpeter therefore became essential. Because large quantities of saltpeter often naturally occur in caves, these subterranean locales became invaluable to the domestic munitions industry. Thus, the numerous limestone caves throughout the southeastern United States played a brief but significant role in both the country's military history and its early industrial development.

While saltpeter mining in American caves began in Virginia in the mid-18th century, it was the rising demand (and price) for the commodity during the American Revolution that led to the emergence of the widespread, if fragmented, mining and processing industry. The subsequent large-scale saltpeter industry clustered in three periods: during the American Revolution, from the early 1790s to the end of the War of 1812, and from the mid-1850s through the Civil War.

THE SEVENTEENTH AND EIGHTEENTH CENTURIES

ca. AD 1600 - The Revolutionary War (ca. AD 1775)

Prior to the 18th century, niter production within the American colonies was primarily a cottage industry, with individual households using saltpeter for food preservation, medicinal use, and small-scale gunpowder manufacture. Much of the saltpeter was procured from artificial niter beds or obtained from organic deposits beneath barns and outbuildings. Finding reliable domestic sources of saltpeter was evidently of interest in the American colonies, for in 1630 the colonial government of Virginia enacted a law to facilitate the production of saltpeter (Douglas 2001a:102; Faust 1964: 31-55; Hening 1823:151). However, no historical documents exist that indicate caves were mined for nitrates at this time.

The Revolutionary War (ca AD 1775-1783)

By the late 18th century, mounting hostilities with England bolstered American colonial efforts to secure more substantial sources of saltpeter for gunpowder manufacture. Though it is unclear exactly when and where caves were first exploited for saltpeter, the colonists were apparently aware of these extensive underground deposits as several Virginia caves are believed to have been mined at this time (De Paepe and Hill 1981; Faust 1964; Hovey 1897; Powers 1981).

The development of the domestic saltpeter industry was further stimulated when in 1774 England halted the exportation of black powder to the American colonies (Douglas 2001a: 105; Wilkinson 1966: 10). The following year, the Continental Congress formed a special committee to facilitate the recovery and proliferation of saltpeter (Faust 1964: 33-35; U.S. Government Printing Office 1906:2: 85). Consequently, a concerted effort was made to find and map suitable saltpeter caves. Such notable figures as James Madison and Thomas Jefferson were involved in the discovery and subsequent survey of saltpeter caves (De Paepe and Hill 1981: 89; Douglas 2001a:106). Although the majority of these Revolutionary War-era mining operations appear to have been concentrated in Virginia, there is some evidence that a fragmentary industry was in place in caves elsewhere, such as Kentucky and Tennessee (Douglas 2001a; Hovey 1897; Faust 1964; Powers 1981; Smith 1990).

Demand for the domestic production of saltpeter declined with the conclusion of the Revolutionary War, and importation of cheap, high-quality saltpeter from British India resumed. Despite a decrease in the number of large-scale operations, saltpeter mining in American caves continued. In the late 18th century, westward movement across the Appalachian frontier by early settlers created a continuous need for reliable, local sources of niter. Essential for both hunting and protection, black powder would have been a critical substance. It was during this time that two of the most well known caves in Kentucky were discovered by white settlers—Great Saltpetre Cave, on Crooked Creek in present-day Rockcastle County (George 2001), and Mammoth Cave, located near the Green River in Edmonson County (De Paepe 1979, 1985; Faust 1967; George 2005). Throughout the War of 1812, both were mined extensively for saltpeter and would prove to be valuable commodities, helping to bolster industry throughout the region.

THE NINETEENTH CENTURY

The War of 1812 (ca. AD 1812-1815)

The beginning of the 19th century saw an increase in the number of large-scale saltpeter mining operations in American caves. The ongoing Napoleonic Wars (ca. 1799 -1815) along with the prospect of a second war with Great Britain meant a reduction and eventual cessation of imported European saltpeter to the

United States. The heightened demand for gunpowder caused a dramatic rise in the price of saltpeter: “The 1810 market price of 17 cents /lb for crude saltpeter, or ‘rough shot-petre’ as it was called, increased to 75 cents to $1.00/lb during the war years” (De Paepe and Hill 1981: 90). As a result, numerous caves in the Midwest and Southeast karst regions of Missouri, Indiana, Virginia, Kentucky, Georgia, Tennessee, and Alabama were explored and developed (Douglas 2001a: 121).

Throughout the War of 1812, two of Kentucky’s saltpeter caves, Great Saltpetre (George 2001) and Mammoth (De Paepe 1979, 1985; Faust 1967, George 2005) became the country’s largest and most profitable manufacturers of saltpeter, making them indispensable to the war effort. Big Bone Cave in present-day Van Buren County, Tennessee was also a substantial producer (Bayless 1982; Maddox 1813, 1821; Smith 1985); An early 19th century account (Maddox 1821) of the Big Bone Cave mining operations states that close to 2,000,000 lbs. of saltpeter was produced between ca. 1811-1815. Col. Randolph Ross, who purchased the cave sometime between the years 1814 – 1817 (Maddox 1821; Smith 1985), fulfilled “…a contract for powder with [the] government during the late war…” that resulted in an estimated profit of $45,000 (Maddox 1821). Of the Alabama caves mined at the time, Sauta Cave, in Jackson County, was the largest producer of saltpeter and thus was an invaluable asset of the U.S. military (Sheridan 1980; Smith 1981; 1983). Concerning the Sauta Cave operations, Sheridan (1980: 26) remarks, “The saltpetre from [the cave] probably helped provide the gunpowder for General

Andrew Jackson's troops against the Creek Indians, and perhaps some was also used in the battle of New Orleans."

After 1815, the price and demand for domestic saltpeter declined and the large-scale, commercial operations at caves such as Great Saltpetre (George 2001), Mammoth (George 1988), Sauta (Sheridan 1980; Smith 1981; 1983), and likely, Big Bone ceased. However, small-scale, cottage industries elsewhere in American caves continued to provide saltpeter for localized use and supplemental income (De Paepe and Hill 1981: 90; O'Dell 1995: 84).

The Civil War (ca. AD 1861-1865)

During the Civil War, Union blockades of Southern ports forced the Confederacy to place heavy priority on developing its many saltpeter caves (De Paepe and Hill 1981; Lynne 1984; Powers 1981; Sheridan 1980; Smith 1981, 1989, 1990, 1997). Although the caves of Kentucky and Virginia had been major producers of saltpeter during previous conflicts, due to their location they were not significant suppliers to the Confederate war efforts. It was the saltpeter mining operations in the caves of Tennessee (Smith 1989, 1997), Alabama (Sheridan 1980; Smith 1983), Arkansas (Johnston 1990; Rains 1882), Georgia (Rains 1882), and Texas (Rains 1882) that became increasingly important. To ensure an adequate supply of gunpowder, in April of 1862, the Confederate Congress formed the C.S.A. Nitre and Mining Bureau (Lynch 1984; Powers 1981; Smith 1987; 1989). Under the direction of Major Isaac M. St. John, "…the Confederacy was divided into districts with a superintendent for each. A plan was devised whereby new saltpeter caves would be hunted, private enterprise would be stimulated by circulars and newspapers and 'when advisable,' to start working private caves on 'Government account' (Smith 1990: 12). Among the most significant sources of saltpeter for the Confederacy were Sauta Cave (Sheridan 1980; Smith 1981, 1983), Big Bone Cave (Bayless 1982; Smith 1985), and Nickajack Cave (Smith 1989), located near Chattanooga in Marion County, Tennessee. By the close of the Civil War, in Tennessee alone, some 250 caves, and an unknown number of rockshelters, were mined for saltpeter during the course of the 19^{th} century (Plemons 1995).

The end of the Civil War also marked the end of the active saltpeter mining era; increasing innovations in gunpowder technology and the cheap overseas niter market lessened the need for domestic saltpeter production. A remnant industry continued post-Civil War, but it soon altogether disappeared. During World War I, Thomas L. Bailey, a geologist for the State of Tennessee, collected sediment samples from caves throughout Middle Tennessee "to determine the value of these caves as possible sources of niter" (1918: 2). However, Bailey concluded that none of these caves contained a significant enough quantity of nitrates to compete with Chilean nitrate deposits or the developing nitrogen fixation technologies.

Summary of Previous Archaeological Research on Saltpeter Mining

The remainder of this chapter provides a summary of previous archaeological research on saltpeter mining. Systematic archaeological investigations of the saltpeter industry have been minimal, as the majority of southeastern cave archaeology has focused on pre-Columbian cave use. The few studies undertaken have been focused primarily in Kentucky and thus provide data concerning site-specific and localized saltpeter mining. Nonetheless, they serve to illustrate both the similarities and differences that existed throughout the industry as a whole.

ROCKSHELTER SITES

Saltpeter Mining in the Big South Fork Area of the Upper Cumberland Plateau

In the Upper Cumberland Plateau (UCP) region of Tennessee and Kentucky, Tom Des Jean (1997) examined saltpeter mining at rockshelter sites within the Big South Fork drainage of the Cumberland River. According to Des Jean (1997: 227), rockshelter mining began on the UCP in the late 18th century when pioneer settlers of the region began making gunpowder for personal use. Increasing demand (and price) of saltpeter through the War of 1812 (ca. 1810-1820) and later, the Civil War (ca. 1861-1865) stimulated niter mining throughout the UCP (as was the case for most of the region). As a result, numerous rockshelters were mined for nitrates. However, the size of these operations was never comparable to the large-scale saltpeter industry within the area's caves (Coy et al. 1984; Des Jean 1997; Fig and Knudson 1984).

Unlike cave saltpeter, comprised of calcium nitrate, saltpeter mined from the sandstone overhangs and cliff walls of the Big South Fork area occurs primarily as potassium nitrate. Therefore the conversion step required in cave saltpeter production was not necessary at such sites. Des Jean (1997: 228) notes that sediments found in the Pennsylvanian-age sandstone shelters of the UCP generally contain higher concentrations of nitrate and lesser impurities than cave sediments. He cites Dr. Samuel Brown's early 19th century reference to this in which Brown states, "Most of our saltpetre-makers find it in their interest to work the sand rock rather that the calcacreous [sic] caverns, which yield a mixture of nitrate of pot-ash and nitrate of lime. The rock saltpetre is greatly preferred by our merchants and powdermakers and commands a higher price" (Des Jean 1997: 290; Maxson 1932: 1854). Brown, a noted Kentucky medical practitioner and professor at Transylvania University in Lexington, was instrumental to the improvement of niter operations at Great Saltpetre Cave and was considered an expert in the manufacture of saltpeter (George 2001).

Archaeological surveys (Ferguson et al. 1986; Funkhouser and Webb 1935; Wilson and Finch 1980) conducted on the UCP and Big South Fork areas have identified numerous large rockshelters mined for saltpeter (Des Jean 1997: 230). The majority of mined rockshelters face to the east; a characteristic that was noted by Dr. Samuel Brown (Des Jean 1997: 230; Maxson 1932: 1854) when he stated that miners "…never saw a rock facing south or west, which was rich in niter." Signal features at these sites include "large amounts of broken down roof fall and boulders, piles of cobbles, drill marks, large or deep piles of sand, and occasionally, hand-adzed troughs and leaching vats" (Des Jean 1997: 230).

Leaching vats found in the area of the Big South Fork are what Des Jean (1997: 232-233) and Fig and Knudson (1984: 69-70) refer to as "Type 3 Hoppers." "The Type 3 Hopper is constructed of slabs of bark or hand-adzed wooden side boards, pinned together with poles and held in place by 'yokes'" (Des Jean 1997: 233-234). This vat was designed to be portable and was easily dismantled for mobility. Therefore, they are rarely found intact at rockshelter sites.

Des Jean (1997: 234) argues that continued use of this vat type during the two main periods of rockshelter mining and niter production, the War of 1812 and the Civil War, "attest to little change in the technology used to exploit these resources in the 60 year period of production." Furthermore, the "…distribution and numbers of mined-out rockshelters attest to a reliance on many sites rather than an intensity of effort at few sites during these cycles of production" (Des Jean 1997: 234).

Niter mining in the in the Big South Fork area appears to have been primarily a cottage industry, as the particular type of leaching vats used were well suited for small-scale saltpeter production by local farmers (Des Jean 1997: 234). Thus, similar to some of the cave operations, much of the rockshelter mining may have been seasonal or semi-contractual (Des Jean 1997: 228; O'Dell 1995: 84-85). Additionally, deficient transportation routes on the Upper Cumberland Plateau throughout much of the 19th century coupled with Confederate and later, Federal, military control over the area during the Civil War likely prohibited development of a larger-scale industry (Des Jean 1997: 234). As was the case throughout much of the Plateau region, small-scale saltpeter mining and production ceased in the area by 1880, when high-quality commercial gunpowder again became affordable (Des Jean 1997: 228).

Saltpeter Mining in the Red River Gorge Area of Eastern Kentucky

Coy et al. (1984) and Fig and Knudson (1984) conducted research on niter mining in the Red River Gorge area of eastern Kentucky. Comparable to the industry in the Big South Fork region (Des Jean 1997), the many sandstone rockshelters of the Red River Gorge were mined during the 19th century for potassium nitrate.

According to Coy et al. (1984: 54-56), the saltpeter-bearing rock that was mined extensively in this region is the Pennsylvanian-age Corbin Sandstone Member, the uppermost sandstone unit of the Lee Formation. This geologic unit is comprised of very fine- to medium-grained sandstone with zones of quartz pebbles. Also similar to saltpeter mining in the Big South Fork (Des Jean 1997), the majority of mined rockshelter sites in the Red River drainage basin face to the east and southeast; such sites tend to be drier and thus more suitable for saltpeter solution and deposition. Coy et al. (1984: 57) attribute this phenomenon to prevailing westerly winds in east-central Kentucky, from which the east and southeast-facing shelters are less exposed. Fig and Knudson (1984: 72) refer to this, stating that saltpeter miners "…discovered that sand and broken rubble within rockshelters protected from the weather would yield niter in paying quantities." A common method used to confirm the presence of potassium nitrate "…involved placing a shallow impression of the hand or foot on a flat surface of the loose soil [sediment]. If the soil [sediment] was rich in nitrate, the impression would disappear in a few hours. If small amounts of nitrate existed, the impression would remain a day or more" (Fig and Knudson 1984: 72).

As a result of their survey work in the Red River Gorge region, Fig and Knudson (1984: 68-71) were able to identify three distinct types of leaching vats used in rockshelter mining:

> (1) Type 1: Simply constructed of small poles supported by forked uprights, the resulting rough square was lined with heavy pieces of bark (usually hemlock) forming an apex as a 'V' along the bottom just above a half-log trough (Figure 3).
>
> (2) Type 2: The hopper was constructed in the general form of a 'V' by using a framework of bored logs to support the sloping sides of usually 'rived' (hand-hewn squared-up) boards. The boards terminated into a hollowed out half-log which acted as a gutter to carry off the liquid into a trough (Figure 4).
>
> (3) Type 3: Constructed of large hand-hewn single boards which formed the sides and were held in place by a removable interlocking brace. The sides were only slightly sloping inward. Smaller boards placed upright on each end of the structure behind the cross-brace formed the ends. The entire structure was built directly over the collection trough which was placed in position first (Figure 5).

Local informants provided Fig and Knudson (1984: 71) with insight into the construction design of the Type 3 vat: "According to some 'old timers' the entire system was portable and many have been dismantled and moved to other

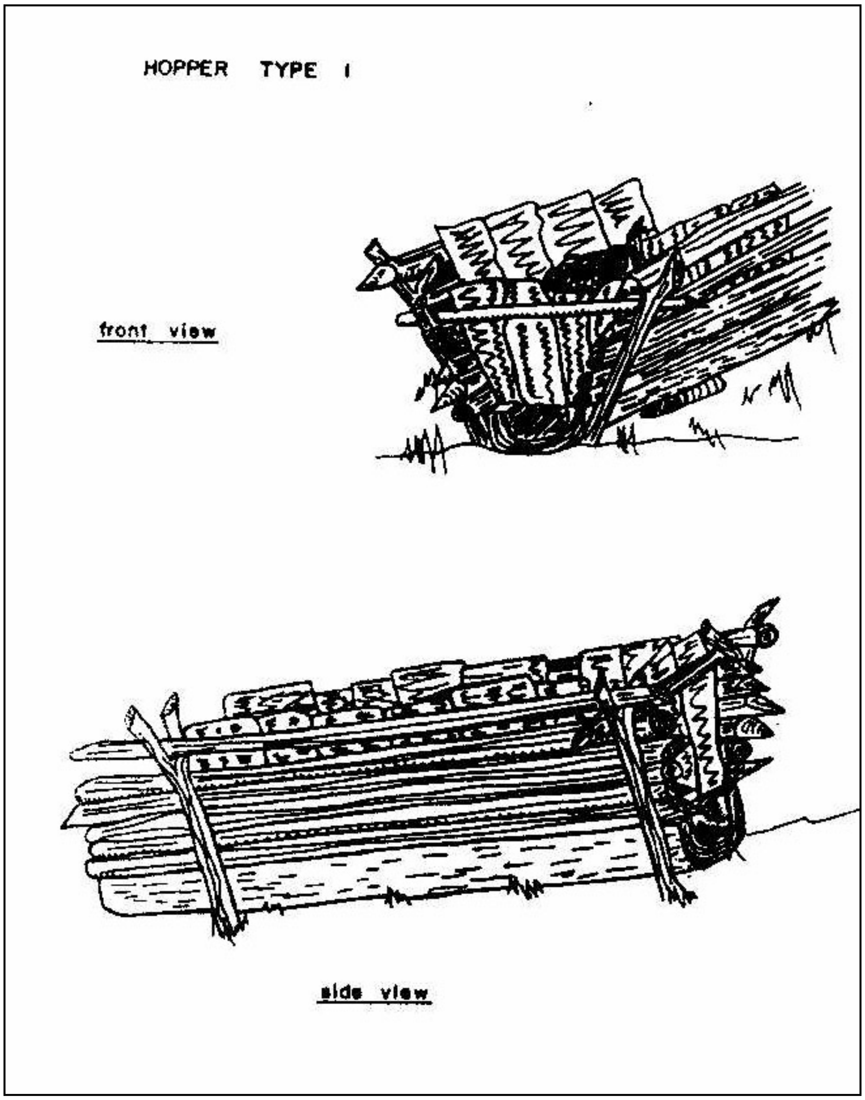

Figure 3. Fig and Knudson's (1984: 69) illustration of a Type 1 vat from the Red River Gorge Region, Kentucky.

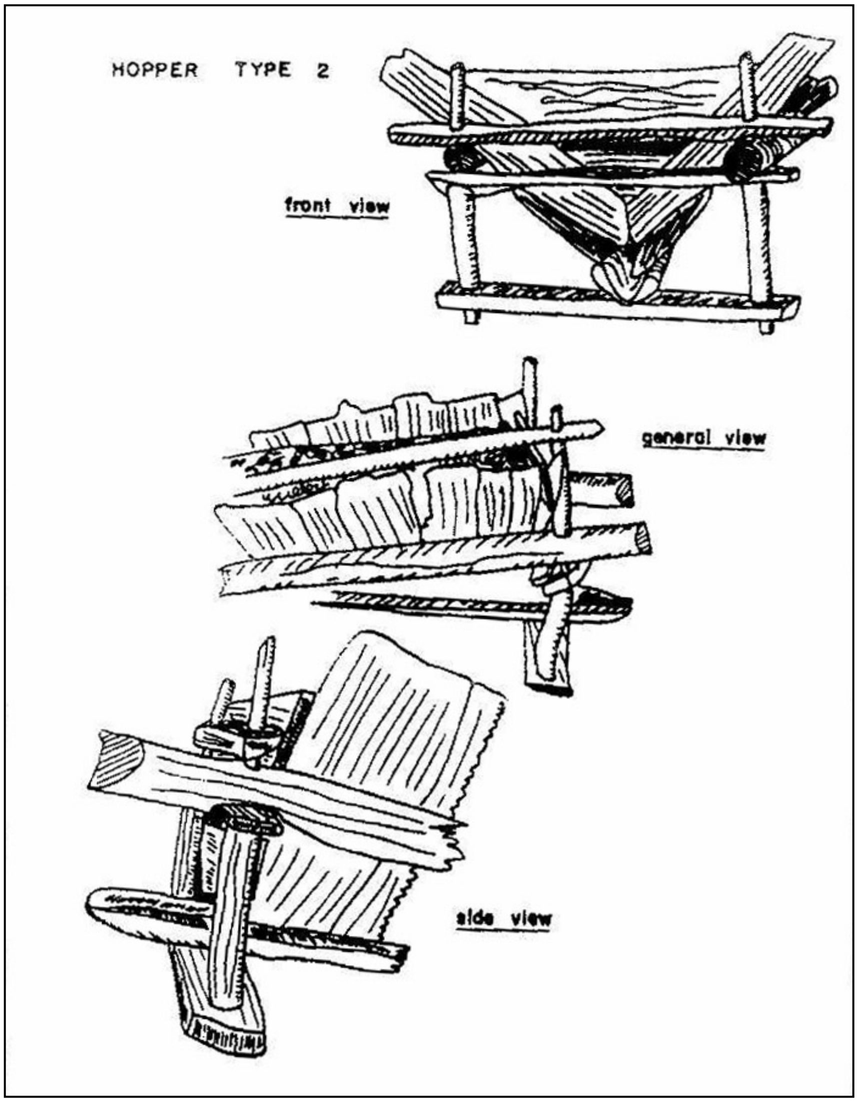

Figure 4. Fig and Knudson's (1984: 70) illustration of a Type 2 vat from the Red River Gorge Region, Kentucky.

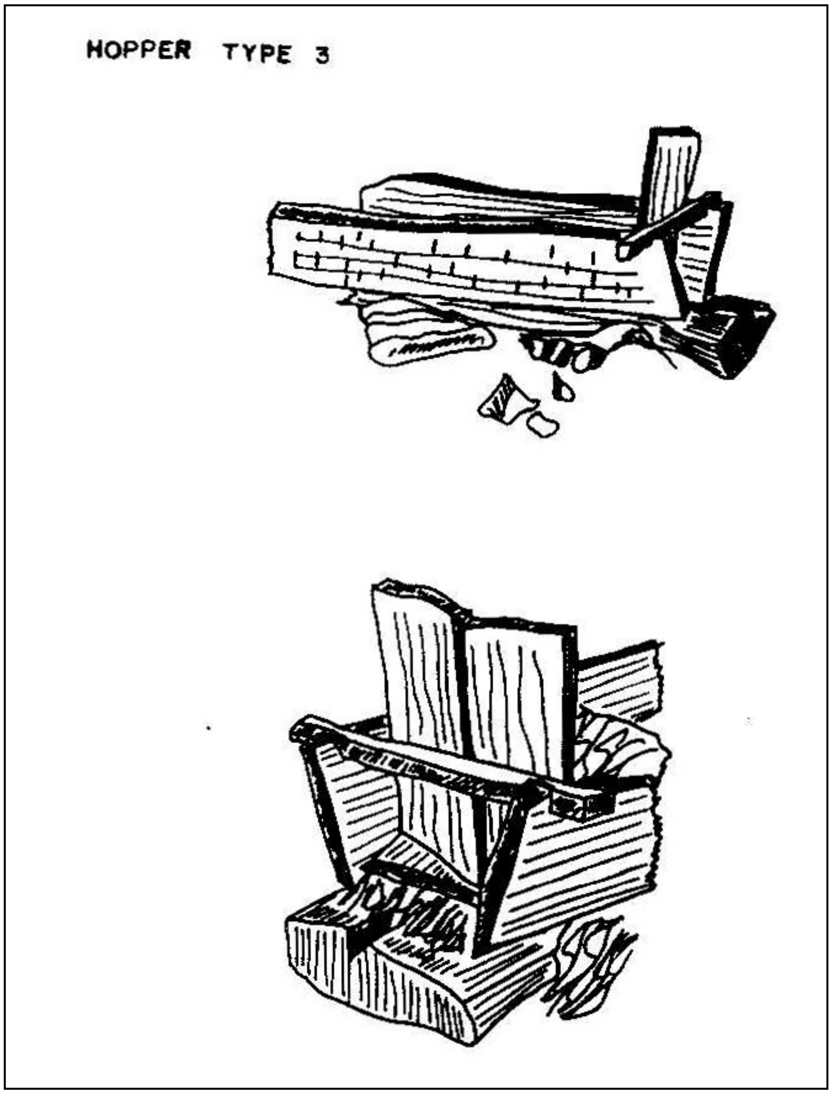

Figure 5. Fig and Knudson's (1984: 71) illustration of a Type 3 vat from the Red River Gorge Region, Kentucky.

locations. This would have eliminated the construction of new hoppers and troughs when one was worked out and another started."

In an attempt to address the chronological aspects of rockshelter mining in the Red River Gorge region, Coy et al. (1984) submitted wood samples removed from preserved saltpeter artifacts to the University of Arizona for dendrochronological dating. C.W. Estes at the University of Arizona compared tree-ring sequences obtained from a preserved trough to five known white oak chronologies from the region. Estes "…found fairly good agreement of the narrow rings that would indicate the cutting date to be somewhere in the early 1800s, probably between 1806 and 1809" (Coy et al. 1984: 58). Attempts to date additional artifacts using dendrochronology were apparently unsuccessful (Fig and Knudson 1984: 73). A date of 1818 inscribed on a rock at one mined rockshelter also provides some information concerning the chronology of saltpeter mining in this region (Coy et al. 1984: 58).

The focus of both Coy et al. (1984) and Fig and Knudson's (1984) historical research is the early period of rockshelter mining in the Red River Gorge Region, just prior to and during the War of 1812. If evidence exists for Civil War-era rockshelter mining in this area it is not discussed in detail. This may simply be due to a lack of historical documentation from this period. It is certainly possible that many of the rockshelters throughout the Red River Gorge drainage were exploited for nitrates during the War Between the States, as was the case throughout much of the Cumberland Plateau region. Fig and Knudson state, “The shelters of the Red River gorge were ideal because of the area’s remoteness and isolation; they could easily be worked without attracting the attention of either army [both Confederate and Federal]” (1984: 68).

CAVE SITES

Mammoth Cave, Kentucky

During the early part of the 19th century, Mammoth Cave, Kentucky was one the largest producers of saltpeter in the Midsouth (De Paepe 1979, 1985; Faust 1967; George 2005). As early as 1816, shortly after the mining operations ceased, Mammoth Cave became the second American tourist cave (George 2005: 181). Today it is the most well-known and researched saltpeter mining site in the United States. Previous research (Borreson 1942; Faust 1967) on the Mammoth Cave operations has been seminal to our understanding of 19th century saltpeter processing techniques. As a result, Mammoth Cave has served as the model for reconstructing mining operations at other, less-preserved large-scale sites, such as Great Saltpetre Cave, Kentucky (George 2001). However, because of the abundance of literature concerning the Mammoth Cave saltpeter works, previous archaeological investigations of the site will only be discussed briefly here.

Scientific inquiry into Mammoth Cave began as early as 1882, when Horace C. Hovey visited the cave and speculated on the saltpeter manufacturing operations (George 2005: 77; Hovey 1882: 57). Interest in reconstructing the saltpeter works took place shortly after 1888, when Henry C. Ganter leased the cave and began making improvements to the public tour routes (Ganter and Darnell 1889a, 1889b; George 2005).

In 1942, Thor Borreson conducted the first archaeological investigations at Mammoth Cave. According to Borreson (1942: 1), "[t]he purpose of this examination was to expose sections of the old saltpeter vats covered with earth so that a thorough study could be made of the vats and other remnants relating to them and the saltpeter works in general." Borreson's (1942) survey and excavations identified the remains of nine leaching vats, three in the Rotunda room and six in the room known as Booth's Amphitheater. Based on his observations, Borreson (1942: 4-5) was the first to propose and draft details on the construction of the vat types (V-shaped and large, rectangular or box-style) used at Mammoth Cave. Additionally, he made several interpretations of the water pipe and hydraulic pumping system, of which little remained at the time of his study (Borreson 1942: 11-14). Borreson's fieldwork would provide the basis for much of the subsequent research (i.e., Faust [1967], De Paepe [1985], Mullin [1986], George [2005]) regarding the engineering details of the leaching vats and water transport installation in the cave (George 2005: 77).

De Paepe (1979, 1985) conducted a survey of Mammoth Cave to locate sites that were mined for saltpeter (Figure 6). Prior to his fieldwork, little was known of the spatial extent of niter mining sites in Mammoth Cave. The significance of this study was explained by De Paepe (1979: 19-21) in his final report:

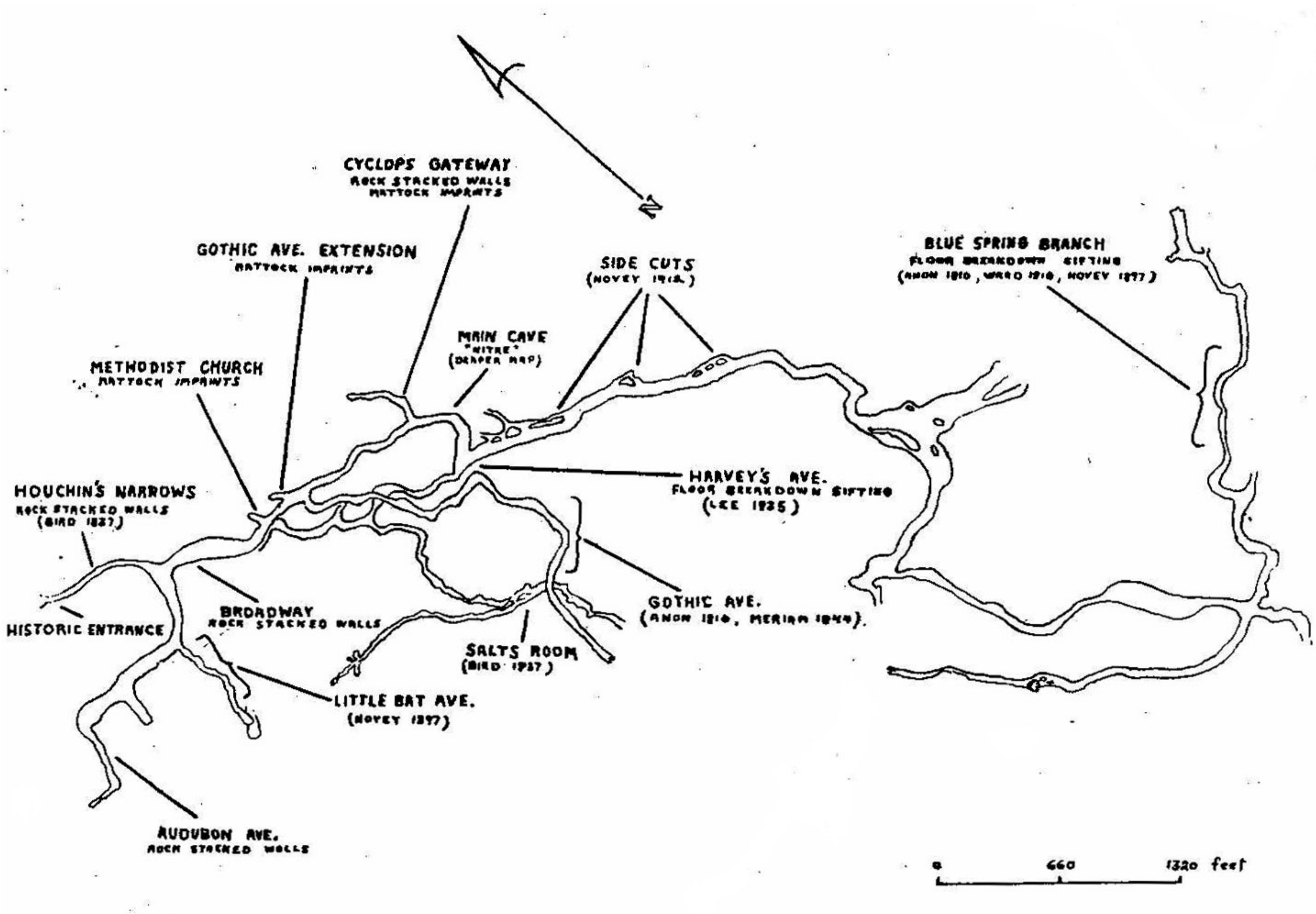

Figure 6. Sites mined for saltpeter within Mammoth Cave (De Paepe 1979: 23).

> A composite picture of the mining activity has now emerged as a result of extensive primary literature research and detailed field reconnaissance. These field observations continue in Mammoth and other park area caves to distinguish circa 1812 nitrate mining sites from prehistoric and later period excavations, which have continued into present times. It is expected that these studies will lead to a saltpetre mining features taxonomy, which will help to distinguish these subtle features from other types of cultural disturbance in cavern sediments.

De Paepe identified mining sites by defining certain diagnostic features, including the presence of stacked rock "walls" and preserved tool marks in sediment. Areas of Mammoth Cave that he (1979: 20, 1985: 12) found to exhibit the former of these features include Houchin's Narrows (the main entry passage to the cave), Cyclops Gateway, Broadway, and Audobon Avenue. De Paepe also identified another diagnostic saltpeter-mining feature at the site, "…a shallow pit ringed with the accumulated debris…[from] the on-site hand sorting of loose rock fragments from the dry 'petre-dirt'" (1979: 20). Harvey's Avenue and Blue Springs Branch of Mammoth Cave were found to contain this type of evidence, along with several other saltpeter caves in the area (1979: 20). Not surprisingly, De Paepe found the most important mining sites in Mammoth Cave to be located near the leaching vats and along the ox-cart trail (1979: 21, 1985: 13). These areas, Methodist Church, the Gothic Avenue, and Cyclops Gateway, exhibit numerous tool marks. According to De Paepe (1979: 23) the highest concentrations of nitrate were found in the top layers of sediment, which was scraped with an "iron hoe-like" (mattock) tool. Based on this observation, he proposed that "[t]he tool imprints from many nitre caves suggest that the miner's mattock was made especially for his work as the blade had a distinctive curved

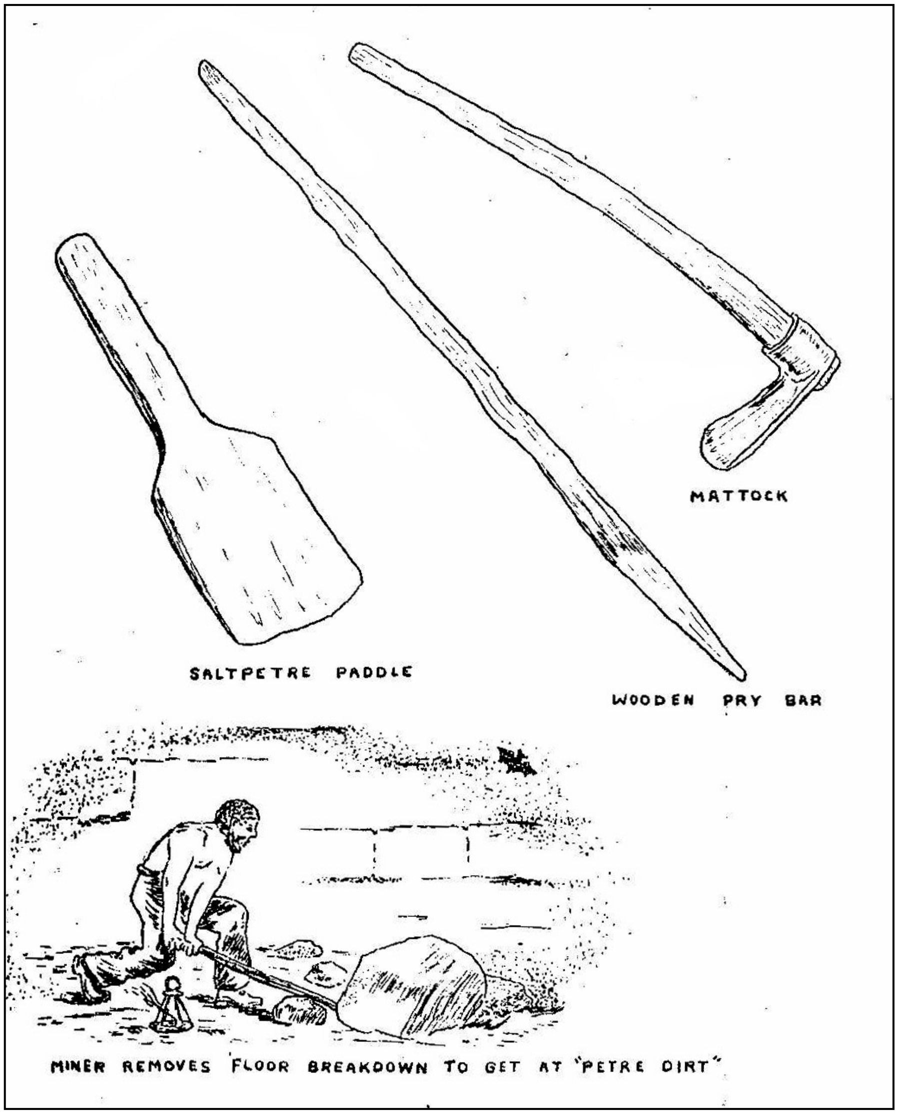

Figure 7. De Paepe's (1979: 24) illustration of saltpeter mining tools.

bit and was narrower than conventional mattocks. The mattock was used to break up the compacted nitrate…and a wooden paddle was used for further digging and scraping "(De Paepe 1979: 23) (Figure 7).

As part of the Historic American Engineering Record [HAER], Mullin (1986) synthesized the aforementioned research of Borreson (1942), De Paepe (1979, 1985), and Faust (1967), and drafted outstanding engineering-architectural drawings of the leaching vats and hydraulic pumping system in Mammoth Cave. Examples of her work are shown in figure 8 and 9.

In summary the pioneering research at Mammoth Cave has contributed greatly to the archaeology of saltpeter mining. Hovey (1887) and Ganter (Ganter and Darnell 1889a, 1889b) were among the first to recognize the significance of this industry. Later, Borreson (1942) conducted the first systematic investigations of a saltpeter-mining site and, in addition, made the first recommendations for the management and preservation of these types of remains. De Paepe (1979, 1985) defined diagnostic features of specific saltpeter mining activities, while Mullin's (1986) architectural and engineering study of Mammoth Cave proved to be an invaluable contribution to the present understanding of the mining operations (George 2005: 77). In regards to the work of Borreson and Mullin, George (2005: 77) states that although their work was never published, "it was used internally within the National Park Service to manage and interpret the artifacts and as a result became one of the cornerstones in the interpretation of Mammoth Cave history." At present, cave

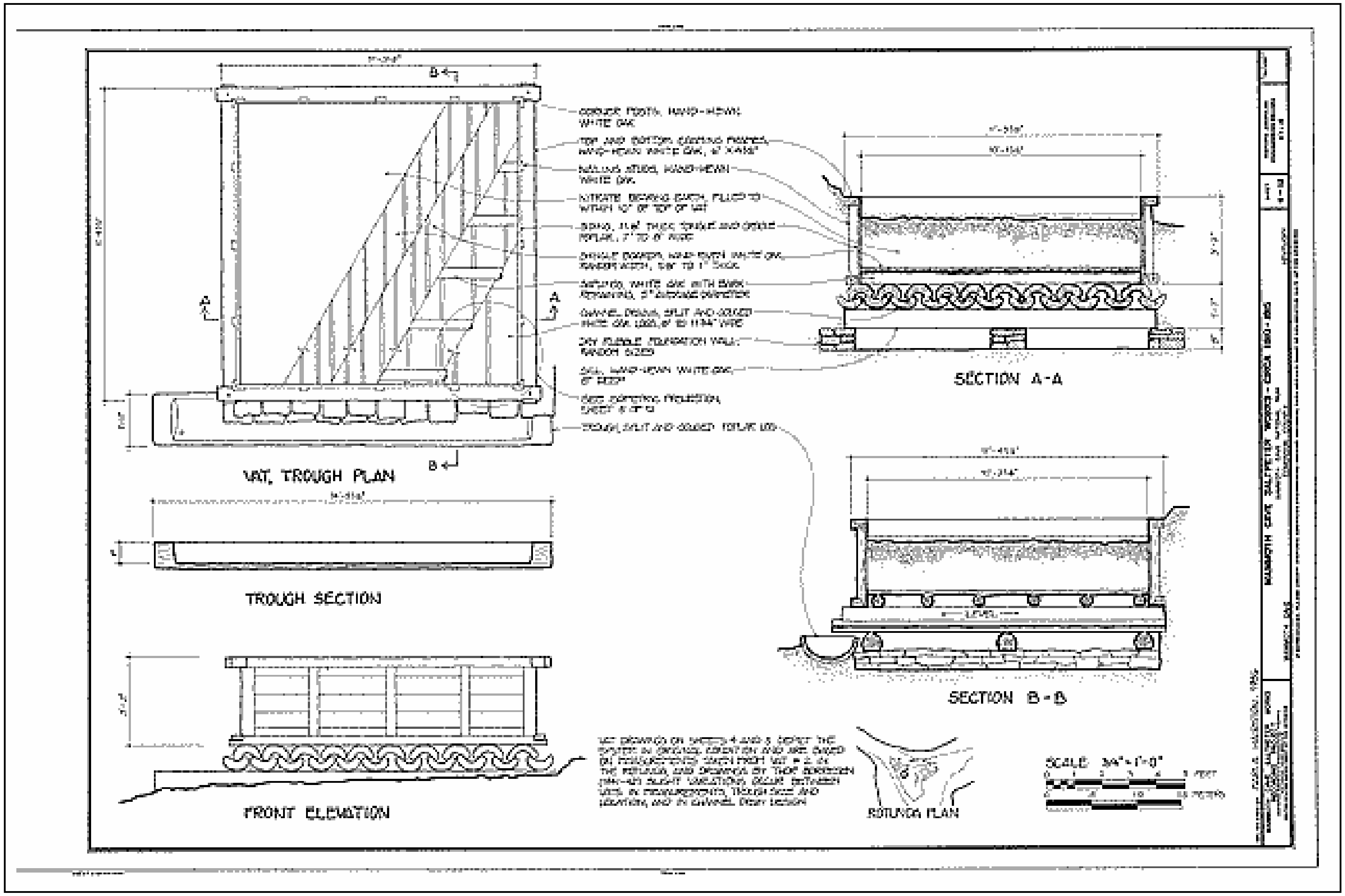

Figure 8. Example of Mullin's (1986) architectural drawings of the Mammoth Cave saltpeter vats. (Library of Congress, Historic American Engineering Record [HAER], HAER KY-18, 31-MAMCA, 4-12. <http://memory.loc.gov/cgi-bin/query/r?ammem/hh:@FIELD(DOCID+@BAND(@lit(KY0272)))>).

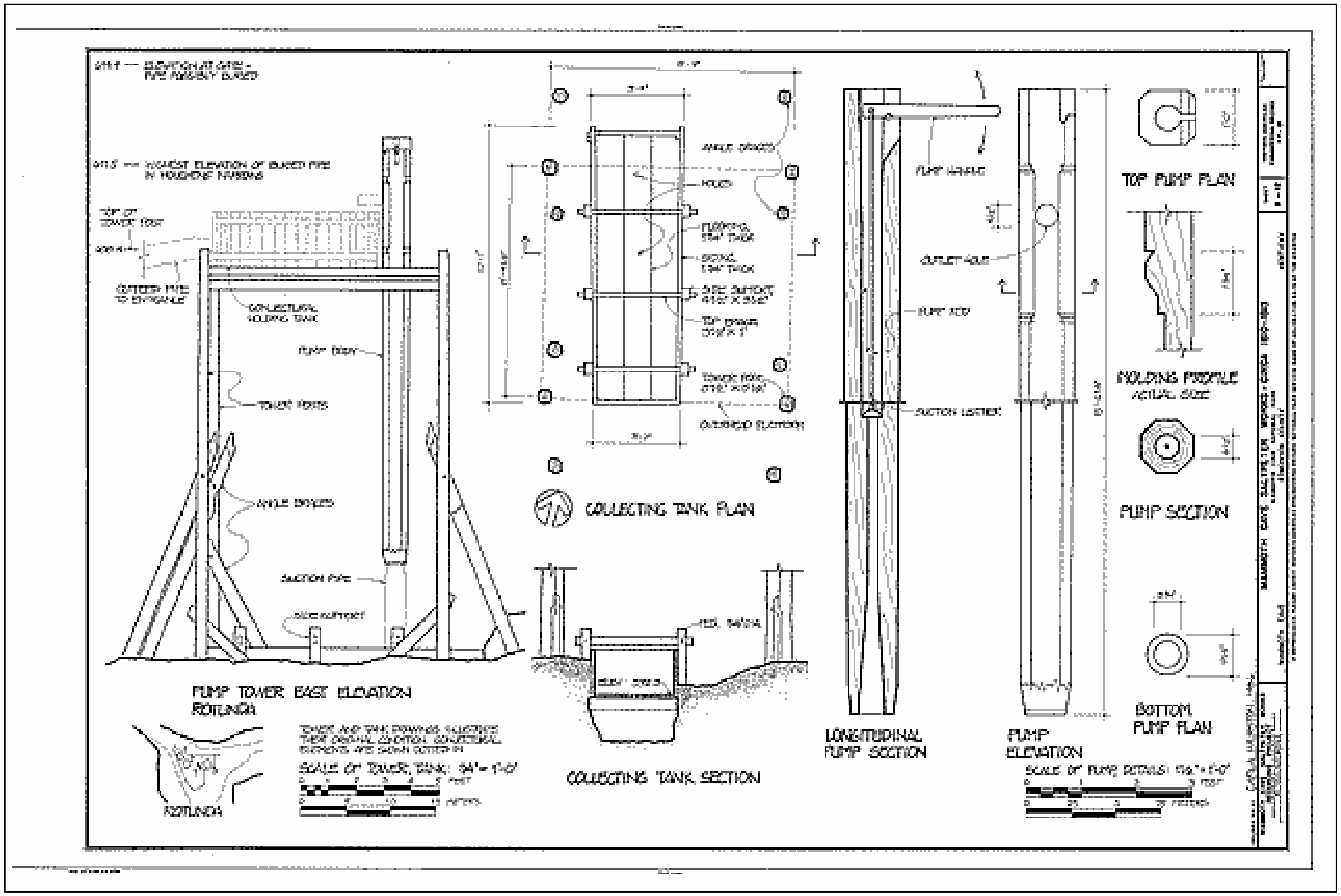

Figure 9. Example of Mullin's (1986) architectural drawings of the Mammoth Cave hydraulic pumping system. (Library of Congress, Historic American Engineering Record [HAER], HAER KY-18, 31-MAMCA, 9 -12. <http://memory.loc.gov/cgi-bin/query/r?ammem/hh:@FIELD(DOCID+@BAND(@lit(KY0272)))>).

historians including George (2005) continue to conduct research on the Mammoth cave saltpeter operations.

Saltpeter Cave (15Cr99), Kentucky

Duncan's (1993) master's thesis research was focused in Saltpeter Cave (15Cr99), in Carter Caves State Resort Park, Kentucky. Along with several other Kentucky caves, the site was a highly productive saltpeter operation during the early 19th century (Duncan 1993, 1995, 1997). Duncan's research involved a stylistic comparison among equipment types employed at Saltpeter Cave and those reported to have been in use at other War of 1812-era saltpeter mining sites, such as Mammoth and Great Saltpetre caves. Drawn from the extant literature, Duncan developed two production models of mining and processing techniques (1995: 55):

> The first, Type A, is a large-scale production system. Mammoth Cave is the most well-documented example of this type. The large-scale system used leaching vats, or hoppers, of the box type that held tons of dirt. A large number of people were employed in the operation, and a complex water-transport system was used. For example, at Mammoth Cave a pump tower and water pipes were constructed to move water from remote parts of the cave to the entrance where the hoppers were located.
>
> The second model, Type B, involved small, cottage-industry operations, such as would be typical in rockshelters. Usually these operations were located near a water source and used a V-vat type of hopper.

To determine "whether or not there was any standardization within the industry as a whole, or if other possibilities exist," her observations on the mining operations at Saltpeter Cave were compared to the two production models outlined above (1993: 3).

Duncan's study identified the remains of at least 26 leaching vats in Saltpeter Cave, 17 of which were concentrated in one room of the cave, designated the "First Room" (Duncan 1993, 1995). Test excavations conducted in this room focused on exposing cross-sections of four of the remaining vats in an attempt to glean information on their construction design. Based on observations from both the excavations and surface features, Duncan argued that the Saltpeter Cave leaching vats were not diagnostic Type A (box-style) or Type B (V-shaped) artifacts. Rather, they exhibited features of both (1997: 92):

> Like Type A vats, these contain sideboards that are horizontal, rather than like the vertical board-and-batten sides of Type B vats. Like Type B vats, the water trough is placed beneath the vats, and the Carter Caves hoppers have a slight V-shape. They have an average volume of approximately one cubic meter, closer in size to Type B vats than to Type A vats. However Type B operations generally seem to have used only one or two vats per site. The primary operation at Saltpeter Cave involved more than 25 vats. Three of these represent post-1814 mining episodes. The remainder of the existing observable vats, and others that the miners subsequently buried beneath spoil dirt piles, were most likely used in pairs.

The results of Duncan's case study indicate that the Saltpeter Cave operations do not conform to the previous models of small-scale (Type B) versus large-scale (Type A) niter production. As opposed to discrete types of saltpeter production and thus, discrete artifact types, there existed regional variation in production equipment throughout Kentucky's War of 1812-era industry. "There is no indication that this was a standardized or regulated industry; rather the entire industry seems to have been quite opportunistic in nature," states Duncan (1995:

63). "Individual producers had a general process for making saltpeter, a process for which tool types and styles varied" (Duncan 1995: 63).

SUMMARY

In summary, archaeological research conducted on saltpeter mining has almost entirely been focused in the Upper Cumberland Plateau region of Tennessee and Kentucky. These studies imply that the majority of saltpeter mining on the UCP took place during the early 19th century, when niter mining intensified prior to and during the War of 1812. This corresponds with historical research on Kentucky's saltpeter industry discussed in Chapter IV, which maintains that well-organized, large-scale operations were not in place in the state during the Civil War. Alternatively, small-scale, cottage-industry niter mining resumed at this time in response to lessening commercial saltpeter supplies.

Furthermore, these previous studies illustrate both the similarities and differences that existed throughout the 19th century saltpeter mining industry. As Duncan (1995: 63) concluded through her research at Saltpeter Cave, Kentucky, region-wide regulation or standardization in the mining operations does not appear to have existed. This also appears to have been the case in Tennessee. Matthews' (1971) survey of several Tennessee saltpeter cave sites identified four distinct types of leaching vats, including square (see Figure 2), V-shaped (see Figure 1), round (Figure 10) and notched-log square (Figure 11). However, similar to comparable sites in Kentucky, tool marks, tally marks, water pipe construction techniques, and the presence of stacked rock walkways and/or

Figure 10. Example of a round vat in Piper Cave, Tennessee (Matthews 1971: 8).

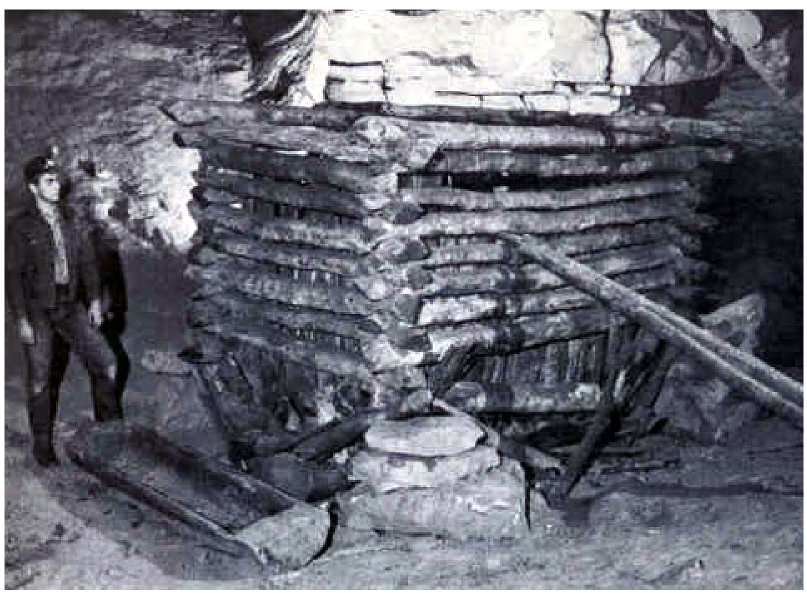

Figure 11. Example of a notched-log square vat in a middle Tennessee cave (Matthews 1971: 9).

“walls” are all common features (although among these variation does exist) (Matthews 1971: 3 -20). In comparison to Kentucky, archaeological research on saltpeter mining in Tennessee (as well as the majority of the southeastern states) is sparse. Crothers (1986, 1987) conducted an extensive survey of the archaeological remains in Big Bone Cave; however, he focused primarily on the prehistoric material. The present study of Cagle Saltpetre Cave is the first in-depth, systematic archaeological work in a saltpeter mining cave site in the state. These investigations are presented in the following chapters of this thesis.

CHAPTER IV
ENVIRONMENTAL SETTING

Site History

Cagle Saltpetre Cave was “officially” documented in 1974, when John and Jean Smyre surveyed the cave and reported it to the Tennessee Cave Survey (Figure 12). During this survey, the cavers identified the site as a historic saltpeter mine and reported numerous preserved remnants of the mining operations, including leaching vats, wooden troughs, “log pipes,” and other historic cultural remains. Prior to 2000 when Fall Creek Falls State Park purchased the site and the surrounding land, it had remained virtually unprotected (Stuart Carroll, personal communication).

Over the last several years the Cave Archaeology Research Team (CART) at the University of Tennessee has been surveying and recording archaeological sites associated with caves in the Cumberland Plateau region. Many caves in this area contain significant evidence of prehistoric occupation and historic industrial use, though a majority have not been formally documented or studied.

Fall Creek Falls State Park, located in the heart of the Cumberland Plateau, has been a focal point of this research over the past five years. With the assistance of a grant from the Tennessee Historical Commission, great strides have been made in the documentation of cultural resources within the Park. An

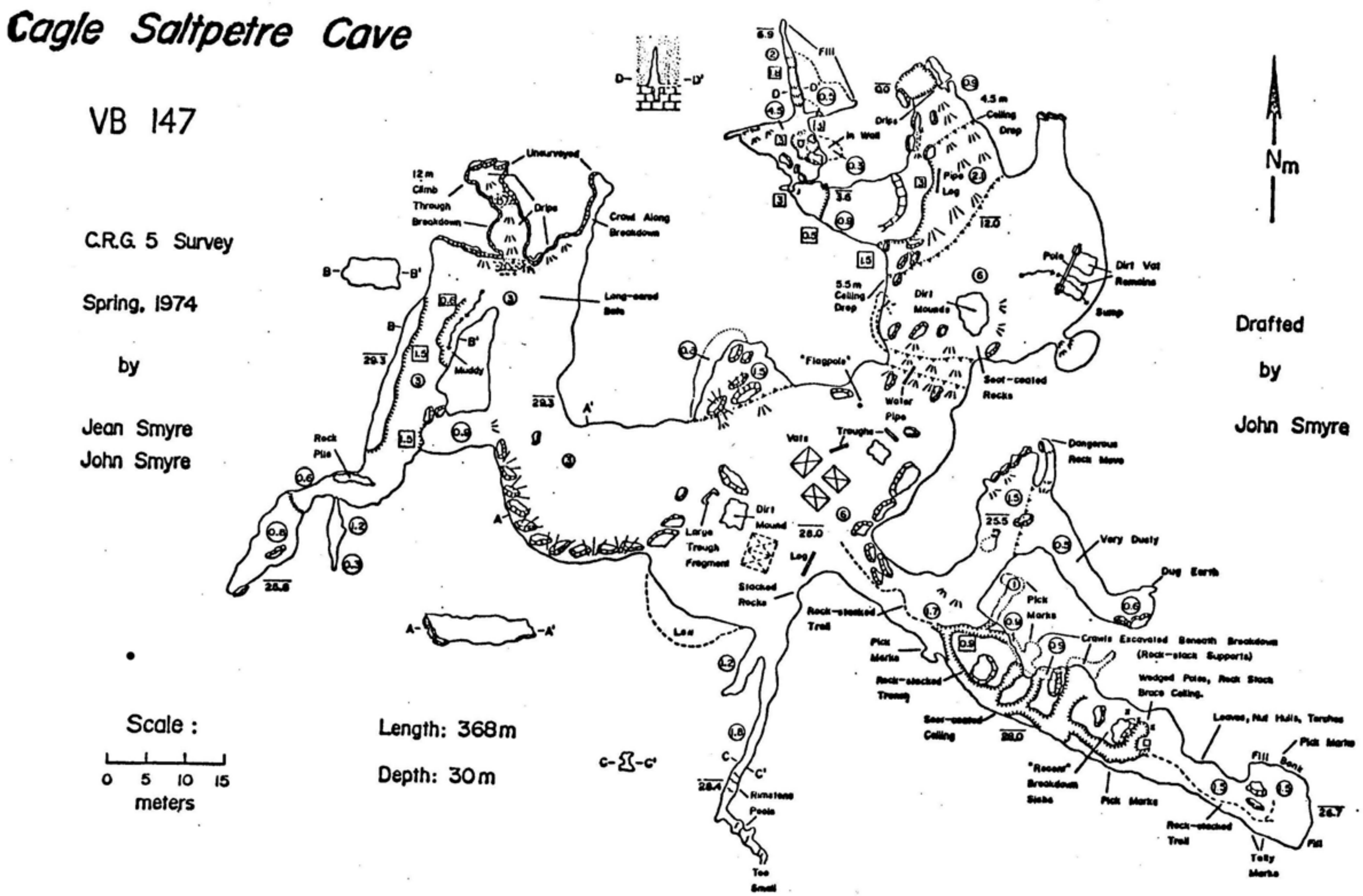

Figure 12. Cave survey map of Cagle Saltpetre Cave (Smyre and Smyre 1974).

examination of the Tennessee State Archaeological Site Files, prior to the beginning of the Fall Creek Falls Archaeological Survey in 2002, revealed that of the Park's 23,000 acres there were no prehistoric sites recorded. There were ten historic sites recorded in the park, but these are all open-air sites, despite the presence of extensive locally-known rockshelter and cave sites. The primary goal for the UTK Fall Creek Falls Archaeological Survey (FCFAS) was to remedy the absence of formal recording or study and to assist the park with the information they need to protect these cultural resources. This survey, which is on-going, is focused on microenvironments such as the ridge tops, narrow alluvial valleys, rockshelters, and deep caves within the park boundaries. These areas are often remote, and sites there are rarely documented and undergo constant looting. The Tennessee state parks are typically understaffed and operate on limited budgets for conservation and planning. Without formal documentation of the archaeological resources it is difficult for the park to manage or protect these sites.

As part of the Fall Creek Falls Archaeological Survey, in 2003 University of Tennessee archaeologists, students, and volunteers from the National Speleological Society (NSS) surveyed almost two-dozen caves in the Park, including both entrance areas and interior passages. Cagle Saltpetre Cave was one of many caves recognized during this survey as containing significant cultural remains that necessitated further study.

In May of 2003, archaeological investigations were initiated at Cagle Saltpetre Cave and provided the basis of the thesis research presented here. In addition to significant archaeological remains, a variety of sensitive biota inhabit the cave, including cave adapted invertebrates, wood rats (*Neotoma floridana*), cave crickets, Rafinesque (*Corynorhinus rafinesquii*) and Eastern Pipistrelle (*Pipistrellus subflavus*) bats, and the federally endangered Indiana Bat (*Myotis sodalis*). For these reasons, it was also an objective of the University of Tennessee CART to help Fall Creek Falls State Park develop effective measures to preserve and protect the site. In the summer of 2005, cavers, Park staff, University of Tennessee archaeologists, and conservationists helped to design and construct a suitable gate at the cave entrance. In February of 2007, the cave was assigned an archaeological site number, 40VB125, by the Tennessee Division of Archaeology.

Physiography

Cagle Saltpetre Cave is located in Van Buren County, Tennessee, and lies along the western escarpment of the Cumberland Plateau physiographic region, which is the southern portion of the Appalachian Plateaus structural province as defined by Fenneman (1938) and Miller (1994). The young valleys of the western escarpment make the topography of this margin somewhat irregular, while the eastern escarpment, the Cumberland Front, is more prominent. The plateau region is characterized by deep gorges and two prominent anticlinal valleys, the northern Elk and the southern Sequatchie. The general plateau elevation ranges from approximately 1700 to 1900 feet; however, some mountainous areas exceed 3000 feet (Miller 1994). To the west, the

Cumberland Plateau is bounded by the eastern component of the Highland Rim, and to the east by the Valley and Ridge region, also called the Valley of East Tennessee.

The Highland Rim is the largest section of the Interior Low Plateau Province and surrounds the Central Basin region of Tennessee. Its Eastern Rim is marked by “a much dissected escarpment” that rises from the lowlands of the Central Basin and is characterized by numerous narrow valleys and areas of extensive karstic terrain (Miller 1994: 5). The Valley and Ridge Province of Tennessee is so-called because of it many characteristic “elongate ridges and intervening valleys” that extend southwesterly from the Unakas, the portion of the Appalachian Mountains in the east, to the escarpment of the Cumberland Plateau (Miller 1994: 3).

Braun (2001 [1950]) identified the vegetation of the Cumberland Plateau in the vicinity of Cagle Saltpetre Cave as belonging to the “Cliff Section” of the Mixed Mesophytic Forest Region. Co-dominant tree species including white oak (*Quercus alba*), red oak (*Quercus rubra*), hickory (*Carya sp.*), white basswood (*Tilia heterophylla*), sweet buckeye (*Aesculus flava*), sugar maple (*Acer saccharum*), hemlock (*Tsuga canadensis*), yellow-poplar (*Liriodendron tulipifera*), and historically, American chestnut (*Castanea dentata*), are the most common canopy types (Braun 2001 [1950]: 40 - 41). Other characteristic non-canopy, tolerant species include dogwood (*Cornus florida*), sourwood (*Oxydendrum arboretum*), American holly (*Ilex opaca*), magnolia (*Magnolia sp.*), and hop hornbeam (*Ostrya virginiana*) (Braun 2001 [1950]: 43). Southern portions of the

Plateau also possess components of Oak-Hickory-Pine Forest, as recognized by Küchler (1964).

Similar to the Unaka region of Tennessee, the Cumberland Plateau is marked by lower average temperatures and higher average rainfall in comparison to areas of lesser elevation across the state. The average annual temperature ranges from 16°C (60°F) - 17°C (62°F) (McNab and Avers [eds.] 1994) and the average annual precipitation is generally 50 – 55 inches, with the greatest precipitation occurring during the winter and early spring (National Climatic Data Center, National Oceanic and Atmospheric Assocation [NCDC, NOAA] n.d.). The general climate of the area surrounding Cagle Saltpetre Cave is, however, somewhat difficult to categorize due to a variety of unique topographic features. As Fleming and Wofford (2004: 167) recognize, "Many of the deep gorges, cave openings, and sinks exhibit a microclimate of cold-air drainage that is more mesic and cooler than that of the surrounding areas of the gorges and plateau surface."

Geology

Cagle Saltpetre Cave has a surveyed length of 368 meters and a total depth of 30 meters. The cave consists of two main levels and three primary passages that extend to the west, south, and southeast from the lower level. The entrance to Cagle Saltpetre Cave is located at the contact of the Hartselle Formation and Monteagle Limestone, both of which formed during the Upper Mississippian geologic subepoch. The Hartselle Formation ranges from 20 – 70 feet in thickness and consists primarily of greenish-gray to yellowish-brown, fine-grained sandstone that is commonly interbedded with gray shale (Hardeman 1966). The cave is formed entirely within the underlying Monteagle Limestone, which is a gray, micrograined to coarse-grained, thick-bedded (ranging from 240 – 310 feet in thickness) limestone. The Monteagle beds are commonly oolitic, dolomitic, and/or cherty (Hardeman 1966). The Hartselle Formation is capped by the Bangor Limestone and the Pennington Formation, respectively, both Mississippian in age. These are overlain by Pennsylvanian-age formations. The Raccoon Mountain Formation is composed of silty to argillaceous shale with minor siltstone. The overlying Warren Point Sandstone is thick-bedded, conglomeritic sandstone with interbedded shale and siltstone in localized areas. This is overlain by the Signal Point Shale formation, composed of silty to argillaceous shale and coal deposits near its upper margin. The upper plateau surface is capped by the Sewanee Conglomerate, primarily composed of conglomerate and conglomeritic sandstone (Hardeman 1966).

CHAPTER V
ARCHAEOLOGICAL INVESTIGATIONS AT CAGLE SALTPETRE CAVE

The archaeological investigation of Cagle Saltpetre Cave involved archival research, a comprehensive survey and mapping project, and Geographical Information Systems (GIS)-based data management and analyses. Archival research was conducted in an attempt to locate records pertaining to the mining operations at Cagle Saltpetre Cave. Three areas of the cave were surveyed and mapped in detail in order to document the location of cultural remains, both prehistoric and historic. The data generated from the mapping project were examined for spatial patterns using GIS software.

Archival Research

In addition to reviewing the literature about saltpeter mining in general (presented in Chapter III), background research was undertaken to find documentation specific to the 19th century mining operations at Cagle Saltpetre Cave. This entailed archival research and informal discussions with local informants, cavers, and cave historians. The results of both archival investigations and interviews are presented below.

Locating early records that reference Cagle Saltpetre Cave was problematic due to the fragmentary nature of documentation from this early part of the Plateau's history. Shifting county boundaries throughout the region during the first half of the 19th century also made archival research difficult; this area was sparsely populated frontier land until 1806, when White County was created from portions of Smith County. It was later incorporated into Van Buren County in 1840. Furthermore, unlike Big Bone Cave, also in present-day Van Buren County, the site has no known historical name. It was officially named "Cagle Saltpetre Cave" in 1974 by John and Jean Smyre who mapped the cave (see Figure 12) and reported it to the Tennessee Cave Survey (TCS). John Smyre recalls that the name "Cagle" was given to him prior to visiting the cave (John Smyre, personal communication). To what person or persons this name refers is not certain. Signatures of a "Davis and Cagle Medley" and "Lester Medley" can be found in the lower level room of the cave; however, these are not 19th century signatures. Lester Medley and his relatives, Davis and Cagle, all natives of Van Buren County, visited the cave in the 1960s and removed several artifacts from the site with the aid of a borrowed tractor (Lester Medley, personal communication). The Medley family did not, however, own the cave or the surrounding acreage. Three individuals with the Cagle surname appear on a petition, dated January 25, 1839, to the General Assembly of the State of Tennessee; this was a formal request for the establishment of a new county (Van Buren) by select citizens of White and Warren counties (Medley 1987: 57). Yet, none of the historical documents examined indicate that any person(s) by that name owned or mined a cave in the area.

OWNERSHIP OF THE CAVE

Based solely on historic graffiti in the cave, Cagle Saltpetre Cave was explored to some degree by at least 1813 (Figure 13), the earliest date found, as it is located on the ceiling of an extensively mined crawlspace. However, no signatures exist that would provide information concerning its ownership during the mining episodes. Due to this lack of evidence, early records from White and Van Buren counties were examined for mention of a cave in the vicinity of presently recognized topographic features, such as Cane Creek. Cane Creek, a branch of the Caney Fork River, runs approximately 61 vertical meters below the cave (Figure 14).

The earliest record is a petition by Sarah Harbert to the White County Court of Pleas and Quarter Sessions, dated March 24, 1817 (White County Courthouse, Sparta, Tennessee [WCC] 1817: Deed and Trust Deeds [DTD] F: 109, 110):

> At April session of White County Court 1817 was filed the following petition Towit [sic].
>
> The worshipful, the County Court for the County of White and State of Tennessee your petitioner Sarah Harbert of said County of White, respectfully Shewitts [sic] to your honorable court, that she is the widdow [sic] of the late Thomas Harbert, who deceased in the month of November last, and who was at the time of his death and for many years previously had been Citizen [sic] of, and dwelt in, said County of White; that the said Thomas Harbert dec,[d] [sic] at the time of his death was seized, or possessed of the lands tenements and heraditaments [sic], herein after particularly described and setforths [sic], and of which the said Sarah prays she may be endowed according to the Laws [sic] in such cases made and provided…

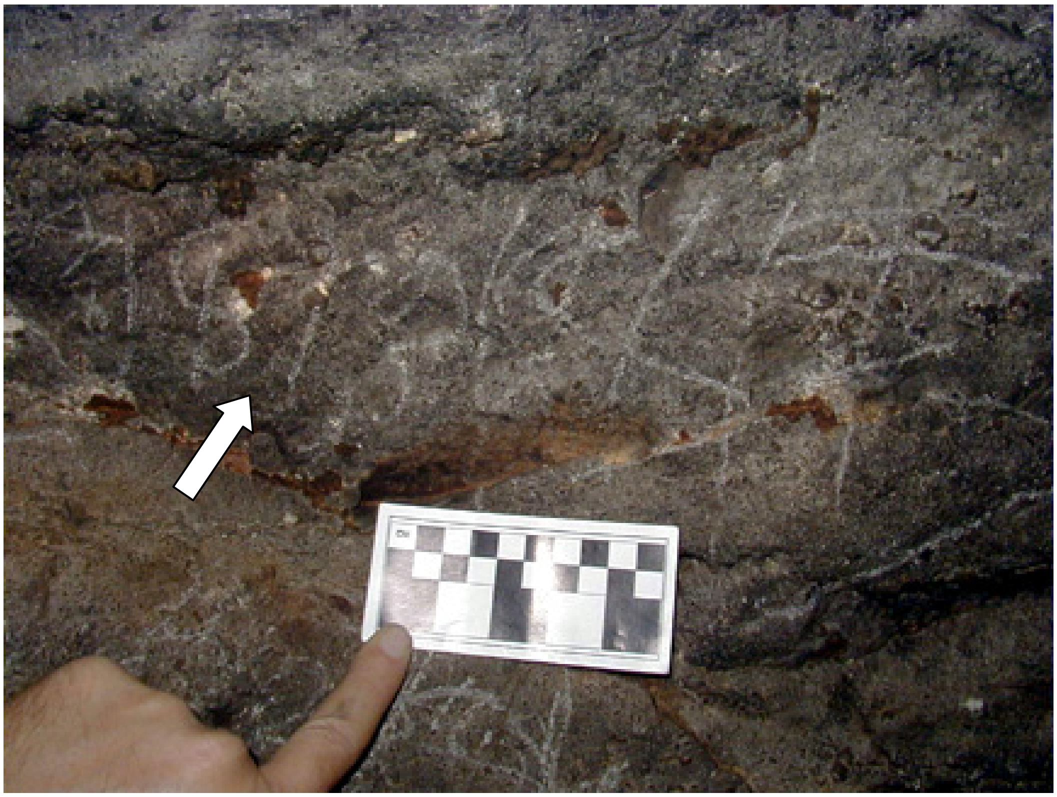

Figure 13. 1813 date in Cagle Saltpetre Cave.

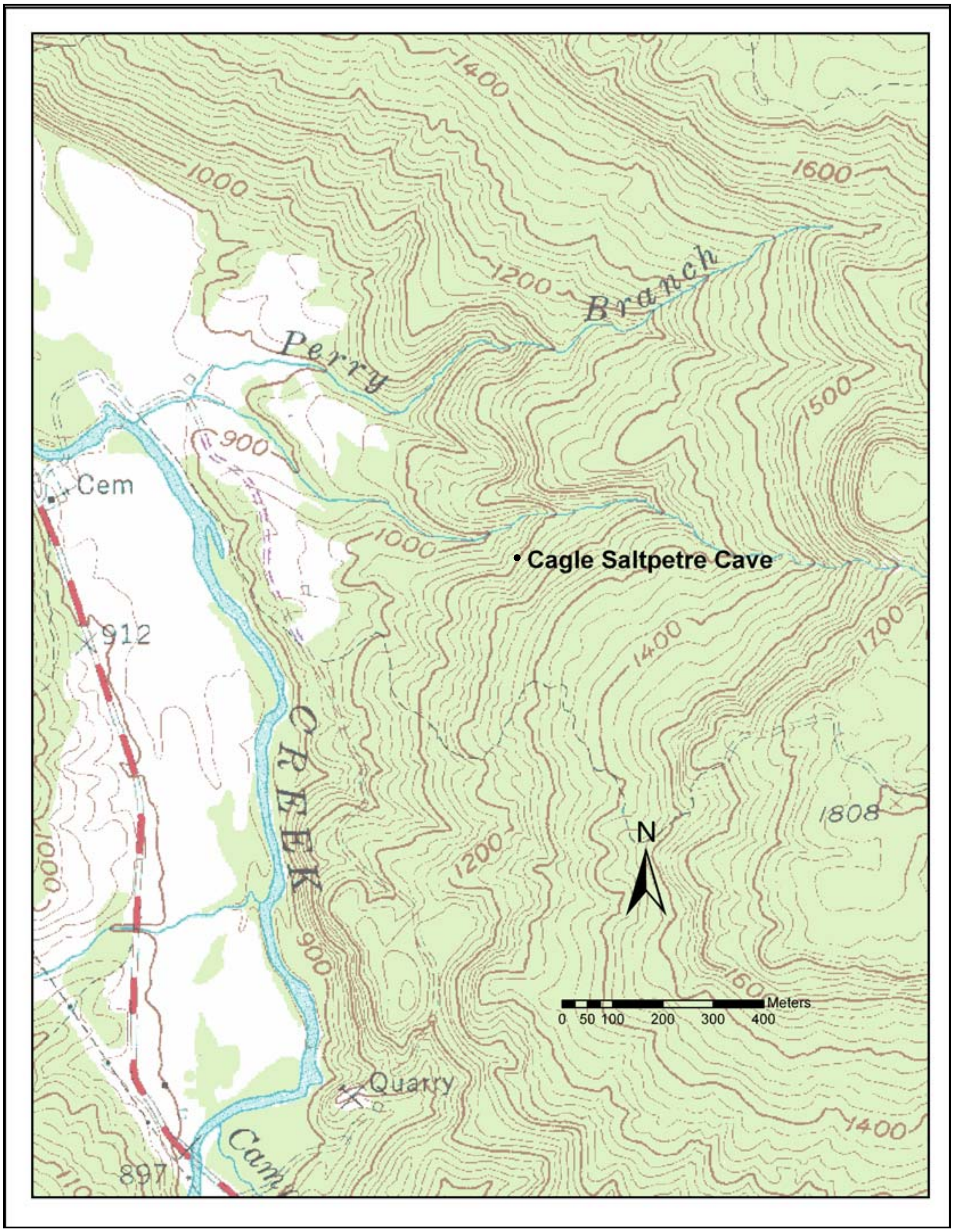

Figure 14. Location of Cagle Saltpetre Cave, Bald Knob Quadrangle, Tennessee.

> The said Thomas Harbert also died posesed [sic] of a certain tract of land containing five acres situate in said County of White on the waters of Cane Creek; Beginning at a spruce pine running thence agreeably to land Law seas [sic] to include a Saltpetre [sic] cave, which he held by lawful entry.—the said Sarah prays she may be endowed of one third of the proceeds & profits that may be produced by said Land [sic] and Saltpetre [sic] cave; the cave being the only object of value included by said land; and as not capable of equitable division by meters & bounds:

The above excerpt gives some indication that this cave was being commercially mined, i.e., mined for profit, prior to 1817 when the petition was filed. According to this petition, Thomas Harbert also owned a profitable saltpeter cave near the Calfkiller River (WCC 1817: DTD F: 109):

> The said Thomas Harbert also died posesed [sic] one other tract of land containing three acres situate in said County of White on the waters of the Calf Killer's fork on the south side of rock mountain; Beginning on a stake standing on north west of a salt-petre [sic] cave cave [sic] found by Benjamin Hutson, Hardy Jones & John Hollingsworth; then running east, south, west, North [sic], including said cave: Which said tract is also holden [sic] by lawfully entry as well as the rest above both in the name of said Harbert –the only object of value in this tract is a salt-petre [sic] cave, which cannot be equitably divided by meters and bounds; the said Sarah Harbert therefore prays she may be endowed with the [illeg] and profits of the same.

Very little is known about Thomas Harbert, save that he was part owner of the Hariot Iron Works, one of White County's early industrial companies (WCC 1813: DTD G: 690-691; WCC 1817: DTD F: 110). Harbert's business partner at the time of his death was Theoderick B. Rice. According to the White County deed records (WCC 1813: DTD G: 690-691), Thomas Harbert and George

Ailsworth entered into a partnership agreement with Theoderick B. Rice and purchased the Hariot Iron Works in September of 1813. In 1817, the Hariot Iron Works consisted "…of three blooming hearths and one Forge [sic]; and also a grist, and a saw mill" (WCC 1817: DTD F: 110). T.B. Rice is acknowledged in Goodpeed's (1979: 797 - 800 [1887]) history of White County as owning, "…in about 1815 or 1820…an iron forge one mile south from Sparta, on Calf Killer River, on the present [1887] site of the cotton factory" along with a corn mill on the Calf Killer that was "operated by water power."

A land grant, dated August 17, 1827, states that Theoderick B. Rice also owned a saltpeter cave near Cane Creek (WCC 1827: White County Grants [WCG] 1: 237):

> On waters of Cane Creek of Caney Fork. Beginning at a red oak on the side of the mountain, N. 7 W. from a head of a spring called the cave spring; thence E. 90 poles to a stake and 2 white oaks on the side of a mountain; thence S. 153-1/3 poles to a stake and pointers; thence W., crossing Cane Creek, 120 poles to a gum and dogwood; thence N., crossing said creek, passing up an impassible clift [sic], 153 1/2 poles to a stake and pointers; thence S. 30 poles to beginning. Including a salt peter cave, occupied at the date of entry, by Mark Glidewell and one entered by Elijah Hill.

This is probably a reference to Rice Cave, which is believed to have been named for Theoderick B. Rice (Marion Smith, personal communication). In his book, *Caves of Tennessee*, Thomas Barr (1961: 466-467) provides a description of Rice Cave; however, he does not indicate that it was a saltpeter-mining site. Recent visits to the cave have located evidence for mining, including remnants of wooden leaching vats and miner's tool marks. However, only Civil War-era dates have been noted at the site (Joseph Douglas, personal communication).

Barr (1961: 461) also describes another cave in proximity to Cane Creek, appropriately named "Cane Creek Saltpeter Cave." When Barr entered the cave in the 1960s, it still contained evidence for saltpeter mining, including the "[r]emains of a half dozen saltpeter vats, all poorly preserved…" (1961: 461). In 2003, the Cave Archaeology Research Team (CART) from the University of Tennessee visited the cave and confirmed Barr's observations. Concurrently, CART visited Sandstone Cave (Barr 1961: 467), located near Cane Creek Saltpeter Cave, where miner's tool marks and wood vat remnants were noted.

Due to both the lack of documentation concerning the mining operations at Cagle Saltpetre Cave and the absence of historic signatures at the site, whether or not Thomas Harbert was indeed the cave's owner during the early 19th century cannot be confirmed. Nonetheless, it is known that Harbert was proprietor of at least two caves that were likely mined for niter prior to his death in 1816, one located near Cane Creek and another near the Calf Killer River. Land descriptions from early trust deed records and grants are quite vague; therefore, it is difficult to differentiate among sites. Because they are all in proximity to Cane Creek, Cagle Saltpetre Cave, along with Cane Creek Saltpeter Cave and Sandstone Cave, could all fit the description of the saltpeter cave from Sarah Harbert's aforementioned petition of 1817.

Attempts to trace White County land transactions from the Harbert family to subsequent owners during the 19th century were unsuccessful. Other references to a cave in the Cane Creek area were not found in either the White or Van Buren County records. The only additional reference to a saltpeter mining operation near Cane Creek is found in Landon Daryle Medley's book, *The History of Van Buren County, Tennessee…*, published in 1987. Medley (1987: 165) states that in addition to Big Bone Cave, "[a]nother saltpetre mine in Van Buren County was also in operation during the [Civil War]. It was located in a cave on Cane Creek and run by Jeff Walker." Medley (1987: 261) notes that one Jefferson J. Walker was the son of David A. and Mary Polly Ann (Stulz) Walker.

A land transaction, dated July 14, 1835, between Cader Measles and Micajah Walker, David A. Walker's father, is the earliest record of the Walker family in the Cane Creek area (Van Buren County Register of Deeds, Spencer, Tennessee [VBCRD] 1835: Deed Book [DB] B: 157):

> …Cader Measles for and in consideration of the sum of eighty five dollars to him in hand paid by Micajah Walker at or before the sealing of these presents the receipt of which is hereby acknowledged hath granted bargained and sold and by these presents doth grant bargain and sell unto the said Micajah Walker his heirs and assigns a certain piece parcel or track [sic] of land situated lying and being in the County of White on the waters of Cane Creek containing thirty five acres…

Several Van Buren County land transactions (e.g., VBCRD 1851: A: 146; VBCRD 1851: A: 261; VBCRD 1853: B: 414; VBCRD 1862: C: 129) were found involving members of the Walker family, including Micajah, David A., and David's son Jefferson J. (J.J.), who is almost certainly the aforementioned "Jeff Walker" that Medley discusses (1987: 261). Unfortunately, the documents do not reference a saltpeter cave. Nonetheless, there is evidence that Jefferson J.

Walker lived in proximity to Cagle Saltpetre Cave and thus may have been involved in the later saltpeter mining operations at the site.

At the formation of Van Buren County on January 3, 1840, the County was divided into 8 Civil Districts. Micajah Walker and his eldest son, David A., are listed as residing in the Fourth District (Medley 1987: 66). Both the Third and Fourth Districts encompassed the Cane Creek area, one of the early communities in the County (Medley 1987: 73). In 1840, Jefferson J. Walker would have been only 13 years old and therefore was not included in the County enumeration (Rhinehart 1983: 149). The 1850 United States Census for Van Buren County lists John J. Walker (Jefferson J.), farmer, and his wife Sinthy (Cynthia) as residing in the Fourth District along with their two children: Mary, age two, and Louisa, age 1.

Medley (1987: 261) states that Jefferson J. Walker "…served as a Confederate soldier and died in Kentucky during the war." Conversely, according to his tombstone inscription, Jefferson J. Walker died November 9, 1906, well after the close of the Civil War (Rhinehart 1983: 149). Rather, it was his brother, Micajah D. Walker, a private in the 35th Tennessee Infantry, who died during a skirmish at Barboursville, Kentucky, in September of 1862 (Medley 1987: 152). J.J. Walker also had two other brothers, Joseph Hardy and George, who served as privates in the Confederate Army (Medley 1987: 144, 159, 261). In the Van Buren County Court Minutes for June 3, 1861, J.J. Walker is listed as an officer (1st Lieutenant) in the Home Guard for District No. 4 (Medley 1987: 133-134). Therefore he did have associations with the Confederate military.

If Jefferson J. Walker did indeed work a saltpeter cave near Cane Creek, his connections with the Confederate Army were likely relevant to the operations. It is well-documented that Big Bone Cave, located nearby in the Big Bone Cave Community of Van Buren County, was an important source of saltpeter for the Confederates (Medley 1987: 164-165; Smith 1985). Throughout 1861, the Tennessee Military and Financial Board, formed in April of the same year, employed "saltpeter agents" to locate caves and obligate Tennesseans to mine them by contract (Smith 1997). From 1861-1863, James Randals, a Van Buren County "Trader," was superintendent of the mining operations at Big Bone Cave and contracted with the State to produce niter for the Confederacy (Smith 1985, 1997). Other caves in the surrounding area were almost certainly mined by contract as well. This is evident in an 1861 letter to Edwin R. Glascock, a State saltpeter agent, from James E. Bailey, member of the State Military Board, in which Glascock was advised to visit Big Bone Cave, along with other caves in Van Buren County, and "…make contracts for all the saltpetre that can be made in eight and Ten [sic] months for 25 cents per pound" (Smith 1997: 102). Furthermore, the Confederate pension application of a John Slatton, who worked at the Big Bone saltpeter operations from 1861-1862, indicates that at least one other Van Buren County cave was mined for the State (Medley 1987: 164-165):

> I, John Slatton, …State that my brother, A.C. Slatton and myself went into the Confederate Army and about the time we were mustered in Savage's Regiment, Captain York's Company there was a great demand for salt petre and owing to our familiarity with the Bone Cave and another cave nearby and there was much in demand by the Confederate authorities with the consent of the Colonel John H. Savage, we were regularly detailed to do this work and we got out and

Figure 15. 1862 date in Cagle Saltpetre Cave.

> Manufactured [sic] large quantities of salt petre for the Confederate Government.

Again, there is no conclusive evidence to indicate who was involved in the mining operations at Cagle Saltpetre Cave during the Civil War. Nonetheless, a date of "1862" (Figure 15), in addition to the dendrochronological dates presented in Chapter VI, indicate that Cagle Saltpetre Cave was mined during this time, concurrent with James Randals' Big Bone Cave operations.

LABOR

Although certainly not of equal scale to that of Mammoth Cave or Big Bone Cave, the extent of the mined passages and the enormity of ceiling breakdown moved during the course of mining (which are described in more detail in the following sections of this chapter) indicate that Cagle Saltpetre Cave was a fairly substantial saltpeter operation. Thus, several individuals would have been required to undertake the saltpeter mining and processing activities. To date, documentation of the labor employed during the mining episodes at Cagle Saltpetre Cave has not been found. However, by examining the literature written about other 19th century saltpeter operations, some inferences can be made concerning the workforce at Cagle Saltpetre Cave. For example, based on the information provided in the extant literature (e.g., Faust 1967; Maddox 1813, 1821; Smith 1985, 1989), it is reasonable to assume that the workforce employed at most (if not all) saltpeter operations, including Cagle Saltpetre Cave, consisted entirely of men.

Regarding the Mammoth Cave operations, Faust differentiates the saltpeter laborers based on the skill that was needed to perform particular tasks (Faust 1967: 58-59):

> A large share of the labor employed in the saltpetre recovery project at Mammoth Cave, such as the miners, wood cutters, fire tenders, ash haulers, teamsters, and others of similar nature, could be classed as unskilled workmen. Also skilled craftsmen such as carpenters, coppers, wagon builders, and blacksmiths were needed…However, probably the most important individual, upon whom the technical aspects of production, and thus the success of the operation depended, was the *saltpetre maker* [sic].

The "*saltpetre maker*" would have overseen the conversion, purification, and refinement steps of saltpeter production. Therefore, "…he had to have a clear understanding of a number of aspects of physics and chemistry. He had to know what chemicals were compatible and would produce a desired end-product" (Faust 1967: 59).

Ebenezer Meriam, who was at Mammoth Cave during a portion of the time (ca. 1810 -1814) it was in production, states that "[t]he workmen employed in the cave were blacks, and were sometimes to the number of 70" (Faust 1967: 74; Meriam 1844: 319). Considering that 40 percent of Kentucky's population in 1810 was enslaved, the workmen described by Meriam were probably slaves, many of whom were likely skilled craftsman (George 2005: 29). George (2005: 31) states that the owners of Mammoth Cave during the early 19th century mining operations, Charles Wilkins and Fleming Gatewood, Sr., were not slave owners.

Therefore, where these laborers were from can only be speculated. George (2005: 31) proposes some possibilities:

> Great Saltpetre Cave ran advertisements in *The Kentucky Gazette* for African-American bondsmen [slaves that could solicit work] to work in the cave. No advertisements for Mammoth Cave workers appeared in *The Kentucky Gazette* or surrounding papers. Almost half the inhabitants of Lexington were slaves and represented a valuable labor pool. Alternately, the workforce could have come from foreclosed properties associated with the Peyton Short Versailles, Kentucky, plantation estates that possessed a large slave workforce…Short was brother-in-law to Wilkins, and owed more money to him then he could possibly pay back in a lifetime.

An 1813 account of the Big Bone Cave mining operations states that the workforce numbered "…about one hundred" (Maddox 1813: 176). However, this account fails to provide more specific information concerning the types of laborers associated with the cave. An enumeration of the White County population for the year 1810 lists 283 slaves (male and female) as residing in the county (Walker [ed.] 1872). Although it is not certain if any of these individuals worked in Big Bone Cave at that time, if the Mammoth Cave operations are any indication, it is plausible. Furthermore, the same may well be said for the early 19th century operations at Cagle Saltpetre Cave.

It appears that the Civil War-era mining operations at Big Bone Cave consisted of a variety of laborers, including Confederate soldiers, civilians, slaves, and "free men of color" (Bayless 1982; Medley 1987; Smith 1985). According to Bayless, "[a]pproximately three hundred men [likely an exaggerated number] operated the mine; some were in the military, but most were civilians" (1982: 17). Bayless further states that John Ross, a freed slave, was paymaster of the operations (1982: 17). The Confederate Conscript Act, passed in April of 1862 stipulated that "…all able-bodied white males between the ages of 18 and 35 were subject to military duty" (Smith 1989: 36). However, working for the Confederate Nitre Bureau as a saltpeter or gunpowder manufacturer exempted an individual from fighting (Smith 1989: 36). Thus, some individuals may have labored in the saltpeter mines to avoid serving in the Confederate military.

Additionally, the little information that is known about other Tennessee caves worked by the Nitre Bureau indicates that, similar to Big Bone Cave, both private citizens and slaves comprised the majority of the workforce. Lookout Cave, in Hamilton County, employed "…from seven to twenty-two workers (including two slaves)" (Smith 1989: 38). The monthly workforce of Tennessee's largest Confederate saltpeter mine, Nickajack Cave, consisted of "forty-nine to sixty-nine" white men and "as many as two slaves" (Smith 1989: 38).

SUMMARY OF ARCHIVAL RESEARCH

In summary, no historic documents specific to the mining operations at Cagle Saltpetre Cave could be found. The rarity of historic graffiti at the site coupled with the scattered nature of archival documents during the 19th century for both White and Van Buren counties, necessitated different approaches to the archival investigations. Although the results are not conclusive, two possible proprietors of Cagle Saltpetre Cave during the 19th century mining operations are proposed on the basis of this research: Thomas Harbert and Jefferson J. Walker, respectively. In addition, while there are no existing documents to account for those who worked at Cagle Saltpetre Cave, based on observations from other, non-cottage industry saltpeter operations, private citizens and slaves likely comprised the employed labor. However, it should be noted that this is highly speculative. Because the archival investigations yielded limited results, the dendrochronological investigations, presented in Chapter VI, and the archaeological survey and mapping project, discussed in the following sections, were required to answer the research questions stated in the introduction to this thesis.

Archaeological Survey and Mapping Project

In order to gain insight into the historic saltpeter operations at Cagle Saltpetre Cave, a comprehensive survey and mapping project was undertaken to thoroughly document the extant material remains. In particular, this investigation focused on *in situ* artifacts and features, as their context provided the most informative data. Also included in this documentation was any potentially informative evidence that might further our knowledge concerning the prehistoric utilization of the cave.

A general description of the surveyed and mapped areas of the site, the methodology involved, and the results of the GIS-based spatial analyses are presented in the remainder of this chapter, along with a discussion of the prehistoric remains documented at the site.

DESCRIPTION OF SURVEYED AREAS

Three areas of Cagle Saltpetre Cave were surveyed and mapped, designated A-C. These areas were selected because they contain both prehistoric remains and artifacts and features pertaining to the historic saltpeter mining operations. Other sections of the cave were examined; however, no other cultural remains were found. Therefore they were omitted from the mapping project.

The upper level of the cave, Area A, is a vadose canyon (Moore and Sullivan 1997:15 -16), approximately 28 m x 24 m in diameter, which is accessed via a talus slope that descends from the cave entrance. This level tends to remain damp due to surface rainwater and organic debris that is often washed in from the cave entrance. Area A contains few extant artifacts and features. The most obvious features here are amorphous piles of sediment (Figures 16 and 17). These represent the last loads of mined "petre-dirt" processed in wooden leaching vats. The water used in the processing steps eventually dissipated, leaving the hardened sediment. In time, the wood disappeared, likely from both weathering and vandalism, which resulted in only casts of the vats remaining. Despite their poor preservation, these vat casts were given vat numbers, Vat 5 (see Figure 16) and Vat 6 (see Figure 17). A stacked rock walkway, likely made by the miners, leads to the lower level of the cave, designated Area B. This room appears to have been used most heavily, as the floor of the room is completely covered by many layers of processed sediments, also called "spoil piles." Among the extant features in this room are three square-type vats (Vats 2-4), one of

Figure 16. Vat cast, designated Vat 5, in Area A of Cagle Saltpetre Cave.

Figure 17. Vat cast, designated Vat 6, in Area A of Cagle Saltpetre Cave.

which can be seen in Figure 18. They remain virtually intact and are similar, if not identical, in construction to those found in Big Bone Cave (Figure 19). The vats are roughly square in shape and of a somewhat standardized size, approximately 3.05 m (10 ft) x 3.05 m (10 ft) wide and 1.22 m (4 ft) in height. Each consists of a log frame with wooden planks placed vertically inside to form the vat walls. The corner of each frame is supported by stacked rock "footers." These footers functioned to both support the frame floor joists, as several tons of saturated dirt would have filled the vats, and to allow the flow of air beneath the vats, helping to dry the wood, thus preventing it from rotting and collapsing under the weight (Faust 1964). As no nails were used in the construction, the frame is secured by mortise-and-tenon joints (Figure 20), hewn by hand at the end of each log. This type of construction was probably due to both a scarcity of metal fasteners and the ease in which the vats could be dismantled, moved, and reused where needed. To construct the vat floor, smaller logs were split into halves, hollowed into troughs, and laid across the bottom frame timbers, concave-side facing upward. A second layer of log troughs was then placed convex-side upward so that they would cover any space between logs in the lower layer. A mat of organic materials, such as twigs or cane, was placed in the bottom of the vats to prevent the leached sediment from clogging the lower layer drainage troughs. The saltpeter-bearing solution would then flow down the middle of the bottom layer of logs and into wooden collection troughs. Two intact poplar troughs are evident in this room and appear to be hand-hewn, one of

Figure 18. Example of a square-type vat in Area B of Cagle Saltpetre Cave.

Figure 19. Example of a square-type vat in Big Bone Cave. Photo by Alan Cressler.

Figure 20. Mortise-and-tenon joint used to secure the frame corners of the leaching vats in Cagle Saltpetre Cave.

which (Figure 21) was most likely placed directly in front of one of the square-type vats. Also in Area B are at least two V-shaped leaching vats that underlie those of square-type construction (Figure 22). However, only one (Vat 1) was sufficiently exposed to map during the project. More of these vat types are likely buried beneath spoil piles. The superposition of square-type vats above the V-shaped vats alone indicates that the former were used during the later mining episodes at the site. However, to establish a more significant level of chronometric control, dendrochronological analyses were conducted on the wood used to construct both vat types. These analyses are presented in Chapter VI.

Area C is a branch of extensively mined passage, consisting of both walkways and crawlspaces that extend toward the southeast from the lower level (Area B). Several extant features reveal the extent of the mining activities in this area, one being the sheer enormity of breakdown moved during the course of mining (Figure 23). Numerous tool marks (Figure 24) from the mining episodes remain preserved in the exposed sediments in Area C. “Tally marks” (Figure 25), sets of deliberate scratches, are prevalent in this area of the cave and are found along the walls and ceilings.

ARCGIS® MAPPING

The mapping project was conducted using a Nikon total station laser transit that was maneuvered along a grid system throughout the cave. The total station was assigned arbitrary datum coordinates of x: 1000 m, y: 5000 m, z: 1000 m and the grid system established along a north-south baseline. Control

Figure 21. A poplar collection trough in Area B of Cagle Saltpetre Cave. Photo by Alan Cressler.

Figure 22. The author sitting next to a V-shaped vat that underlies those of square-type construction in Area B of Cagle Saltpetre Cave. Photo by Alan Cressler.

Figure 23. Ceiling breakdown moved by the saltpeter miners in Area C of Cagle Saltpetre Cave. Photo by Alan Cressler.

Figure 24. Saltpeter miner's tool marks preserved in excavated sediments in Area C of Cagle Saltpetre Cave.

Figure 25. A set of “tally marks” at Cagle Saltpetre Cave.

points, consisting of small nails placed in the limestone cave walls, were positioned throughout the cave and their coordinates collected using the total station and a prism target. When traversing the instrument throughout the cave, these known control points were used to reestablish the total station on the grid system by process of triangulation. Generally, points were collected from a central location on an artifact or feature. Several points were collected in different locations for larger material including leaching vats and collection troughs.

Once collected, the data (i.e., *x*, *y*, *z* [Cartesian] spatial coordinates or points) generated from the mapping project were transferred from the total station using Nikon/TDS TransIt® software. From this program, data were downloaded as a table into the ArcCatalog® application of ArcGIS®, an integrated GIS software program. Using the ArcMap® application, these data were then generated as a map and each mapped point was given a special color designation. An existing map of Cagle Saltpetre Cave, drafted by John and Jean Smyre (1974) (see Figure 12), was scanned and imported as a jpeg image into ArcMap® and the points were then georeferenced with survey stations indicated on the map.

ArcGIS® Spatial Analyses

Geographical Information Systems has been widely used in archaeology for the management, visualization, and analyses of spatial data (Burrough 1986; Ebert 2004; Goodchild 1996; Kvamme 1999; Snow 1996). With the use of management and visualization tools in GIS software programs, this approach can aid archaeologists in identifying patterns and relationships among both intersite and intrasite data. As Kvamme notes, "[w]hen viewing people working with GIS, one soon appreciates how often patterns or relationships are discovered. Merely by displaying maps of archaeological sites with other spatial variables, new associations or tendencies frequently are realized" (1999: 160).

The high rate of preservation at Cagle Saltpetre Cave provided a unique opportunity to identify spatial patterns among *in situ* artifacts and features and reconstruct specific components of the mining operations. The data generated from the mapping project were examined using the ArcGIS® software program, as outlined in the previous section. These GIS-based analyses had two primary objectives, (1) to examine the distribution of "tally marks" and their relationship to separate activity areas identified within the cave and (2) to reconstruct the location of the water transport installation that was once present at the site.

TALLY MARK DISTRIBUTION

"Tally marks," rows of deliberate marks etched into the cave walls and ceiling, are common features at saltpeter-mining sites and have generally been interpreted as a counting system for miners. However, exactly what they were counting has been largely speculative. Previous work (e.g., De Paepe 1979; 1981; Faust 1964; Matthews 1971) concerning saltpeter mining has implied that tally marks probably represented units of mined cave earth. However, no historic documentation exists that accounts for this activity. Furthermore, no systematic study has been conducted in an attempt to explain this phenomenon.

The objective of this analysis was to examine the distribution of tally marks and their relationship to separate activity areas identified within the cave, namely saltpeter processing and saltpeter mining. Although mining artifacts and features at sites such as Big Bone Cave and Mammoth Cave are also well-preserved, these sites are so large and extensively mined, that a fair amount of “noise” is present in the archaeological record; processing areas and mining areas are often commingled, thus it is difficult to ascertain if tally marks were associated with a specific activity.

Methodology

In the present study, processing areas and mining areas were defined by the following criteria: Processing areas are those areas containing artifacts related to saltpeter processing, such as leaching vats, vat casts, and collection troughs. Mining areas are those areas that exhibit tools marks, which are indicative of sediment removal (De Paepe 1979, 1985). In order to identify and differentiate these discrete activity areas within Cagle Saltpetre Cave, during the survey and mapping project, artifacts and features related to saltpeter processing and mining were mapped using the Nikon total station. A series of points were collected for larger artifacts and features, including the mining areas, and the leaching vats, casts, and troughs indicative of saltpeter processing activities. Points were collected from the central location of tally marks.

Results

Using the ArcGIS® software program, artifacts and features associated with saltpeter processing and saltpeter mining were mapped and examined for spatial patterns. A map of these data, shown in Figure 26, clearly identifies discrete activity areas within Cagle Saltpetre Cave. These results indicate that saltpeter processing activities took place in Areas A and B of the cave, while saltpeter mining was restricted to Areas B and C.

In all, 38 sets of tally marks were identified and mapped. Spatial examination of these features mapped using the ArcGIS® software program, shown in Figure 27, indicates a direct association between tally marks and a specific activity, namely saltpeter mining. From these results, it can be deduced that tally marks were used to record the amount of sediment that was mined and collected at a given time. If the tally marks represented amounts of processed leachate, it is assumed that they would be found in association with the processing areas. Although there are numerous places in both Areas A and B on which to place tally marks, such as ceiling breakdown, none were identified in close proximity to artifacts and features related to saltpeter-processing. The exact quantity of mined sediment each tally represented is not known. As discussed in Chapter III of this thesis, a variety of methods were employed for transporting the mined sediment to the processing equipment, and the types selected depended upon the particular operation. The large-scale operations at sites such as Great Saltpetre (George 2001), Mammoth (Faust 1967; George 2001), and Sauta Cave (Faust 1955; Smith 1983), employed ox- or mule-drawn

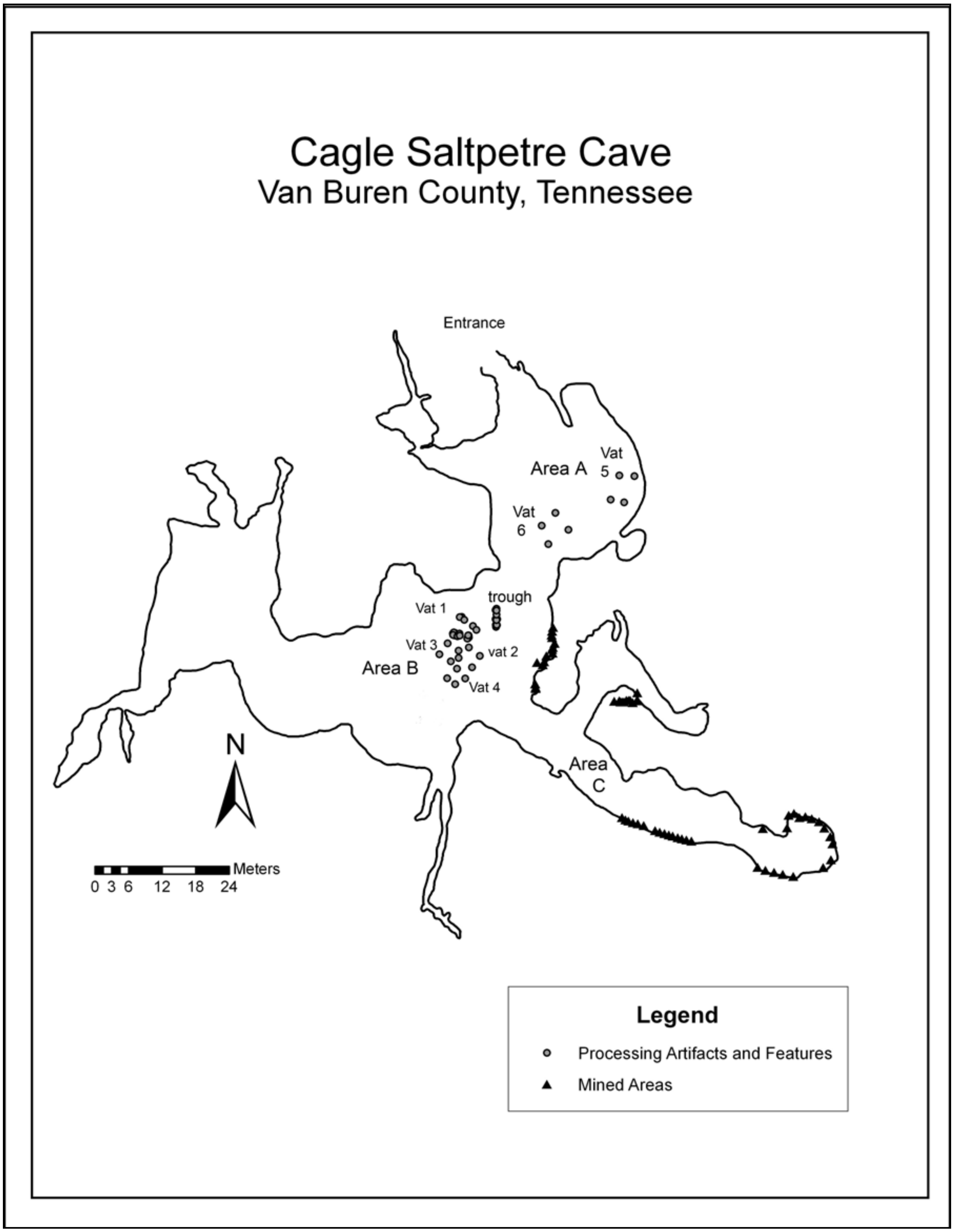

Figure 26. ArcGIS® map of the locations of processing areas and mined areas in Cagle Saltpetre Cave.

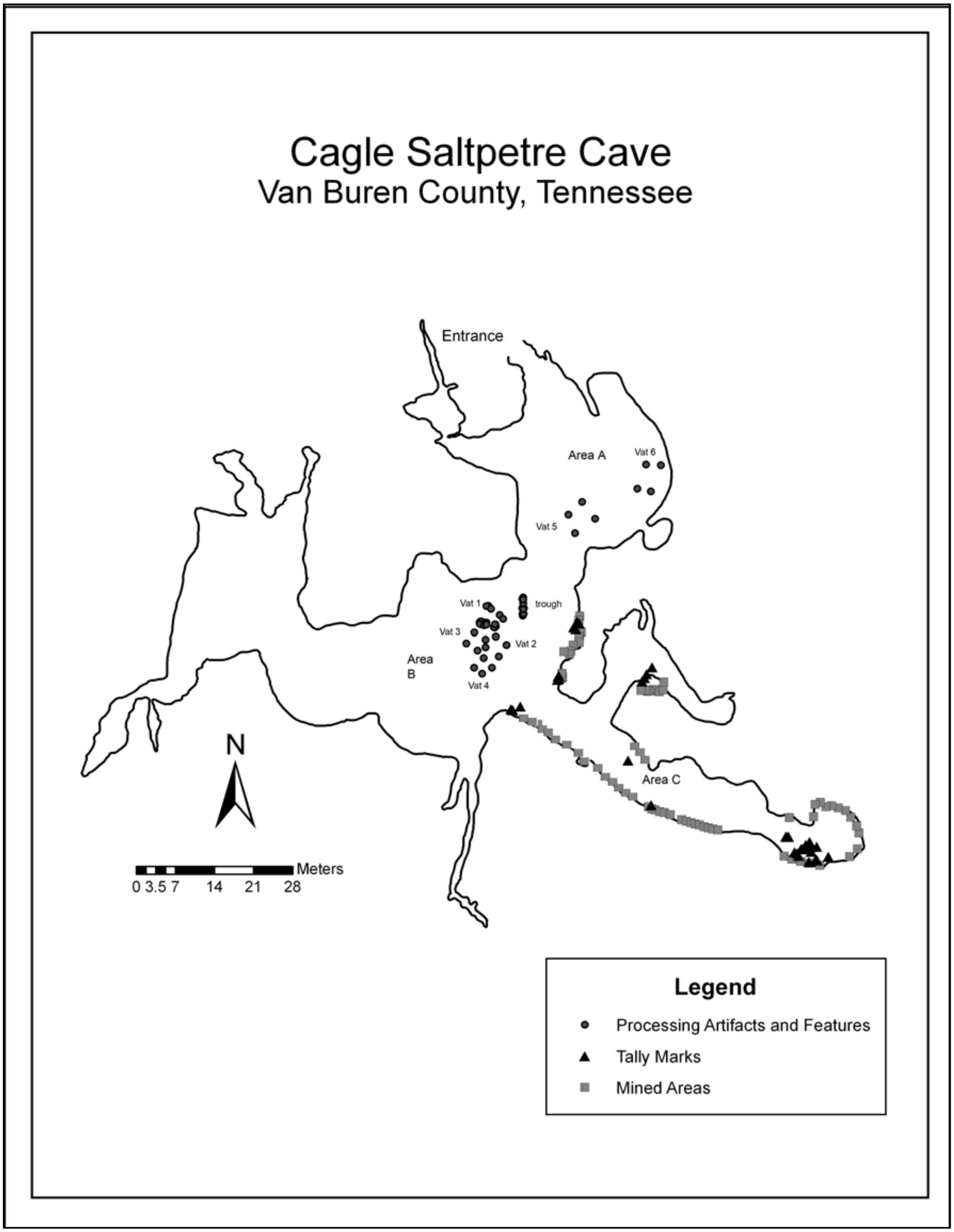

Figure 27. ArcGIS® map of the locations of processing areas, tally marks, and mined areas in Cagle Saltpetre Cave.

carts to transport cart-loads of “petre-dirt” to the processing areas. Faust (1955) also discusses sites where sediments were collected in burlap bags or gunny sacks and then transported via manual labor. A contemporaneous account of the early 19th century operations at Big Bone Cave states that sediment was collected in such a manner (Maddox 1813: 175):

> The sun was declining in the west, and his rays bore in a direct line against the mouth of the cavern, intermixing light and darkness with such hideous perplexity, as to leave the mind in doubt, which of the two to adopt. At the same time that there is issued from its mouth a column of smoke, occasioned by the burning torches within, which gave to the whole an appearance that seemed to realize the most exaggerated picture of the infernal regions! While a smutty crew in tatters, resembling nothing but devils incarnate, bore in black sacks, the nitre and bitumen which seemed to constitute the horrors of the place.

RECONSTRUCTING THE LOCATION OF THE WATER TRANSPORT SYSTEM

The lixiviation of nitrates from cave sediments required a considerable supply of fresh water. Elaborate water transport systems at large-scale mining operations in caves such as Great Saltpetre (George 2001), Mammoth (Borreson 1942; De Paepe 1979, 1985), and Big Bone (Matthews 1967, 1971), used hollowed log pipes to carry fresh water to the leaching areas and leach-water out of the caves. Few areas in Cagle Saltpetre Cave have noticeable amounts of water and would certainly have not been sufficient for the processing activities. There is some evidence for a fresh-water transport system at Cagle Saltpetre Cave, although it was probably not of equal scale to those found at the abovementioned sites. A hollowed log, assumed to be a component of the water transport system (Figure 28), is present in Area B of the lower level of the cave though it has most likely been moved from its original location. In addition, five “flagpoles,” or long, thin saplings cut to form a “Y” at one end (Figure 29), are also present in Area B, and are similar to those used in some areas of Mammoth Cave to support and elevate the end of the water pipe system (George 2005: Figure 1-12; 78). A ca. 1889 (Ganter and Darnell 1889a; George 2005) reconstruction of the Mammoth Cave pipeline using these types of forked trees for support is shown in Figure 30 (*Note:* According to George [2005: 79], the stacked rock support pillars seen in Figure 30 are an erroneous reconstruction.)

The greatest evidence for a water transport system at the site is the presence of wooden trough sections, or “gutters,” strategically placed on stacked stone pillars that begin near the cave entrance (Figure 31). In order to determine the exact location of such an installation at Cagle Saltpetre Cave, the locations of both the rock pillars and trough remnants throughout the length of the cave were mapped and spatially examined using ArcGIS® software.

Methodology

During the survey and mapping project, artifacts and features believed to be representative of the water installation system at Cagle Saltpetre Cave were mapped using the Nikon total station. Included in this investigation were the “flagpoles” and hollowed log pipe discussed in the preceding section, and the

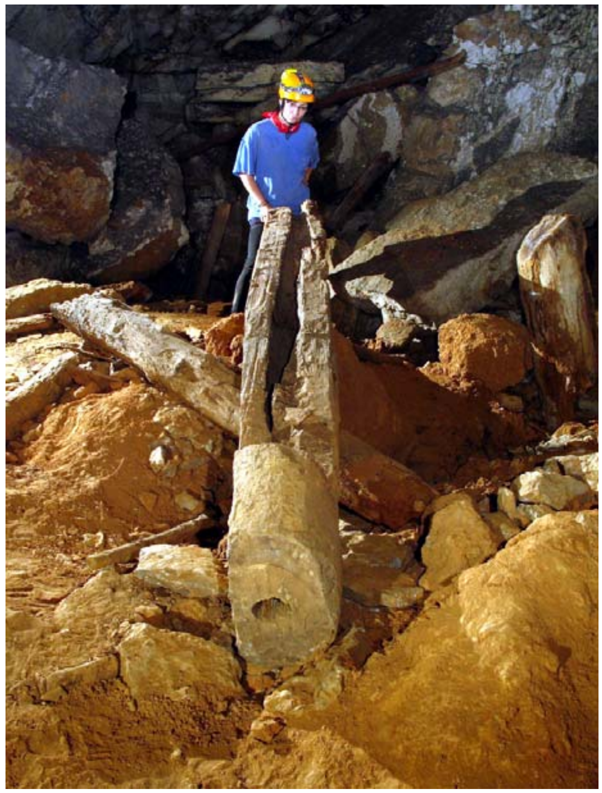

Figure 28. Hollowed log pipe section in Area B of Cagle Saltpetre Cave.
Photo by Alan Cressler.

Figure 29. “Flagpole” in Area B of Cagle Saltpetre Cave.

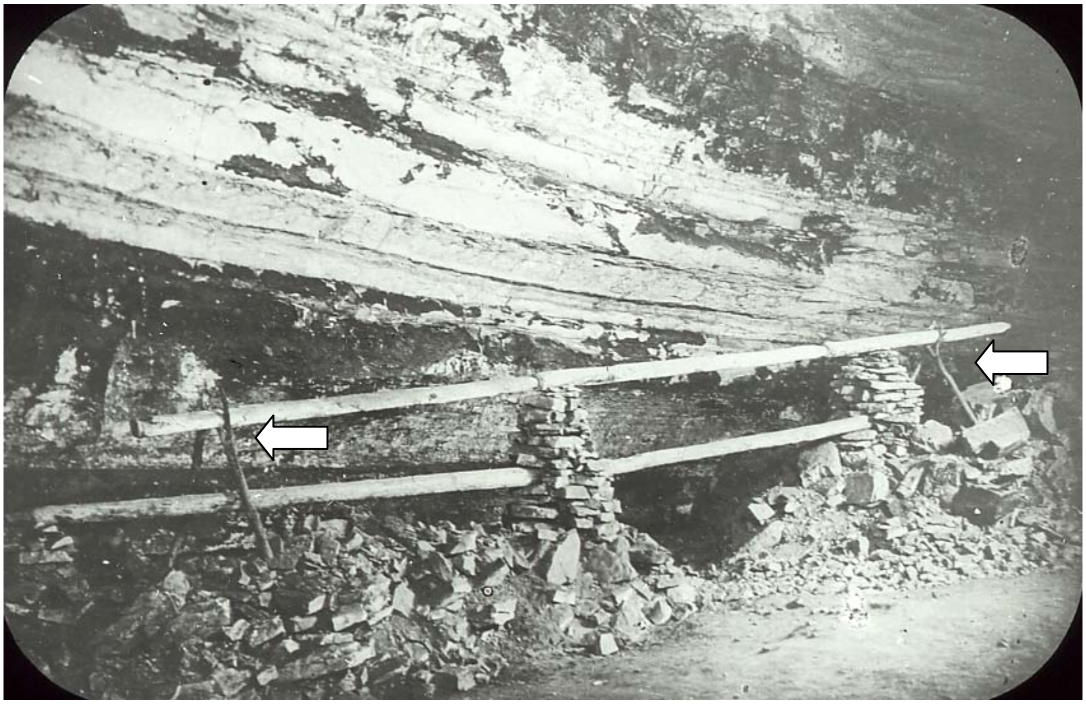

Figure 30. Examples of Y-shaped “flagpoles” used in construction of the water transport system in Mammoth Cave. (Mammoth Cave Series, Mammoth Cave, Kentucky. Old Entrance. *Sections of original wooden pipe in position as they were used in securing salt peter; one line brings fresh water in, the other line carries water, loaded with salt peter, out. slide*, The Jesse Earl Hyde Collection, Case Western Reserve University [CWRU] Department of Geological Sciences, Cleveland, Ohio).

Figure 31. A wooden trough section or “gutter” on a stacked stone pillar at Cagle Saltpetre Cave.

stacked stone pillars and *in situ* trough remnants. Points were collected from the central location of the stone pillars and trough remnants. A series of points were collected for larger artifacts, including the "flagpoles" and log pipe section.

Results

The results of the water transport installation mapping project and ArcGIS® analysis are shown in Figures 32 and 33. Twenty-three *in situ* stone pillars were identified and mapped along with eight trough remnants remaining in their original context. Spatial examination of these remains indicates that the pillars were constructed along the natural talus slope from the cave entrance to the leaching vats in Areas A and B. Thus the water would have been conveyed to the processing areas with the aid of gravity. There is no evidence (e.g., a pump system similar to that of Great Saltpetre [George 2001] and Mammoth Cave [Borreson 1942; De Paepe 1979, 1985; Faust 1967]) to conclude that the leach water was conveyed to the cave entrance using such an installation. Therefore, the leach water may have been transported to the entrance via manual labor and the final processing steps, i.e., boiling and refining, conducted outside the cave. Conversely, this final process may have taken place inside the cave. An interview with a local informant, Lester Medley, in June of 2005 confirmed the results of the water transport system mapping project and ArcGIS® analysis and provided further insight into how this installation may have originally looked. Medley and his father visited Cagle Saltpetre Cave a number of times during the 1960s and removed several artifacts, including "eleven poplar troughs"

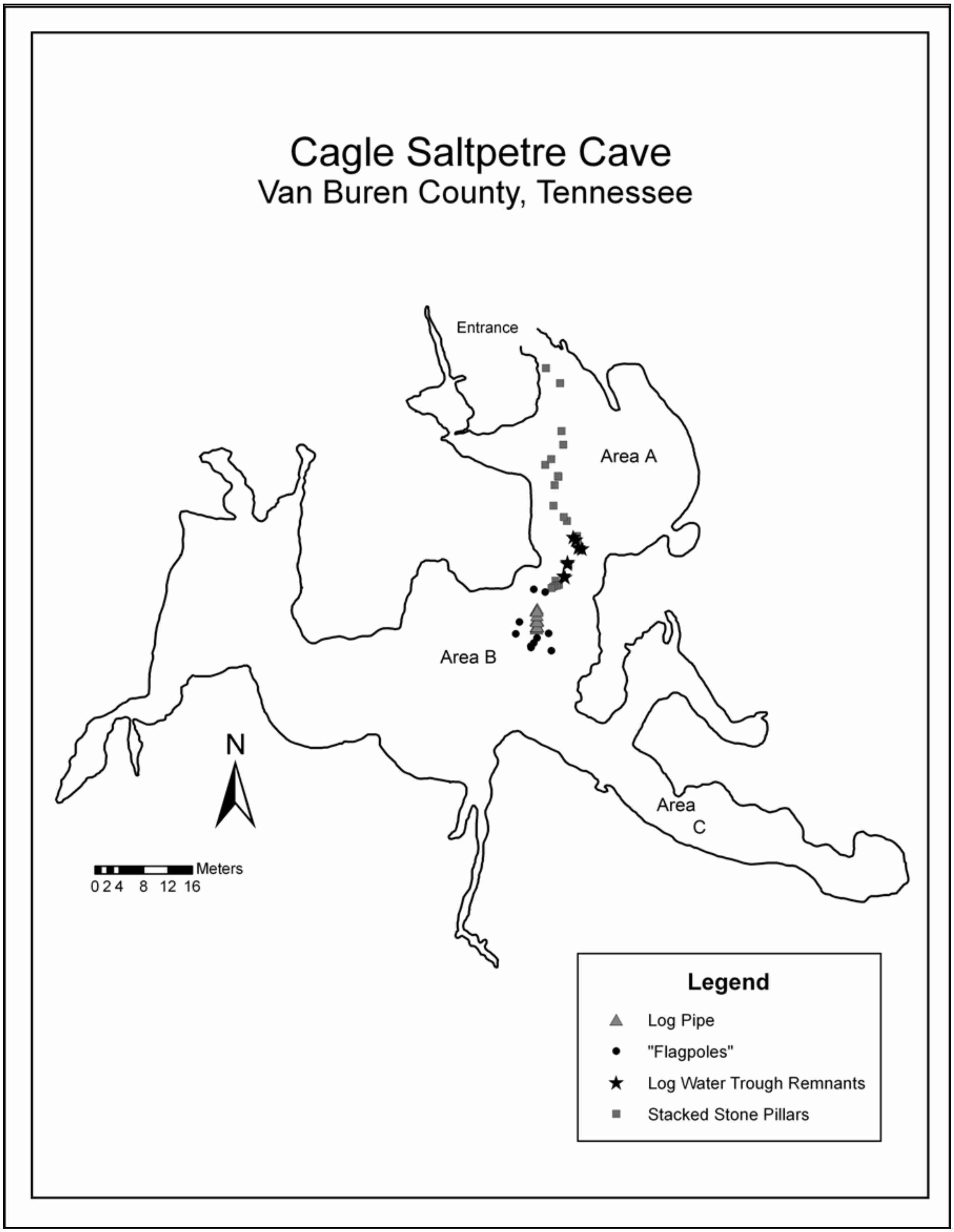

Figure 32. ArcGIS® map of the water transport system and artifacts related to this installation at Cagle Saltpetre Cave, full view.

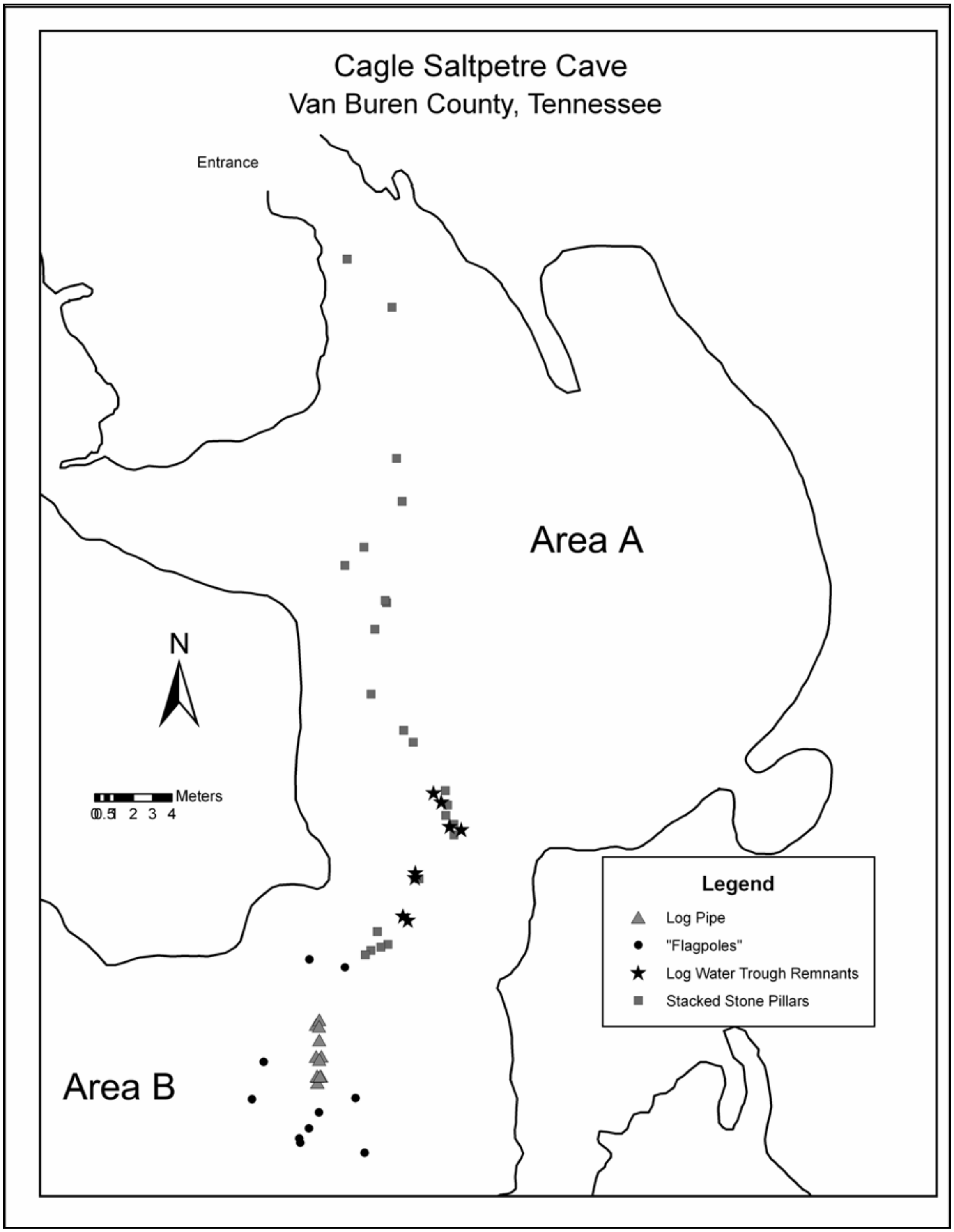

Figure 33. ArcGIS® map of the water transport system and artifacts related to this installation at Cagle Saltpetre Cave, close view.

and “one cedar trough” (Lester Medley, personal communication). Whether these troughs were used to collect leachate or were associated with the fresh water transport system is not known. Only two preserved poplar troughs still remain at the site. At that time, Medley stated that several components of the water “piping” installation were still intact. A “…trough was set at the drip line [at the cave entrance] and [the water] ran down like rain in gutters to the vats” (Lester Medley, personal communication). He also remembers the troughs being “lazy overlapped” along the stacked stone pillars. In other words, they were laid in a zig-zag fashion (Figure 34). There is a 13 m elevation change from the cave entrance to the first processing area, Area A, and another 12 m descent to the lower level vat area, Area B. Accordingly, the zig-zag construction design probably served to slow the propulsion of the water as it flowed down the system, helping to keep the troughs in place. According to Medley, the water installation system terminated in Area B where the “flagpoles” “…were standing up at that time holding the troughs” (Lester Medley, personal communication). Medley states that the fresh water appeared to have been collected in red cedar barrels, one of which he and his father removed from the cave. No other barrels or remnants of such have been found at the site. During the winter and spring, the drip line at the entrance of the cave would have provided the volume of water needed for the leaching process. Therefore, it is possible that operations in the mine were sporadic, or seasonal, depending upon rainfall. There is some evidence that other small-scale industries were particularly active after the end of the growing season, late fall, winter, and early spring, when farming demanded

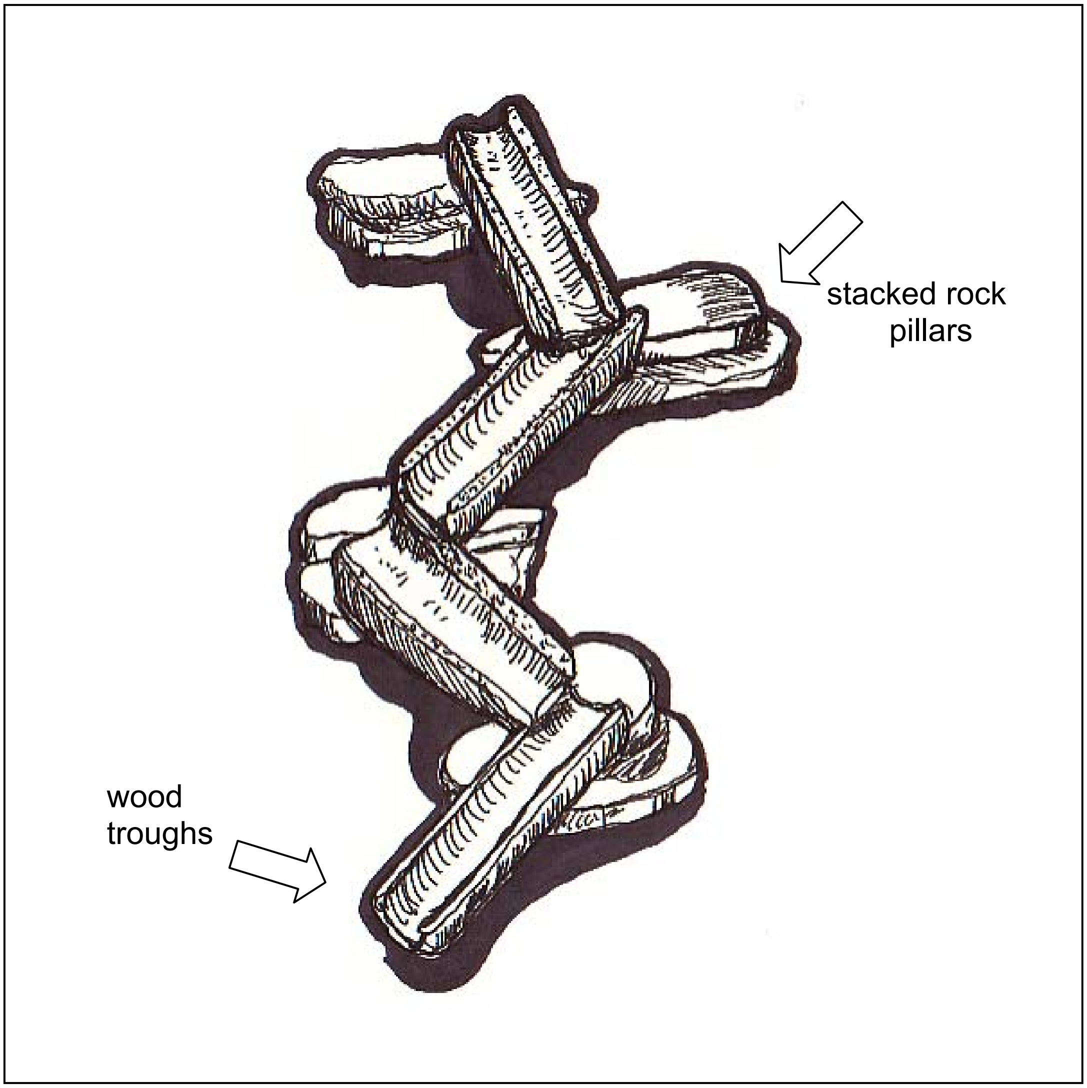

Figure 34. Author's conception of the water transport system at Cagle Saltpetre Cave. Drawing by Matthew Stewart.

less time (Douglas 1993; Garner and Pace 1985). This is illustrated in an account of Thomas Rogers (1871), a rural Kentuckian whose family occasional made gunpowder for supplemental income (O'Dell 1995: 84):

> Every summer after the corn was laid by and harvest over we would make powder a month or so and attend at the courts to sell it…This was a pretty profitable business at that time and when [father] concluded to move to Ohio [in 1797], he made a couple of bags full, 75 pounds each, and packed them on a horse. When we came to Chillicothe I sold them for one dollar and twenty-five cents a pound to James and McCoy, merchants.

Conversely, fresh water from Cane Creek or a small branch of the creek that runs approximately 54 m below the cave may have been brought to the cave entrance.

Prehistoric Utilization of Cagle Saltpetre Cave

If much prehistoric material remained at Cagle Saltpetre Cave prior to the 19th century, it was likely destroyed and/or disturbed during the historic saltpeter mining episodes. However, some evidence concerning the prehistoric utilization of the cave is still present at the site and was documented during the survey and mapping project (Figure 35). These findings are discussed in the following sections.

PREHISTORIC ARTIFACTS AND FEATURES

Pottery

Only three fragments of prehistoric ceramics were identified at Cagle Saltpetre Cave. Two of these fragments were found *in situ* in an alcove near the cave entrance (see Figure 35) and were left in place. At least one, shown in

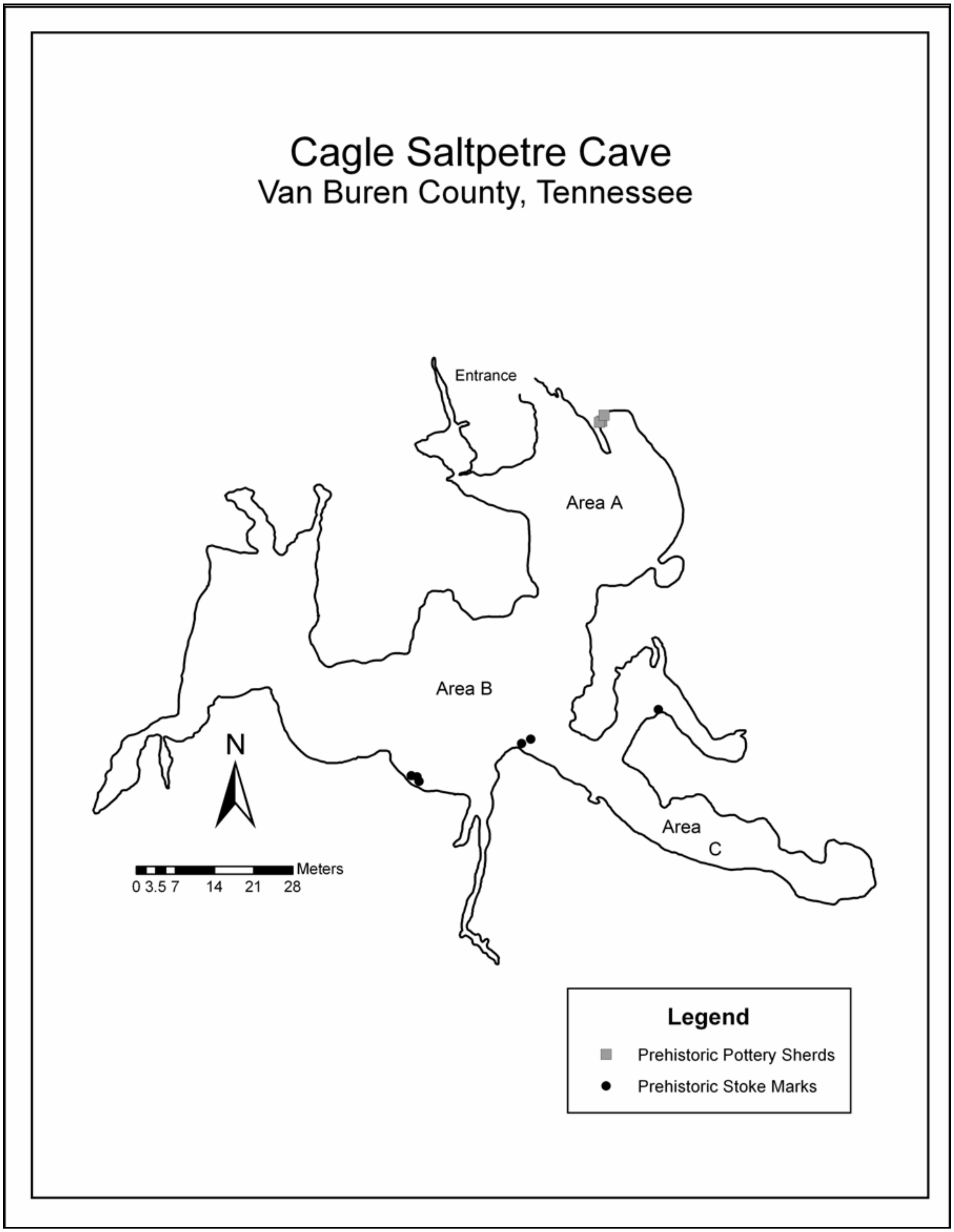

Figure 35. ArcGIS® map of the location of prehistoric artifacts in Cagle Saltpetre Cave.

Figure 36, is a rim sherd. These *in situ* sherds were not removed and are covered with a heavy patina, thus it was not possible to identify certain diagnostic characteristics such as temper, surface treatment, and rim diameter (which would provide insight into vessel form) that might help to anchor these artifacts chronologically. A third sherd was recovered near the cave entrance. It is a limestone-tempered body sherd with no evidence of surface treatment. Because of an absence of other diagnostic elements, a temporal assignment for this sherd cannot be confidently made. Nonetheless, limestone tempered pottery was not common in this region of Tennessee until the Long Branch phase (ca. 400 BC – 200 BC) of the late Early Woodland period (Faulkner 2002). This type of temper was predominant (but with variations in surface treatment) throughout subsequent phases of the Woodland in this region until the Mason phase, ca. AD 800, when ceramics began being tempered with crushed chert (Faulkner 2002). By the Mississippian period (ca. AD 1000 – 1600) pottery tempering shifted from a predominance of the abovementioned tempering agents to the use of shell (Smith 1986). However, based on these observations, a date range of ca. 400 BC – AD 400 for this sherd can be proposed, which indicates that the cave was utilized to some degree during the late Early Woodland to late Middle Woodland periods.

Stoke Marks

Six sets of prehistoric, river cane (*Arundinaria sp.*) stoke marks were identified and mapped at Cagle Saltpetre Cave (see Figure 35). An example of

Figure 36. *In situ* prehistoric ceramic rim sherd in Cagle Saltpetre Cave.

these features is shown in Figure 37**.** These indicate that prehistoric peoples did indeed explore the dark zone of the cave. At present, stoke marks have only been identified in Areas B and C of the cave. If more of these features are present at the site, they are likely just unseen under the thick layers of torch soot that cover the cave walls and ceilings; a result of the historic mining episodes.

River Cane Fragments

As discussed in the overview of cave archaeology in Chapter II, it has been well documented that river cane (*Arundinaria sp.*) was often used by prehistoric peoples as a light source in dark zone cave environments. Therefore, in addition to stoke marks, fragments of the river cane torches themselves are certainly indicative of prehistoric dark zone exploration. Two cane torch fragments were identified and recovered from Cagle Saltpetre Cave. These remains were located under sections of ceiling breakdown in Area B (Figure 38).

The cane torch fragments were submitted to Beta Analytic, Inc. for AMS radiocarbon dating. These radiocarbon assays are shown in Table 1 and include an uncalibrated date of 3970 ± 40 (Beta-205515; cane charcoal; $\delta^{13}C = -27.6^{0}/_{00}$) and an uncalibrated date of 3760 ± 40 (Beta-205516; cane charcoal; $\delta^{13}C = -27.2^{0}/_{00}$). For the date 3970 ± 40 the two possible calibrated age ranges are 2550-2540 cal. BC (p =.05) and 2490-2300 cal. BC (p = .95) (Calibrated at 2σ with the program INTCAL98 [Stuiver et al. 1998]). For the date 3760 ± 40 the calibrated age range is 2210 – 2010 cal. BC (p = .95) (Calibrated at 2σ with the program INTCAL98 [Stuiver et al. 1998]). These dates indicate that prehistoric

Figure 37. River cane stoke marks in Cagle Saltpetre Cave.

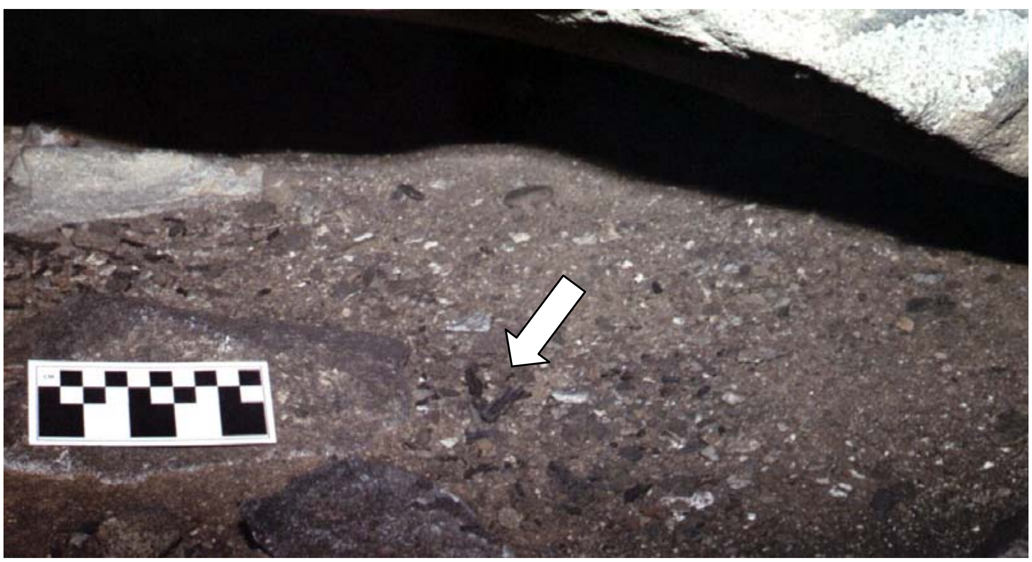

Figure 38. River cane torch fragments under ceiling breakdown in Cagle Saltpetre Cave.

Table 1. AMS radiocarbon determinations from Cagle Saltpetre Cave.

SAMPLE NUMBER	**MEASURED RADIOCARBON AGE**	**±**	**CALIBRATED DATE RANGE**
Beta-205515	3970	40	2550 - 2540 cal. BC; 2490 - 2300 cal. BC
Beta-205516	3760	40	2210 - 2010 cal. BC

hunter-gatherers explored Cagle Saltpetre Cave during the Late Archaic period, as early as 4500 ± 20 cal. B.P., and place Cagle Saltpetre Cave among the earliest sites (e.g., Jaguar Cave [Robbins et al. 1981] and 3rd Unnamed Cave [Crothers et al. 2002] in Tennessee and Lee Cave [Watson, ed. 1974], and Mammoth Cave [Watson, ed. 1974] in Kentucky) of prehistoric dark zone exploration in the Midsouth.

CHAPTER VI
DENDROCHRONOLOGICAL INVESTIGATIONS AT CAGLE SALTPETRE CAVE

Tree-ring analyses make possible the assignment of precise calendar years to wood specimens from a variety of contexts; thus the application of dendrochronological techniques to archaeology has allowed unparallel accuracy in establishing specific ranges of dates for archaeological sites (Bannister 1965, 1969; Douglass 1921, 1935; Nash 1996; Schulman 1952; Smiley 1951; Stallings 1939). In the southeastern U.S., dendrochronology has been used only sparingly in archaeological research on prehistoric sites (Bell 1952; Hawley 1938) and on historic structures (Bortolot et al. 2001; Langley 2000; Mann 2002; Stahle 1979; Stahle and Wolfman 1985; Wight and Grissino-Mayer 2004). Contributing to this paucity of studies is a long history of regional timber exploitation and deforestation in the southeastern U.S. that has removed many of the older tree specimens required for developing the reference chronologies needed to date archaeological samples. Additionally, the warmer, more humid environment of the Southeast is not conducive to the preservation of wood, as it generally promotes more rapid fungal decay (Wight and Grissino-Mayer 2004: 92).

The dry caves common to the karst plateaus of the Southeast provide an environment in which conditions are often favorable for the preservation of wood and other organic material. The exceptional preservation of extant wooden artifacts at Cagle Saltpetre Cave provided a unique opportunity to use tree-ring analyses to better understand the historic mining operations that took place at the site.

Field Methods

In the summer of 2005, a total of 93 sections of wood from white oak (*Quercus alba*) planks used in the construction of the leaching vats in Cagle Saltpetre Cave was removed for tree-ring analysis. Samples were taken from each of the three square-type vats, designated Vat 2, Vat 3, and Vat 4, and the exposed V-shaped vat, designated Vat 1. To maintain provenience, each sample was mapped using a Trimble laser transit total station prior to removal and labeled accordingly (Figure 39). Because the majority are buried, only one exposed V-shaped vat could be dated by tree-ring analysis; therefore, the total number of V-shaped vats employed within the cave is not known. However, the dated V-shaped vat is directly associated with at least one other, as they were built within a single log frame, similar to those shown in Figure 40.

Analytical Methods

Prior to the dating process, the dendrochronological samples were qualitatively examined to assess their crossdating potential. Samples that were both well preserved and exhibited 50 or more annual rings with variable widths were selected for analyses. The variation in ring width from year to year is particularly important, as it is the recognizable sequence of wide and narrow

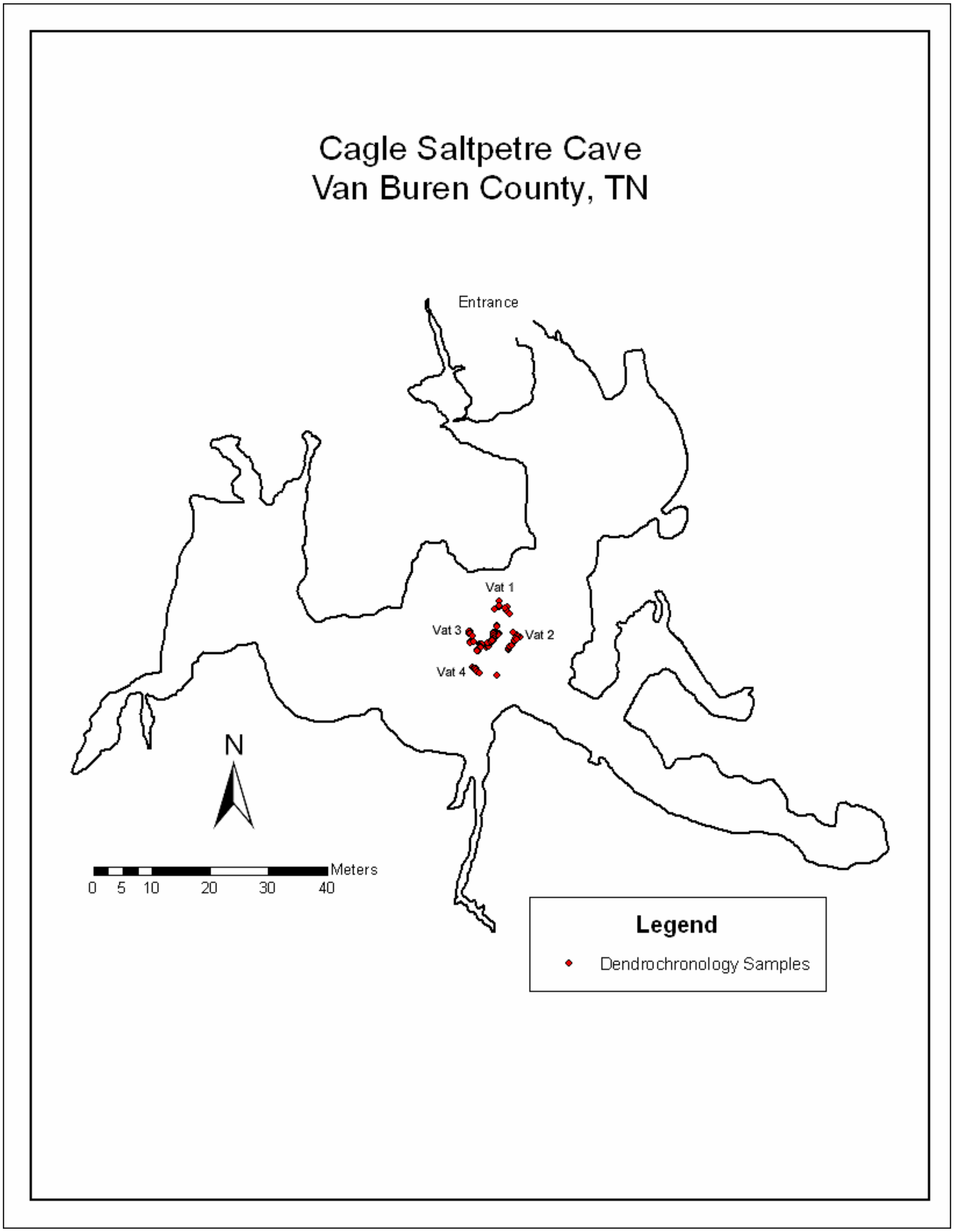

Figure 39. ArcGIS® map showing the locations of dendrochronological samples from Cagle Saltpetre Cave.

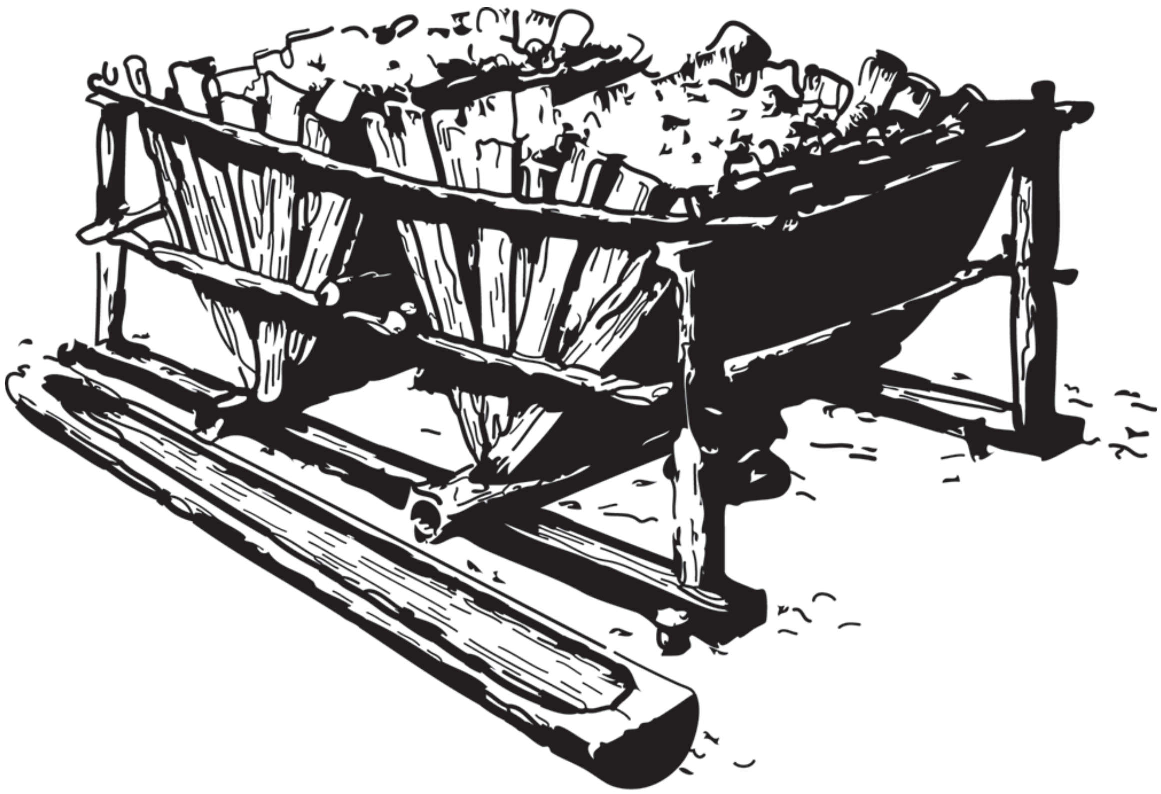

Figure 40. V-shaped vats built using a single log frame (from Faust 1967:47).
Drawing by Matthew Stewart.

rings that makes crossdating possible. In preparation for dating, each sample was sectioned by band saw and surfaced using progressively finer sandpaper, beginning with ANSI 100-grit (123-149 µm) and ending with ANSI 320-grit (32.5-36 µm) (Orvis and Grissino-Mayer 2002; Wight and Grissino-Mayer 2004). To begin the dating process relative dates were assigned to 62 undated series. The innermost ring on each sample was set to the relative year "0" and every subsequent tenth ring was marked by mechanical pencil.

To help assign absolute dates to all samples, all tree-ring widths were measured to the nearest 0.001 mm using a Velmex measuring system interfaced with Measure J2X® measuring software. The measurement series from the 62 undated samples were next statistically crossdated to regional chronologies obtained from the International Tree-Ring Data Bank (2005) using the computer program COFECHA, testing 40-year segments (with a 20-year overlap) of each undated segment series with the respective segment contained within the reference chronology (Grissino-Mayer 2001; Holmes 1983). The Piney Creek Pocket Wilderness (Duvick 1983) and Norris Dam State Park (Duvick 1981) (in the neighboring Valley and Ridge region) white oak reference chronologies were selected to represent similar elevation sites in the Cumberland Plateau physiographic province, where Cagle Saltpetre Cave is located (ITRDB 2005) (Figure 41). When a series was shown to be significantly correlated ($p < 0.001$) with other series within a regional reference chronology, the EDRM (Edit Ring Measurement) program (Holmes 1992a; Wight and Grissino-Mayer 2004) was used to assign absolute dates to each sample. Those series that were

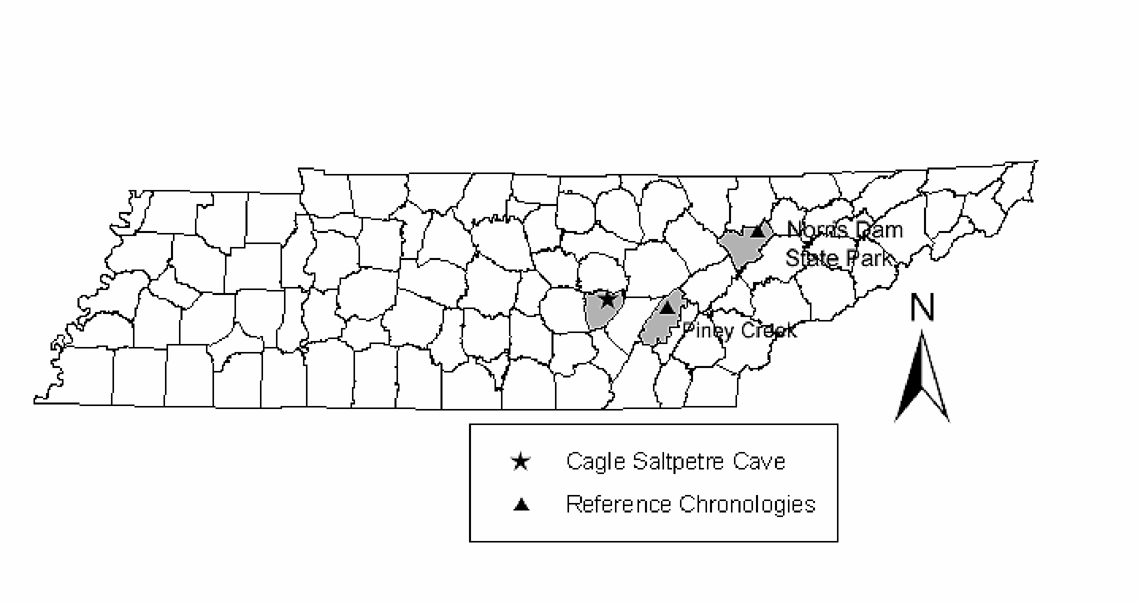

Figure 41. Locations of Cagle Saltpetre Cave (Van Buren County), the Piney Creek Pocket Wilderness reference chronology (Rhea County), and the Norris Dam State Park reference chronology (Anderson County).

confidently crossdated to a regional reference chronology were then compiled to build an intrasite chronology. Again using COFECHA, the intrasite chronology was used to statistically crossdate the remaining undated series. The CRONOL computer program (Cook 1985; Holmes 1992b) was used to create a final chronology from all dated series.

Results

Of the 62 measured series, 23 could not be confidently crossdated to a regional reference chronology nor to the intrasite chronology and were not included in further analyses. The lack of confident dating by COFECHA for these samples could occur because (1) preservation of these samples is inferior to other series, which would lessen the accuracy of annual ring measurements, or (2) their ring segments are complacent thus precluding successful dating by statistical techniques. The latter explanation is possible, as the mean sensitivity of the crossdated series (0.175) is lower than the average mean sensitivity (0.22) for white oak (*Quercus alba*) contained within the ITRDB (2005) (see page 172 of the Appendix). The mean sensitivity is a measurement of the "relative difference in width from one ring to the next" (Fritts 2001: 257). Lower values of mean sensitivity indicate more low-frequency variance and therefore less year-to-year ring-width variations (Fritts 2001: 260-261).

When the undated series were compared with each individual regional chronology, only one match was found that was statistically convincing. Eight of the undated series showed a significant correlation with the Norris Dam State

Park white oak chronology from Anderson County, Tennessee, which spans from 1633 to 1980 (Duvick 1981). This result indicates that the Cagle Saltpetre Cave chronology extends from 1692 to 1861 (Figure 42). Also observed was a significant correlation among the remaining undated series and the intrasite reference chronology as indicated by the statistically significant correlation coefficients in nearly all comparisons. The interseries correlation coefficient (which indicates the quality of crossdating among all series with the master chronology) for the 39 samples was 0.587, a significant value by dendrochronological standards (see page 172 of the Appendix) (Henri Grissino-Mayer, personal communication). COFECHA flagged only seven 40-year segments for possible errors out of the 161 segments tested (see page 172 of the Appendix). Closer inspection of these 10 segments indicated significant correlations at the current dated position, while the alternative placements suggested by COFECHA were unrealistic.

CUTTING DATES

Because the bark and outermost rings were still present, it was possible to determine the exact year in which the trees were cut for 30 of the 39 crossdated samples (see page 172 of the Appendix). Establishing a range of dates for an archaeological site based on tree-ring dates, however, can be difficult, as timbers can be stored, reused, and replaced throughout the occupational history of a site (Dean 1997; Grissino-Mayer and van de Gevel 2007). To minimize possible errors when interpreting crossdated cutting dates, observations are based on the

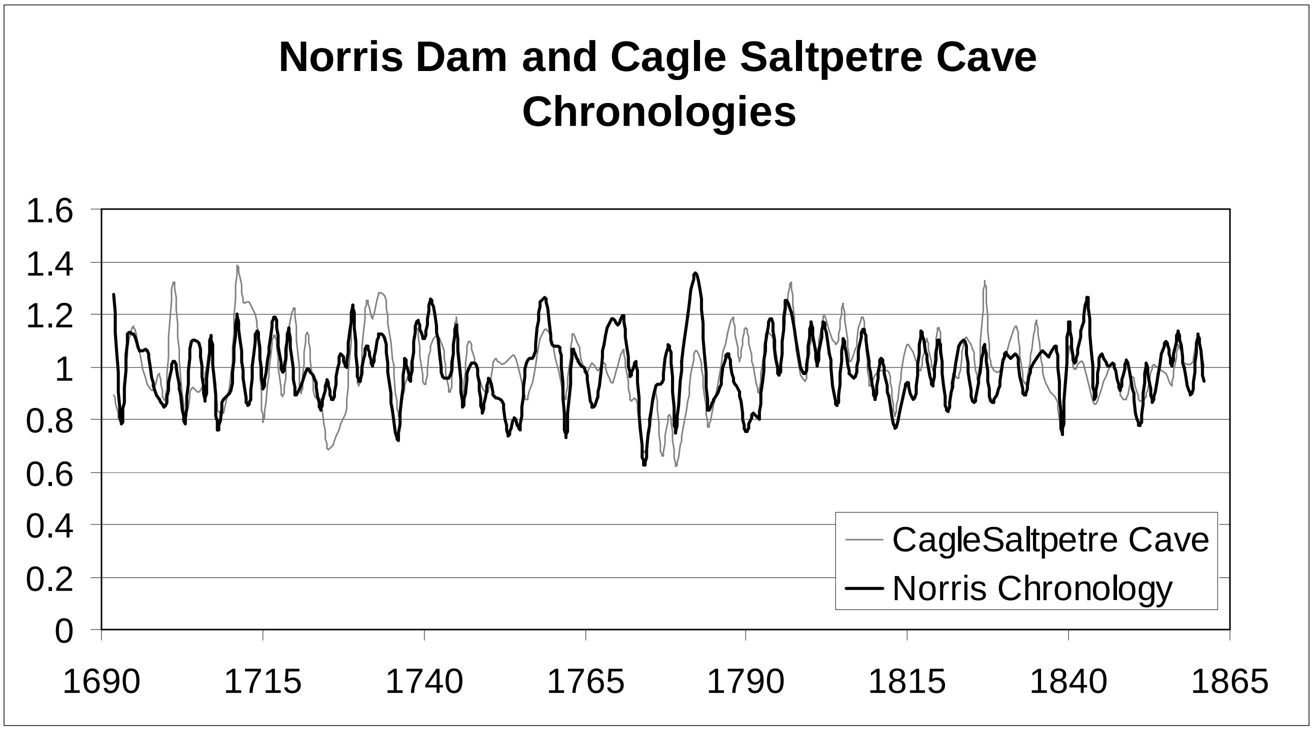

Figure 42. Comparison of the Norris Dam State Park reference chronology and the Cagle Saltpetre Cave white oak chronology developed in this study.

degree of clustering associated with these dates (Grissino-Mayer and van de Gevel 2007; Stahle 1979). The cutting dates of these samples do provide a *terminus post quem* for when these particular leaching vats were in use at Cagle Saltpetre Cave.

The cutting dates for four of the five dated samples associated with Vat 1, the V-shaped vat, clustered on the year 1811. The outer ring on the remaining sample is 1807. This was not a cutting date because the bark and outermost rings had been removed as the logs were scored and hewn. Samples from the three, overlying square-type vats yielded later dates. Seven of the crossdated series from Vat 3 had cutting dates of 1854. The outermost ring on one sample is 1853, which is a non-cutting date as the bark and outer rings are no longer present. The outermost ring of the remaining sample from Vat 3 is 1859, a later date than all other crossdated series associated with this vat. This sample could indicate later repair and reuse of Vat 3, or may simply be an issue of provenance. In comparison to the other square-type vats, Vat 3 is in a more advanced state of disrepair. Given their close proximity, it is possible that this sample may have been associated with Vat 2 or Vat 4. Cutting dates for Vat 4 clustered on the year 1860. Four additional timbers had outermost dates in the 1850s, all non-cutting dates. Ten of the 12 dated planks associated with Vat 2 clustered on the year 1861, with the remaining having outermost dates in the mid- to late 1850s, all of which were non-cutting dates.

Discussion

When considering the political and economic conditions in the United States during the early 19th century, an 1811 construction date for the underlying V-shaped vat is certainly plausible. As discussed in Chapter III, prior to this time, the American colonies (and later, the United States) had not developed an extensive saltpeter industry and relied heavily on imported gunpowder and refined saltpeter from Great Britain (George 1988; O'Dell 1995; Smith 1990). In regions of British India, high concentrations of potassium nitrate could be found in certain surface deposits. This gave Britain control over one of the world's most extensive and easily obtainable supplies of saltpeter. Imported British saltpeter was of such high quality and low cost that domestic sources were often not worth mining. However, the period 1807 to 1815 was characterized by disrupted shipping in the Atlantic. France and Britain, engaged in war since 1803, both restricted trade in any ports controlled by their adversaries. The American responses to these blockades, the 1807 Embargo Act, the 1809 Non-Intercourse Act, the 1810 Macon's Bill Number Two, and finally the American war with Britain (declared in June of 1812), further hindered U.S. trade with Europe (George 1988; Hickey 1989; O'Dell 1995; Smith 1990).

As a result, the demand and price for saltpeter increased as the U.S. became reliant on domestic sources. This is illustrated in an 1829 correspondence from E.I. du Pont, then proprietor of America's largest gunpowder manufacturer, the du Pont Powder Works, to Lieutenant-Colonel George Bomford, of the U.S. Ordance Department (George 1988: 19):

> The high prices of Saltpetre and brimstone from 1804 to 1807 were due in part to the general war in Europe and more to the circumstance that at that time the greatest proportion of Gunpowder used in the country being imported and but a few powder mills being in operation, no regular supply of materials had yet been established.
>
> It is to be observed that during the Six [sic] years of restrictions on commerce and war, the whole supply of saltpetre was furnished from the caves of Kentucky, Virginia and Tennessee; that although the great encrease [sic] of capital and industry which had been directed to the extraction of Saltpetre from the natural caves contributed until 1814 to prevint [sic] an extraordinary rise in the value of the article, a much greater change would have taken place if the war had continued a year longer.

The value of the Midsouth states' saltpeter caves is evident in the 1810 Arts & Manufactures Census (Coxe 1814), in which Kentucky, Tennessee, and Virginia are listed as supplying the bulk of the country's domestic saltpeter. Additionally, White County, which at the time would have encompassed Cagle Saltpetre Cave, and adjacent Warren County, are listed as producing close to 130,000 pounds of saltpeter in 1810, more than 3/4 the total amount produced in western (now Middle) Tennessee. The majority of saltpeter produced in White County likely came from Big Bone Cave. An 1813 account of the Big Bone Cave operations states, "[t]his cave…employs at present about one hundred workmen, who manufacture five hundred pounds of nitre per day" (Maddox 1813: 176).

A somewhat substantial commercial enterprise was certainly in place in western (middle) Tennessee during this time, as 22 caves are listed as being mined for saltpeter in 1810, 19 of which were in White County; this number, however, is likely understated (Joseph Douglas, personal communication). Twenty-one gunpowder mills were also in operation, three in White County producing the majority of gunpowder in the western district (Coxe 1814; see pages 42, 138–139 and 142–143). Although caves were commercially mined prior to the early 19th century, a large number of smaller caves throughout the Southeast, such as Cagle Saltpetre Cave, were used during the period 1807 to early 1815 as a result of the embargoes and second war with Britain.

A possible construction date of 1854 for Vat 3 could again reflect disrupted shipping of refined British saltpeter. Great Britain and France entered into the Crimean War with Imperial Russia in 1854, which may have necessitated stricter British control over the export of saltpeter (Anderson 1967). In the mid-1850s, there is other evidence of a renewed interest in saltpeter mining in Tennessee (Smith 1990: 7-8), specifically at Big Bone Cave (Smith 1985: 1):

> By a deed dated December 3, 1855, David Williams granted Thomas B. Eastland and Montgomery C. Dibrell use of water and timber adjoining Big Bone Cave for saltpetre manufacturing. In February, 1856, Eastland and Dibrell were incorporated by the legislature, with the name "White County Mining and Saltpetre Mining and Manufacturing Company."…Also in the late 1850's, additional Van Buren County deeds show that Charles, Charles C., and George Henshaw of Boston Massachusetts, and William Campbell and M.D.W. Loomis of Cincinnati, Ohio, each briefly held shares in the mining of Bone Cave.

Additionally, the mining of Cagle Saltpetre Cave, Big Bone Cave, and other caves throughout the Cumberland Plateau during the first half of the 19th century is certainly due in part to the inaccessibility of the region. At the time, poor roads and the absence of railroads undoubtedly made travel through the

Cumberland Mountains and to and from middle Tennessee difficult. Thus, Tennessee was incompletely integrated into the greater saltpeter market. Gunpowder was needed for both hunting and protection, therefore local production was essential.

Later construction dates of 1854, 1860, and 1861 for the square-type vats denote changes in saltpeter processing technology during the course of mining episodes at Cagle Saltpetre Cave. One apparent advantage of the square-type construction was its ability to hold several hundred cubic feet of cave sediment. During the leaching process, this would have provided a greater yield of leachate compared to the smaller, V-shaped vats. In addition, use of the square-type vats may indicate a more organized and perhaps, larger-scale operation, as it would have taken several men to mine and process the cave sediment.

Even before Tennessee withdrew from the Union in June 1861, Tennesseans took quick action to ensure that the State would be prepared for war. Among their chief concerns was securing an adequate supply of gunpowder, of which saltpeter was the critical component. As discussed in Chapter V, prior to secession, the Tennessee legislature established a three member Military and Financial Board to encourage the production or purchase of gunpowder and saltpeter (Horn [ed.] 1965; Smith 1990, 1997). “To acquire saltpeter, contracts were made with individuals or companies, and up to $2,000 per contractor was advanced to help start an operation” (Smith 1990: 8). In July of 1861, board member James E. Bailey gave the following instructions to Edwin Glascock, one of the Board’s employed saltpeter agents (Smith 1997: 102):

> We wish you to visit salpetre caves near Chattanooga; viz [*sic*] Nicajack, Lookout, & Sauta Caves (the latter in Jackson cty Ala) the Big bone [sic] caves in Van Buren Cty worked by Mr Randal & other caves in that & adjoining counties, & the caves being worked through the mountains.
>
> We wish you…to get parties to work all the Caves where sal-petre can be made. To this end we authorize you to make contracts for all the salpetre that can be made in eight & Ten months for 25 cents per pound delivered on the railroads.

Although no records exist that indicate Cagle Saltpetre Cave was commercially mined during this time, the Military Board records do suggest that, in addition to Big Bone Cave, a number of caves in Van Buren County may have supplied the Confederate war efforts.

CHAPTER VII
SUMMARY AND CONCLUSIONS

The industrial use of caves in the Midsouth "…had a significant impact upon local, regional, and national economies, and is part of a larger story of the history of the American environment" (Douglas 2001b: 251). Although saltpeter mining was among the most important early industries within America's caves, not much is known about day-to-day mining operations. Systematic research of these sites is integral to a greater understanding of this early extractive industry, yet little archaeological research has been conducted on this subject. The few studies undertaken have been focused primarily in Kentucky. This research has illustrated that although some similarities within the industry did exist, the methods employed in the mining operations often varied. These previous investigations are certainly informative; however, if we are to better understand the industry as a whole, we cannot rely solely on the data generated from the study of only one or two sites.

While saltpeter mining in general was a widespread, regional industry, the majority of saltpeter mining was conducted on a small scale. As a result, contemporaneous accounts of the mining and production processes are often non-existent. Furthermore, unlike the more well-known and well-researched, large-scale sites (such as Mammoth Cave), there is a paucity in archaeological inquiry into these small-scale operations. The archaeological and dendrochronological investigations of Cagle Saltpetre Cave presented in this thesis have helped to remedy the lack of formal study at such sites. Moreover, archaeological research concerning the saltpeter industry in Tennessee is sparse. Therefore, this study also contributes to our understanding of localized saltpeter operations, particularly in middle Tennessee.

The research goals outlined at the beginning of this study were: to examine specific mining activities and saltpeter processing technologies employed at Cagle Saltpetre Cave, to establish specific temporal parameters for when the mining activities took place, and to delineate changes in processing technology over time. Each of these questions has been addressed in this study by employing both an archaeological and dendrochronological approach.

The archaeological investigations of Cagle Saltpetre Cave included archival research, a comprehensive survey and mapping project, and GIS-based spatial analyses. The archival research, designed to find documentation of the mining operations at the site, produced primarily negative results, although some evidence concerning the ownership of the cave was located. Based on this research, two possible proprietors of Cagle Saltpetre Cave during the 19th century mining operations are proposed, Thomas Harbert and Jefferson J. Walker, respectively. The latter of the two may have worked the cave during the Civil War. If Jefferson J. Walker did indeed oversee the Civil War-era operations at Cagle Saltpetre Cave, his associations with the Confederate Army are probably significant, as many of the caves in the area, including Big Bone Cave, were worked at that time under government contract.

The survey and mapping portion of this research successfully documented for the first time the precise location of many of the preserved *in situ* artifacts and features resulting from both the prehistoric and historic utilization of the cave. This provides Fall Creek Falls State Park a detailed record of the cultural remains at the site, which will help them better manage and protect it. The data generated from this project also allowed the examination of spatial patterns in the archaeological record. On the basis of these results, interpretations have been made concerning specific mining activities that occurred at the site. In addition, the mapping project allowed the reconstruction of a specific component of the mining operations.

Spatial patterning of tally marks and artifacts and features associated with both saltpeter processing and saltpeter mining indicates that tally marks were used to record the amount of sediment that was mined and collected at a given time. Thus, these features are associated with a specific activity at the site, namely saltpeter mining, rather than saltpeter processing. Although the presence of tally marks has been noted at a number of sites, the purpose of these features has been largely speculative. This was the first systematic study conducted in an attempt to account for this phenomenon.

Certain remains believed to be related to the water transport system in Cagle Saltpetre Cave were also mapped and spatially examined. Primary evidence for such an installation consists of wooden trough sections, or “gutters,” located on stacked stone pillars within the cave. Spatial examination of these artifacts indicates that the pillars were constructed along the natural talus slope from the cave entrance to the leaching vats in Areas A and B. Thus using this installation, fresh water was conveyed from the cave entrance to the processing areas via gravity. Based on the results of this study and an interview with a local informant, it is now possible to reconstruct with a fair level of confidence the 19th century water installation in Cagle Saltpetre Cave.

Although the prehistoric utilization of Cagle Saltpetre Cave was not the primary focus of this thesis, the archaeological survey did identify the cave as a prehistoric site. Chronologically, the cave was explored to some extent as early as the Late Archaic period. AMS radiocarbon dates obtained from river cane fragments within Area B of the cave indicate that prehistoric hunter-gathers traversed the dark zone of the cave between 2550 ± 10 cal. BC and 2110 ± 10 cal. BC. This places Cagle Saltpetre Cave among the earliest sites of prehistoric dark zone exploration in the Midsouth. A single ceramic sherd recovered near the cave entrance may also indicate prehistoric occupation/utilization of the twilight zone of the site during the late Early Woodland to late Middle Woodland periods. Furthermore, two *in situ* rim sherds identified near the cave entrance may be indicative of food storage activities. However, because these artifacts were left in place, the author was not able to properly analyze them. Therefore, a temporal assignment for these artifacts cannot be made at this time.

Dendrochronological analyses were employed to establish a significant level of chronometric control for when mining activities took place at Cagle Saltpetre Cave. The results of tree-ring analyses indicate that the site was mined at various times during the 19th century. Cutting dates established for the preserved leaching vats clustered on four discrete dates: Vat 1, the V-shaped vat dates to 1811; Vat 3, a square-type vat dates to 1854; Vat 4, a square-type vat, dates to 1860; and Vat 2, a square-type vat, dates to 1861. Cagle Saltpetre Cave was likely mined during these times in reaction to both local and global politico-economic pressures. The earlier mining episodes at Cagle Saltpetre Cave and, furthermore, the intensification of the saltpeter industry as a whole during the early 19th century, reflect domestic responses to fluctuations in the global saltpeter market during the years 1807-1811 and 1854. Thus, in addition to other 19th century industries, the exploitation of American caves, even those in remote areas, were part of and affected by the broader global marketplace, or world-system (Wallerstein 2004). During the Civil War, Union blockades of southern ports caused the Confederate States to place heavy priority on the production of saltpeter. Consequently, a number of caves in the region, including Cagle Saltpetre Cave, were mined during the initial years of the Civil War (1860-1861).

The results of the dendrochronological analyses also demonstrate that throughout the 19th century, saltpeter processing technology used at the site changed during the course of mining, i.e., processing technology shifted from the use of V-shaped vats during the War of 1812-era mining episodes, to the use of the square-type vat during the mid-19th century. The latter vat type was also used during the Civil War-era mining episodes.

This study represents the first dendrochronological dating of a saltpeter-mining cave site and developed the first tree-ring chronology from artifacts preserved in a cave context in the Midsouth. It may now be possible to obtain dendrochronological dates for other saltpeter mining sites from the region by using the reference chronology developed in this study.

RECOMMENDATIONS FOR FUTURE RESEARCH

While the archaeological and dendrochronological investigations presented in this study offer an important contribution to the understanding of the saltpeter industry in Tennessee, future studies of additional saltpeter mining sites will be required to complete our understanding of this early extractive industry. A systematic archaeological and dendrochronological study of the saltpeter works in Big Bone Cave in particular would provide important data for this area of research. Because the preservation of saltpeter mining artifacts in Big Bone Cave is remarkable, it should be possible to date these artifacts dendrochronologically. If successful, the tree-ring chronology developed from such analyses would be invaluable. Furthermore, I believe that the mining operations at Big Bone Cave and Cagle Saltpetre Cave are in some way connected. As mentioned previously in this thesis, the vat types used in both Cagle Saltpetre Cave and Big Bone Cave are almost identical. Additionally, the historic documentation and research undertaken by Smith (1985, 1987) concerning the Big Bone Cave operations has indicated that Cagle Saltpetre Cave and Big Bone Cave were mined concurrently. Again, dendrochronological analyses would be required to conclusively establish a chronology for the mining activities.

In closing, the remarkable preservation of the extant archaeological record within dry caves provides a unique opportunity for examining historic exploitation of the underground environment. However, as time goes on, because many of these sites remain unprotected, the conditions of these remains are deteriorating due to increasing recreational traffic. Therefore, additional research is needed before these important cultural resources are irrevocably damaged.

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APPENDIX

The following are the descriptive statistics and results from the segment testing conducted by COFECHA for the 39 measured series from Cagle Saltpetre Cave.

```
 []  DENDROCHRONOLOGY PROGRAM LIBRARY                                      Run MASTE  Program COF  16:17  Tue 22 NOV 2005  Page   1
 []
 []  P R O G R A M      C O F E C H A                                                                        Version 3.00P    25895
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QUALITY CONTROL AND DATING CHECK OF TREE-RING MEASUREMENTS

File of DATED series:   newmast.txt

CONTENTS:

   Part 1:  Title page, options selected, summary, absent rings by series
   Part 2:  Histogram of time spans
   Part 3:  Master series with sample depth and absent rings by year
   Part 4:  Bar plot of Master Dating Series
   Part 5:  Correlation by segment of each series with Master
   Part 6:  Potential problems: low correlation, divergent year-to-year changes, absent rings, outliers
   Part 7:  Descriptive statistics

RUN CONTROL OPTIONS SELECTED                             VALUE

        1  Cubic smoothing spline 50% wavelength cutoff for filtering
                                                           32 years
        2  Segments examined are                           50 years lagged successively by  25 years
        3  Autoregressive model applied                     A  Residuals are used in master dating series and testing
        4  Series transformed to logarithms                 Y  Each series log-transformed for master dating series and testing
        5  Critical correlation, 99% confidence level   .3281
        6  Master dating series saved                       N
        7  Ring measurements listed                         N
        8  Parts printed                              1234567
        9  Absent rings included in master series           N

Time span of Master dating series is  1692 to  1861   170 years
Continuous time span is               1692 to  1861   170 years
Portion with two or more series is    1697 to  1861   165 years

                                       ****************************************
                                       *C* Number of dated series        39 *C*
                                       *O* Master series 1692 1861  170 yrs *O*
                                       *F* Total rings in all series   3992 *F*
                                       *E* Total dated rings checked   3987 *E*
                                       *C* Series intercorrelation     .587 *C*
                                       *H* Average mean sensitivity    .175 *H*
                                       *A* Segments, possible problems    7 *A*
                                       ****************************************
ABSENT RINGS listed by SERIES:            (See Master Dating Series for absent rings listed by year)
No ring measurements of zero value
```

```
PART 2:  TIME PLOT OF TREE-RING SERIES:                                                           16:17  Tue 22 NOV 2005  Page   2
-----------------------------------------------------------------------------------------------------------------------------------
1000      1100      1200      1300      1400      1500      1600      1700      1800      1900      2000             Beg   End
                                                                                                        Ident    Seq year year   Yrs
  :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    : -------- --- ---- ---- ----
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .<=========>   .    .    . CAGV4009   1 1765 1860    96
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    <==============>    .    .    . CAGV4004   2 1705 1854   150
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    <==============>    .    .    . CAGV4011   3 1702 1859   158
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    <=========>    .    .    . CAGV4015   4 1751 1859   109
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <========>   .    .    . CAGV2006   5 1774 1861    88
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .   <======>   .    .    . CAGV219B   6 1791 1861    71
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .   <===========>   .    .    . CAGV2001   7 1746 1861   116
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .<=========>   .    .    . CAGV2003   8 1760 1861   102
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <=======>    .    .    . CAGV2005   9 1779 1858    80
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <========>   .    .    . CAGV2009  10 1776 1861    86
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .<=========>   .    .    . CAGV2013  11 1763 1861    99
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <======>    .    .    . CAGV2015  12 1786 1855    70
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    <==========>   .    .    . CAGV2017  13 1750 1861   112
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  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <=======>   .    .    . CAGV2016  16 1784 1861    78
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .<=========>   .    .    . CAGV2018  17 1769 1861    93
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .   <===========>   .    .    . CAGV4001  18 1743 1860   118
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .   <==========>    .    .    . CAGV4003  19 1743 1859   117
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <========>   .    .    . CAGV4006  20 1771 1860    90
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  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    <=====>   .    .    .    . CAGV1005  26 1751 1811    61
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .   <======>   .    .    .    . CAGV1008  27 1747 1811    65
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    <=====>   .    .    .    . CAGV1006  28 1752 1811    60
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .   <=====>    .    .    .    . CAGV1003  29 1749 1807    59
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    <=====>   .    .    .    . CAGV1007  30 1756 1811    56
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <============>    .    .    . CAGV3001  31 1724 1854   131
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    <==============>    .    .    . CAGV3009  32 1705 1854   150
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  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    <=========>    .    .    . CAGV3019  34 1752 1854   103
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  .    .    .    .    .    .    .    .    .    .    .    .    .    .    <==============>    .    .    . CAGV3031  36 1701 1854   154
  .    .    .    .    .    .    .    .    .    .    .    .    .    .   <===============>    .    .    . CAGV4006  37 1697 1853   157
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <===========>    .    .    . CAGV3017  38 1733 1854   122
  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    <=========>    .    .    . CAGV3023  39 1753 1859   107

  :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :
1000      1100      1200      1300      1400      1500      1600      1700      1800      1900      2000
```

Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab
															1692	-.947	1
															1693	-2.471	1
															1694	1.197	1
															1695	1.960	1
															1696	.808	1
															1697	.048	2
															1698	-.373	2
															1699	.191	2

Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab
1700	-.797	2	1750	-.967	16	1800	.006	39	1850	.358	34						
1701	2.595	3	1751	.250	18	1801	-.432	39	1851	-.869	34						
1702	.642	4	1752	-.119	20	1802	.998	39	1852	-.739	34						
1703	-1.171	4	1753	.356	21	1803	.511	39	1853	.624	34						
1704	-.337	4	1754	.092	21	1804	.093	39	1854	.494	33						
1705	-.842	7	1755	-.544	21	1805	1.555	39	1855	.043	25						
1706	-.212	7	1756	-1.754	22	1806	-.306	39	1856	-.900	24						
1707	.825	7	1757	-.450	22	1807	.108	39	1857	1.020	24						
1708	-1.542	7	1758	.772	22	1808	1.151	38	1858	-.059	24						
1709	-1.682	7	1759	.915	22	1809	-1.226	38	1859	-.083	23						
1710	-.313	7	1760	.695	23	1810	-.601	38	1860	.955	19						
1711	1.979	7	1761	-.161	23	1811	-.489	38	1861	.247	10						
1712	1.325	7	1762	-.877	23	1812	-.509	34									
1713	1.355	7	1763	1.205	24	1813	-2.569	34									
1714	.954	7	1764	.913	24	1814	-.398	34									
1715	-1.790	7	1765	.058	26	1815	.733	34									
1716	-.368	7	1766	.379	26	1816	.334	34									
1717	.625	7	1767	.574	26	1817	-.300	34									
1718	-.578	7	1768	.537	26	1818	.984	34									
1719	.924	7	1769	.101	27	1819	-.336	34									
1720	1.383	7	1770	.753	27	1820	1.295	34									
1721	-.643	7	1771	1.200	28	1821	-2.041	34									
1722	.914	7	1772	-.095	30	1822	-.543	34									
1723	-.657	7	1773	.037	30	1823	-.683	34									
1724	-.524	8	1774	-1.660	32	1824	.726	34									
1725	-2.121	8	1775	-.678	32	1825	.298	34									
1726	-1.659	8	1776	.344	33	1826	-.700	34									
1727	-.870	8	1777	-1.290	33	1827	2.401	34									
1728	-.958	8	1778	-.453	33	1828	-.168	34									
1729	1.176	8	1779	-2.038	34	1829	-.393	34									
1730	-.506	8	1780	-.828	34	1830	.011	34									
1731	1.463	8	1781	.114	35	1831	.796	34									
1732	1.086	8	1782	1.258	35	1832	1.034	34									
1733	1.677	9	1783	.703	35	1833	-.773	34									
1734	1.545	9	1784	-1.192	36	1834	.181	34									
1735	.147	9	1785	-.863	36	1835	1.559	34									
1736	-1.729	9	1786	.032	37	1836	-.029	34									
1737	-.897	9	1787	.851	37	1837	-.815	34									
1738	-.271	9	1788	1.237	37	1838	-1.098	34									
1739	.940	9	1789	-.055	37	1839	-2.714	34									

1740	-.653	9	1790	.748	37	1840	1.080	34
1741	.586	9	1791	-.296	38	1841	.460	34
1742	.983	9	1792	-1.309	38	1842	.759	34
1743	.169	11	1793	.573	38	1843	.038	34
1744	-1.123	11	1794	.385	38	1844	-.897	34
1745	1.330	11	1795	-1.092	39	1845	-.442	34
1746	-1.016	12	1796	.827	39	1846	.595	34
1747	.512	13	1797	1.786	39	1847	.728	34
1748	-.203	14	1798	-.427	39	1848	-.524	34
1749	-.896	15	1799	-1.479	39	1849	-.799	34

```
-------------------------------------------------------------------------------------------------------------------------------------
  Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value
                                  1700--c         1750-d          1800-----@      1850------A
                                  1701----------J 1751------A     1801---b        1851--c
                                  1702-------C    1752-----@      1802---------D  1852--c
                                  1703-e          1753------A     1803-------B    1853-------B
                                  1704----a       1754-----@      1804-----@      1854-------B
                                  1705--c         1755---b        1805----------F 1855-----@
                                  1706----a       1756g           1806----a       1856-d
                                  1707--------C   1757---b        1807-----@      1857---------D
                                  1708f           1758--------C   1808---------E  1858-----@
                                  1709g           1759--------D   1809-e          1859-----@
  ----            ----            ----            ----            ----            ----            ----            ----
                                  1710----a       1760-------C    1810---b        1860--------D
                                  1711----------H 1761----a       1811---b        1861------A
                                  1712----------E 1762-d          1812---b
                                  1713----------E 1763---------E  1813j
                                  1714--------D   1764--------D   1814----b
                                  1715g           1765-----@      1815--------C
                                  1716----a       1766------B     1816------A
                                  1717-------C    1767-------B    1817----a
                                  1718---b        1768-------B    1818---------D
                                  1719--------D   1769-----@      1819----a
  ----            ----            ----            ----            ----            ----            ----            ----
                                  1720----------F 1770--------C   1820---------E
                                  1721--c         1771---------E  1821h
                                  1722--------D   1772-----@      1822---b
                                  1723--c         1773-----@      1823--c
                                  1724---b        1774g           1824--------C
                                  1725h           1775--c         1825------A
                                  1726g           1776------A     1826--c
                                  1727--c         1777-e          1827----------J
                                  1728-d          1778---b        1828----a
                                  1729---------E  1779h           1829----b
  ----            ----            ----            ----            ----            ----            ----            ----
                                  1730---b        1780--c         1830-----@
                                  1731----------F 1781-----@      1831--------C
                                  1732---------D  1782---------E  1832---------D
                                  1733----------G 1783-------C    1833--c
                                  1734----------F 1784-e          1834------A
                                  1735------A     1785--c         1835----------F
                                  1736g           1786-----@      1836-----@
                                  1737-d          1787--------C   1837--c
                                  1738----a       1788---------E  1838-d
                                  1739--------D   1789-----@      1839k
  ----            ----            ----            ----            ----            ----            ----            ----
```

```
               1740--c         1790--------C   1840---------D
               1741-------B    1791----a       1841-------B
1692-d         1742---------D  1792-e          1842--------C
1693j          1743------A     1793-------B    1843-----@
1694---------E 1744-d          1794------B     1844-d
1695----------H 1745----------E 1795-d         1845---b
1696--------C  1746-d          1796--------C   1846-------B
1697-----@     1747-------B    1797----------G 1847--------C
1698----a      1748----a       1798---b        1848---b
1699------A    1749-d          1799f           1849--c
```

Correlations of 50-year dated segments, lagged 25 years
Flags: A = correlation under .3281 but highest as dated; B = correlation higher at other than dated position

Seq	Series	Time_span		1675 1724	1700 1749	1725 1774	1750 1799	1775 1824	1800 1849	1825 1874
1	CAGV4009	1765	1860				.71	.64	.65	.57
2	CAGV4004	1705	1854		.70	.67	.69	.79	.79	.79
3	CAGV4011	1702	1859		.55	.61	.74	.73	.66	.62
4	CAGV4015	1751	1859				.77	.77	.73	.58
5	CAGV2006	1774	1861				.77	.80	.77	.65
6	CAGV219B	1791	1861					.68	.73	.67
7	CAGV2001	1746	1861			.33A	.32A	.48	.56	.59
8	CAGV2003	1760	1861				.33	.50	.55	.68
9	CAGV2005	1779	1858					.72	.67	.64
10	CAGV2009	1776	1861					.43	.73	.74
11	CAGV2013	1763	1861				.50	.64	.70	.69
12	CAGV2015	1786	1855					.54	.48	.48
13	CAGV2017	1750	1861				.12B	.42	.47	.49
14	CAGV4002	1781	1860					.67	.69	.57
15	CAGV2008	1774	1861				.67	.68	.56	.62
16	CAGV2016	1784	1861					.68	.69	.74
17	CAGV2018	1769	1861				.80	.81	.74	.72
18	CAGV4001	1743	1860			.44	.47	.75	.54	.42
19	CAGV4003	1743	1859			.57	.64	.70	.64	.59
20	CAGV4006	1771	1860				.68	.71	.75	.70
21	CAGV4008	1765	1860				.75	.70	.57	.49
22	CAGV4010	1748	1860			.63	.68	.72	.61	.59
23	CAGV4012	1795	1860					.75	.73	.67
24	CAGV4014	1772	1860				.70	.70	.67	.61
25	CAGV4016	1772	1860				.67	.71	.68	.58
26	CAGV1005	1751	1811				.37	.18B		
27	CAGV1008	1747	1811			.44	.50	.50		
28	CAGV1006	1752	1811				.46	.42		
29	CAGV1003	1749	1807			.38B	.39	.28A		
30	CAGV1007	1756	1811				.43	.37		
31	CAGV3001	1724	1854		.61	.62	.57	.65	.64	.62
32	CAGV3009	1705	1854		.57	.61	.70	.52	.55	.53
33	CAGV3013	1705	1854		.73	.71	.62	.63	.55	.51
34	CAGV3019	1752	1854				.76	.59	.50	.52
35	CAGV3021	1692	1854	.51	.51	.59	.80	.50	.43	.50
36	CAGV3031	1701	1854		.75	.67	.62	.57	.66	.68
37	CAGV4006	1697	1853	.67	.69	.63	.69	.71	.70	.70
38	CAGV3017	1733	1854			.59	.55	.36B	.42	.44
39	CAGV3023	1753	1859				.61	.70	.70	.61

```
------------------------------------------------------------------------------------------------------------------------------------

For each series with potential problems the following diagnostics may appear:

[A] Correlations with master dating series of flagged  50-year segments of series filtered with  32-year spline,
    at every point from ten years earlier (-10) to ten years later (+10) than dated

[B] Effect of those data values which most lower or raise correlation with master series

[C] Year-to-year changes very different from the mean change in other series

[D] Absent rings (zero values)

[E] Values which are statistical outliers from mean for the year
====================================================================================================================================

CAGV4009  1765 to  1860      96 years                                                                                    Series   1

[B] Entire series, effect on correlation (  .623) is:
      Lower   1822  -.024   1839  -.022   1857  -.022   1792  -.018  Higher   1813   .018   1809   .017   1827   .016   1774   .012

====================================================================================================================================

CAGV4004  1705 to  1854     150 years                                                                                    Series   2

[B] Entire series, effect on correlation (  .749) is:
      Lower   1751  -.017   1838  -.011   1756  -.010   1709  -.008  Higher   1839   .019   1813   .017   1821   .011   1827   .006

====================================================================================================================================

CAGV4011  1702 to  1859     158 years                                                                                    Series   3

[B] Entire series, effect on correlation (  .641) is:
      Lower   1815  -.032   1839  -.015   1727  -.013   1713  -.010  Higher   1813   .019   1821   .012   1756   .011   1827   .009

[E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1858 +3.1 SD
====================================================================================================================================

CAGV4015  1751 to  1859     109 years                                                                                    Series   4

[B] Entire series, effect on correlation (  .667) is:
      Lower   1851  -.053   1855  -.014   1760  -.013   1806  -.009  Higher   1813   .021   1839   .017   1779   .015   1756   .014

[C] Year-to-year changes diverging by over 4.0 std deviations:
      1850 1851   4.5 SD
```

```
[E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1851 +5.9 SD
==================================================================================================================================

CAGV2006  1774 to  1861      88 years                                                                                    Series   5

[B] Entire series, effect on correlation (  .658) is:
      Lower   1855  -.039   1853  -.013   1774  -.012   1856  -.012  Higher   1839   .049   1813   .047   1821   .015   1805   .010

==================================================================================================================================

CAGV219B  1791 to  1861      71 years                                                                                    Series   6

[B] Entire series, effect on correlation (  .639) is:
      Lower   1794  -.057   1851  -.019   1837  -.015   1792  -.012  Higher   1813   .026   1839   .018   1809   .016   1805   .012

==================================================================================================================================

CAGV2001  1746 to  1861     116 years                                                                                    Series   7

[A] Segment   High   -10    -9    -8    -7    -6    -5    -4    -3    -2    -1    +0    +1    +2    +3    +4    +5    +6    +7    +8    +9   +10
   ---------  ----   ---   ---   ---   ---   ---   ---   ---   ---   ---   ---   ---   ---   ---   ---   ---   ---   ---   ---   ---   ---   ---
   1746 1795    0    .01 -.22 -.11 -.06 -.05  .09  .08  .13 -.14  .05  .33* .00 -.14 -.12  .03  .16  .14 -.16 -.14 -.25 -.22
   1750 1799    0    .13 -.17 -.09 -.06 -.09  .07  .06  .14 -.12  .12  .32*-.07 -.14 -.08  .08  .18  .15 -.12 -.15 -.18 -.13

[B] Entire series, effect on correlation (  .411) is:
      Lower   1760  -.031   1798  -.021   1746  -.019   1750  -.019  Higher   1839   .033   1756   .029   1813   .025   1779   .013
    1746 to 1795 segment:
      Lower   1760  -.064   1746  -.048   1750  -.045   1762  -.027  Higher   1756   .082   1795   .044   1779   .030   1782   .017
    1750 to 1799 segment:
      Lower   1760  -.058   1798  -.046   1750  -.044   1762  -.026  Higher   1756   .081   1795   .047   1779   .031   1782   .016

[E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
      1750 +3.5 SD;    1798 +3.6 SD
==================================================================================================================================

CAGV2003  1760 to  1861     102 years                                                                                    Series   8

[B] Entire series, effect on correlation (  .512) is:
      Lower   1802  -.050   1780  -.019   1815  -.015   1774  -.012  Higher   1813   .044   1821   .026   1839   .014   1827   .012

[E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
      1767 +3.6 SD;    1781 +3.3 SD
==================================================================================================================================

CAGV2005  1779 to  1858      80 years                                                                                    Series   9
```

```
[B] Entire series, effect on correlation (  .665) is:
      Lower   1840  -.039   1845  -.022   1853  -.016   1785  -.012  Higher   1839   .056   1813   .011   1821   .010   1835   .009

[E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1845 +3.4 SD
=================================================================================================================================

CAGV2009  1776 to  1861      86 years                                                                                Series  10

[B] Entire series, effect on correlation (  .537) is:
      Lower   1797  -.045   1795  -.027   1777  -.025   1809  -.024  Higher   1813   .052   1839   .051   1799   .014   1827   .013

=================================================================================================================================

CAGV2013  1763 to  1861      99 years                                                                                Series  11

[B] Entire series, effect on correlation (  .614) is:
      Lower   1794  -.019   1796  -.017   1770  -.014   1858  -.014  Higher   1839   .037   1813   .035   1821   .016   1827   .013

=================================================================================================================================

CAGV2015  1786 to  1855      70 years                                                                                Series  12

[B] Entire series, effect on correlation (  .512) is:
      Lower   1849  -.069   1806  -.062   1821  -.024   1822  -.021  Higher   1813   .087   1839   .030   1827   .016   1792   .014

[E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
      1806 +5.1 SD;    1849 +5.3 SD
=================================================================================================================================

CAGV2017  1750 to  1861     112 years                                                                                Series  13

[A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
   ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
   1750 1799   -3   -.02  .02  .07  .12 -.18  .08 -.09  .29* .18  .06  .12|-.18 -.21 -.05  .08  .20 -.10 -.04 -.11 -.27  .13

[B] Entire series, effect on correlation (  .322) is:
      Lower   1758  -.037   1759  -.027   1756  -.024   1840  -.021  Higher   1839   .044   1813   .030   1774   .018   1799   .012
    1750 to 1799 segment:
      Lower   1758  -.072   1759  -.053   1756  -.044   1787  -.037  Higher   1774   .058   1799   .039   1784   .038   1779   .037

=================================================================================================================================

CAGV4002  1781 to  1860      80 years                                                                                Series  14

[B] Entire series, effect on correlation (  .572) is:
```

```
      Lower   1856  -.041   1828  -.018   1854  -.016   1787  -.016  Higher   1821   .045   1813   .038   1809   .024   1827   .022

[E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1856 +3.8 SD
====================================================================================================================================

CAGV2008  1774 to  1861      88 years                                                                                    Series  15

[B] Entire series, effect on correlation (  .587) is:
      Lower   1848  -.021   1839  -.015   1809  -.013   1774  -.011  Higher   1813   .061   1821   .012   1820   .010   1777   .008

[E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1804 +3.1 SD
====================================================================================================================================

CAGV2016  1784 to  1861      78 years                                                                                    Series  16

[B] Entire series, effect on correlation (  .696) is:
      Lower   1809  -.028   1837  -.014   1828  -.013   1858  -.012  Higher   1839   .038   1821   .027   1813   .022   1835   .008

====================================================================================================================================

CAGV2018  1769 to  1861      93 years                                                                                    Series  17

[B] Entire series, effect on correlation (  .728) is:
      Lower   1839  -.012   1837  -.012   1774  -.010   1778  -.010  Higher   1813   .036   1821   .017   1779   .013   1835   .008

====================================================================================================================================

CAGV4001  1743 to  1860     118 years                                                                                    Series  18

[B] Entire series, effect on correlation (  .482) is:
      Lower   1774  -.043   1839  -.035   1857  -.015   1855  -.013  Higher   1813   .022   1827   .022   1821   .021   1809   .021

[E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
      1774 +4.0 SD;    1855 +3.6 SD
====================================================================================================================================

CAGV4003  1743 to  1859     117 years                                                                                    Series  19

[B] Entire series, effect on correlation (  .602) is:
      Lower   1839  -.022   1747  -.021   1850  -.013   1799  -.013  Higher   1821   .031   1827   .016   1797   .012   1809   .012

====================================================================================================================================

CAGV4006  1771 to  1860      90 years                                                                                    Series  20
```

```
[B] Entire series, effect on correlation (  .652) is:
      Lower   1780  -.024   1839  -.024   1787  -.023   1828  -.011  Higher   1813   .043   1827   .014   1779   .013   1809   .013

[E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1780 +3.3 SD
==================================================================================================================================

CAGV4008  1765 to  1860      96 years                                                                                 Series  21

[B] Entire series, effect on correlation (  .605) is:
      Lower   1847  -.017   1858  -.017   1828  -.016   1780  -.016  Higher   1813   .023   1779   .022   1774   .018   1809   .014

[E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1858 +3.7 SD
==================================================================================================================================

CAGV4010  1748 to  1860     113 years                                                                                 Series  22

[B] Entire series, effect on correlation (  .608) is:
      Lower   1749  -.020   1857  -.016   1832  -.015   1760  -.012  Higher   1813   .028   1774   .014   1827   .012   1809   .011

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CAGV4012  1795 to  1860      66 years                                                                                 Series  23

[B] Entire series, effect on correlation (  .702) is:
      Lower   1834  -.032   1859  -.029   1839  -.023   1828  -.018  Higher   1821   .027   1813   .026   1809   .016   1827   .009

[E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1859 +4.1 SD
==================================================================================================================================

CAGV4014  1772 to  1860      89 years                                                                                 Series  24

[B] Entire series, effect on correlation (  .641) is:
      Lower   1855  -.014   1831  -.011   1844  -.008   1826  -.008  Higher   1809   .015   1827   .012   1774   .009   1820   .008

[E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1855 +3.4 SD
==================================================================================================================================

CAGV4016  1772 to  1860      89 years                                                                                 Series  25

[B] Entire series, effect on correlation (  .589) is:
      Lower   1774  -.028   1775  -.019   1826  -.019   1832  -.017  Higher   1821   .025   1809   .018   1827   .015   1839   .015

[E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
```

```
      1775 +3.3 SD;    1855 +3.9 SD
==================================================================================================================================

CAGV1005  1751 to  1811      61 years                                                                                    Series  26

[A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
   ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
   1762 1811    6   -.12  .22 -.05 -.04  .07  .08  .04 -.26 -.24  .05  .18| .05 -.07 -.08 -.56  .11  .26* .10  .01  .08 -.12

[B] Entire series, effect on correlation (  .308) is:
      Lower   1809  -.082   1795  -.027   1762  -.024   1780  -.023  Higher   1756   .115   1774   .035   1797   .022   1782   .020
    1762 to 1811 segment:
      Lower   1809  -.108   1795  -.033   1762  -.032   1780  -.030  Higher   1774   .068   1779   .045   1797   .040   1782   .035

[E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1809 +3.8 SD
==================================================================================================================================

CAGV1008  1747 to  1811      65 years                                                                                    Series  27

[B] Entire series, effect on correlation (  .493) is:
      Lower   1747  -.021   1795  -.020   1777  -.019   1766  -.019  Higher   1805   .024   1756   .024   1799   .022   1782   .019

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CAGV1006  1752 to  1811      60 years                                                                                    Series  28

[B] Entire series, effect on correlation (  .382) is:
      Lower   1809  -.032   1762  -.026   1775  -.026   1752  -.026  Higher   1774   .061   1756   .042   1795   .034   1779   .034

==================================================================================================================================

CAGV1003  1749 to  1807      59 years                                                                                    Series  29

[A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
   ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
   1749 1798    6    .01 -.02 -.18  .13 -.01  .01  .15 -.20 -.10  .02  .38| .25  .02 -.02 -.31  .19  .39* .25 -.11 -.20 -.08
   1758 1807    0    .07 -.12 -.12  .12 -.15  .09  .16 -.24 -.01 -.01  .28* .21 -.07  .03 -.21  .15  .21  .21  .01 -.05  .02

[B] Entire series, effect on correlation (  .320) is:
      Lower   1762  -.040   1805  -.031   1775  -.025   1777  -.022  Higher   1774   .073   1779   .052   1782   .026   1797   .024
    1749 to 1798 segment:
      Lower   1762  -.045   1775  -.028   1759  -.028   1777  -.024  Higher   1774   .076   1779   .055   1782   .027   1771   .025
    1758 to 1807 segment:
      Lower   1762  -.049   1805  -.036   1775  -.032   1777  -.024  Higher   1774   .103   1779   .074   1782   .030   1797   .028

[E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
```

```
      1762 +3.4 SD
==================================================================================================================================

CAGV1007  1756 to  1811      56 years                                                                                    Series  30

[B] Entire series, effect on correlation (  .431) is:
      Lower   1802  -.036   1777  -.027   1800  -.027   1775  -.024  Higher   1756   .080   1774   .060   1799   .026   1797   .025

==================================================================================================================================

CAGV3001  1724 to  1854     131 years                                                                                    Series  31

[B] Entire series, effect on correlation (  .618) is:
      Lower   1782  -.021   1813  -.014   1754  -.013   1851  -.009  Higher   1809   .010   1839   .008   1827   .008   1736   .008

[E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1767 +3.6 SD
==================================================================================================================================

CAGV3009  1705 to  1854     150 years                                                                                    Series  32

[B] Entire series, effect on correlation (  .592) is:
      Lower   1809  -.016   1808  -.010   1849  -.010   1776  -.009  Higher   1839   .035   1779   .008   1756   .007   1797   .007

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CAGV3013  1705 to  1854     150 years                                                                                    Series  33

[B] Entire series, effect on correlation (  .624) is:
      Lower   1842  -.020   1825  -.017   1850  -.012   1851  -.011  Higher   1839   .031   1725   .013   1774   .011   1821   .008

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CAGV3019  1752 to  1854     103 years                                                                                    Series  34

[B] Entire series, effect on correlation (  .604) is:
      Lower   1848  -.030   1808  -.027   1842  -.026   1813  -.014  Higher   1839   .042   1821   .021   1827   .013   1756   .011

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CAGV3021  1692 to  1854     163 years                                                                                    Series  35

[*] Early part of series cannot be checked from 1692 to 1696 -- not matched by another series

[B] Entire series, effect on correlation (  .558) is:
      Lower   1703  -.020   1813  -.019   1806  -.016   1802  -.013  Higher   1839   .018   1779   .013   1725   .013   1774   .012
```

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===================================================================================================================================

CAGV3031  1701 to  1854     154 years                                                                                    Series  36

[B] Entire series, effect on correlation (  .677) is:
      Lower   1749  -.019   1806  -.009   1756  -.009   1793  -.008  Higher   1839   .024   1725   .009   1774   .009   1827   .006

[E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1749 +3.4 SD
===================================================================================================================================

CAGV4006  1697 to  1853     157 years                                                                                    Series  37

[B] Entire series, effect on correlation (  .684) is:
      Lower   1806  -.017   1736  -.011   1840  -.009   1808  -.007  Higher   1813   .017   1827   .009   1701   .008   1821   .008

===================================================================================================================================

CAGV3017  1733 to  1854     122 years                                                                                    Series  38

[A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
   ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
   1775 1824   -3   -.13 -.21  .17  .13  .08  .00  .10  .39*-.20 -.16  .36| .04 -.09 -.06 -.06  .01  .04  .16 -.25  .04  .00

[B] Entire series, effect on correlation (  .518) is:
      Lower   1816  -.036   1813  -.024   1848  -.022   1809  -.016  Higher   1839   .042   1736   .014   1774   .013   1827   .009
    1775 to 1824 segment:
      Lower   1816  -.087   1813  -.042   1809  -.034   1824  -.032  Higher   1797   .033   1805   .028   1777   .023   1795   .023

===================================================================================================================================

CAGV3023  1753 to  1859     107 years                                                                                    Series  39

[B] Entire series, effect on correlation (  .628) is:
      Lower   1813  -.018   1756  -.016   1754  -.016   1852  -.014  Higher   1839   .049   1774   .015   1827   .012   1797   .011

===================================================================================================================================
```

						Corr	//-------- Unfiltered --------\\					//---- Filtered -----\\			
Seq	Series	Interval	No. Years	No. Segmt	No. Flags	with Master	Mean msmt	Max msmt	Std dev	Auto corr	Mean sens	Max value	Std dev	Auto corr	AR ()
1	CAGV4009	1765 1860	96	4	0	.623	1.54	2.72	.395	.728	.145	2.05	.417	.038	1
2	CAGV4004	1705 1854	150	6	0	.749	1.28	2.24	.312	.442	.208	2.03	.344	-.037	1
3	CAGV4011	1702 1859	158	6	0	.641	1.09	2.02	.357	.798	.159	2.11	.387	.006	1
4	CAGV4015	1751 1859	109	4	0	.667	1.57	3.08	.378	.583	.152	2.51	.485	.049	1
5	CAGV2006	1774 1861	88	4	0	.658	1.65	2.48	.298	.292	.162	1.95	.353	-.009	1
6	CAGV219B	1791 1861	71	3	0	.639	2.16	3.07	.363	.528	.127	1.99	.475	.015	1
7	CAGV2001	1746 1861	116	5	2	.411	1.29	2.31	.385	.759	.149	1.94	.315	.020	1
8	CAGV2003	1760 1861	102	4	0	.512	1.34	3.67	.455	.471	.218	2.38	.478	-.024	2
9	CAGV2005	1779 1858	80	3	0	.665	1.48	2.52	.379	.615	.179	1.90	.312	.052	1
10	CAGV2009	1776 1861	86	3	0	.537	1.57	2.27	.267	.304	.152	2.20	.460	.138	1
11	CAGV2013	1763 1861	99	4	0	.614	1.42	2.52	.354	.611	.149	2.19	.469	.036	1
12	CAGV2015	1786 1855	70	3	0	.512	1.67	4.31	.497	.406	.192	2.38	.374	.024	1
13	CAGV2017	1750 1861	112	4	1	.322	1.30	2.21	.347	.544	.203	2.00	.404	.028	2
14	CAGV4002	1781 1860	80	3	0	.572	1.42	2.33	.317	.547	.161	2.07	.421	-.028	1
15	CAGV2008	1774 1861	88	4	0	.587	1.81	2.65	.310	.144	.176	2.00	.322	-.004	1
16	CAGV2016	1784 1861	78	3	0	.696	1.80	2.55	.274	.463	.130	1.91	.438	-.021	1
17	CAGV2018	1769 1861	93	4	0	.728	2.13	3.11	.415	.552	.139	2.07	.331	.024	1
18	CAGV4001	1743 1860	118	5	0	.482	1.28	2.62	.370	.606	.188	2.10	.353	.041	1
19	CAGV4003	1743 1859	117	5	0	.602	1.29	2.85	.395	.696	.170	2.15	.357	.009	1
20	CAGV4006	1771 1860	90	4	0	.652	1.39	2.41	.335	.529	.171	2.10	.399	.011	1
21	CAGV4008	1765 1860	96	4	0	.605	1.78	2.76	.395	.574	.147	2.15	.421	.065	1
22	CAGV4010	1748 1860	113	5	0	.608	1.52	2.86	.386	.709	.150	1.96	.342	-.001	1
23	CAGV4012	1795 1860	66	3	0	.702	1.59	2.63	.404	.663	.159	2.25	.480	.034	1
24	CAGV4014	1772 1860	89	4	0	.641	1.69	2.63	.371	.672	.138	2.11	.454	.030	1
25	CAGV4016	1772 1860	89	4	0	.589	1.75	2.58	.321	.595	.127	2.11	.383	-.023	1
26	CAGV1005	1751 1811	61	2	1	.308	2.57	4.69	.802	.655	.156	1.81	.292	.090	1
27	CAGV1008	1747 1811	65	3	0	.493	1.80	3.73	.385	-.092	.192	2.22	.503	-.002	1
28	CAGV1006	1752 1811	60	2	0	.382	2.16	3.74	.824	.827	.166	2.03	.418	-.004	2
29	CAGV1003	1749 1807	59	3	2	.320	2.61	4.25	.731	.720	.149	2.11	.491	-.025	2
30	CAGV1007	1756 1811	56	2	0	.431	2.96	4.53	.698	.618	.142	2.00	.362	-.014	2
31	CAGV3001	1724 1854	131	6	0	.618	1.25	2.56	.307	.360	.215	2.23	.398	-.012	1
32	CAGV3009	1705 1854	150	6	0	.592	1.21	2.11	.339	.481	.226	1.88	.294	.000	1
33	CAGV3013	1705 1854	150	6	0	.624	1.20	2.46	.321	.488	.220	2.03	.338	-.027	1
34	CAGV3019	1752 1854	103	4	0	.604	1.19	2.05	.279	.306	.194	1.95	.345	-.020	1
35	CAGV3021	1692 1854	163	7	0	.558	.97	1.45	.181	.259	.186	1.93	.369	-.046	1
36	CAGV3031	1701 1854	154	6	0	.677	1.24	1.93	.271	.390	.188	2.09	.364	-.035	1
37	CAGV4006	1697 1853	157	7	0	.684	1.32	2.86	.400	.697	.181	2.16	.402	-.014	1
38	CAGV3017	1733 1854	122	5	1	.518	1.27	1.95	.262	.414	.181	1.92	.327	-.010	2
39	CAGV3023	1753 1859	107	4	0	.628	1.41	2.43	.347	.465	.202	1.85	.255	-.004	1
Total or mean:			3992	164	7	.587	1.49	4.69	.367	.522	.175	2.51	.382	.005	

VITA

Sarah Anne Blankenship was born in Jasper, Alabama on December 31, 1977. Sarah resided in Jasper for the next eighteen years of her life, where she graduated from Walker High School in 1996. In the fall of 1996, Sarah enrolled in Auburn University. At the end of her sophomore year, she decided to declare Anthropology as her major, as she had aspired to be an archaeologist since the age of six. Under the advisement of Dr. John Cottier at Auburn, she worked as a field assistant during the archaeological excavations of Ft. Mitchell in Russell County, Alabama. Sarah graduated from Auburn University in December of 2001 with a Bachelor of Arts degree in Anthropology. The following year, she was admitted into the Master's Program in Anthropology at the University of Tennessee. Sarah's primary research interests include historic archaeology, cave archaeology, prehistoric rock art, and archaeological chemistry. She received a Master of the Arts degree in Anthropology from the University of Tennessee in May of 2007. She is currently enrolled in the Doctoral Program in Anthropology at the University of Tennessee.