12-2009

Prehistoric Bone Grease Production in Wisconsin's Driftless Area: A Review of the Evidence and Its Implications

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Recommended Citation

Baker, Jonathan Douglas, "Prehistoric Bone Grease Production in Wisconsin's Driftless Area: A Review of the Evidence and Its Implications. " Master's Thesis, University of Tennessee, 2009.
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To the Graduate Council:

I am submitting herewith a thesis written by Jonathan Douglas Baker entitled "Prehistoric Bone Grease Production in Wisconsin's Driftless Area: A Review of the Evidence and Its Implications." 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.

Walter E. Klippel, Major Professor

We have read this thesis and recommend its acceptance:

David G. Anderson, Michael H. Logan

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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PREHISTORIC BONE GREASE PRODUCTION IN WISCONSIN'S DRIFTLESS AREA: A REVIEW OF THE EVIDENCE AND ITS IMPLICATIONS

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

Jonathan Douglas Baker
December 2009

DEDICATION

This thesis is dedicated to my wife, Stephaine Michelle Baker,
who has provided infinite support and encouragement over the past fourteen years.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank my family for their unwavering support of my academic pursuits. In particular, my parents, Steven and Colleen Baker, have always encouraged me to follow my interests in archaeology. Over the past decade, my wife Stephaine Baker has put up with many sleepless nights, tons of dirty field clothes, numerous dead animals, malodorous comparative specimens, and even moved to Tennessee, all with very few complaints. Without her endless support this thesis may have never reached fruition.

I would like to thank my committee members Drs. David Anderson and Michael Logan, and particularly my chair Dr. Walter Klippel, for reading drafts of this document and providing invaluable comments and suggestions regarding my research on bone grease production in Wisconsin's Driftless Area. Dr. Klippel also obtained the modern white-tailed deer from Tennessee that was used in the bone grease production experiment. I would like to thank Dr. James Theler (University of Wisconsin-La Crosse) for encouraging my interests in zooarchaeology and specifically for convincing me to take on the study of bone grease production in the Driftless Area. Dr. Theler also provided unpublished data on faunal remains from the Preston and Gottschall rockshelters and assisted in securing the faunal materials that were analyzed in this study. Robert Boszhardt (Mississippi Valley Archaeology Center) provided data on excavations at the Krause Site and the Sanford Archaeological District and his early encouragement is largely responsible for my pursuit of a career in archaeology. Dr. Constance Arzigian (Mississippi Valley Archaeology Center) supplied data on recent and past excavations at the Long Coulee Site. Wendy Holtz-Leith (Mississippi Valley Archaeology Center) also

supplied data from the excavation of Feature 205 at the Sanford Archaeological District. Lindsay Maass provided data on the bird remains from Feature 205 at the Sanford Archaeological District. Elizabeth Tereba-Leith and Luther Leith analyzed the floral remains from Feature 438 at the Krause Site. A number of volunteers in the Zooarchaeology Laboratory at the University of Tennessee spent considerable time measuring the size of the bone fragments from the bone grease assemblages and their help is much appreciated. Landon Karr gave me a copy of his unpublished manuscript on bone grease production at the Mitchell Village Site in South Dakota. Dr. Alan Outram and Claire Saint-Germain both supplied me with copies of their publications related to bone grease manufacturing. My brother, Josh Baker, obtained the white-tailed deer from Wisconsin for the grease production experiment. Naturally, any errors or omissions in this paper remain the sole responsibility of the author.

ABSTRACT

The evidence for bone grease processing in Wisconsin's Driftless Area is addressed. A four-fold methodology for the identification of grease production is developed. This methodology includes an examination of: (1) bone fragment size, (2) fracture patterns, (3) overall taphonomy, and (4) archaeological context. The methodology is applied to the analysis of eight Driftless Area faunal assemblages and is also used to reevaluate previous accounts of grease production. Based upon the analysis, evidence for grease manufacture is present and ubiquitous at seven Archaic/Woodland sites. Evidence for grease production is also present in five Oneota assemblages from the La Crosse area.

Grease production is interpreted through a behavioral ecology framework, with particular reference to the prey-as-patch model. This model implies that increases in carcass processing intensity are associated with reductions in kill frequencies. It is suggested that in certain circumstances, the predictions of the model maybe inaccurate. These inaccuracies are highlighted by evidence from Archaic and Woodland sites that indicates grease production was not related to lower kill rates, but instead associated with intensive fall harvests and processing white-tailed deer (*Odocoileus virginianus*). At this time, processing multiple animals simultaneously could have produced large quantities of grease and lowered production costs. The grease was stored for use during the spring and winter, when deer were lean and very low in fat content, and few other fat or carbohydrate sources would have been available.

Grease production on the Oneota sites occurred in a different cultural context. Here, bone grease manufacture was sporadic and associated with fall-winter seasonal indicators. This means that grease production occurred when the La Crosse area Oneota appeared to have abandoned their villages to pursue American bison (*Bos bison*) in the prairies of Minnesota. It is suggested that certain individuals (particularly, the young, elderly and sick) likely stayed behind. Faced with more limited hunting abilities, large mammal kills may have been uncommon. Consistent with predications of the prey-as-patch model, these individuals intensively processed the carcasses of single animals, including bone grease manufacture. Here, fat would have been a critical winter resource and used to supplement stored agricultural products.

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CHAPTER I
INTRODUCTION

Introduction

Today, one of the most significant health concerns facing American society is the obesity epidemic (Hedley 2004; Kopelman 2000; Morrill 2004). It is estimated that nearly 67 percent of Americans are overweight, with 34 percent being considered obese (National Center for Health Statistics 2006). The current prevalence of obesity ultimately stems from our creation of a novel environment where manufactured fats and carbohydrates are not only abundant, but in many cases difficult to avoid (James 1996; Lambert 2004; Ravussin 1995). Faced with the realization that obesity is a leading contributor to hypertension, osteoarthritis, dyslipidemia, Type 2 diabetes, coronary heart disease, stroke, gallbladder disease, sleep apnea, respiratory ailments, and certain types of cancer (Kopelman 2000; National Institutes of Health 1998; Strum 2002), as well as a pervasive social stigma, many of us have come to view fats with a severe negative connotation. In this light we often forget that fat is an essential nutrient, necessary to the survival of all humans. It is the single most concentrated form of dietary energy and to many pre-agricultural societies it was a critical resource.

In many ways, our failure to recognize fat as vital nutrient has been passed onto studies of archaeological subsistence patterns. Although there has been much anthropological discussion over the past several decades (e.g. Cordain et al. 2000; Saint-Germain 2005; Speth 1990; Speth and Spielmann 1983)as to the importance of fat among indigenous peoples, most archaeologists have failed to distinguish the relevance of fat in relation to other bulk nutrients. All too often, zooarchaeologists simply calculate "useable meat weight” or “biomass” estimates (e.g Davis 1987:36; Reitz and Wing 1999:221-231; White 1953) in order to determine the relative dietary contribution of various animal species. Although the problem is commonly acknowledged, most researchers that utilize meat weight estimates fail to focus on the fact that “meat” is not of a static, homogeneous composition. It is comprised of many different nutrients that vary in relative abundance depending on body portion, season, age, sex, and health of the animal.

The ethnographic and historical literature is replete with examples of how only considering the meat weight of an animal is inappropriate. Outside of the modern world, it is common knowledge that the human body cannot survive on a diet of lean meat alone. As discussed in Chapter III, the consumption of excess protein can cause hyperammonemia and hyperaminoacidemia, which produce the symptoms of “rabbit starvation” commonly described by northern explorers (Cordain et al. 2000; Speth and Spielmann 1983). Failure to incorporate appropriate amounts of fat, or carbohydrates, into the diet can ultimately lead to death. The risk of these conditions increases dramatically during the late-fall through early-spring months, particularly in the Arctic and northern temperate latitudes, where carbohydrate sources are rare. During the cold season, animals in these latitudes survive primarily by mobilizing their internal fat stores accumulated during the summer and fall, therefore becoming fat depleted. Although many large mammals, such as American elk (*Cervus elaphus*), American bison (*Bos bison*), deer (*Odocoileus*sp.) and caribou (*Rangifer tarandus*), may be easily taken during the cold season, they may be so lean as to be considered of little use (Speth 1983:148-153). These concerns clearly illustrate the necessity of archaeologists to carefully consider the role of various nutrients in prehistoric economies. While calculating biomass and meat weight estimates are essential for zooarchaeologists to reconstruct past subsistence patterns, we must not forget that these measures may be biased, and not fully reflect the true nature of past behaviors.

This thesis attempts to move beyond these standard measures of dietary contribution and focuses on the role that specific nutrients, in this case fat, play in prehistoric subsistence systems. Any researcher will immediately realize that it is impossible to provide an accurate quantification of the relative amount of protein and fat available from each animal carcass, as such data does not preserve in the archaeological record. Specific butchery techniques, however, may provide archaeologically identifiable signatures of the exploitation of particular types of fat. The extraction of both bone marrow and bone grease result in distinct and recognizable patterns of bone fracture.

Bone marrow is the soft tissue found within the interior cavities of adult animal bones. In addition to being responsible for the production of new blood cells, the bone marrow of healthy individuals is extremely rich in fat. The bone marrow found in the medullary cavity of long bones can be easily removed by cracking the bone with a heavy, blunt instrument and manually extracting the marrow with one’s hands, a sharp implement, or by sucking. This results in a number of distinct fracture patterns (Binford 1981; Lyman 1994). For the duration of this thesis, marrow of this type will be referred to as “bone marrow” or “medullary bone marrow.” Given its high fat content and ease of procurement, most prehistoric and early historic peoples of eastern North America seem to have regularly cracked open the major long bones of large mammals in order to access the bone marrow. In fact only a few, rare examples of predominately unfragmented bone assemblages exist from this region (e.g. Parmalee and Klippel 1983).

Bone grease is fat that is rendered from marrow stored in the cancellous tissue (spongy/trabecular bone) of the flat bones and the epiphyses of major long bones. Unlike the medullary bone marrow, bone grease extraction requires considerable effort. First, the cancellous portion of the bone must be broken into small fragments, thus increasing the surface area and destroying the structure of the trabecular bone. These fragments are then boiled for several hours. Upon cooling, the grease congeals on the surface and can be readily removed by mechanical means. The labor investment necessary for bone grease extraction, and the relatively low yield of an individual animal carcass, has led many researchers to conclude that bone grease is a marginal resource that should only be utilized during food shortages or in regions (such as the northern and temperate latitudes) where chronic resource stress is present for large portions of the year. This assertion is further supported by the fact that bone marrow and grease are among the last stores of fat to be mobilized by an animal during times of stress. Therefore, identifying bone fat utilization, particularly bone grease extraction, can be vital in providing a more comprehensive view of both short-term and long-term fluctuations in past economic systems.

While changes in the intensity of grease production may reflect fluctuations in resource stress, it should be emphasized that the simple identification of the process should not be used as signature of stress. As will be discussed in the following chapters, grease was frequently produced during times of plenty, often in preparation for the winter. Only when diachronic changes in the frequency of grease manufacture can be observed should we use it to evaluate levels of resource stress. Evidence for bone grease must be evaluated within the whole scope of a culture's economic practices before we can begin to understand the motivations behind its production.

This thesis explores archaeological bone grease production among the Archaic, Woodland, and Oneota populations of the Driftless Area in southwestern Wisconsin. Although much is know about the subsistence practices of these people, there has been little formal attempt to identify bone grease production in the faunal assemblages from this region. Specifically, this thesis addresses the question: *were prehistoric groups in the Driftless Area producing bone grease and, if so, in what contexts did this practice occur*? In order to answer this question, I first develop a methodology appropriate for identifying bone grease production in archaeological contexts from this region and then provide a review of the literature on previously analyzed Driftless Area assemblages from which bone grease production has been suggested. Following this review, I present the results of an analysis of eight faunal assemblages from the area using the methodology developed earlier. Finally, I explore the results of the literature review and analysis to develop a more comprehensive understanding of prehistoric bone fat utilization in the upper Midwest and thus provide a more detailed understanding of the considerable variability that existed in the ancient economies of this region.

History of the Problem

Although there has been little formal examination of prehistoric bone grease production in the upper Midwest, the circumstantial identification of bone grease from the archaeological record has a long history in Wisconsin zooarchaeology. In the earliest systematic analysis of archaeological faunal remains from Wisconsin's Driftless Area, Parmalee (1959) noted that the mammal bones from the Raddatz Rockshelter (47SK5) were of a highly fragmented condition, likely the result of marrow extraction. Since that time, nearly every analysis of rockshelter faunal assemblages from the region has documented heavily fragmented remains that are frequently cited to have been the result of bone grease production (Berwick 1975; Storck 1972; Theler 1983; Theler and Chalkley-Hubbell 1984; Baker 2003). Unfortunately, most of these observations are far from systematic and often based upon the simple assumption that a heavily fragmented assemblage must be the product of bone grease manufacture. Furthermore, in most of these cases, bone grease is only mentioned in passing, with little attention or assertion of significance.

In addition to the rockshelter assemblages, bone grease production was also suggested from the faunal remains recovered at Millville Village (47GT53), an open-air Middle Woodland site in Grant County, Wisconsin (Pillaert 1969; Vehik 1977). In fact, Millville was one of three sites selected by Vehik (1977) for her now classic examination of bone grease production in the northern Plains and the upper Midwest. In the article, Vehik (1977:172-175) proposed three criteria for the identification of bone grease manufacture on archaeological sites: the presence of many small bone fragments, artifacts used in the manufacture of the bone grease, and contextual evidence.

Though Vehik’s (1977) criteria are valuable in establishing the presence of bone grease production in archaeological contexts, they remain qualitative and in many cases highly circumstantial. The situation is even more problematic with the rockshelter faunal assemblages. While bone grease manufacture probably occurred to at least some extent at both Millville and the rockshelter sites, the major problem with all of these analyses is that they are only a qualitative assessment of bone grease production. With the single exception of Theler and Chalkley-Hubbell's (1984) analysis of white-tailed deer (*Odocoileus virginianus*) phalanx fragmentation rates from the Preston Rockshelter (see also Theler 1983), there is no means to compare the level of bone fragmentation and grease production at either the intra- or inter-site level. In order to understand the role of bone grease production in the prehistoric economies of this region, we will ultimately need to make such comparisons.

Therefore, much of this thesis is focused not only on determining if bone grease production was practiced in the Driftless Area, but also developing a methodology that allows for comparisons regarding the degree of bone grease production/carcass utilization within and between sites. If bone grease production is indeed tied to resource stress (e.g. Burger et al. 2005; Outram 2004), it will be vital to utilize a methodology conducive to exploring variation in grease preparation at both seasonal and long-term scales. Such a measure is particularly important in light of a recent assertion that resource stress and over-exploitation of the white-tailed deer population may have caused the collapse of Late Woodland societies in the Driftless Area and ultimately resulted in the shift to intensive village agriculture (Theler and Boszhardt 2006).

More recent excavations in the La Crosse Area produced several fragmentary Oneota faunal assemblages that provided further impetus for this research. At least six pit features from this region produced substantial quantities of large mammal bone that was mostly broken beyond recognition. Such assemblages appeared to be quite unique among the thousands of excavated pit features form this area, and initial analysis suggested that they were the products of bone grease preparation (Baker 2001). Even more intriguing was that the Oneota grease production appeared to have occurred in a completely different cultural context than that represented by the rockshelter and Millville remains.

Most of the rockshelter assemblages date to the Archaic and Woodland traditions and appear to have been associated with cool season micro-band occupations focused on the harvest of white-tailed deer and other large terrestrial mammals (Theler 1987; Theler and Boszhardt 2003; Stoltman 1997; Stevenson et al. 1997; Storck 1974). Here, the apparent ubiquity of bone grease production may have been tied to the accumulation of vital fat stores necessary for the survival during the winter months. The Oneota assemblages, however, come from large agricultural village sites that have little evidence for fall and winter occupation. They appear to have been inhabited primarily during the spring through early fall, with an emphasis upon agriculture and floodplain resource procurement. Unlike the rockshelters, there is little evidence for substantial, focused white-tailed deer harvests at these sites. It has been suggested that the Oneota of the La Crosse Area may have seasonally abandoned the region in the fall and winter in order to pursue bison hunting on the prairies of Minnesota (Boszhardt 2000a; Sasso 1993). Therefore, it currently appears that if the Oneota assemblages are the result of bone grease production, this grease production occurred in a distinctly different context than that observed on earlier sites. A substantial portion of this thesis is dedicated to resolving these issues and determining the various reasons why bone grease was being produced by the prehistoric occupants of the Driftless Area.

Research Objectives

In the preceding sections I have identified that the primary goal of this thesis is to establish whether or not bone grease was being produced by the prehistoric occupants of

Driftless Area and, if so, provide an interpretation regarding the nature of its manufacture. Based upon the discussion of the historical context of this problem, it is obvious that providing an answer to this question will not be a straightforward pursuit. Instead, this research will require a multi-faceted approach. Below, I outline five research objectives that clarify the main problem and provide a more concise research agenda:

1.) *Establish the potential economic uses and value of bone grease*. While bone grease seems to have been manufactured primarily for consumption as food, several non-subsistence uses for grease are reported in the ethnographic record (Vehik 1977). It will be necessary to review the ethnographic and archaeological literature to determine the probable functions that bone grease may have served in the prehistoric economies of the Driftless Area. An accurate estimate of the yields and costs of bone grease production will help to document the relative economic value of this product and may be particularly critical in determining if bone grease manufacture is related to resource stress. Such estimations could be best made through experimental work with modern animal carcasses.

2.) *Develop a methodology appropriate for identifying and quantifying bone grease production in the archaeological record of the Driftless Area.* In addition to simply establishing the archaeological correlates of bone grease production, it will be necessary to develop a method that allows for the comparison of the relative degree of bone grease production between and within archaeological sites. As discussed in Chapter II, a number of techniques have been developed in recent years to provide a quantitative measurement of bone fragmentation rates. As many of these methods are prone to inter-observer bias, and often do not control for non-human agents of bone fracture, great care must be taken in selecting a method able to provide accurate and replicable results.

3.) *Review and evaluate existing data regarding archaeological bone grease production in the Driftless Area.* In the existing archaeological literature, it has been suggested that there is evidence for bone grease production at a minimum of seven prehistoric sites from the region. Most of these accounts mention grease production only in passing and it is unclear if the remains from the sites are indeed the residue of bone grease manufacture. In this thesis, I intend to provide an extensive review and analysis of these reports to make a more accurate appraisal of the relative extent of bone grease production at these sites. Unfortunately, as Millville was the only one of these sites available for laboratory reanalysis, assessment of these sites must be based solely upon careful reading and consideration of the previously reported data. While this makes it impossible to precisely determine the extent of bone grease production present at these sites, a closer examination of the data can provide for a more accurate evaluation of the assemblages.

4.) *Analyze available assemblages to determine if they are the result of bone grease production.* As mentioned above, several recently excavated Oneota assemblages have been suggested to be the result of bone grease production. As all of these assemblages are available for analysis, they should be examined using the aforementioned methodology to determine if they are indeed the result of grease production. As many of the Oneota assemblages occurred as discrete piles of crushed bone found in refuse pits, there seems to be little doubt that they are indeed residue of grease manufacture. As these assemblages may be "pure" products of bone grease production with little intrusive materials, they should be very carefully examined and quantified as they may serve as standards against which other, more mixed assemblages may be compared. Two assemblages for which bone grease production is less evident, if not completely lacking, were selected to serve as control samples against which the Oneota pit features could be compared.

5.) *Examine the role bone grease played in the prehistoric societies of Wisconsin's Driftless Area.* After determining the extent to which bone grease was being produced at sites in this region, we are left with one final question – why? To resolve this matter, data from all of the preceding research objectives will need to be combined. In order to establish how bone grease production fit into the prehistoric economies of the region it will be necessary to review what is know about the subsistence practices of these people. This must include a detailed examination of the bone grease assemblages to determine the time of year grease was being produced as well as what species and portions of the carcass were being utilized. Furthermore, traditional models, such as those from behavioral ecology/optimal foraging theory, have recently been applied to carcass processing intensity to help show evidence of resource stress. These models must be carefully scrutinized to determine how well they may apply to bone grease production in the upper Midwest.

Research Framework

In order to achieve the research objectives outlined above, Chapters II-IV are dedicated to providing essential background information on bone grease production and the prehistoric economies of the Driftless Area. Chapter II examines the ethnographic and archaeological contexts in which bone grease has been produced throughout the world. These data provide a baseline perspective on how bone grease was produced by indigenous peoples and for what purposes. Through careful analogy these data can be cautiously applied in developing models of bone grease production in the Driftless Area and help understand how this process may be observed archaeologically. At least four criteria are recognized as necessary in the archaeological identification of grease production: fragment size, determination of fracture agent, overall taphonomic history, and context.

Following a review of the ethnographic and archaeological observations of bone grease production, Chapter III focuses on providing a theoretical grounding for the interpretation of bone grease production. This chapter is heavily focused on establishing the nutritional value of fat and how it relates to the stimuli for bone grease production. An examination of how grease production and marrow extraction have been previously approached by anthropologists is reviewed. Most importantly, this chapter takes an evolutionary approach to bone grease production through the field of behavioral ecology. This approach draws upon optimal foraging models and specifically applies the marginal value theorem to animal carcass butchery and utilization. It is traditionally suggested that as bone grease manufacture has a relatively small yield for the amount of energy required for production, it may be only used in times of stress or in environments that are chronically lacking adequate fat and carbohydrate resources. The implications and limitations with this model are carefully considered and the extent to which bone grease production is always indicative of resource stress is questioned.

Chapter IV presents a review of what is known of the prehistoric economies of the Driftless Area and what environmental resources were available to its inhabitants. This chapter focuses on establishing the cultural context in which bone grease production occurred. The subsistence practices of the Archaic and Woodland traditions are compared to those of the Oneota in order to understand how bone grease production may have fit into the economy of each culture. Of further importance is a review of the environmental resources available to these people. This establishes what resources were present and to what extent we could expect seasonal or inter-annual fluctuations in the availability of critical resources.

The materials and methodology used during the course of this research are detailed in Chapter V. Based upon the criteria developed in Chapter II, a fourfold methodology is adopted for the identification and quantification of bone grease production: evaluation of provenience/context, analysis of fracture patterns, measurement of bone fragment size, and examination of overall taphonomy. This chapter also includes a detailed description of the laboratory procedures used for the taxonomic identification of the bone material.

Chapter VI reports the results of the review and analysis of the archaeological materials. The chapter begins with the Archaic and Woodland assemblages. As most of this material was not available for reanalysis, this portion of the chapter focuses on an in-depth review of what has already been reported on these remains. I focus on the data that will help determine the extent to which these assemblages are the result of grease manufacture. In the Archaic and Woodland section I also provide the results of the analysis of two sites: the Millville Village Site (47GT53) and the Gottschall Rockshelter (47IA80). Material from both of these sites was available for analysis and was examined using the techniques discussed in the previous chapter. Millville was included in the study as initial evaluation of the material indicates that it is likely a classic bone grease assemblage. Gottschall was included as it has numerous intact long bone epiphyses and serves as a comparison to the other assemblages with much higher rates of fragmentation.

Following the Archaic and Woodland material I present the results of the analysis of six Oneota assemblages. One of the Oneota assemblages, Feature 205 from the Sanford Archaeological District (47LC394-32) is unique compared to the rest in that it comes from a very large and materially rich feature. This feature appears to have been filled over a period of at least several years and contains faunal remains that are undoubtedly the product of many different activities. Accordingly, this feature makes an excellent comparison to the other Oneota assemblages that appear to be the result of single activities.

In Chapter VII, I report on the results of experimental work conducted with bone grease from two modern white-tailed carcasses. Previous experimental work (e.g. Church and Lyman 2003) has suggested that white-tailed deer elements produce extraordinarily little grease and indicate that this resource should only have been used during the direst of circumstances. This research finds that although grease extraction requires considerable effort, the overall yield for an entire carcass is substantially more than previous work has suggested. Furthermore, it is found that processing more than one carcass at a time may substantially lower processing costs. The experimental work also provides a number of insights into prehistoric butchering techniques through the observation of fracture patterns.

A discussion of the results of the analysis and the experimental work is provided in Chapter VIII. This chapter first examines the results of the analysis in order to determine the extent to which bone grease production was present at these sites. Although, it is still difficult to evaluate the previously published material on the Archaic and Woodland rockshelters, the ubiquity of heavily fragmented bone at these sites does seem to indicate that their past occupants were manufacturing bone grease to at least some degree. The analysis of the Millville assemblage indicates that the bones were intentionally broken into very small fragments and were undoubtedly the result of bone grease production. The same is true for most of the Oneota assemblages, excluding Feature 205 from the Sanford Archaeological District. Both Feature 205 and the Gottschall Rockshelter remains show clear signs of fracturing, but have not been fragmented as intensely as the other assemblages. The Gottschall remains include many intact long bone epiphyses and, as they come from a discrete deposit within the shelter, appear to have been processed solely for marrow,not for grease. The Feature 205 bones show an intermediate pattern between the Gottschall remains and the other assemblages. As this is such a large feature that likely contains an accumulation of residue from many different activities, it is difficult to estimate the relative amount of bone grease production.

The second portion of Chapter VIII is dedicated to exploring the role that bone grease played in the prehistoric societies of the Driftless Area. It appears as though evidence for grease production is ubiquitous at Archaic and Woodland rockshelter sites, which were primarily occupied during the fall and winters months as the occupants harvested white-tailed deer in large quantities. Grease production, however, remains rare at open-air warm season sites dating to this time. It is suggested that grease production was an attempt to create vital stores of fat to survive the lean winter and early spring months. Experimental work shows that grease from a single adult deer could have provided enough calories for three person-days.

The ubiquity and intensity of grease production at these sites show that grease production was unlikely the result of severe resource stress. Traditional interpretations of optimal foraging models are reviewed. These models have a major deficiency in that they only account for the processing of *individual* animal carcasses. The mass harvest of white-tailed deer may have allowed these groups to process many animals at once, therefore lowering grease production costs and increasing its overall value. While the discussion does indicate some concerns with these models, it is suggested that they should be modified, rather than abandoned, as they still have the ability to serve as important interpretive tools.

Oneota grease production appears to have also occurred primarily during the fall. This is particularly intriguing as there is very little evidence for Oneota occupation of the La Crosse Area during the fall and winter months. The area may have been abandoned during this time of the year as individuals moved west to pursue bison on the prairies of Minnesota. It is suggested here that some of the Oneota (e.g. the sick, young, and elderly) may have remained in the La Crosse villages, while only the more fit individuals were able to take place in the bison hunts. It is likely that local hunting success would have been greatly reduced and that these individuals would have tried to maximize the amount of nutrients that could be obtained from a carcass whenever a large mammal was killed. This would have included bone grease production.

Chapter IX is used to briefly summarize the research conducted in this thesis and review what has been learned. This chapter ends by making a number of suggestions regarding future research into bone grease production in the Driftless Area.

CHAPTER II
ETHNOGRAPHIC AND ARCHAEOLOGICAL OBSERVATIONS

Introduction

As defined in the previous chapter, “bone grease” is fat that is recovered from marrow stored in the cancellous tissue of long bone epiphyses, vertebrae, ribs, and the flat bones (Leechman 1951). Unlike the removal of marrow from the medullary cavity of long bones, a substantial amount of labor must be devoted to the production of bone grease. Ethnographic data indicates that the bones must be broken into small fragments and boiled in order to extract the grease (cf. Church and Lyman 2003). The considerable labor investment required for grease manufacture, combined with the relatively small yield of a single animal, has led many researchers to conclude that bone grease was a marginal resource that was only utilized during times of resource stress or in environments chronically lacking a supply of more readily available fats or carbohydrates (e.g. Church and Lyman 2003; Munro 2004; Munro and Bar-Oz 2005;Outram 1998, 2003, 2004; Speth 1989, 1990; Speth and Spielmann 1983; Ugan 2005; Vehik 1977). The intent of this chapter is to provide a background on the role that bone grease has played in traditional societies, examine how it was produced, use ethnographic data to construct criteria for the identification of bone grease production in the archaeological record, and to briefly discuss the antiquity of this practice.

Ethnographic Evidence Regarding Grease Production

Although the antiquity of bone grease production is not well known, the process has been consistently documented in the ethnographic record. Based upon ethnographic data, bone grease manufacture appears to be limited to Arctic, Subarctic, and temperate environments (Binford 1978, Leechman 1951, 1954; Vehik 1977; Saint-Germain 1997). With the single exception of Yellen's (1977) account of bone grease manufacture and fragmentation patterns among the !Kung bushmen, there does not seem to be any extensive evidence of grease exploitation from regions with warm climates (Outram 1998).

In general, bone grease appears to have been most significantly valued for its consumption as fat. Furthermore, it was often seen as one of the most delicious sources of fat (Binford 1978; Wilson 1924) and was occasionally produced as a "treat" or food to break up the monotony of a winter diet based upon dried foods. As a food, it was used in several different ways. It could be consumed in raw form, or stored and added to other foods, such as soups (Vehik 1977). In this sense, it can be seen as something similar to butter or lard. One of the most important subsistence products made from bone grease was pemmican (Leechman 1951). Pemmican consisted of dried meat that had been pounded into tiny pieces (Liboiron and St-Cry 1988). Bone fat was mixed with the pieces of meat to form a substance similar to summer sausage. For added taste and nutrition, dried berries, fruits, and/or nuts were frequently incorporated with the mixture. Pemmican formed a winter dietary staple in the northern Plains and Subarctic regions and was highly regarded for its taste and energy content (e.g. Bradley 1923; Densmore 1918; Glover 1962; Grinell 1962; James 1905; Schoolcraft 1851; Stefansson 1944, 1956; Wissler 1910). It was also a valued trade commodity in historic times (Saint-Germain 2005; Speth and Speilmann 1983). One of the most important characteristics of bone grease/pemmican was its storability. Leechman (1951) reported stores of grease could last up to three years without becoming spoiled.

Although the predominant value of bone grease was in its energy content, it was also produced for a number of non-subsistence reasons. Various uses included hair grease, tanning oil, waterproofing of hides, treatment of bowstrings, fuel for candles, and as an aid for starting and maintaining fires (Binford 1978; Garbarino and Sasso 1994:125-126; Kehoe 1967; Saint-Germain 1997; Vehik 1977). Most archaeological investigations of bone grease production have focused on its use as a food resource. While most of these studies are probably correct, we should be careful not to overlook the alternate reasons for bone grease production.

The production of bone grease appears to have principally been a female activity. Schoolcraft (1854, cited in Leechman 1951) and Bonnichsen (1973:10) indicate that men may have been involved in the crushing of the bones. In every other source that provided data on the sex of the participants involved in grease production, the work was all done by women (Binford 1978; Leechman 1951; Kinietz 1947; and see Vehik 1977).

Vehik (1977:169-170) suggested that there was no data in the ethnographic record of North America to indicate that bone grease production was limited to any particular season. Citing extensive ethnographic review, Saint-Germain (1997:154), however, indicates that while grease could be made at any time during the year, it seems to have been most frequently rendered during the fall and early winter. This is the time of the year when animals are at their fattest and would have produced the highest grease yields. Binford (1978) reports that, among the Nunamiut, bones were often stored and accumulated throughout the winter months to be processed in large batches. In northern climates, most ungulates readily deplete their fat supplies, including bone marrow, during the winter months (Speth 1983, 1990). In males, much fat is lost during the mating season, or “rut” of the late fall and early winter. Female animals retain fat further into the winter, but quickly loose their stores following the spring birthing season. Binford (1978:213) indicates that among the Nunamiut, bone grease processing was more limited and highly selective during the spring. Only elements from the marrow rich lower limbs were utilized at this time of the year.

Extensive grease production appears to be most frequently associated with the mass harvest of large ungulates (Binford 1978; Leechman 1951; Saint-Germain 1997; Vehik 1977; Wilson 1924). As animals were taken in large quantities, during prime condition, their bones could have been processed simultaneously to provide a store of fat for the lean times of the year. In many instances, only the highest-ranked elements of the animals were processed for grease. Binford (1978:32,157) indicates that among the Nunamiut, the epiphyseal ends of the major long bones, including the humeri, femora, metapodials, and tibiae, were preferred for grease production. Bones of the axial skeleton were rarely used except for during lean times, and the skull, antlers, and scapula were never known to have been used (Binford 1978:32). The bones located further from the backbone (i.e. the metapodials) were the most prized because they produced the highest quality fat. This high quality grease was referred to as “white grease” and analysis has shown that it was significantly higher in unsaturated fats, specifically oleic acid (Binford 1978). Several other sources (Rogers 1973; Saint-Germain 1997; Vehik1977; Wilson 1924:174; Wissler 1910) also indicated that the articular ends of long bones were preferred for grease. While there seems to be an emphasis on long bones, other records indicate that vertebrae and ribs (Dorsey 1884; Jenness 1922; Nagy 1990; Rogers 1973), innonimates (Bonnichsen 1973), and shoulders/scapulas (Wilson 1924) were also utilized for bone grease.

The realization that some bones may be preferred, due to grease quantity and/or quality, has led researchers to create bone marrow and grease utility indices. The intent of these indices has been to better understand factors that dictated the inclusion of certain elements in a grease processing event (see discussion in Chapter III). There seems to be a general consensus that most societies preferred the major long bone epiphyses. This was particularly true in situations where a large number of animals could have been taken simultaneously, or where cool winter temperatures allowed stores of unprocessed bones to be accumulated for several weeks to several months (Binford 1978).

Despite the emphasis on the selective use of large mammal long bone epiphyses, in association with mass animal harvests, bone grease was also a significant starvation resource. In the upper Midwest, most large ungulates build up internal fat deposits during the late summer and fall (Jackson 1961). These fat stores, however, become readily depleted during the rut in the late fall and often reach their minimum by the spring birthing season. Bone marrow is one of the last forms of fat to be depleted by these ungulates (Speth 1983), and therefore may have been one of the last supplies of fat available to hunters who had taken nutritionally stressed animals. In this context, grease may have been a crucial starvation resource when other fat sources were not readily obtainable.

Given the demanding labor requirements and relatively small yields of grease production, many archaeologists have tended to focus on its role as a “marginal” resource and used it as an indicator of dietary stress (e.g. Berwick 1975; Logan 1998; Outram

1999, 2003, 2004; Munro 2004; Munro and Bar-Oz 2005; Pillaert 1969; Ugan 2005; cf. Brink 1997; and Prince 2007). Certainly, grease production represents a very intensive utilization of an animal carcass and can be viewed a less than optimal resource; however, for many cultures it seems to have been a regular activity in the annual subsistence cycle. While we may see it as a "marginal" resource from a comparative perspective, it is unlikely that traditional peoples saw it in such a light. On the other hand, in many circumstances it was clearly a starvation resource. This all points out that to better understand the nature of bone grease exploitation, each example of production must be viewed in a broader cultural and economic context.

Ethnographic Descriptions of the Grease Production Process

There is some variation within the ethnographic literature as to what bones were exploited for grease, what time of year the practice occurred, how much grease could be obtained, how the grease was used, and the conditions under which it was produced; however, the methods utilized to produce the grease were remarkably similar. The single most detailed description of traditional bone grease processing comes from Lewis Binford's (1978) work with the Nunamuit of northern Alaska. Although Binford's observations could be paraphrased, several large passages from his work have been included inorder to provide a comprehensive description of the process and to give the reader a better appreciation of the labor commitment necessary for the production of bone grease:

> The woman sat on a folded skin…with a large hide placed in front of her as a working surface. On this hide was placed the anvil stone. In the old days a stone maul was used for pulverizing the articulator ends…The procedure is to place an articulator end on the anvil and hold it with one hand while delivering a series of light blows aimed at crushing the outer

> surface of the articulator end. This has the effect of "seating" the bone on the anvil so that heavy blows may be delivered without fear of the bone flying off the anvil if the blow is not perfectly directed. Once the bone is seated heavy blows are delivered until the articulator end is pulverized into tiny chunks of bone tissue. Once the bone is sufficiently pulverized a small stick or the hand is used to wipe the pulverized material off the anvil onto the hide and another articulator end is placed on the anvil. This procedure is followed until all the accumulated articulator ends are pulverized. Generally two or more women are engaged in the activity. When a large quantity of pulverized bone is available a fire will be started and a large iron kettle used for rendering the bone grease. The procedure is to bring the kettle to a boil, dump a quantity of pulverized bone into the kettle (the amount depends on the size of the kettle), and bring the contents to a slow boil again. As the grease begins to rise to the surface, handfuls of snow are added to the top of the kettle. The snow quickly cools the surface water and the grease begins to solidify. A ladle is used to scoop the solidified grease off the surface of the water. Then the contents of the pot are stirred vigorously with a stick and allowed to come to a slow boil again, at which time the adding of snow and the scooping of grease from the surface are repeated [Binford 1978:157-158].
>
> Today two kettles are used. Once the contents of one kettle are considered processed and exhausted of grease the hot water is poured off into another kettle, which contains a new supply of pulverized bone. This kettle is placed on the fire and the process is started again. The first kettle is then emptied, generally to one side of the fire. More water is added and it is placed near the fire to warm up while the contents of the second kettle are being processed. Such activity may go on continuously for from 1 to 3 days in early spring. This is a labor-intensive activity, requiring great amounts of firewood, patience and labor [Binford 1978:158].

Based upon these preceding paragraphs it is clear that the act of producing bone grease requires a considerable amount of labor and dedication. The commitment to this process would have been even more substantial before adoption of "modern" technologies by the Nunamiut. In the following paragraph, Binford (1978:158-159) illustrates some of the additional costs that would have been associated with more traditional bone grease production methods:

> Prior to the availability of metal kettles, wooden buckets and a stone boiling technique were used. Only once was this method demonstrated to

> me, and I was overwhelmed by the sheer activity levels that had to be maintained to process large quantities of bone successfully. Added labor consisted of (*a*) collecting the large quantity of stones needed for the operation, (*b*) collecting increased amounts of firewood needed to reheat the cooled and wet stones, (*c*) attending the pot continuously, and (*d*) manipulating the stones into the pot, out of the pot, into a pile beside the fire for drying, examining them for breakage, placing them back into the fire, and finally returning them to the pot. All of this was accomplished while watching the grease level on the top, placing snow in the pot, and scooping off the grease [Binford 1978:158-159].

Binford's (1978:157-159) descriptions highlight several issues that are worth discussing in greater detail. First, he indicates that all of the bones were pulverized to a substantial extent. This was considered necessary to expose the marrow contained within the cancellous tissue so that it could be rendered from the bone via boiling. The emphasis upon fragmentation was present in every ethnographic record of bone grease production that could be located (i.e. Binford 1978; Bonnichsen 1973; Densmore 1929; Dorsey 1884; Grinnell 1972; Leechman 1951; Lowie 1924; Opler 1941; Peale 1871; Rogers 1973; Speth and Spielman 1983; Wilson 1924; Wissler 1910; Yellen 1977; and Zierhut 1967) In summarizing ethnographic accounts of bone fracturing in the northern Plains and upper Midwest, Vehik (1977:169) stated that "bone grease and/or soup seemed to be the only reason that bone was finely crushed."

Church and Lyman (2003) provided a further review of the ethnographic and archaeological literature relating to grease production and concluded that the comminution of bone was one of the most consistent signatures of bone grease manufacture. In fact, they suggested that the reliance upon bone fragmentation for the identification of grease production is so ubiquitous that it has become "a part of zooarchaeology's conventional wisdom" (Church and Lyman 2003:1077). While bone fragmentation is clearly an important component of grease manufacture, Church and Lyman (2003) indicate that there are some discrepancies in the ethnographic and archaeological data as to an optimal fragment size. Descriptions of fragment sizes ranged from little pieces "as big as fingernails" (Julia McDonald as cited in Leechman 1951:355) to those averaging around 8 cm in maximum dimension (Yellen 1977:302-303). Citing archaeological work (e.g. Smith and McNees 2000), Church and Lyman (2003:1078) provided some evidence that optimal fragment sizes may have varied between animal taxa. Naturally, bones from animals such as bison and American elk may not have been as extensively fragmented as those from smaller animals like pronghorns (*Antilocapra americana*) and white-tailed deer.

Two other points worth examining from Binford's (1978) description of grease production relate to the physical context in which this activity occurred. Bone grease manufacture requires a number of tools and facilities. Unfortunately, most of technology involved in grease production is either rarely preserved archaeologically (e.g. hides and wooden vessels), or can be used for numerous other activities (e.g. hammerstones, anvil stones, boiling stones, and cooking vessels). Archaeologically, these tools may only represent circumstantial evidence of bone grease production.

While these tools are part of the overall context of grease manufacture, the physical setting of the activity may be of even more significance. As seen in Binford's (1978) observations, and Vehik's (1977) review, grease production can occur in a number of contexts, ranging from short-term hunting/processing camps to large, permanent or semi-permanent villages. The number of activities and length of occupation have a tremendous impact on how easily the products of grease manufacture are recognized archaeologically. Binford (1978) notes that at a residential camp, when the boiling is complete:

> the contents of the container are dumped, the bone meal from the crushed articulator ends is discarded along with the many small chips resulting from the marrow cracking…The presence of a dump containing the bone meal resulting from bone grease rendering would have made such an activity identification certain [Binford 1978:397].

In most instances, Binford (1978:159) emphasized that disposal of grease residue resulted in a "large pile of pulverized bone approaching the appearance of bone meal." Certainly, such a product is key to recognizing bone grease both ethnographically and archaeologically, but it becomes problematic if the site is inhabited for long periods or reoccupied frequently. In such circumstances, Vehik (1977:174) notes that this signature of grease production is likely to become homogenized into the archaeological record, and obscured by the refuse of many other activities. This issue is returned to in the following section.

Archaeological Accounts

Now that we have examined some of the ethnographic data regarding bone grease production, it is appropriate to review the antiquity of grease manufacture. This is not meant to be an exhaustive review of the archaeological data, but a summary of some of the more compelling examples of grease exploitation. This review is intended to back up the ethnographic data discussed above, highlight the conditions under which societies chose to exploit grease, and examine some of the additional challenges involved in identifying grease production in the archaeological record. Although a number of previous archaeological examples of grease manufacture exist from Wisconsin's Driftless Area, they are not covered in this section as they are more extensively reviewed in

Chapter VI and play a significant role in answering the specific questions proposed in this thesis.

The utilization of bone fat has roots well into the hominid fossil record (Bunn 1981; de Heinzelin et al. 1999) and paleolithic bone fragmentation has proved to be a very controversial topic, both in the Old and New Worlds (e.g. Brain 1989; Dart 1957; Haynes 1983, 2002). These earliest accounts of bone fat exploitation date to the Plio-Pleistocene and appear to be solely in the form of marrow extraction from long bone cavities; not bone grease production. The earliest known reports of grease production are much later, dating to Epipalaeolithic (14,500 – 21,500 cal. B.P.) sites in the Levant (Munro 2004; Munro and Bar-Oz 2005). Here, grease production is associated with an intensified utilization of the mountain gazelle (*Gazella gazella*) and may provide evidence for significant changes in resource procurement strategies and population growth just prior to the development of agriculture. Evidence for grease production at this time includes: a heavily fragmented bone assemblage, green bone fractures, and the underrepresentation of cancellous bones (which were presumably fragmented beyond recognition) (Munro and Bar-Oz 2005). While the survivorship of cancellous bones is correlated to bone density, the authors suggest that this is not attributable to post-depositional attrition, but rather intense peri-mortem fragmentation (Munro and Bar-Oz 2005:233). Given the lack of ceramic vessels, grease production in the Epipaleolithic would have required some form of organic containers and stone boiling technology. Few, if any additional accounts of grease production date to this age. Their absence, however, may be largely attributable to lack of research focus.

While several Stone and Copper age sites from Europe have produced evidence of grease production (see Outram 1998), it was difficult to find published examples from this area of the World. Nagaoka (2005) has suggested that evidence for grease production exists in late prehistoric deposits (A.D. 1,250 – 1,450) at the Shag River Mouth Site in New Zealand. Here, the proposed grease production is associated with declining foraging efficiency of moas (Aves: Dinornithiformes), several species of large flightless birds that were endemic to the region and have since become extinct. Nagoaka (2005:1335-1337) based the suggestion of grease extraction upon ratios of the number of identified specimens (NISP) to the minimum number of elements (MNE), and the number of specimens (NSP) to the NISP. These comparisons indicated a heavy fragmentation rate of particular elements (i.e. the grease rich tibiotarsus). Although in the end it was difficult to determine if grease production increased through time, this example clearly highlights a growing realization in the archaeological community that grease extraction represents an intensified exploitation of the animal carcass and may serve as a marker of resource stress (e.g. Burger et al. 2005; Outram 2004).

The New World, and specifically North America, has produced many archaeological examples of grease production. I suspect that the practice may have been just as common in other portions of the world (or at least those in temperate, Subarctic, and Arctic latitudes); however, extensive historic and ethnographic documentation of this practice has likely made researchers more aware of grease production in North America and, perhaps, allowed archaeologists to draw stronger analogies between the ethnographic data and the archaeological record. In his brief, although now classic paper, Leechman (1951) appears to have been the first researcher to suggest the existence of bone grease production in the archaeological record. Leechman (1951:355) proposed that "the enormous quantities of comminuted bones found in the neighborhood of old buffalo jumps and pounds" could be seen as analogous to the refuse of grease manufacture that he had observed among the Loucheux people of the northern Yukon. Specifically, Leechman (1951:356) indicated that while working on an unnamed site in southern Ontario, he encountered such piles of broken bone and "it was easy to recognize the remains as the waste material left over from making 'bone grease'." It was furthermore inferred that the process of making bone grease was likely common among many aboriginal peoples who hunted big game.

While Leechman (1951) may have been the first to recognize the archaeological signatures of bone grease production, Susan Vehik (1977) helped to popularize the study of bone grease in her paper on grease manufacture in the Plains and Midwest. In this now classic paper, Vehik (1977) provided a review of ethnographic data, and described three categories of evidence for archaeological grease production: condition of the animal bones, associated tools, and overall site context.

The first category related to the condition of the animal remains and was considered to be the primary line of evidence. It was straightforward – we should expect to encounter large quantities of heavily fragmented bone at locations where grease had been produced (Vehik 1977:172). Furthermore, it was suggested that there should be negative evidence for the grease-rich elements and element portions. It was hypothesized that these should have been broken beyond recognition (Pillaert 1969:101; Vehik 1977:172). Both of these suggestions seem quite reasonable, although they do need to be qualified. First, we should expect an extremely fragmented bone assemblage; however, additional work must be done to determine that the fragmentation was indeed the result of human activity and not due to other taphonomic factors. Second, while prehistoric cultures would have certainly focused upon grease-rich elements, it may be debatable as to the exact extent that they would have been “battered beyond recognition.” Many high-yield grease elements consist of the articular ends of long bones that exhibit highly diagnostic features that may be identified even upon extensive fracturing. These two issues are returned to in the following section.

Vehik’s (1977:172-173) second category of evidence for bone grease included the tools utilized in its manufacture. It was recognized that a number of tools were required during the production process and many of these should be preserved. Tools included mauls or hammerstones, anvil stones, fire pits, burned or unburned “boiling-size” stones and pottery (Vehik 1977:173). As Vehik pointed out, all of these tools serve multiple functions and their presence alone cannot be taken as evidence for grease production. Instead, their context at a site and, in particular, their association with a highly fragmented bone assemblage would provide additional evidence for grease production.

The overall site context was a third category of data related to bone grease production (Vehik 1977:173-175). The idea of context referred to the nature/function of the settlement where bone grease had been produced. Vehik (1977:173-175) described two different types of settlements, but emphasized that these were the end points on a broad spectrum of possible site types. This spectrum ranged from small, ephemeral special-purpose camps to large, permanent settlements. The basic idea behind this category is that in smaller, more briefly occupied sites, we should expect the evidence for grease production to have been more likely left in its original context (Vehik 1977). The “spent” bones would have been deposited near where production occurred and retained a stronger association with the tools and site features utilized in grease manufacture. On the other hand, at a large, permanent site, the bones would have been more likely to become disassociated with each other and the items utilized in grease production. Tools found on large sites were more likely to have been utilized in multiple activities and become increasingly difficult to associate with grease production.

Perhaps the greatest problem with identifying grease manufacture on large sites is the additional taphonomic agents that may have acted upon the bones. After grease manufacture the bones would have been easily spread across the site and more easily destroyed by a wide variety of processes. The best evidence for grease production at a large site would be if the bones were dumped into a trash pit/heap after boiling. In this case, they would appear to the archaeologist as a discrete deposit of highly fragment bones.

In addition to identifying some of the archaeological correlates of grease manufacture, Vehik examined evidence for bone grease production at three archeological sites: Quast, Huff, and Millville Village. Quast was a small, unaffiliated (c. A.D. 1,250) site located on the James River in North Dakota. The site appeared to be a fairly small special purpose camp, with no substantial house or storage structures. It produced over 4000 fragments of unidentifiable large animal bone (presumably bison) and several tools (i.e. anvil fragments, pottery, and possible boiling stones) that may have been used in grease production. Given the quantity of crushed animals bones, the associated artifacts, and the site’s appearance as a small meat processing camp, Vehik (1977:178) stated that there was enough evidence to suggest that grease production had occurred at Quast.

The other two sites examined by Vehik were larger, more permanent settlements. The Huff site was a terminal Middle Missouri village in North Dakota and Millville Village was a late Middle Woodland site located in southwest Wisconsin. Both of these sites fit Vehik's model in which the evidence for grease production at larger sites was likely to have been more scattered and disassociated with its original context. Based primarily upon the quantity of crushed bone and the absence of high-yield grease elements (thought to have been pulverized beyond recognition) Vehik (1977:178) also felt that there was sufficient evidence for grease production at these two sites. While it is quite possible that bone grease had been manufactured at these two sites, I think that additional evidence is needed for a more definitive conclusion. The issue of grease production at Millville is addressed at more length in Chapter VI and includes the results of an analysis of a bone assemblage that was obtained from this site. Unfortunately, Vehik (1977) did not discuss the greater cultural implication of bone grease production at these sites.

In addition to the work of Leechman (1951) and Vehik (1977), a number of additional accounts of bone grease production are present in the archaeological record of North America. Most of these accounts come from the Plains and provide us with some insight regarding the cultural motivations for grease production. While it has been made clear that grease manufacture is a laborious process and thus frequently tied to times of resource stress, archaeological examples from the Plains indicate that this may not have always been the case.

Bone grease production appears to have been a prominent activity at the protohistoric Rush Site in west-central Texas(Quigg 1997). This site dates to approximately 375 B.P. and was a likely processing locale for a nearby bison harvest, where at least 50 individuals were taken. The faunal assemblage consisted almost exclusively of fragmented large mammal bone. At least seven adult bison and two deer were present in the analyzed assemblage and Quigg (1997:157) indicates that of the over 11,000 remains, 92 percent were broken to a size of less than 3 cm in length. Only 3 percent were greater than 9 cm in length. Most of the fragments were from major long bones, while elements of the axial skeleton were less frequently fractured. Ageable remains indicate that the bison were killed during the month of November. Despite the lack of a specific analysis, the remains appear to indicate a significant degree of bone grease production.

In addition to the animal remains, features and artifacts from the Rush Site are also consistent with bone grease manufacture. The site had four hearths and several specific ash dump locales, indicating that fires were well-maintained and used for a considerable period, as would be expected for bone grease production. The stone tool assemblage consisted of remains directed at "resource procurement, game processing, and consumption" (Quigg 1997:150) and included a number of hammerstones and anvils. At least seven ceramic vessels were present at the site and carbon stable isotope analysis of the residue in five pots produced $\delta^{13}C$ values consistent with bison grease/fat (Quigg 1997:155).

Based upon the size of the site and extent of the unexcavated areas, it is estimated that at least 50 bison were processed at the Rush Site, indicating that grease production occurred as part of a communal processing event. Given the quantity of crushed bone and comparison to ethnographic data, Quigg (1997:158-159) believes that grease manufacture at Rush was probably intended for pemmican production. Pemmican was made by adding pulverized dried meat to melted grease/fat. Often other materials, such as nuts and berries, were added for additional flavor. The entire mixture was stuffed into an intestine and could be stored for up to three years. The substance was high in energy and valued for its nutrition, storability, and transportability.

In addition to the Rush Site, Quigg (1997:158-159) discussed a number of additional southern Plains sites that produced evidence of grease manufacture. These sites included the Broken Jaw (ca. 375 B.P.) and Sanders (ca. 2,100 B.P.) sites of the northern Texas panhandle. Both Broken Jaw and Sanders were late winter bison processing sites with large quantities of crushed bone, resembling that seen at Rush. Additionally Quigg mentioned evidence of bone grease production, in the form of crushed bones, at a number of Antelope Creek Phase (ca. 400-850 B.P.) sites in the Texas panhandle. Similarly, large quantities of crushed bone have also been interpreted as bone grease production in Garza Complex occupations (ca. A.D. 1,650) at the Lubbock Lake and Garza sites in northwest Texas. Additionally, six Toyah Phase sites in central Texas have produced evidence of bone grease manufacture. At least two of the Toyah Phase sites have been interpreted as communal kill sites, and one, 21HY209T, was a processing site associated with a deer and pronghorn harvest. Unfortunately, all of the references provided by Quigg (1997:159) in regards to the preceding sites were unavailable grey literature, or personal communications.

Moving northward onto the central Plains, we see several additional examples of bone grease production. One such example comes from the White Rock Site (14JW1) in north central Kansas (Logan 1998). This is the type-site for the White Rock Phase of western Oneota occupations and dates from A.D. 1,300-1,500. One feature from the site has produced a large pile of crushed bison bone, consisting primarily of lower limb elements. The bone pile is a very discrete deposit and may represent either an in situ cooking event or be the result of secondary refuse disposal. Logan (1998:358-359) indicates that the preponderance of lower appendicular elements may be interpreted in two ways. First, relying on knowledge that fat in the lower legs is among the last fat to be metabolized by nutritionally stressed animals (Speth 1983), it may indicate that the grease production was an attempt to secure some of the last available animal fat. In this sense, the assemblage may be an indication of resources stress. Alternatively, since fat from the lower limbs was generally considered to be of high quality (e.g. Binford 1978; Wilson 1924), the remains may indicate a more selective grease processing event focused on securing only the most desirable fat.

Logan (1998:360-361) also makes reference to two additional bone grease sites on the central Plains. Two protohistoric Lower Loup Phase sites in Nebraska yielded a significant quantity of fragmented bison bone that has been interpreted as the result of bone grease manufacture (Peterson et al. 1993; and Roper 1989; both cited in Logan 1998:360). These two Lower Loup Phase sites appear to hunting camps.

Several additional archaeological accounts of bone grease production come from the northern Plains, where the antiquity of the practice may date back 5,000 to 7,000 years (Reeves 1990; Walker 1992). Frison (1991) has described features at both the Big Goose Creek and Piney Creek sites in Wyoming that were likely associated with grease production. These features include pits for heating boiling stones and piles of fragmented bone. Brink and Dawe (1989) have recorded bone boiling features at a processing area associated with the Head-Smashed-In bison jump in Alberta. As already noted above, Leechman (1951) mentioned that crushed bone piles on northern Plains and Midwestern sites were likely the product of grease production. Also previously mentioned is Vehik's (1977) account of bone grease production at the Quast and Huff sites in North Dakota. Finally, Karr et al. (2005) has also provided evidence for bone grease production at the Mitchell Prehistoric Indian Village in South Dakota. The site was a Middle Missouri Tradition settlement and faunal assemblages from at least two earth lodges have been interpreted as the product of grease manufacture. Both of the assemblages consisted of heavily fragmented bison remains that were fractured while the bones were still fresh. Much of the methodology used in identifying grease production was based upon work by Outram (1998, 2001, 2002) and is discussed further in following sections. The evidence at the site suggested "that bone fat exploitation was neither a limited nor circumstantial occurrence, but rather, that it was a continued, long-understood, and well-practiced set of processes among the inhabitants of the Mitchell site" (Karr et al. 2005:44). Grease production at the site has been attributed to the production of pemmican, a well-documented and important resource among historic Plains cultures.

The preceding discussion was not intended to be a complete summary of all accounts of bone grease production in the archaeological record of North America, but to highlight the fact that bone grease manufacture was common in many areas of the ancient continent and produced under a variety of circumstances. While bone grease production is often interpreted as a response to resource stress (e.g. Broughton 1999; Outram 1999, 2004; Speth 1990; Speth and Spielmann 1983), many of the ethnographic and archaeological examples cited above indicate that grease manufacture was frequently associated with the mass harvest and processing of large animals. In the second situation, grease production was a regular part of the yearly subsistence cycle (see Brink 1997). On the Plains it was produced in large quantities and used in the manufacture of pemmican, a critical food that could be easily stored for use in the lean portions of the year or be traded for other valuable goods. While grease production may have still have been the result of an environment chronically lacking high quality animal fats, it was unlikely viewed by the ancient inhabitants of the region as a marginal resource. Bone grease was, in many cases, a critical, high quality, storable fat that was produced at lower production costs when it could be manufactured in large quantities as the result of mass harvests of large mammals.

From this review, we see that the archaeologist is faced with not only determining if bone grease production was present at a site, but also interpreting the reasons for which the grease was manufactured. These issues are discussed in greater detail in the following chapters.

Criteria for the Identification of Archaeological Grease Production

Based upon the preceding discussion of ethnographic and archaeological data, four criteria seem to be crucial in identifying bone grease production in the archaeological record. Although these criteria are based heavily upon the work of others (e.g. Binford 1978; Lechman 1951; Outram 1998, 2001, 2002, 2004, 2005; Vehik 1977), they have rarely been laid out specifically. It is all too often the case that researchers equate highly fragmented bone assemblages with grease production. While this may be the case, there are a number of additional factors that must be considered before assigning such a designation. The four criteria discussed below must not be viewed as mutually exclusive, but rather need to be considered together if one is to definitively identify grease production in the archaeological record.

It is also important to note that in many archaeological examples not all of the criteria may be fully met. This brings up a problem of equifinality. In some cases an assemblage may indeed be the result of grease production, but concerns over its context or taphonomic history could make it impossible to confirm. In order to contend with this issue, some researchers (e.g. Broughton 1999; Nagaoka 2005; Outram 2004; Wolverton 2002) have focused more upon measuring diachronic changes in bone fragmentation rates to evaluate the intensity of carcass utilization through time. While I agree that increased bone fragmentation may indeed be the result of more intensive carcass utilization, I am very hesitant to attribute such changes directly to a greater frequency of bone grease production. In order to definitively identify archaeological bone grease production, the following four criteria must be met (see Chapter V for a specific methodology as to how they were applied to remains from the Driftless Area):

1.) Fragment Size

In the first archaeological identification of bone grease production, Leechman (1951) analogically inferred that comminuted bone piles commonly observed on many Plains sites were akin to the debris of bone grease processing events observed among the Loucheux of the northern Yukon. Although Leechman's report on grease production is rather brief, it serves to illustrate the fact that the most obvious product of bone grease manufacture is a highly fragmented bone assemblage. This notion of highly fragmented bones was replete in the ethnographic examples discussed above and has become the principal criteria through which zooarchaeologists have identified grease production. It seems that there are few, if any, other reasons why humans fracture bone to the extent used in grease production (Vehik 1977:169).

While the importance of small fragments is well accepted by most zooarchaeologists as a signature of grease manufacture, Church and Lyman (2003) have recently questioned the necessity of small fragments for grease production. They conducted an experiment in which several lots of white-tailed deer long bone epiphyses were cut into cubes of varying size: 4 cm, 2 cm, and 1 cm. The cubes were boiled and their grease yield was measured hourly for 14 hours. It was determined that there was no statistically significant difference in the efficiency of grease extraction between the sizes, thus leading to the conclusion that intense fragmentation may not have been as important as previously thought (Church and Lyman 2003). A careful review of their data (see Chapter VII)indicated substantial differences in the extraction efficiency after 1-2 hours of boiling. It is likely that these differences would have been even more significant among populations utilizing traditional boiling techniques (for a similar critique see Nagaoka 2005). Given these concerns, and that all ethnographic descriptions of grease production describe extensive bone fracturing, a heavily fragmented bone assemblage still seems to be the most classic signature of grease manufacture.

In order to make accurate comparisons, a method must be employed to quantify fragmentation rates. Wolverton (2001, 2002) has specifically examined fragmentation in relation to bone grease production and suggests that as bone grease extraction intensifies, the NISP per individual skeletal element should increase, as each bone is being broken into a greater number of fragments. Thus, ruling out all other taphonomic factors, one can simply calculate the NISP:MNE ratio to make intra- and inter-site comparisons of carcass processing intensity (an presumably grease extraction). The problem in doing so is that as fragmentation increases, there becomes a point when the remains are reduced to such a size that they are no longer identifiable (Marshall and Pilgram 1993). Accordingly, a heavily fragmented assemblage could have an NISP:MNE ratio similar to that of lightly fragmented assemblage. To contend with this problem, Wolverton (2002) suggests that a NSP:NISP ratio would be a good measure of the fragmentation intensity. This ratio is basically the percent identified, which has already been established by Gifford-Gonzales (1989) and is commonly recorded in most faunal reports.

Although this approach has been used in recent studies (e.g. Munro and Bar-Oz 2005; Nagaoka 2005), it should be employed with great caution. Both the NISP:MNE and NSP:NISP ratios can be heavily affected by taphonomic processes, recovery methods, and the *skills and intents of different analysts*. Therefore it may only be useful when comparing fragmentation within a site or between sites that have been examined by the same analyst and have very similar taphonomic histories. It may serve as a useful heuristic device when looking at the intensity of fragmentation on Midwestern sites, but I do not believe that it should be used as the sole method to identify grease production, nor should it be relied upon extensively.

A number of other approaches have also looked at the intensity of fragmentation in relation to bone fat exploitation and carcass processing. These include estimating percent completeness (Morlan 1984; Todd and Rapson 1988) and comparing counts of diaphysis to epiphysis fragments (Broughton 1999). Although these methods are more easily replicated, their application to bone grease studies has not been thoroughly evaluated.

The least biased method of measuring fragmentation rates involves an actual measure of fragment size. Outram (1998, 2001) has developed such a method that is aimed specifically at bone grease studies. In this approach, the fragments are sorted into major size classes based upon their maximum dimension. This can be preformed quickly by passing the fragment over a series of concentric circles, each with a specific diameter. Outram (1998, 2001) used the following size classes (mm): 0-20, 20-30, 30-40, 40-50, 50-60, 60-80, 80-100, and >100. Whole bones and epiphyses were sorted out of the material and counted separately. Additionally, the bones can be grouped into major classes (such as epiphyses, compact diaphyses, ribs, vertebrae, miscellaneous cancellous tissue, and other) prior to measurement, allowing for a more in-depth look at the various cultural and natural processes that may have impacted the remains.

In addition to a count, the bones from each size class are weighed. Outram (1998, 2001) stresses the importance of measuring the weight, as it indicates the actual mass of bone represented in each size category. Thus one large, non-fractured bone represents as much mass as many smaller fragments. Although I agree that looking at mass is important, it can also bias the sample as a nearly complete element accidentally included in a trash deposited with a heavily fractured assemblage can create a major bias towards the larger specimens.

The real advantage of Outram's approach is that it is readily repeatable and that it provides quantitative measures than can be easily displayed in the form a histograms or line graphs. Furthermore, Outram (1998, 1999, 2001, 2002, 2003, 2004, 2005) has applied the method to numerous assemblages and demonstrated that it is very effective in comparing fragmentation intensity and exploring bone grease production. Other than being a bit time consuming, I believe that this particular method may be the most effective for future studies of bone grease exploitation in the Midwest. Unfortunately, like the other methods, it does not provide a "cut-off point" to determine if bone grease extraction has occurred. Instead this decision remains to be a judgment call of the analyst based upon the overall fracture and fragmentation patterns, the ability to rule out other taphonomic factors, and the overall context of the bone remains

2.) Fracture Patterns/Determination of Fracture Agent

In addition to demonstrating that an assemblage has been heavily fragmented, one must also establish that the fragmentation was the result of intentional human activity. Numerous agents (e.g. butchering, carnivore feeding, weathering, burning, sediment overburden, volcanic activity) can fracture bones (see Lyman 1994:324-328 for a review). It is first necessary to determine if the bone was fractured while fresh (referred to as "green"), or if it occurred when it was dry. Only fresh bones would have been processed for grease. Dry bones can be fractured both prior to and following deposition; however, a number of features allow dry fractures to be distinguished from fresh, or green fractures.

To determine if fragments were produced from fresh bone, Outram (1998, 2001, 2002) developed what he termed the Fracture Freshness Index (FFI). This was based upon rigorous experimental work in fracturing bones and it was intended to provide a quick, although accurate, assessment of the assemblages. For the index, fractures were broken into three components: fracture angle, fracture surface texture, and fracture outline. Each of these criteria was judged on a scale of 0 to 2, with 0 indicting clear signs of fresh fracture, 1 denoting mixed signs, and 2 representing a clearly non-fresh fracture.

The scores for the three components were combined to produce a composite index of 0 to 6. As cancellous tissue does not show clear signs of fracture type, the index could only be applied to diaphysis fragments.

Outram's FFI method (1998, 2001, 2002) was developed specifically for the identification of bone grease production, and would seem to be particularly useful in a number of situations: (1) when examining a large bone assemblage that has come from more dispersed midden-type deposits, where the remains are likely from multiple activities and have different taphonomic histories, (2) when examining an assemblage that has experienced a significant degree of taphonomic modification (e.g. animal gnawing, burning, density-mediated attrition, etc.), and (3) when attempting to make intra- and inter-site comparisons, especially when the assemblages come from dissimilar contexts or have unique taphonomic histories. In these scenarios, particularly those where comparisons are conducted, having a rigorous and objective method for documenting fracture patterns is not only quite useful, but also necessary in determining the extent of bone grease production.

In other situations, however, the application of a recording method, such as the FFI, may prove overly labor intensive and unnecessary for the documentation of grease manufacture. For example, in cases where a discrete deposit of fragmented bone has been recovered from a trash pit or other isolated context, a less intense analysis/description of the bone fracture patterns could provide equally substantial evidence for fragmentation by a human agent. In situations such as this, where the bones are likely the product of a single activity, and have experienced few taphonomic modifications beyond fragmentation, a more simple description and count of the fracture patterns may suffice.

Certainly, instances of these isolated contexts are much less frequent than bone from midden deposits, yet the majority of the assemblages specifically analyzed in this study came from discrete deposits. Therefore, attention is devoted to the more traditional techniques of documenting the agent responsible for bone fracture.

Analysis of bone fracture patterns has a long, and often controversial, history in archaeology (see review by Lyman 1994:315). Numerous researchers have examined bone breakage through actualistic studies (e.g. Davis 1985; Johnson 1985; Morlan 1984; Outram 1998, 2001; Villa and Mahieu 1991) and discovered a number of characters that help distinguish between bone that was broken while fresh, or green, and that broken after becoming dry. These characters can be broken down into several different criteria, including: fracture outline/shape, fracture surface/edge texture, and fracture angle.

The fracture outline/shape is description of the shape of the fracture's margin and includes a number of different types, such as spiral/helical, perpendicular/transverse, longitudinal, v-shaped, stepped, and flaked fractures (Gifford-Gonzalez 1989; Johnson 1985; Marshall 1989; Shipman 1981). The specific definition of fracture shapes/types varies between authors and most are not specific to a particular fracture agent. The spiral/helical fracture type has received significant attention among many zooarchaeologists. This type of fracture was originally believed to have been the result of marrow extraction by humans (Dart 1957), but has since been determined to be the produced by a number of different agents (Lyman 1994:324). Johnson (1985) has described two types of helical/spiral fractures: those that form on dry bone and true helical fractures that result from the fragmentation of green bone. True helical fractures are curved, spiral around the diaphysis of a long bone, and have a rough fracture surface

(Johnson 1985:175). While fracture shapes are important in documenting the agent responsible for fracture, they cannot be solely relied upon for this task. One must also examine the surface texture of the facture edge.

The nature of the fracture surface texture allows one to determine if the bone has been fractured recently (i.e. during excavation or laboratory handling) or in the past. Recently fractured bones usually exhibit a light color on the fracture surface, with little to no adhering soil. They also exhibit other features of dry broken bones, such as rough surface texture and fracture angles at approximately 90 degrees to the cortical surface. Conversely, bones that were fractured in ancient times have a fracture surface color that matches that of the bone exterior and are often covered with equal amounts of soil. While color helps determine if the bone was fractured during, or subsequent to, excavation, it does not clarify whether the bone was broken while fresh or upon becoming dry. Bones that were fractured while fresh typically display a smooth fracture surface, while those that were broken after some drying usually have a rough/bumpy fracture surface (Johnson 1985:186; Outram 2002). The exception to this rule is bones that have experienced true helical fractures (Johnson 1985:175).

Finally, the angle of the fracture is critical in identifying green bone fractures. In terms of this criterion, freshly fractured bones typically display fractures that are at acute or obtuse angles to the exterior cortical surface of the bone (Johnson 1985; Lyman 1994). Again, this characteristic alone cannot be used to determine whether are not a bone was fractured while fresh. When one examines all three criteria together, however, a reasonable evaluation of the freshness of the fracture can be made.

After determining if bone was fractured while fresh or dry, a number of taphonomic signatures can aid in determining what agent was responsible for the fragmentation. Bones fractured by burning are obviously distinguished by color changes resulting from heat alteration. Carnivores systematically attack the epiphyseal ends of long bones and can create splintered epiphyses. Carnivore activity leaves specific marks, including pits, scores, and punctures on the bone (for a more complete description see Bonnichsen 1973; Binford 1981; Johnson 1985). Conversely, fracturing by humans can leave a number of distinct features upon bones, including: dynamic loading points/fractures (Johnson 1985:192), conchoidal fractures and flakes (Johnson 1985; Lyman 1987; White 1992:135-137), and crushing (White 1992:138). When all of the above fracture criteria are considered together the extent to which humans acted as agents of bone fracture is fairly apparent.

3.) Other Taphonomic Considerations

A number of taphonomic processes can potentially mimic or obscure evidence for bone grease production. Burning, animal gnawing, and post-depositional preservation/fragmentation were considered to be among the primary factors that would mask grease production or make comparisons between assemblages exceedingly difficult. In instances of mixed, secondary deposits, it maybe impossible to definitively identify grease production. Here, authors have relied more upon comparing rates of bone fragmentation at the intra- and inter-site levels to evaluate levels of carcass processing intensity (e.g. Outram 2004; Nagaoka 2005). It is in these circumstances were analysts must pay very close attention to taphonomy. If two assemblages have undergone different taphonomic histories (e.g. one heavily burned and one not) comparisons regarding fragmentation rates may be meaningless. Certainly, no two assemblages have the same taphonomic history, but a careful evaluation of bone modifications must be made in order to determine the extent to which the assemblages can be compared without too much bias. Since there are no obvious benchmarks for establishing the extent to which two assemblages are comparable, the decision must be left up to the informed judgment of the analyst. The degree of potential taphonomic bias should always be considered and discussed whenever comparing fragmented assemblages, particularly when determining if they are the product of grease production.

In the analysis of possible bone grease assemblages, careful attention must be given to documenting all noticeable taphonomic modifications. The bones should be examined for signs of heat alteration and can be assigned to various categories: unburned, scorched, burned/carbonized, and calcined. These categories represent different degrees of burning (Lyman 1994:384-391). Scorching or superficial burning darkens or blackens the surface or portions of the bone but leaves the rest unaltered. Longer exposure to heat carbonizes more of the collagen, causing burned or carbonized bone that is darkened or black throughout. If the heat exposure continues, the newly carbonized material begins to oxidize and change color from black to white or grayish blue. This white or gray, calcined bone also has a chalkier texture.

The remains should also examined for indications of animal modification, including rodent gnawing, carnivore gnawing, and ingestion (see Binford 1981; Klippel et al. 1987; Lyman 1994 for a description of these modifications). Extensive carnivore gnawing and ingestion can destroy bones and/or produce a fragmentary assemblage. The bones should also be examined for cut marks, which may reveal butchery patterns and thus indicate possible human created biases in the assemblages.

Perhaps the most significant taphonomic factors that would influence a bone grease assemblage are those that would occur post deposition: density-mediated attrition, and sediment overburden/trampling. Numerous factors (e.g. soil pH, aeration, water regime, and microbial action) can contribute to the decay of bone (Chaplin 1971; Lyman 1994) and it has been well demonstrated that different bones are more likely to be destroyed than others (see Guthrie 1967; Lyman 1994). The effect of density-mediated destruction can be determined by comparing the elements and element portions of bones from an archaeological assemblage to the known bone density values for that species (e.g. Brain 1969, Kreutzer 1992; Lyman 1984; see Lyman 1994 for a review). While knowing the extent to which density mediated attrition has affected an assemblage is important, it becomes difficult to determine in situations where the bone has been heavily fragmented (Lyman 1994:254; Lyman et al. 1992). In these circumstances, bone survivorship is obscured because extensive fragmentation differentially reduces the ability to identify particular elements (Lyman and O’Brien 1987). This means that standard approaches to studying density-mediated attrition may not be viable when studying bone grease assemblages.

As noted above, bone fragments can be divided into cancellous (less dense and more easily destroyed) and compact (more dense and less easily destroyed) bone. While other factors may come into play, one should generally expect the proportion of these fragment types to be similar across assemblages that have experienced extensive fragmentation. Fortunately, in this study, all of the assemblages were well-preserved and contained significant quantities of pure cancellous bone fragments. This suggests that they should be comparable. In instances where the ratio varies significantly, one would have to pay much closer attention to this issue and develop a better method for quantifying the impacts of density mediated attrition on heavily fragmented assemblages.

Sediment overburden and trampling may fracture the bones (Haynes 1991; Villa and Mahieu 1991) but its extent can be evaluated by the study of fracture patterns (see above). If the most of the fractures on the bones occurred while the bone was fresh (green bone fractures) it is unlikely that that had experienced little post-depositional breakage and it is more likely that they were intentionally broken. The percent of green bone fracturing on compact bone fragments should be carefully considered when evaluating the assemblages. Bones occurring in sealed contexts, such as refuse pits, are also less likely to have been trampled.

Besides addressing potential biases in the assemblages, taphonomy is also considered important in determining the context of the bones (e.g. primary, secondary-mixed, secondary-discrete). Bones with minimal taphonomic modifications, other than fracturing, are more likely to be from a primary or secondary-discrete deposit. Those with extensive taphonomic modifications (e.g. carnivore gnawing, ingestion, burning, weathering) are more likely from a mixed secondary deposits. The implications of context are discussed below.

4.) Context

The final criterion involved in the identification of bone grease production is the archaeological context of the assemblage. As discussed above, evidence for grease production could occur in two contexts: primary and secondary (it should be noted that division between these contexts is somewhat arbitrary and they are perhaps best viewed as two ends of a spectrum). In a primary context, the bones remain directly associated with the tools and site facilities used in grease production (e.g. hammerstones, anvils, hearths, etc.). Grease residue in a primary context is most likely to occur at a small, briefly occupied processing camps (Vehik 1977). As the fragmented bones would more closely retain their associations with the processing equipment, such an assemblage would provide very strong evidence for grease production.

Grease production becomes more difficult to identify in secondary contexts. On this end of the spectrum, the fragmented bone remains have become disassociated with processing equipment and possibly the original activity area. This is most likely to occur at larger, more permanent sites, where multitudes of other activities serve to scatter and obscure the evidence for grease production. In such cases, it becomes increasingly difficult and, perhaps, impossible to make definitive conclusions regarding the presence or absence grease production, thus creating the problem of equifinality. If the bone refuse from grease production was dumped about the surface of the site, it was likely to have become quickly scattered and mixed with the remains of many other activities. In this scenario one has to rely more heavily upon the previous three criteria to make a judgment regarding the existence of grease production. If, however, the bone residue was deposited into an isolated pile and quickly covered with sediment, such as in a refuse pit, bone grease production would be significantly easier to indentify. Here, we would expect to find a very discrete deposit, or pile, of crushed bone. If it could be demonstrated that the remains from such a deposit were highly fragmented as the result of human activity (following the above three criteria), there would seem to be few explanations other than grease manufacture.

The contexts of the bone assemblages can be classified as either primary, mixed secondary, or discrete secondary. A deposit would be considered primary if the site was small, and contained bone refuse in association with materials that may have been utilized in the production of bone grease. Mixed secondary deposits are those in which the bone was dispersed about the site or mixed within a large feature, with no discrete "piles" of crushed bone. A bone pile can be defined as a deposit containing at least 100 bone fragments that were clearly associated and preferably in direct contact with one another (see descriptions and photos of Features 438 and 441 from the Krause site in Chapter VI for good examples of bone piles). Finally, a discrete secondary deposit is defined as a provenience that contained bone piles. Such contexts would greatly aid in the identification of grease manufacture, as they are the result of single activities. The context of the discrete deposits and any associated materials should also be considered in determining the nature and extent of bone grease production.

CHAPTER III
THEORETICAL BACKGROUND

Introduction

This chapter focuses on providing a theoretical grounding for the interpretation of bone grease production in the archaeological record. The nutritional value of fat and the roles it played in prehistoric subsistence systems are emphasized. The data discussed in the chapter demonstrate that cultures living in regions with scarce quantities of fats and carbohydrates may have been forced to turn to non-traditional fat sources, including bone grease. Since a single animal yields a relatively small quantity of grease, and processing costs are typically quite high, many have seen bone grease manufacture as an indicator of resource stress.

While it is certainly true that bone grease may have been one of the last viable fats available to a stressed population, the data in this chapter indicate that grease production should not always be viewed in such a manner. As is discussed below, in regions where cultures harvested large mammals, in mass numbers, the processing costs associated with grease production may have been greatly reduced. Here, the large-scale production of grease may have been vital in creating a readily storable, high-energy food necessary for survival during lean months. Although this is indicative of a less productive environment, it is unlikely that these past peoples viewed themselves as living a marginal existence. In fact, grease production may have been seen by many ancient cultures as part of the normal seasonal subsistence cycle.

In order to better understand the motivations behind ancient grease production, and help to determine if grease manufacturing events were the result of acute resource stress, or the product of an environment chronically lacking in year-round supplies of fat, this thesis utilizes theoretical concepts from the field of behavioral ecology. This approach draws upon optimal foraging models and specifically applies the marginal value theorem to animal carcass butchery and utilization (prey-as-patch modeling). As discussed below, this model implies that as ancient groups experienced resource stress, they would increasingly utilize less valuable portions of each animal carcass in order to meet nutritional needs. This theory relates not only to meat selection and transport, but also to bone grease manufacture. Societies that were involved in the large-scale production of grease (in association with mass harvests of large animals) may have preferentially selected only the highest yielding and least costly bones for grease manufacture. Conversely, societies who were making grease during times of starvation may have been less picky about the elements selected for grease manufacture and would have likely processed many more low-yielding elements. Careful consideration is paid to the fact that although optimal foraging models have been shown to be quite successful in predicting human decisions they do not always accurately reflect human behavior.

Dietary Importance of Fat

As discussed in the introductory chapter, humans today often fail to recognize the dietary significance of fat. The current overabundance and overconsumption of this nutrient has led to a major health crisis in the United States. With the rise of these concerns many have come to see fat as something to be avoided and forget that it is a critical component of the human diet. While large quantities of fat are certainly bad, it is still a necessary part of the diet and the ability to acquire reliable quantities of fat undoubtedly played a major role in shaping the subsistence strategies of many ancient cultures.

Fat is a crucial nutrient for a number of reasons. First, fat is a very satisfying resource that not only tastes goods but gives one a feeling of fullness and satisfaction upon consumption (Cordain et al. 2000). Fat is the most concentrated form of dietary energy as it supplies more than twice the caloric content of equal quantities of carbohydrates or proteins (Erasmus 1986; Mead et al. 1986). Fat is also metabolized more efficiently than protein (Mead et al. 1986; Speth 1990). Additionally, fats are often an important source of many lipid soluble vitamins (e.g. A, D, E, and K) and certain fatty acids are necessary to maintain proper bodily functions (Mead et al. 1986).

While the above reasons make it abundantly clear that fat is an essential nutrient, there is one other factor that makes the consumption of fat absolutely critical to those living in certain environments. This additional factor is related to the body's ability to process large quantities of protein. In many regions of the world, sources of carbohydrates and fats are scarce and become even more limited on a seasonal basis (particularly during the winter). In these regions, especially those in the extreme northern latitudes, diets often consisted nearly exclusively of hunted or fish animals (Kelly 1995; Murdock 1967; Speth 1990). This dependence upon animals meant that a large portion of dietary energy came from protein. The problem with reliance on large quantities of protein is that humans cannot tolerate diets where more than 35 to 50 percent of the total energetic intake is derived from protein (Cahill 1986; Cordian et al. 2000; McGilvery 1983; Speth 1990; Speth and Spielmann 1983).

When the consumption of protein exceeds the above quantities, the human body begins to exhibit symptoms described ethnographically as “rabbit starvation” (Speth and Speilmann 1983). Early explorers and traders traveling through the northern United States and Canada encountered situations where the only available food was lean meat lacking any appreciable quantities of fat and comprised almost exclusively of protein. In these instances, excessive consumption of lean meat led to nausea, diarrhea, and ultimately death.

The physiological reasons behind the symptoms of rabbit starvation are due to the body’s limited ability to metabolize amino acids and to synthesize and excrete urea (Cordain et al. 2000; Rudman et al. 1973; Speth 1990). This results in conditions clinically referred to as hyperammonemia and hyperaminoacidemia, which were likely responsible for the symptoms described as rabbit starvation (Cordain et al. 2000). While this condition has rarely been documented among human subjects in clinical settings (see Speth 1990 for a discussion of high protein intakes in laboratory rats), it is quite clear that there is an upper threshold for safe protein consumption in humans. Cordain et al (2000:688) suggest that the limit for safe protein consumption is around 35-40 percent of the total energetic intake. Speth (1990) suggests that societies living in areas with limited carbohydrates and fats may have built tolerances where upwards of 50 percent of the dietary energy could have been derived from protein. Furthermore, Speth (1990:155-156) indicates that in pregnant women the safe upper limit for protein consumption may be around 20 percent of the total diet. Excessive consumption of protein during pregnancy may lead to lower birth weights, increased perinatal mortality and developmental problems.

In order to avoid the health problems associated with excessive protein intake, one must incorporate greater quantities of carbohydrates *or fat* into the diet. Cordain et al. (2000:689) list six possible methods by which prehistoric cultures could have avoided excessive protein consumption:

> They could have *1*) increased their [plant to animal] subsistence ratios by eating more plant food energy; *2*) hunted larger animals because percentage body fat increases with increasing body size; *3*) hunted smaller animals during the season in which body fat is maximized; *4*) selectively eaten only the fattier portions of the carcass, *including lipids boiled from the cancellous tissues of bones*, and discarded the rest; *5*) increased their intake of concentrated sources of carbohydrate such as honey; or *6*) implemented ≥ 2 of the 5 options [Cordain et al. 2000:689; emphasis added].

Perhaps the best way to avoid the protein ceiling is to follow the first option suggested by Cordain et al. (2000:689): to increase the in take of energy through the consumption of more plant food. Unfortunately, in many environments, such as those located in the northern temperate and Arctic/Subarctic latitudes, the availability of plants (and concentrated carbohydrate sources) may be severely limited. In these regions, prehistoric hunters had to turn to animal fats to attain a balanced diet. For example, many traditional Inuit populations were almost completely carnivorous (Speth 1990; Stefansson 1944, 1956), with only limited carbohydrates coming from the stomach contents of caribou (Eidlitz 1969). While these carnivorous populations subsisted almost exclusively upon animal resources, their prey species (particularly sea mammals) supplied a large quantity of fat, thus making high protein intakes viable (Speth 1990; Speth and Spielmann 1983).

To demonstrate the viability of a completely carnivorous diet, the explorer Vilhjalmur Stefansson lived for an entire year (1928-1929) by consuming only animal fat and protein (Stefansson 1956). At the time of his experiment, Stefansson resided in New

York City and consumed various animal meats, with 25 percent of his average daily caloric intake coming from protein, and the remaining 75 percent from fat. Stefansson (1956) remained healthy during the course of his experiment and did not exhibit any nutritional deficiencies.

While ethnographic and experimental data demonstrate that it is possible for a human to subsist completely on protein and fat, sufficient sources of animal fat were often far from abundant. Many groups residing in Subarctic and northern temperate latitudes obviously did not have access to the abundant fat stores of sea mammals, and also lacked sufficient quantities of available carbohydrates. In these situations, indigenous peoples relied on the fat of large animals, such as caribou, bison, American elk, moose (*Alces alces*), bear (*Ursus* sp.), and white-tailed deer. The fat content of these animals, however, varies considerably throughout the year. During the late spring, summer, and early fall, these animals are generally healthy and have abundant body fat. Furthermore, during this time of the year the environment may also supply humans with additional fats and carbohydrates that help avert the protein ceiling. As the seasons cool and plant foods begin to diminish, these large animals become more reliant upon stored energy and begin to mobilize their fat reserves (Speth 1983; Speth and Spielmann 1983). The fat levels of large animals are generally lowest following the rut (breeding season) for males, and during gestation and lactation for females. Additionally, very young and old animals, as well as those is poor health, generally have lower meat-to-fat ratios.

In addition to this seasonal variation in large mammal fat abundance, prehistoric hunters would have also been aware of the fact that an animal’s fat reserves are mobilized in a particular sequence. The issue and order of fat mobilization among large animals has been well established by Speth (1983, 1990) and is summarized below. When an animal becomes stressed and begins to mobilize its fat supplies, the first to be utilized are those on the back and rump. The next to be utilized are the subcutaneous stores on the torso and other portions of the body. From there, the fat of body cavity and viscera begin to disappear. The final fat reserves to be mobilized are those stored as marrow within the bones. This generic sequence of fat utilization has been specifically observed in white-tailed deer (Harris 1945). Even within the bones, there is a specific order in which the marrow fat is mobilized. Generally, the first marrow fat to be mobilized is that of the large upper limb bones, the humeri and femora. The utilization of marrow fat continues down the limbs, and ultimately to the phalanges. The fat in the mandible and that in the cancellous tissue of the vertebrae are also among the last to be mobilized. Brink (1997:271) has further suggested that within specific bones, bone marrow from the medullary cavities was likely mobilized prior to that stored in the cancellous tissues (bone grease).

The significance of bone marrow and grease is further highlighted by the fact that bone fat contains higher quality fat (greater percentage of fatty acids/chemical fat) than that found in the rest of an animal carcass (Brink 1997; Emerson 1990). As bone grease was one of the last dependable sources of high-quality fat, its production may have been crucial for the survival of ancient human cultures, where supplies of fats and carbohydrates were seasonally limited. Furthermore, since the manufacture of bone grease results in a number of distinct archaeological signatures (see previous chapter) this activity may be one of the best methods by which to observe the dynamic nature of ancient subsistence patterns and explore how past societies coped with both long- and short-term episodes of nutritional stress.

Since bone grease manufacture is both labor intensive and focuses upon the last remaining fat supplies, it is often viewed as a starvation activity – something that one would turn to only in the direst of circumstances(e.g. Broughton 1999; Outram 1999, 2004; Speth 1990; Speth and Spielmann 1983). It has also been seen as indicative of cultures inhabiting “marginal environments” (e.g. Outram 2004). Certainly, bone grease would have been a critical source of high quality fat during times of famine and acute nutritional stress; however, as the ethnographic data discussed in Chapter II indicate, it was also produced in times of plenty. In this context, bone grease was manufactured in association with the mass harvest of large mammals (see also the discussion by Brink 1997:271-272). When bone grease was rendered from multiple animals in prime condition, the processing costs would have been reduced and substantial quantities of high quality fats could have been obtained. These fats may have been stored and served as critical supplies to survive lean times, or been highly valued trade commodities.

Historically, on the Plains and in the sub-Arctic, much effort was afforded to the acquisition of fats and the production of pemmican (see Stefansson 1956; and references in Brink 1997:272). It was often made from the high quality fats from bone marrow and grease (Grinnell 1962; Schoolcraft 1851; Teit 1930; Wissler 1910) and could be stored for upwards of three years (Leechman 1951). Given the emphasis upon the use of bone grease in pemmican manufacture, “it would be inappropriate to assume that archaeological evidence of grease rendering always indicates desperate nutritional conditions or the spring season” (Brink 1997:272).

While environments, such as the Plains and Subarctic, had substantial seasonal variation in the availability of fats and carbohydrates, it is apparent that the ancient residents of these lands were aware of these conditions. They prepared for seasonal food shortages through the storage of high quality fats when they could be obtained and processed in abundance. Were these areas environmentally less productive than other regions? Certainly. Did their ancient inhabitants see themselves as living out a substandard form of existence, or living by means of a starvation diet in a "marginal environment"? Unlikely. In these circumstances, bone grease production was a regular activity that was performed on a seasonal basis year-after-year. While it may have occasionallybeen turned to as a starvation resource, it was probably seen more as a regular and integral part of the economy. This means that we cannot propose one single interpretation for archaeological evidence of bone grease production.

In order to better understand the reasons for grease manufacture, we must turn to additional archaeological data. This includes placing grease production into a larger cultural context and examining other issues, such as the seasonal timing of grease production, the inclusion of multiple animals in a grease processing event, and the extent to which each animal carcass was utilized in grease manufacture (i.e. were only high yield elements processed, or were lower ranking elements included as well?). Furthermore, we should not focus on singular occurrences of grease production, but rather need to examine this activity from a diachronic perspective. We need to ask questions such as: Did grease production increase or decrease in frequency through time? Did the seasonal timing of this activity change? Did people begin to focus on extracting grease from lower-raking elements or smaller prey animals? Only by exploring these issues can we begin to use bone grease production as a marker for changes in nutritional stress and as a tool for exploring how prehistoric peoples adapted to changing cultural and environmental conditions.

In the Driftless Area, white-tailed deer (the most abundant large animal in the region) begin rutting in late October and often continue well into December (Jackson 1961:419). Gestation continues through the winter and spring, with most fawns being born in late May or early June (Jackson 1961:419). Given the significance of white-tailed deer to the diet of the prehistoric inhabitants of the Driftless Area (see Chapter IV), the time from the end of the rut, through early spring, may have been a period of chronic resource stress. Given the predictability of the winter resource limitations in the Driftless Area, its ancient inhabitants likely took measures to prevent severe nutritional stress and the over-consumption of lean venison. This likely included drying and storing plant based carbohydrates and fats (nuts) and the rendering and storage of various animal fats, perhaps in the form of pemmican. During later times it may have included the storage of carbohydrates in the form of agricultural crops. Alternatively, the societies of this region undoubtedly had to deal with unpredictable resource failures and famine. Such situations may have necessitated the utilization of all available fat supplies, including bone grease. As noted above, additional archaeological data will need to be examined to offer more robust interpretations regarding the prehistoric motives behind grease manufacture.

Behavioral Ecology

Although the archaeological occurrence of bone grease production has been discussed for sometime, it was not until more recently that a rigorous theoretical framework was developed to connect it to human behavior. The most applicable theoretical models for understanding bone grease production are drawn from the field of behavioral (evolutionary) ecology, and specifically, optimal foraging theory. This particular field developed in the biological sciences to examine predator-prey relationships and has been adopted, to a limited extent, by anthropologists (Bird and O'Connell 2006; Kelly 1995; Winterhalder and Smith 1992).

Behavioral ecology attempts to explain how humans interact with their environment through an evolutionary framework, with a specific focus on natural selection. Cultural ecologists had assumed humans simply made "rational choices" when faced with decisions regarding interaction with the natural and cultural worlds. Behavioral ecologists realize that the notion of making rational choices "presupposes not only a set of goals (e.g. foraging efficiency) but preferences for strategies with a high degree of probability of meeting those goals" (Kelly 1995:50). Moving beyond the idea of rational choices, behavioral ecologists see that "a process of natural selection must be responsible for fixing, maintaining, and altering these goals and preferences" (Kelly 1995:50). Behavioral ecologists have not completely rejected the tenets of cultural ecology, but rather strengthened it with the addition of an explanatory mechanism – natural selection (Kelly 1995:51; Winterhalder and Smith 1992:51).

It is important to remember that behavioral ecologists do not believe that genetics directly determine human behavior, but rather that natural selection has endowed humans the ability to consciously and unconsciously make decisions that improve their reproductive fitness. When faced with economic decisions, such as those regarding foraging strategies, humans choose from a variety of different behaviors in order to accomplish the task at hand. Those humans who have the ability to carefully evaluate the reproductive consequences of these decisions should have greater fitness and thus pass this cognitive ability on to future generations.

Behavioral ecology relies upon two major assumptions. The first assumption is that selection acts upon the individual rather than the group. Many critics of behavioral ecology feel that this means that individuals must act independently of their culture, a proposition that is not true. It must be remembered that "the drive to 'succeed' probably entails not only biological directives (to reproduce), but cultural directives as well…" (Kelly 1995:53). In other words, a person's ability to successfully reproduce is limited by existing cultural norms and expectations.

The second major assumption of behavioral ecology is that of optimization. Most anthropologists have tended to focus upon optimization in relation to human foraging strategies and thus formed a large subset of behavioral ecology, referred to as "optimal foraging theory" (Charnov 1976; Kelly 1995; Smith 1979; Stephens and Krebs 1986). The general premise behind optimal foraging theory is that humans (and other animals) have evolved, through natural selection, the ability to forage in an optimal and efficient manner. In other words, humans should try to maximize the rate of food acquisition (which may be measured through a variety of currency) and minimize the amount of effort put into the food getting activity. This does not mean that humans always forage in the most efficient way possible, but seek to act optimally in the face of various cultural and natural restraints.

Humans should be expected to forage optimally if at least one of four conditions is met (Kelly 1995; Stephens and Krebs 1986; Smith 1983). First, if specific nutrients are limited in availability, humans should be expected to attempt to maximize their rate of acquisition. Second, humans should forage optimally when time spent in non-foraging activities would increase the chance of reproductive success. Third, optimization should also be expected if time spent foraging is particularly dangerous (e.g encounters with dangerous prey, treacherous landscapes, or extreme climatic conditions). Finally, optimality should be sought if the acquisition of excess food or prestigious food would increase reproductive fitness (e.g. increasing mating opportunities or setting up reciprocal relationships). At least one of these conditions is always met by traditional foraging societies.

Relying upon the tenets of optimal foraging theory, researchers have developed numerous models to predict how humans should be expected to behave when faced with a variety of foraging decisions. Most of these models were originally developed for the study of non-human behavior (Stephens and Krebs 1986), but have been successfully adapted to human foragers. Models of optimality have three mains components: a decision factor, a currency, and a set of constraints (Stephens and Kerbs 1986:5-11).

The decision factor is the most easily defined, and is simply the behavior that is being examined, such as the amount of time to spend foraging, what prey species should be taken upon encounter, or, in this instance, how extensively an animal carcass should be processed. Currency is a measurement scale for evaluating the possible decision outcomes, and is generally set as the overall energetic return. However, other variables must be considered as possible currencies. This is particularly true in the case of this thesis, where other nutrients, such as fat, may have been of greater concern. As noted above, in many environments large animals become fat depleted during the winter months. While these animals would still provide a large energetic return (due to their protein content), there may not be enough fat to offset the ceiling on daily protein consumption. In these situations, humans may have been foraging in a manner more consistent with the acquisition of fat. Other possible currencies, including specific nutrients, taste, and social prestige should also be considered. The final component of optimal foraging models is a set of constraints. Constraints are any number of factors (biological, cultural, or technological) that limit and confine the relationship between the currency and decision variables.

Although the use of behavioral ecology and optimal foraging in both biology and anthropology has been well critiqued (Gould and Lewontin 1979; Keene 1983), much of the criticism is not well founded (see discussions by Broughton 1999; Smith and Winterhalder 1992). Furthermore, optimization models have been shown to have a high degree of explanatory power for human foraging societies (Bird and O'Connell 2006; Kaplan and Hill 1992). A common anthropological critique of optimal foraging theory is it is deterministic. Though we should not attribute human behavior directly to environmental conditions, it is important to realize that the environment does set certain limitations to which behavior must conform. Certainly, maize agriculture cannot be carried out in the Arctic, nor can an economy focused on marine resources be feasible in Kansas. Behavioral ecology models do not determine human behavior; they only set reasonable limits as to how we should expect humans to behave, given specific environmental constraints.

In the following sections, I examine three popular optimal foraging models that are particularly relevant to understanding the bone grease production. These models lay the foundation for understanding the motivations behind prehistoric grease manufacture. When considering these models, it must be remembered that:

> The role of optimal foraging theory in evolutionary biology as well as anthropology is not to demonstrate that foragers optimize but to generate hypotheses that attempt to explain patterning in foraging behavior, or in the results of foraging behavior, both past and present [Broughton 1999:8].

Therefore, the intent of this study is not to explore the validity of the optimization models or to determine if the prehistoric inhabitants of the Midwest were foraging in an optimal manner, but instead to use these models as guides for expected behavior. Much information is gleaned when the evidence of human behavior does not match that as predicted by the model. This does not imply any inherent flaw in the model, or mean that societies were not acting optimally. Instead, these discrepancies indicate that we have erroneously estimated one of the model's components – decisions, currencies, or constraints. It is in these situations that we can learn the real factors that were guiding human behavior and gain a better understanding of past economies and cultural dynamics.

The Diet-Breadth Model

The diet-breadth model is one of the most common and frequently applied optimal foraging models in anthropology and archaeology. The model is also known as the "encounter-contingent prey choice model" the "basic prey model" and the "optimal diet model" (Bird and O'Connell 2006:147). In the traditional sense, this model is used to look at the number of species that are likely to be included in the diet (Charnov 1976; MacArthur and Pianka 1966). More specifically, it models which prey species will be harvested, or passed over, upon encounter by foragers searching a patch (with a relatively homogeneous distribution of resources). The decision variable is straightforward – whether to harvest a particular resource, or continue searching. The model balances total foraging costs against the net currency return and assumes that the goal is to maximize the net rate of return.

The model distinguishes between search costs and handling costs. Search costs are assigned to the resources as a whole, while handling costs are assigned to each individual prey species. Handling costs include all expenditures related to actually consuming the animal once it has been encountered (tracking, killing, butchery, transport, processing, cooking, etc.). The currency utilized is generally energetic (caloric) return, but could be any other variable (e.g. fat or hides) can be used, depending upon the goals of the forager. Most importantly, it is assumed that the forager has a reasonable estimate of the actual handling costs and post-encounter return rates for each species. The largest constraint of the model is the assumption that foragers are searching a homogenous environment, where resources are distributed evenly, as opposed to being in "patches" or "clumps." As this assumption is rarely met in most environments, the decision should be, more appropriately, whether to enter a particular patch, or continue searching the rest of the environment. The concerns raised over patchy environments are dealt with through additional models, including the patch-choice model (see below).

The decision to harvest a particular resource is based upon an ordinal rank of all resources available within a particular environment. Resources are ranked from highest to lowest based upon the ratio of post-encounter returns to handling costs. It is expected that the highest ranked resource (that providing the greatest return for the least amount of effort) will always be taken upon encounter. Resources of lower rank will also be taken, in descending order, until the post-encounter return rate of a particular resource falls below the overall expected return rate for the environment.

The diet-breadth model makes a number of important predictions (see Bettinger 1991; Broughton 1999; Kelly 1995; Smith 1991) regarding human foraging strategies. Perhaps the most significant prediction is that the decision to harvest a particular resource is not dependent upon its own abundance, but rather upon its post-encounter return, and the likelihood that all higher-ranked resources will be encountered (Bird and O'Connell 2006:147). This means that as higher-ranked resources become less abundant (through environmental change or over-harvest), we should expect more lower-ranked items to be included in the diet. Additionally, if the handling costs for particular resources can be reduced through technological innovation, the rate of return, and thus rank of that species, should increase.

The diet-breadth model has been applied widely in archaeology, particularly to address issues of resource intensification, human over-harvesting, foraging efficiency, and the development of a broad spectrum diet (see Bird and O'Connell 2006; Kaplan and Hill 1992; Kelly 1995; Winterhalder and Smith 2000 for reviews). Although, the diet-breadth model has proven quite powerful and useful in archaeological situations, it is not directly relevant to bone grease production. More recently, however, the diet-breadth model has been adapted to the study of carcass transport and processing decisions (Bettinger 1991; Outram 2003). In this sense, each individual animal carcass is seen as analogous to the complete resource make up of the environment. The portions of the animal are then ranked based upon their net return, in relation to their handling (processing/cooking) costs. Based upon extensive work in the creation of utility indices (e.g. Brink 1997; Binford 1978; Jones and Metcalfe 1988; Madrigal and Capaldo 1999), we see that different portions of the animal carcass have dramatically different economic values (and processing costs). Therefore, the various portions of the carcass can be ranked, just as specific resources were in the more general diet-breadth model.

If a forager is processing a carcass, with the goal of obtaining fat, the fat yielding portions of the animal can be ranked by their value, in relation to their processing costs. In this scenario, the highly accessible fatty portions of the animal (subcutaneous and inter-muscular fat stores) should be ranked highest, and then medullary bone marrow, and ultimately bone grease. Remembering that fat stores on individual animals are mobilized in a specific order during times of resource stress, bone grease should not be utilized unless the other fatty portions of the carcass have already been mobilized. This model, therefore, suggests that bone grease is among the least optimal fat supplies on an animal. Even more specifically, the bones of the animal can also be ranked, as they contain different quantities and *qualities* of grease. Many indices (ranks) have been developed for bone marrow (e.g. Brink 1997; Binford 1978; Jones and Metcalfe 1988; Madrigal and Capaldo 1999), but few have been calculated specifically for bone grease (cf. Binford 1978). While these utility indices are useful in understanding the order in which various elements may be utilized in times of resource stress, some caution must be applied. Some indices measure only fat quantity, while others measure fat quality (essential fatty acid content) and it may not be clearwhat specific measure of fat was being targeted as the selected currency. That being said one can still produce general ranks of bone grease elements, where the smallest and most difficult to access bones (carpals, tarsals, phalanges) should be ranked quite low.

The Patch-Choice Model/Marginal Value Theorem

The second major behavioral ecology model that can be related to carcass processing activity is the marginal value theorem, or patch-choice model. The following description is a rather brief generalization of the model. For a more complete review of the model, its implications, and its constraints, the reader is referred to classic sources, such as Bettinger (1991) Kaplan and Hill (1992), Kelly (1995), and Stephens and Krebs (1986). The patch-choice model assumes that the environment is heterogeneous and resources are dispersed over it unevenly, in patches (Charnov 1976). The purpose of the model (the decision variable) is to predict how long an individual organism will exploit a particular patch that yields resources at a diminishing rate. Return rates can diminish as the result of increased patch residence time and harvesting effort, or through natural forces. As the return for the patch decreases, the individual is expected to remain in the patch until the marginal return rate drops below the average return rate for the entire environment. As handling time increases with diminishing returns, we should not expect the patch to be completely exploited, but should see the individual move onto a new, unharvested patch when the resources of the current patch become difficult to exploit and the cost of traveling to a new patch is less than the cost of seeking out the remaining resources of the current patch. If the overall return of the environment is low or patches are rare and widely spaced, we would expect patch residence time to increase.

The patch-choice model is displayed graphically in Figure 1 (after Bettinger 1991:Figure 4.3). The positive diagonal line that passes through the y-axis represents the overall rate of return (currency) from the environment. This is calculated based upon travel, search, and handling times compared to returns for the environment as a whole.

The steepness of the line should vary based upon the overall productivity of the environment. A steeper line would equate to a more productive overall environment. The curved line represents the amount of energetic return from a particular patch and diminishes as a result of the amount of time spent foraging (right side of x-axis). If the return rate for a particular patch falls below that of the environment as a whole, the patch should be ignored. In a patch that has a greater rate of return than the environment, then the forager should be expected to stay there until the patch return rate drops below that of the environment as a whole. This point is considered the optimal departure time and coincides with where the curved (patch return) and diagonal (environmental return) lines intersect. The portion of the graph to the left of the y-axis represents amount of time considered acceptable to travel to a new patch. In a more productive environment, the diagonal line intersects the patch return line earlier, meaning the optimal time to remain in a particular patch should be less, and should also correspond to a shorter acceptable travel time between patches. It is assumed that human foragers have a reasonable estimate of the actual returns, as well as the travel, search, and handling costs.

Once again, the patch-choice model has proven useful for understanding human foraging and settlement decisions (see Kelly 1995); however, it is not directly applicable to the study of bone grease production. That being said, the model can be readily adapted to the harvest of individual animals and the processing of their carcasses (see Burger et al. 2005; Outram 2004). In this adaptation, the model is referred to as the “prey-as-patch model” and it is discussed in greater detail below.

The Prey-As-Patch Model

A great deal of recent attention has been given to the application of the patch-choice model to the study of carcass processing intensity (Burger et al. 2005; Nagaoka 2005; Outram 2004). In this model, we see that each individual animal is considered a "patch" and the intensity to which the carcass is processed is analogous to the amount of time spent exploiting a patch. Thus, as the overall return of the environment decreases, we should see a respective increase in the degree to which individual animal carcasses are being exploited. The decision variable is transformed from "how long to remain in a patch?" into "how long to process an animal carcass?" The success of adapting the marginal value theorem to carcass processing intensity has been demonstrated both theoretically and ethnographically (Burger et al. 2005).

The prey-as-patch model is represented graphically in Figure 2. In this graph, the diagonal lines (*a* and *b*) represent two hypothetical environments, with different overall energetic return rates. Line *a* is steeper and therefore represents a more productive environment. Line *b* is flatter and represents a less productive environment. The curved line represents the amount of energy that can be acquired from a particular kill. It should be noted that with increased processing, the rate of return from an individual carcass will quickly diminish. It is expected that in more productive environments (again represented by line *a*) that times between kills should be more frequent and therefore the optimal cut-off point for processing time should be reduced. Conversely, in less productive environments (line *b*), time between kills is longer and it should be expected that more time should be spent processing an individual carcass. The respective optimal cut-off

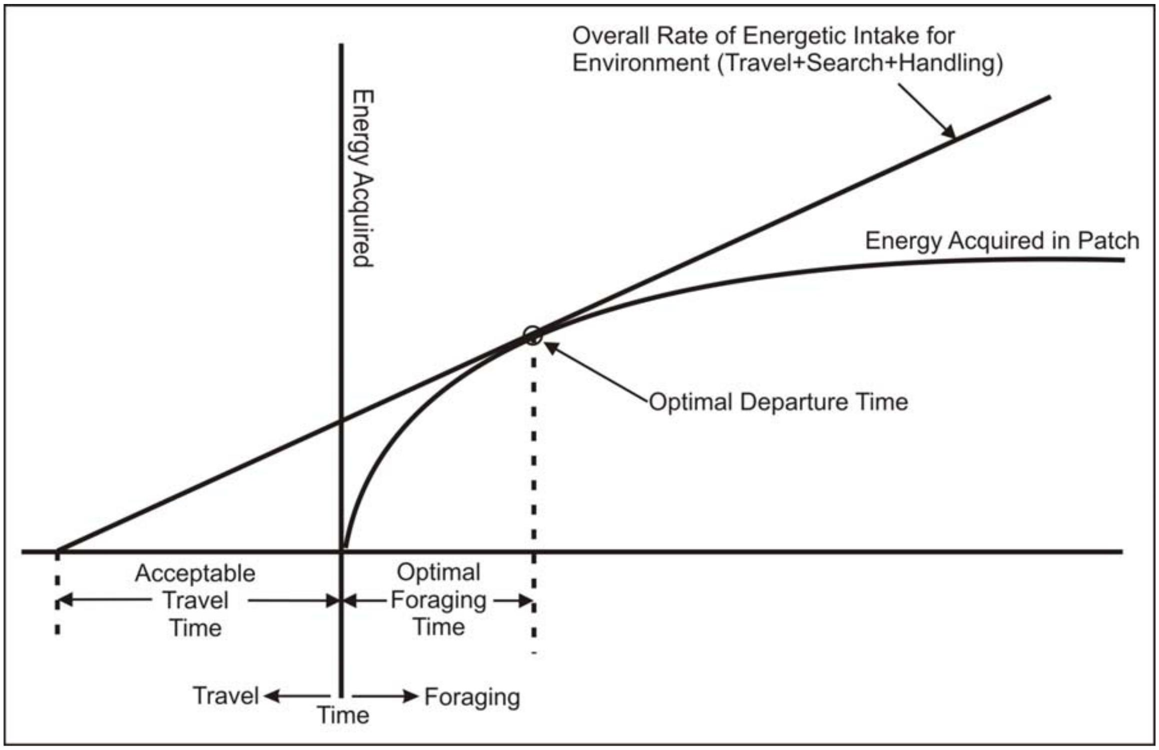

Figure 1. A graphical representation of the Marginal Value Theorem as applied to the Patch-Choice Model (after Bettinger 1991:Figure 4.3).

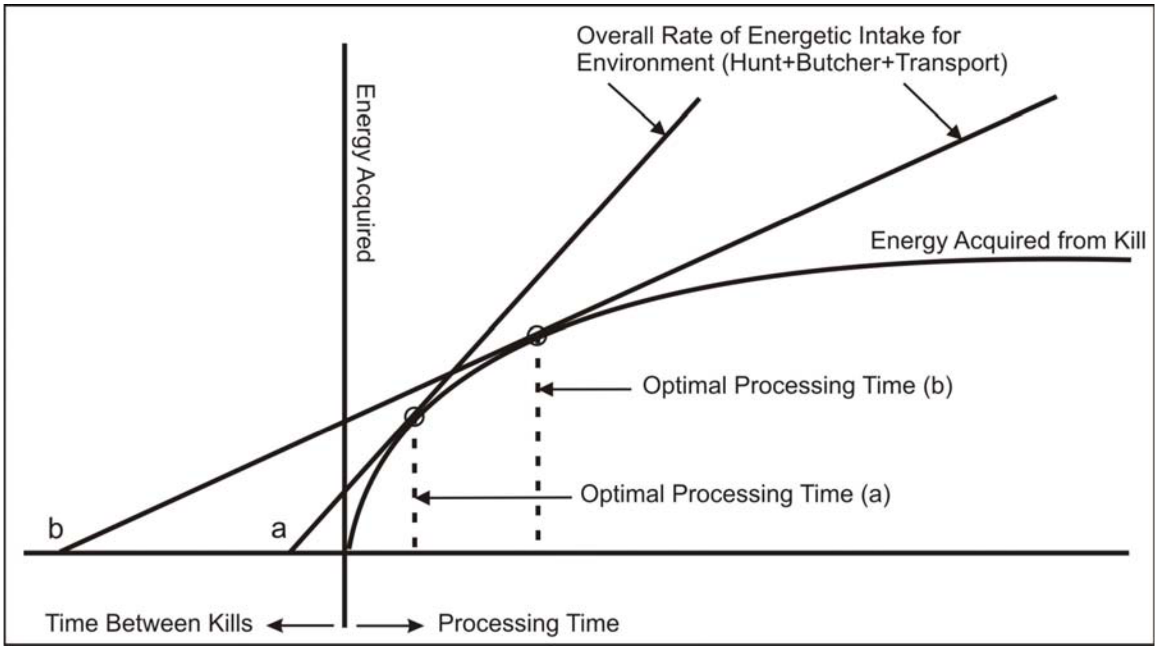

Figure 2. A graphical representation of the Marginal Value Theorem as applied to animal carcass processing and transport decisions.

points are marked by the tangent intersection of the diagonal environmental return lines with the curved carcass return line.

The prey-as-patch model not only predicts the optimal cut-off point for how long a carcass should be processed, but it also utilizes the marginal value theorem to predict the order in which anatomical portions should be utilized (Burger et al. 2005). As noted above, the anatomical units of an animal vary considerably in terms of their energetic yield. The profitability of these animal units can be ranked based upon their energetic return in relation to average processing times (e.g. Binford 1978; Brink 1997; Jacobson 2000; Jones and Metcalfe 1988; Madrigal and Holt 2002). While attention is often given to the overall energetic return of these units, Burger et al. (2005) argue that the role of specific nutrients, particularly fat, may have played more significant roles in carcass processing decisions. In environments where fat supplies were scarce, or seasonally restricted, the desire to obtain fat may have been the primary factor dictating what portions of a carcass were transported, processed and consumed. The utility of the prey-as-patch model is made even more significant by the fact that animal butchery and processing frequently results in a number of readily identifiable archaeological signatures. This is particularly true in the case of bone fat exploitation.

Critical to the application of the prey-as-patch model to issues of bone fat exploitation, including grease production, is that specific elements have different economic returns and continued processing of the bones from a single carcasses results in a condition of diminishing returns. It is expected that ancient foragers would have had a reasonable knowledge of the returns and processing costs for specific elements and would have tried to optimize returns. Even though there has been some disagreement as to how elements should be ranked in terms of their fat returns (fat quantity versus fat quality), it is quite clear that there are certain practices that would have only been conducted during times of some resource stress. Foragers who were not restricted by fat supplies should not have utilized bone marrow, let alone bone grease. This condition is quite rare and, prehistorically, most of the major long bones from large animals were cracked open to obtain the fat rich marrow. That being said, smaller and more difficult to access bones, such as phalanges and mandibles, should not have been utilized unless there was a greater need for fat (see Binford 1978; Jones and Metcalfe 1988). Furthermore, bone grease, being even more labor intensive, should not have been manufactured unless there was a significantly diminished harvest rate of large animals, or if those animals were in poor health and had already mobilized their more accessible fat stores.

Summarizing, the prey-as-patch model infers that as harvest rates of large animals diminished, carcass-processing intensity should have increased (Bruger et al. 2005). While I feel that this model is quite powerful and should serve as useful heuristic device in understanding the motives behind grease production, there are several concerns that seem to be frequently over-looked. The first is that this model assumes that the only way human foragers could have adapted to decreased large animal harvests is through increased processing intensity. Although this was probably true in most cases, returns may have been also improved by directing additional efforts to harvesting lower-ranked prey items. Therefore, this model should be used in concert with the diet-breadth model in order to understand how foragers responded to instances of resource stress.

The other major concern of this model is its principal prediction: that decreased harvest rates should have meant increased processing. Based upon ethnographic data discussed in Chapter II, as well as earlier in this chapter, we see that in some situations bone grease was manufactured in association with mass harvests of large animals. This was particularly true on the Plains and in the Sub-Arctic where grease and pemmican were produced in significant quantities following large bison hunts. These situations should not negate the prey-as-patch model, but rather indicate that in certain scenarios the constraints need to be carefully considered. These mass harvest situations change the constraints of the model in that the ability to process multiple animals simultaneously would have lowered processing costs. The lowering of processing costs means that the production of grease may have now been a more profitable resource and should fall before the optimal cut-off point on the diminishing returns graph.

Even in the case of mass processing, we should still be able to place some judgment on the degree of resource stress. Here, careful attention must be given to the elements included in grease manufacture. In mass processing events, there should have still been a focus upon higher-yield grease elements. The inclusion of too many low-yield elements (phalanges, tarsals/carpals, mandibles, crania, scapulae, etc.) would have slowed the process and made it inefficient. Therefore, where there is evidence for the large-scale production of bone grease, we should not immediately judge the activity as the result of severe resource stress. Rather, attention needs to be placed upon the actual elements included in the manufacturing event in order to better gauge the motives of this activity.

CHAPTER IV
CULTURAL AND ENVIRONMENTAL SETTING

Introduction

The Driftless Area presented its prehistoric inhabitants with an environment that required a number of unique adaptations, making this region a natural study unit for ancient cultural developments and activities, including bone grease production. This chapter briefly reviews the physical setting of the Driftless Area in order to provide a better understanding of its environment and to establish the resources that were potentially available to its prehistoric inhabitants. Bone grease production in the Driftless Area appears to have occurred within two distinct cultural contexts: Archaic/Woodland settlements and Oneota villages. Therefore, this chapter provides background data on the subsistence and settlement practices of the Archaic/Woodland and Oneota populations of the region in order to place bone grease production in a better frame of reference.

Environment of the Driftless Area

The Driftless Area (Martin 1965; Omernik et al. 2000) covers 41,965 km^2 (16,203 miles^2) in the upper Midwest. The majority of the Driftless Area is located in southwest Wisconsin (Figure 3), but it also includes adjoining portions of northwest Illinois, northeast Iowa, and southeast Minnesota. The Driftless Area gets its name from the fact that it escaped glaciation during the last four major glacial periods of the Pleistocene. Although there is no direct evidence of glaciation dating to these later glacial periods, the major river valleys do contain glacial outwash deposits (Mickelson et al. 1982). The lack of glaciation had the effect of preserving an ancient landscape that is characterized by a heavily dissected upland plateau in the southwest and an inner lowland plain in the

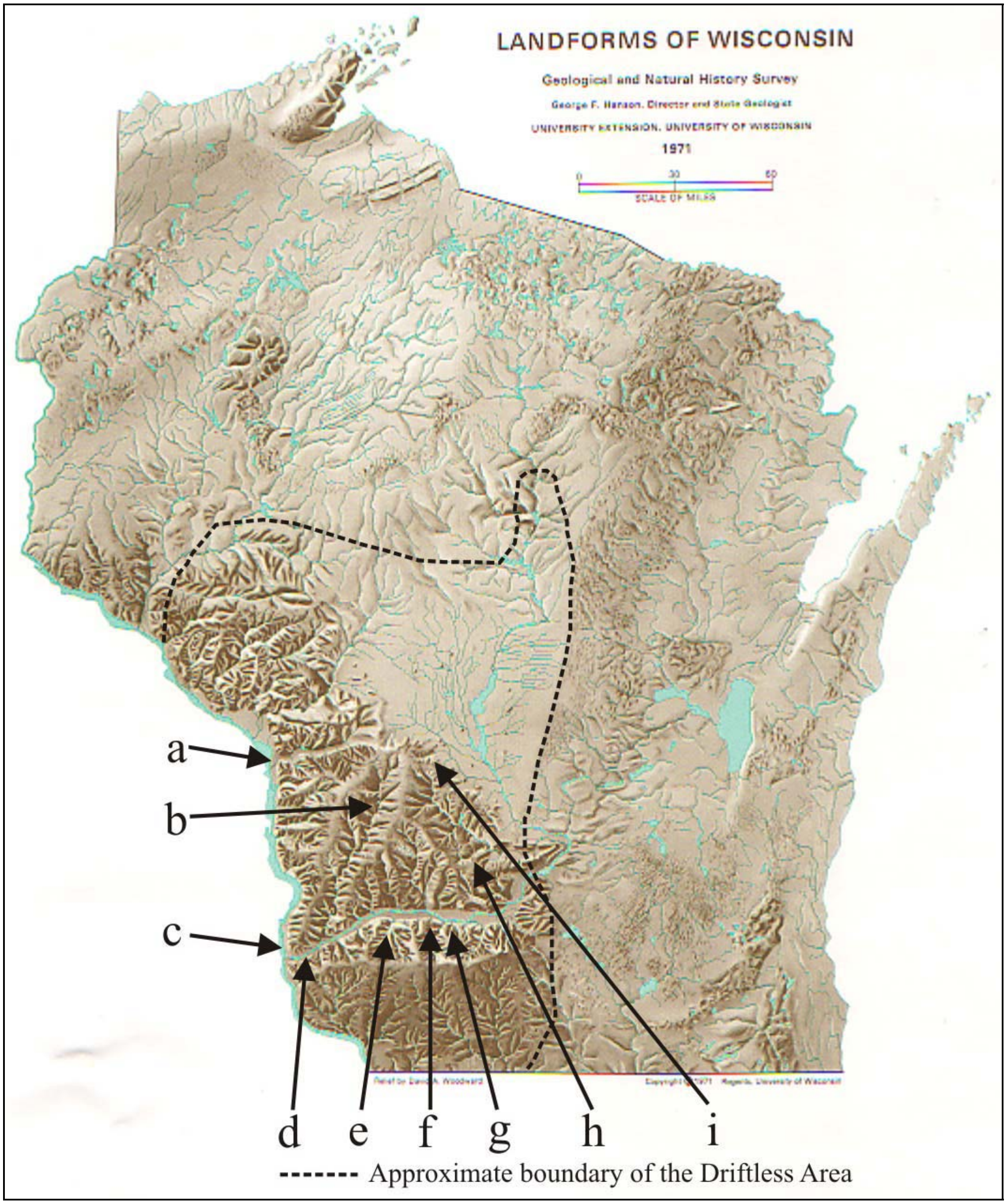

Figure 3. Location of major sites discussed in the text: (a) La Crosse Locality; (b) Lawrence I Rockshelter; (c) Prairie du Chien Area; (d) Millville Village; (e) Preston Rockshelter; (f) Gottschall Rockshelter; (g) Mayland Cave; (h) Raddatz and Durst Rockshelters; (i) Warsaw Rockshelter.

northeast (Martin 1965). As all of the archaeological assemblages discussed in this study come from the upland plateau, in the southwestern portion of the Driftless Area (Figure 3), it is the focus of the remaining description of this region.

The upland plateau has been heavily dissected by a dendritic drainage system. The region contains numerous small streams and is drained by two major river systems: the Mississippi River along the west and the Wisconsin River that drains much of southwest Wisconsin. The streams of the region are heavily incised into the local bedrock, creating steep sided valleys with precipitous outcrops of sandstone and limestone. In some cases, these escarpments exceed over 150 m in local elevation. Many of the sandstone outcrops contain well-eroded fissures and overhangs that served as rockshelters for the region's prehistoric inhabitants. While many of the valleys are quite narrow, others contain expansive bottomlands and meandering river channels with extensive wetlands and floodplain environments. Narrow upland ridges separate the valleys and often contain karst features.

Today agricultural fields and pastureland dominate the environment of the Driftless Area. The areas not used for agriculture, either due to topography or hydrology, are mostly covered by mixed deciduous or floodplain forests. The pre-European landscape, however, was significantly different. In 1854, Edward Daniels, Wisconsin's first state geologist, described the region:

> About one-third of the surface is prairie, dotted and belted with beautiful groves and oak-openings. The scenery combines every element of beauty and grandeur – giving us the sunlit prairies, with its soft swell, waving grasses and thousands of flowers, the sombre [*sic*] depths of primeval forests; and castellated cliffs, rising hundreds of feet, with beetling crags which a Titan might have piled for his fortress [Daniels 1854, cited in Martin 1965:84].

Daniels' description indicates that a substantial portion of the landscape was historically covered by prairies and oak savannas (see also Anderson 1998; Curtis 1959). Paleoenvironmental data indicates that Wisconsin's savannas formed some 8,000 years ago with the onset of warm and dry conditions of the mid-Holocene Altithermal (Anderson 1998; Bartlein and Webb 1982). With the end of the Altithermal (c. 3,500 B.P.), moister conditions prevailed, yet the savannas of this region remained until Euro-American settlement. Today, many researchers attribute the persistence of the savannas to annual Native American burning (Anderson 1998; Curtis 1959; Denevan 1992). Most of the region's current forests did not originate until Euro-American settlers suppressed natural fires and failed to maintain anthropogenic fire regimes (Anderson 1998; Williams 1989). The savannas, which were primarily located in the uplands and river terraces, would have provided the area's ancient inhabitants with periodic yields of nut masts (e.g. acorns, hickory, walnut, and hazelnut), along with upland game birds, several small-medium sized mammals, and most significantly, white-tailed deer and American elk.

The edge habitat of the savannas, with its grasslands and sporadic oak trees and groves, would have been prime habitat for the white-tailed deer. It has been suggested that the pre-European landscape could have supported between 20 and 50 deer per square mile (2.59 km^2) (Dahleberg and Guettinger 1956; Jackson 1961). Although the environment may have been able to support these numbers, it is likely that hunting pressures from Native Americans kept them significantly lower (Kay 1979; Theler and Boszhardt 2006). The importance of the white-tailed deer among the prehistoric inhabitants of the Driftless Area cannot be overstated. Theler and Boszhardt (2006:448) have described it as "the crucial first line Woodland winter resource." The deer was valued not only for its meat, but for its hides as well. It has been estimated that a Archaic/Woodland population of 20 individuals would have needed to harvest 70 deer annually in order to support their needs for clothing and protein (Theler and Boszhardt (2006:451-452, also see Gramly 1977 in relation to the importance of deer hides).

The white-tailed deer would have been most frequently harvested during their mating season (or rut), which, in Wisconsin, lasts from late October through early December (Jackson 1961:429). During the rut, deer are typically less cautious and more easily taken by hunters. This is also the time of year that they reach their peak condition. Throughout the fall deer consume mass quantities of nuts and forage to build up winter fat stores (Jackson 1961). While deer may also be taken easily during the late winter as they congregate and are less mobile due to deep snow cover, by this time many have mobilized their internal fat stores and their lean venison is no longer as valuable. For additional data on prehistoric white-tailed deer populations of the Driftless Area and their relationship to human activity, the reader is referred to Theler and Boszhardt (2006).

While white-tailed deer could have been taken year-round, the most valuable warm season resources would have been found in the rivers and floodplains of the lowlands. Areas along the Mississippi and Wisconsin rivers would have been particularly productive, providing fish, turtles, waterfowl, and riverine mammals (Theler 1987, 2000), as well as many marshland plants, such as wild rice (Gallagher and Stevenson 1982). As the Mississippi River channel narrowed above its confluence with the Wisconsin River at Prairie du Chien, the fast flowing waters of this region would have provided optimal habitat for large freshwater mussel beds. These mussels appear to have been a significant warm season resource among the populations of this area (Stoltman 1990; Theler 1987), although they could have been readily dried and stored for most of the year (Theler 1987; see also Waselkov 1982). The seasonal abundance of these resources may have allowed the gathering of large populations (macrobands) in these riverine areas during the warm months (Theler 1987; Theler and Boszhardt 2000, 2006). During the cool season, the major rivers would have frozen over, forcing the populations to disperse into the uplands and pursue white-tailed deer and mast resources.

Archaic and Woodland Subsistence and Settlement Patterns

As is the case with all archaeological knowledge, our understanding of Archaic and Woodland subsistence patterns is most certainly a very simplified version of its true nature. Through several decades of research, however, a number of patterns have emerged regarding prehistoric subsistence practices in the Driftless Area that are relevant to our discussion of bone fat exploitation. The first, and perhaps most significant, aspect of the prehistoric economy was the presence of a seasonal round. The existence of a seasonal round was first proposed by Storck (1972, 1974) based upon excavations of Middle and Late Woodland components at Mayland Cave (47IA38) in Iowa County, Wisconsin (Figure 3). Seasonal data from the cave (primarily in the form of white-tailed deer dentition and frontals) indicated a fall through spring occupation of the site (Storck 1972:366-369). Of the 87,000 plus bone fragments from this site, 90 percent were mammal and of the identified mammal remains, over 86 percent were white-tailed deer (Table 1). Theler (1987a: Table 19) estimated that deer contributed over 70 percent of the caloric yield from the harvested mammal remains found at this site. It was suggested by Storck (1972:411-414, 1974:277-278) that interior sites, such as Mayland Cave, wereresidentially occupied by small family groups (microbands) who dispersed into the dissected uplands during the fall and winter to pursue an intensive harvest of white-tailed deer.

Though the data from Mayland Cave are singularly interesting, the examination of several other sites further supports Storck's hypothesis and demonstrates that the white-tailed deer provided a critical cool-season resource to the region's Archaic and Woodland occupants. Much of the data on fall and winter sites have been evaluated by Theler (1983, 1987:33-47) and is reviewed here to further develop the context for bone grease production.

The analysis of numerous Driftless Area sites (Table 2) produced evidence for fall and winter occupations. With the exception of Millville Village (see discussion in Chapter VI), all of these sites were well-protected rockshelters located in the dissected valleys and uplands of Driftless Area, generally far from the major rivers and wetlands. The most prominent feature of the faunal assemblages from these sites was that they were nearly exclusively dominated by the remains of white-tailed deer. Mammal remains typically comprised up 90 to 95 percent of these assemblages. As can be seen in Table 1, white-tailed deer represented 71 to 97 percent of the identified mammal remains, and when these numbers were converted to meat weights, deer contributed 43 to 94 percent (with an average of 74 percent) of the total caloric yield from the harvested animals (Table 3). Most of the remaining meat in the diet was derived from large mammals, such as American elk, black bear (*Ursus americanus*), and bison. Although numerous species of smaller mammals were present, they never appear to have beenprocured to any great extent. Smaller quantities of birds and turtles were also common, while fish and mussels were never represented to any significant degree.

Table 1. Comparison of the relative percentage of white-tailed deer remains between Archaic, Woodland and Oneota sites from Western Wisconsin.

Archaic	**NISP Deer**	**NISP Mammal**	**% Deer**	**Woodland**	**NISP Deer**	**NISP Mammal**	**% Deer**	**Oneota**	**NISP Deer**	**NISP Mammal**	**% Deer**
Lawrence	3829	3939	**97.2**	Durst	3806	3917	**97.2**	Pammel	82	164	**50.0**
Durst	854	893	**95.6**	Lawrence	831	869	**95.6**	Sandford	94	277	**33.9**
Raddatz	4409	4792	**92.0**	Millville	1567	1736	**90.3**	Farley Village	30	100	**30.0**
Preston	456	560	**74.5**	Mayland	5736	6649	**86.3**	Midway	19	82	**23.2**
				Preston	1156	1623	**71.2**	Valley View	172	792	**21.7**
								Gundersen	89	427	**20.8**
Average			**82.3**	**Average**			**88.1**	**Average**			**29.9**

Table 2. Driftless Area Archaic and Woodland sites with evidence for cool-season occupations.

Site	**Location**	**Cultural Components***	**Subsistence References**
Battey Rockshelter (13JK21)	Jackson Co., IA	MW, LW	Jaehnig 1975
Brogley Rockshelter (47GT156)	Grant Co., WI	MA, LA, MW, LW	Emerson 1979; Tiffany 1974
Durst Rockshelter (47SK3)	Sauk Co., WI	MA, LA, MW, LW	Parmalee 1960
Hadfields Cave (13JN3)	Jones Co., IA	MW, LW	Benn 1976, 1980
Henry Schnoor Rockshelter (13JK20)	Jackson Co., IA	MW, LW	Jaehnig 1975
Lawrence I Rockshelter (47VE154)	Vernon Co., WI	EA, MA, LA, MW, LW	Berwick 1975
Mayland Cave (47IA38)	Iowa Co., WI	LW	Storck 1972
Millville (47GT53)	Grant Co., WI	MW	Pillaert 1969; Theler and Pillaert 1983
Preston Rockshelter (47GT157)	Grant Co., WI	LA, MW, LW	Chalkley 1976; Theler 1983; Theler and Chalkley-Hubbell 1984
Raddatz Rockshleter (47SK5)	Sauk Co., WI	EA, MA, LA	Parmalee 1959
Warsaw Rockshelter (47MO537)	Monroe Co., WI	EW, MW, LW	Baker 2003

*Cultural components include: Early Archaic (EA), Middle Archaic (MA), Late Archaic (LA), Early Woodland (EW), Middle Woodland (MW), and Late Woodland (LW).

Table 3. Relative contribution (in percentage of kilocalories) of major animal taxa from selected Archaic and Woodland occupations in the Driftless Area (adapted from Theler 1987: Table 19).

	Large Mammals								
Sites	**Deer**	**Elk**	**Bear**	**Bison**	**Small mammal**	**Bird**	**Turtle**	**Fish**	**Mussel**
Late Woodland									
Preston (I)	69.24	16.71	0	0	11.32	2.50	0.03	0.14	0.06
Schnoor[1]	47.24	32.39	15.91	0	2.81	1.58	0.01	0.05	0.01
L. Middle Woodland/ Late Woodland									
Lawrence I	94.81	0	0	0	4.69	0.30	0.08	0.10	0.02
Mayland Cave	71.30	7.15	3.51	12.26	3.69	1.91	0.08	0.08	<0.01
Hadfields Cave	59.30	9.38	9.22	5.36	11.01	3.27	0.16	2.05	0.25
Battey[b]	61.23	31.49	0	0	5.91	1.23	0.02	0.05	0.07
L. Middle Woodland									
Preston (II)	90.59	0	0	0	6.92	2.38	0.02	0.04	0.05
Millville Village	63.92	31.30	0	0	3.70	0.59	0.12	0.32	0.05
Schnoor[2]	88.19	0	0	0	11.77	0	0.03	0	0.02
Late Archaic									
Raddatz	91.57	6.08	0	0	1.72	0.39	0.25	0	?
Lawrence I	89.90	0	5.05	0	4.78	0.27	0	0	0
Preston (III)	42.61	19.48	0	33.38	3.24	1.27	0.01	0	0.01
Preston (IV)	52.09	35.71	0	0	10.50	1.55	0.02	0.05	0.08
Middle Archaic									
Raddatz	94.22	1.91	0	0	2.86	0.65	0.36	0	?
Lawrence	90.51	0	0	0	9.34	0.15	0	0	0

[1] Henry Schnoor Rockshelter (13JK20), Jackson Co., IA (see Jaehnig 1975)

[2] Battey Rockshelter (13JK21), Jackson Co., IA (see Jaehnig 1975)

Examination of white-tailed deer dental eruption and wear patterns (*sensu* Severinghaus 1949), as well as male frontal bones, indicated that the majority of deer were harvested in the early-fall to mid-winter, with some evidence for a much reduced spring harvest (Berwick 1975:59-61; Emerson 1979:Figure 1; Jaehnig 1975; Storck 1972:366-368; Theler 1987:Table 9; Theler and Chalkley-Hubbell 1984:20-21; Theler and Pillaert 1983). In an analysis of white-tailed deer dental cementum annuli, Benn (1980:154-159) has also showed that the deer harvest at Hadfields Cave occurred primarily in the fall and winter. Although Emerson (1979) has cautioned us not to equate seasonal exploitation with seasonal occupation, and has argued that the rockshelters do contain some signs for warm-season habitation, the evidence still seems to be overwhelming in favor of their use as fall to winter residential camps or hunting stands (Theler and Boszhardt 2000, 2006).

Unfortunately, the analysis of floral remains from the rockshelter sites has not been conducted as consistently as that for the faunal materials. Despite the rather sparse knowledge of plant utilization at these sites, that which does exist also supports a fall to winter occupation. Plant remains from the Brogley Rockshelter (Tiffany 1974) and Hadfields Cave (Benn 1980) were dominated by the remains of nutshell, including walnut (*Juglans*sp.), hickory (*Carya* sp.) and hazelnut (*Corylus*sp.). These nuts were most likely harvested upon ripening in the mid-fall and could have easily been stored for use throughout the winter and spring. Nuts are rich in fat and would have undoubtedly been an important supplement to a diet based predominately on lean animal protein. It is interesting to note that acorns (*Quercus* sp.) were extremely rare to absent at these sites, despite the fact that oaks were undoubtedly a key constituent of the prehistoric floral community (Curtis 1959). The near complete lack of acorns appears to be a real phenomenon and not the soleproduct of a preservation bias commonly associated with these remains (e.g. Yarnell and Black 1985). Acorns are only a useful food for humans upon intense processing to remove tannic acid. Other plants found at the rockshelter sites include wild rice (*Zizania*sp.), goosefoot (*Chenopodium*sp.), raspberry (*Rubus*sp.), grapes (*Vitus*sp.), elderberry (*Sambucus canadensis*), and cherry (*Prunus*sp.). Maize (*Zea mays*) and sunflower (*Helianthus annus*) were common at Hadfields Cave (Benn 1980) and maize was ubiquitous in Woodland levels at Brogley (Tiffany 1974). Although maize is common at these sites, it does not appear to have become an important component of the diet until the terminal Late Woodland (Arzigian 1987; Theler and Boszhardt 2006).

It was not until the University of Wisconsin-Madison instituted an intensive research program in the Prairie du Chien area (Figure 3) that a more complete picture of the prehistoric seasonal round was recognized. Excavations in the late 1970s and early 1980s focused on numerous Woodland shell midden sites along the Mississippi River near its junction with the Wisconsin River. Unlike the interior rockshelters, these sites were dominated by summer resources, including massive quantities of freshwater mussels, as well as fish, turtles, and some riverine mammals and birds (Stoltman 1990; Theler 1983, 1987). Comparatively, large mammals (including deer, elk, bear, and bison) were generally rare to absent. Floral assemblages were indicative of a late-summer to early-fall occupation (Arzigian 1987).

Harvested in mass numbers, freshwater mussels could have been dried and stored for use in the winter (Theler 1987:55-57). Although mussel tissue has a lower overall caloric value than animals of higher trophic levels, approximately one-half of its caloric content is derived from carbohydrates and fat (Parmalee and Klippel 1974:Table 4). As the nutritional value of most large mammals is predominately in the form of protein, dried and stored mussels could have been an important winter food supplement.

It has been suggested that the Prairie du Chien locality represented an area where small family groups, who had dispersed to the various interior sites during the fall and winter, congregated into “macrobands” during the spring and summer months (Theler 1987; Theler and Boszhardt 2000, 2006). Such gatherings would have allowed for the renewal of social bonds, selection of marriage partners, and burial of the dead/construction of earthworks (see Wobst 1974; Charles and Buikstra 1983). As cultigens were adopted during the Woodland, they would have also been grown at this time and harvested prior to fall dispersion into the uplands.

Based on the preceding discussion, we can see that the settlement-subsistence pattern during the Woodland Tradition was characterized by dispersal into small family groups in the fall, winter, and early-spring. These groups occupied numerous interior sites, such as small, well-protected rockshelters where they pursued an intensive fall deer harvest and “sat-out the winter months…hunting as weather permitted and using stored rations as necessary” (Theler and Boszhardt 2006). Following the spring thaw, these groups would have left their protected winter sites and congregated into “macro-bands” at major riverine settings. This pattern of congregation and dispersal likely has roots deep into the Archaic (Storck 1974; Theler 1987; Theler and Boszhardt 2000, 2006) and is well documented in the ethnographic literature (Benn 1980).

As emphasized above, perhaps one of the most important characteristics of Archaic and Woodland subsistence patterns was the fall and winter white-tailed deer hunt. The timing of this event was by no means accidental.

In Wisconsin, deer enter the mating season (or rut) during the end of October and continue until mid-December (Dahlberg and Guettinger 1956; Jackson 1961). During the rut, bucks actively pursue does and engage in battles with rival males. In doing so, they loose much of the caution that they possess through out the rest of the year, making them particularly vulnerable to human predation. Other than meat, deer are highly valued for their hides and it is estimated that an individual adult would have required 3.5 deer hides annually for clothing alone (Gramly 1977:602). Furthermore, deer obtain their fall coat during September (Jackson 1961:414), and hides obtained during the fall and winter are much thicker and preferred to summer hides when making clothing. Of most significance to our discussion, deer also contain the most fat during the fall. Both sexes obtain their highest fat content just prior to the rut, with bucks having quickly exhausted their supplies by the end of the breeding season, and fat content in does steadily decreases through the birthing season in spring (Cothran et al. 1987; Harris 1945). It is clear that the fall-harvested white-tailed deer provided the perfect (and readily transportable) package of meat, fat, and hides for the region's prehistoric foragers.

Archaeological remains from Driftless Area rockshelter sites stand as a testament to the importance of the white-tailed deer. The significance of this animal is seen not only in its relative contribution to the diet (as discussed above), but also in the intensity to which it was processed. Skeletal part abundances for white-tailed deer remains from select Driftless Area cool-season sites are presented in Table 4. A careful review of this

Table 4. Summary of white-tailed deer elements from Archaic and Woodland cool season occupations.

Element	47IA38[1]	47VE154[2]	47GT157[3]	47IA80[4]	Total
antler	20	11	-	-	**31**
cranial	436	145	171	8	**760**
mandible	292	110	252	4	**658**
teeth	483	250	35	-	**768**
hyoid	-	9	1	1	**11**
atlas	39	5	8	-	**52**
axis	39	4	13	-	**56**
vertebrae	804	172	41	-	**1017**
ribs	282	111	-	-	**393**
sternum	47	1	-	-	**48**
innonimate	57	33	38	1	**129**
scapula	87	24	24	2	**137**
humerus					
proximal	39	18	3	-	**60**
diaphysis	36	45	-	-	**81**
distal	49	10	21	-	**80**
radius					
proximal	101	26	33	1	**161**
diaphysis	44	65	-	-	**109**
distal	44	17	21	1	**83**
ulna					
proximal	*59	12	66	-	**78(*59)**
diaphysis	-	24	-	-	**24**
distal	-	5	7	1	**13**
carpals	193	78	-	-	**271**
metacarpal					
proximal	59	37	35	3	**134**
diaphysis	85	31	-	1	**117**
distal	46	14	13	1	**74**
femur					
proximal	69	6	20	-	**95**
diaphysis	60	68	-	-	**128**
distal	67	14	11	-	**92**
patella	16	3	-	-	**19**
tibia					
proximal	62	21	10	-	**93**
diaphysis	112	104	-	-	**216**
distal	64	27	31	4	**126**
tarsals	234	82	98	4	**418**
metatarsal					
proximal	65	38	28	2	**133**
diaphysis	309	174	-	-	**483**
distal	38	15	8	7	**68**
metapodial					
proximal	-	-	-	-	
diaphysis	227	47	-	-	**274**
distal	1	58	15	-	**74**
residuals	177	135	-	-	**312**
sesmoids	176	78	-	-	**254**
1st phalanx	352	263	262	-	**877**
2nd phalanx	246	220	205	-	**671**
3rd phalanx	152	79	141	-	**372**
indet. phalanx	183	-	-	-	**183**
Total	**5951**	**2689**	**1611**	**41**	**10292**

[1] Mayland Cave, Iowa Co., WI (Storck 1972)
[2] Lawrence I Rockshelter, Vernon Co., WI (Berwick 1975)
[3] Preston Rockshelter, Grant Co., WI (Theler 1987; Theler and Chalkley 1984)
[4] Gottschall Rockshelter, Iowa Co., WI (Theler 1993)
*element portion not differentiated

evidence indicates that all parts of the animal (including long bones and axial elements) were consistently being transported back to the sites. Although there are some discrepancies, most are likely attributable to inter-observer variation, with some analysts not recording less diagnostic elements, such as ribs and vertebrae. There does not appear to be any substantial evidence for significant field butchery and disposal of certain parts, which is regularly seen at later Oneota sites (see below). If bone grease production occurred at these fall-winter sites, it would have been associated with an intensive cool season deer harvest and likely been a part of the systematic butchery and preparation of these animals.

Oneota Subsistence and Settlement Patterns

Moving on to the Oneota, we see a subsistence-settlement pattern that is markedly different from that of the Archaic and Woodland traditions. Although it is a highly controversial topic (see review in Theler and Boszhardt 2006), the Oneota of Wisconsin appear to have emerged in relation to the collapse of the Late Woodland life way and following the intrusion of Middle Mississippian peoples and ideas into southern Wisconsin (Boszhardt 1998, 2004; Theler and Boszhardt 2006; cf. Overstreet 1998, 2001). As such, Oneota can be seen as a blending of Late Woodland and Middle Mississippian cultural elements (Theler and Boszhardt 2003).

A recent study has suggested that increasing populations seen during the Late Woodland led to “packing” of the interior valleys of Driftless Area and caused a breakdown in the annual seasonal round (Theler and Boszhardt 2006). As groups were forced to take-up year round residence at these interior sites, they placed increasing stress upon the region’s resources (including highly valued firewood) and may have created a catastrophic collapse in the white-tailed deer population. With the close of the Woodland Tradition, we see a near exclusive abandonment of the interior Driftless Area until historic times and a congregation of groups at major terraces along the Mississippi River. Initially, occupation of the river terraces was located in the Red Wing area, to the north, and the Apple River Area, to the south of La Crosse. Following the abandonment of the Red Wing area (A.D. 1350), Oneota groups moved into the La Crosse locality (Figures 3, 4), where they established numerous agricultural villages over the next three centuries.

In the La Crosse Area, Oneota subsistence is characterized by a marked reliance upon agricultural and wetland resources. Specifically, Gallagher and Arzigian (1994) propose that La Crosse Oneota agriculture was "intensive." Perhaps the best evidence regarding the nature of this agricultural production comes from excavations conducted at the Sand Lake Site (47LC44) during the early 1980s. This project revealed a vast system of Oneota ridged fields, which had been buried beneath several meters of colluvium (within 50 years of construction) due to an intensive pattern of Oneota occupation and land clearance (Boszhardt et al. 1985; Gallagher et al. 1985). Beyond ridged fields, Oneota sites are littered with large subterranean storage pits, indicative of intense agriculture among seasonally sedentary societies (DeBoer 1988). Furthermore, Oneota assemblages from the La Crosse Area are replete with other clear indications of agricultural reliance, including numerous bison scapula hoes (Theler 1994a) and the generally ubiquitous remains of maize, beans (*Phaseolus vulgaris*), squash (*Cucurbita pepo*), and gourds (*Lagenaria siceraria*) (Arzigian 1989, 1994).

Although cultigens undoubtedly played an important role in the Oneota diet, hunted and gathered resources were still of considerable significance and may well have

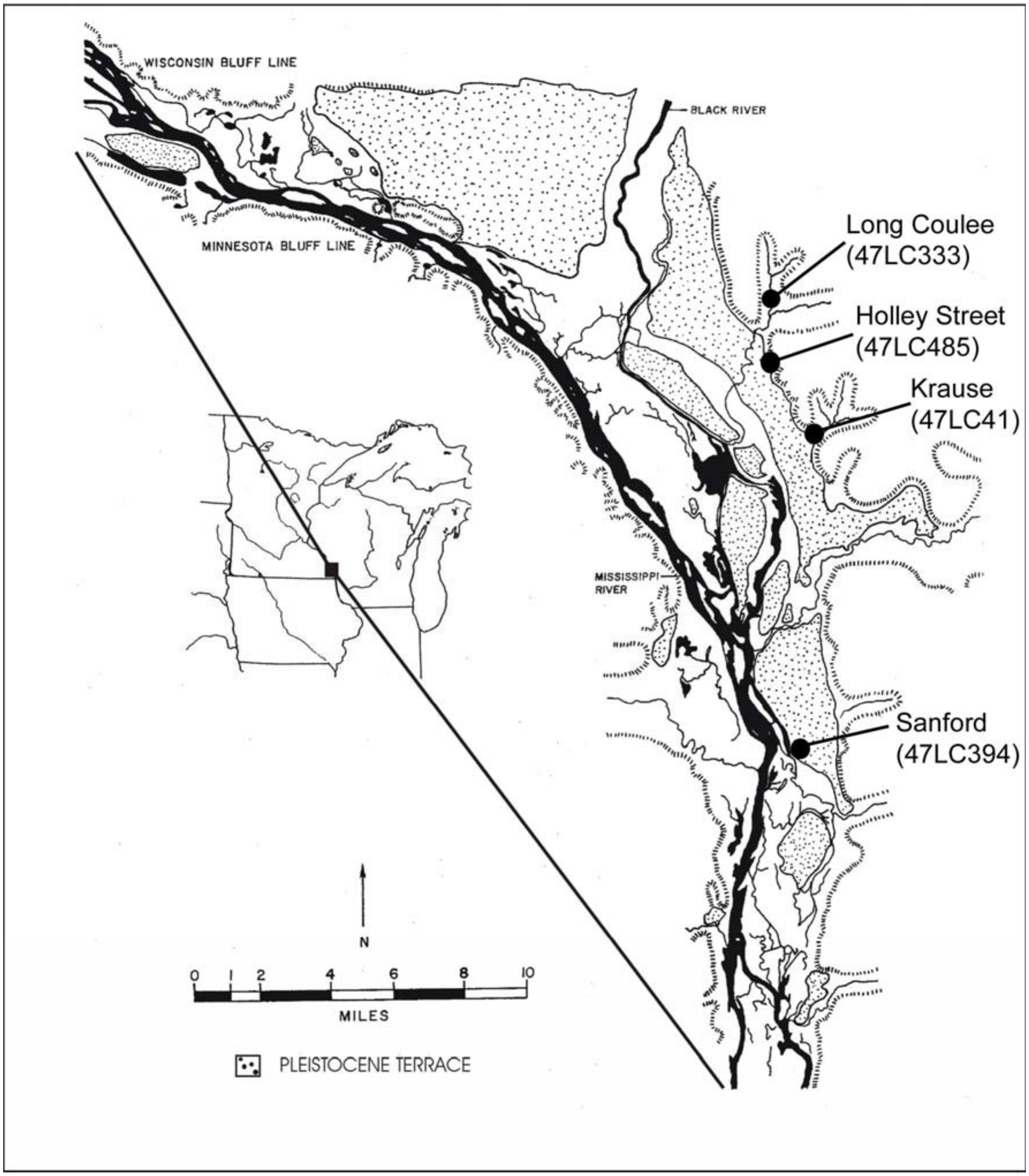

Figure 4. Location of Oneota sites in the La Crosse Area examined for evidence of bone grease production (base map courtesy of the Mississippi Valley Archaeology Center).

made up a large portion of the economy. Based upon faunal remains, we can see that the Oneota were exploiting a diverse array of habitats; however, the focus seems to have been upon wetland resources (Theler 1989, 1994a, 1994b, 2000; Styles and White 1993, 1994, 1995). Remains of numerous fish species often dominate the faunal assemblages, with riverine mammals, aquatic turtles, and mussels also being common. For example, the Pammel Creek (47LC61) site produced over 17,600 animal remains, of which 13,250 (75.3 percent) are fish, while only 1,481 (8.4 percent) are mammals (Theler 1989). The importance of the aquatic resources is further demonstrated by the fact that they were being consistently transported to bluff side sites, such as Sand Lake, located nearly two miles from the Mississippi's backwaters.

Compared to the Archaic and Woodland sites discussed above, white-tailed deer are not nearly as abundant. Fish and other aquatic animals dominate the assemblages and deer never comprise more than 50 percent of the mammal remains (Table 1). Additionally, deer skeletal part frequencies (Table 5) show a distinct overrepresentation of the extremities (particularly the phalanges) when compared to the major long bone elements. This pattern has been interpreted as the result of kill site butchering and selective transport of the elements (Theler 1989:223-235, 2000).

Overall, white-tailed deer never appear to have been actively harvested in mass by the Oneota. There are a number of interrelated factors that can account for this observation. First, the Oneota appear to have followed a seasonal settlement pattern; living and farming on the La Crosse terraces from early spring through mid-fall and then moving into the prairies of Minnesota to pursue bison hunting during the fall and winter (Arzigian et al. 1989; Boszhardt 2000a). This would have placed the Oneota outside of

Table 5. Summary of white-tailed deer elements from La Crosse area Oneota Occupations.

Element	47LC43[1]	47LC44[2]	47LC61[3]	47LC176[4]	21HU2[5]	47LC394[6]	Total
antler	-	-	3	1	-	-	**4**
cranial	-	1	5	-	-	2	**8**
mandible	-	10	14	-	-	8	**32**
teeth	1	5	6	4	2	5	**23**
atlas	-	-	-	-	-	-	**-**
axis	-	-	-	-	-	1	**1**
vertebrae	-	-	1	-	-	-	**1**
ribs	-	-	-	-	-	-	**-**
innonimate	-	-	1	1	-	1	**3**
scapula	-	-	1	-	-	7	**8**
humerus							
proximal	-	-	-	-	-	-	**-**
diaphysis	-	-	-	-	-	-	**-**
distal	-	1	-	-	-	5	**6**
radius							
proximal	-	2	1	-	-	2	**5**
diaphysis	-	-	-	-	-	-	**-**
distal	-	1	-	-	-	-	**1**
ulna							
proximal	-	-	-	-	-	4	**4**
diaphysis	-	-	-	-	-	-	**-**
distal	-	-	-	-	-	-	**-**
carpals	-	9	-	-	-	1	**10**
metacarpal							
proximal	*1	-	-	-	-	1	**1(*1)**
diaphysis	-	-	-	-	-	-	**-**
distal	-	-	1	-	-	-	**1**
femur							
proximal	-	-	-	-	-	-	**-**
diaphysis	-	-	-	-	-	-	**-**
distal	-	-	-	-	-	-	**-**
tibia							
proximal	-	-	-	-	-	-	**-**
diaphysis	-	-	-	-	-	-	**-**
distal	-	-	1	-	-	3	**4**
tarsals	-	9	8	1	4	12	**34**
metatarsal							
proximal	-	-	-	-	-	*2	***2**
diaphysis	-	-	-	-	-	-	**-**
distal	-	1	-	-	-	-	**1**
metapodial							
proximal	-	-	*2	-	-	*1	***3**
diaphysis	-	-	-	-	-	-	**-**
distal	-	-	-	-	-	-	**-**
residuals	-	8	2	-	4	4	**18**
sesmoids	-	5	2	1	2	3	**13**
1st phalanx	1	14	11	1	9	10	**46**
2nd phalanx	-	12	5	-	1	6	**24**
3rd phalanx	-	6	20	-	1	8	**35**
Total	**3**	**84**	**84**	**9**	**23**	**86**	**289**

[1] Herbert Site, La Crosse Co., WI (Boszhardt et al. 1985)
[2] Sand Lake Site, La Crosse Co., WI (Theler 1985)
[3] Pammel Creek Site, La Crosse Co., WI (Theler 1989)
[4] State Road Coulee Site, La Crosse Co., WI (Theler 1994b)
[5] Farley Village Site, Houston Co., MN (Theler 1994a)
[6] Gundersen Site/Sandford Archaeological District, La Crosse Co., WI (Theler 1994b)
*element portion not differentiated

the Driftless Area when deer were at their prime condition and most vulnerable state. Deer that could have been taken during the spring and summer may not have been of as much value. The procurement of bison hides (Boszhardt and McCarthy 1999) may well have replaced the need for deerskins. Second, the Oneota established rather extensive settlements, to which they returned year-after-year. In line with central place foraging theory (Kelly 1995), this heavy occupation likely resulted in a substantial reduction of the deer population in the areas adjacent to the sites (patch depression), requiring hunters to travel farther and thus reducing the overall economic value/ranking of deer. As noted above, deer skeletal part representation supports this hypothesis, as carcasses would need to be reduced to an easily portable load in order to manage the greater transport distances. Finally, the Oneota reliance on stored agricultural crops (and bison) may well have diminished the necessity of taking deer in mass numbers to support the subsistence base.

The reduced importance of deer in the Oneota diet is further reflected in the extent to which the carcasses were processed. Unlike the Archaic and Woodland sites discussed above, I am unaware of any previous mention of bone grease processing for any Oneota site in the upper Midwest. In recent years, a number of La Crosse Area sites have produced possible evidence for bone grease production and they are reviewed in Chapter VI in order to provide a meaningful comparison to the Archaic and Woodland materials.

CHAPTER V
MATERIALS AND METHODOLOGY

Introduction

This chapter presents the materials and methods employed in the examination of bone grease production in the Driftless Area. It is divided into three sections. The first section briefly reviews the assemblages that were analyzed in this study, highlighting why they were selected. The second section covers the standard zooarchaeological techniques that were used to construct a basic understanding of the composition and context of each assemblage. The third section describes the specific methodology employed by this study to determine if the assemblages were indeed the result of bone grease production. This final section is heavily based upon the four criteria that were outlined in Chapter II as necessary for the identification of archaeological bone grease manufacture.

Archaeological Assemblages

In order to determine the extent and role of bone grease production in the Driftless Area, this thesis reviewed existing accounts of grease manufacture and analyzed a number of previously unexamined archaeological assemblages. A thorough review of the literature relating to zooarchaeological material from the Driftless Area was conducted to locate any previous accounts of bone grease production. In total, seven prior reports of bone grease production were found in the literature (Table 6). All of these accounts were from Archaic and Woodland contexts and appear to have been associated with fall-winter occupations. Each of these assemblages was thoroughly reviewed in the following

Table 6. Summary of archaeological sites and assemblages examined in this thesis for evidence of bone grease production. This includes: seven sites with previous reference to bone grease production in the literature, which were reviewed for this study, but not reanalyzed; seven assemblages that were specifically analyzed in this study as they were initially determined to likely be the residue of bone grease production; and two assemblages that were analyzed in this study to use as "control samples" against which the suspected bone grease assemblages could be compared. For site locations see Figures 3 and 4.

Site Name	Site #	Cultural Affiliation	Faunal Reference	Archaeological Reference
Sites with Previous Reference to Bone Grease Production				
Raddatz Rockshelter	47SK5	Middle Archaic	Parmalee 1959	Wittry 1959a
Durst Rockshelter	47SK2	Middle Archaic-Late Wood.	Parmalee 1960	Wittry 1959b
Lawrence I	47VE154	Early Archaic-Late Wood.	Berwick 1975	Halsey 1976
Mayland Cave	47IA38	Late Woodland	Storck 1972	Storck 1972
Preston Rockshelter	47GT157	Late Archaic-Late Wood.	Theler and Chalkley-Hubbell 1984	Theler 1983
Warsaw Rockshelter	47MO537	Early Wood.-Late Wood.	Baker2003	Baker 2003
Millville Village	47GT53	late Middle Wood.	Pillaert 1969; Vehik 1977	Freeman 1969
Assemblages Analyzed in this Study for Bone Grease Production				
Millville Village (Feat. 95)	47GT53	late Middle Wood.	This Study	Freeman 1969
Krause (Feat. 82)	47LC41	Oneota	This Study	Boszhardt 2000b
Krause (Feat. 438)	47LC41	Oneota (Valley View Phase)	This Study	Boszhardt 2000b
Krause (Feat. 441)	47LC41	Oneota	This Study	Boszhardt 2000b
Long Coulee (Feat. 1)	47LC333	Oneota	This Study	Burkart and Woolley 1996
Holley Street (Feat. 1)	47LC485	Oneota	This Study; Theler 1994a	Boszhardt 1994b
Assemblages Analyzed in this Study as Control Samples				
Gottschall Rockshelter	47IA80	Late Wood.	This Study; Theler 1993	Salzer and Rajnovich 2000
Sanford Archaeological District – Locality 32	47LC394-32	Oneota	This Study; Maass 2006	Boszhardt 2002; see also Arzigian et al. 1994

chapter in relation to the criteria established in Chapter II for the identification of bone grease in the archaeological record.

In addition to the existing accounts of bone grease production, six suspected bone grease assemblages were analyzed for this thesis. One of these assemblages came from Middle Woodland contexts at the Millville Village (47GT53) and the remaining five came from Oneota sites located in the La Crosse Area (Figure 4, Table 6). All of these assemblages were initially suspected to be the result of bone grease production based upon their overall context and contents. They were systematically analyzed following the methodology outlined below and judged against the criteria established in Chapter II for the identification of bone grease production.

Finally, two additional archaeological assemblages (Table 6) were analyzed to serve as control samples against which the suspected bone grease assemblages could be compared. One of these assemblages came from a Late Woodland deposit at the Gottschall Rockshelter (47IA38) and the other from an Oneota feature at the Sanford Archaeological District (47LC394-32). A preliminary review of these assemblages indicated that they were unlikely the sole product of grease manufacture. To evaluate this hypothesis they were analyzed following the same procedures as the suspected bone grease assemblages and evaluated in reference to the criteria proposed in Chapter II.

Zooarchaeological Methods

Prior to examining the assemblages for evidence of bone grease production it was necessary to conduct a standard zooarchaeological analysis of the material. This was done to provide a basic understanding of each of the assemblages in terms of how many species and individuals were present, what elements and portions of the animal(s) were utilized, what season the animals may have been harvested, how they were butchered, and if they had experienced any relevant taphonomic modifications. Although all of these features were not directly necessary to determining if grease production occurred, they were vital for discerning the cultural context in which the remains were utilized.

Identification

All faunal remains from the assemblages analyzed in this study were identified, by the author, through direct comparison to modern specimens housed in the zooarchaeological collection of the Department of Anthropology at the University of Tennessee, Knoxville. The remains were identified to the most specific taxonomic designation possible, with element, side, and portion being recorded where appropriate. The total number of identified specimens (NISP) was counted for each species and the minimum number of individuals (MNI) was calculated for each species based upon the presence of overlapping element portions. Additionally, the minimum number of elements (MNE) was determined in a similar fashion. The remains were also examined for any relevant taphonomic modifications, such as burning, animal gnawing, ingestion, and fracturing. All of this information was recorded on a paper data sheet and entered into an electronic database to aid in quantification and analysis. A detailed summary of the identified remains is provided within the tables of the Appendix. Taxonomic nomenclature used in this report follows the *Peterson Field GuideSeries*: Reid (2006) for mammals;Peterson and Peterson (1980) for birds;Conant and Collins (1998) for reptiles and amphibians; and Page and Burr (1991) for fish. Turgeon et al. (1998) was consulted regarding freshwater mussels.

All of the remains were placed in polyethylene bags with a paper tag that included appropriate taxonomic and provenience data. Following the analysis, the remains from the Millville Village Site were returned to the Wisconsin Historical Society and those from the La Crosse Area Oneota sites were returned to the Mississippi Valley Archaeology Center, University of Wisconsin-La Crosse for permanent curation.

Seasonality

In order to determine the role that bone grease played in the prehistoric economies of the region, it was necessary to make an attempt to assign the assemblages to a particular season. Estimates of seasonality were accomplished either directly from the faunal remains or from associated materials. Direct estimates of seasonality were preferred, but available in only a few instances. These direct estimates of seasonality were based upon eruption/wear patterns in white-tailed deer dentition (following Severinghaus 1949) and antler pedicles on male deer frontals. In a couple of instances, seasonality estimates could not be made directly from the faunal remains, but were based upon associated floral remains. While not as precise as direct estimates, those based upon associated remains were believed to be reliable and were often backed by additional cultural data. In at least two instances (i.e. Feature 82 at the Krause Site, and Feature 1 at the Holley Street Site), no reliable estimates of seasonality could be assigned.

Identification of Grease Production in the Archaeological Record

While basic identification, quantification, and determination of seasonality are vital to understanding the nature of any faunal assemblage, they are also necessary to determine the context of, and motives for, prehistoric grease production. A separate methodology, however, must be first in place to determine if an assemblage is the product of grease manufacture. In Chapter II, four criteria were identified as necessary for the identification of archaeological grease production: fragment size, fracture pattern/determination of fracture agent, overall taphonomic history, and context. The following sections illustrate how these criteria were specifically quantified and applied to the assemblages analyzed in this study. Again, it should be noted that much of the evidence for grease production in the Driftless Area comes from previously reported assemblages. Unfortunately, only one of these sites was available for reanalysis; therefore, these methods could only be applied to the assemblages specifically analyzed in this study. While the previously reported examples of grease production could not be directly evaluated and quantified with these methods, they were carefully judged against the four criteria to make a better determination as to their likelihood of being the product of grease manufacture.

1.) Fragment Size

The most obvious result of bone grease production is a highly fragmented faunal assemblage. The review in Chapter II revealed several methods for quantifying the size of bone fragments. Most of these methods rely upon ratios of identified to unidentified specimens or the frequency of complete elements. While these methods theoretically reflect the degree of fragmentation, they are open to many biases and inter-observer errors. It was determined that the best method to quantify fragmentation involved the actual measurement of fragment size.

A modification of Outram's (1998, 2001) method of placing the fragments into size classes has been adopted in this thesis. In this method the bone fragments were sorted into size classes by passing them over a graduated scale to measure their maximum

Table 7. Size categories used for measurement of fragmented bone assemblages.

Category	**Size (cm)**
1	1.0-1.49
2	1.5-1.99
3	2.0-2.49
4	2.5-2.99
5	3.0-3.49
6	3.5-3.99
7	4.0-4.49
8	4.5-4.99
9	5.0-6.99
10	7.0-8.99
11	9.0-10.99
12	≥11.0

dimension. The fragments were sorted into 12 size classes (in cm): 1.0-1.49, 1.5-1.99, 2.0-2.49, 2.5-2.99, 3.0-3.49, 3.5-3.99, 4.0-4.49, 4.5-4.99, 5.0-6.99, 70-8.99, 9.0-10.99, and ≥110 (see Table 7). Although similar, these size classes were smaller than those utilized by Outram (1998, 2001). It was found that these narrower size classes provided a more detailed resolution of fragment size and may be more appropriate for studying grease production in the Driftless Area, or in other regions. As Outram developed his classes primarily for large domestic animals, it was determined to be more advantageous to utilize the narrower size categories to measure the smaller ungulates (i.e. white-tailed deer) of the prehistoric Midwest. The assemblages analyzed in this study were originally recovered using several different screen sizes, ranging from 1/4 inch (6.35 mm) to 1/16 inch (1.59 mm) mesh. To avoid any biases resulting from screen size, all of the assemblages were re-screened through 1/4 inch mesh prior to analysis.

Prior to measuring the size of the fragments, all of the specimens were sorted into five major categories: cancellous bone, compact bone, vertebrae, ribs, and complete elements/epiphyses. Specimens were placed into the cancellous bone category if at least 50 percent of the fragment was composed of cancellous/trabecular bone tissue. Conversely, if more than 50 percent of the fragment was composed of compact bone, it was placed into the compact bone category. Vertebrae and ribs were determined based upon gross morphological characteristics. Isolated teeth and tooth fragments were not included in the analysis of fragment size. The bones were sorted into these categories to compare the relative composition of the assemblages and to determine if particular bone types were being fragmented to a greater or lesser extent. Additionally, a count of complete elements/epiphyses would reveal if certain elements were not being processed for grease.

As noted in Chapter II, the weight of bones in each size category is equally, or perhaps even more, significant than count. The weight of the bones in each size category reveals the extent to which the actual bone *mass* was fragmented (see Outram 1998, 2001). For example, bones from an assemblage may contain several elements that were fragmented to a significant extent, yet contain numerous unfragmented epiphyses or elements. A simple count of the size categories would likely indicate a highly fragmented assemblage, as there would still be many more fragments than complete or nearly complete elements. The weights of the size categories would, however, show that a significant portion of the bone mass was in larger size categories. By weighing the bone in each size category one gets a better picture of how much of the assemblage was actually being processed for grease. An unfragmented long bone epiphysis would only add a single number to the total count, but may represent a significant mass of potential, yet unexploited, grease. To contend with this issue, all of the bones from each size category were weighed to the nearest tenth of a gram.

2.) Fracture Patterns/Determination of Fracture Agent

In addition to demonstrating that an assemblage was heavily fragmented, one must also establish that the fragmentation was the result of intentional human activity. Although complex recording techniques have been developed for fracture pattern analysis (e.g. Biddick and Tomenchuck 1975; Davis 1985; Munzel 1986; Outram 1998, 2001), most are quite time consuming and not logistically applicable to large assemblages. Since most of the assemblages analyzed in this study were from discrete bone piles and had experienced few additional taphonomic modifications, it was determined that a complex recording procedure was not necessary.

For the purposes of this study, the determination of fracture type/agent was first made by examining the bones for characteristics of green bone fractures (as discussed in Chapter II). Since fracture types are distinguishable on compact bone, but not on spongy (or cancellous) bone, fracture types were only recorded for fragments that retained enough compact bone to make a determination of fracture type. To determine the freshness of the fracture, the bones were examined for fracture shape, fracture edge/surface, and fracture angle (see Chapter II for discussion of the characteristics of these categories). On bones that retained enough compact tissue to make a determination of fracture freshness, they were recorded as fresh or green, dry, recent (resulting during recovery), indeterminate, and not broken. This determination was based upon the observer's overall impression of the bone fracture, in accordance with the characteristics of green bone fractures discussed in Chapter II.

Although this method is not as systematic as some of the more complex recording procedures mentioned above, it is believed that it gave a reasonable estimate of fracture freshness for the assemblages examined in this study. This is particularly true, since most of the analyzed assemblages came from discrete deposits, where the agent of the fracture was readily apparent. It is suggested that a more systematic and quantitative system, such as that developed by Outram (1998, 2001), should be utilized if one conducts an analysis of larger, more mixed deposits.

While an examination of fracture shape, fracture surface texture, and fracture angle can help to establish whether or not a bone was broken while fresh, it does not immediately indicate what agent was responsible for the fracture. Possible fracture agents/mechanisms include human butchering, carnivore feeding, weathering, burning, sediment overburden, trampling, and volcanic activity (see Lyman 1994:324-328 for a review). In order to determine that humans were indeed responsible for the bone fragmentation, all of the specimens were examined for characteristics of human induced breakage. Features associated with human bone breakage include dynamic loading points/fractures (Johnson 1985:192), conchoidal fractures and flakes (Johnson 1985; Lyman 1987; White 1992:135-137), and crushing (White 1992:138). For further discussion on the characteristics of human cased bone fractures, the reader is referred to classic sources, such as Binford (1981), Johnson (1985), Lyman (1994), and White (1992), as well as the discussion in Chapter II of this thesis.

In order to rule out non-human fracture agents, the bones were also examined for features associated with activities such as carnivore gnawing (see Binford 1981) and trampling (see Haynes 1991). Other fracture agents, such as sediment overburden and weathering can be easily ruled out as they produce dry, as opposed to green bone, fractures. Also, fragmentation due to burning can be readily dismissed based upon the resulting color changes. All features related to the bone fractures were recorded and taken into consideration when determining the agent responsible for the fragmentation of the assemblage. Once again, this procedure was fairly straightforward with the assemblages examined in this study as most came from discrete bone pile deposits and appeared to be the product of a single activity. In situations were the bone was more scattered, a more intense and systematic procedure may need to be employed in the analysis of fracture agents.

3.) Other Taphonomic Considerations

As discussed in Chapter II, careful attention must be afforded to taphonomy in the analysis of potential bone grease assemblages. While the study of fragmentation rates and fracture agents all belong to the field of taphonomy (Lyman 1994), other factors that can potentially mimic or obscure evidence for bone grease production must also be carefully considered. A proper understanding of these additional processes is important for not only determining if an assemblage is the result of bone grease production, but is of critical concern when attempting to make comparisons between multiple bone grease assemblages (see extended discussion in Chapter II). Burning, animal gnawing, and post-depositional preservation/fragmentation were considered to be among the primary factors that would mask grease production or make comparisons between assemblages exceedingly difficult.

In order to address the potential taphonomic biases in the assemblages analyzed in this study, the remains were thoroughly examined for both natural and cultural modifications. Any noteworthy modifications were recorded in the Appendix tables and are discussed for each respective assemblage in the following chapter.

First, the assemblages were examined for any signs of heat alteration (burning). Where evidence of burning was encountered, it was classified into three categories: scorched, burned/carbonized, and calcined (see Lyman 1994:384-391). The remains were also examined for signs of animal modification, such as carnivore and rodent gnawing (see Binford 1981; Klippel et al. 1987; and Lyman 1994 for a description of these modifications). Any human produced cutmarks were also recorded to help determine if there were any potential butchery or element transportation biases in the record.

Among the most significant processes that may mask evidence of bone grease production are those that occur in the post-depositional environment. These factors include density mediated attrition and sediment overburden/trampling and their effect on bone grease assemblages was discussed in Chapter II. While the effects of density mediated attrition are usually assessed by means of comparing the represented elements to tables of known bone density values (e.g. Brain 1969; Kreutzer 1992; Lyman 1984), the impact of this process is much more difficult to determine in a heavily fragmented assemblage (Lyman 1994:254; Lyman et al. 1992). Therefore, this study had to rely on less traditional approaches to this problem.

To evaluate the possible affect of density mediated bone destruction, careful attention was given to the ratio of cancellous to compact bone in assemblages studied below. Counts were made of cancellous and compact bone fragments for each assemblage and are reported in the following chapter. Since cancellous bone is significantly less dense that compact bone, there should be far fewer cancellous bone fragments in an assemblage that has been heavily modified by post-depositional processes. While other factors may come into play, one should generally expect the proportion of these fragment types to be similar across assemblages that have experienced extensive fragmentation. Fortunately, in this study, all of the assemblages were well-preserved and contained significant quantities of pure cancellous bone fragments (see Tables in the following chapter). This suggests that they should be comparable. In instances where the ratio varies significantly, one would have to pay much closer attention to this issue and develop a better method for quantifying the impacts of density mediated attrition on heavily fragmented assemblages.

Besides addressing potential biases in the assemblages, taphonomy was also considered important in determining the context of the bones (e.g. primary, secondary-mixed, secondary-discrete). Bones with minimal taphonomic modifications, other than fracturing, are more likely to come from a primary or secondary-discrete deposit. Those with extensive taphonomic modifications (e.g. carnivore gnawing, ingestion, burning, weathering) are more likely to be found in mixed secondary deposits. The implications of context are discussed below.

4.) Context

The final criterion involved in the identification of bone grease production is the archaeological context of the assemblage. In Chapter II, it was determined that evidence for grease production could occur in three contexts: primary, mixed secondary, and discrete secondary. In a primary context, the bones remain in direct association with the tools and site facilities used in grease production (e.g. hammerstones, anvils, hearths, etc.). Since the bone fragments in primary contexts retain association with tools and facilities used in grease production, they provide very strong evidence for grease manufacture. Here, the analyst is not required to rely on the condition of the bones alone. These situations are most likely to occur in small, briefly occupied processing camps (Vehik 1977).

The remains of bone grease production can also be found in secondary contexts. Here the bone has been removed from its original context and is no longer in association with the artifacts and facilities involved in grease production. This scenario is more likely to occur at larger, more permanently occupied sites. In these situations the bone can be deposited in two ways: mixed and discrete. In mixed secondary deposits the refuse from grease production becomes scattered about the site and intermingled with the products from many different activities. Furthermore, in this context, the bone is more likely to experience additional taphonomic modifications that act to mask the evidence for grease production. In these scenarios, grease manufacture is exceedingly difficult to identify and the analyst must rely solely on the condition of the bone. Here, the issue of equifinality becomes a critical concern and suggestions of grease production from mixed secondary deposits should be very carefully scrutinized.

A discrete secondary deposit is the third and final context from which evidence of bone grease production can be recovered. While the remains in discrete secondary deposits have been removed from the facilities and artifacts used in their processing, they can provide potentially strong evidence for bone grease production. Discrete secondary contexts occur where the refuse from grease production (boiled bone fragments) was dumped into an isolated deposit, such as trash pit. Here the bones may have been covered quickly and protected from much destruction and dispersal. Remains from these deposits would appear as a pile of crushed bone upon excavation and would be quite recognizable. If it could be demonstrated the bones from such a pile were heavily fragmented as the result of human activity, there would seem to be few explanations other than grease production to account for this pattern.

In order to determine the context of the bone assemblages analyzed in this study, field maps, photographs, and excavation notes were carefully examined in conjunction with the overall condition of the remains. The criteria used for the identification of bone grease production in a primary context follow those proposed by Vehik (1977), although no such examples were specifically identified in this study. Bones were considered to be from a mixed secondary deposit if they were dispersed about a site or mixed within a large feature, with no discrete “piles” of crushed bone. For the purposes of this analysis, a bone “pile” was defined as an isolated deposit containing at least 100 fragments of crushed bone that were in clear association with one another. The presence of a bone pile was the defining characteristic of a discrete secondary deposit. The overall taphonomic condition of the bones was also evaluated to help determine if those found within a single “pile” were indeed associated with each other.

CHAPTER VI
RESULTS: ARCHAEOLOGICAL MATERIAL

Introduction

This chapter reviews seven previously reported accounts of bone grease production at Driftless Area (Table 6) sites in regards to the criteria established in the previous chapters for the identification of bone grease manufacture in the archaeological record. In addition to this review, the chapter presents the analysis of remains from six assemblages initially suspected to be the result of bone grease production (Table 6). The chapter also presents the analysis of faunal material from two additional assemblages (Table 6) that were not suspected to be the product of bone grease manufacture, but were included to serve as a control samples. The chapter is divided into two major sections – the Archaic and Woodland assemblages and the Oneota assemblages – as grease production appears to have occurred in distinct cultural contexts between them. The Archaic and Woodland section includes: a review of the seven previously described bone grease assemblages from the Driftless Area (as they all came from this time period), the results of the current analysis of a suspected bone grease assemblage from the Millville Village, and an analysis of remains from Gottschall Rockshelter that will be used for comparative purposes. The Oneota section reports on the analysis of five suspected bone grease assemblages (from three different sites) and material from the Sanford Archaeological District that will also be used for comparative purposes.

Archaic and Woodland Assemblages

The earliest reports of bone grease production in the Driftless Area come from Archaic and Woodland sites. A total of six rockshelters and one open-air site have previously produced evidence of bone grease manufacture (Table 6, Figure 3). All of these sites appear to have been occupied primarily during the fall and winter months during which white-tailed deer were harvested in significant numbers. It has been suggested that these sites were inhabited by microbands that dispersed into the uplands and interior portions of the Driftless Area during the winter months (Storck 1974; Theler 1983, 1987; cf. Emerson 1979). They survived the harsh winter conditions by living in these sheltered settlements and subsisting on stores of nuts dried deer meat (presumably preserved as pemmican (Storck 1972, 1974)), and other stockpiled foods. As such, grease production may have been a necessary part of the yearly subsistence cycle in a region of moderate productivity.

In the following section, I review the existing evidence for grease production at seven Driftless Area Archaic-Woodland sites and present the analysis of new material from the Millville Village. Additionally, I report the results of an analysis of remains from a Late Woodland context at the Gottschall Rockshelter. Initial analysis indicated that the Gottschall assemblage was not the product of bone grease production and it was included in this study to serve as a control sample against which the more obvious examples of bone grease manufacture could be compared.

Raddatz (47SK5) and Durst (47SK2) Rockshelters

The earliest mention of bone fat exploitation from an archaeological site in the region comes from one of the first systematic analyses of Wisconsin faunal material. In his examination of animal remains from the Raddatz and Durst rockshelters, Paul Parmalee (1959, 1960) developed the baseline dataset for understanding Archaic and Woodland period subsistence in Wisconsin. Both rockshelters are located less than a mile apart in Sauk County, Wisconsin (Figure 3) and were excavated by Warren Wittry (1959a, 1959b).

The Raddatz Rockshelter is a large sandstone shelter with an approximate area of 350 m^2 inside of the dripline. Excavations at Raddatz revealed nearly three meters of cultural deposits (Wittry 1959a). Although a substantial volume of soil had been removed from the cave during historic times, the remaining deposits were essentially intact and dated primarily to the Middle Archaic. The site produced a considerable quantity of cultural material and is the type-site for the Raddatz Side-Notched point (Wittry 1959a:44-46).

The Durst Rockshelter is a prominent sandstone overhang covering roughly 300 m^2 inside the shelter's dripline. Unlike Raddatz, the Durst Rockshelter was relatively shallow, with a maximum depth of only one meter. It too produced a substantial assemblage of cultural material and serves as the type-site for the Durst Stemmed point (Wittry 1959b:179-180). Deposits at the shelter range in age from the Middle Archaic through the Late Woodland.

As both shelters were protected by rock overhangs and had deposits composed primarily of well-drained sands, they had excellent faunal preservation. Although no fine screen techniques were employed, all sediments from both shelters were screened through 1/4 inch mesh (Wittry 1959a:39, 1959b:163), which resulted in the recovery of thousands of animal remains.

The faunal assemblage from Raddatz was dominated by large mammal remains, particularly white-tailed deer. In total, the site produced 4,409 identifiable deer remains and an additional 32,300 unidentified large mammal fragments, of which most are probably attributable to white-tailed deer (Parmalee 1959:89). Citing the lack of waterfowl remains, along with the presence of antlerless male white-tailed deer frontals, Parmalee (1959:89) suggested that the site may have been primarily occupied during the winter.

Of particular significance to this study is the condition of the animal bone. It was noted that extraordinary few complete large mammal bones were recovered and "nearly all of the deer bones had been broken, possibly for the purpose of securing marrow, and consequently a tremendous number of bone chips and fragments resulted" (Parmalee 1959:89).

Although this account of bone fragmentation makes no explicit mention of bone grease production it is quite indicative of a heavily modified assemblage and is consistent with other Driftless Area rockshelters for which bone grease manufacture has been postulated. Furthermore, this analysis was conducted well before most zooarchaeologists were thinking of bone grease production. As the assemblage from this site was not available for reanalysis, it is very difficult to apply the four criteria for the evaluation of bone grease production that were developed in the previous chapters.

While Parmalee (1960) never explicitly addressed the fragmentation of bones from Durst, the degree of fracture closely paralleled that seen at Raddatz (Paul W. Parmalee, personal communication 2005). At Durst, 4,660 identifiable deer remains were recovered and of 34,633 unidentified large mammal remains, most were probably deer. The Durst Rockshelter also produced nine frontals from male white-tailed deer, all of which were taken during the antlerless season (Parmalee 1960:17), again suggesting a winter to early spring encampment.

Lawrence I Rockshelter (47VE154)

The Lawrence I Rockshelter, located in Vernon County, Wisconsin (Figure 3), was excavated by the Wisconsin State Historical Society (Halsey 1976) as part the Lake LaFarge Project. The site is formed by a large sandstone overhang/shelter with cultural deposits to a depth of approximately three meters. In total, a 260 m^2 area was excavated, comprising nearly the entire site on both sides of the dripline. All sediments were screened through 1/4 inch mesh (Halsey 1976:119). Cultural material from the site spans the Early Archaic through Late Woodland, although relatively little faunal material was recovered from levels dating prior to the Late Archaic (Berwick 1975).

Over 48,771 bone fragments were recovered from the site, most of which were designated as unidentified large mammal. In total, 4,660 specimens were positively identified as white-tailed deer. Only limited numbers of other mammals were identified and birds, fish, reptiles, and amphibians were particularly scarce. It is suggested that the site was primarily occupied during the late fall and winter months based upon aged white-tailed deer mandibular dentition and antlerless male frontals (Berwick 1975:59-62).

Berwick (1975) makes considerable reference to the pulverized condition of the bones and notes that only 5.83 percent of the remains were identifiable. While he attempts do demonstrate that this percentage is small in relation to other analyzed sites, I must again state that such comparisons are extremely tenuous and vary considerably by skill of the analyst, recovery methods, and the taphonomic histories of the assemblages. Although it is difficult to compare fragmentation rates solely through the percentage of identified bones, it is quite clear that bones from the Lawrence I Rockshelter were been heavily fragmented. It was suggested that “the extreme fragmentary nature of the bone at

Lawrence I may be related to the practice of preparing bone grease by a method of breaking bone into small pieces and boiling off the grease" (Berwick 1975:19).

Since this assemblage was not reanalyzed for this study, one cannot provide a quantitative assessment of the extent of bone breakage and grease production present at the site. This being said, Berwick's descriptions and impressions seem to clearly indicate that the fragmented bone from the site was the residue of bone grease production.

In addition to simply suggesting that bone grease production was present at the Lawrence I Rockshelter, Berwick considers the social implications of bone grease manufacture:

> It is interesting to speculate whether bone grease was a desirable commodity or if it may in some way represent a lower standard of living of certain groups of aboriginal peoples. Pillaert (personal communication) refers to these extremely low identifiable bone sites as "soup-pot cultures" and suggests that it may be an indication of a starvation diet. Sites such as these show a complete utilization of the white-tailed deer [Berwick 1975:19].

Berwick (1975:19) goes on to suggest that bone grease production, being a time consuming process, may be indicative of "lower standard of living" and could be representative of a "starvation diet."

While bone grease production may certainly be representative of a diet chronically short in supply of fats and carbohydrates, one must be very cautious in stating that it may be associated with a "lower standard of living." As will be discussed in greater detail in the following chapters, bone grease production among the Archaic and Woodland cultures of the Driftless Area is strongly associated with an intensive white-tailed deer harvest. In this context, grease could have been produced much more efficiently, as many individual animals could have been processed simultaneously. While this may reflect the utilization of a less productive environment, it is unlikely that the inhabitants would have seen themselves as eking out some form of secondary existence.

Mayland Cave (47IA38)

The next, and most explicit, description of bone fat exploitation from the Driftless Area comes from Peter Storck's (1972) analysis of the faunal remains from Mayland Cave in Iowa County, Wisconsin (Figure 3). Mayland Cave may be more appropriately referred to as a rockshelter since is formed along a vertical fissure in sandstone bedrock and not a karst feature. The rockshleter covers approximately 42 m^2 inside of the dripline and was excavated by a University of Wisconsin field school in 1968 (Storck 1972). A total of 213 m^3 of soil was excavated, which was estimated to have been approximately 85 to 90 percent of the inhabited portion of the site. All soil was screened through 1/4 inch mesh (Storck 1972:41). The cultural deposits at the site appear to have been primarily restricted to the Late Woodland, with some Oneota materials near the surface.

Mayland Cave produced an incredible faunal assemblage with over 87,000 specimens and at least 41 individual white-tailed deer. Although 85 different species were identified from the remains, over 90 percent of the material was classified as mammal (Storck 1972:292, Table 48). White-tailed deer and elk dominated the identified mammal remains (Storck 1972:294, Table 59) and most of the unidentified remains were attributed to large mammals, probably deer (Storck 1972:341). With the exception of birds, which comprised just over seven percent of the assemblage, all other animal classes were considerably scarce. Through analysis of white-tailed deer dentition, antler pedicles, and the presence of seasonally specific taxa (e.g. ducks), Strorck (1972:361-369) suggests that the site was primarily occupied during the fall, as well as winter and spring. In the absence of negative evidence, however, a summer occupation could not be completely ruled out.

In regards to bone fragmentation and grease production at the site, Storck notes that:

> The deer bone is highly fragmentary and, of the more than 5600 identified specimens, very few were complete elements or even articular ends. Even the phalanges and other small bones were generally broken. In addition, over 53,000 fragments were so small they could only be identified on the basis of the thickness and structure of the bone as belonging to a "large mammal" although most if not all of this material probably belongs to deer. Most of the bone seems to have been broken by pounding…The fragmentary condition of the deer bone suggests that fats and other substances, loosely termed "bone grease", were extracted from the bones, possibly for use in the making of pemmican [Storck 1972:347].

As evidence that the bone fragmentation was indeed the result of human agency, Storck described one particularly interesting specimen:

> The outer table of the bone exhibited numerous shallow and contiguous concussion marks and under ten power magnification several minute chert particles could be seen embedded in the bone. This indicates that a chert nodule was used as a maul or pounding implement. Some of the bone may also have been cut but very few specimens exhibited evidence of this [Storck 1972:347].

In addition to attributing the fragmentary nature of the remains to bone grease production, Storck noted two other characteristics of the assemblage that are relevant to understanding the nature of bone grease production in the Driftless Area:

> All portions of the skeleton are represented in the 6000 plus specimens of identified deer bone. This indicates that the entire animal was brought back to the site for butchering after which the bones were broken up for the extraction of "bone grease" [Storck 1972:351].
>
> "Bone grease", and presumably pemmican, does seem, however, to have been made during the entire occupational history of the site as highly fragmented deer bone, or unidentified "large mammal" bone which is presumably from deer, occurs throughout the deposits [Storck 1972:349].

Once again, while the description of the faunal remains from Mayland Cave prevents a quantitative assessment of bone modification, it seems quite clear that heavily fragmented assemblage is indeed the result of bone grease production. Storck's (1972) descriptions of the assemblage are consistent with the ethnographic data on grease production and fit well with observations from the other Driftless Area rockshelter sites. As noted above, Storck (1972) provided several other important observations regarding the nature of bone fragmentation at the site. First, Storck (1972:347) was one of the earliest to provide a taphonomic description of the fracture patterns, indicating that the fractures were indeed the result of human action. Second, Storck (1972:351) noted that every portion of the deer seems to have been represented at the site and that even the smallest bones (phalanges, carpals, tarsals, etc.) were fragmented. This is significant as it indicates a complete utilization of the carcass, including the elements of low economic value. The implications of this will be discussed in the following chapters. Finally, and perhaps most significantly, Storck (1972:349) mentions that bone fragmentation rates appear to have been consistent throughout the vertical distribution of deposits at the site. While this is simply an observation and not based upon any quantitative analysis, it appears to indicate that bone grease production was not an isolated event as one might expect of a starvation resources, but instead it appears to have been a regular cultural practice.

Preston Rockshelter (47GT157)

A heavily fragmented faunal assemblage was also observed at the Preston Rockshelter in Grant County, Wisconsin (Figure 3). This site was excavated in the late

1960s under the direction of Harris A. Palmer of the University of Wisconsin-Platteville and all faunal remains were recovered through 1/4 inch mesh (Theler and Chalkley-Hubbell 1984). The site contained cultural deposits to an approximate depth of 5 m and total of 124 m^3 of soil were excavated. Four cultural components identified at the site included: Late Archaic (pre-Durst), Late Archaic (Durst), Late Middle Woodland (Millville Phase), and Late Woodland (Eastman Phase) (Chalkley 1976; Stoltman 1979:133-139; Theler 1983:80-85; Theler and Chalkley-Hubbell 1984:3).

Nearly 3,000 identified and 50,000 unidentified animal remains were recovered from the Preston Rockshelter, with a total of 67 taxa present (Theler 1983; Theler and Chalkley-Hubbell 1984). Like the other rockshelters described above, the assemblage was dominated mammal remains. While bird species were not uncommon at the site, large mammals made up 90 percent of the estimated useable meat represented by the faunal material (Theler and Chalkley-Hubbell 1984:Table 14). All other animal classes were generally scarce. White-tailed deer was the dominant animal species and made up over half of the identified specimens with at least 49 individuals represented. Based upon aged white-tailed deer mandibles and seasonally specific species, the majority of occupation at Preston appeared to have taken place from September through January, with some additional evidence of a small spring habitation (Theler and Chalkley-Hubbell 1984:20-21,51-52,71-72).

In reference to bone fragmentation and grease production/marrow extraction at the site, Theler and Chalkley-Hubbell noted that:

> The major bones of large and medium sized mammals were found to be consistently fragmented in all 4 components at Preston. It is suggested that the extraction of bone marrow was the principal reason for bone

> fragmentation at the site. The frequency of bone breakage was high and consistent for white-tailed deer elements. The frequency of bone breakage was particularly high and consistent for white-tailed deer elements. In addition to the invariably shattered long bone shafts; *vertebrae, ribs, mandibles and the articular ends of long bones having marrow rich cancellous bone were consistently found to be broken or crushed*. [Theler and Chalkley-Hubbell 1984:22; emphasis added].

It was further implied that the fragmentation may have been related to bone grease production and pemmican manufacture (Theler and Chalkley-Hubbell 1984:22-23).

The intensity of bone breakage at the site was addressed through an examination of deer phalanges (Theler and Chalkley-Hubbell 1984:23-24, Table 9). The phalanges where highly fragmented and when the MNE was calculated, only 8.4 percent of the first phalanges (MNE = 131) from the entire site were found to be in an unbroken state. As for the second phalanges (MNE = 121), just over 20 percent were unbroken. However, for the marrow-poor third phalanges (MNE = 141), over 90 percent were not fractured. As phalanges are generally considered a low yield element (Binford 1978:31; Jones and Metcalfe 1988:420-421), their consistent fragmentation was seen as evidence for an intense use of the white-tailed deer carcass.

The remains from the Preston Rockshelter provide clear evidence for bone grease production, particularly given the excessive quantity of unidentified large mammal bone fragments and Theler and Chalkley-Hubbell's (1984:22) reference to the consistently fragmented and "crushed cancellous bone" portions. While Theler and Chalkely-Hubbell do make an attempt to quantify bone fragmentation at the site through their analysis of broken deer phalanges, it cannot be determined to what degree this represents actual bone grease extraction as opposed to simple marrow removal. Furthermore, no other researchers have provided equivalent data from the Driftless Area, so one cannot use this analysis to make inter-site comparisons. Despite the lack of applicable quantitative data, it is obvious that the Preston remains demonstrate an intensive utilization of the white-tailed deer carcass and provide evidence for bone grease production for the entire occupational history of the site. Once again this fits a consistent pattern seen among Driftless Area rockshelter sites.

Warsaw Rockshelter (47MO537)

The Warsaw Rockshelter was located along a tributary of the Little Lemonweir River in Monroe County, Wisconsin (Figure 3). Test excavations were conducted at the site by the author during 2001 (Baker 2003). A small, southeast facing, sandstone overhang formed the site, and excavations were limited to two small test pits outside of the dripline. Cultural components identified at the site indicated a near continuous occupation from late Early Woodland through Late Woodland (Baker 2003).

While less than 8 m^3 of soil were excavated from the site, over 1,100 faunal remains were recovered (Baker 2003:18-42). Of these, nearly 97 percent were from mammals and white-tailed deer comprised the vast majority of the identified remains. Due to the relatively small sample of remains, seasonality indicators were scarce. Given the similarity of the assemblage to other Driftless Area rockshelters (see Theler 1983, 1987), it seems reasonable to assume that the primary occupation occurred from the fall through spring.

Although all of the remains from the Warsaw rockshelter were recovered from outside of the shelter's dripline, and hence not as well-preserved as those from other shelters, they were still indicative of a highly fragmented assemblage. Nearly all of the bone that had well-preserved margins displayed green bone fractures and other signs indicative of human manipulation (Baker 2003:34). The high frequency of fragmented large mammal bones and under representation of long bone articular fragments was interpreted to be the result of bone grease production (Baker 2003:34). As no quantitative data is available on the fragmentation of remains from this site, it is difficult to make any substantive inter-site comparisons, but the nature of the assemblage does seem to be consistent with other Driftless Area rockshelters.

Millville Village (47GT 53)

The Millville Village has been previously suggested as a site with evidence for bone grease production in the Driftless Area (Pillaert 1969; Vehik 1977). A sample of crushed large mammal remains from this site was obtained in order to conduct a more thorough analysis. Before presenting the results of the current analysis, a brief description of the site and the previous evidence for grease manufacture are given.

In the first thorough examination of bone grease production in the Midwest and Plains, Vehik (1977) focused on three sites, including the Millville Village, located along the southern bank of the Wisconsin River in Grant County, Wisconsin (Figure 3). This site was threatened by proposed highway construction and was excavated by the Wisconsin State Historical Society in 1962 (Freeman 1969). Although the site was not completely excavated, 14 houses, 139 refuse pits, 40 hearths, and 4 burials were uncovered (Figure 5). Based upon ceramics and radiocarbon dates, the site appears to have been a nearly exclusive late Middle Woodland occupation. The chronology and cultural affiliation of the site was later refined by Stoltman (1990), who used it as the type-site for the Millville phase. The Millville phase represents the late Middle Woodland

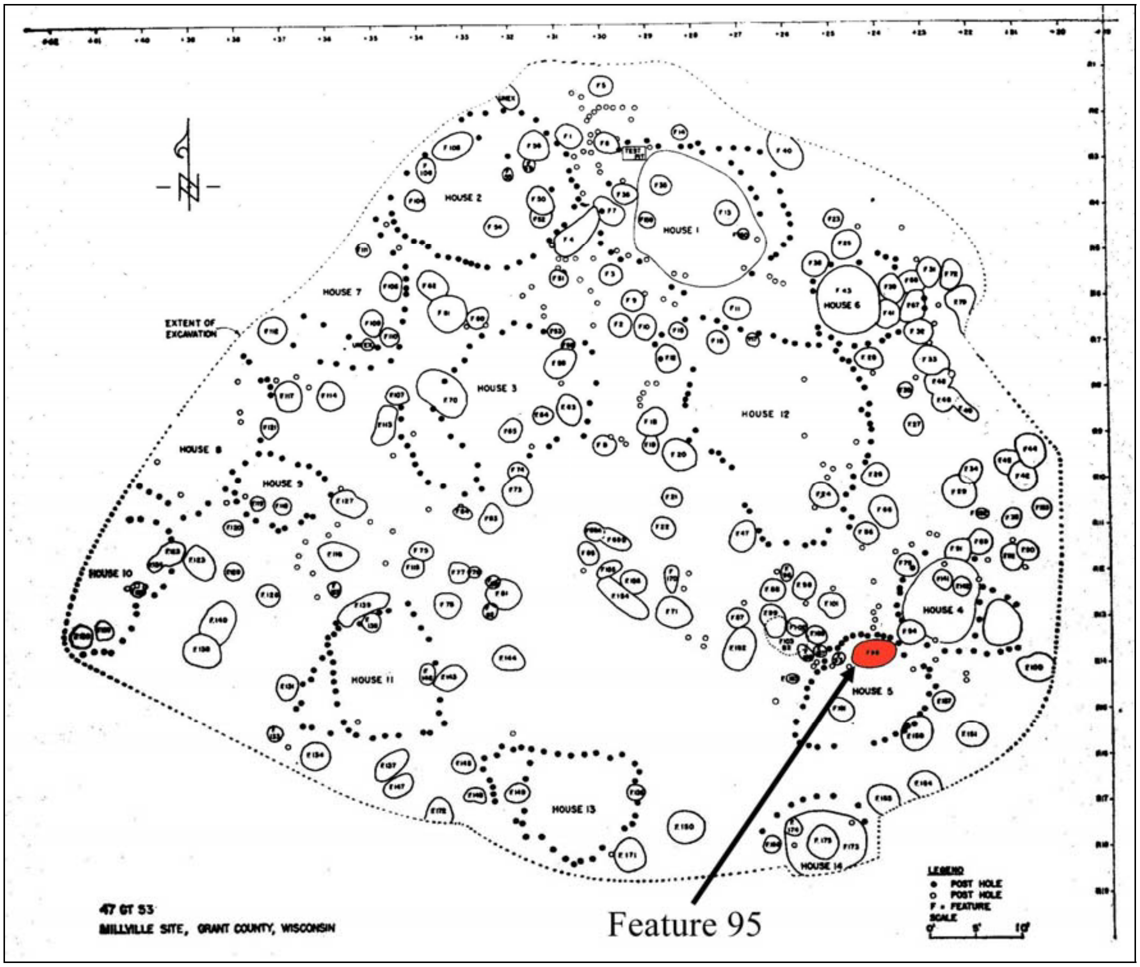

Figure 5. Millville Village (47GT53) site map, illustrating the location of Feature 95 in House 5 (base map from Freeman 1969:Figure 1).

(A.D. 200-500) occupation of southwest Wisconsin and shows strong affinities to the post-Havana, Weaver Culture (Griffin 1952) of Illinois and the Linn Farm phase (Logan 1976) of northeast Iowa. Eight uncalibrated radiocarbon dates from the site range from A.D. 190 to A.D. 310 (Freeman 1969:86-87).

Millville produced a substantial faunal assemblage including 5,674 specimens that were examined by Elizabeth Pillaert (1969) as part of the original site analysis. Of the remains analyzed by Pillaert, nearly 93 percent were mammal and of the identified specimens, the vast majority belonged to white tailed deer. Birds, turtles, fish, and freshwater mussels were also present in small numbers (Pillaert 1969:Tables 1,2). Analysis of white-tailed deer mandibular dentition and male frontals indicate that the site was occupied from late-summer through mid-winter (Theler and Pillaert 1983).

Although Vehik (1977) did not list any quantitative data on the faunal remains from Millville, she believed that it was a likely candidate for bone grease processing. This was based upon Pillaert's (1969) observation that most of the mammal bone from the site was heavily fragmented and missing marrow rich elements that were assumed to have been pulverized beyond recognition:

> A pattern does seem to be present in [the most abundant deer elements at the site]. All are bones that are so low in marrow content that conceivably they were not utilized in the preparation of bone grease. If the people at the Millville Site were exhausting the resources of the white-tailed deer then one might expect the elements high in marrow or grease content to be battered beyond recognition, and this may be the reason [that high yield elements are under represented in the assemblage]. The presence of large quantities of bone splinters (3,530), of which the majority are deer, helps substantiate this premise [Pillaert 1969:101].

Based upon Pillaert's (1969) descriptions, Vehik (1977) proposed that Millville had produced substantial evidence of bone grease production. In her paper, Vehik proposed a dichotomous model of bone grease manufacture: the first scenario consisted of bone grease production at a short-term butchering/processing campsite, and the other end of the spectrum was bone grease production at a more permanent site. In the first situation, evidence of bone grease production should have been preserved in a primary context and the associated features and artifacts should have provided additional evidence for grease manufacture. In the second situation, bone grease production would be more difficult to recognize, because the residue of bone grease production and its associated artifacts were likely to become redeposited throughout the site. Here, grease production could only be recognized through the presence of a heavily fragmented bone assemblage or if the residue had been placed in a discrete deposit, such as a refuse pit. Vehik (1977) noted that Millville, with its house structures and substantial number of features, fit the second scenario much better and relied solely upon the heavily fragmented bone assemblage as evidence for grease production at the site.

In order to more thoroughly evaluate the proposition of bone grease production at Millville, the author obtained the faunal assemblage from Feature 95. This particular feature contained a large quantity of crushed mammal bones and was located within House 5 (Freeman 1969:47-48) (Figure 5). Unfortunately, there is no data on the artifact content of Feature 95. The feature was a refuse pit that measured approximately 1 m by 1.5 m and appears to be directly associated with the house. No depth measurements were given for the feature. The house itself was 3.4 m by 3.9 m in dimension and had a floor basin that was .12 m deep. It appears that the bone was dumped into the feature in a discrete depositional event and therefore seems to be the result of a single activity.

Although there are no radiocarbon dates from the feature or the house, the entire site appears to be an exclusive Millville Phase occupation.

The faunal assemblage from Feature 95 contained a total of 1,823 bones larger than 1/4 inch (Table 8). Of the identified remains (*n* = 332), most were attributable to white-tailed deer (*n* = 330, 99.4 percent). Based upon the anterior axis vertebra, at least four individual deer were present. A single snapping turtle and one centrachid fish were also identified. In addition to the identified remains, 1,491 were considered unidentifiable beyond the class level (Table 8). Of these unidentified remains, 1,477 were considered large mammal and most, if not all, are likely from white-tailed deer. Several unidentified fish, turtle, and bird remains were also present.

Upon initial inspection, the overall condition and context of the bones indicated that they were likely the product of bone grease manufacture. All of the bones were heavily crushed (Figure 6) and, as noted above, their occurrence in the feature appeared to be the result of a single activity. More thorough analysis revealed that 508 specimens exhibited clear signs of green bone fracture (Table 9), thus indicating that they had been fractured while fresh, and not following deposition. Although the number of specimens with green bone fractures only comprised 28.2 percent of the measurable assemblage, this number is remarkable considering the fact that only 359 of the Feature 95 specimens were compact bone. It is difficult, if not impossible, to identify green bone fractures on non-compact (i.e. cancellous) bone. Nearly 100 percent of the compact bone displayed green bone fractures. The reason why there are more specimens with green bone fractures than there are compact bone fragments is due to the fact that some of the specimens classified as cancellous bone also retained some compact bone (again, to be classified as

Table 8. Summary of animal remains from Feature 95 at the Millville Village Site (47GT53).

Taxon	**Common Name**	**NISP**	**MNI**
Centrachidae	bass/sunfish	1	1
Chelydra serpentina	snapping turtle	1	1
Odocoileus virginianus	white-tailed deer	330	4
	subtotal	**332**	**6**
	unidentified fish	1	-
	unidentified turtle	2	-
	unidentified bird	11	-
	unidentified lg. mammal	1477	-
	total	**1823**	**6**

Table 9. Summary of taphonomic modifications identified among the bone assemblages analyzed in this study.

		Complete[2]		**GBF**[3]		**Heat Altered**[4]		**Gnawed**[5]	
Site	**Total**[1]	*n*	%	*n*	%	*n*	%	*n*	%
47GT53	1801	9	0.5	508	28.2	0	0.0	0	0.0
47LC41-F.82	126	4	3.2	51	40.5	0	0.0	0	0.0
47LC41-F.438	798	5	0.6	194	24.3	0	0.0	0	0.0
47LC41-F.441	525	1	0.2	125	23.8	0	0.0	0	0.0
47LC333	829	24	2.9	375	45.2	0	0.0	2	0.2
47LC485	304	21	6.9	154	50.7	6	2.0	0	0.0
47IA80	563	33	5.9	263	46.7	133	23.6	2	0.4
47LC394	4201	275	6.5	548	13.0	1184	13.0	157	3.7

[1] Total number of measured bones from the assemblage (does not include small mammals or isolated teeth).

[2] Number of complete elements or complete epiphyses from the assemblage. Percent is calculated from the total number of measured bones.

[3] Number of specimens from the assemblage exhibiting “green bone fractures.” Percent is calculated from the total number of measured bones.

[4] Number of specimens from the assemblage that have been scorched burned or calcined. Percent is calculated from the total number of measured bones.

[5] Number of specimens from the assemblage exhibiting rodent or carnivore gnawing. Percent is calculated from the total number of measured bones.

Figure 6. Fragments of cancellous bone from Feature 95 at Millville Village (47GT53).

cancellous bone, the specimen had only to possess 50 percent or more cancellous bone). Therefore, several of the cancellous bone fragments had enough compact bone on which green bone fractures could be identified. Furthermore, none of the bones displayed any additional signs of taphonomic modification (e.g. burning, gnawing, ingestion, etc.) to indicate that they were further manipulated or exposed for any considerable length of time either before or after being fractured. This, again, points to the fact that they were likely the product of a single activity.

An examination of the bone fragment size indicates that they were extensively fractured and broken into very small pieces, consistent with ethnographic descriptions of bone grease production. Of the 1,823 specimens from the entire assemblage, 1,801 (882.0 g) were considered measurable. All non-mammalian remains and any isolated teeth/tooth fragments were excluded from the fragment size analysis. Only 9 bones were found to be unbroken and no intact long bone epiphyses were present (Table 10, Appendix: Table A.1). The 9 unbroken bones consisted exclusively of small carpals, tarsals, and sesamoids (Table 10). Even during a systematic grease-processing event, it would have been very easy to miss these elements and they may not have been highly targeted for fracture given their minimal grease yield. The rest of the measurable assemblage was heavily fragmented, with 45 percent of the pieces being less than 1.5 cm in maximum dimension and 90 percent being less than 2.5 cm in maximum dimension (Table 11). Even by weight, 59.9 percent of the bone was less than 2.5 cm in maximum dimension (Table 12).

A comparison of fragmentation across bone types (Table 11) indicated that although the compact bone was still highly fractured, it was not as systematically fractured to the same small size as the cancellous bone. This, again, fits the expectations

Table 10. Summary of white-tailed deer elements from Feature 95 at the Millville Village Site (47GT53).

Element	**NISP**	**MNE**	**Complete Epiphyses**	**Complete Elements**
cranial	16	1	-	-
mandible	1	1	-	-
isolated teeth	6	3	na	na
hyoid	-	-	-	-
vertebrae	138	6	-	-
ribs	5	1	-	-
innonimate	1	1	-	-
scapula	-	-	-	-
humerus	11	2	-	-
radius	9	4	-	-
ulna	5	2	-	-
carpals	8	7	-	2
metacarpal	3	1	-	-
femur	3	1	-	-
tibia	10	6	-	-
tarsals	26	17	-	5
metatarsal	22	4	-	-
metapodial	42	-	-	-
residuals	2	2	-	-
sesamoids	5	5	-	2
1st phalanx	6	1	-	-
2nd phalanx	4	1	-	-
3rd phalanx	7	1	-	-
total	**330**	**67**	**-**	**9**

Table 11. Size distribution of bone fragment counts by type from the Millville Village Site (47GT53).

	Cancellous		**Compact**		**Vertebrae**		**Ribs**		**Complete**		**Total**	
Size	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
1	734	56.9	55	15.3	15	10.9	2	40.0	4	44.4	810	45.0
2	351	27.2	94	26.2	45	32.6	0	0.0	4	44.4	494	27.4
3	144	11.2	83	23.1	40	29.0	0	0.0	1	11.1	268	14.9
4	36	2.8	43	12.0	19	13.8	0	0.0	0	0.0	98	5.4
5	14	1.1	37	10.3	16	11.6	1	20.0	0	0.0	68	3.8
6	7	0.5	22	6.1	3	2.2	0	0.0	0	0.0	32	1.8
7	2	0.2	9	2.5	0	0.0	1	20.0	0	0.0	12	0.7
8	1	0.1	6	1.7	0	0.0	1	20.0	0	0.0	8	0.4
9	1	0.1	7	1.9	0	0.0	0	0.0	0	0.0	8	0.4
10	0	0.0	2	0.6	0	0.0	0	0.0	0	0.0	2	0.1
11	0	0.0	1	0.3	0	0.0	0	0.0	0	0.0	1	0.1
12	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	**1290**	**-**	**359**	**-**	**138**	**-**	**5**	**-**	**9**	**-**	**1801**	**-**

Table 12. Size distribution of bone fragment weight by type from the Millville Village Site (47GT53).

	Cancellous		**Compact**		**Vertebrae**		**Ribs**		**Complete**		**Total**	
Size	W(g)	%	W(g)	%	W(g)	%	W(g)	%	W(g)	%	W(g)	%
1	131.7	28.6	15.4	5.0	3.1	3.0	0.2	6.7	2.1	22.3	152.5	17.3
2	130.3	28.3	39.2	12.9	20.5	19.8	0	0.0	5.3	56.4	195.3	22.1
3	101.4	22.0	49.9	16.4	27.9	26.9	0	0.0	2.0	21.3	181.2	20.5
4	40.3	8.7	37.4	12.3	19.8	19.1	0	0.0	0	0.0	97.5	11.1
5	19.6	4.3	42.8	14.0	24.1	23.3	0.8	26.7	0	0.0	87.3	9.9
6	12.0	2.6	34.3	11.2	8.2	7.9	0	0.0	0	0.0	54.5	6.2
7	6.4	1.4	19.8	6.5	0	0.0	0.8	26.7	0	0.0	27.0	3.1
8	4.8	1.0	14.4	4.7	0	0.0	1.2	40.0	0	0.0	20.4	2.3
9	14.5	3.1	23.8	7.8	0	0.0	0	0.0	0	0.0	38.3	4.3
10	0	0.0	12.0	3.9	0	0.0	0	0.0	0	0.0	12.0	1.4
11	0	0.0	16.0	5.2	0	0.0	0	0.0	0	0.0	16.0	1.8
12	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.0	0.0
Total	**461.0**	**-**	**305.0**	**-**	**103.6**	**-**	**3.0**		**9.4**	**-**	**882.0**	**-**

for grease production. Since compact bone contains only a negligible amount of grease, there would have been little reason to break it down any further than what was necessary to expose the marrow cavity. Compact bone fragments were also much less abundant in the assemblage when compared to cancellous bone (Table 11). Most of the compact bone from the feature still retained some cancellous bone and fragments of "pure" compact bone were uncommon. Once again, since compact bone contains only a marginal amount of grease, many of the compact bone fragments from the carcass(es) may been tossed away prior to boiling.

Turning to the skeletal part representation of the identified white-tailed deer remains, all long bones were present, and most are well represented (Table 10). Many vertebrae were also present. The only elements that seemed to be underrepresented were the phalanges, scapulae, ribs, and innonimates. Binford (1978:32) has noted that among the Nunamiut, ribs and scapulae are considered to produce lower quality grease and are generally not employed in bone grease production, except for in times of scarcity. Phalanges are also considerably low in grease content and marrow content. While elements with low grease yield, such as the carpals and tarsals, are common in the assemblage, their presence is likely attributable to the fact that they, unlike the phalanges, are difficult to separate from the lower limb bones which are valued for their grease content. Furthermore, they may also be over-represented due to the fact that they retain many of their diagnostic landmarks even after extensive fragmentation.

Finally, no specific seasonal data are available from the feature, yet an examination of white-tailed deer dentition and male frontal bones indicates that the site was primarily occupied from late summer through mid-winter (Theler and Pillaert 1983).

Accordingly, the postulated bone grease production at the Millville Village Site fits the pattern observed among the Archaic and Woodland occupations of the Driftless Area rockshelters: production during the fall/winter in association with intensive white-tailed deer harvests.

Gottschall Rockshelter (47IA80)

The Gottschall Rockshelter is located near the head of a small valley, eight miles south of the Wisconsin River, in Iowa County, Wisconsin (Figure 3). Excavations have been conducted at the site for over the past two decades under the direction of Robert Salzer (1987; Salzer and Rajnovich 2000). The shelter measures 10 m by 20 m in maximum dimensions and covers approximately 160 m^2 beneath the dripline. Although the shelter has a maximum depth of 6.5 m, most of the cultural deposits are not much greater than 1.5 m in maximum thickness. Currently, a little under half of the shelter has been excavated, producing evidence of Late Archaic through Oneota occupations. The site is certainly best known for its extensive pictographs and unusual artifacts, such as a human head sculpted from sandstone (known to the excavators as “Mr. Head”). The rock art includes a painted panel that may well represent the exploits of the figure “Red Horn” as documented in Ho-Chunk mythology (Salzer 1993; Salzer and Rajnovich 2000). Radiocarbon dates on associated materials have placed the age of this panel at A.D. 900-1000 (Late Woodland/Emergent Mississippian), indicating a possible 1000-year continuity in the oral record (Salzer 1993).

Meticulous excavations at the site have produced a tremendously large faunal assemblage that was recovered through both 1/4 inch mesh and finer screening techniques. A systematic analysis of the faunal material is still underway; however, preliminary review indicates that the remains very closely parallel those found at other Driftless Area rockshelters (James L. Theler and Katherine P. Stevenson, personal communication 2005). Large animal remains, particularly white-tailed deer, dominate the assemblage. Birds, fish, reptiles/amphibians, and mollusk are present in much smaller quantities. Preliminary data on white-tailed deer dentition demonstrate a fall through early spring occupation. Although it has been suggested that the shelter was a special-purpose ritual site or shrine (e.g. Salzer and Rajnovich 2000), so far the faunal material does not substantiate this claim and instead resembles the assemblages found at all other Archaic/Woodland rockshelters from the region.

Since the faunal analysis of the site is not complete, there is no comprehensive data on bone fragmentation or grease production. From the author's own perusal of the remains, the overall condition of the assemblage appears to be comparable to the other rockshelters described above: heavily fragmented, including many crushed cancellous bone pieces. Although this appears to be the case for most of the remains from Gottschall, it is not completely consistent.

Several specific deposits from the shelter contained bones that were not as heavily fragmented as those from other portions of the site. It is quite likely that this variability was present at the other sites described above, but it was likely masked by the fact that the faunal remains from these shelters were analyzed as a whole, or by cultural affiliation, and not by specific provenience. Even if bone grease production was a regular activity (as it appears to have been), it is unlikely that every large animal harvested during a site's entire occupational history would have been processed for grease. Conceivably, the bones of some of the animals may have only been processed very minimally, such as just the removal of marrow from the major long bones. The extent of processing was likely tied to several factors, including resource abundance, season, the condition of the animal, the number of occupants, the number of animals harvested simultaneously, etc. Under certain conditions it may not have been beneficial to spend time processing bones for grease.

During the 1992 field season at Gottschall, a concentration of bone fragments was found in association with the carved sandstone head ("Mr. Head" – EB 3/47) in Unit S23 W13. The head and associated material all appear date to the Late Woodland Effigy Mound culture (Eastman Phase). Initial inspection of the bones indicated that although they were fractured, they possessed enough intact epiphyses that the fragmentation was probably not the result of bone grease production. These specimens were obtained by the author and analyzed for this study in order to compare with assemblages from other sites that were suspected to be the product of bone grease manufacture. Theler (1993) has previously analyzed these remains and provided basic identifications along with a brief discussion on skeletal part representation. The current analysis did not reveal any misidentifications, although several of the previously unidentified remains were narrowed down to specific elements (see Appendix for identifications).

In total, the "Mr. Head" bone pile produced 573 bones/bone fragments larger than 1/4 inch (Table 13, Appendix: Table A.2). Of the, identified remains (*n* = 137), most were attributable to white-tailed deer (*n* = 130, 94.9 percent). Based upon left maxillae, at least 5 individual deer were present. In addition, a few passenger pigeon, cottontail, canid, and raccoon bones were identified, and one human femur fragment was also present (Table 13). Not counting the specifically identified remains, 436 specimens could only be characterized as large mammal. Most of these unidentified mammal bones were likely from white-tailed deer. In total, 563 of the bones were measureable.

A detailed examination of the bones revealed that most were fractured, and only 33 (5.9 percent) specimens were not broken. The fractured edges of many of the bones had acute/obtuse fracture angles, smooth fracture surfaces, and other characteristics of green bone fractures, thus indicating that they were broken while fresh and not following deposition. A total of 263 specimens, or 46.7 percent of the assemblage, exhibited green bone fractures (Table 9). While this percentage represents less than half of the bones, one must remember green bone fractures are difficult to identify on small fragments and/or those composed primarily of cancellous bone. This being said, it appears that most of the bones were fractured while fresh, with minimal post-depositional modification.

Although the specimens from the “Mr. Head” bone pile appear to have been extensively fractured, the degree of fragmentation was not nearly as intense when compared to the other assemblages examined in this study. An examination of the fragment size (Table 14) and the fragment weight by size (Table 15) indicates that the specimens from this assemblage were generally of a much larger size than those of the other assemblages measured for this study. In particular, the majority of the bone mass from the assemblage was in the Size 9 category and above (greater than 5 cm in maximum length). This means that although the bone was extensively fractured, only a relatively small portion of the assemblage was made up of small fragments.

Another indication of the less fragmentary nature of this assemblage was the number of unbroken bones. In total, 33 specimens were either complete elements or epiphyses. This comprises 5.9 percent of the total assemblage. While this percentage is

Table 13. Summary of animal remains from the “Mr. Head” Bone Pile (S23, W13) at the Gottschall Rockshelter (47IA80).

Taxon	**Common Name**	**NISP**	**MNI**
Ectopistes migratorius	passenger pigeon	1	1
Sylvilagus floridanus	eastern cottontail	2	1
Canis sp.	dog/wolf/coyote	2	1
Procyon lotor	northern raccoon	1	1
Odocoileus virginianus	white-tailed deer	130	5
Homo s. sapiens	human	1	1
	subtotal	**137**	**10**
	unidentified lg. mammal	436	-
	total	**573**	**10**

Table 14. Size distribution of bone fragment counts by type from the “Mr. Head” bone pile (S23, W13) at the Gottschall Rockshelter (47IA80).

	Cancellous		**Compact**		**Vertebrae**		**Ribs**		**Complete**		**Total**	
Size	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
1	19	19.4	64	15.1	0	0.0	0	0.0	0	0.0	83	14.7
2	22	22.4	74	17.5	0	0.0	0	0.0	0	0.0	96	17.1
3	14	14.3	68	16.1	1	33.3	1	16.7	3	9.1	87	15.5
4	9	9.2	40	9.5	0	0.0	0	0.0	1	3.0	50	8.9
5	8	8.2	25	5.9	1	33.3	0	0.0	1	3.0	35	6.2
6	6	6.1	33	7.8	0	0.0	0	0.0	3	9.1	42	7.5
7	2	2.0	22	5.2	0	0.0	1	16.7	1	3.0	26	4.6
8	5	5.1	12	2.8	0	0.0	0	0.0	3	9.1	20	3.6
9	10	10.2	49	11.6	1	33.3	2	33.3	10	30.3	72	12.8
10	3	3.1	18	4.3	0	0.0	0	0.0	6	18.2	27	4.8
11	0	0.0	12	2.8	0	0.0	1	16.7	4	12.1	17	3.0
12	0	0.0	6	1.4	0	0.0	1	16.7	1	3.0	8	1.4
Total	**98**	**-**	**423**	**-**	**3**	**-**	**6**	**-**	**33**	**-**	**563**	**-**

Table 15. Size distribution of bone fragment weight by type from the “Mr. Head” bone pile (S23, W13) at the Gottschall Rockshelter (47IA80).

	Cancellous		**Compact**		**Vertebrae**		**Ribs**		**Complete**		**Total**	
Size	W(g)	%	W(g)	%	W(g)	%	W(g)	%	W(g)	%	W(g)	%
1	3.2	1.7	11.8	1.5	0	0.0	0	0.0	0	0.0	15.0	1.1
2	9.9	5.2	22.3	2.8	0	0.0	0	0.0	0	0.0	32.2	2.4
3	9.8	5.2	27.9	3.5	0.5	6.6	0.6	4.4	4.2	1.3	43.0	3.2
4	10.4	5.5	25.8	3.2	0	0.0	0	0.0	2.1	0.6	38.3	2.9
5	19.9	10.6	26.0	3.3	3.4	44.7	0	0.0	3.4	1.0	52.7	3.9
6	13.3	7.1	37.0	4.6	0	0.0	0	0.0	13.9	4.2	64.2	4.8
7	6.5	3.4	37.3	4.7	0	0.0	0.4	2.9	8.8	2.7	53.0	4.0
8	23.3	12.4	32.8	4.1	0	0.0	0	0.0	25.2	7.6	81.3	6.1
9	62.1	32.9	214.0	26.8	3.7	48.7	3.6	26.5	100.4	30.3	383.8	28.7
10	30.2	16.0	115.2	14.4	0	0.0	0	0.0	104.4	31.5	249.8	18.7
11	0	0.0	117.5	14.7	0	0.0	4.7	34.6	67.1	20.3	189.3	14.1
12	0	0.0	130.6	16.4	0	0.0	4.3	31.6	1.8	0.5	136.7	10.2
Total	**188.6**	**-**	**798.2**	**-**	**7.6**	**-**	**13.6**	**-**	**331.1**	**-**	**1339.1**	**-**

not as high as some of the others examined in this study, an examination of the actual elements involved reveals a significant difference. In many of the other assemblages, most, if not all, of the complete elements are those that contain very low quantities of bone grease (e.g. carpals, tarsals, phalanges, residual foot elements). The complete elements from the "Mr. Head" bone pile are dominated by complete epiphyses of the major long bones (Table 16 and Figure 7). If this assemblage was the product of bone grease production, one would expect that these epiphyses should have been more completely fragmented. In their complete state, they represent a significant mass of potential, yet unused bone grease.

A comparison of the relative amounts of cancellous and compact bone (see totals in Table 14) in the assemblage provides additional evidence that the bones were likely not processed for grease production. Based upon weight, over half of the bones from the Gottschall assemblage were compact. In contrast, all of the other assemblages examined in this study contained more cancellous bone than compact bone. These differences do not appear to be related to preservation issues, as many low-density epiphyses and fragments were present in the assemblage. As noted above, one should expect a greater quantity of cancellous bone in a bone grease assemblage as compact bone contains little grease and would not have been subjected to a high degree of fragmentation. Furthermore, the compact bone may have even been tossed prior to the boiling event.

Although nearly every portion of the deer carcass was represented by the "Mr. Head" bones, there seems to have been a clear emphasis upon the major long bones (Table 16). Very few carpals, tarsals, phalanges, vertebrae and ribs were present. Most of

Table 16. Summary of white-tailed deer elements from the "Mr. Head" Bone Pile (S23, W13) at the Gottschall Rockshelter (47IA80).

Element	**NISP**	**MNE**	**Complete Epiphyses**	**Complete Elements**
cranial	8	5	-	-
mandible	5	4	-	2
isolated teeth	3	3	na	na
hyoid	1	1	-	1
vertebrae	3	3	-	1
ribs	6	3	-	-
innonimate	1	1	-	-
scapula	2	2	2	-
humerus	5	3	2	-
radius	9	4	3	-
ulna	1	1	-	-
carpals	-	-	-	-
metacarpal	14	3	4	-
femur	4	2	-	-
tibia	22	4	4	-
tarsals	6	6	-	5
metatarsal	32	7	7	-
metapodial	5	-	-	-
residuals	-	-	-	-
sesamoids	-	-	-	-
1st phalanx	2	1	1	-
2nd phalanx	-	-	-	-
3rd phalanx	1	1	-	1
total	**130**	**55**	**23**	**10**

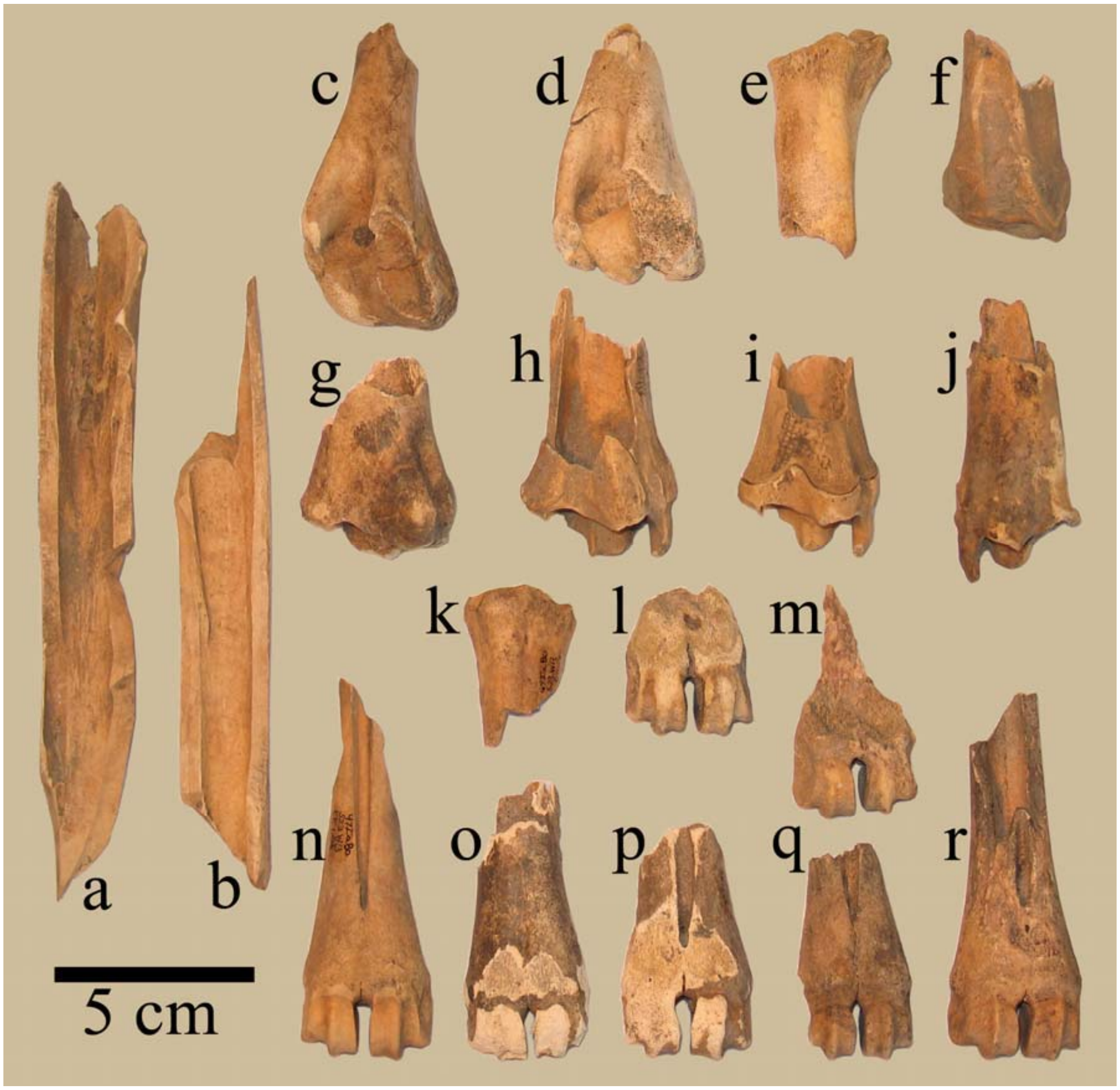

Figure 7. Complete white-tailed deer epiphyses and diaphyses from the "Mr. Head" Bone Pile (S23,W13) at the Gottschall Rockshelter (47IA80): (a-b) tibia diaphyses; (c-d) distal humeri (c-d); (e) proximal radius; (f) distal radius; (g-j) distal tibiae; (k) proximal metacarpal; (l-r) distal metapodials.

the bones present were those which contain substantial amounts of easily accessible bone marrow within their medullary cavities. It appeared that much of the fragmentation observed among the bones from the “Mr. Head” bone pile was the result of simple bone marrow removal, with no attempt to extract the grease contained in the cancellous tissue.

Several of the white-tailed deer mandibles from the assemblage were able to be aged and indicate that the deer were likely harvested in the late-fall or early-winter months (October-December). This is consistent with deer harvest events from the other Archaic and Woodland rockshelters from the Driftless Area.

Oneota Assemblages

Unlike the Archaic and Woodland assemblages described above, evidence for bone grease production among La Crosse Area Oneota groups occurred in a distinctly different cultural context. Most of the La Crosse Area Oneota settlements are relatively large village sites that appear to have been occupied primarily during the warm months when the inhabitants managed fields of maize, beans, and squash and pursued wild game in the floodplains, terraces, and uplands (Arzigian et al. 1989; Gallagher and Arzigian 1994; Gallagher and Stevenson 1982; Sasso 1993; Tubbs and O’Gorman 2005). It has been suggested that these villages may have been largely abandoned during the fall and winter as the occupants moved westward into the prairies of Minnesota to hunt bison (Arzigian et al. 1989; Boszhardt 2000a; Sasso 1993). More recent data indicate that at least some of the occupants may have stayed behind in these villages during the bison hunts (Arzigian 2001; Theler 2001). Data from the assemblages reported below indicate that much of the grease production observed at the Oneota settlements may have occurred at the time of the year when most of the residents had moved to the west. This suggests that grease may have not been a regular part of the diet, but a supplement or starvation resource utilized by those presumably less active individuals who remained behind.

In this section I present the results of the analysis of five Oneota assemblages that were initially suspected to the product of bone grease manufacture (Table 6). These five assemblages come from refuse pits at three different Oneota sites: Krause, Long Coulee, and Holley Street. For comparative purposes, this section also includes the analysis of the faunal remains from a feature at the Sanford Archaeological District.

Krause Site (47LC41)

The Krause Site (47LC41) is located at the mouth of Sand Lake Coulee in the City of Onalaska, Wisconsin (Figure 4). Here, it is situated along Sand Lake Creek and is part of the Sand Lake Archaeological District. Upon exiting the mouth of the coulee, the creek is blocked by the sandy La Crosse terrace and, prior to historic activities, formed a natural lake surrounded by dark, fertile soils. It was this resource that undoubtedly attracted prehistoric agriculturists to the area. Ridged agricultural fields were constructed at the Sand Lake Site around A.D. 1,400 and used until A.D. 1,450 when they were covered by an alluvial fan formed by anthropogenic erosion (see Gallagher et al.1985 and Gallagher and Sasso 1987 for a description of the Sand Lake Site). Initial Oneota occupation of the Krause Site likely served as a habitation component associated with the ridged fields of the Sand Lake Site. Most of the occupation at Krause dates from the late Brice Prairie through early Valley View phases (A.D. 1,400-1,600).

Extensive excavations at the Krause Site were conducted in the summer of 2000 by the Mississippi Valley Archaeology Center (MVAC) and the University of Wisconsin-La Crosse (UW-L), prior to subdivision development (Boszhardt 2000b). Nearly 50 acres of farmland were stripped with heavy equipment to remove the plow-zone overburden. In doing so, over 600 pit features, four burials, and one house were uncovered. Approximately 300 of the pit features were at least partially excavated.

A systematic analysis of the Krause faunal remains has yet to be completed; however, preliminary data indicated a pattern similar to that observed at other La Crosse Area Oneota sites. The diet was based heavily upon maize agriculture and supplemented by hunted and gathered wild resources. Although upland animals, principally white-tailed deer, played a significant role in the diet, there was a clear focus upon aquatic animals, particularly those available in backwater habitats. One pit from early excavations at the Krause Site contained over 14,000 bones, most of which were fish, including at least 400 individuals of 16 different species (Theler 2000:132). The same pit also contained other aquatic species, including tiger salamanders, turtles, water fowl, and crawfish. It appeared to represent a backwater seining event. Aquatic species, including several caches of freshwater mussels, were generally abundant at the site. Although the nearby Sand Lake may have provided habitat to some aquatic species, seasonal fluctuations and frequent desiccation would have prevented extensive resource harvesting from this locality. Instead, most of the aquatic animals found at the Krause Site were likely harvested from the backwaters of the Black and Mississippi rivers located over 1.5 miles (2.4 km) to the west of the site (Figure 4).

Like most La Crosse Area Oneota sites, main seasonal indicators point towards a warm season occupation of the site. Some material from Krause, however, indicates an additional small and perhaps periodic late-fall and winter occupation (Arzigian 2001; Theler 2001). This evidence includes a possible semi-subterranean house and several surrounding pit features that produced cool season indicators, such as large quantities of nuts and male white-tailed deer frontals with attached antlers.

Three features from Krause also produced evidence of bone grease production. Two of these features (F. 438 and 441) were located near the possible house and likely associated with the limited cool season occupation. A third feature was located some distance away and cannot be assigned to a particular season. The faunal remains from all three features were obtained by the author and are reported below.

Feature 438

Located in the eastern portion of the Krause Site, and perhaps associated with the cool season house, Feature 438 produced fairly classic evidence of bone grease production. This pit was a circular basin with a diameter of 130 cm and a maximum depth of 55 cm. The feature appeared to be typical refuse pit and had a single fill zone that contained a dense concentration of crushed white-tailed deer bone at a depth of 20 to 30 cm (Figure 8). The bone pile was surrounded by at least 10 large pieces of fire-cracked limestone.

In addition to the pile of deer bone, Feature 438 produced a substantial artifact assemblage. In total, the pit contained over 100 shell-tempered pottery sherds and many pieces of lithic debitage. A human frontal bone was also found in the feature, although it does not appear to be directly associated with the crushed deer remains. Scattered human remains are not an uncommon occurrence in La Crosse Oneota features. A “mini-pot” found near the bone pile (Figure 9) has fine lip top notching typical of Valley View phase ceramics (Boszhardt 1994a:207-210), thus giving the feature a likely date of A.D. 1,500-1,600.

Figure 8. Pile of crushed white-tailed deer bone surrounded by fire-cracked rock from Feature 438 at Krause (47LC41) (photo courtesy of James L. Theler).

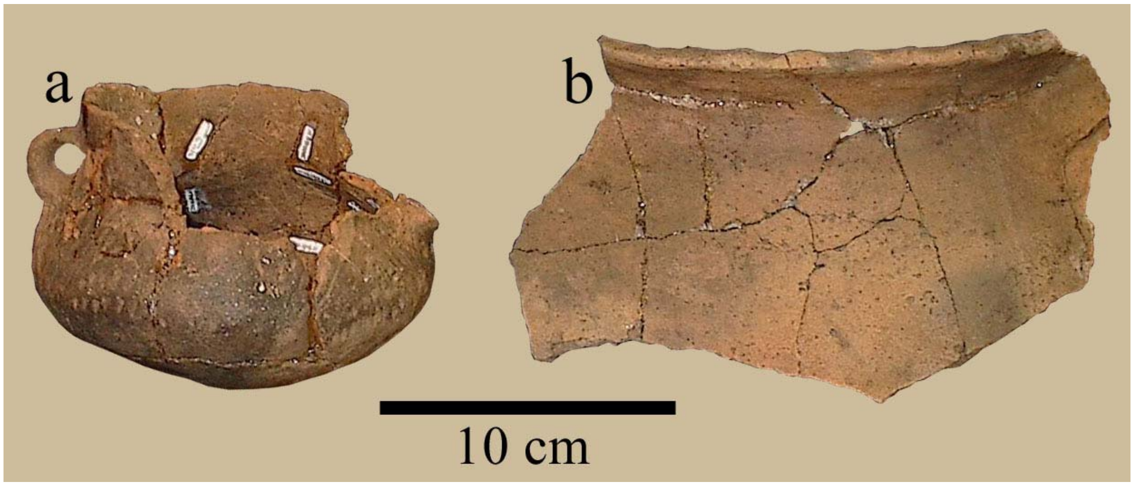

Figure 9. Diagnostic ceramics recovered from Feature 438 at Krause (47LC41): (a) Valley View phase "mini-pot"; (b) Pammel Creek phase rim sherd.

Five freshwater mussel valves and two American elk bone fragments were the only faunal material, other than the pile of white-tailed deer bone, to come from the feature (Table 17, Appendix: Table A.3). An analysis of floral remains from the feature resulted in the identification of maize, wild rice, goosefoot, several species of grass (Gramineae), and a number of nutshell fragments.

In total, there were 865 fragments of bone from the concentration. All of the bone from the concentration appeared to be white-tailed deer and 217 specimens were confidently identified to this species (Table 18). The presence of deciduous maxillary dentition (aged at one and a half years) and adult mandibular dentition (aged over three years) indicated that at least two individual deer were present.

Initial field observations of the context and condition of the bones indicated that they were likely the product of bone grease manufacture. All of the bones were heavily crushed and their deposition in the pit resulted in large “pile”, which appeared to be the result of a single activity. At least 194 of the specimens displayed distinct green bone fractures and additional evidence that they were broken while fresh. These green bone fractures were observed on nearly all of the pieces of compact bone and also on some of the large pieces of cancellous bone, which retained compact tissue. None of the bones had any additional signs of taphonomic modification, such as burning or gnawing that would have indicated exposure or further manipulation. This data, again, pointed to the fact that the occurrence of these specimens was the result of a single activity.

Examination of bone fragment size provides additional evidence that the Feature 438 specimens were the result of bone grease production. All of the specimens were

Table 17. Summary of animal remains from Feature 438 at the Krause Site (47LC41).

Taxon	**Common Name**	**NISP**	**MNI**
Pygonadon grandis	giant floater	1	1
Amblema plicata	threeridge	1	1
Cervus elaphus	American elk	2	1
Odocoileus virginianus	white-tailed deer	217	2
	subtotal	**221**	**5**
	unidentified naiad	3	-
	unidentified lg. mammal	648	-
	total	**872**	**5**

Table 18. Summary of white-tailed deer elements from Feature 438 at the Krause Site (47LC41).

Element	**NISP**	**MNE**	**Complete Epiphyses**	**Complete Elements**
cranial	55	1	-	-
mandible	5	2	-	-
isolated teeth	67	21	na	na
hyoid	-	-	-	-
vertebrae	45	3	-	-
ribs	7	1	-	-
innonimate	-	-	-	-
scapula	-	-	-	-
humerus	2	2	-	-
radius	5	2	-	-
ulna	3	1	-	-
carpals	-	-	-	-
metacarpal	2	2	-	-
femur	1	1	-	-
tibia	2	1	-	-
tarsals	-	-	-	-
metatarsal	-	-	-	-
metapodial	3	-	-	-
residuals	-	-	-	-
sesamoids	2	2	-	2
1st phalanx	12	3	-	-
2nd phalanx	6	3	3	-
3rd phalanx	-	-	-	-
total	**217**	**45**	**3**	**2**

broken into very small pieces consistent with our model of bone grease manufacture. Of the 865 bones from the concentration, 798 (285.3 g) were considered measurable (teeth/tooth fragments were not included in the analysis). Only 2 bones were found to be unbroken and an additional three were unfragmented epiphyses (Table 18; Appendix: Table A.3). The two unbroken bones were sesamoids and the unbroken epiphyses were all second phalanges. These elements are quite small and may have been easily missed even during an intensive bone grease processing event. The remaining bones were heavily fragmented, with 37 percent less than 1.5 cm in maximum dimension and 96 percent being less than 3 cm in maximum dimension (Table 19). By weight, at least 78 percent of the bone was less than 3 cm in maximum dimension (Table 20)

Nearly every part of the deer skeleton was present in this assemblage (Table 18). The most common elements were those belonging to the head (cranium/mandible/isolated dentition) and vertebrae. It should be noted, however, that there was likely some bias towards these parts, as they retain many of their diagnostic features even after heavy fragmentation. In addition to the head, vertebrae, and ribs (Figure 10), all of the major long bones and extremities (i.e. phalanges and sesamoids) were also present, indicating a fairly complete utilization of the deer carcass.

Finally, in terms of seasonality, the bone pile contained deciduous maxillary teeth, including a fourth premolar that was heavily worn and nearly expelled (Figure 11). Although most sources on the aging of white-tailed deer dentition (e.g. Severinghaus 1949) focus on mandibular teeth, comparison to several specimens of known age indicates that the individual was most likely killed in November or December. This interpretation is supported by floral remains from the pit, which contain several pieces of

Table 19. Size distribution of bone fragment counts by type from Feature 438 at the Krause Site (47LC41).

	Cancellous		**Compact**		**Vertebrae**		**Ribs**		**Complete**		**Total**	
Size	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
1	250	40.6	46	34.6	2	5.4	0	0.0	0	0.0	298	37.3
2	206	33.4	42	31.6	5	13.5	0	0.0	2	40.0	255	32.0
3	104	16.9	20	15.0	12	32.4	2	28.6	1	20.0	139	17.4
4	42	6.8	16	12.0	14	37.8	3	42.9	0	0.0	75	9.4
5	9	1.5	5	3.8	4	10.8	0	0.0	0	0.0	18	2.3
6	2	0.3	1	0.8	0	0.0	0	0.0	1	20.0	4	0.5
7	2	0.3	3	2.3	0	0.0	0	0.0	0	0.0	5	0.6
8	0	0.0	0	0.0	0	0.0	1	14.3	0	0.0	1	0.1
9	1	0.2	0	0.0	0	0.0	0	0.0	1	20.0	2	0.3
10	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
11	0	0.0	0	0.0	0	0.0	1	14.3	0	0.0	1	0.1
12	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	**616**	**-**	**133**	**-**	**37**	**-**	**7**	**-**	**5**	**-**	**798**	**-**

Table 20. Size distribution of bone fragment weight by type from Feature 438 at the Krause Site (47LC41).

	Cancellous		**Compact**		**Vertebrae**		**Ribs**		**Complete**		**Total**	
Size	W(g)	%	W(g)	%	W(g)	%	W(g)	%	W(g)	%	W(g)	%
1	31.1	17.4	5.1	13.5	0.7	2.3	0	0.0	0	0.0	36.9	12.9
2	49.7	27.7	8.5	22.5	1.5	4.9	0	0.0	1.0	3.2	60.7	21.3
3	44.6	24.9	7.5	19.8	9.4	30.9	0.3	4.7	0.7	2.2	62.5	21.9
4	37.9	21.2	9.9	26.2	13.6	44.7	2.0	31.3	0	0.0	63.4	22.2
5	7.9	4.4	3.0	7.9	5.2	17.1	0	0.0	0	0.0	16.1	5.6
6	4.0	2.2	0.7	1.9	0	0.0	0	0.0	8.1	25.6	12.8	4.5
7	2.0	1.1	3.1	8.2	0	0.0	0	0.0	0	0.0	5.1	1.8
8	0	0.0	0.0	0.0	0	0.0	1.1	17.2	0	0.0	1.1	0.4
9	1.9	1.1	0.0	0.0	0	0.0	0	0.0	21.8	69.0	23.7	8.3
10	0	0.0	0.0	0.0	0	0.0	0	0.0	0	0.0	0.0	0.0
11	0	0.0	0.0	0.0	0	0.0	3.0	46.9	0	0.0	3.0	1.1
12	0	0.0	0.0	0.0	0	0.0	0	0.0	0	0.0	0.0	0.0
Total	**179.1**	**-**	**37.8**	**-**	**30.4**	**-**	**6.4**	**-**	**31.6**	**-**	**285.3**	**-**

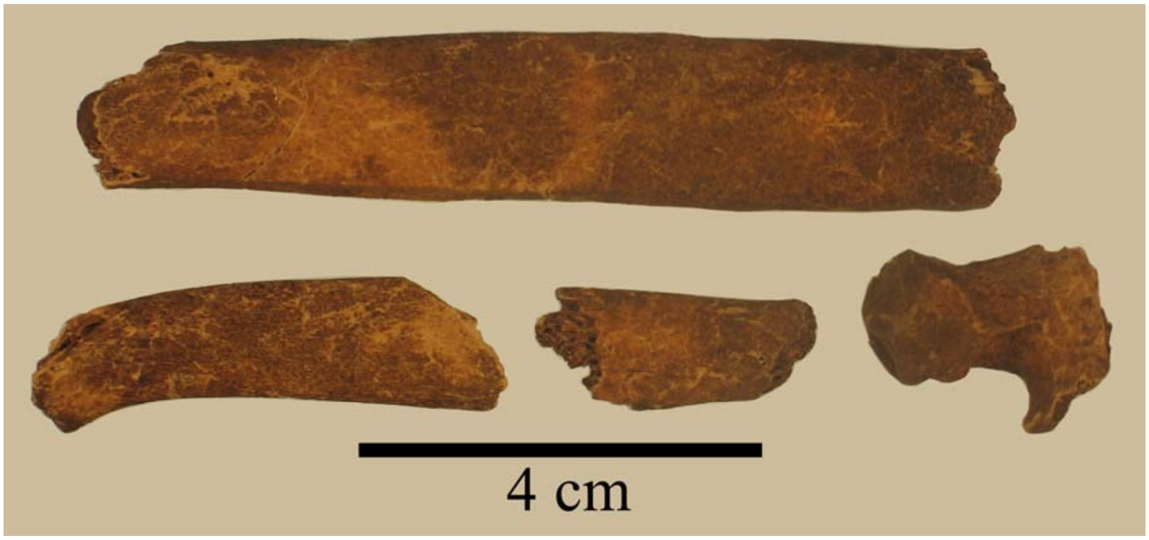

Figure 10. White-tailed deer ribs from Feature 438 at Krause (47LC41).

Figure 11. White-tailed deer dentition from Feature 438 at Krause (47LC41). Note sub-adult maxillary dentition (aged 1.5 years) and adult mandibular dentition (aged 2.5+ years).

nutshell and wild rice. Both of these items are rare on La Crosse Area Oneota sites and could reflect fall to winter occupations (Arzigian 1989:142-146).

Feature 441

Located near Feature 438, in the eastern portion of the site, Feature 441 also contained evidence of bone grease processing. Like the previous feature, it too was basin shaped, although slightly shallower, with a maximum depth of 35 cm. A total of four zones were identified in the pit based upon soil color and texture differences observed during excavation. The uppermost zone contained a very dense pile of crushed American elk bone (Figure 12 and 13).

An examination of the artifact assemblage from Feature 441 yielded some clues as to its age and cultural affiliation. The feature contained five Woodland (grit-tempered) sherds. These were most likely the result of the Oneota disturbance of a pre-existing Woodland component at the site. The nearly 100 shell-tempered sherds (Oneota) from the pit are probably a much more accurate reflection of the feature's age. Unfortunately, none of the sherds were diagnostic to a more specific cultural component. The composition of the lithic assemblage shed some more light on this issue. In total, there were 672 pieces of lithic debitage, of which 585 (87.1 percent) were made of local Prairie du Chien chert. The emphasis on locally available lithic materials is characteristic of later Oneota occupations (Boszhardt 1994b). Accordingly, the feature likely belongs to the late Pammel Creek Phase or Valley View Phase, thus giving it a date of A.D. 1,450-1,600.

Three freshwater mussel valves and an American beaver (*Castor canadensis*) mandible were the only faunal material, other than the pile of American elk bone, to

Figure 12. Excavation of pile of crushed American elk bone from Feature 441 at Krause (47LC41) (photo courtesy of the Mississippi Valley Archaeology Center).

Figure 13. Pile of crushed American elk bone from Feature 441 at Krause (47LC41) (photo courtesy of the Mississippi Valley Archaeology Center).

come from the feature (Table 21, Appendix: Table A.4). A nine-liter floatation sample from in and around the bone pile produced 176 fragments of hickory (*Carya*sp.) nutshell. As noted above, large quantities of nutshell are an uncommon occurrence in Oneota pits from La Crosse and could been interpreted as a fall/winter seasonal indicator (Arzigian 1989:142-146). This sample also contained several burned maize (*Zea mays*) kernels and a tobacco (*Nicotiana tabacum*) seed.

All of the animal remains from the bone pile in Feature 441 were consistent with American elk. A total of 525 fragments made this the second largest bone grease assemblage from Krause by NISP, while a total weight of 481.1 grams made it the largest by mass. Of the 525 fragments, only 28 (5.3 percent) were positively identified to skeletal element (Table 22). Based upon overall size, shape, and thickness, the unidentified fragments all appeared to be American elk. Overall, the specimens from Feature 441 were quite robust and comparison to modern individuals suggested that they were likely from an adult male. Since no overlapping elements were found, an MNI of one elk was calculated for the feature.

The context and condition of the bone from Feature 441 pointed to bone grease manufacture. As noted above, the bones were found in a discrete pile (Figures 12 and 13), thus indicating that they were likely deposited as the result of a single activity. Nearly all of the bones from the concentration were fragmented and many had evidence of green bone fractures (Table 9). These green bone fractures were observed on nearly all of the pieces of compact bone and also on some of the larger pieces of cancellous bone, which retained compact tissue. None of the bones had any additional signs of taphonomic

Table 21. Summary of animal remains from Feature 441 at the Krause Site (47LC41).

Taxon	Common Name	NISP	MNI
Tritogonia verrucosa	pistolgrip	1	1
Castor canadensis	American beaver	1	1
Cervus elaphus	American elk	28	1
	subtotal	**30**	**3**
	unidentified naiad	25	2
	unidentified lg. mammal	497	-
	Total	**552**	**5**

Table 22. Summary of American elk elements from Feature 441 at the Krause Site (47LC41).

Element	NISP	MNE	Complete Epiphyses	Complete Elements
cranial	-	-	-	-
mandible	-	-	-	-
isolated teeth	-	-	-	-
hyoid	-	-	-	-
vertebrae	-	-	-	-
ribs	-	-	-	-
innonimate	-	-	-	-
scapula	-	-	-	-
humerus	1	1	-	-
radius	8	1	-	-
ulna	1	1	-	-
carpals	-	-	-	-
metacarpal	-	-	-	-
femur	2	1	-	-
tibia	15	2	-	-
tarsals	1	1	-	1
metatarsal	-	-	-	-
metapodial	-	-	-	-
residuals	-	-	-	-
sesamoids	-	-	-	-
1st phalanx	-	-	-	-
2nd phalanx	-	-	-	-
3rd phalanx	-	-	-	-
total	**28**	**7**	**0**	**1**

modification, such as burning or gnawing indicative of exposure or further manipulation. This data further confirm that the occurrence of was the result of a single activity.

An examination of the degree of fragmentation also indicated that the bone concentration was from bone grease production. The specimens were extensively broken and a single complete lateral malleolus was the only unfractured bone in the assemblage. This small bone could have been easily missed and it may not have been targeted due to its low grease yield. The rest of the bones were all fragmented and of the 525 measurable specimens, 171 (32.6 percent) were less than 1.5 cm in maximum dimension (Table 23). Additionally, 459 fragments (87.4 percent) were less than 3 cm in maximum dimension. Only 44.7 percent of the bone weight, however, was represented by specimens measuring less than 3 cm (Table 24). Overall, the specimens from Feature 441 were larger than those from the other proveniences mentioned above. This is likely attributable to the fact that this assemblage was comprised of elk bone, unlike the aforementioned deposits, which were primarily white-tailed deer. A greater labor investment would have been required to break the bones to those the size of the deer remains, with, perhaps, little increase in grease extraction efficiency.

Excluding the lateral malleolus, all of elk the specimens from Feature 441 were long bones, including the humerus, radius, ulna, tibia, and femur, but no metapodials. Since some of the high-yield grease elements, such as the metapodials and vertebrae, were missing, it is unlikely that the element representation is explained by selective processing. The element representation may be more likely the product of selective transport, if the animal was killed at some distance from the site. Unless it was killed very

Table 23. Size distribution of bone fragment counts by type from Feature 441 at the Krause Site (47LC41).

	Cancellous		**Compact**		**Vertebrae**		**Ribs**		**Complete**		**Total**	
Size	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
1	156	37.0	15	14.7	0	0.0	0	0.0	0	0.0	171	32.6
2	109	25.8	20	19.6	0	0.0	0	0.0	0	0.0	129	24.6
3	91	21.6	30	29.4	0	0.0	0	0.0	0	0.0	121	23.0
4	27	6.4	11	10.8	0	0.0	0	0.0	0	0.0	38	7.2
5	20	4.7	6	5.9	0	0.0	0	0.0	0	0.0	26	5.0
6	6	1.4	9	8.8	0	0.0	0	0.0	1	100.0	16	3.0
7	4	0.9	7	6.9	0	0.0	0	0.0	0	0.0	11	2.1
8	6	1.4	1	1.0	0	0.0	0	0.0	0	0.0	7	1.3
9	3	0.7	3	2.9	0	0.0	0	0.0	0	0.0	6	1.1
10	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
11	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
12	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	**422**	**-**	**102**	**-**	**0**		**0**	**-**	**1**	**-**	**525**	**-**

Table 24. Size distribution of bone fragment weight by type from Feature 441 at the Krause Site (47LC41).

	Cancellous		**Compact**		**Vertebrae**		**Ribs**		**Complete**		**Total**	
Size	W(g)	%	W(g)	%	W(g)	%	W(g)	%	W(g)	%	W(g)	%
1	27.0	7.5	3.1	2.7	0	0.0	0	0.0	0	0.0	30.1	6.3
2	43.2	12.0	8.0	6.9	0	0.0	0	0.0	0	0.0	51.2	10.6
3	65.8	18.3	18.6	16.0	0	0.0	0	0.0	0	0.0	84.4	17.5
4	37.6	10.5	12.1	10.4	0	0.0	0	0.0	0	0.0	49.7	10.3
5	51.4	14.3	11.2	9.6	0	0.0	0	0.0	0	0.0	62.6	13.0
6	17.5	4.9	16.1	13.9	0	0.0	0	0.0	6.1	100.0	39.7	8.3
7	17.2	4.8	25.6	22.0	0	0.0	0	0.0	0	0.0	42.8	8.9
8	34.9	9.7	4.0	3.4	0	0.0	0	0.0	0	0.0	38.9	8.1
9	64.2	17.9	17.5	15.1	0	0.0	0	0.0	0	0.0	81.7	17.0
10	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
11	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
12	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	**358.8**		**116.2**		**0**	**-**	**0**	**-**	**6.1**	**-**	**481.1**	**-**

locally, one would not expect the very heavy axial skeleton (e.g. ribs and vertebrae) or the meat-poor metapodials to have been transported back to the village.

Feature 82

Situated in the southern portion of the Krause Site, Feature 82 also contained evidence of bone grease production. This feature was a typical Oneota refuse pit with a diameter of 150 cm and a maximum depth of 55 cm. The feature had three discrete fill zones that were identified on the basis of soil color and texture changes. The uppermost zone produced 126 fragments of crushed mammal bone (248.7 grams). Based upon overall size, shape, and thickness these remains appear to be American elk. Unlike Features 438 and 441, the bone in this pit was not deposited in a discrete pile, rather it was dispersed about the uppermost zone of the feature. Since the quantity of bone is rather small and appears to be from a single animal, it was likely produced during a single activity; however, since it was not deposited as a single pile it may provide a slightly biased view of its source. The material still appeared to be the product of bone grease manufacture, but it may not have been deposited immediately following the processing event. It seemed to have been scattered or scavenged prior to deposition and was therefore biased towards large fragments.

Other than the crushed elk bone, little else was recovered from Feature 82. In total, 17 shell tempered pottery sherds and five unmodified pieces of debitage were found in the entire pit. The zone containing the crushed bones also contained a modest 56 grams of fire-cracked limestone. Given the lack of artifacts, there is no specific information on chronology or seasonality.

Of the 126 bones from the feature, 25 (19.8 percent) could be positively identified as American elk. All of the unidentified specimens were clearly from a large mammal and were probably elk as well (Table 25, Appendix: Table A.5). Overall, the specimens were quite robust and comparison to modern individuals suggested that they were likely from an adult male. As no overlapping element parts were found, an MNI of one was calculated. The presence of a distal right tibia from both Feature 441 and Feature 82, however, indicated that at least two individual elk were present between the pits. All identified elements came from the appendicular skeleton (Table 26) and most belonged to the major long bones (e.g. humerus, radius, femur, tibia, and metapodials). Several phalanges and tarsals were also identified. The absence of any axial elements suggests that, like Feature 441, the animal may have been selectively butchered in the field.

The bones from the feature were heavily fragmented, supporting the initial hypothesis that they were the result of bone grease production. A total of 51 specimens (40.5 percent) exhibited signs of green bone fractures (including non-diagnostic cancellous bone), indicating that they were broken while fresh. None of the bone had any additional signs of manipulation, such as burning or gnawing. Given the high frequency of carnivore gnawing on La Crosse Oneota sites, this would indicate that the remains were likely deposited shortly after processing. Their greater dispersion throughout the pit, however, suggests that some of the bones may have been lost and that other materials were incorporated with them prior to disposal.

Although the bones were generally larger than those from the other proveniences examined in this thesis, an analysis of fragment size suggests that they were extensively and systematically fractured. Of the 126 measureable bone fragments, 87 (69 percent)

Table 25. Summary of animal remains from Feature 82 at the Krause Site (47LC41).

Taxon	Common Name	NISP	MNI
Cervus elaphus	American elk	25	1
	subtotal	**25**	**1**
	unidentified lg. mammal	101	-
	total	**126**	**1**

Table 26. Summary of American elk elements from Feature 82 at the Krause Site (47LC41).

Element	NISP	MNE	Complete Epiphyses	Complete Elements
cranial	-	-	-	-
mandible	-	-	-	-
isolated teeth	-	-	-	-
hyoid	-	-	-	-
vertebrae	-	-	-	-
ribs	-	-	-	-
innonimate	-	-	-	-
scapula	-	-	-	-
humerus	1	1	-	-
radius	2	1	-	-
ulna	-	-	-	-
carpals	-	-	-	-
metacarpal	2	1	-	-
femur	2	1	-	-
tibia	4	1	-	-
tarsals	6	4	-	2
metatarsal	3	2	-	-
metapodial	3	-	1	-
residuals	-	-	-	-
sesamoids	-	-	-	-
1st phalanx	1	1	-	-
2nd phalanx	1	1	1	-
3rd phalanx	-	-	-	-
total	**25**	**13**	**2**	**2**

were less than 3 cm in maximum dimension (Table 27). The weight of the fragments, however, showed that most of the mass of the bone falls into the 3.5 cm to 9.0 cm size categories (Table 28). While this could indicate that much of the bone mass was not utilized for its grease content, it was more likely that the assemblage was biased towards large fragments as a result of how it was disposed. Overall, the lack of non-fractured bones and complete epiphyses suggested a high level of fragmentation that was consistent with bone grease production.

<u>Long Coulee (47LC333)</u>

Remains from the Long Coulee Site also appeared to have been the product of bone grease production. The site was located in Long Coulee, just to the northwest of the present-day city of Onalaska, Wisconsin (Figure 4). The University of Wisconsin-La Crosse conducted a field school at the Long Coulee Site in 1990, which revealed an extensive Oneota occupation, and included a massive cache of freshwater mussels (Theler 1990). MVAC conducted additional test excavations at several locations of the site during the summer of 1995 (Burkart and Woolley 1996). Excavation of Feature 1 on the "Upper Garden Terrace" portion of the site revealed a significant quantity of fractured large mammal remains.

Feature 1 was a relatively large, oblong pit, with a length of 200 cm and a width of 95 cm. The feature was at least 105 cm deep and had several distinct fill lenses. Time constraints prevented the excavation of the entire pit, so its total depth and contents are unknown (Burkart and Woolley 1996). The pit produced a substantial artifact assemblage, including shell tempered ceramics, lithic debitage, fire-cracked rock, and a bison scapula hoe. A ceramic rim sherd, belonging to the type *Koshkonong Bold*,

Table 27. Size distribution of bone fragment counts by type from Feature 82 at the Krause Site (47LC41).

	Cancellous		**Compact**		**Vertebrae**		**Ribs**		**Complete**		**Total**	
Size	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
1	26	28.9	3	9.4	0	0.0	0	0.0	0	0.0	29	23.0
2	26	28.9	2	6.3	0	0.0	0	0.0	1	25.0	29	23.0
3	14	15.6	2	6.3	0	0.0	0	0.0	0	0.0	16	12.7
4	11	12.2	2	6.3	0	0.0	0	0.0	0	0.0	13	10.3
5	4	4.4	3	9.4	0	0.0	0	0.0	1	25.0	8	6.3
6	2	2.2	5	15.6	0	0.0	0	0.0	1	25.0	8	6.3
7	3	3.3	1	3.1	0	0.0	0	0.0	0	0.0	4	3.2
8	2	2.2	5	15.6	0	0.0	0	0.0	0	0.0	7	5.6
9	2	2.2	7	21.9	0	0.0	0	0.0	1	25.0	10	7.9
10	0	0.0	2	6.3	0	0.0	0	0.0	0	0.0	2	1.6
11	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
12	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	**90**	**-**	**32**	**-**	**0**	**-**	**0**	**-**	**4**	**-**	**126**	**-**

Table 28. Size distribution of bone fragment weight by type from Feature 82 at the Krause Site (47LC41).

	Cancellous		**Compact**		**Vertebrae**		**Ribs**		**Complete**		**Total**	
Size	W(g)	%	W(g)	%	W(g)	%	W(g)	%	W(g)	%	W(g)	%
1	3.2	3.3	0.5	0.4	0	0.0	0	0.0	0	0.0	3.7	1.5
2	5.5	5.6	0.1	0.1	0	0.0	0	0.0	0.5	2.4	6.1	2.5
3	11.4	11.6	0.9	0.7	0	0.0	0	0.0	0	0.0	12.3	4.9
4	15.5	15.8	4.0	3.1	0	0.0	0	0.0	0	0.0	19.5	7.8
5	8.0	8.1	6.6	5.1	0	0.0	0	0.0	3.8	18.3	18.4	7.4
6	10.2	10.4	17.0	13.1	0	0.0	0	0.0	4.6	22.1	31.8	12.8
7	14.2	14.5	7.5	5.8	0	0.0	0	0.0	0	0.0	21.7	8.7
8	9.1	9.3	27.2	21.0	0	0.0	0	0.0	0	0.0	36.3	14.6
9	21.1	21.5	34.3	26.4	0	0.0	0	0.0	11.9	57.2	67.3	27.1
10	0	0.0	31.6	24.4	0	0.0	0	0.0	0	0.0	31.6	12.7
11	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
12	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	**98.2**	**-**	**129.7**	**-**	**0**	**-**	**0**	**-**	**20.8**	**-**	**248.7**	**-**

suggested a Pammel Creek Phase affiliation (see Boszhardt 1994b). A wood charcoal sample from the pit produced a calibrated radiocarbon date of A.D. 1,350, predating the generally accepted age of the Pammel Creek Phase by 50 years. Given the highly diagnostic sherd, it seems likely that the feature is of Pammel Creek age. Furthermore, Burkart and Woolley (1996) fail to list the standard deviation for the date, and therefore it may actually fall within the traditional age range for Pammel Creek. Excavations conducted during the summer of 2004 produced evidence for a cool season occupation for the site (Constance M. Arzigian, personal communication 2005).

The faunal assemblage from Feature 1 included a bison scapula hoe, several fish remains, and a concentration of large mammal bone (Table 29). Most of the fish reamins were too incomplete to be identified, but several were determined to be suckers (Catostomidae), redhorse suckers (*Moxostoma* sp.), and bass (*Micropterus* sp.). Although the fish remains would seem to indicate a warm season occupation, they were not directly associated with the concentration of large mammal bone. As the feature contained several stratigraphic lenses, it seems that the fish, which came from much higher in the feature, may be part of different fill episode and therefore cannot be used to assign a season to the concentration of crushed bone.

In total, the concentration of large mammal remains produced 829 bone fragments (Figure 14). All of the specimens were consistent with white-tailed deer and 135 (16.3 percent) were confidently identified to this species (Table 30, Appendix: Table A.6). The quantity of distal first and second phalanges indicated that at least two individual deer were present. Like the other Oneota assemblages discussed above, the condition of the bone was highly indicative of bone grease production. At least 375 (45.2 percent) of the

Table 29. Summary of animal remains from Feature 1 at the Long Coulee Site (47LC333).

Taxon	**Common Name**	**NISP**	**MNI**
Moxostoma carinatum	river redhorse	2	1
Moxostoma sp.	redhorse sucker	3	-
Catostomidae	sucker	8	-
*Micropterus*sp.	bass	1	1
Odocoileus virginianus	white-tailed deer	135	2
	subtotal	**149**	**4**
	unidentified fish	30	-
	unidentified lg. mammal	694	-
	total	**873**	**4**

Table 30. Summary of white-tailed deer elements from Feature 1 at the Long Coulee Site (47LC333).

Element	**NISP**	**MNE**	**Complete Epiphyses**	**Complete Elements**
cranial	-	-	-	-
mandible	-	-	-	-
isolated teeth	-	-	-	-
hyoid	-	-	-	-
vertebrae	-	-	-	-
ribs	33	3	-	-
innonimate	-	-	-	-
scapula	3	1	-	-
humerus	3	1	-	-
radius	4	2	-	-
ulna	3	2	-	-
carpals	16	13	-	11
metacarpal	1	1	-	-
femur	3	2	-	-
tibia	3	1	-	-
tarsals	6	5	-	3
metatarsal	2	1	-	-
metapodial	3	-	-	-
residuals	3	2	-	-
sesamoids	-	-	-	-
1st phalanx	26	13	7	-
2nd phalanx	24	12	3	-
3rd phalanx	2	2	-	-
total	**135**	**61**	**10**	**14**

Figure 14. Crushed white-tailed deer bone from Feature 1 at Long Coulee (47LC333) (photo courtesy of James L. Theler).

bones had green bone fractures (Table 9). These green bone fractures were observed on nearly every piece of compact bone and also on the larger pieces of cancellous bone, which retained compact tissue. Only two of the bones, which had been gnawed by a carnivore, showed any additional evidence of modification. This relative lack of additional modifications, combined with the fact that the bone was found in a single concentration, indicates that it was likely deposited in the pit as the result of a single activity, with little exposure following initial processing.

In addition to the numerous green bone fractures, the size of the bone fragments further supported the hypothesis that they were bone grease refuse. All of the 829 bone fragments from the concentration were measured for the size analysis. Most of the remains were very small, with 311 (37.5 percent) of the fragments being less than 1.5 cm in maximum length and 773 (93.2 percent) fragments being less than 3.0 cm in maximum length (Table 31). The weight distribution of the fragments demonstrated that most of the total bone mass was also fragmented to a significant extent. Over 78 percent of the bone mass was present in the size categories under 3.0 cm and only a minimal amount of bone mass was from the size categories greater than 4.0 cm (Table 32). Although 14 bones were not broken at all, and 11 were complete epiphyses (Table 30), all were small elements that could have been easily missed or ignored during bone grease production. The complete elements consisted entirely of small carpals and tarsals and the complete epiphyses were from first and second phalanges.

An examination of the skeletal element representation indicates that all portions of the appendicular skeleton were present (Table 30). Most of the mass of the remains came from the major long bones, and all were represented. The carpals, tarsals, residual

Table 31. Size distribution of bone fragment counts by type from the Long Coulee Site (47LC333).

	Cancellous		Compact		Vertebrae		Ribs		Complete		Total	
Size	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
1	219	47.9	90	28.6	0	0.0	2	6.1	0	0.0	311	37.5
2	153	33.5	92	29.2	0	0.0	5	15.2	0	0.0	250	30.2
3	65	14.2	63	20.0	0	0.0	11	33.3	8	33.3	147	17.7
4	15	3.3	33	10.5	0	0.0	9	27.3	8	33.3	65	7.8
5	2	0.4	17	5.4	0	0.0	3	9.1	5	20.8	27	3.3
6	0	0.0	18	5.7	0	0.0	3	9.1	1	4.2	22	2.7
7	1	0.2	2	0.6	0	0.0	0	0.0	2	8.3	5	0.6
8	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1
9	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1
10	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
11	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
12	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	**457**	**-**	**315**	**-**	**0**	**-**	**33**	**-**	**24**	**-**	**829**	**-**

Table 32. Size distribution of bone fragment weight by type from the Long Coulee Site (47LC333).

	Cancellous		Compact		Vertebrae		Ribs		Complete		Total	
Size	W(g)	%	W(g)	%	W(g)	%	W(g)	%	W(g)	%	W(g)	%
1	29.7	18.1	14.3	12.5	0	0.0	0.1	1.4	0	0.0	44.1	13.0
2	52.2	31.8	24.1	21.0	0	0.0	0.5	6.9	0	0.0	76.8	22.7
3	48.6	29.7	21.7	19.0	0	0.0	2.2	30.6	13.8	26.0	86.3	25.5
4	22.5	13.7	17.2	15.0	0	0.0	1.8	25.0	16.3	30.8	57.8	17.1
5	3.0	1.8	11.6	10.1	0	0.0	1.2	16.7	13.8	26.0	29.6	8.7
6	0	0.0	22.0	19.2	0	0.0	1.4	19.4	2.9	5.5	26.3	7.8
7	1.9	1.2	3.6	3.1	0	0.0	0	0.0	6.2	11.7	11.7	3.5
8	2.7	1.6	0	0.0	0	0.0	0	0.0	0	0.0	2.7	0.8
9	3.3	2.0	0	0.0	0	0.0	0	0.0	0	0.0	3.3	1.0
10	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
11	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
12	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	**163.9**	**-**	**114.5**	**-**	**0**	**-**	**7.2**	-	**53.0**	**-**	**338.6**	**-**

foot elements, and numerous phalanges were also present. Excluding 33 rib fragments, no portions of the axial skeleton (e.g. cranium and vertebrae) were identified. The ribs made up 24.4 percent of the identified remains, making this the only Oneota assemblage examined in this thesis to produce a significant quantity of rib fragments. Despite the lack of axial elements, the feature produced a quantity and diversity of long bones not typically observed in most traditional La Crosse Oneota faunal assemblages (see Theler 1994a:386-387). This suggested less selective field butchering and the transport of a greater number of grease rich bones back to the village. Overall, the heavily fragmented assemblage of long bones was quite consistent with bone grease production.

Holley Street (47LC485)

A pit feature from the Holley Street Site produced a heavily fragmented faunal assemblage that is likely the product of bone grease manufacture. The Holley Street Site is located at the base of the Mississippi River valley bluffs near the present-day Village of Holmen, Wisconsin (Figure 4). The site is set in a swale between the bluffs and the La Crosse terrace to the west, placing it in an environmental setting similar to that of the Sand Lake Archaeological District (Boszhardt 1994b:167). Excavations were conducted at the site in 1991, prior to construction activities. Mechanical stripping of the plow-zone revealed 85 Oneota pit features, 12 of which were selected for excavation. Diagnostic ceramics from the site indicated that it was occupied from A.D. 1,450-1,650 by Pammel Creekand Valley View phase peoples (Boszhardt 1994b:168).

The only feature from Holley Street to produce any faunal remains was Feature 1. Unfortunately, no artifact inventory was available for the feature, so the faunal remains could not be placed in a better context. The feature is certainly Oneota and, as the site was occupied from A.D. 1,450-1,650, it likely fit into this time frame. The faunal remains from this feature were originally reported by Theler (1994a:363-364) and were reanalyzed for this study. No significant differences exist between this analysis and that presented by Theler (1994a:364), other than the identification of a few previously indeterminate fragments.

Feature 1 contained 304 pieces of crushed bone that were consistent with white-tailed deer. A total of 81 fragments (26.6 percent) were identified to skeletal element (Tables 33 and 34, Appendix: Table A.7). It is unclear if the bones were found in a concentration, but their occurrence in the pit appeared to be the result of a single activity. Just over 50 percent of the bones (*n* = 154) displayed evidence of green bone fractures, indicating that they were broken while fresh. Nearly all of the compact bone fragments had green bone fractures, as did the pieces of cancellous bone that retained small portions of compact bone. A limited number of the bones (*n* = 6) had been burned (Table 9), but none showed any signs of other cultural or natural modifications. Again, these data help confirm that the bones were deposited in the pit as the result of a single activity and were fractured by human actions.

A size analysis of the bone fragments also indicated that they were the product of bone grease manufacture. All of the 304 bone fragments were able to measured and 136 (44.7 percent) were less than 1.5 cm in maximum dimension (Table 35). Additionally, 93.4 percent (*n* = 284) were less than 3.0 cm in maximum dimension. Seventy-seven percent of the bone weight was from the size categories less than 3.0 cm (Table 36). The 16 complete elements and 5 complete epiphyses from the feature were all small elements that could have been ignored or missed during bone grease production (Table 34). The

Table 33. Summary of animal remains from Feature 1 at the Holley Street Site (47LC485).

Taxon	**Common Name**	**NISP**	**MNI**
Ameiurus melas	black bullhead	1	1
Ictaluridae	catfish	2	1
Odocoileus virginianus	white-tailed deer	81	2
	subtotal	**84**	**4**
	unidentified fish	1	-
	unidentified lg. mammal	223	-
	total	**308**	**4**

Table 34. Summary of white-tailed deer elements from Feature 1 at the Holley Street Site (47LC485).

Element	**NISP**	**MNE**	**Complete Epiphyses**	**Complete Elements**
cranial	3	1	-	-
mandible	-	-	-	-
isolated teeth	-	-	-	-
hyoid	-	-	-	-
vertebrae	22	-	-	-
ribs	-	-	-	-
innonimate	-	-	-	-
scapula	-	-	-	-
humerus	-	-	-	-
radius	-	-	-	-
ulna	-	-	-	-
carpals	5	5	-	5
metacarpal	-	-	-	-
femur	-	-	-	-
tibia	-	-	-	-
tarsals	-	-	-	-
metatarsal	-	-	-	-
metapodial	4	1	-	-
residuals	7	7	-	7
sesamoids	3	3	-	3
1st phalanx	23	6	3	-
2nd phalanx	13	5	2	-
3rd phalanx	1	1	-	1
total	**81**	**29**	**5**	**16**

Table 35. Size distribution of bone fragment counts by type from the Holley Street Site (47LC485).

	Cancellous		**Compact**		**Vertebrae**			**Ribs**	**Complete**			**Total**
Size	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
1	89	57.4	43	40.6	3	13.6	0	0.0	1	4.8	136	44.7
2	36	23.2	33	31.1	6	27.3	0	0.0	3	14.3	78	25.7
3	18	11.6	17	16.0	6	27.3	0	0.0	5	23.8	46	15.1
4	8	5.2	7	6.6	3	13.6	0	0.0	6	28.6	24	7.9
5	2	1.3	3	2.8	2	9.1	0	0.0	3	14.3	10	3.3
6	2	1.3	3	2.8	0	0.0	0	0.0	2	9.5	7	2.3
7	0	0.0	0	0.0	2	9.1	0	0.0	0	0.0	2	0.7
8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
9	0	0.0	0	0.0	0	0.0	0	0.0	1	4.8	1	0.3
10	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
11	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
12	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	**155**	**-**	**106**	**-**	**22**	**-**	**0**	**-**	**21**	**-**	**304**	**-**

Table 36. Size distribution of bone fragment weight by type from the Holley Street Site (47LC485).

	Cancellous		**Compact**		**Vertebrae**			**Ribs**	**Complete**			**Total**
Size	W(g)	%	W(g)	%	W(g)	%	W(g)	%	W(g)	%	W(g)	%
1	15.5	30.8	7.8	17.1	1.0	5.4	0	0.0	0.3	0.9	24.6	16.8
2	10.9	21.6	10.9	24.0	3.6	19.5	0	0.0	1.9	5.9	27.3	18.6
3	12.7	25.2	11.9	26.2	3.7	20.0	0	0.0	4.3	13.3	32.6	22.2
4	7.3	14.5	4.4	9.7	4.5	24.3	0	0.0	12.3	38.0	28.5	19.4
5	0.4	0.8	7.1	15.6	2.5	13.5	0	0.0	8.0	24.7	18.0	12.3
6	3.6	7.1	3.4	7.5	0	0.0	0	0.0	5.0	15.4	12.0	8.2
7	0	0.0	0	0.0	3.2	17.3	0	0.0	0	0.0	3.2	2.2
8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
9	0	0.0	0	0.0	0	0.0	0	0.0	0.6	1.9	0.6	0.4
10	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
11	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
12	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	**50.4**	**-**	**45.5**	**-**	**18.5**	**-**	**0**	**-**	**32.4**	**-**	**146.8**	**-**

complete elements were carpals, residual foot bones, sesamoids, and a third phalanx. The complete epiphyses were from first and second phalanges.

Nearly 70 percent of the identified remains came from the extremities: carpals, metapodials, residuals, sesamoids, and phalanges (Table 34). Four metapodial fragments, which were considered extremities, represented the only long bones identified from the feature. The remaining specimens were all vertebral and cranial fragments. The elements present in the assemblage indicated that the animal was either selectively butchered in the field, or that the other elements were deposited elsewhere on the site. Most deer remains from Oneota sites have typically been such extremities, which Theler (1989, 1994a, 1994b) has interpreted this to be the result of field processing to aid in carcass transport.

As fractured extremities dominated the assemblage it would not seem to support an interpretation of bone grease production. Elements, such as the phalanges and carpals, were exceedingly low in grease content (Binford 1978; Jones and Metcalfe 1988). The phalanges, however, were intentionally fractured and broken well beyond the point necessary for simple marrow extraction. Experimental work (see Chapter VII) showed that a single blow to the medial or lateral surface of the phalanges would have been sufficient to expose the medullary marrow cavity. With this method, both the distal and proximal epiphyses remained intact. The phalanges from Holley Street showed a different pattern. They were all heavily fractured, as though several hammer blows were administered to the entire element. This pattern was more consistent with grease production, as it would have opened the very small pockets of cancellous tissue in the epiphyses of the elements. Furthermore, at least 22 crushed vertebrae fragments were present, and the majority of the unidentified remains were comprised of cancellous bone

(Table 35). Once again, there are few explanations, other than bone grease production, that would account for such an extensive fracturing of cancellous bone.

In addition to the fractured deer bone, the feature also produced a pectoral spine from a black bullhead (*Ameiurus melas*) and two indeterminate catfish (Ictaluridae) remains (Table 33). Although, these animals are generally indicative of summer activities, the lack of contextual information for the feature means that they could not be confidently associated with the deer remains. Furthermore, three fish bones are hardly enough to serve as the base of a seasonal assessment for the feature. These bones could have been scattered around the site and easily incorporated into the pit at any time of the year.

Sanford Archaeological District (47LC394) – Locality 32

The final La Crosse Area Oneota site examined in this study was the Sanford Archaeological District. This site was a large Oneota village complex located in present-day downtown La Crosse (Figure 4). As a result of development during the past twenty years, a number of excavations have been conducted at this site. The most extensive excavations were carried out in 1991 by MVAC as a salvage project to mitigate impacts to the site prior to construction activity (Arzigian et al. 1994). These excavations revealed over 500 pit features, 53 burials, and several possible longhouse-type structures The site's occupation dated from the Brice Prairie through Valley View phases. Theler (1994b) analyzed the faunal remains from the 1991 excavations. Although Theler's (1994b) analysis focused on the mammals, birds, and freshwater mussels (and excluded fish), the remains were consistent with those from other La Crosse Oneota sites (see Chapter IV). In general, the site's faunal material showed that the inhabitants focused on two major environments: riparian/floodplain habitats as evidenced by numerous fish, reptile, waterfowl, and freshwater mussel remains, and the uplands/terraces as documented by a preponderance of white-tailed deer and American elk.

Additional excavations were conducted at the Sanford Archaeological District-Locality 32 in the summers of 2003-2004 prior to highway improvements (Boszhardt 2002). Over 100 features were found during this mitigation, including Feature 205.The mammal remains from Feature 205 were analyzed to serve as means of a control sample, against which the possible bone grease assemblages could be compared. A report on the 2003-2004 excavations, including the faunal analysis, is currently in preparation.

Feature 205 was located along the eastern margin of the Sanford Archaeological District and therefore near the edge of the La Crosse terrace. This feature was rather unique and appeared to have been a refuse filled gully that flowed off the edge of the terrace. As such, the feature was quite large and had a very complex stratigraphy. At the time of writing, the feature could not be attributed to a particular Oneota phase due to lack of information on dates or diagnostic material.

The bird remains from Feature 205 were examined by Maass (2006) and have been summarized in Table 37. A total of 195 bird remains, representing 19 species were identified from the feature and an additional 634 bird remains were not diagnostic beyond the class level. The avian assemblage was dominated by species, such as Canada geese (*Branta canadensis*), ducks (*Anas*/*Aythya*/*Mergus*), and red-winged blackbirds (*Agelaius phoeniceus*). These species would have been readily available in wetland habitats. Several upland species were also present:wild turkey (*Meleagris gallopavo*), greater

Table 37. Summary of bird remains from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32). All identifications and data are from Maass (2006).

Taxon	**Common Name**	**NISP**	**MNI**
Branta canadensis	Canada goose	23	2
cf. *Branta canadensis*	Canada goose?	2	-
Branta canadensis interior	Canada goose interior	10	2
cf. *Branta canadensis interior*	Canada goose interior?	6	-
Branta canadensis maxima	giant Canada goose	4	1
Anas platyrhynchos,*A. rubripes*	mallard or American black duck	17	3
Anas discors, *A. crecca*	blue or green-winged teal	14	1
Anas sp.	dabbling ducks	27	-
Aythya collaris	ring-necked duck	3	1
Mergus merganser	common merganser	3	1
cf. *Buteo jamaicensis*	red-tailed hawk?	1	1
Tympanachus cupido	greater prairie chicken	3	1
Meleagris gallopavo	wild turkey	2	1
Fulica americana	American coot	4	2
Porzana carolina	sora	12	3
cf. *Porzana carolina*	sora?	5	1
Ectopistes migratorius	passenger pigeon	6	2
cf. *Ectopistes migratorius*	passenger pigeon?	6	-
cf. *Melanerpes erythrocephalus*	red-headed woodpecker?	1	1
Dryocopus pileatus	pileated woodpecker	2	1
Corvus brachyrhynchos	American crow	1	1
cf. *Corvus brachyrhynchos*	American crow	1	-
Sialia sialis	eastern bluebird	1	1
Toxostoma rufum	brown thrasher	1	1
cf. *Toxostoma rufum*	brown thrasher?	1	-
Bombycilla cedrorum	cedar waxwing	1	1
Agelaius phoeniceus	red-winged blackbird	15	4
cf. *Agelaius phoeniceus*	red-winged blackbird?	15	-
Quiscalus quiscula	common grackle	6	1
cf. *Quiscalus quiscula*	common grackle?	2	-
	subtotal	**195**	**33**
	unid. bird	634	-
	total	**829**	**33**

prairie chicken (*Tympanachus cupido*), woodpecker (*Melanerpes*/*Dryocopus*), crow (*Corvus brachyrhynchos*), and passenger pigeon (*Ectopistes migratorius*). Overall, the bird remains showed the exploitation of multiple habitats and the presence of several migratory specimens indicated at least a spring through fall occupation.

Although an analysis of the fish, amphibian, and reptile remains has yet to be completed, all were abundant in Feature 205. Preliminary data indicated that backwater habitats were targeted for fish, such as bullheads (*Ameirus*sp.), gar (*Lepisosteus* sp.) drum (*Aplodinotus grunniens*), bowfin (*Amia calva*), and suckers (Catostomidae), as well as several turtle species. These remains indicated a warm season occupation.

The mammal remains from this feature were analyzed by the author in order to serve as a control sample against which possible bone grease assemblages could be compared. At total of 4,450 mammal remains were recovered from the pit and 868 (19.5 percent) were identified to at least the family level (Table 38, Appendix: Table A.8). Seventeen species were present in the assemblage, which was dominated by white-tailed deer, American beaver, American elk, common muskrat, and canids (dog/wolf/coyote). This mix of upland and wetland animals has been commonly observed at other La Crosse Oneota site (e.g. Theler 1989, 1994a, 2000). An examination of skeletal part frequencies for white-tailed deer (Table 39) and American elk (Table 40) indicated that nearly all portions of these large animals were utilized, returned to the site, and potentially available for grease production. This contrasts to most La Crosse Oneota sites, where elements from the extremities dominate the large animal remains (e.g. Theler 1989, 1994a).

Table 38. Summary of mammal remains from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

Taxon	**Common Name**	**NISP**	**MNI**
Castor canadensis	American beaver	90	3
cf.*Castor canadensis*	American beaver?	6	-
cf. *Spermophilus tridecemlineatus*	thirteen-lined ground squirrel	1	1
Sciurus carolinensis	eastern gray squirrel	1	1
Geomys bursarius	Plains pocket gopher	16	2
Ondatra zibethicus	common muskrat	46	3
cf.*Ondatra zibethicus*	common muskrat?	5	-
Rodentia	rodent family	2	-
Lynx rufus	bobcat	2	1
Canis lycaon (= *C. lupus*)	eastern timber wolf	1	1
Canis cf. *C. lycaon* (= *C. lupus*)	eastern timber wolf?	2	-
Canis lupus familiaris[1]	domestic dog	27	3
*Canis*cf.*C.l. familiaris*[1]	domestic dog?	4	-
Canis sp.	dog/wolf/coyote	39	-
cf.*Canis* sp.	dog/wolf/coyote?	3	-
Canidae	dog family	31	-
Ursus americanus	black bear	8	1
Procyon lotor	northern raccoon	10	1
Mephitis mephitis	striped skunk	1	1
Mustela vison	American mink	2	1
Taxidea taxus	American badger	3	1
Lontra canadensis	northern river otter	1	1
Cervus elaphus	American elk	80	2
Odocoileus virginianus	white-tailed deer	367	7
cf.*Odocoileus virginianus*	white-tailed deer?	17	-
Cervidae	deer/elk family	99	-
Bos bison[2]	American bison	4	1
	subtotal	**868**	**31**
	unid. sm. mammal	11	-
	unid. med. mammal	100	-
	unid. lg. mammal	119	-
	unid. mammal	3352	-
	total	**4450**	**31**

[1] The designation of the domestic dog as *Canis lupus familiaris* follows Wilson and Reeder (2005).

[2] The American bison was represented only by modified scapulae (imported as tools).

Table 39. Summary of white-tailed deer elements from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

Element	**NISP**[1]	**MNE**	**Complete Epiphyses**	**Complete Elements**
cranial	19	3	-	-
mandible	11	4	-	-
isolated teeth	24	12	na	na
hyoid	-	-	-	-
vertebrae	24	7	-	4
ribs[2]	-	-	-	-
innonimate	4	2	-	-
scapula	6	4	-	-
humerus	20	5	4	-
radius	15	6	6	-
ulna	14	7	6	-
carpals	20	20	-	19
metacarpal	13	5	5	-
femur	12	3	4	-
patella	3	2	-	2
tibia	22	9	11	-
tarsals	31	29	-	21
metatarsal	21	8	3	-
metapodial	10	-	5	-
residuals	22	21	-	6
sesamoids	5	5	-	5
1st phalanx	37	19	27	1
2nd phalanx	28	9	12	1
3rd phalanx	23	19	4	14
total	**384**	**199**	**87**	**73**

[1] Counts include "cf." specimens.

[2] A total of 127 medium-large mammal rib fragments were identified from Feature 205, although none were securely identified as white-tailed deer.

Table 40. Summary of American elk elements from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

Element	**NISP**	**MNE**	**Complete Epiphyses**	**Complete Elements**
cranial	1	1	-	-
mandible	-	-	-	-
isolated teeth	1	1	na	na
hyoid	-	-	-	-
vertebrae	7	6	-	4
ribs[1]	-	-	-	-
innonimate	1	1	-	-
scapula	2	2	-	-
humerus	1	1	-	-
radius	-	-	-	-
ulna	-	-	-	-
carpals	3	3		3
metacarpal	-	-	-	-
femur	-	-	-	-
tibia	1	1	-	-
tarsals	3	2	-	2
metatarsal	3	2	1	-
metapodial	2	1	2	-
residuals	2	2	-	-
sesamoids	5	5	-	5
1st phalanx	23	9	9	1
2nd phalanx	21	9	15	2
3rd phalanx	4	3	3	1
total	**80**	**49**	**30**	**18**

[1] A total of 127 medium-large mammal rib fragments were identified from Feature 205, although none were securely identified as American elk.

Given the diversity of faunal remains, the Feature 205 assemblage was unique compared to the bone grease assemblages discussed above in that it was the product of multiple activities. It may well represent years of deposits. Although bone grease refuse could have been dumped into the feature, many more remains were likely placed there as a result of numerous other activities. Since the assemblage was a composed of remains from many different activities, it was not possible to separate out the evidence of grease manufacture. Therefore, one cannot use the context of these remains to infer the presence or absence of bone grease production. When we turn to the condition of the remains (i.e. fracture types, fragment size, and taphonomy), we find an equally problematic situation.

Only 13 percent of the mammal remains from Feature 205 exhibited green bone fractures (Table 9). This frequency was lower than any of the other assemblages analyzed in this study by at least 10 percent. Excluding, the Gottschall Rockshelter, this was the only analyzed assemblage that had more fragments of compact bone than cancellous bone (see Table 41). As fracture patterns are generally only preserved on compact bone, one would expect that if the bones from Feature 205 had experienced a high degree of intentional fracturing, the percent of specimens with green bone fractures should have been much higher. This assemblage was well-preserved (as indicated numerous fish bones and long bone epiphyses), so the relative lack of green bone fractures was probably not the result of natural taphonomic factors. Additionally, given the smaller quantity of cancellous bone fragments, it appeared that the grease rich portions of the bones were not fractured as often as those from the other assemblages. While these factors would seem to point to an absence of grease production, it cannot be ruled out. Some of the remains from the feature were still broken intentionally and some portions of cancellous bone

Table 41. Size distribution of bone fragment counts by type from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

	Cancellous		**Compact**		**Vertebrae**		**Ribs**		**Complete**		**Total**	
Size	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
1	314	18.8	331	17.3	9	4.3	4	3.1	2	0.7	660	15.7
2	488	29.2	540	28.2	39	18.8	14	11.0	24	8.7	1105	26.3
3	290	17.3	376	19.6	41	19.8	14	11.0	31	11.3	752	17.9
4	231	13.8	265	13.8	41	19.8	18	14.2	28	10.2	583	13.9
5	157	9.4	152	7.9	27	13.0	12	9.4	21	7.6	369	8.8
6	70	4.2	65	3.4	22	10.6	15	11.8	25	9.1	197	4.7
7	59	3.5	56	2.9	9	4.3	13	10.2	27	9.8	164	3.9
8	30	1.8	43	2.2	6	2.9	8	6.3	26	9.5	113	2.7
9	30	1.8	61	3.2	12	5.8	15	11.8	41	14.9	159	3.8
10	4	0.2	14	0.7	1	0.5	11	8.7	23	8.4	53	1.3
11	0	0.0	8	0.4	0	0.0	2	1.6	15	5.5	25	0.6
12	1	0.1	7	0.4	0	0.0	1	0.8	12	4.4	21	0.5
Total	**1674**	**-**	**1918**	**-**	**207**	**-**	**127**	**-**	**275**	**-**	**4201**	**-**

Table 42. Size distribution of bone fragment weight by type from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

	Cancellous		**Compact**		**Vertebrae**		**Ribs**		**Complete**		**Total**	
Size	W(g)	%	W(g)	%	W(g)	%	W(g)	%	W(g)	%	W(g)	%
1	61.3	3.8	74.0	4.7	2.3	0.6	1.1	0.8	0.9	0.0	139.6	2.3
2	190.5	11.7	201.1	12.7	17.4	4.6	3.3	2.4	12.3	0.5	424.6	6.9
3	208.5	12.8	194.8	12.3	35.7	9.3	7.2	5.2	34.6	1.4	480.8	7.8
4	236.8	14.6	210.4	13.3	48.9	12.8	13.2	9.5	66.5	2.7	575.8	9.4
5	231.2	14.2	170.2	10.7	50.8	13.3	7.7	5.5	66.0	2.7	525.9	8.5
6	187.4	11.5	100.4	6.3	47.7	12.5	11.1	8.0	89.1	3.7	435.7	7.1
7	209.6	12.9	133.6	8.4	23.7	6.2	12.7	9.1	141.3	5.8	520.9	8.5
8	113.4	7.0	99.3	6.3	20.9	5.5	7.2	5.2	200.3	8.3	441.1	7.2
9	138.5	8.5	27.8	1.8	109.5	28.7	26.1	18.8	319.7	13.2	621.6	10.1
10	40.9	2.5	106.7	6.7	25.1	6.6	40.2	28.9	470.4	19.4	683.3	11.1
11	0	0.0	93.3	5.9	0	0.0	7.0	5.0	297.2	12.3	397.5	6.5
12	8.2	0.5	172.9	10.9	0	0.0	2.3	1.7	724.6	29.9	908.0	14.8
Total	**1626.3**	**-**	**1584.5**	**-**	**382.0**	**-**	**139.1**	**-**	**2422.9**	**-**	**6154.8**	**-**

were exposed. This could mean that some of the remains from the feature were the product grease production manufacture, but were masked by the refuse of many other activities. An examination of fragment size produced a similar conclusion.

After excluding small mammals (i.e. those smaller than a raccoon) and isolated tooth fragments, 4,201 bones were measured for the size analysis (Tables 41 and 42). Interestingly, nearly 74 percent (*n* = 3,100) of the remains were less than 3.0 cm in maximum dimension. While this figure is 13 percent lower than any of the probable bone grease assemblages discussed above, it still seems to be rather high. This number may be inflated, because it included medium sized mammals, whereas the bone grease assemblages were comprised exclusively of white-tailed deer or American elk. An examination of the bone weight distribution provided a better contrast. In this case, approximately 74 percent of the bone mass was present in the size categories *larger than* 3.0 cm. This indicated that although a substantial number of small bone fragments were present, most of the bone, had not been fractured extensively.

This issue of fragment size created a problem similar to that of the fracture patterns. Since most of the bone mass was represented in the large size categories, one could make the interpretation that the remains from Feature 205 were not the product of bone grease production. A fairly large number of fragments were, however, present in the small size categories, indicating that at least some of the bone had been broken to a size consistent with bone grease production. Once again, we come to the conclusion that some of the remains from Feature 205 could have been the products of bone grease manufacture, but our ability to recognize them as such has been masked by a multitude of other activities which are undoubtedly represented in the pit. The factor most responsible for these uncertainties is the mixed context of the remains. As Feature 205 was excavated according to natural stratigraphy it was possible to look at some internal differences in the distribution of bone fragment size. Unfortunately, most of the zones were large enough that they were not discrete deposits of refuse from single activities. This issue of addressing composite assemblages is returned to in the discussion of Chapter VIII.

CHAPTER VII
RESULTS: EXPERIMENTAL WORK

Introduction

The nutritional value and yield of white-tailed deer bone grease has been seriously challenged (Church and Lyman 2003). Based upon experimental data, Church and Lyman (2003) suggested that only 28-29 ml (35-36 g) of wet grease can be obtained from six deer long bones: the right and left humeri, the right and left femora, and the right and left tibiae. With an energy yield of 9.37 kcal/g (McCullough and Ullrey 1983) for deer marrow fat, Church and Lyman (2003:1081) predicted that these elements would only yield 330-335 kcal. This led to the conclusion that one would "have to wonder why anyone would break deer bones into small pieces to extract grease by boiling?" (Church and Lyman 2003:1081). They went further and suggested that the grease may have been more valued for its vitamin and mineral content, rather than fat calories. As it has been suggested, and will be further addressed in Chapter VIII, one of the primary conclusions of this thesis is that bone grease production was regular seasonal activity among Archaic and Woodland populations of the Driftless Area. The inferences proposed by Church and Lyman (2003) significantly challenge the assumption that grease production (from white-tailed deer) could have been a regular cultural activity, as opposed to a starvation food.

While I do not question the fact that the vitamins and minerals in bone grease may be of significant value, I find some concern in Church and Lyman's (2003) conclusions regarding the overall grease yield of white-tailed deer. To evaluate these concerns more thoroughly, bone boiling experiments were conducted with two fresh white-tailed deer carcasses. The intent of these experiments was not to determine how much grease could be obtained from individual elements (i.e. creating a grease utility index) nor was it to evaluate the efficiency of grease extraction. Instead, the experiment was aimed solely at determining how much bone grease could be rendered from a single white-tailed deer.

Materials

In order to investigate the quantity of bone grease that can be rendered from a white-tailed deer, two fresh carcasses were obtained. The first deer was a road-kill from Knox County, Tennessee taken on November 11, 2005. This specimen weighed 57.25 kg (126.5 lbs) and was aged at approximately 1.5 years, based upon mandibular dentition. The deer was in good physical condition (the only fractures were to the cranium) and was obtained less than one hour after its death. The carcass was skinned and defleshed while still fresh, although all of the bones were frozen prior to being processed for grease. Ample stores of subcutaneous fat indicated that the deer was healthy and likely had not yet depleted its marrow fat. An observation of the long bone marrow showed that it was white in color and ranged from a waxy consistency to greasy liquid, thus further demonstrating that the marrow was of a high quality and from a healthy individual (see Cheatum 1949).

A second white-tailed deer was obtained from Sauk County, Wisconsin during the fall archery season of 2006. This specimen was taken on October 21, 2006 and was estimated to have had live weight in excess of 91 kg (200 lbs). A more specific weight was not available as the specimen had been field dressed. Mandibular dentition revealed that the deer was approximately 1.5 years of age. The specimen was skinned and defleshed and the bones were frozen prior to grease processing. Like the first specimen, this carcass also had abundant supplies of subcutaneous fat, thus indicating it was a healthy individual that likely had high quality bone marrow. This was further confirmed based upon the color and texture of the long bone marrow, which was the same as that of the first specimen.

Methods

In order to determine the potential grease yield of a white-tailed deer, I attempted to replicate traditional grease extraction methods as closely as possible (see Chapter II for a description of traditional methods); however, as seen in the following paragraphs, a few exceptions had to be made. After the specimens were butchered, the bones were frozen and subsequently thawed and processed at a later date. The butchered bones possessed significant quantities of attached muscle and connective tissues (Figure 15) and had to be scraped clean (Figure 16) prior to further processing. These attached tissues were removed by scraping the bones with stone flakes and all elements were disarticulated and weighed. The long bones, mandibles and first and second phalanges were all broken open using a stone hammer and anvil (Figure 17) to remove the easily accessible marrow from the medullary cavity. This marrow was removed using a metal probe and weighed individually for each element.

After the long bone marrow had been removed, the bones from each deer were divided into five groups that were processed and weighed separately: the cranium/mandible, the vertebrae, the ribs, the limbs, and the pelvis/scapulae. The bones in each of these groups were broken into small fragments with a stone hammer and anvil. The brain was removed prior to fracturing the cranium. An attempt was made to replicate the relative size of the fragments observed at the suspected bone grease assemblages from

Figure 15. Defleshed left limbs of white-tailed deer used in bone grease production experiment.

Figure 16. Defleshed and scraped left hind limb elements of white-tailed deer used in bone grease production experiment.

the Driftless Area. All of the fragments were collected on a deer hide that had been draped over the work area. The fragments from each of five bone groups were then boiled separately using a metal pot on an electric stove (Figure 18). Each group was boiled for eight hours, as Church and Lyman (2003:Table 2) suggested that a majority of the grease is extracted within this time frame. The pots were allowed to cool over night in a refrigerator (c. 2.5^{o} C, or 36.5^{o} F), which caused the grease to congeal on the surface. The congealed bone grease was easily removed by hand and any remaining liquid grease was carefully scooped from the surface with a shell spoon. After removal, the grease from each group was placed into glass jars, melted, and poured into a graduated cylinder for measurement. Once poured into the graduated cylinder, the grease was given several minutes to settle so any remaining water could separate from the mixture and be subtracted from the total volume contained in the cylinder. The volume of grease was measured to the nearest tenth of a milliliter.

Amount of Grease Obtained

The two white-tailed deer processed in this study produced a surprising quantity of bone grease. The results for each of the specimens are presented in Table 43. The larger Wisconsin deer yielded 642.4 ml of grease and the Tennessee Deer produced 478.0 ml of grease (Table 43). The amount of grease from the Wisconsin deer is an absolute minimum estimate as a problem was encountered while boiling the limb elements from this deer and some grease was lost. It is likely that the actual yield of this individual may have been in excess of 50 ml greater. Overall, the limb bones produced the most grease, followed closely by the vertebrae, with lesser amounts coming from the scapulae/pelvis, ribs, and cranium/mandible.

Figure 17. Smashing white-tailed deer bones in bone grease production experiment.

Figure 18. Boling white-tailed deer bones in bone grease production experiment. Note grease at surface and edges of the pot.

Table 43. Grease yields and estimated nutritional values for white-tailed deer bone grease as determined by experimental work in this study.

Elements	**WI Deer (volume in ml)**	**TN Deer (volume in ml)**	
cranial	36.20	12.00	
vertebrae	226.40	142.20	
ribs	60.80	40.00	
scapulae/pelvis	98.00	47.40	
limbs	[a]221.00	236.40	
total volume	**642.40**	**478.00**	ml
	x .84	x .84	grease wt. (g/ml)[b]
total weight	539.60	401.50	g
	x 9.37	x 9.37	kcal yield (kcal/g)[c]
est. kcal yield	**5056.10**	**3762.20**	

[a] A problem was encountered during the grease recovery for limb elements from the Wisconsin deer and the actual grease yield is likely significantly higher than the absolute minimum measurement presented here.

[b] The average grease weight was based upon results of this study.

[c] The kcal yield of grease was based upon McCullough and Ullrey (1983).

Again, no attempt was made to calculate the quality of the grease (i.e. oleic acid content), but instead the study focused on estimating the total quantity of available grease. While some have argued that oleic acid content was more important in selecting bones for marrow and grease processing (Binford 1978; Morin 2007), others have demonstrated that overall quantity of grease was a more important factor (Brink 1997; Jones and Metcalfe 1988). As these arguments are still unresolved, and given that there was a fairly even distribution of skeletal elements from many of the Driftless Area bone grease assemblages, this study focused more upon determining overall nutritional value of white-tailed deer bone grease.

To calculate caloric content, the grease volume was converted to weight. It was found in this study that 1.0 ml of grease weighed .84 g. There was a disparity between this estimate and that determined by Church and Lyman (2003:1081), who found that 1.0 ml of white-tailed deer bone grease weighed 1.25 g. Church and Lyman's (2003) estimate is puzzling considering that, by definition, 1.0 ml of water weighs 1.0 g. Their estimate of 1.25 g would thus imply that grease is denser than water. As grease floats, rather than sinks, it seems as though the estimate provided by Church and Lyman (2003) must be in error. Accordingly, the estimate of .84 g per 1.0 ml of grease was found to be a more reliable measurement and was the conversion factor utilized in this study. When transformed to weight, the Wisconsin deer produced 539.6 g of grease and the Tennessee deer yielded 401.5 g (Table 43). McCullough and Ullrey (1983) found that 1.0 g of white-tailed deer bone marrow contained 9.37 kcal. After applying this conversion, it was determined that the grease from the Wisconsin deer equated to 5,056.1 kcal and that of the Tennessee deer to 3,762.2 kcal (Table 43).

Following a recommended daily caloric intake of 2,400 kcal for active adult females (ages 19-30) and 3,000 kcal for active adult males (ages 19-30) (USDHHS and USDA 2005) the grease from these two deer could have solely supported an adult male for nearly 3 days and adult female for 3.67 days. If only the limb elements, which produced the highest quality grease (as a consequence of their high unsaturated fat content), were processed, the Wisconsin and Tennessee deer would have yielded 1,739.4 kcal and 1,860.7 kcal respectively (some grease was lost while boiling the Wisconsin deer's limb elements). While not enough to support a single individual for an entire day, the limb element yields were, nonetheless, fairly substantial. It was unlikely that grease was consumed by itself, but instead mixed with other foods and used to create products, such as pemmican (see Chapter II). Therefore the grease from a single deer could have easily been spread across numerous meals.

Although the caloric values for bone grease presented here should be taken as estimates, they are significant and indicate that manufacturing white-tailed deer bone grease should not be seen as the desperate activity which others have suggested (Church and Lyman 2003:1081-1083). That being said, the process of making bone grease is still very labor intensive and would not have been among the high priority fat and/or calories sources sought by most traditional peoples. What this does indicate, is that white-tailed deer bone grease may have still been an important resource in environments where other sources of fats or carbohydrates were seasonally restricted.

Anecdotal Observations Regarding Extraction Efficiency

The primary intent of the experimental work was to document the amount of bone grease that could be rendered from a single white-tailed deer; however, several observations made during the course of the work are worth additional discussion. As noted above, Church and Lyman (2003) have seriously questioned the effectiveness and necessity of crushing bones into small fragments for grease production. They have suggested that there was no statistically significant difference in the efficiency of grease extraction from bones broken into many small fragments compared to those broken into only a few large fragments. Although they note that there was substantial variability in the ethnographic record as to fragment size (Church and Lyman 2003:1077-1078), most reliable sources indicate that bones had to be heavily fragmented in order to retrieve their grease (see discussion in Chapter II). Their conclusion questioned some of the "conventional wisdom of zooarchaeology" (Church and Lyman 2003:1083) and brought into doubt the logic of using small bone fragments as an archaeological indicator of bone grease production. A review of their data, however, indicated that after one hour of boiling, bones cut into 4 cm cubes yielded 41.41 percent of their grease, wile those cut into 1 cm cubes yielded 63.31 percent of their grease – a 21.9 percent difference. Although the grease yield evened out after three hours, these data still suggested that if boiling time was a limiting factor, the size of the fragments would have been significant.

Church and Lyman (2003:1078-1079) also utilized a stainless-steel pot and, presumably, modern heating methods. As such, the role of small fragments may have been underestimated. In the Midwest, prehistoric cultures would have relied upon ceramic vessels (Woodland and Oneota) or stone boiling in hide-lined pits/wooden vessels (Archaic) in order to produce bone grease. Given these less efficient technologies, the differences in extraction efficiency observed after one hour were likely quite significant. Nagaoka (2005:1332) and Munro and Bar-Oz (2005:225) have echoed similar concerns about Church and Lyman's (2003) results.

In addition to raising the questions regarding Church and Lyman's (2003) work on grease extraction efficiency, several observations were made during this experiment that circumstantially point to the importance of small bone fragments for grease extraction. First, it should be noted that in Church and Lyman's (2003) study, they divided the bones into several lots and *cut* each lot into cubes of a pre-determined size, ranging from one to four centimeters. Additionally, they fragmented one of the lots with a hammerstone into "pieces ≤ 5 cm in maximum dimension to simulate prehistoric conditions" (Church and Lyman 2003:1078). Many of the bone fragments from the Dirftless Area bone grease assemblages were less than 1.5 cm in maximum dimension and most were less than 3 cm maximum dimension. This suggests that Church and Lyman's bones may not have been as extensively fractured as those from the prehistoric record. Furthermore, most of the bones used in the study were *cut* and not fractured.

It was found during the course of the current experiment that fracturing the bone may not have been as important as pulverizing the bone. While fracturing the long bone epiphyses/vertebrae, it was found that it took several very hard blows to achieve an initial fracture in the bone. After this point it was generally quite easy to break up the remaining portion of the bone. From this point, the fragments were easily hammered to near the point of pulverization. Few fragments larger than 2 cm in maximum dimension remained. It was found that as the bone reached the point of being pulverized, it was not only being broken into smaller fragments, but the hammering also served to flatten/damage the structure of the cancellous bone. In doing, so much of the marrow contained within the pores of the cancellous tissue was pressed out of the bone. In fact, enough much grease was pushed out of the bone that it made the hammerstone and anvil so oily that they had to be regularly wiped clean. Furthermore, several larger fragments that escaped extensive pulverization during this study were examined after the eight-hour boil. When examined under low magnification one cold see that all of the grease had been removed from the porous cancellous tissue on surface of the specimen. When the bones were cut open, it was found that the interior cancellous bone still contained significant quantities of grease.

Another factor regarding efficiency that was observed during this study was that when more bone were processed simultaneously the rate of processing efficiency increased substantially. Given the author's lack of previous experience in grease production, it is quite likely that the time involvements forprocessing white-tailed deer were a bit over-estimated. That being said, processing a single white-tailed deer for bone grease required a tremendous labor investment. After the deer had been defleshed, it took an estimated nine hours (including three hours of boiling) to process all the bones from single white-tailed deer and recover their grease). If, however, the bones of multiple individuals could have been scraped, broken, and boiled simultaneously, the overall rate of processing efficiency should have increased substantially. Binford (1978, 1981:158) indicated that, among the Nunamiut, caribou bones were regularly reserved for some time prior to a grease processing event precisely for this reason. As long as the bones were kept cool or frozen they could have be saved for several months without spoiling.

Based upon these data, one could conclude that if we see an archaeological assemblage that is the product of bone grease production, and contains the bones of multiple individuals, the activity may have been a regular subsistence practice, presumably related to the amassing stores of grease/fat. On the other hand if an archaeological bone grease assemblage contained the remains of only a single individual, particularly if it included low quality/yield elements, it may have been more likely the result of acute resource stress. The amount of labor that goes into processing a single-white tailed deer for bone grease, makes the net energy yield relatively small.

CHAPTER VIII
DISCUSSION

Introduction

In the following sections, I review the material presented in the previous chapters in order to determine if bone grease was indeed being manufactured in the Driftless Area, and to better understand what factors motivated its production. The first section of this discussion focuses on verifyingthe extent to which the evidence presented in Chapter VI is consistent with bone grease production. It reviews the data in relation to the four criteria established for the identification of bone grease in the archaeological record: fragment size, agent of fracture, overall taphonomy, and archaeological context. Some of the assemblages were analyzed and can be directly compared to these criteria; however, some of the assemblages were not available for reanalysis and must be judged solely by their existing descriptions.

The second section of this chapter focuses more upon the general aspects of bone grease production and its implications for the study of ancient subsistence systems. This thesis has produced a wealth of data that are valuable beyond understanding the ancient economies of the Driftless Area. Therefore, I explore grease production from a larger theoretical perspective and show when it may or may not be used as a marker of resource stress.

The final two sections of this chapter explore the ancient motives behind bone grease production in the Driftless Area. One of the sections is devoted to the occurrence of grease production in Archaic in Woodland cultures, while the other examines grease manufacture in Oneota societies. They are divided into discrete sections as the nature of grease production in these cultures seems to have been considerably distinct.

Evidence for Bone Grease Production

In Chapter II, four criteria were listed as necessary for the identification of bone grease production: fragment size, agent of fracture, overall taphonomy, and archaeological context. Chapter V was used to develop a methodology to specifically apply these criteria to prehistoric sites from the upper Midwest. This thesis then utilized the criteria and methodology to explore evidence for archaeological bone grease production in 14 prehistoric faunal assemblages from Wisconsin’s Driftless Area (Table 6). Of these assemblages, seven came from Archaic and Woodland sites for which the presence of bone grease production had already been suggested: Raddatz Rockshelter, Durst Rockshelter, Lawrence I Rockshelter, Mayland Cave, Preston Rockshelter, Warsaw Rockshelter, and Millville Village.

With the exception of the remains from Millville Village, none of these assemblages were available for reanalysis. For these sites, the determination of bone grease production had to be made based solely upon a careful review of the existing descriptions of these assemblages with general comparison to the four criteria. Remains from Feature 95 at the Millville Village were available and were analyzed in accordance with methodology developed in Chapter V.

Five faunal assemblages from three La Crosse Area Oneota sites were also suspected to be the result of bone grease production: Krause (Features 82, 438, and 441), Long Coulee, and Holley Street. All of these assemblages were available for study and were analyzed according to the Chapter V methodology. Additionally, assemblages from two other sites, the Gottschall Rockshelter and the Sanford Archaeological District, were obtained and analyzed in accordance with the Chapter V methodology. Unlike the other sites, the remains from Gottschall and Sanford were never suspected to have been the product of grease manufacture. They were analyzed with the intent to serve as control samples against which the other more probable bone grease assemblages could be compared. It was hoped that the inclusion of these two additional sites would help demonstrate the effectiveness of the methodology for distinguishing between bone grease and non-bone grease assemblages.

The following sub-sections review the results of the analysis presented in Chapter VI to determine the extent to which all of the assemblages meet the criteria for grease production. It is important to remember that these criteria should not be seen as individual markers of grease production, but rather must considered in concert to definitively identify episodes of grease manufacture.

Fragment Size

As discussed throughout many of the preceding chapters, the primary archaeological signature of bone grease production is heavily fragmented animal bone. Extensive bone fragmentation has long been considered necessary for bone grease manufacture. Fracturing exposes the interior marrow fat and creates a larger surface area, thus expediting fat extraction during boiling. Church and Lyman (2003) have questioned the necessity of small fragments, yet all ethnographic accounts of grease production clearly reference the presence of extensive bone fragmentation (see Chapter II). Furthermore, experimental work reported in Chapter VII also hints at the utility of intense fragmentation.

While it is quite clear that bone fragmentation was necessary for grease production, there is no clear cut-off point to a minimum or maximum fragment size. In fact there are some discrepancies in the ethnographic record as to the preferred size (Church and Lyman 2003:1078). These variations may be due in large part to the animal taxa involved, as well as the accuracy of the recorder. So the question then becomes, "how small of fragments should we expect"? This question is very difficult to answer. It seems that in many cases we can anticipate that most, although not all, of the bones should have been fragmented beyond easy recognition. Rather than approaching this problem by means of developing an arbitrary average fragment size cut-off, there seems to be more value in making comparisons in fragment size between assemblages. With this method, one can achieve a relative approximation of the fragmentation intensity of a given assemblage and can incorporate additional data regarding taphonomy and context to better determine if it was the result of bone grease production. In order to make such comparisons, one must employ a standardized method to record fragment size. As discussed in Chapter IV, the method utilized in this study involved placing the fragments into size categories based upon their maximum dimension.

The eight assemblages available for direct analysis (Table 6) were all systematically measured, and produced several interesting patterns. The relative frequency distribution of bone fragment size is presented in Figure 19 and a cumulative frequency distribution of fragment size can be seen in Figure 20. These graphs show a general trend in that all of the analyzed assemblages had a greater quantity of bones in the small size categories, as opposed those in the large size categories. Since some of the larger size categories could include fairly large and even unbroken bones, the general

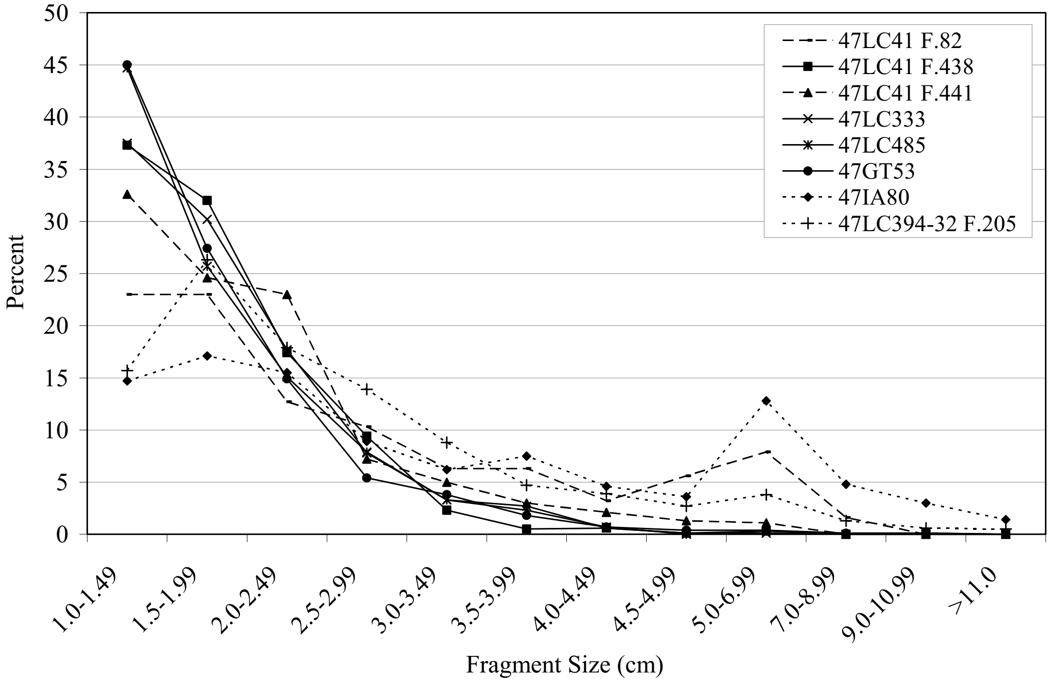

Figure 19. Relative frequency distribution of bone fragments by size category for Driftless Area bone grease assemblages.

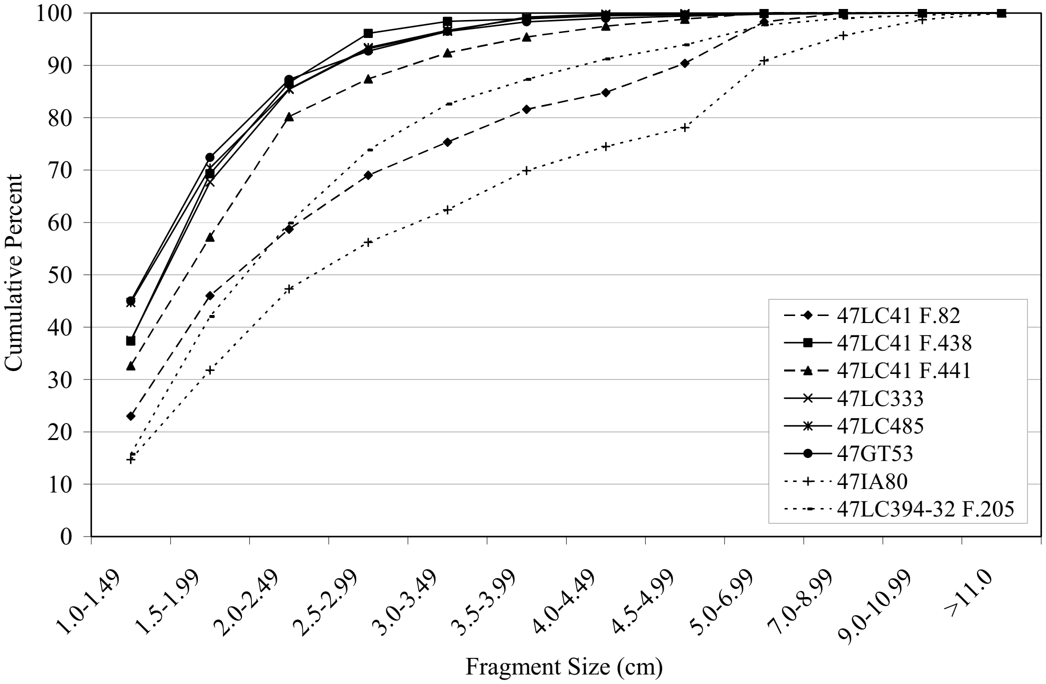

Figure 20. Cumulative frequency distribution of bone fragments by size category for Driftless Area bone grease assemblages.

trend towards the smaller size categories is not unexpected. An important difference is that four of the assemblages show a remarkable similarity in the distribution of bone fragment size. These four assemblages are represented by the solid lines in Figures 19 and 20 and include the remains from Feature 438 at Krause (47LC41), Long Coulee (47LC333), Holley Creek (47LC485), and Millville Village (47GT53). To isolate the consistency of these four assemblages, they have been graphed separately in Figures 21 and 22. The frequency charts demonstrate that over 70 percent of the bone in these four assemblages was reduced to less than 2.0 cm in maximum dimension. Furthermore, 90 percent of their remains were less than 4.0 cm in maximum size. The rate of bone fragmentation across these four assemblages is clearly quite intense, astonishingly uniform, and consistent with ethnographic accounts of grease production.

The Krause (Feature 438), Long Coulee, Holley Creek, and Millville Village assemblages hold an important characteristic in common: they all represent discrete deposits, or piles, of fractured *white-tailed deer bone*. In comparison, the remains from the two other Krause proveniences (Features 82 and 441) were comprised exclusively of fractured *American elk bone*. The distribution of their bone fragment sizes shows a bias towards larger fragments. Although the Feature 441 remains are slightly larger, the pattern of their size distribution is quite similar to that of the previous four assemblages. The remains were still extensively fragmented, with 50 percent of the bones less than 2.0 cm in size and over 80 percent smaller than 4.0 cm. While slightly larger, the distribution of the remains from Feature 441 is still consistent with that of the four previously discussed assemblages. Given this consistency, it is likely that the Feature 441 remains were modified through bone grease production. The slightly larger size of the fragments

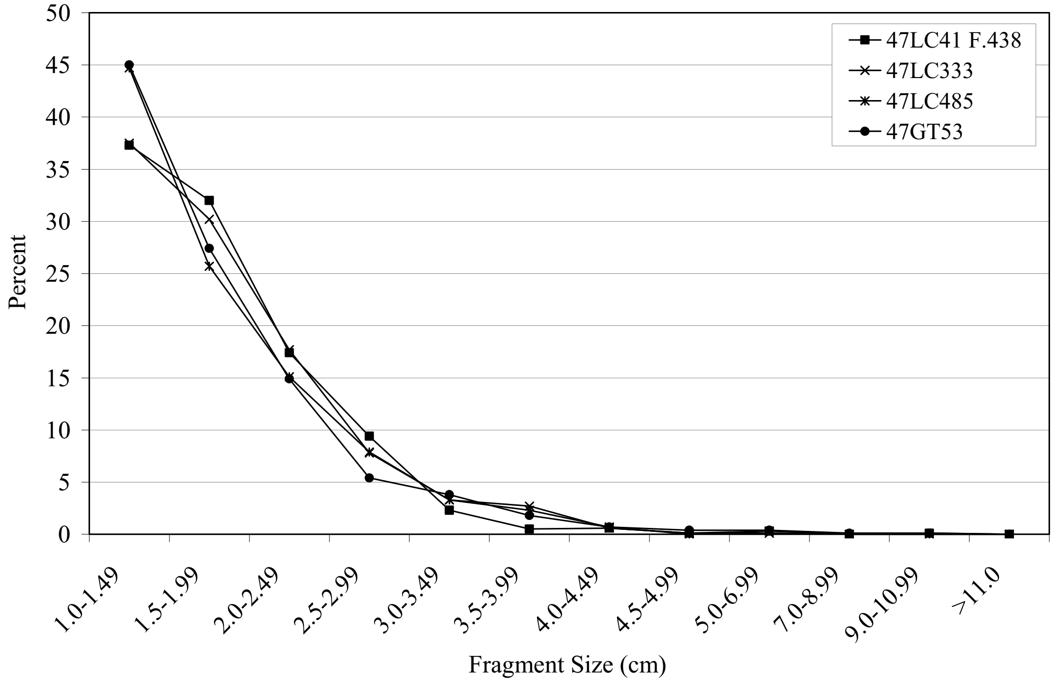

Figure 21. Relative frequency distribution of bone fragments by size category for "pure" bone grease assemblages from the Driftless Area.

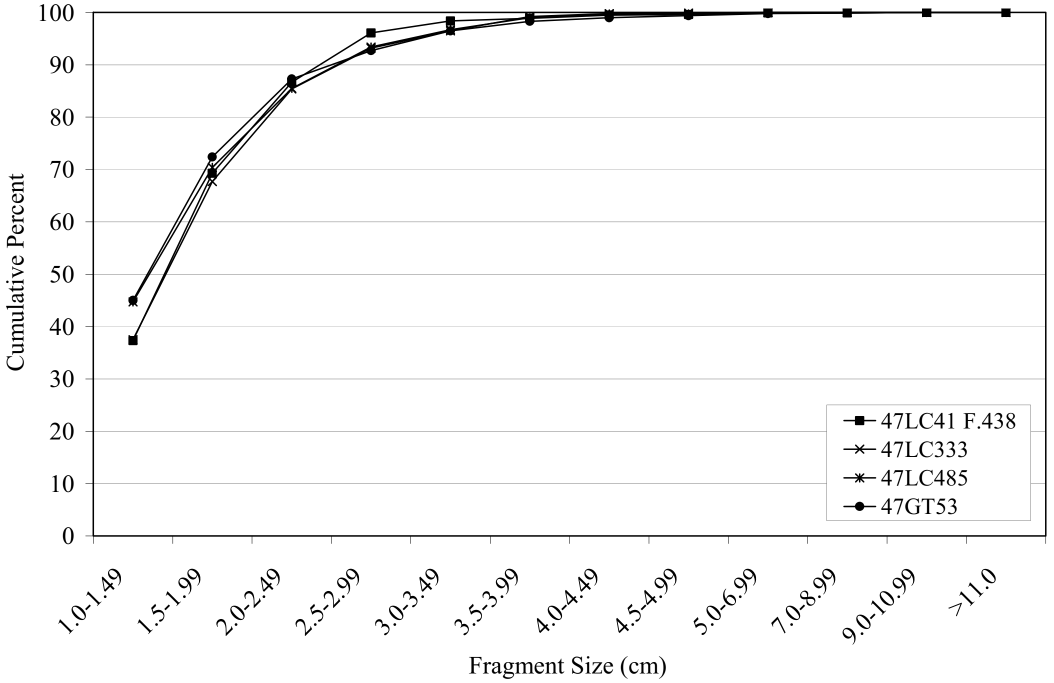

Figure 22. Cumulative frequency distribution of bone fragments by size category for "pure" bone grease assemblages from the Driftless Area.

from Feature 441 was probably attributable to the fact that they came from American elk, as opposed to the much smaller white-tailed deer.

The bones from Feature 82 at Krause were also composed entirely of American elk, yet the fragments were generally larger than the elk remains from Feature 441 (Figure 20). The reason for this difference seems to be related to context. The bones from Feature 441 were found in a dense bone pile (see Figures 12 and 13) within a small refuse pit. Although the bones from Feature 82 were still recovered from a single refuse pit, they were not found in a discrete bone pile. Instead, the bones from Feature 82 were spread throughout the uppermost zone of the pit. As such, they do not seem to represent a direct dump of material, but may have been placed into the pit as the result of a larger cleaning activity. Additional data (see Chapter VI and below) still indicate that they are the result of grease manufacture, but many of the smaller bones appear to have been lost prior to deposition.

The two sites selected as comparative samples – the Sanford Archaeological District (47LC394-32) and the Gottschall Rockshelter (47IA80)– also have interesting patterns of bone fragment size. The most pronounced of these is the Gottschall Rockshelter. The remains from Gottschall have the largest bone fragments of any site analyzed in this thesis (Figures 19 and 20). Over half of the bones from this site are greater than 2.5 cm in maximum dimension and 30 percent were larger than 4.0 cm. The cumulative frequency curve (Figure 20) for these fragments is significantly lower than the remains from any other site. The discussion of the Gottschall remains in Chapter VI indicates that while the assemblage appears to be from a discrete bone pile, the bones are much more intact than those of the assemblages discussed above. The presence of many intact long bone epiphyses and large diaphysis fragments argues against grease manufacture. Comparatively, this assemblage may be an excellent example of a bone marrow extraction event, with no further processing of the elements.

The assemblage from Sanford shows a bone fragment size distribution that seems to fall somewhere between that of Gottschall and the more fragmented remains from Krause (Features 438 and 441), Long Coulee, Holley Street, and Millville Village (Figures 19 and 20). The assemblages from Gottschall and these other sites have one thing in common: they were recovered from discrete bone piles and are thus the result of single activities. Those from the Gottschall pile appear to be from long bone marrow extraction, and those from the other sites may well be from grease production. The bones from Sanford, however, came from a composite assemblage that was recovered from across multiple zones of single, yet massive feature. Furthermore, they represent the remains of many different taxa and their occurrence in the pit is surely the result of many different activities. Some may be from intensive carcass processing events, including grease manufacture, while others certainly represent less extreme forms of carcass utilization. Given the mixed nature of these deposits, we are faced with the problem of equifinality.

As discussed in Chapter II, when examining fragmentation intensity, one must not only quantify the distribution of fragment size, but must also consider the distribution of fragment weight. The breakage of a single bone may result in hundreds, or even thousands, of counted fragments. This creates an extreme bias against unbroken, or minimally broken elements. To contend with this problem, the weight of the fragments from each size class was measured to understand how much of the actual bone mass was fractured. The relative frequency distribution of bone weight, by fragment size, is presented in Figure 23 and a cumulative frequency distribution of bone weight, by fragment size, can be seen in Figure 24.

The size distributions of bone weight help to confirm the patterns observed among bone fragment size. The four assemblages from white-tailed deer bone piles (Feature 438 at Krause, Long Coulee, Holley Street, and Millville Village) show a very consistent distribution of bone weight. They have been isolated in Figures 25 and 26 to better illustrate this consistency. The data for these assemblages show that over 50 percent of the bone mass was broken to less than 2.5 cm in size and over 80 percent of the mass was less than 3.5 cm in size. Again, this distribution is consistent with ethnographic descriptions of bone grease manufacture.

The two Krause features (82 and 441) that contained American elk bone had more bone mass present in the larger size categories. In the case of Feature 441, this was probably due to the fact that the bones were from elk, as opposed to deer. The size distribution of the elk remains from Feature 441 showed that they were slightly larger than those from the white-tailed deer assemblages (Figure 20). It would have taken much additional work to reduce elk bone to the same size as those from the deer, so it should be of no surprise that the elk remains are slightly larger in both size and mass. The elk bones from Feature 82, however, were much larger and had much more mass present in the larger size categories (Figures 20 and 24). Again, these remains still appeared to be the residue of grease manufacture (see below), but since they were not placed into the pit as the result of a single dump, many of the smaller fragments were probably lost prior to deposition.

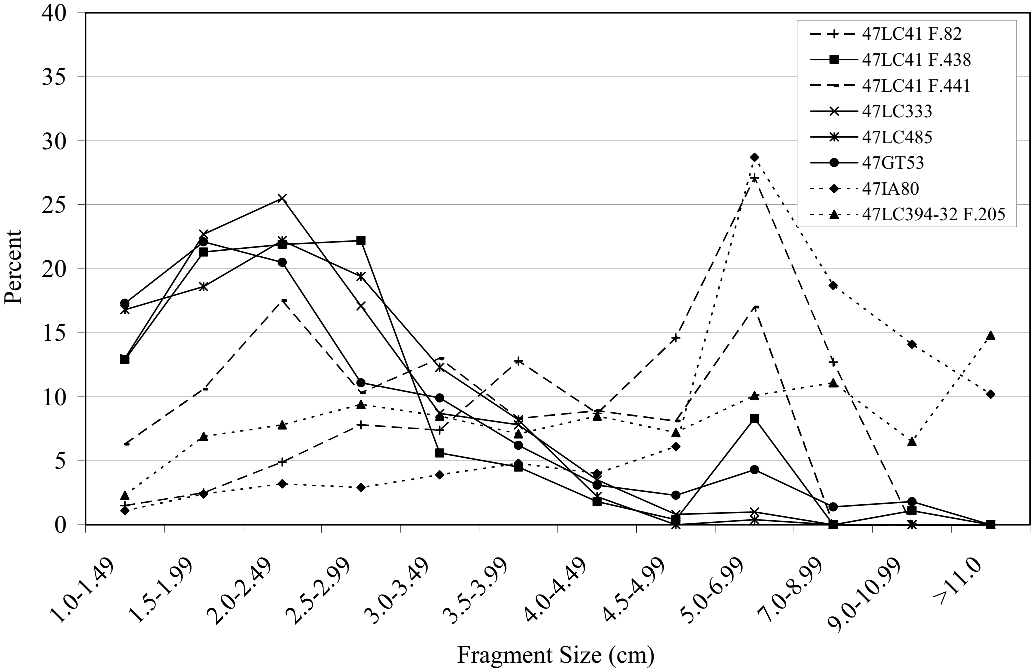

Figure 23. Relative frequency distribution of bone weight by fragment size category for Driftless Area bone grease assemblages.

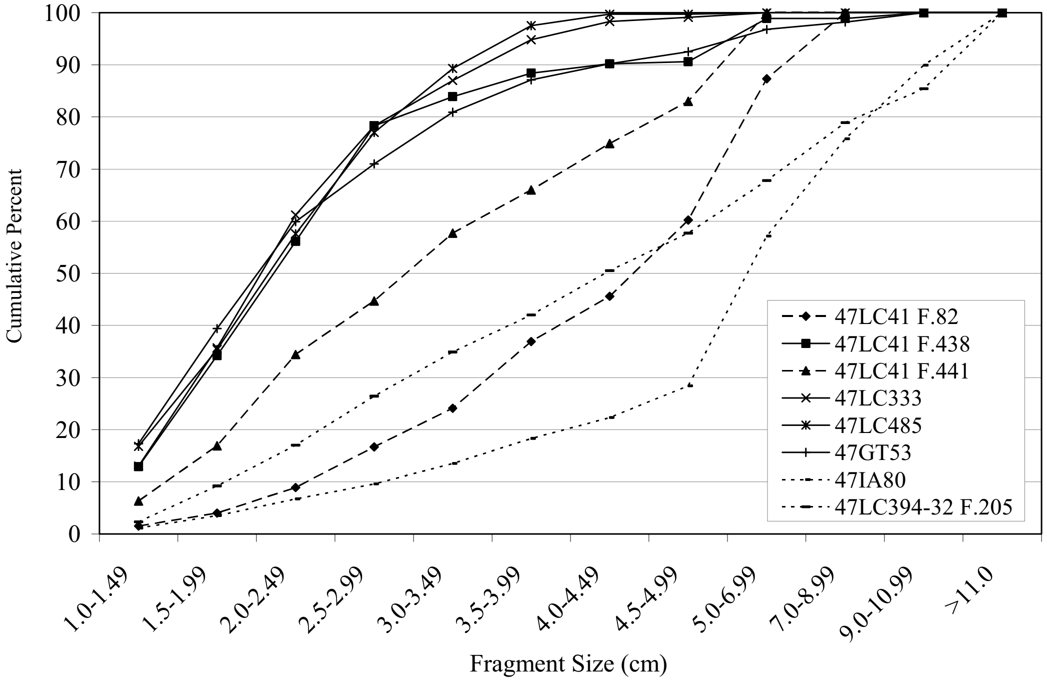

Figure 24. Cumulative frequency distribution of bone weight by fragment size category for Driftless Area bone grease assemblages.

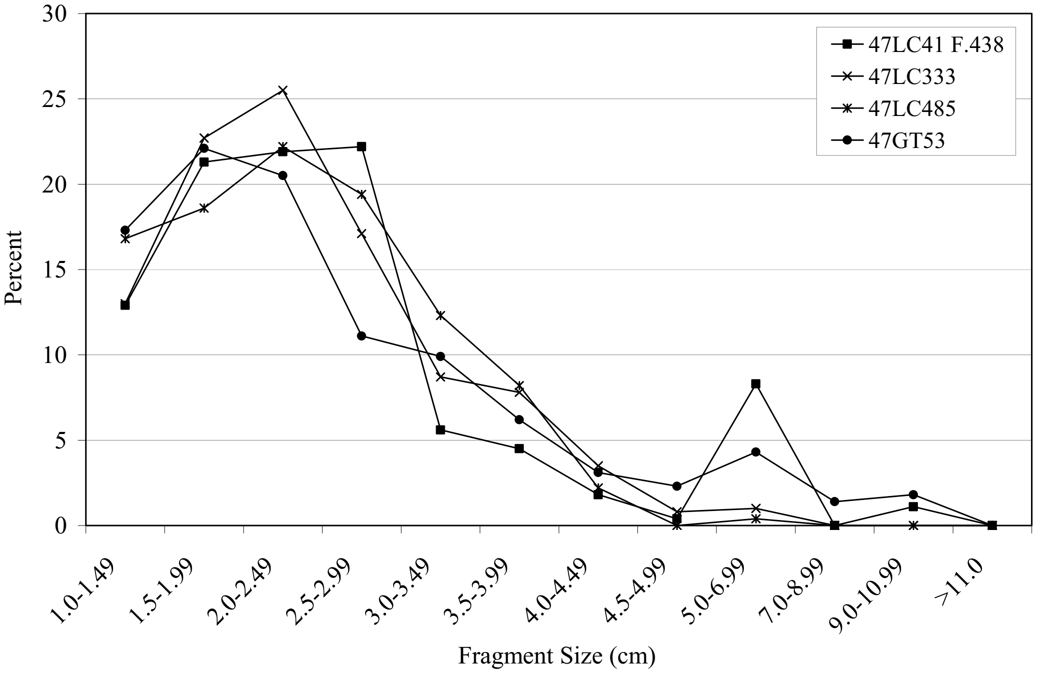

Figure 25. Relative frequency distribution of bone weight by fragment size category for "pure" bone grease assemblages from the Driftless Area.

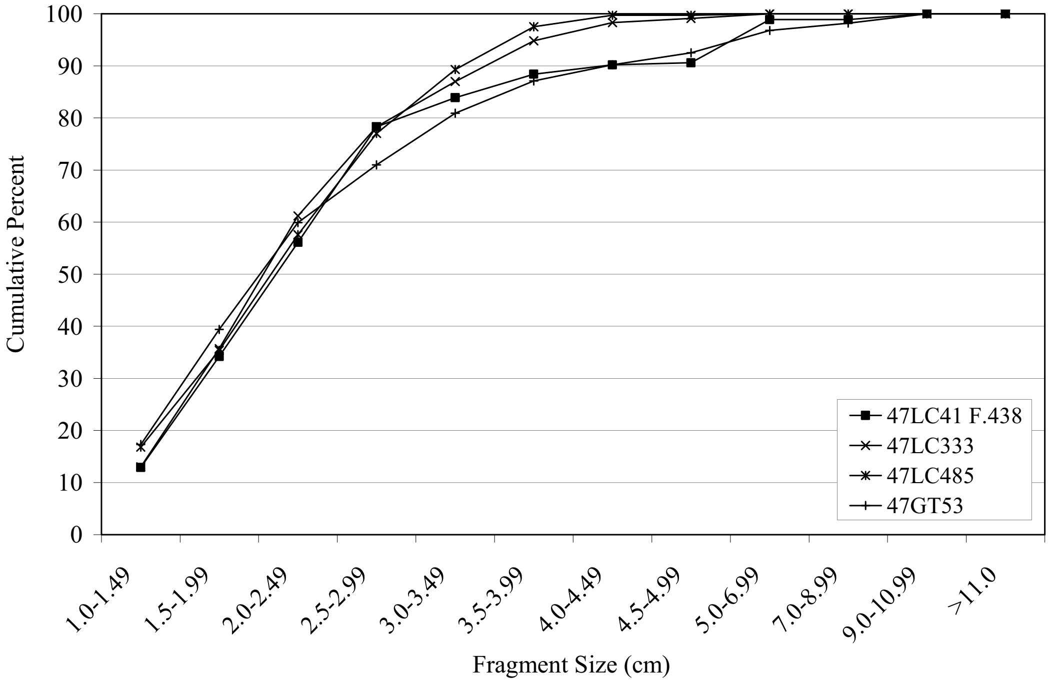

Figure 26. Cumulative frequency distribution of bone weight by fragment size category for "pure" bone grease assemblages from the Driftless Area.

Moving onto the remains from Sanford and Gottschall, we see that much of the fragment weight in these assemblages was present in the upper size classes. This was particularly true for the bone pile from Gottschall. Here, more than 70 percent of the bone mass was from fragments greater than 4.5 cm in maximum dimension (Figure 24). There was a clear spike in the weight of fragments between 4.5 cm and 9.0 cm in size. The bones in these size categories included many complete epiphyses and large diaphysis fragments. Both the weight and size data from Gottschall indicated that the remains were not the product of bone grease manufacture. They were more likely the result of simple long bone breakage and marrow extraction.

The weight distribution of the remains from Sanford showed an intermediate distribution between the more classic examples of grease production (Krause – Features 438 and 441, Long Coulee, Holley Street, and Millville Village) and that of marrow extraction at Gottschall (Figures 23 and 24). At Sanford, there was a pretty even distribution of bone mass between the size categories. This indicated that both unbroken and heavily fragmented remains were present in the feature and again confirmed that the assemblage was likely a composite of many different activities, some of which may have included grease manufacture.

Overall fragment sizes and weights aid considerably in the identification of grease production, but looking at the fragmentation rates of specific bone types can be even more helpful. A comparison of cancellous and compact bone helps demonstrate the extent to which humans focused upon fracturing the grease-rich portions of the bone. Since compact bone contains only a negligible quantity of grease, minimal effort should have been given to its breakage beyond that necessary for accessing the medullary marrow cavity. Conversely, cancellous tissue contains the most grease and should have been heavily pulverized for grease production. Furthermore, since the grease content of compact bone is limited, we should also expect that many diaphysis fragments might have been discarded prior to the boiling event, as they would have lowered the efficiency of grease extraction. This means that bone grease assemblages should have greater quantities of cancellous bone in comparison to compact bone, and that the cancellous fragments should be smaller. This is precisely the pattern that we see at all of the Krause assemblages and in the remains from Long Coulee, Holley Street, and Millville Village. Comparatively, at Gottschall there is much more compact bone and the cancellous bone fragments that are present are fairly large. Similarly, at Sanford compact bone is also more abundant; however, a substantial quantity of small cancellous fragments is also present.

Another measure of fragmentation intensity was the number of complete elements and epiphyses present in the assemblages (see Table 9 for a summary). Holley Street was the assemblage with the largest percentage of unbroken elements; however, most of these bones were small carpals and residual metapoidals/phalanges. Even in a very intensive bone grease manufacturing episode, these small elements could have easily escaped destruction. The other two assemblages with high quantities of complete elements and epiphyses were Gottschall and Sanford. At Gottschall, 33 (5.9 percent) of the remains were complete. Unlike Holley Street, most of the complete elements at Gottschall were the unbroken epiphyses of major long bones (see Table 16 and Figure 7). These epiphyses represented a large quantity of unused grease and suggested that this assemblage was not the product of grease manufacture. Sanford also had a relatively high percentage of complete elements. Here, 275 (or 6.5 percent) of the elements were considered complete. Like Gottschall, many of these complete elements were the unbroken epiphyses of major long bones (Tables 39 and 40). Again this suggested that much of the Sanford assemblage was not the product of grease manufacture. All of the remaining assemblages had lower quantities of complete elements, and those that were unbroken were generally small elements that could have been readily overlooked during grease production.

Summarizing the data regarding fragmentation intensity, we see that the degree of breakage observed at Krause (Feature 438), Holley Street, Long Coulee, and Millville Village is quite consistent with that expected for bone grease manufacture. Although not quite as intense, the remains from Features 82 and 441 at Krause are also heavily broken and consistent with grease production. The reason for the slightly larger size of these remains is probably due to the taxonomic differences (American elk versus white-tailed deer) and depositional context (at least for Feature 82). Conversely, remains from the "Mr. Head" bone pile at Gottschall appear to have been much less intensively fragmented and are more consistent with simple long bone marrow extraction. The Sanford Archaeological District remains show mixed fragmentation intensity, which is probably attributable to the fact that they are from a mixed assemblage.

In addition to the eight assemblages discussed above, this thesis also explored previous accounts of bone grease production at seven Driftless Area sites (Table 6): Raddatz Rockshelter, Durst Rockshelter, Lawrence I Rockshelter, Mayland Cave, Preston Rockshelter, Warsaw Rockshelter, and Millville Village. With the exception of Millville, no material from these sites was available for reanalysis, so determination of grease production depended solely upon the existing descriptions of these assemblages. While we cannot quantify the intensity of fragmentation at these sites, a review all the previously reported data suggest that the large mammal bone had been extensively fragmented at all of these sites (see descriptions in Chapter VI). In fact, most descriptions of these sites specifically mention bone grease production as being responsible for the observed level of fragmentation.

Storck's (1972) descriptions of bone fragmentation at Mayland Cave give a particularly good indication that bones were broken to a size consistent with grease manufacture. Mayland Cave produced over 53,000 fragments that wereso extensively broken that they could only be identified as large mammal (Storck 1972:347). Theler and Chalkley-Hubbell (1984:22) also noted extensive fragmentation at the Preston Rockshelter and indicated that "vertebrae, ribs, mandibles and the articular ends of long bones having marrow rich cancellous bone were consistently found to be broken or crushed." Intense fragmentation at Preston was also evidenced by phalanges. Only 8.4 percent of the first phalanges from the site were found to be unbroken (Theler and Chalkley-Hubbell 1984:23-24). Similar descriptions of bone fragmentation existed for the other Archaic/Woodland sites and clearly illustrated that much of their large mammal assemblages seemed to have been fragmented to a degree expected for bone grease manufacture. Of even greater significance is that these sites span thousands of years and heavily fragmented bone appears to have been quite ubiquitous throughout their deposits.

Fracture Patterns/Fracture Agent

Based on the data summarized above, fragmentation intensity was quite high at Krause (Features 82, 438, and 441), Long Coulee, Holley Street, and Millville Village

(Feature 95). Additionally, remains from the Archaic and Woodland rockshelters also seem to have been heavily fragmented, despite the lack of quantitative data. The level of fragmentation at these sites is consistent with bone grease production; however, as discussed in Chapter II, other taphonomic processes can produce a heavily fragmented faunal assemblage.

To rule out post-depositional forms of bone breakage, the bones were examined for evidence of green bone fractures, characteristic of breaks on fresh bones (see Chapters II and V). The remains from Krause (Features 82, 438, and 441), Long Coulee, Holley Creek, and Millville Village (Feature 95) all showed clear evidence of fresh bone breakage. Table 9 shows the percentage of bones from each assemblage that exhibited evidence of green bone fractures. Even though some of these percentages seemed to be rather low, one must remember that evidence of green bone fractures is only preserved on compact bone, not cancellous bone. When looking at just the compact bone from these sites, we saw that nearly all of the fragments displayed green bone fractures. At many of these sites, the number of fragments with green bone fractures was greater than the number of compact bone fragments. This was because some of the bones classified as cancellous bone still retained enough compact bone to make a determination of fracture freshness. Classic examples of green bone fracturing, such as acute/obtuse fracture angles and smooth fracture surfaces, were present on almost all of diaphysis fragments from these assemblages. Figure 27 illustrates some of the obvious examples of green bone fractures from Feature 95 at Millville Village.

Evidence of green bone fracturing was also quite prevalent at the “Mr. Head” Gottschall Rockshelter assemblage. Here, over 46 percent of the remains had

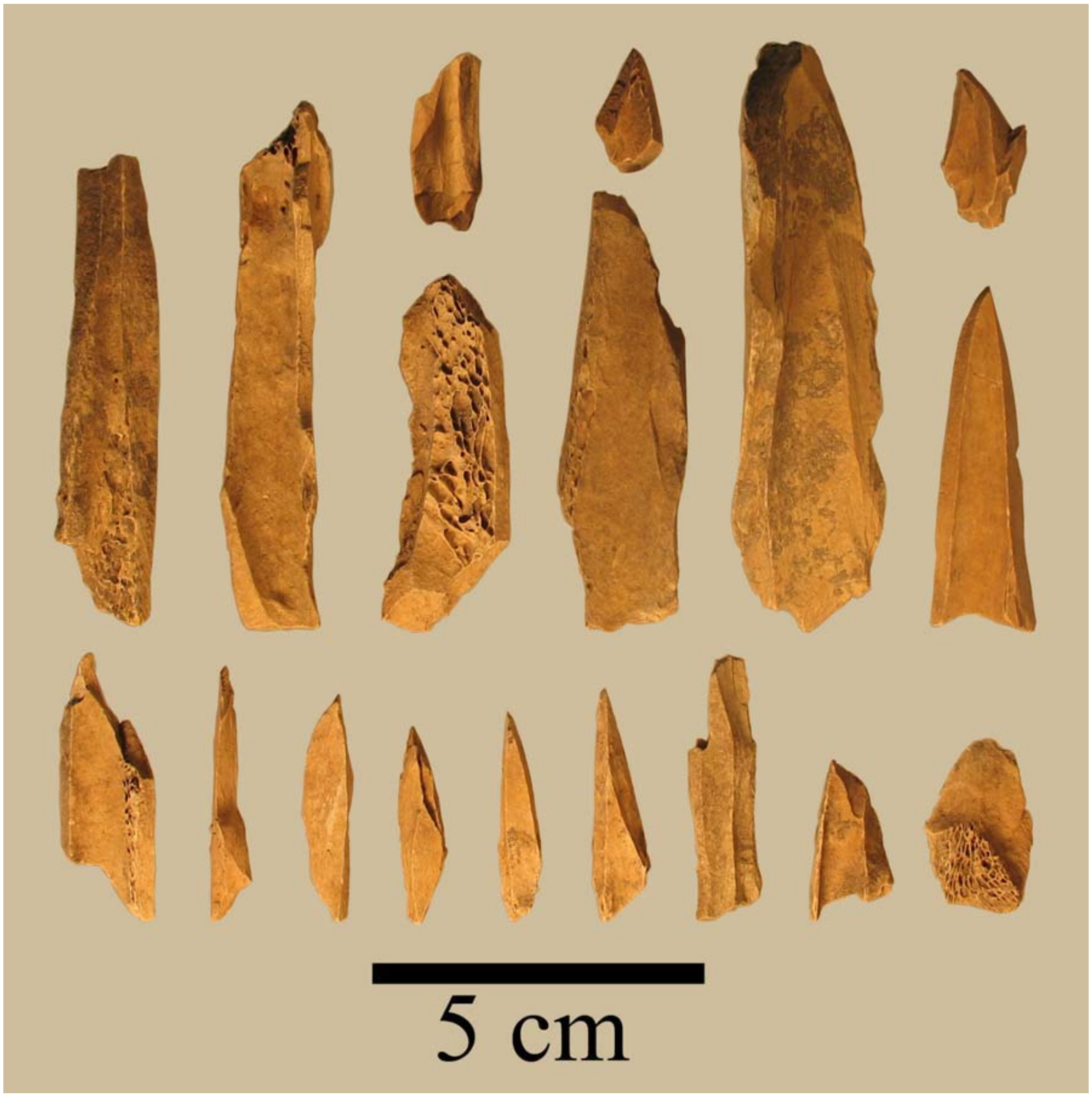

Figure 27. Long bone diaphysis fragments from Feature 95 at Millville Village (47CT53) with smooth fracture surfaces and acute/obtuse fracture angles, typical of green bone breaks.

characteristics of freshly fractured bone (Table 9). The prevalence of green bone fractures in this assemblage indicated that it had been intentionally broken, yet the larger size of the fragments and the number of complete epiphyses suggests that the fragmentation was the result of bone marrow removal and not more intensive grease extraction.

The Sanford Archaeological District assemblage had the lowest percentage of bones with green bone fractures (Table 9). Although it had the lowest rate of green bone breakage, 13 percent of the bones still had evidence of fresh fractures. This indicated that at least some of remains were broken while fresh and may have been utilized for marrow or grease. Once again the mixed nature of this assemblage created an issue of equifinality. In these situations we must rely upon *comparisons* of processing intensity, rather than focusing upon making absolute determinations regarding the presence or absence of grease production.

Besides just demonstrating that the bones were broken while fresh, it must also be shown that they were broken as the result of intentional human activity, and not due to some other agent, such as burning or carnivore gnawing. The remains were all carefully inspected for taphonomic signatures of fracture agents (see Chapter II). The assemblages from Krause (Features 82, 438, and 441), Holley Street, Long Coulee, and Millville Village (Feature 95), had no obvious taphonomic markers of non-human fracture agents (Table 9). Only two bones from Long Coulee had carnivore gnawing and only six remains from Holley Street had been burned.

The lack of non-human modification, along with the high frequency of green bone fractures suggested that humans were responsible for the bone damage. Numerous remains with signatures of human breakage further supported this proposition. These diagnostic marks included dynamic impact points (see Figures 28 and 29) and conchoidal fractures (Figure 30). Many small bones (carpals, tarsals, and metapodial condyles) displayed extensive green bone fractures and loading points suggestive of human breakage (Figures 31 and 32). These elements were quite dense and their breakage would have required intensive human hammering. Furthermore, the breakage patterns seen on distal metapodials from these assemblages, particularly Millville Village (Figure 32), were highly consistent with those observed during the experimental work conducted for this thesis (Chapter VII). These factors provided additional evidence that the Krause, Long Coulee, Holley Street, and Millville Village assemblages were the residue of bone grease production.

Turning to the comparative samples from Gottschall and Sanford, we did see evidence for non-human modification. At Gottschall, over 23 percent of the bones had been burned or scorched. On most of these specimens the burning appears to have occurred after the bones were broken and may have been related to marrow removal. Much of the burning at Gottschall occurred in the form of scorching on diaphyses and the medial ends of long bone epiphyses. It appears as though the bones were broken and then laid along the margins of a fire, which may have served to melt the medullary bone marrow and aid in its extraction. Overall, the bones from Gottschall still appeared to have been intentionally fractured by humans, but simply for marrow extraction and not to the extent of bone grease production.

The remains from the Sanford Archaeological District also had evidence for non-human modification. Thirteen percent of the remains had been burned and 3.7 percent had evidence of carnivore gnawing. This was further evidence that the remains from this

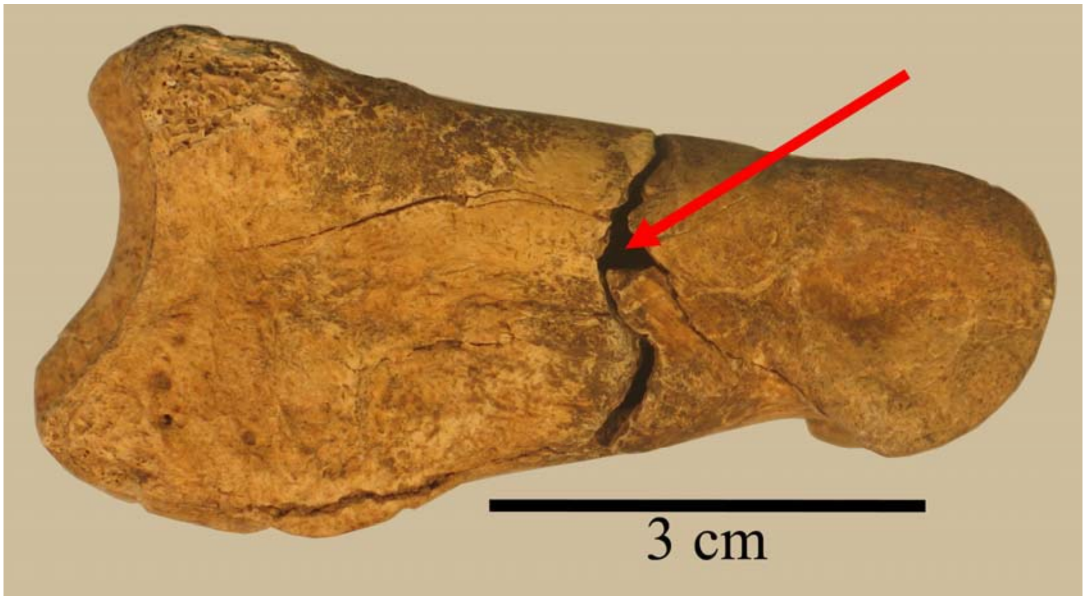

Figure 28. A single American elk phalanx from Feature 438 at Krause (47LC41) with a dynamic impact point and radiating fracture lines.

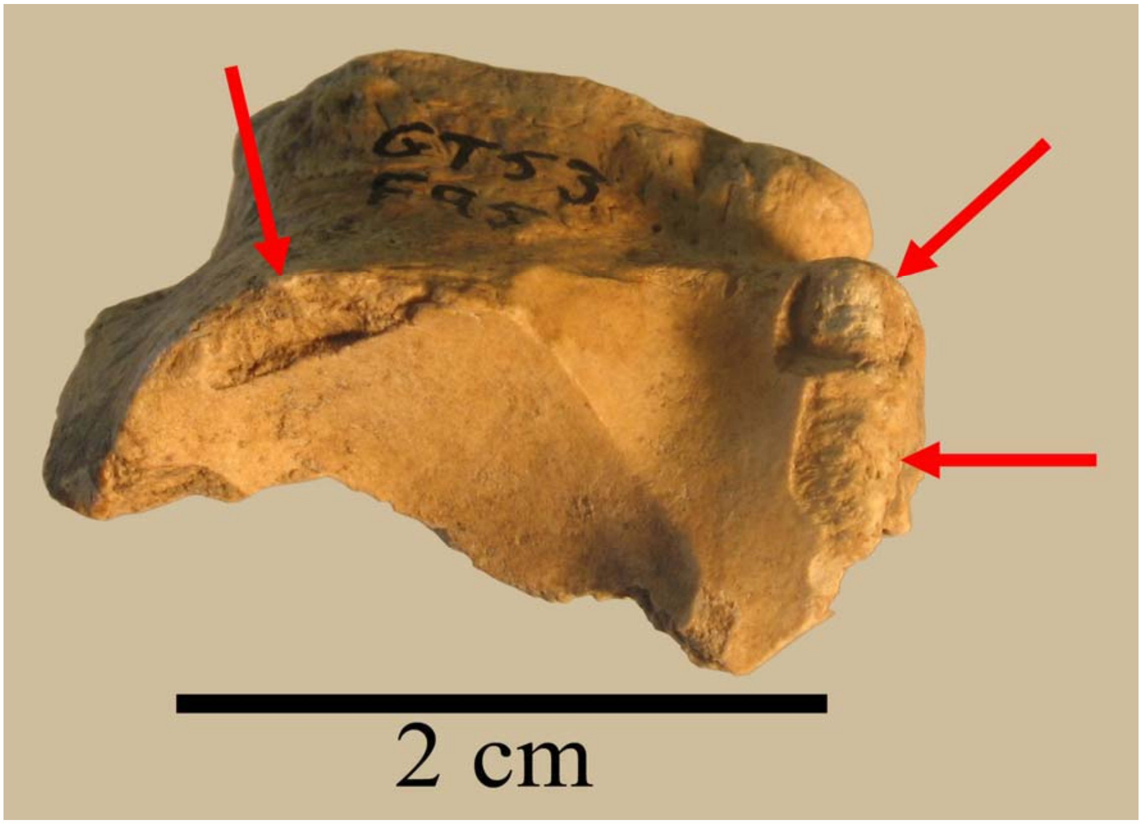

Figure 29. A right naviculo-cuboid of a white-tailed deer from Feature 95 at Millville Village (47GT53) with multiple dynamic impact points.

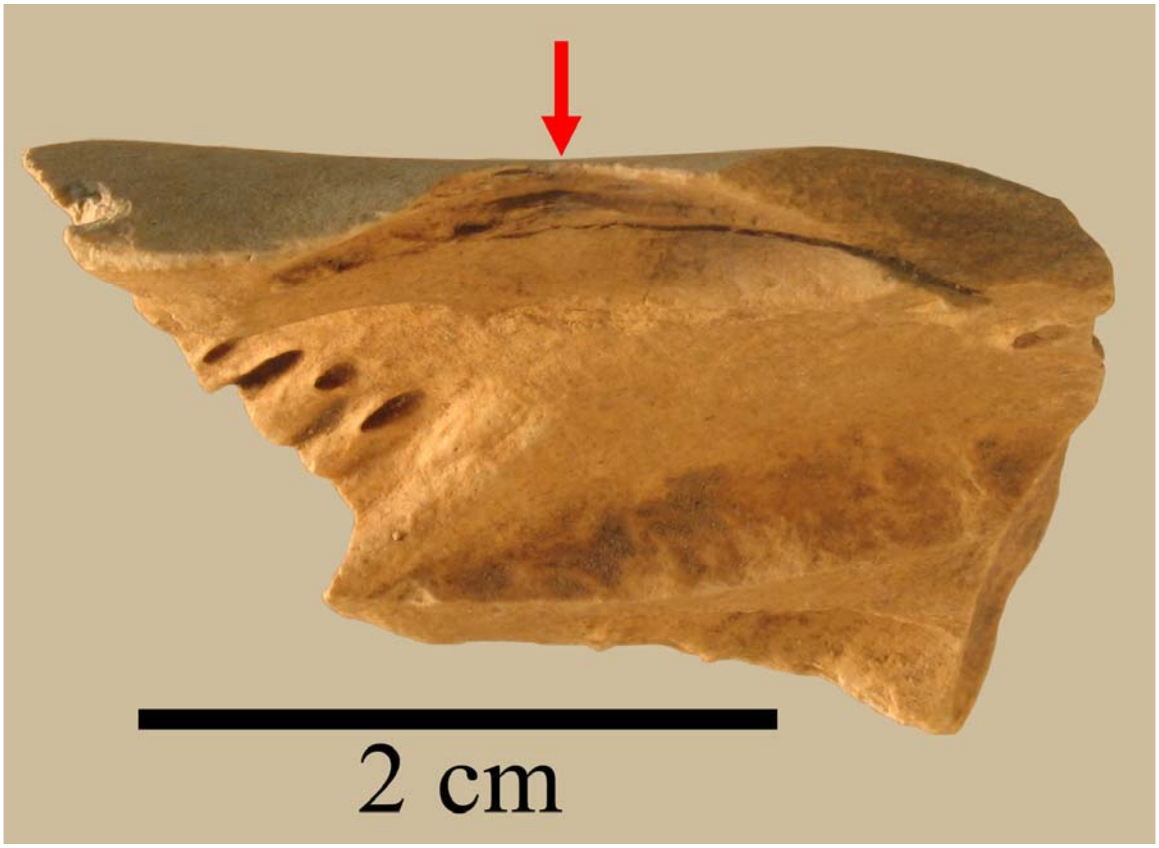

Figure 30. Long bone diaphysis fragment from Feature 95 at Millville Village (47GT53) with a dynamic impact point and conchoidal fracture.

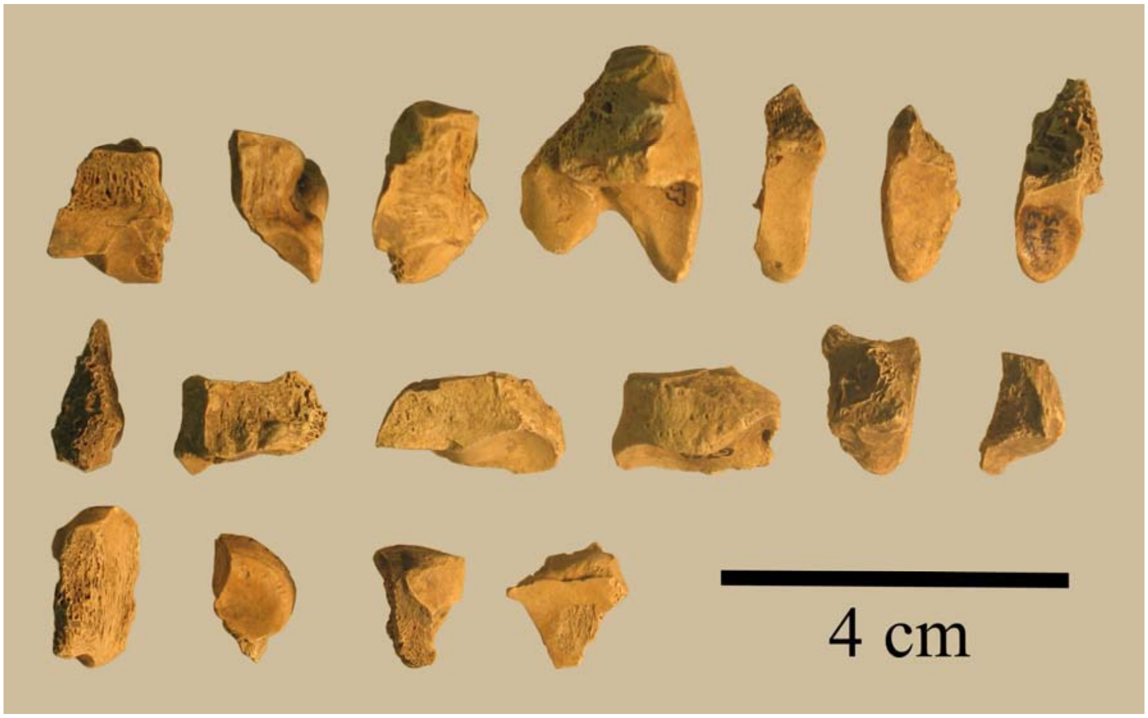

Figure 31. Heavily fragmented white-tailed deer naviculo-cuboids from Feature 95 at Millville Village (47GT53) exhibiting green bone fractures.

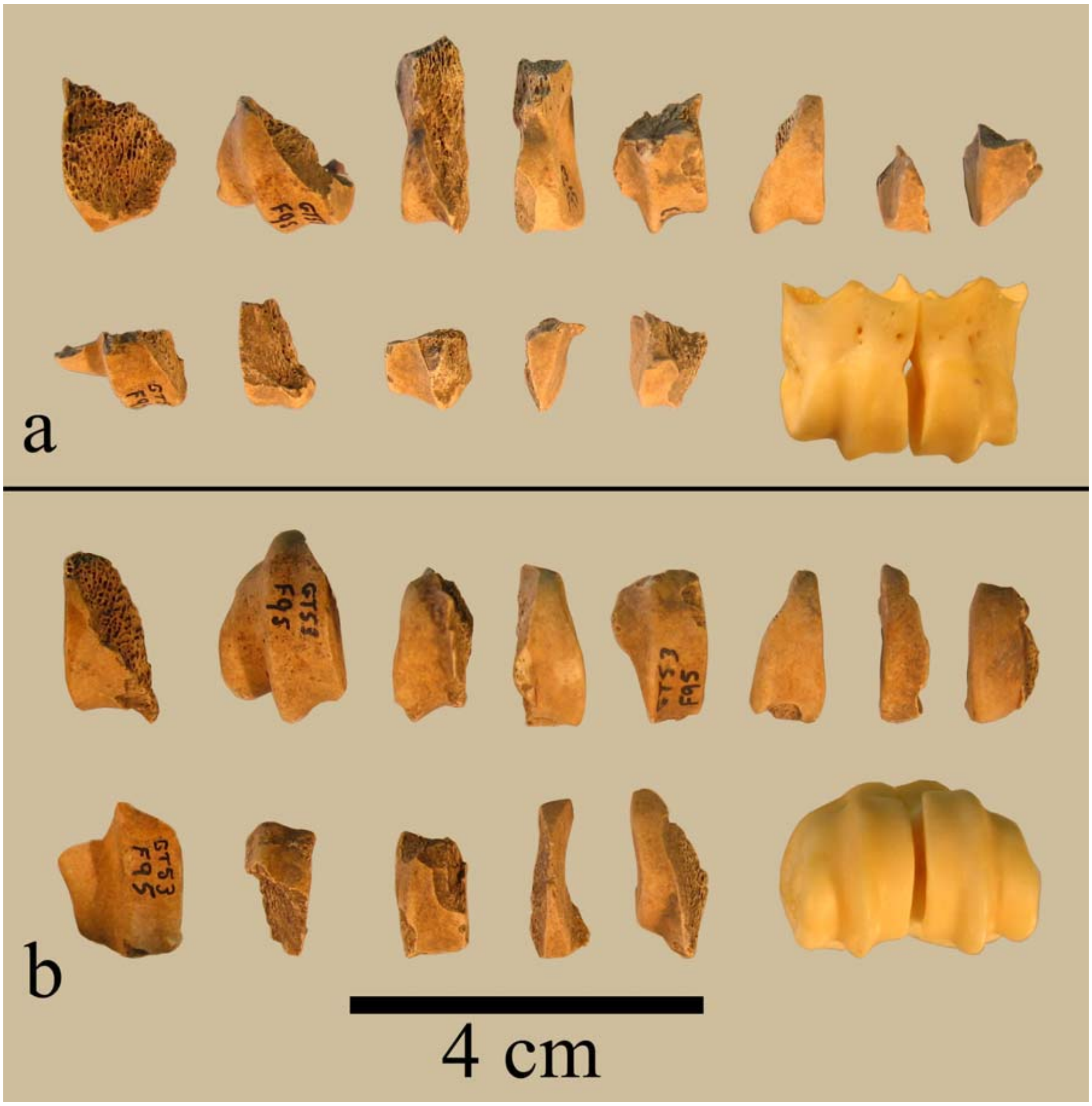

Figure 32. Distal white-tailed deer metapodial fragments from Feature 95 at Millville Village (47GT53): (a) dorsal view; (b) distal view. Note that the condyles are heavily fragmented with transverse green bone fractures (bone in lower right of each view is a modern specimen shown for comparative purposes).

feature represented a mixed assemblage created by numerous activities. This does not rule out grease production, but indicates that if it was present, it was masked by the remains from other events.

The extent of human fragmentation was much more difficult to address at Archaic/Woodland sites, for which material was not available for analysis. Despite the lack of quantitative data from these sites, it appeared that most of the bones were broken due to human action. Parmalee (1959:89) described numerous "bone chips" from the Raddatz Rockshelter and implied that bone had been extensively fragmented by humans. At the Lawrence I Rockshelter, Berwick (1975) also explicitly mentionedthat the bones appeared to have been fragmented by human activity. Theler and Chalkley-Hubbell (1984:22) described the bone at the Preston Rockshelter as "shattered" and "crushed" and further indicated that the remains were broken for the extraction of marrow and grease. Nearly all of the well-preserved compact bone fragments at the Warsaw Rockshelter had green bone fractures, indicating fresh breaks and apparent human manipulation (Baker 2003). Finally, Storck (1972) provided convincing descriptions of human caused bone breakage at Mayland Cave. He said the bones seem "to have been broken by pounding" (Storck 1972:347) and described once specimen that had numerous "concussion marks" and embedded chert fragments. In reference to the general assemblage from the Millville Village, Pillaert (1969:101) also described numerous bone splinters and suggested that the deer bone had been "battered beyond recognition." The descriptions for all of the Archaic/Woodland sites were consistent with remains that had been intentionally broken by humans, and further supported suggestions of bone grease production at these sites.

Other Taphonomic Considerations

When investigating archaeological occurrences of bone grease production, it is necessary to consider other taphonomic factors that may act to mask or mimic grease production. This is of greatest concern in assemblages that lack discrete bone deposits and where the remains have been scattered across wide portions of the site. Furthermore, the issue of taphonomy must be carefully considered when making comparisons between multiple assemblages. Many agents can act to reduce bone size and differentially destroy particular elements. If two assemblages have experienced dissimilar taphonomic histories, little confidence should be afforded to their comparison.

The remains were all carefully examined for any signs of taphonomic modification. As noted above, the assemblages from Krause (all three features), Holley Creek, Long Coulee, and Millville Village showed very little evidence of taphonomic modifications. Only two bones from Long Coulee had carnivore gnawing and only six remains from Holley Street had been burned (Table 9). None of these remains had any additional signs of modification (e.g. rodent gnawing), and all appeared to be very well-preserved. No obvious signs of extensive deterioration (root acid etching, sun bleaching/weathering, flaking, etc.) were seen on any of the bones. Since the assemblages were so fragmented, it was difficult to judge the potential impact of density-mediated attrition through standard procedures (Lyman 1994:254; Lyman et al. 1992). The large quantity of pure cancellous bone fragments at all of the sites, however, suggested that the assemblages had only experienced minimal post-depositional alteration. Therefore the assemblages should be fairly comparable and did not have any modifications that seemed to be masking or mimicking grease production. Furthermore, the general lack of modifications among these assemblages suggested that they represented discrete secondary deposits of singular activities, presumably bone grease manufacture.

The "Mr. Head" bone pile from Gottschall Rockshelter was also well-preserved and had few modifications. Although 23 percent of the bones had been burned (Table 9), it appeared that the burning occurred after breakage and was perhaps conducted to facilitate marrow removal. Two of the bones from Gottschall had been gnawed, although no others exhibited any form of modification. Preservation also appeared to be quite good at Gottschall; however, the assemblage was dominated by intact long bone epiphyses with high-density values. While the presence of such specimens may have suggested that cancellous fragments were destroyed through attrition (thus masking grease production), this did not appear to be the case. The presence of many intact epiphyses (and large diaphysis fragments) would strongly argue against extensive post-depositional alterations.

The remains from Feature 205 at the Sanford Archaeological District had substantially greater evidence for taphonomic modification. Nearly four percent of the bones had been gnawed (both carnivore and rodent) and 13 percent had been burned (Table 9). They also showed some additional signs of intentional human modification, including the presence of cutmarks and evidence of tool production (grooved-and-snapped bones). The degree of preservation seemed to vary substantially through the feature, with some zones producing fairly weathered bones and others producing well-preserved low-density elements (proximal humeri and femora). The variability seen with in this feature again highlighted the fact that it was a composite assemblage, which contained the refuse of many different activities. Some of the material may have been produced through grease manufacture, but the ability to definitively identify that activity was obscured by the products of so many others.

Once again, the ability to accurately judge the Archaic/Woodland Rockshelter assemblages was greatly hampered by the fact that the material was not available for reanalysis. Based upon the author's general experience with faunal assemblages from Driftless Area rockshelters, it was suspected that the remains were all well-preserved. These sites were generally quite dry and have produced some of the only Archaic faunal assemblages from southwestern Wisconsin. Although the preservation was very good at these sites, there was some degree of variability. For example, Berwick (1975) mentioned that bone preservation seemed to be poor in the oldest (Early Archaic) deposits from the Lawrence I Rockshelter. Barring potential biases with some of the older deposits, most of the material seemed to be preserved well enough that evidence for grease production was still present. As mentioned above, the quantity of small and heavily fragmented bone was ubiquitous in the assembalge descriptions. Theler and Chalkley-Hubbell (1984) explicitly stated that numerous fragments of smashed cancellous bone were present at the Preston Rockshelter.

Although these sites clearly have well-preserved faunal assemblages, that contain evidence of grease production, the extent of this activity is unclear. The sites served as long-term winter camps that were reoccupied over thousands of years. The multitude of activities that occurred at these sites made it difficult to judge the significance of grease production. These assemblages contained remains with many different forms of modification, including burning, gnawing, cutmarks, and tool manufacture, all indicative of composite assemblages. Despite these modifications, the assemblages still seemed to be dominated by small bone fragments produced as the result of human activity, which was most likely bone grease manufacture. While, we cannot judge diachronic changes in the frequency of bone grease production at these sites with the existing data, the quantity and apparent ubiquity of small, intentionally fractured, bone fragments throughout their occupational history indicated that grease production was probably a regular activity, performed for thousands of years. If one were to able to analyze the remains from these sites, greater attention should be given to the incidence of taphonomic modifications in order to accurately assess differences in the frequency of grease production. This would apply to both intra- and inter-site analyses.

Archaeological Context

The final and perhaps most important criteria for identifying archaeological bone grease production is the physical context of the remains. As discussed in Chapter II, the residue of bone grease manufacture can be deposited several ways:primary, mixed secondary, or discrete secondary.

In a primary context the bones remain directly associated with the tools and site facilities used in grease production (e.g. hammerstones, anvils, hearths, etc.). Grease residue in a primary context is most likely to occur at a small, briefly occupied processing camps (Vehik 1977). As the fragmented bones would more closely retain their associations with the processing equipment, such an assemblage would provide very strong evidence for grease production.

Grease production becomes more difficult to identify in secondary contexts. On this end of the spectrum, the bone fragments loose their association with processing equipment and possibly the original activity area. This was termed a mixed secondary deposit. These deposits are most likely to occur at larger, more permanent sites, where multitudes of other activities serve to scatter and obscure the evidence for grease production. In such cases, it becomes increasingly difficult, and even impossible, to make definitive conclusions regarding the presence or absence grease production. Thus, we are frequently faced with equifinality in these situations. If the bone refuse from grease production was dumped about the surface of the site, it was likely to have become quickly scattered and mixed with the remains of many other activities. In this scenario one has to rely more heavily upon the previous three criteria to make a judgment regarding the existence of grease production.

If, however, the bone residue was deposited into a discrete pile and quickly covered with sediment, bone grease production would be significantly easier to indentify. These were termed discrete secondary deposits. Here we would expect to find a large pile of crushed bone. If it could be demonstrated that the remains from such a deposit were highly fragmented as the result of human activity (following the above three criteria), there would seem to few explanations other than grease manufacture.

The remains from Features 438 and 441 at the Krause Site, as well as the assemblages from Holley Creek, Long Coulee, and Feature 95 at Millville Village all come from discrete secondary deposits. They all occurred as large dumps, or piles, of bones within refuse pits. Classic examples of these bone piles can bee seen in photographs of Features 438 and 441 at Krause (Figures 8, 12, and 13). The discovery of these remains within isolated contexts strongly suggested that they were the product of a single activity. Furthermore, data discussed above indicate that they were all highly fractured as the result of human manipulation. In these instances, the context and condition of the remains strongly suggests bone grease production.

The remains from Feature 82 at Krause were also found within a refuse pit, but were spread throughout one zone of the feature, rather than occurring in a discrete pile. The bones from this assemblage were heavily fragmented by human activity, but were slightly large than those from the other elk assemblage at Krause (Feature 438). While the remains did not occur in a single pile, and were somewhat larger, their overall condition (highly fragmented, with numerous green bone fractures, and cancellous bone fragments), still suggested grease production. The nature of the context was probably somewhere between a discrete secondary and a mixed secondary deposit. It appeared as though the bones were placed in the pit as part of a larger cleaning event. Perhaps they had been dumped elsewhere (presumably near the original processing area) and later cleaned up and placed into the pit with additional refuse. This would certainly explain why smaller bone fragments were less frequent in this assemblage. The remains still appeared to be the product of grease production, although some of the smaller fragments may have been lost in the disposal process.

Moving on to the “Mr. Head” bone assemblage from Gottschall Rockshelter, we see that it to appeared to be in either a primary or a discrete secondary deposit. The bones were closely associated with one another and all exhibited similar modifications. In this case, when we compare the context with the condition of the remains, we see a much different pattern than that of the assemblages discussed above. Here, many of the specimens were large bone fragments and included numerous intact long bone epiphyses.

The condition and context of the remains suggested that they were the product of a marrow extraction event, not grease production.

The Sanford Archaeological District assemblage was much different from the other proveniences discussed above. As noted in Chapter VI, the remains from this site came from an extraordinarily large refuse deposit. They had experienced a number of very different modifications and were clearly the result of many different activities. While the products of bone grease manufacture may have been present in the feature, they weredisguised by the remains of these other activities. Some of the remains appeared to have been intensively processed, but so many others exhibited only minimal modification. If bone grease production was present, its extent was impossible to judge.

Turning to the Archaic/Woodland Rockshelters, we once again see that exact nature of the remains was difficult to judge because they were not available for reanalysis. Most of these assemblages had been previously analyzed as composite assemblages, and came from sites that were reoccupied for thousands of years. The remains were obviously the products of many different activities. That being said, the descriptions of the bone fragmentation and references to grease production at all of these sites is quite ubiquitous. Even though we may not be able to make accurate intra- and inter-site comparisons with these sites, the evidence for grease manufacture is apparent.

Summary of Evidence for Bone Grease Production

Taken together, the preceding evidence strongly suggests that bone grease production was present at Krause (Features 438 and 441), Long Coulee, Holley Street, and Millville Village (Feature 95). All of these assemblages came from isolated, discrete bone piles that had been extensively fragmented and fractured by intentional human activity. In fact, the degree to which these remains had been broken was remarkably consistent (see Figures 21, 22, 25, and 26). It was very interesting that these fragmentation rates were so similar between different sites and time periods (Oneota v. Middle Woodland). Furthermore, the American elk remains from Krause (Feature 441) also showed a remarkably similar fragmentation rate, with only a few larger pieces. The data from these assemblages suggested that the prehistoric hunters had a perceived notion of optimal fragment size (cf. Church and Lyman 2003). One additional assemblage (Feature 82 at Krause) is also a very likely candidate for grease production, yet some of the original fragments seem to have been lost prior to deposition; perhaps as the result of a larger cleaning event. In general, the Driftless Area fragments were very similar in size to bison remains from Plains sites were bone grease manufacture was postulated and fragment size has been measured (Logan 1998; Quigg 1997). As these Wisconsin assemblages appeared to be pretty clear examples of *discrete* grease processing events, it is hoped that the size data generated from them will serve as the standard for the future identification of bone grease production in the Midwest.

The assemblages from the “Mr. Head” bone pile at Gottschall Rockshelter, and Feature 205 at the Sanford Archaeological District were used as comparative samples. These two assemblages provided a clear contrast in comparison to the remains from theother sites. At Gottschall, the deer bones were recovered from a discrete pile and all taphonomic modifications indicated that they were likely the product of a single activity. Despite good preservation; these bones were much less fragmented than the bone grease assemblages discussed above. Of greatest significance was that the remains included a large number of complete long bone epiphyses, which would not be expected with bone grease production. The condition of the bones indicated that they were clearly broken by human activity, but more likely in the pursuit of bone marrow extraction. In this sense, the assemblage is quite significant in that it seems to be a discrete deposit of bones from the extraction of bone marrow. It was clearly distinguished from the bone grease assemblages, by the size and weight of the fragments (Figures 20 and 24) and may serve as a standard example of less intense bone fat exploitation, against which other future analyses can be compared.

Feature 205 at the Sanford Archaeological District, represented a more typical faunal assemblage from the Driftless Area, in that it did not contain a discrete dump of bones or bone fragments. Instead, it was a very large feature, with a significant quantity of bone mixed throughout its deposits. The feature had been filled over a long time period (perhaps on the order of several years) and its contents undoubtedly represented the remains of numerous activities. Since the feature was composite assemblage, it was difficult to separate out the individual activities. Bone grease residue may have been dumped into Feature 205, but since it appeared to be a large, open gully, the remains may have quickly been mixed with those from other activities.

These mixed assemblages bring up the issue of equifinality. In these cases, it may be impossible to come up with a definitive identification of grease production. Rather than relying on absolute fragment size (or other taphonomic cut-offs) for determining the presence of bone grease production, we are best left with measures of carcass processing intensity. As long as the assemblages are well-preserved and have not experienced significantly different taphonomic modifications, they should be comparable by means of fragment size and fracture patterns. The fragment size data from Sanford indicate that the bones were not nearly as intensively processed as those from the other Oneota sites, or from Millville Village. Conversely, when compared to the bones from Gottschall, the Sanford remains do appear to have been somewhat more intensively broken. While some of this may be attributable to taxonomic differences (Gottschall was exclusively white-tailed deer, while Sanford included a few medium sized mammals), there does seem to be a substantial difference in processing intensity. The utility of this comparative approach would be strengthened if additional sites could be included or individual deposits from within Feature 205 could be examined separately.

Excluding the Millville Village (Feature 95) assemblage, all of the data regarding Archaic and Woodland bone grease production come from previously published material. As such, it cannot be carefully evaluated using the more rigorous methodology. Despite the lack of quantitative, we can reasonably assume that the rockshelter assemblages were heavily structured through bone grease production. First, all of the rockshelter faunas were reported to have extremely fragmented large mammal material, often hypothesized to have been the result of bone fat exploitation. Second, due to the dry environmental conditions, the faunal assemblages exhibited extraordinary preservation and appeared to have undergone little post-depositional alteration/fragmentation. Although the remains did exhibit some signs of carnivore modification, it is unlikely that this process would have resulted in the extent and intensity of the observed fragmentation. Finally, when seen in a broader context, the faunal assemblages were the product of substantial deer harvests and processing. The exploitation of bone fat (both marrow and grease) is a logical extension of mass harvests and intense processing.

The Role of Grease Production in Prehistoric Societies: Resource Stress?

Data from the Archaic and Woodland rockshelters, along with ethnographic and archaeological examples discussed in Chapters II and III indicate that bone grease production was a common and regular practice in many ancient and historic groups. The ubiquity of this practice among numerous socieites challenges the common assumption that bone grease production was indicative of resource stress or cultures inhabiting "marginal environments" (Burger et al. 2005; Outram 2004). Before moving onto specific discussion of the role that bone grease may have played in Archaic, Woodland, and Oneota societies, I first want to address some more general concerns regarding the interpretation of bone grease manufacture.

Based upon the predictions of the prey-as-patch model (Burger et al. 2005), we expect the intensity of individual carcass processing to increase as large mammal kill frequencies decrease. Processing a carcass results in a situation of diminishing returns, where the longer one spends processing, the less energy is acquired, per unit of time. At some moment during the processing, a point of diminishing returns is encountered and it is then less profitable to continue working a single carcass, as opposed to moving onto new prey. The exact cut-off point is determined by the likelihood of encountering another animal. As time between kills increases, more time should be dedicated to processing an individual carcass, and vice versa. Since bone grease manufacture is a labor-intensive process, with relatively low yields, the model traditionally predicts that it should only be utilized when times between animal kills are long and when humans are experiencing resource stress (Burger et al. 2005). This model has recently been applied to the interpretation of bone grease production in the archaeological record (e.g. Nagaoka 2005; Outram 2004).

While, I feel that the prey-as-patch model is an important heuristic device in understanding carcass processing intensity and the relative importance of bone grease and, its application to the archaeological record needs to be used with some care. The most significant issue with the model is that it only examines carcass processing costs and returns of *individual* animals. The model is based upon the more traditional patch-choice model, which naturally infers that a person can only exploit one patch at a time (Kelly 1995:90-97). The prey-as-patch model analogizes time spent exploiting a patch to time spent processing an animal carcass. Both assume that additional time spent in a patch or processing a carcass will result in diminishing returns. Whereas a human is only able to physically exploit one patch at a time, there are fewer restrictions on how many animals may be processed simultaneously.

There are numerous ethnographic examples of hunters throughout the world taking large animals in mass quantities (e.g. Plains bison harvests). Furthermore, other people are known to have reserved portions of animal carcasses for mass processing events. For example, the Nunamiut often saved caribou bones during the winter in order to process the grease from multiple animals simultaneously (Binford 1978). The ability to process multiple carcasses (either through mass harvests or storage) means that processing costs for particular anatomical portions or resources (i.e. bone grease) may have been substantially reduced. When processing a single animal for its grease content, one has to deflesh the animal, clean its bones, crush the bones, and boil them. In such situations, the overall processing costs for grease are quite high. Most of the time is spent crushing the bones and significant energy is also expended during the boil (especially with traditional boiling techniques). If, however, multiple animals could be processed, the amount of energy spent crushing the bones would be reduced and less time would have to be dedicated to set-up and clean-up times per animal. Another factor, discovered during the experimental worked conducted for this thesis, is that when processing numerous bones, a person gets into a very efficient mode of work. This factor is very difficult to describe (much less quantify), other than saying that one “gets into the zone”, and when processing many bones, one can move through individual elements at a faster pace. This would be particularly true, if a large number of bones were reserved and one could focus on processing all of the same elements at once. Perhaps the greatest reduction in costs would come from the boiling process, where bones from multiple individuals could be boiled simultaneously.

The issue of harvesting/processing multiple animals does not negate the prey-as-patch model, but rather suggests that we should not equate time spent exploiting a patch to time spent processing a *single* animal carcass. Instead, it may be more appropriate if the model focused on the costs of processing an entire animal harvest, which may include multiple individuals. In this sense, we would be treating the entire kill as a patch, rather than equating individual carcasses to patches. By doing so, the model would still be valid and make accurate predictions about carcass processing intensity. Even when multiple animals were harvested, the key assumption of diminishing returns should still hold true; however, the processing costs for particular resources, such as bone grease, may be substantially reduced. Here the decision of how long to process a particular carcass may not be based upon the time expected before encountering another large animal (as the prey-as-patch model predicts), but rather upon the time expected before being able to make another mass kill.

In addition to focusing on individual animal carcasses, I see another concern with the prey-as-patch model: the focus upon immediate need. Again, this problem does not negate the basic predictions of the model, but rather indicates that we need to be more cautious with its direct application to the archaeological record. In highly seasonal environments, one may be able to obtain an abundant supply of nutrients during a particular portion of the year. During these periods, times between animal kills may be quite short. In these scenarios, the standard version of the prey-as-patch model would predict that time spent processing an individual carcass should be relatively brief. Here, the hunter is expected to take the best parts of the animal and move onto the next readily available kill. The problem is that most of these foraging models were originally developed based upon the behavior of non-human animals (Stephens and Krebs 1986). While a number of non-human animals are able to create resource stores for the winter (or other lean times), most rely upon storing energy in the form of bodily fat. Humans, however, are capable of amassing stores of resources during times of plenty and saving the nutrients for times of scarcity. As such, the time spent processing a carcass may be dictated, not by the expected time between kills, but rather by the expected need for a particular nutrient over the course of several months. Therefore, why should not we expect humans to intensively process animals when they are readily available and create resource stores for the months to come?

A corollary to the above concern with long-term need, is the fact that not only does animal availability vary throughout the year, but so do specific nutrients within those animals. While it is acknowledged that fat, as opposed to overall caloric return, may be the primary factor driving carcass processing intensity (Burger et al. 2005), little attention is given to the human ability to plan for these predictable shortages. Chapter III focused on the role of fat in the diets of human societies. It should be remembered that in certain environments, supplies of fats and carbohydrates may be seasonally limited. In these environments, protein (in the form of large animals) may be available year-round, yet humans are physiologically limited in the amount of protein they can consume. Approximately 35 to 50 percent (Speth 1990) of daily energy consumption can be derived from protein, while the remaining 50 to 65 percent must come from fats or carbohydrates. Since carbohydrates are usually quite rare in environments where the protein ceiling is a concern, most societies confronted the problem of protein over-consumption by focusing on the acquisition of fat.

While the protein ceiling may be averted by fat consumption, the availability of fat varies considerably throughout the year. As discussed in Chapter III, most large ungulates begin to metabolize their fat supplies during the rut and continue to become depleted throughout the winter. This means that hunters may be faced with severe resource stress during the winter months. Although animals may be available, they may have so little fat that they would be considered of minimal value. The fact that bone grease is one of the last fat stores to be metabolized by large ungulates, and therefore potentially one of the last fat supplies available to humans, has typically led to its interpretation as a starvation food or indicator of resource stress. Certainly, it is true that bone grease may have been turned to in these dire situations; however, should it always be seen as an indicator of marked resource stress? Perhaps humans prepared for these expected resource depressions through intensive processing of animal carcasses, while they were abundant and healthy to specifically create vital stores of high quality fat.

Ethnographic data indicate that such preparation and storage practices did, in fact, exist. Perhaps the best data on bone grease production during times of plenty come from the historic cultures of the Great Plains (see Chapter II). On the Plains, many cultures were actively involved in the production of pemmican, a substance comprised of dried meat and fat. This product was high in nutritional value and could be stored upwards of three years. Pemmican was a highly valued substance and an important trade commodity (see references and discussion in Chapter III). This energy concentrated food was critical for the survival of the winter months. Pemmican was often produced in concert with the large fall harvest and processing of bison. Ethnographic records specifically reference the production of pemmican through the large-scale processing of both bone marrow (Grinnell 1962:207; Hamilton 1905; Schoolcraft 1851:175) and bone grease (Bradley 1923:260; Teit 1930:94; Wissler 1910:23). As bone grease is a high quality fat (in terms of essential fatty acid content), it was particularly valued for pemmican manufacture. Therefore, "it would be inappropriate to assume that archaeological evidence of grease rendering always indicates desperate nutritional conditions or the spring season" (Brink 1997:272).

The simple identification of bone grease production on an archaeological site should not be seen as an immediate indication of resource stress. It is unlikely that cultures living in the Plains, or Subarctic saw themselves as chronically stressed just because they had to produce large quantities of grease on a yearly basis.. They most certainly realized that the winter would bring hard times, but they prepared for them through the processing of meat, marrow, and grease. Doing so was a regular part of the economy, and although it involved substantial work, grease production was unlikely seen as a stressful activity. They probably did not view themselves as eking out a substandard existence in a marginal environment. On the other hand, they knew very well the annual stress of living in their environment and bone grease production was one of many strategies employed to contend with this regular environmental variability. Furthermore, the costs of its production were greatly reduced through mass harvests and processing events.

Again I must, emphasize that the prey-as-patch model is not invalidated by these concerns, but rather these issues must be carefully considered when applying it to the archaeological record. The model still helps us understand that carcass processing intensity is tied to resource stress, but we must better understand the cultural context of the processing events (whether they were associated with mass kills or single harvests) and overall need for particular nutrients. Even in mass harvest events, the assumption of diminishing returns is still meant, meaning that we should expect more intensive processing with increased times between harvests (or perhaps with greater anticipated need). Although the costs to produce grease during mass harvest events would be lowered, we should still expect elements of limited grease quantity and quality (phalanges, carpals, tarsals, ribs, etc.) to be excluded from grease production. If harvests were to decrease, or anticipated need was to increase, we should expect larger numbers of lower-ranked elements to be included in grease production.Therefore, careful consideration of the elements included in a grease production event may yield clues regarding the circumstances dictating its manufacture.

Grease production may also serve as a marker of resource stress if we can identify diachronic changes in the frequency of this practice. If production became more regular and/or intense, it would be reasonable to assume that populations were experiencing increased levels of resource stress. Increased intensity could be measured through the inclusion of lower-ranked grease elements, and perhaps a trend towards smaller average fragment sizes.

In sum, bone grease production should not always be seen as marker of resource stress. In order to understand the factors that motivated a particular episode of grease manufacture, *the evidence must be placed within a broader cultural context*. If the grease was produced in concert with a mass harvest of large animals, it should not necessarily be viewed as evidence for resource stress. As seen on the Plains, mass production events may have lowered overall processing costs and thus made bone grease a highly valued commodity that could be stored for times of anticipated need. Certainly, these groups faced chronic seasonal fat shortages, but the simple determination of grease production does not mean that they were experiencing resource stress. These environments may have been less productive, or more seasonally variable, in comparison to other portions of the world; however, these groups were well adapted to their environment and mass bone grease production may have been among the more optimal sources of high quality fat.

Determination of resource stress must be made through careful comparisons that document changes in processing intensity through time. Groups still had to contend with both short- and long-term variations in resource variability. When large animals became less abundant, either through environmental change or overharvest, societies would have been more stressed in obtaining adequate supplies of fat to survive the winter. While it may be difficult to archaeologically observe annual stresses, long-term changes should still be apparent through increased processing intensity. Even though grease production may have been a common practice, it is likely that it would have become intensified during times of resource stress. This may be seen as diachronic changes in fragment size and the inclusion or exclusion of low-ranked elements in grease processing. Furthermore, observed changes in processing intensity should also be tied to other changes in subsistence patterns, such as an expansion of the diet-breadth, in order to better demonstrate episodes of resource stress. In this sense, bone grease may provide critical evidence for long-term changes in human economies and allow us to better understand the factors that drove past cultural change.

Although, interpretations of resource stress are strongest when long-term changes in carcass processing intensity can be established, the ability to observe acute episodes of nutritional stress through grease production should not be completely eliminated. Bone grease manufacture is still a very labor-intensive activity, and produces relatively small yields, when single carcasses are involved. Therefore, isolated occurrences of this activity may be indicative of short-term episodes of resource stress. In order demonstrate that grease was produced as the result of immediate resource stress, it must be shown to have been outside the range of normal subsistence behaviors. For example, if evidence of grease production was found where only single individuals were processed and the event included many low-ranked elements, it may have been in response to acute resource stress. This argument could be strengthened if it could be shown that the culture rarely fractured bones beyond the extent of simple marrow extraction. Furthermore, if evidence for grease production coincides with late-winter, or early spring seasonal indicators, it may have also been the result of resource stress. During this time of year, bone grease may have been one of the only remaining fat sources and could have been a starvation food. Such episodes of short-term stress would be almost impossible to identify, unless they occurred in discrete, isolated contexts.

Role of Bone Grease in Archaic and Woodland Societies

We have seen that bone grease production in the Driftless Area appears to have been common throughout the Archaic and Woodland traditions. Its occurrence has been mentioned in every rockshelter faunal assemblage that has been analyzed from the region (Baker 2003; Berwick 1975; Parmalee 1959; Storck 1972; Theler 1983; Theler and Chalkley-Hubbell 1984). Clear evidence also exists for grease production at Millville Village, which was a fall-winter Middle Woodland occupation (see Vehik 1977 and this thesis). While we cannot measure its specific intensity at these sites, or its frequency through time, it appears to have been a ubiquitous practice, seen throughout the occupational histories of these shelters (Storck 1972). Grease production does not seem to have occurred sporadically, but rather seems to have been a regular part of the Archaic and Woodland economies.

Since grease production occurred in rockshelter settings, it was associated with an intensive harvest and utilization of the white-tailed deer (Theler 1987; Theler and Boszhardt 2006). As discussed in Chapter IV, these sites were primarily occupied in the late-fall through early-spring, by small microbands who dispersed into the protected uplands during the cool season. Here they actively pursued white-tailed deer, along with other large game, and supplemented their diet with an array of smaller mammals and birds. While paleoethnobotanical data are limited, mast resources were also probably an important dietary component (Benn 1980; Tiffany 1974). The significance of the white-tailed deer is indicated, not only by its dominance of the faunal assemblages (Table 1), but also by an intensive utilization of its carcasses. Based upon the available data, it appears that entire deer carcasses were regularly transported back to the shelters, with minimal field processing (see Table 4, and discussion in Chapter IV). Dental eruption patterns show that most of the deer were taken during the late-fall and early-winter. This coincides with the breeding season, or rut, when deer could have been more easily harvested. It is also at this time of the year that hides were at their thickest and before their fat supplies were depleted.

Bone grease production does not appear to have been actively pursued at other times of the year, as evidenced by the relative lack of deer remains at warm-season occupations (Theler 1987). Instead, grease production seems to be exclusively associated with these intensive fall-winter deer harvests. While deer may not have been taken in mass kills, like the bison of the Plains, they would have been more readily available at this time of year. The cool weather may have allowed the bones from multiple individuals to be stored for massive grease processing events. As discussed in the preceding section, the ability to process more than one carcass simultaneously would have substantially lowered overall handling costs. Furthermore, experimental work (see Chapter VII) shows that white-tailed deer grease yields may have been greater than previously suggested (cf. Church and Lyman 2003). A prime Wisconsin 1.5 year old male deer produced 539 g of grease, equating to approximately 5,056 kcal (Table 43). This would have been enough grease to support a single individual for up to two days, with no additional food supplies. While many hours of work were put into processing this entire animal, the returns still appeared to be fairly plentiful. If multiple animals could have been processed simultaneously, the net yield would have surely been much greater.

The data from the Archaic and Woodland sites confirms the suggestions above and indicates that there is indeed a problem with the *straightforward* application of the prey-as-patch model. The model predicts that grease, a low ranked resource, should only be produced in times when the harvest rate for large animals is low (Burger et al. 2005; Outram 2004). The data from the shelters, however, indicate that the exact opposite has happened. Here, grease seems to have been produced in concert with intensified white-tailed deer harvests. As discussed in the preceding section, the problem with the traditional prey-as-patch model is that it assumes that carcasses are processed individually. However, with mass harvests and/or the ability to store elements, many carcasses can be processed simultaneously. The ability to process multiple carcasses may substantially lower the overall costs for certain resources, including bone grease. Therefore, bone grease may not only be produced in times of starvation, but also during times of plenty, when costs can be lowered, and stores can be created for times of anticipated need.

Both fats and carbohydrates may have been very difficult to come across in the pre-agricultural Midwest, particularly during the winter months. Therefore, when we apply optimal foraging models to the ancient cultures of this region, we must realize that a simple currency, such as overall caloric return, is probably inappropriate. Instead, the acquisition of fat may have been an equally important motivating factor in the deer harvest. Bone grease may well have been one of the more optimal sources of fat. The fact that deer were already highly-valued and sought after for their hides, meat, sinew, and bones may have further increased the overall value of bone fat. Deer obtained for the meat and hides could have been transported back to camp and then their bones could have been processed for marrow and grease. This would have created the advantage of not having to seek out alternate sources of fat. Midwestern winters can be rather harsh and the amount of time that one can spend out of the elements and consuming easily stored resources, such as bone grease, would have undoubtedly increased one's overall fitness.

The ability to transport carcasses back to the shelters and process grease at later times highlights another problem with simple applications of the prey-as-patch model. This model is based upon the patch-choice model (see Kelly 1995), which is ultimately built upon the marginal value theorem (see Stephens and Krebs 1986). The marginal value theorem assumes that processing time is separate from travel time (between kills). Although, there would still have been a cost in transporting the carcass back to the shelter, the actual processing of the animal, would not have necessarily interfered with time spent searching for additional animals. The processing of grease was likely undertaken by those excluded from hunting, due to age, sex, health, or other factors. These people would have remained at the shelter and could have produced grease, while others were hunting. This would have increased the overall return on activities, such as grease production, as it meant that more time could be spent hunting.

Although the production of bone grease among Archaic and Woodland peoples certainly indicates a chronic need for fat, its production should not be viewed as marginal, nor should it be immediately considered a starvation resource. Although grease production is a labor-intensive process, it should not be automatically considered a low-ranking resource, as the traditional applications of behavioral ecology models would seem to imply (see similar arguments by Brink 1997 and Prince 2007). This by no means indicates that these models are incorrect, it just means that we need to more carefully define their components, particularly their currencies and constraints, when looking at grease production.

In describing the archaeological application of the prey-as-patch model, Burger et al. (2005:1149) state that:

> As archaeology deals with past decisions, the decisions themselves cannot be predicted. Rather, the model offers a theoretically grounded method for retrodicting the conditions under which the foraging decisions were made. In doing so, we shift the emphasis toward using foraging models to *identify the important constraints and currencies* that conditioned past decisions [emphasis added].

When applying optimal foraging models to archaeology, it is critical to realize that archaeological data cannot provide tests for the reliability of the models. The basic tenets of the models are expected to hold true, and have been demonstrated through ethnography. Instead, archaeologists must understand that the value of these models comes from scenarios where they do not accurately fit ancient datasets. In these situations, the model itself is not inherently flawed, but we have probably misjudged the currencies or constraints involved. Through these errors, and their reassessments, we come to understand the real factors that guided ancient foraging decisions.

In the case of the Archaic and Woodland bone grease manufacture, we have seen a number of areas where the traditional currencies and constraints of the prey-as-patch model have been wrong. First, we see that the probable currency was not simply overall energetic return. The intensity deer carcass processing was probably determined just as significantly for fat as for meat. Additionally, common constraints of the model did not hold true. Multiple individuals could be processed simultaneously and grease production likely did not interfere with hunting time. These two factors mean that the overall value of bone grease was higher, because the costs of its production were lower. These misjudgments of typical currencies and constraints do not mean that the model is wrong, rather they show us that fall and winter economies during the Archaic and Woodland were heavily conditioned by the acquisition of fat. Furthermore, they show us that fat supplies were acquired through large-scale processing events that were associated with extensive deer harvests. Through reassessing the currencies and constraints, we have come to understand that bone-grease was not a second-line resource, but rather one of the optimal sources of fat in this environment.

Prehistoric societies of the Driftless Area were not using bone grease as part of a "starvation diet" (cf. Berwick 1975:19), but were utilizing white-tailed deer in an intensive fashion. It was, without question, the most important animal species to the prehistoric cultures of this region and data from Archaic and Woodland rockshelters show that is comprised more than 80-90 percent of the animal diet. These people were focused on harvesting a very high-ranking resource and do not appear to have been stressed to the point of seeking out numerous small-bodied animals that may have been easier to catch, but provided much lower returns. The deer was harvested for many reasons: hides, meat, bones, sinew, antlers, and fat. The fact that deer provided more than just meat meant that people had to turn to fewer resources to meet their needs.

Although Archaic and Woodland peoples seem to have regularly produced bone grease, there is likely a great deal of variability in the frequency and intensity of this practice. Unfortunately, there is not enough data to specifically look at these issues. Again, while grease may have been a higher-ranked resource than previously suggested, this does not invalidate the prey-as-patch model. This model still allows us to see that as foraging efficiency declines, the intensity and frequency of grease production should increase. During times of abundance, the carcasses should be processed more minimally, and grease production may have only included the highest-ranked elements. In certain situations, grease may not even be produced due to an abundance of other fat sources.

The white-tailed deer remains from the "Mr. Head" bone pile at the Gottschall Rockshelter showed no signs of grease manufacture, but seemed to have been the residue of simple marrow extraction (see Chapter VI). This example serves to show that even though grease production was common at these sites, it was not always consistent. In certain situations, harvests may have been very large and other fat sources (such as nuts) may have been so abundant that grease production was not necessary, or at least more limited. Conversely, in times of hardship, great effort was likely placed into processing low-yielding elements of the carcass. Remains from Millville Village (Table 10) show that here nearly every portion of the carcass was used in grease production (including the cranium, vertebrae, ribs, phalanges, carpals, and tarsals). This represents a very intensive utilization of the deer carcass, and may have been carried out due decreased encounters with white-tails, or because of a greater anticipated need.

The key to understanding actual fluctuations in resource availability and foraging efficiency, comes not from isolated examples like Gottschall and Millville Village, but from long-term measures in the frequency and intensity of grease production. In order to accomplish this task, we must be able to analyze stratified faunal assemblages and compare levels of fragment size and element utilization. To do so, the rockshleter assemblages need to be reanalyzed with the methodology developed earlier in this thesis and segregated by major stratigraphic or cultural divisions. These data should also be correlated with additional information on diet-breadth and paleoenvironmental reconstructions to better evaluate economic changes. By doing so, we may better understand how people responded to climatic events, such as the altithermal, or to changing cultural conditions. Theler and Boszhardt (2006) have suggested that human overpopulation and overharvest of the white-tailed deer may have led to the collapse of Late Woodland societies and the adoption of Oneota life-ways. The measurement of grease production intensity through stratified Woodland deposits, would certainly provide a powerful test for this hypothesis.

Role of Bone Grease in Oneota Society

Grease production among the La Crosse Area Oneota appears to have taken place in a much different context than that observed among the earlier Archaic and Woodland societies. Overall, there is no evidence for widespread grease production at any of these sites. Evidence for grease production has only recently started to emerge from this region, despite long-term excavations in the area. In fact, the only known examples of grease production from La Crosse Area Oneota sites are those analyzed in this thesis. Analysis conducted herein, indicate that five Oneota assemblages have strong evidence for grease production: Krause (Features 82, 438, and 441), Long Coulee, and Holley Street. Remains from Feature 205 at the Sanford Archaeological District are more mixed and represent the products of many different activities. Grease production may have been present, but it is extremely difficult to identify in a composite assemblage.

Once again, the key to understanding the motivating factors behind Oneota grease production comes from a careful examination of the overall context. Here, we see that evidence for grease manufacture looks much different from that seen in Archaic and Woodland rockshelters. Rather than being abundant and wide-spread at the Oneota sites, evidence for grease production comes from isolated pit features. Futhermore, grease production at Oneota sites is not associated with the intense harvest of large animals, such as white-tailed deer. The Oneota diet seems to have been much more reliant upon agricultural products and smaller-bodied floodplain resources (see discussion in Chapter IV). White-tailed deer remains were much less abundant on Oneota sites and only comprised an average of 30 percent of the mammalian faunal assemblages (Table 1). Comparatively, deer made up average of 82 and 88 percent of the mammalian faunal remains from Archaic and Woodland rockshelters, respectively (Table 1).

The reason for the lower frequency of deer remains at Oneota sites was probably two-fold. First, Oneota settlements were very large agricultural villages and were occupied for a long portion of the year. Unlike, Archaic and Woodland groups who could have more easily relocated upon exhausting the resources of one area, Oneota societies were tied to specific locales. Even though the white-tailed deer was probably a valued resource among the Oneota, its populations would have quickly diminished in the vicinity of the villages as a result of patch depression. This meant that in order to harvest deer, hunters would have needed to travel some distance from the villages. The increased travel costs would have certainly reduced the overall value of this animal (see predictions of the central place foraging model (Kelly 1995)). Alternatively, the resource rich floodplain of the nearby Mississippi River may have been more attractive. While riverine resources would not have provided as great of a return as the white-tailed deer, they would have been easily harvested in large quantities, which likely outweighed the costs of traveling further to find deer. Remains from Oneota sites do show an emphasis upon wetland resources (see Chapter IV). Furthermore, white-tailed deer remains from these sites show a highly biased representation of skeletal elements. Remains of the lower limbs are greatly overrepresented (see Table 5), which Theler (1989:223-235, 2000) has interpreted to be the result of significant field butchery. This scenario is again consistent with the predictions of the central place foraging model (Kelly 1995).

The second reason that white-tailed deer may not have been as frequently harvested by the Oneota is that their villages seem to have been largely abandoned during the late fall and winter. It has been suggested that the Oneota moved westward onto the prairies of Minnesota to harvest bison at this time of the year (Arzigian et al. 1989; Boaszhardt 2000a; Sasso 1993). This would have placed the Oneota outside of the Driftless Area during the white-tailed deer rut. It is at this time of the year that deer would have been in their prime condition and most easily harvested. Deer that were taken during the summer may not have been of as much value, as their hides would have been thinner and they would have been less fat. Overall, evidence for Oneota fall and winter occupation of the La Crosse region seems to be very slim. More recent evidence (Arzigian 2001, Theler 2001) suggests that limited cool season occupations did occur at some sites. This should not be surprising, as we would expect that not all members of the society could have been able to make the westward bison hunting trip. Those in poor health, the very young and old, and perhaps those who were heavily pregnant or nursing may have remained behind and lived off stored crops and any other resources they could capture.

Given the general lack of fall and winter seasonal indicators on La Crosse Oneota sites, it is intriguing that three of the five bone grease assemblages contained evidence for a cool season occupation. The other two assemblages did not have reliable indicators of seasonality. Deer remains from Feature 438 at the Krause Site included deciduous maxillary teeth of an individual that was one-and-a-half years old and was likely taken during November or December (see Chapter VI). The same pit also contained pieces of nutshell and wild rice. Both of these items are rare on Oneota sites and could reflect fall-winter occupations (Arzigian 1989:142-146). Remains from Feature 441 at Krause also contained numerous hickory nutshell fragments, again suggestive of a cool season occupation. Both Features 438 and 441 were located very near, and perhaps associated with, a house structure at Krause that seems to have been occupied during the winter. Additionally, the bone grease assemblage from the Long Coulee Site may have also been produced during the winter. More recent excavations at the site indicated that much of the site may have been occupied during the winter (Constance M. Arzigian, personal communication 2005). The remains from Feature 82 at the Krause Site, and those from the Holley Street Site, could not be assigned to a specific season.

The overall context of these remains hints that they may be more indicative of stressful situations, as compared to the evidence for regular, widespread grease production in earlier rockshelter assemblages. First, the grease manufacture on the Oneota sites occurred in the absence of intensive large mammal harvests. The Long Coulee assemblage, and Feature 438 at Krause each contained the remains of two white-tailed deer All the other examples of Oneota grease production seem to have involved single individuals. Therefore, the costs of grease production may have been significantly higher, and the decision to produce grease may have been made in the realization that few more optimal sources of fat were likely to be encountered. Additionally, since at least three of the assemblages come from the fall-winter, the less active members of the society may have made the kills. Fewer hunters, and fewer good hunters, certainly meant that large mammal kill frequencies would have been reduced. This may have been further impetus for intensive carcass processing and grease production.

The relative intensity of grease production is well demonstrated in the remains from Feature 438 at Krause. Here, nearly every portion of the animal was fragmented. The ribs, vertebrae, crania, mandibles, and phalanges were all included in grease manufacture (Table 18). These elements are low-ranked in terms ofboth their small grease yield and low grease quality. Many are difficult to remove from the hide and attached tissues. The amount of work necessary to process these elements suggests that they should have only been utilized in stressful circumstances. High intensity grease production is also seen at Long Coulee, where the assemblage included numerous ribs, phalanges, and carpals/tarsals (Table 30); again, all low-ranked grease elements. While these assemblages may have been processed under times of stress, there is some variability in the remaining three assemblages.

The remains from Holley Street were interesting in that they were dominated by low-ranked deer elements (vertebrae, metapodials, phalanges, and carpals), to the near exclusion of high-ranked resources. If fat was a crucial driving force behind the acquisition of this animal, we should have expected the high-ranked elements to have also been included in grease production. This assemblage was difficult to interpret. Since most of the remains come from the lower limbs, it is possible that it may be indicative of starvation, as these elements would have been the last to retain fat on highly stressed animal (see Chapter III). Conversely, the lower elements are also higher in essential fatty acid content (Binford 1978), so even though they yield less grease, that which can be obtained is a very high quality fat. In this case, they may have been targeted as more of a delicacy. Yet another possible explanation is that the element representation may have been conditioned by in field transport decisions. As noted above, most deer remains on Oneota sites are lower limb elements that may have "ridden" back to the site while attached to the hide.

The two remaining Oneota bone grease assemblages came from Features 82 and 441 at the Krause Site. Interestingly, both were comprised of American elk bone, as opposed to white-tailed deer. Both of these assemblages were dominated by all of the major long bones, most of which were high-ranked grease elements in terms of either quality or quantity (Binford 1978; Brink 1997). A few phalanges and tarsals were present, but most of the low-ranked grease elements were absent. Since the American elk was a much larger animal than the white-tailed deer, the skeletal part frequencies in these assemblages were probably much more biased by field butchery and transport decisions. Even if the animal was taken very near the site, it would have been very difficult to transport the entire carcass back to the village. Some elements must have been culled. Since many of the elements present in these assemblages would have also held large meat packages, it is difficult to determine if transport decisions were conditioned more by the need for protein, fat, or both. That being said, as a relatively small quantity of bones from individual animals were processed for grease, it seems that fat was in great enough demand that considerable labor was afforded to its acquisition.

Taken together, the Oneota assemblages are difficult to interpret as they are all isolated examples of bone grease production and thus do not provide for a diachronic assessment of its relative frequency. All seem to show some hints of resource stress. The most convincing examples are Feature 438 at Krause and the assemblage from Long Coulee. Both are associated with limited cool season occupations and both show a very intensive utilization of the animal carcass. Both would have required considerable labor in relation to their overall yield, and the inclusion of extremely low ranked elements (phalanges and cranium) suggests some degree of desperation. The utilization of only low ranked elements at Holley Street may correlate to the processing of an extremely stressed animal, where these were only remaining elements with appreciable quantities of fat. Finally, the elk assemblages from Krause contained only the limb elements (probably dictated by transport decisions), yet were all extensively processed for grease. Even though these animals were fairly large, the grease yield must have been relatively small in comparison to the amount of work involved in its production.

While it is tempting to view all of these assemblages as the product of acute resource stress, some other factors must be considered. First, unlike Archaic and Woodland populations, the inhabitants of the Oneota villages should have possessed ample supplies of agricultural crops. Since these foods are high in carbohydrates, the concerns about the protein ceiling would not have been as great among the Oneota. While living off these crops through the winter would have been physiologically possible, it may have been a very monotonous diet. The natural human desire for fat may have outweighed some of the costs involved in grease production. Furthermore, since the grease was likely produced back at the village, independent of hunting time, the overall costs may not have been as substantial. Even if grease was targeted for production to break up the monotony of the winter diet, the amount of labor involved in its production was substantial. Since only one, or two, animals were processed simultaneously, the desire for fat must have been intense.

CHAPTER IX
CONCLUSION

In this final chapter, I look back upon the principal findings of this thesis and contemplate their greater anthropological significance. In the first section, I review the research and analysis conducted in this study in order to provide the reader with a concise summary of the knowledge learned here within. Following this summary, I consider some of the more general conclusions derived from this research. In doing so, I examine it's implications for the archaeological exploration of prehistoric economies across the globe and then take a retrospective look at bone grease production and its relevance to understanding important anthropological topics, such as the remarkable versatility of human culture and adaptability. In the final section of this thesis, I explore potential avenues for future research that may strengthen and expand the results of this investigation.

Summary

The primary question addressed by this thesis was*did prehistoric groups in the Driftless Area produce bone grease, and, if so, in what contexts did this practice occur*? While the question seemed pretty straightforward, it required a substantial literature review and the analysis of numerous faunal assemblages. To better manage and understand the question, research was divided into five major topics. The following sub-sections summarize how these topics were approached, what was learned, and how that information relates back to addressing the primary goal of this thesis.

1.) Establish the Potential Economic Uses and Value of Bone Grease

Before beginning an in depth review of bone grease production in the Driftless Area, it was necessary to develop some basic background information regarding bone grease. Ethnographic and archaeological data was reviewed to better determine how bone grease was produced and under what circumstances its production occurred. It was shown that bone grease production occurred in two major cultural contexts: (1) during times of starvation, and (2) when large animals were harvested in mass numbers, resulting in lowered production costs. Bone grease seemed to have been most commonly consumed as a food, although other utilitarian purposes could not be completely ruled out.

Previous work had shown that white-tailed deer would have produced an exceedingly limited quantity of bone grease (Church and Lyman 2003). To better evaluate this hypothesis, experimental work was conducted to determine how much grease could be obtained from an entire deer carcass. Two white-tailed deer were processed for bone grease and they yielded 5,056 kcal and 3,762 kcal, respectively. While a tremendous amount of labor was required to obtain the grease, the resulting yields proved to be fairly substantial. This indicated that bone grease production might not have been as desperate of an activity as previously suggested.

Recent applications of optimal foraging theory (i.e. the prey-as-patch model) to carcass processing intensity have suggested that bone grease should have been among the last energy sources extracted from an animal carcass (Burger et al. 2005; Outram 2004). In light of this model, grease has been seen as a marginal resource that should have only been utilized in times of resource stress. The review of ethnographic data, however, showed that grease was frequently produced during times of plenty. In these cases, it was associated with mass animal harvests and manufactured in order to create stores for the lean winter months. These data indicated a number of potential problems with the straightforward application of the prey-as-patch model. The primary issue was that the model assumed that every animal carcass would have been processed individually. In the cases of mass harvests, or where bones can be stockpiled for later use, multiple individuals can be processed simultaneously, therefore lowering the overall cost of grease manufacture. This concern does not invalidate the model, it just means that we have to understand the cultural context in which grease production occurred in order to determine its motivating factors.

2.) Develop a Methodology Appropriate for Identifying and Quantifying Bone Grease Production in the Archaeological Record of the Driftless Area

During the review of the ethnographic and archaeological data, four criteria were determined to be of significance when attempting to identify bone grease production in the archaeological record. First, it was noted that we should expect all bones to have been heavily fragmented to aid in grease extraction. In order to determine the fragmentation intensity and make inter-site comparisons it was necessary to establish a quantitative measure of bone fragment size. This was accomplished by measuring all bones and placing them into size categories based upon their maximum length (Table 7). Counts and weights were calculated for each size category, allowing for graphical representation and comparisons of fragmentation intensity.

The second criterion was that all bones should have displayed signs that they were fragmented while fresh and as the result of intentional human activity. The remains were inspected for evidence of green bone fractures and signatures of human caused bone breakage. The bones were also examined for signs of non-human modification to rule out other possible fracture agents.

The third criterion involved and examination of the overall taphonomic history of the bones. This was considered necessary in order to make accurate comparisons between assemblages. The remains were all examined for modifications that may have mimicked or obscured evidence of bone grease production. These modifications included burning, animal gnawing, weathering, and post-depositional attrition.

The final criterion includes an evaluation of the physical context of the remains. Ethnographic data indicate that evidence for bone grease production could occur in three contexts: primary, mixed secondary, and discrete secondary. Remains in a primary context retain their original association with the tools and facilities involved in bone grease production. Primary contexts are more common in briefly occupied, special-purpose camps. At larger, more permanent settlements, the bones are more likely to lose this association, leaving them in a secondary context. In secondary contexts, remains of grease production occur as either mixed or discrete deposits. In mixed secondary deposits, bone is spread across the site and more likely modified/destroyed, thus limiting the archaeological visibility of grease manufacture. Bones in discrete secondary deposits are those that occur as piles of crushed bone within refuse pits or other features. Here, grease production is more recognizable as the bones have less of an opportunity to become modified and mixed with the remains associated with other activities.

All four criteria are important in evaluating the archaeological occurrence of bone grease production, but none of them should be considered individually. They must all be taken together in order to definitively identify grease production. Also, it should be noted that none of the criteria provide an easy cut-off point for the recognition of grease manufacture. Ultimately, this determination must be left up to the analyst. In mixed deposits, one may have to rely more upon intra- and inter-site comparisons of relative fragmentation rates (fragment size and fresh fracture frequency) inorder to make meaningful conclusions regarding carcass processing intensity.

3.) Review and Evaluate Existing Data Regarding Archaeological Bone Grease Production in the Driftless Area

Evidence for bone grease production was previously discussed at seven sites: Raddatz Rockshelter, Durst Rockshelter, Lawrence I Rockshelter, Mayland Cave, Preston Rockshelter, Warsaw Rockshelter, and Millville Village. With the exception of Millville, none of the remains from these sites were obtained for reanalysis. Therefore, a determination of the grease production at these sites had to be made based upon the existing descriptions of the assemblages. All of the descriptions were carefully scrutinized in regard to the four criteria discussed above. Based upon this review, all of the sites do seem to have contained ample evidence of bone grease production. While changes in the frequency of grease manufacture at these sites could not be measured, evidence for bone grease was abundant and ubiquitous throughout their deposits.

All of these sites were Archaic and Woodland settlements that were primarily inhabited during the fall and winter. They were occupied by microbands who dispersed into the uplands to ride out the winter in protected settlements. These people actively pursued white-tailed deer during the late-fall and early-winter, when they were probably harvested in substantial numbers. Element representation indicates that the entire deer carcass was transported back to the site.

4.) Analyze Available Assemblages to Determine if they are the Result of Bone Grease Production

In addition to the previously reported accounts of bone grease production from the Driftless Area, eight assemblages were obtained from six sites to be evaluated for bone grease production (Table 6). Six of these assemblages were initially suspected to have been the product of grease manufacture and were systematically analyzed here for further confirmation. The other two assemblages were analyzed because preliminary review indicated that they were probably not the result of grease production. It was hoped they could be used as comparative samples to contrast against the more obvious bone grease assemblages. One of the suspected grease assemblages was from late Middle Woodland deposits at the Millville Village. The other five suspected bone grease assemblages were all from La Crosse Area Oneota villages: Krause (Features 82, 438, and 441), Long Coulee, and Holley Street. The comparative samples came from a Late Woodland deposit at the Gottschall Rockshelter and a large Oneota feature at the Sanford Archaeological District.

All of these assemblages were analyzed in regard to the criteria established above to determine the extent of grease production/carcass processing. The Millville Village, Krause, Long Coulee, and Holley Street assemblages were all from discrete bone piles in refuse pits. They had all been very intensively fragmented, and evidence showed that the breakage was undoubtedly the result of human activity. Furthermore, they were very well-preserved and did not have any taphonomic modifications that would have masked or mimicked grease production. Their occurrence as discrete deposits of heavily fragmented bone pretty clearly indicated that they were in fact the result of grease manufacture. With the exception of Millville Village, all of these bone grease assemblages were from Oneota features and contained the remains of only one or two individual animals each. Additionally, three of the Oneota features had evidence that the grease production occurred during the late-fall or early-winter.

The two comparative assemblages from Gottschall and Sanford looked much different. While the remains from the Gottschall Rockshelter where found in a discrete deposit, they did not appear to have been the product of grease manufacture. The bones were not very fragmented and the assemblage included many unbroken long bone epiphyses. This example appeared to have been result of simple marrow extraction. The assemblage from the Sanford Archaeological District showed a pattern of fragmentation somewhere between that of the more classic bone grease assemblages and that seen at Gottschall. This was not surprising, considering that the Sanford remains were not from a discrete deposit, but were spread throughout a very large refuse feature. This feature contained the residue of many different activities, and as such, it is difficult to determine if single episodes bone grease production were represented in the mix of remains.

5.) Examine the Role that Bone Grease Played in the Prehistoric Societies of Wisconsin's Driftless Area

Bone grease production in the Driftless Area occurred in two distinct cultural contexts: Archaic/Woodland rockshelters and Oneota villages. At the Archaic and Woodland sites, evidence for bone grease production was very abundant and has been recognized for some time. Here, grease production occurred in connection with an intense fall harvest of white-tailed deer. The deer were primarily taken during the rut and would have been in their prime condition at this time of the year. It seems that rather than being the result of resource stress, bone grease was produced in large quantities in order to create stores for the winter months. Since deer would have been taken frequently, and bones could have been stockpiled for large processing events, the costs of making bone grease would have been substantially reduced. While grease production was common at these sites, there was likely some degree of variability in the intensity of its manufacture. When times were hard, more lower-raking elements should have been included in the processing and grease manufacture would have been much more intense. Currently, data are not available to document these diachronic changes, although this should be the focus of future work as it may help us understand prehistoric changes in foraging patterns.

At the Oneota sites, evidence for bone grease production was quite rare. Despite extensive excavations over the past several decades, the only know examples of bone grease production on La Crosse Area Oneota sites were those examined in this thesis. Even more interesting was that three of the five examples of Oneota grease production likely occurred during the fall or early winter (the other two could not be assigned to a season). It has been suggested that the Oneota peoples largely abandoned the La Crosse Area at this time of the year to pursue bison hunting on the prairies of Minnesota. Undoubtedly, some of individuals would have needed to stay behind due to poor health or physical disabilities. These individuals would have certainly been stressed during the winter and probably had few sources of fat. When deer and elk were harvested they were undoubtedly processed very extensively to acquire as much fat as possible. This appears to have included bone grease production. Carcass utilization seems to have been very intense with the Feature 438 remains from Krause, where all the major elements of two white-tailed deer had been processed for grease. In these scenarios, grease manufacture does seem to be indicative of acute resource stress.

Conclusions

The focus of this thesis has been upon the role of bone grease production among the prehistoric societies of the upper Midwest; however, the results of the study have implications far beyond this limited geographic area. Perhaps the single most significant finding of this research is that bone grease production is not always linked to resource stress, as many authors seem to indicate (e.g. Berwick 1975; Broughton 1999; Church and Lyman 2003; Logan 1998; Outram 1999, 2003, 2004; Munro 2004; Munro and Bar-Oz 2005; Pillaert 1969; Ugan 2005). As demonstrated above, bone grease was a regular part of the diet among the Archaic and Woodland cultures of the Driftless Area. While, it certainly could have been a critical starvation resource, it wasn't produced only in times of scarcity; it was also manufactured with great ubiquity throughout much of prehistory. The most extensive episodes of grease production occurred not when resources were limited, but rather when white-tailed deer and other large mammals where harvested in large numbers. In these situations grease could have been produced in substantial quantities and stored for the winter season when the need for fat would have been considerable. While this indicates that the environment had a chronically insufficient supply of readily accessible fats (at least during the winter), it should not imply that the inhabitants were economically stressed. Large amounts of grease could have been rendered in mass production events, thus reducing the cost of processing a single animal. Similar opinions regarding the manufacture of surplus grease during times of plenty, for storage, have been echoed elsewhere (Brink 1997; Prince 2007).

Furthermore, grease production occurred at a time of the year when the weather would have been quite harsh, making search conditions for other resources sub-optimal. As deer were already valued for their hides and meat, they were the focus of hunting efforts. While other fat sources may have been easier to process, the fact that deer were already being harvested and returned to camp for reasons beyond grease, meant that time would not have to be afforded to search for additional fat sources. The amount of labor involved in grease production apparently did not outweigh that required for searching out and processing other animal based fats.

Multitudes of past cultures throughout North America, as well as the rest of the world, lived regions with similarly pronounced seasonal food shortages. These people were intimately aware of their environments and prepared for these anticipated shortages in many ways. Most stockpiled resources when they were abundant and could have been easily harvested and processed. In many instances, processing of resources for storage was extensive, taking days, weeks, or even months (e.g. salmon on the Northwest Coast and bison on the Plains). Although these people dedicated extensive time to these activities, we should not see them as indicators of resource stress. They were a regular part of the economy, practiced for thousands of years. Certainly, these people lived in regions with chronic seasonal fluctuations in the abundance of particular resources, but that does not mean that they would have seen themselves living a stressed lifestyle.

The acknowledgement that bone grease production is motivated by a variety of factors (not simply resource stress) is an important lesson that should be heeded not only by those studying the ancient inhabitants of the Driftless Area, but by all anthropologists interested in understanding the nature past human economies. Archaeologists shouldn’t consider a particular behavior to be exclusively associated with a single set of past economic, environmental, or social conditions. This review has demonstrated that bone grease was produced under a variety of circumstances, and that in order to understand the motivating factors, we must place the behavior in a larger social context. If we are to determine the presence of resource stress, we must take a broader perspective, looking at how resources, such as bone grease fit into the economy, and whether or not the frequency of their utilization varied through time.

Beyond the specific and more general implications of this research, the study of bone grease gives us some insight as to ingenuity and adaptability of human society. Bone grease is a rather obscure resource. Cancellous bone tissue is a fat source that is not only often disregarded or unnoticed by most animals, but is also something that is exceedingly difficult to access and consume. Excluding large carnivores (such as canids) and certain rodents (i.e. rats; see Klippel and Synstelien 2007), most animals are unable to access the rich fat supplies stored in the cancellous tissue of large mammal bones.

Humans, however, have long recognized the value of bone fat. Hominids were apparently consuming bone marrow by at least the late Pliocene (Bunn 1981; de Heinzelin et al. 1999), and the earliest evidence for bone grease exploitation comes from late Pleistocene cultures (Epipaleolithic) of the Levant (Munro 2004; Munro and Bar-Oz 2005). Bone grease production was not a simple endeavor, but one of considerable effort. It required the harvest of a large animal, transport of the carcass to processing area, removal of the overlying tissues, pulverization of the bones, boiling (something even more involved for pre-ceramic cultures), and recovery/storage of the grease.

This method for the retrieval of rich bone fat was not haphazardly utilized by human societies, but was specifically employed under particular circumstances. Perhaps most uniquely, was its use in survival situations, where starvation was imminent. Here, humans found a method to exploit a high-energy food from a source that was usually discarded or ignored. More significantly, they discovered that not only could the fat be obtained from these bones, but also that it was frequently one of the last remaining fat sources in an environment, present after other resources had been consumed and persisting in animals that had already diminished their subcutaneous and inter/inter-muscular fat stores. In these scenarios, bone grease extraction reflects the ingenuity of human survival tactics and our ability to find and utilize seemingly obscure resources.

Bone grease production also demonstrates the human ability to adapt to unique, and sometimes challenging environments. The ethnographic review in Chapter II showed that bone grease has been produced by many cultures, particularly those in regions of regular (and predictable) seasonal food shortages. Only through our culture and ability to recognize/extract resources, such as bone grease, have humans been able to adapt to and survive in these environments. The ubiquity of bone grease production in temperate, sub-arctic, and arctic latitudes demonstrates that this process was critical for the survival of humans in these regions. Data from places, such as the Driftless Area, where bone grease had been produced for thousands of years further demonstrate the significance of this resource. Once again, it should be emphasized that people inhabiting these environments with a chronic deficit of year-round fat supplies, unlikely saw themselves as overly stressed. Instead, through classic human ingenuity, they were able to take a seemingly limited and obscure resource, produce it in substantial quantities (when plentiful), and use it as stored resource critical to the survival of the lean winter months.

Areas for Future Research

Although this thesis brought together a great deal of data on bone grease production in the Midwest, and helped to place it in a better cultural context, a number of questions remain unresolved. Therefore, I would like to conclude with several important issues that deserve further research:

1.) The remains from the Archaic and Woodland rockshelters need to be more carefully examined. In this study, I was only able to explore previously published data – which implied bone grease production. In all likelihood there is more variability in the rockshelter assemblages. What elements were being processed for grease? Was it only the high-yield bones, or were others being processed too? Were more low-utility elements being fragmented in times of resource stress? Can we observe diachronic changes in the frequency and intensity of grease manufacture? Evidence from these sites should not only be approached through the systematic methodology outlined in this thesis, but should also be analyzed by major stratigraphic/cultural divisions in order to observe these changes. This would certainly provide a good test for Theler and Boszhardt's (2006) model of white-tailed deer population collapse and the end of the Woodland Tradition.

2.) What is the nature and degree of Oneota bone grease processing? Although I have argued that bone grease exploitation was never abundant on Oneota sites (as compared to earlier rockshelters), its full extent remains unclear. La Crosse Oneota sites are quite large and the debris from grease processing events could have become easily scattered. Unless the bone fragments were always deposited in pit features (as they most certainly were not), the frequency of grease production was underestimated. It is hoped that further studies will utilize the methods developed by Outram (1998, 2001, 2002), and expanded upon here, to examine/compare bones from a wider array of contexts in order to better resolve this issue.

3.) More work should be done to identify bone grease production through the physical and chemical effects it leaves on bones. While small bone fragments are key in the identification of bone grease production, they are subject to many factors that may obscure evidence for grease manufacture. The ability to determine if the bones had actually been boiled would certainly strengthen any argument for grease production. Additional work should be done to identify physical signs of boiling, such as White's (1992:120-128) "pot polish." Even more intriguing is the possibility of recognizing boiling through microscopic and chemical means. Recent work has demonstrated collagen loss in boiled/cooked bones (Roberts et al. 2002). In particular, the use of Transmission Electron Microscopy has shown the ability to observe damage on collagen fibers in boiled/cooked bones and was successful in separating archaeological samples of presumably cooked from non-cooked bone (Koon et al. 2003, 2009). Further research should be conducted in this area, and it would be interesting to submit several of the archaeological specimens analyzed in this thesis to the methods developed by Koon et al. (2009) in an attempt to observe damage to collagen fibers.

4.) Models relying on optimal foraging theory need to be more comprehensively developed for the study of animal carcass utilization. Those that currently exist are derived from analogies to the behavior of non-human predators. Although these models are useful in understanding the motivations behind past human behavior, a number of problems remain in their direct application to the archaeological record. In particular, the prey-as-patch model (which infers that carcass processing intensity is tied to resource abundance) has a number of issues that were touched upon in this thesis. While the model is not critically flawed, and can still serves as a useful heuristic device for exploring carcass processing decisions, it needs to be adjusted to contend with these issues. Most importantly, it needs to be amended to include scenarios of mass kills/processing events. Furthermore we need to also bring the focus away from immediate need and towards more long-term need. Humans can often anticipate seasonal food shortages and avert stress through the accumulation of resource stores.

5.) Evidence for grease production should be integrated with additional data to better interpret its economic role/significance. This is particularly true if we wish to focus upon long-term variations in the factors dictating its manufacture. While understanding the driving factors behind grease production requires a comprehensive view of all cultural aspects, a strong focus should be placed upon those related to environmental and economic change. Most importantly we need to be looking at faunal data for changes in animal processing/butchery, carcass transport, diet breadth, etc. Similar data on floral resources, as well as evidence for past climate/environmental change, should also be incorporated.

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APPENDIX

Table A.1. Identified faunal remains from Feature 95 at the Millville Village Site (47GT53).

Taxon	NISP	Element	Side	Portion	Description	#GBF
Odocoileus virginianus	11	cranial	?	fragment	-	5
	1	occipital	axial	dorsal	-	1
	1	internal auditory meatus	?	fragment	-	1
	1	maxilla	left	-	w/M1	1
	1	maxilla	left	-	w/M2/M3	1
	1	maxilla	right	-	w/P3 & socket for P4	1
	1	mandible	right	posterior	ascending ramus fragment	1
	1	m1/m2?	left	-	-	0
	2	m1/m2?	right	-	-	0
	3	premolar/molar?	?	-	-	0
	3	axis vertebra	axial	anterior	anterior surface	3
	4	axis vertebra	axial	anterior	left 1/2 of dens	4
	131	vertebra*	axial	fragment	-	0
	5	rib*	?	fragment	-	0
	5	humerus	?	distal	condyle fragment	5
	1	humerus	?	proximal	head fragment	0
	1	humerus	left	diaphysis	anterior-medial fragment	1
	1	humerus	left	diaphysis	distal-posterior fragment	1
	1	humerus	left	distal	medial epicondyle	1
	1	humerus	left	proximal	posterior head fragment	1
	1	humerus	right	proximal	lateral tuberosity	1
	2	ulna	?	proximal	fragment	1
	2	ulna	left	distal	styloid process	2
	1	ulna	left	proximal	olecranon process	1
	1	radius	left	diaphysis	posterior-lateral fragment	1
	2	radius	left	distal	anterior	2
	1	radius	left	distal	anterior-lateral fragment	1
	1	radius	left	distal	medial-anterior	1
	1	radius	left	distal	posterior	1
	1	radius	left	proximal	posterior	1
	1	radius	right	distal	anterior	1
	1	radius	right	distal	posterior-medial fragment	1
	1	radial carpal	left	nearly complete	-	1

Table A.1 (continued). Identified faunal remains from Feature 95 at the Millville Village Site (47GT53).

Taxon	NISP	Element	Side	Portion	Description	#GBF
Odocoileus virginianus	1	radial carpal	right	complete	-	0
	1	intermediate carpal	left	complete	-	0
	1	2nd + 3rd carpal	left	lateral	-	1
	1	2nd + 3rd carpal	left	ventral	-	1
	1	2nd + 3rd carpal	right	lateral	-	1
	1	4th carpal	right	medial	-	1
	1	accessory carpal	?	nearly complete	-	0
	3	metacarpal	?	diaphysis	-	3
	1	ilium	right	-	acetabulum	1
	1	femur	?	distal	condyle fragment	1
	1	femur	?	proximal	head	1
	1	femur	left	proximal	neck	1
	2	tibia	?	proximal	condyle fragment	1
	1	tibia	left	diaphysis	posterior-medial fragment	1
	2	tibia	left	proximal	lateral condyle	2
	1	tibia	left	proximal	posterior portion of lateral condyle	1
	1	tibia	right	diaphysis	anterior	1
	3	tibia	right	distal	medial malleolus	3
	1	lateral malleolus	left	fragment	-	1
	1	lateral malleolus	right	nearly complete	-	0
	1	astragalus	?	fragment	-	1
	2	calcaneus	left	distal	w/ articulation for astragulus	2
	1	calcaneus	right	anterior	anterior process	1
	1	naviculo-cuboid	left	dorsal	-	1
	1	naviculo-cuboid	left	lateral	-	1
	2	naviculo-cuboid	left	medial	-	2
	2	naviculo-cuboid	right	dorsal	-	2
	3	naviculo-cuboid	right	lateral	-	3
	4	naviculo-cuboid	right	medial	-	4
	5	1st tarsal	?	complete	-	0

Table A.1 (continued). Identified faunalremains from Feature 95 at the Millville Village Site (47GT53).

Taxon	NISP	Element	Side	Portion	Description	#GBF
Odocoileus virginianus	2	2nd + 3rd tarsal	right	nearly complete	-	1
	9	metatarsal	?	diaphysis	dorsal shaft w/ vascular groove	9
	3	metatarsal	?	diaphysis	proximal fragment	3
	2	metatarsal	left	proximal	dorsal-lateral fragment	2
	1	metatarsal	left	proximal	dorsal-medial fragment	1
	2	metatarsal	left	proximal	ventral-lateral fragment	2
	1	metatarsal	left	proximal	ventral-medial fragment	1
	2	metatarsal	right	proximal	dorsal-lateral fragment	2
	2	metatarsal	right	proximal	ventral-medial fragment	2
	1	metapodial	?	diaphysis	distal fragment	1
	5	metapodial	?	diaphysis	dorsal fragment	5
	34	metapodial	?	distal	condyle fragment	32
	2	metapodial	?	proximal	fragment	2
	4	sesamoid	?	complete	-	0
	1	sesamoid	?	fragment	-	1
	5	1st phalanx	?	distal	fragment	4
	1	1st phalanx	?	proximal	fragment	1
	3	2nd phalanx	?	distal	fragment	3
	1	2nd phalanx	?	proximal	-	1
	7	3rd phalanx	?	fragment	-	7
	2	residual 3rd phalanx	?	complete	-	0
Centrachidae	1	dentary	right	nearly complete	-	0
Chelydra serpentina	1	carapace	?	fragment	-	0
unid. lg. mammal	1477	-	-	-	-	348
unid. fish	1	-	-	-	-	0
unid. turtle	2	carapace	?	fragment	-	0
unid. bird	11	-	-	-	-	0

*specimens compare favorably (cf.)

Table A.2. Identified faunal remains from the "Mr. Head" Bone Pile (S23, W13) at the Gottschall Rockshelter (47IA80).

Taxon	NISP	Element	Side	Portion	Description	#GBF	Comments
Sylvilagus floridanus	1	humerus	right	distal	-	0	-
	1	astragalus	right	complete	-	0	-
Canis sp.	1	lumbar vertebra	axial	nearly complete	-	0	1-RG
	1	innominate	right	acetabulum	-	0	-
Procyon lotor	1	fibula	left	complete	-	0	-
Odocoileus virginianus	1	frontal	right	fragment	-	1	-
	1	internal auditory meatus	right	nearly complete	-	0	-
	1	external auditory meatus	right	nearly complete	-	0	-
	1	maxilla	left	-	w/ dP2, dP3, dP4, M1	0	1-RG
	1	maxilla	left	-	w/ dP2, dP3, dP4, M1	0	-
	1	maxilla	left	-	w/ dP2, dP3, dP4, M1, M2	0	-
	1	maxilla	left	-	w/ dP3, dP4, M1	0	-
	1	maxilla	left	-	w/ P2, P3, P4, M1, M2, M3	0	-
	1	M1/M2?	left	complete	-	0	-
	1	mandible	left	horizontal ramus	w/ m2	1	-
	1	mandible	left	horizontal ramus	w/ p2, p3, p4, m1	0	-
	1	mandible	right	horizontal ramus	w/ dp2, dp3, dp4, m1, m2	1	-
	1	mandible	right	horizontal ramus	w/ dp2, dp3, dp4, m1, m2	1	-
	1	mandible	right	horizontal ramus	w/ m3	0	-
	1	i1	right	complete	-	0	-
	1	premolar/molar?	?	fragment	-	0	-
	1	hyoid	left	nearly complete	-	0	-
	1	thoracic vertebra	axial	nearly complete	-	0	-
	1	lumbar vertebra	axial	dorsal	-	0	-
	1	vertebra	axial	fragment	-	0	-
	3	rib	?	diaphysis	-	0	-
	2	rib	left	diaphysis	-	0	-
	1	rib	right	diaphysis	-	0	-
	2	scapula	left	distal	-	0	-
	1	humerus	left	diaphysis	posterior-medial fragment	1	-
	2	humerus	left	distal	epiphysis	1	-
	1	humerus	right	diaphysis	-	1	-
	1	humerus	right	diaphysis	distal-medial shaft	1	-

Table A.2 (continued). Identified faunal remains from the "Mr. Head" Bone Pile (S23, W13) at the Gottschall Rockshelter (47IA80).

Taxon	NISP	Element	Side	Portion	Description	#GBF	Comments
Odocoileus virginianus	1	ulna	right	medial	-	0	-
	2	radius	?	diaphysis	posterior	2	-
	1	radius	left	diaphysis	posterior	1	-
	1	radius	left	distal	epiphysis	0	1-calcined
	1	radius	left	proximal	epiphysis	0	-
	1	radius	left	proximal	fragment	0	1-calcined
	1	radius	left	proximal	medial fragment	0	1-calcined
	1	radius	right	distal	epiphysis	0	-
	1	radius-ulna (fused)	right	diaphysis	posterior	1	-
	6	metacarpal	?	diaphysis	dorsal fragment w/ vascular groove	6	-
	1	metacarpal	?	diaphysis	dorsal shaft fragment	1	-
	2	metacarpal	?	diaphysis	ventral fragment	2	-
	1	metacarpal	?	distal	epiphysis	1	-
	2	metacarpal	left	proximal	epiphysis	2	-
	1	metacarpal	right	distal	epiphysis	0	-
	1	metacarpal	right	proximal	fragment	1	-
	1	pubis	left	-	acetabulum	0	-
	1	femur	?	diaphysis	fragment	1	-
	1	femur	left	diaphysis	-	1	-
	1	femur	right	diaphysis	lateral	1	-
	1	femur	right	diaphysis	posterior	1	-
	2	tibia	left	diaphysis	anterior crest	2	-
	6	tibia	left	diaphysis	posterior	6	-
	3	tibia	left	distal	epiphysis	2	-
	2	tibia	right	diaphysis	anterior crest	2	-
	1	tibia	right	diaphysis	distal-lateral shaft	1	-
	7	tibia	right	diaphysis	posterior	7	-
	1	tibia	right	distal	epiphysis	0	-
	3	lateral malleolus	left	complete	-	0	1-burned
	1	naviculo-cuboid	left	complete	-	0	-
	1	naviculo-cuboid	left	lateral	-	0	1-calcined
	1	naviculo-cuboid	right	nearly complete	-	0	-

Table A.2 (continued). Identified faunal remains from the "Mr. Head" Bone Pile (S23, W13) at the Gottschall Rockshelter (47IA80).

Taxon	NISP	Element	Side	Portion	Description	#GBF	Comments
Odocoileus virginianus	11	metatarsal	?	diaphysis	dorsal fragment w/ vascular groove	10	-
	4	metatarsal	?	diaphysis	ventral fragment	4	1-calcined
	2	metatarsal	left	diaphysis	dorsal fragment w/ vascular groove	2	-
	2	metatarsal	left	diaphysis	lateral	2	-
	5	metatarsal	left	distal	epiphysis	3	-
	1	metatarsal	left	proximal	dorsal fragment	0	-
	2	metatarsal	right	diaphysis	dorsal fragment w/ vascular groove	2	1-burned
	2	metatarsal	right	distal	epiphysis	0	-
	1	metatarsal	right	proximal	dorsal fragment	1	-
	1	metatarsal	right	proximal	lateral fragment	1	-
	1	metatarsal	right	proximal	ventral fragment	1	-
	5	metapodial	?	distal	condyle fragment	1	2-burned, 2-calcined
	1	1st phalanx	?	distal	ventral fragment	0	1-calcined
	1	1st phalanx	?	proximal	-	0	1-burned
	1	3rd phalanx	?	complete	-	0	-
Homo s. sapiens	1	femur	?	diaphysis	anterior fragment	1	-
Ectopistes migratorius	1	humerus	right	distal	-	0	-
unid. lg. mammal	436	-	-	-	-	186	52-burned, 68-calcined

Table A.3. Identified faunal remains from Feature 438 at the Krause Site (47LC41).

Taxon	NISP	Element	Side	Portion	Description	#GBF	Comments
Cervus canadensis	1	1st phalanx	?	distal	-	1	-
	1	1st phalanx	?	proximal	-	1	-
Odocoileus virginianus	47	cranial	?	fragment	-	13	-
	1	cranial	left	occipital/ temporal fragment	-	1	-
	1	frontal	axial	dorsal	frontal suture	1	-
	1	frontal	left	fragment	-	1	-
	2	occipital	axial	dorsal	foramen magnum fragment	2	-
	1	occipital	left	condyle	-	1	-
	1	occipital	right	condyle	-	1	-
	1	maxilla	right	anterior	-	1	-
	1	dP2	left	nearly complete	-	0	-
	1	dP2	right	nearly complete	-	0	-
	1	dP3	right	nearly complete	-	0	-
	1	dP4	left	nearly complete	-	0	aged at 18 mos.
	2	M1/M2?	right	nearly complete	-	0	-
	2	M1/M2/M3?	right	nearly complete	-	0	-
	1	mandible	?	ventral	ventral border fragment	1	-
	1	mandible	left	horizontal ramus	w/ socket for p2	0	-
	1	mandible	left	posterior	angle	1	-
	1	mandible	left	posterior	ascending ramus	1	-
	1	mandible	right	horizontal ramus	w/ sockets for i1-i4	0	-
	1	i1	left	nearly complete	-	0	-
	1	i1	right	nearly complete	-	0	-
	1	i2	left	nearly complete	-	0	-
	1	i2	right	nearly complete	-	0	-
	1	i1/i2/i3?	left	nearly complete	-	0	-
	1	i1/i2/i3?	right	nearly complete	-	0	-
	1	p2	left	nearly complete	-	0	-
	1	p3	left	nearly complete	-	0	-
	1	p4	left	nearly complete	-	0	-
	1	p4	right	nearly complete	-	0	-

Table A.3 (continued). Identified faunal remains from Feature 438 at the Krause Site (47LC41).

Taxon	NISP	Element	Side	Portion	Description	#GBF	Comments
Odocoileus virginianus	1	m1/m2?	left	nearly complete	-	0	-
	1	m3	left	nearly complete	-	0	-
	1	m3	right	nearly complete	-	0	aged at 3+ years
	46	premolar/molar?	?	fragment	-	0	-
	1	atlas vertebra	axial	anterior	left 1/2	0	-
	1	atlas vertebra	axial	anterior	right 1/2	1	-
	1	atlas vertebra	axial	posterior	right 1/2	1	-
	1	axis vertebra	axial	anterior	indet. fragment	0	-
	2	axis vertebra	axial	anterior	left 1/2	2	-
	2	axis vertebra	axial	anterior	right 1/2	1	-
	37	vertebra*	axial	fragment	-	0	-
	7	rib*	?	fragment	-	0	-
	1	humerus	left	distal	olecranon fossa	1	-
	1	humerus	right	proximal	head	1	-
	1	ulna	left	diaphysis	-	1	-
	1	ulna	left	proximal	posterior olecranon	1	-
	1	ulna	left	proximal	semi-lunar notch	1	-
	1	radius	left	distal	medial fragment	0	-
	1	radius	left	proximal	lateral portion w/ radial tuberosity	1	-
	1	radius	right	distal	medial fragment	1	-
	1	radius	right	proximal	lateral portion w/ radial tuberosity	1	-
	1	radius	right	proximal	posterior-medial fragment	1	-
	1	metacarpal	left	proximal	lateral fragment	1	-
	1	metacarpal	right	proximal	medial fragment	1	-
	1	femur	?	proximal	head	1	-
	1	tibia	left	proximal	posterior surface	1	-
	1	tibia	left	distal	medial malleolus	1	-
	3	metapodial	?	distal	condyle fragment	3	-
	2	sesamoid	?	complete	-	0	-

Table A.3 (continued). Identified faunal remains from Feature 438 at the Krause Site (47LC41).

Taxon	**NISP**	**Element**	**Side**	**Portion**	**Description**	**#GBF**	**Comments**
Odocoileus virginianus	3	1st phalanx	?	distal	dorsal fragment	3	-
	3	1st phalanx	?	distal	ventral fragment	3	-
	3	1st phalanx	?	proximal	dorsal fragment	3	-
	3	1st phalanx	?	proximal	ventral fragment	3	-
	2	2nd phalanx	?	distal	-	2	-
	1	2nd phalanx	?	lateral	-	1	-
	3	2nd phalanx	?	proximal	-	3	-
Pygonadon grandis	1	valve	right	-	-	0	-
Amblema plicata	1	valve	left	-	-	0	-
unid. lg. mammal	648	-	-	-	-	128	-
unid. naiad	2	valve	?	fragment	-	0	-
	1	valve	left	-	-	0	-

*specimens compare favorably (cf.)

Table A.4. Identified faunal remains from Feature 441 at the Krause Site (47LC41).

Taxon	NISP	Element	Side	Portion	Desc Port	#GBF
Castor canadensis	1	mandible	left	nearly complete	-	0
Cervus canadensis	1	humerus	?	proximal	head	1
	1	ulna	left	proximal	semi-lunar notch	1
	2	radius	right	diaphysis	medial border	2
	1	radius	right	distal	fragment	1
	1	radius	right	proximal	anterior portion	1
	2	radius	right	proximal	lateral portion w/ radial tuberosity	2
	1	radius	right	proximal	medial portion	1
	1	radius	right	proximal	posterior w/ ulnar facets	1
	1	femur	right	distal	intercondyloid fossa	1
	1	femur	right	distal	medial condyle	1
	1	tibia	?	proximal	condyle surface	1
	1	tibia	left	diaphysis	anterior crest	1
	1	tibia	left	diaphysis	medial fragment	1
	1	tibia	left	distal	anterior portion	1
	1	tibia	left	distal	medial malleolus	1
	1	tibia	left	proximal	intercondyloid fossa	1
	1	tibia	left	proximal	medial condyle	1
	1	tibia	left	proximal	medial-anterior portion	1
	1	tibia	left	proximal	posterior portion	1
	1	tibia	right	distal	anterior fragment	1
	1	tibia	right	distal	lateral fragment	1
	1	tibia	right	distal	medial malleolus	1
	1	tibia	right	distal	posterior-lateral fragment	1
	1	tibia	right	proximal	lateral condyle	1
	1	tibia	right	proximal	posterior fragment	1
	1	lateral malleolus	left	nearly complete	-	1
Tritogonia verrucosa	1	valve	right	nearly complete	-	0
unid. lg. mammal	497	-	-	-	-	97
unid. naiad	23	valve	?	fragment	-	0
	1	valve	left	fragment	-	0
	1	valve	right	fragment	-	0

Table A.5. Identified faunal remains from Feature 82 at the Krause Site (47LC41).

Taxon	NISP	Element	Side	Portion	Description	#GBF
Cervus canadensis	1	humerus	right	distal	lateral condyloid crest	1
	1	radius	right	diaphysis	posterior fragment w/ nutrient foramen	1
	1	radius	right	proximal	lateral glenoid cavity	1
	1	metacarpal	right	proximal	dorsal portion w/ vascular groove	1
	1	metacarpal	right	proximal	lateral portion of proximal surface	1
	1	femur	right	distal	lateral condyle	1
	1	femur	right	proximal	lesser trochanter	1
	1	tibia	right	diaphysis	w/ popliteal line	1
	1	tibia	right	distal	lateral fragment	1
	1	tibia	right	distal	medial malleolus	1
	1	tibia	right	proximal	lateral condyle	0
	1	lateral malleolus	right	complete	-	0
	1	astragalus	right	lateral	w/ proximal trochlear ridge	1
	1	naviculo-cuboid	right	dorsal	-	0
	1	naviculo-cuboid	right	proximal	calcaneum facet	1
	1	naviculo-cuboid	right	lateral	-	1
	1	1st tarsal	right	complete	-	0
	1	metatarsal	?	diaphysis	posterior fragment	1
	1	metatarsal	left	proximal	lateral-dorsal portion	1
	1	metatarsal	right	proximal	lateral-ventral fragment	1
	2	metapodial	?	distal	condyles	1
	1	metapodial	?	distal	ventral foramen	1
	1	1st phalanx	?	diaphysis	dorsal fragment	1
	1	2nd phalanx	?	proximal	-	1
unid. lg. mammal	101	-	-	-	-	31

Table A.6. Identified faunal remains from Feature 1 at the Long Coulee Site (47LC333).

Taxon	NISP	Element	Side	Portion	Description	#GBF	Comments
Odocoileus virginianus	33	rib*	-	fragment	-	0	-
	1	scapula	?	-	spine fragment	0	-
	1	scapula	right	anterior	anterior border	1	-
	1	scapula	right	distal	glenoid	0	1-CG, 1-RG
	2	humerus	?	distal	condyle fragment	2	-
	1	humerus	left	distal	medial epicondylar ridge	0	-
	1	ulna	left	diaphysis	proximal	1	-
	1	ulna	right	diaphysis	proximal	1	-
	1	ulna	right	distal	styloid process	1	-
	1	radius	right	distal	medial fragment	1	-
	1	radius	right	distal	posterior fragment	1	-
	2	radius	right	proximal	medial condyle	2	-
	1	radial carpal	left	dorsal	-	1	-
	1	radial carpal	left	ventral	-	1	-
	3	radial carpal	right	complete	-	0	-
	2	ulnar carpal	left	complete	-	0	-
	1	ulnar carpal	right	dorsal	-	0	-
	1	intermediate carpal	left	complete	-	0	-
	2	intermediate carpal	right	fragment	-	2	-
	1	2nd + 3rd carpal	left	complete	-	0	-
	1	2nd + 3rd carpal	right	complete	-	0	-
	1	4th carpal	left	nearly complete	-	0	-
	2	4th carpal	right	nearly complete	-	0	-
	1	metacarpal	?	diaphysis	dorsal fragment	1	-
	2	residual metacarpal	?	fragment	-	0	-
	1	femur	?	proximal	head	1	-
	1	femur	left	diaphysis	linea aspera	1	-
	1	femur	right	distal	supra-condyloid fossa	1	-
	1	tibia	?	proximal	condyle surface	1	-
	1	tibia	left	diaphysis	anterior crest	1	-
	1	tibia	left	proximal	posterior lateral condyle	1	-
	1	calcaneus	?	proximal	tuber calcis	0	-
	1	astragalus	left	distal	lateral fragment	1	-
	1	astragalus	left	distal	medial fragment	1	-

Table A.6 (continued). Identified faunal remains from Feature 1 at the Long Coulee Site (47LC333).

Taxon	NISP	Element	Side	Portion	Description	#GBF	Comments
Odocoileus virginianus	2	astragalus	left	nearly complete	-	0	-
	1	2nd + 3rd tarsal	right	complete	-	0	-
	1	metatarsal	right	proximal	dorsal	1	-
	1	metatarsal	right	proximal	lateral	1	-
	3	metapodial	?	distal	condyle fragment	3	-
	1	1st phalanx	?	diaphysis	-	1	-
	13	1st phalanx	?	distal	-	12	MNE=12
	1	1st phalanx	?	proximal	-	1	-
	7	1st phalanx	?	proximal	dorsal	7	-
	4	1st phalanx	?	proximal	ventral	4	-
	12	2nd phalanx	?	distal	-	12	MNE=11
	1	2nd phalanx	?	proximal	-	1	-
	6	2nd phalanx	?	proximal	dorsal	6	-
	5	2nd phalanx	?	proximal	ventral	4	-
	2	3rd phalanx	?	distal	-	1	-
	1	residual 1st phalanx	?	proximal	-	0	-
Moxostoma carinatum	2	pharyngeal arch	?	fragment	-	0	-
Moxostoma sp.	1	ethmoid	axial	nearly complete	-	0	-
	1	vomer	axial	nearly complete	-	0	-
	1	basioccipital	axial	nearly complete	-	0	-
Catostomidae	3	cranial	?	nearly complete	-	0	-
	1	hyomandibular	?	nearly complete	-	0	-
	1	cleithrum	?	fragment	-	0	-
	1	ceratohyal	?	complete	-	0	-
	1	epihyal	?	complete	-	0	-
	1	pharyngeal arch	right	mid-section	-	0	-
Micropterus sp.	1	dentary	left	nearly complete	-	0	-
unid. lg. mammal	694	-	-	-	-	298	-
unid. fish	30	-	-	-	-	0	-

*specimens compare favorably (cf.)

Table A.7. Identified faunal remains from Feature 1 at the Holley Street Site (47LC485).

Taxon	NISP	Element	Side	Portion	Description	#GBF	Comments
Odocoileus virginianus	1	cranial	?	fragment	-	0	-
	1	parietal	left	fragment	-	1	-
	1	antler	?	tip	-	0	-
	22	vertebra*	axial	fragment	-	16	-
	1	radial carpal	left	complete	-	0	1-calcined
	1	ulnar carpal	left	nearly complete	-	0	1-calcined
	2	ulnar carpal	right	nearly complete	-	0	1-calcined
	1	2nd + 3rd carpal	left	nearly complete	-	1	-
	2	residual metacarpal	?	nearly complete	-	0	1-calcined
	1	metapodial	?	distal	-	1	-
	2	metapodial	?	distal	condyle fragment	2	-
	1	metapodial	?	proximal	-	1	-
	3	sesamoid	?	complete	-	0	1-calcined
	6	1st phalanx	?	distal	-	6	1-burned
	1	1st phalanx	?	proximal	-	0	-
	15	1st phalanx	?	proximal	fragment	13	-
	1	1st phalanx	?	proximal	ventral fragment	1	-
	5	2nd phalanx	?	distal	-	5	-
	5	2nd phalanx	?	proximal	-	5	-
	3	2nd phalanx	?	proximal	fragment	2	-
	1	3rd phalanx	?	complete	-	0	-
	1	residual 1st phalanx	?	complete	-	0	-
	3	residual 2nd phalanx	?	nearly complete	-	0	-
	1	residual 3rd phalanx	?	complete	-	0	-
Ictaluridae	1	hyomandibular	right	complete	-	0	-
	1	2nd dorsal spine	axial	complete	-	0	-
Ameiurus melas	1	pectoral spine	left	complete	-	0	-
unid. lg. mammal	223	-	-	-	-	100	-
unid. fish	1	-	-	-	-	0	-

*specimens compare favorably (cf.)

Table A.8. Identified mammal remains from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

Taxon	**NISP**	**Element**	**Side**	**Portion**	**Description**	**#GBF**	**Comments**
Rodentia	2	incisor?	?	fragment	-	0	-
cf. *Spermophilus tridecemlineatus*	1	tibia	left	diaphysis	-	0	-
Sciurus carolinensis	1	humerus	left	distal	-	0	1-scorched
Geomys bursarius	1	cranium	axial	anterior	-	0	-
	1	maxilla	left	complete	-	0	-
	1	mandible	left	nearly complete	-	0	-
	1	mandible	right	fragment	-	0	-
	1	incisor?	?	fragment	-	0	1-burned
	1	humerus	left	nearly complete	-	0	-
	1	humerus	right	nearly complete	-	0	-
	1	ulna	right	proximal	-	0	-
	1	radius	right	nearly complete	-	0	-
	1	innominate	right	-	60%	0	-
	1	femur	left	diaphysis	-	0	-
	1	femur	left	proximal	75%	0	-
	1	femur	right	nearly complete	-	0	-
	1	femur	right	proximal	-	0	-
	1	tibia	left	diaphysis	-	0	-
	1	tibia	left	distal	-	0	-
Castor canadensis	1	cranial	na	-	25%, frontals, molars	0	-
	1	internal auditory meatus	right	complete	-	0	-
	1	external auditory meatus	left	nearly complete	-	0	-
	1	occipital	axial	fragment	-	0	-
	2	occipital	left	condyle	-	0	1-calcined
	2	occipital	right	condyle	-	0	-
	1	premaxilla	left	dorsal	-	0	-
	1	premaxilla	right	dorsal	-	1	-
	1	premaxilla	right	ventral	-	0	-
	1	maxilla	axial	-	no teeth	0	-
	1	maxilla	right	posterior	-	0	-

Table A.8 (continued). Identified mammal remains from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

Taxon	**NISP**	**Element**	**Side**	**Portion**	**Description**	**#GBF**	**Comments**
Castor canadensis	2	P4	left	complete	-	0	-
	1	P4/M1?	right	fragment	-	0	-
	2	M1	left	nearly complete	-	0	-
	1	M1	right	complete	-	0	-
	1	M2	left	nearly complete	-	0	-
	1	M2	right	complete	-	0	-
	1	mandible	left	horizontal ramus	w/ p4, m1, m2, m3	0	-
	1	mandible	left	nearly complete	-	0	-
	1	mandible	left	posterior	angle	0	-
	2	mandible	left	posterior	condyle	0	-
	1	mandible	right	-	massetianc fossa	0	-
	1	mandible	right	fragment	-	1	1-burned
	1	mandible	right	nearly complete	w/ p4, m1, m2, m3	0	-
	1	i1	left	fragment	-	0	-
	1	i1	right	nearly complete	-	0	-
	1	p4	right	nearly complete	-	0	-
	1	m2	right	nearly complete	-	0	-
	20	incisor?	?	fragment	-	0	-
	1	premolar/molar?	?	fragment	-	0	-
	3	vertebra	axial	fragment	-	0	-
	1	vertebra	axial	nearly complete	-	0	-
	1	lumbar vertebra	axial	nearly complete	-	0	-
	3	caudal vertebra	axial	nearly complete	-	0	1-burned
	1	scapula	right	distal	glenoid	0	1-CG
	1	humerus	left	distal	-	1	-
	1	humerus	left	nearly complete	-	0	-
	2	humerus	right	distal	-	0	1-calcined
	1	humerus	right	nearly complete	-	0	-
	1	ulna	left	nearly complete	-	0	1-CG
	2	ulna	left	proximal	-	0	1-calcined
	1	ulna	right	distal	-	0	-
	1	metacarpal	?	nearly complete	-	0	-

Table A.8 (continued). Identified mammal remains from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

Taxon	NISP	Element	Side	Portion	Description	#GBF	Comments
Castor canadensis	2	innominate	right	acetabulum	-	0	2-CG, 1-RG
	1	innominate	right	posterior	-	0	1-calcined
	1	ilium	left	nearly complete	-	0	-
	1	femur	right	diaphysis	-	0	1-calcined, 1-CG
	1	tibia	right	distal	-	0	1-calcined
	1	tibia	right	distal	unfused epiphysis	0	-
	1	fibula	?	fragment	-	0	-
	1	fibula	left	diaphysis	distal fragment	0	-
	1	fibula	right	diaphysis	-	0	-
	1	fibula	right	proximal	-	0	-
	1	calcaneus	left	fragment	-	0	-
	1	1st metatarsal	left	complete	-	0	-
	1	4th metatarsal	right	nearly complete	-	0	-
	2	metapodial	?	proximal	-	0	1-calcined
	1	3rd phalanx	?	complete	-	0	-
cf. *Castor canadensis*	2	incisor	?	fragment	-	0	-
	3	thoracic vertebra	axial	fragment	-	0	-
	1	femur	?	proximal	unfused epiphysis (head)	0	-
Ondatra zibethicus	1	cranial	left	malar	-	0	-
	1	zygomatic	left	nearly complete	-	0	-
	1	maxilla	axial	fragment	-	0	-
	1	maxilla	left	-	w/ M1, M2	0	-
	1	maxilla	right	-	w/ M1	0	-
	1	maxilla	right	-	w/ M2	0	-
	1	M1	left	complete	-	0	-
	1	mandible	left	nearly complete	-	0	-
	1	mandible	right	nearly complete	-	0	-
	1	mandible	right	horizontal ramus	w/ m1, m2, m3	0	-
	1	incisor?	?	fragment	-	0	-
	2	atlas vertebra	axial	nearly complete	-	0	-
	1	caudal vertebra	axial	complete	-	0	-

Table A.8 (continued). Identified mammal remains from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

Taxon	NISP	Element	Side	Portion	Description	#GBF	Comments
Ondatra zibethicus	1	scapula	left	distal	-	1	-
	1	scapula	right	proximal	-	0	-
	1	humerus	left	distal	-	0	-
	1	humerus	right	distal	-	0	-
	1	ulna	left	proximal	-	0	-
	1	ulna	right	nearly complete	-	0	-
	1	ulna	right	proximal	-	0	-
	1	innominate	left	acetabulum	-	0	1-calcined
	1	innominate	right	nearly complete	-	0	-
	2	ilium	left	nearly complete	-	0	1-burned
	1	ilium	right	nearly complete	-	0	1-burned
	1	femur	left	diaphysis	-	0	-
	3	tibia	left	diaphysis	-	1	1-burned
	3	tibia	left	distal	-	2	1-burned
	4	tibia	right	diaphysis	-	0	1-scorched, 1-CG
	2	tibia	right	distal	-	0	1-CG
	3	tibia	right	proximal	-	0	1-burned
	1	tibia-fibula	right	diaphysis	-	0	-
	1	calcaneus	left	nearly complete	-	0	-
	1	calcaneus	right	nearly complete	-	0	-
	1	1st metatarsal	left	complete	-	0	-
cf. *Ondatra zibethicus*	1	I1	left	nearly complete	-	0	-
	1	i1	left	fragment	-	0	-
	2	vertebra	axial	nearly complete	-	0	-
	1	caudal vertebra	axial	nearly complete	-	0	-
Canis familiaris	1	cranium	na	posterior	posterior 25%	0	-
	1	frontal	left	nearly complete	-	0	-
	1	frontal	right	nearly complete	-	0	-
	1	maxilla	left	-	w/ P3, P4	0	-
	1	maxilla	right	-	50 %	0	-
	1	mandible	left	horizontal ramus	w/ c, p2, p3, m2	0	-

Table A.8 (continued). Identified mammal remains from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

Taxon	**NISP**	**Element**	**Side**	**Portion**	**Description**	**#GBF**	**Comments**
Canis familiaris	1	mandible	left	horizontal ramus	w/ p4, m1, m2	0	-
	1	mandible	right	nearly complete	w/ p3, m2	0	-
	2	m1	left	complete	-	0	-
	2	m1	right	complete	-	0	-
	1	axis vertebra	axial	anterior	-	0	1-CG
	1	humerus	right	proximal	-	0	-
	1	ulna	left	distal	-	1	-
	2	ulna	left	proximal	-	1	1-CG
	1	ulna	right	proximal	semi-lunar notch	0	-
	2	radius	left	proximal	-	1	-
	1	2nd metacarpal	right	nearly complete	-	0	1-CG
	1	3rd metacarpal	left	complete	-	0	-
	1	innominate	right	acetabulum	-	1	-
	2	femur	right	proximal	-	2	-
	1	astragalus	left	nearly complete	-	0	1-calcined
	1	calcaneus	right	complete	-	0	1-CG
Canis cf. *C. familiaris*	1	P3	left	nearly complete	-	0	-
	1	M1	left	nearly complete	-	0	-
	1	mandible	left	anterior	w/ p2	0	-
	1	metapodial	?	proximal	-	0	-
Canis lupus	1	ulna	left	proximal	-	1	1-CG
Canis cf. *C. lupus*	1	humerus	left	distal	-	1	1-CG
	1	3rd metatarsal	right	proximal	-	0	grooved and snapped
Canis sp.	1	cranium	left	-	squamous temporal	0	-
	1	nasal	right	nearly complete	-	0	-
	1	premaxilla	right	-	w/ I1, I2, I3	0	-
	1	maxilla	left	-	w/ M1	0	-
	1	P1	left	nearly complete	-	0	-
	1	p2/p3?	right	nearly complete	-	0	-
	1	p3/p4?	right	complete	-	0	-
	1	incisor?	?	nearly complete	-	0	-

Table A.8 (continued). Identified mammal remains from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

Taxon	NISP	Element	Side	Portion	Description	#GBF	Comments
Canis sp.	1	canine?	?	nearly complete	-	0	-
	1	premolar?	?	fragment	-	0	-
	1	premolar?	?	complete	-	0	-
	1	axis vertebra	axial	body	-	0	1-CG, 1-RG
	1	axis vertebra	axial	nearly complete	-	0	-
	1	cervical vertebra	axial	nearly complete	-	0	-
	1	thoracic vertebra	axial	body	-	0	-
	1	humerus	left	distal	-	1	1-calcined
	1	humerus	left	proximal	-	0	1-CG, 1-RG
	1	ulna	right	diaphysis	-	0	1-RG
	2	ulna	right	proximal	semi-lunar notch	0	1-calcined, 2-CG
	1	radius	right	diaphysis	-	0	-
	1	radius	right	proximal	-	0	-
	1	2nd metacarpal	left	complete	-	0	-
	1	3rd metacarpal	left	complete	-	0	-
	1	4th metacarpal	left	complete	-	0	-
	1	5th metacarpal	left	proximal	-	0	-
	1	5th metacarpal	right	complete	-	0	-
	1	5th metacarpal	right	proximal	-	0	-
	1	tibia	left	distal	-	0	-
	1	tibia	right	distal	-	0	-
	1	fibula	right	distal	-	0	-
	1	astragalus	left	nearly complete	-	0	-
	1	calcaneus	right	complete	-	0	-
	2	metapodial	?	nearly complete	-	0	1-RG
	1	metapodial	?	proximal	-	0	-
	1	metapodial	?	distal	unfused epiphysis	0	-
	1	1st phalanx	?	complete	-	0	-
	1	1st phalanx	?	nearly complete	-	0	-
cf. *Canis* sp.	1	fibula	left	proximal	-	0	1-calcined
	1	metapodial	?	proximal	-	0	1-calcined

Table A.8 (continued). Identified mammal remains from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

Taxon	NISP	Element	Side	Portion	Description	#GBF	Comments
cf. *Canis* sp.	1	1st phalanx	?	complete	-	0	-
Canidae	1	I2	right	complete	-	0	-
	1	M1	left	complete	-	0	1-burned
	1	m1	left	nearly complete	-	0	-
	1	canine?	?	fragment	-	0	-
	1	canine?	right	nearly complete	-	0	-
	1	atlas vertebra	axial	nearly complete	-	0	-
	4	cervical vertebra	axial	nearly complete	-	0	-
	1	vertebra	axial	fragment	-	0	-
	1	vertebra	axial	nearly complete	-	0	-
	1	rib	?	nearly complete	-	0	-
	1	rib	left	complete	-	0	-
	1	humerus	left	diaphysis	deltoid tuberosity	1	-
	1	humerus	right	diaphysis	deltoid tuberosity	1	-
	1	radius	left	proximal	-	0	1-CG
	1	2nd metacarpal	right	complete	-	0	-
	1	3rd metacarpal	right	complete	-	0	-
	1	4th metacarpal	right	complete	-	0	-
	1	femur	left	proximal	-	1	-
	2	femur	right	proximal	-	0	1-CG
	1	tibia	left	proximal	-	1	1-CG
	1	tibia	right	diaphysis	-	0	-
	2	tibia	right	proximal	-	1	-
	1	tibia	right	proximal	lateral fragment	0	-
	1	calcaneus	left	distal	-	0	1-calcined
	1	5th metatarsal	left	proximal	-	1	-
	1	metapodial	?	distal	-	0	-
Ursus americanus	1	vertebra	axial	nearly complete	-	0	1-CG
	1	humerus	right	diaphysis	deltoid tubersoity	1	-
	1	ulna	right	proximal	-	1	very large individual
	1	innominate	right	acetabulum	-	1	-

Table A.8 (continued). Identified mammal remains from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

Taxon	**NISP**	**Element**	**Side**	**Portion**	**Description**	**#GBF**	**Comments**
Ursus americanus	1	metapodial	?	distal	-	0	1-RG
	1	astragalus	right	nearly complete	-	0	1-CG
	1	4th metatarsal	left	complete	-	0	-
	1	3rd phalanx	?	nearly complete	-	0	1-burned
Procyon lotor	1	cranium	axial	-	75% complete	0	-
	1	M2	left	nearly complete	-	0	-
	1	mandible	left	anterior	-	0	-
	1	mandible	left	-	w/ sockets for m1, m2	0	-
	1	mandible	right	fragment	-	0	-
	1	mandible	right	horizontal ramus	-	0	1-burned
	1	m2	left	nearly complete	-	0	-
	1	ulna	left	proximal	semi-lunar notch	0	-
	1	ulna	right	proximal	-	0	-
	1	tibia	left	distal	-	0	-
Mustela vison	1	cranium	axial	anterior	-	0	-
	1	mandible	right	horizontal ramus	-	0	-
Taxidea taxus	1	occipital	axial	occipital crest	-	0	-
	1	scapula	left	distal	glenoid	0	-
	1	humerus	left	distal	-	0	-
Mephitis mephitis	1	maxilla	left	nearly complete	-	0	-
Lutra canadensis	1	mandible	left	horizontal ramus	-	0	1-calcined
Lynx rufus	1	tibia	right	distal	-	0	1-calcined
	1	astragalus	left	nearly complete	-	0	1-ING
Cervidae	97	antler	?	fragment	-	0	-
	2	tooth	?	fragment	-	0	-
Cervus canadensis	1	frontal	right	nearly complete	w/ attached antler base	0	-
	1	premolar/molar?	?	fragment	-	0	-
	1	atlas vertebra	axial	nearly complete	-	0	lg - male?
	2	thoracic vertebra	axial	body	-	0	1-CG
	3	lumbar vertebra	axial	complete	-	0	-
	1	vertebra	axial	spinous process	-	0	-
	1	scapula	left	posterior	posterior border	1	-

Table A.8 (continued). Identified mammal remains from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

Taxon	NISP	Element	Side	Portion	Description	#GBF	Comments
Cervus canadensis	1	scapula	right	proximal	ventral fragment	0	-
	1	humerus	right	distal	medial condyle fragment	1	-
	1	ulnar carpal	left	complete	-	0	1-CG
	1	4th carpal	right	complete	-	0	-
	1	accessory carpal	right	complete	-	0	-
	1	innominate	right	acetabulum	-	1	1-CG
	1	tibia	left	distal	anterior process	1	-
	1	metatarsal	?	proximal	ventral fragment	1	-
	1	metatarsal	right	distal	missing UE	1	1-CG
	1	metatarsal	right	proximal	ventral fragment	1	-
	1	astragalus	left	complete	-	0	-
	1	astragalus	right	complete	-	0	-
	1	astragalus	right	proximal	medial condyle	1	-
	1	metapodial	?	distal	-	1	1-CG
	1	metapodial	?	distal	unfused epiphysis	0	-
	1	residual metapodial	?	proximal	-	0	-
	5	sesamoid	?	nearly complete	-	0	-
	1	1st phalanx	?	diaphysis	-	1	1-calcined
	1	1st phalanx	?	diaphysis	dorsal	0	-
	1	1st phalanx	?	diaphysis	ventral	1	-
	9	1st phalanx	?	distal	-	6	1-burned, 1-CG
	1	1st phalanx	?	dorsal	-	0	-
	1	1st phalanx	?	nearly complete	-	1	-
	1	1st phalanx	?	posterior	-	1	-
	8	1st phalanx	?	proximal	-	6	1-CG
	2	2nd phalanx	?	complete	-	0	-
	6	2nd phalanx	?	distal	-	4	1-CG
	3	2nd phalanx	?	distal	dorsal fragment	0	-
	9	2nd phalanx	?	proximal	-	9	1-CG
	1	2nd phalanx	?	proximal	dorsal-medial fragment	1	-
	1	3rd phalanx	?	complete	-	0	-
	1	3rd phalanx	?	distal	-	0	-

Table A.8 (continued). Identified mammal remains from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

Taxon	**NISP**	**Element**	**Side**	**Portion**	**Description**	**#GBF**	**Comments**
Cervus canadensis	2	3rd phalanx	?	proximal	-	0	1-CG
	1	residual 2nd phalanx	?	nearly complete	-	0	1-burned
Odocoileus virginianus	1	cranial	right	-	squamous temporal	0	-
	1	frontal	axial	-	both right and left	0	fawn
	1	frontal	right	-	w/ sphenoid	0	-
	1	frontal	right	anterior	-	0	-
	1	zygomatic	right	nearly complete	-	0	-
	1	parietal	left	fragment	-	1	-
	1	palatine	axial	fragment	-	0	-
	1	occipital	axial	dorsal	-	0	-
	1	occipital	axial	ventral	-	0	-
	1	occipital	left	occipital condyle	-	0	-
	1	occipital	right	condyle	-	0	-
	1	occipital	right	fragment	-	0	-
	1	occipital	axial	ventral	-	0	1-CG, 1-UE
	1	antler	?	fragment	-	0	-
	1	antler	?	fragment	-	0	1-calcined
	1	antler	?	tip	-	0	-
	1	premaxilla	left	nearly complete	-	0	-
	1	maxilla	left	-	w/ P4, M1, M2, M3	0	aged 2-3 years
	1	maxilla	right	-	w/ dP2, dP3, dP4, M1, M2	0	aged 13-17 months
	1	P2	right	complete	-	0	-
	1	M1	right	nearly complete	-	0	-
	1	M2	right	nearly complete	-	0	-
	2	M2	right	nearly complete	-	0	-
	1	M3	left	fragment	-	0	-
	2	M3	right	nearly complete	-	0	-
	1	mandible	left	anterior	w/ mental foramen	0	1-burned
	1	mandible	left	condyle	-	0	1-burned
	1	mandible	left	diastema	-	0	-
	1	mandible	left	posterior	w/ angle and condyle	0	-

Table A.8 (continued). Identified mammal remains from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

Taxon	NISP	Element	Side	Portion	Description	#GBF	Comments
Odocoileus virginianus	1	mandible	right	anterior	-	1	-
	1	mandible	right	anterior	fragment w/ mental foramen	0	1-burned
	1	mandible	right	anterior	w/ mandibular foramen	0	-
	1	mandible	right	horizontal ramus	w/ p2, p3, p4, m1, m2	1	aged 5-6.5 years
	1	mandible	right	horizontal ramus	w/ sockets for p2, p3, p4, m1	0	-
	1	mandible	right	posterior	angle	1	-
	1	mandible	right	posterior	condyle	0	1-CG
	1	p2	right		-	0	-
	1	m1	right	nearly complete	-	0	aged 3-3.5 years
	1	m2	right	nearly complete	-	0	aged 3-3.5 years
	1	m1/m2/m3?	right	nearly complete	-	0	-
	5	premolar/molar?	?	fragment	-	0	-
	3	molar?	?	fragment	-	0	-
	4	tooth	?	fragment	-	0	-
	1	atlas vertebra	axial	lateral	left 1/2	0	1-CG
	1	atlas vertebra	axial	right	-	0	-
	1	axis vertebra	axial	anterior	-	0	-
	1	axis vertebra	axial	posterior	spinous process	0	-
	1	cervical vertebra	axial	lateral	-	0	-
	1	cervical vertebra	axial	nearly complete	-	0	1-CG
	1	cervical vertebra	axial	posterior	-	0	-
	1	lumbar vertebra	axial	dorsal	spinous process	0	-
	1	lumbar vertebra	axial	lateral	lateral process	0	-
	1	lumbar vertebra	axial	nearly complete	-	0	-
	1	caudal vertebra	axial	nearly complete	-	0	-
	1	vertebra	axial	nearly complete	-	0	-
	2	scapula	left	posterior	posterior border	1	1-CG

Table A.8 (continued). Identified mammal remains from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

Taxon	NISP	Element	Side	Portion	Description	#GBF	Comments
Odocoileus virginianus	1	scapula	left	posterior	posterior border and angle	0	-
	1	scapula	right	anterior	anterior border + spine	0	-
	1	scapula	right	proximal	-	0	1-CG
	1	humerus	?	distal	condyle fragment	0	-
	2	humerus	left	diaphysis	olecranon fossa	2	1-CG
	2	humerus	left	diaphysis	posterior fragment	2	-
	1	humerus	left	distal	epiphysis	1	-
	1	humerus	left	distal	lateral condyle fragment	1	-
	1	humerus	left	distal	medial condyle	1	-
	1	humerus	left	proximal	lateral tubersoity	0	-
	1	humerus	left	proximal	unfused epiphysis	0	-
	1	humerus	right	diaphysis	anterior fragment	1	-
	1	humerus	right	distal	epiphysis	0	-
	3	humerus	right	distal	lateral condyle	1	-
	1	humerus	right	distal	medial 1/2 of olecranon fossa	1	-
	1	humerus	right	distal	medial condyle	1	-
	1	humerus	right	proximal	head fragment	0	-
	1	humerus	right	proximal	unfused epiphysis (lateral tuberosity)	0	-
	1	ulna	left	diaphysis	-	0	-
	2	ulna	left	distal	-	0	-
	2	ulna	left	proximal	olecranon process	1	-
	2	ulna	left	proximal	semi-lunar notch	1	1-calcined
	1	ulna	right	diaphysis	-	0	-
	1	ulna	right	distal	styloid process	0	-
	1	ulna	right	proximal	-	0	-
	4	ulna	right	proximal	semi-lunar notch	2	-
	1	radius	?	diaphysis	posterior fragment	1	-
	1	radius	left	diaphysis	lateral fragment	1	1-calcined
	1	radius	left	distal	-	1	-
	1	radius	left	distal	posterior fragment	1	-

Table A.8 (continued). Identified mammal remains from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

Taxon	NISP	Element	Side	Portion	Description	#GBF	Comments
Odocoileus virginianus	1	radius	left	proximal	-	1	-
	1	radius	left	proximal	medial fragment	1	-
	1	radius	left	proximal	posterior fragment	1	-
	1	radius	right	diaphysis	distal-lateral fragment	1	-
	1	radius	right	distal	-	0	1-CG
	1	radius	right	distal	anterior fragment	0	-
	2	radius	right	distal	unfused epiphysis	0	-
	1	radius	right	proximal	-	1	-
	1	radius	right	proximal	medial 1/2	0	-
	1	radius	right	proximal	ulnar articular facets	0	-
	2	radial carpal	left	complete	-	0	-
	1	radial carpal	right	complete	-	0	-
	1	radial carpal	right	nearly complete	-	0	-
	2	ulnar carpal	left	complete	-	0	-
	4	ulnar carpal	right	nearly complete	-	1	2-CG, 1-ING
	1	intermediate carpal	left	complete	-	0	-
	1	intermediate carpal	right	complete	-	0	-
	2	2nd + 3rd carpal	left	complete	-	0	-
	2	4th carpal	left	complete	-	0	-
	1	4th carpal	left	fragment	-	0	1-ING
	1	4th carpal	right	nearly complete	-	0	-
	1	accessory carpal	?	nearly complete	-	0	-
	1	accessory carpal	right	complete	-	0	-
	1	metacarpal	?	diaphysis	-	1	-
	2	metacarpal	?	diaphysis	dorsal fragment w/ vascular groove	0	1-burned
	2	metacarpal	?	distal	epiphysis	0	-
	1	metacarpal	left	proximal	-	1	-
	2	metacarpal	left	proximal	dorsal fragment	1	1-CG
	1	metacarpal	right	diaphysis	lateral fragment	1	-
	1	metacarpal	right	distal	35%	1	-
	1	metacarpal	right	proximal	epiphysis	1	-

Table A.8 (continued). Identified mammal remains from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

Taxon	**NISP**	**Element**	**Side**	**Portion**	**Description**	**#GBF**	**Comments**
Odocoileus virginianus	1	metacarpal	right	proximal	lateral 1/2	0	1-calcined
	1	metacarpal	right	proximal	medial fragment	0	-
	4	residual metacarpal	?	distal	-	0	-
	1	residual metacarpal	?	nearly complete	-	0	-
	1	residual metacarpal	?	proximal	-	0	-
	1	innominate	left	acetabulum	-	1	-
	1	innominate	left	acetabulum	posterior 1/3 of acetabulum	1	-
	1	pubis	right	acetabulum	-	1	-
	1	femur	left	diaphysis	ventral fragment	1	-
	2	femur	left	distal	fragment	1	-
	1	femur	left	distal	medial condyle	0	-
	1	femur	left	proximal	greater trochanter	0	-
	1	femur	left	proximal	unfused epiphysis (head)	0	-
	1	femur	right	diaphysis	distal fragment	0	-
	2	femur	right	diaphysis	posterior w/ linea aspera	2	-
	1	femur	right	proximal	epiphysis	1	1-CG
	2	femur	right	proximal	unfused epiphysis (head)	0	-
	1	patella	?	fragment	-	0	-
	1	patella	right	complete	-	0	-
	1	patella	right	nearly complete	-	0	-
	2	tibia	left	diaphysis	anterior crest	1	-
	1	tibia	left	diaphysis	distal	1	1-scorched, 1-CG
	2	tibia	left	diaphysis	distal-anterior fragment	2	1-burned
	1	tibia	left	distal	medial malleolus	1	-
	2	tibia	left	distal	epiphysis	1	-
	2	tibia	left	distal	unfused epiphysis	0	-
	1	tibia	left	proximal	epiphysis	1	-
	1	tibia	left	proximal	unfused epiphysis (lateral condyle)	0	-
	1	tibia	right	diaphysis	proximal fragment	1	-
	2	tibia	right	distal	epiphysis	2	-

Table A.8 (continued). Identified mammal remains from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

Taxon	NISP	Element	Side	Portion	Description	#GBF	Comments
Odocoileus virginianus	1	tibia	right	distal	lateral-anterior fragment	0	-
	1	tibia	right	distal	unfused epiphysis	0	-
	2	tibia	right	proximal	unfused epiphysis	0	-
	1	tibia	right	proximal	posterior fragment	1	-
	1	lateral malleolus	left	complete	-	0	-
	1	lateral malleolus	left	nearly complete	-	0	-
	2	metatarsal	?	diaphysis	dorsal fragment	2	-
	4	metatarsal	?	diaphysis	dorsal w/ vascular groove	3	-
	1	metatarsal	?	distal	epiphysis	0	-
	1	metatarsal	?	proximal	ventral fragment	0	-
	1	metatarsal	left	diaphysis	dorsal w/ vascular groove	1	-
	1	metatarsal	left	proximal	epiphysis	1	1-CG
	2	metatarsal	left	proximal	dorsal fragment	2	-
	2	metatarsal	left	proximal	dorsal-lateral fragment	0	-
	2	metatarsal	right	diaphysis	dorsal w/ vascular groove	2	1-calcined
	1	metatarsal	right	diaphysis	ventral fragment	1	-
	1	metatarsal	right	proximal	epiphysis	0	-
	2	metatarsal	right	proximal	dorsal fragment	2	-
	1	metatarsal	right	proximal	ventral fragment	1	-
	2	metapodial	?	diaphysis	-	2	1-CG
	3	metapodial	?	distal	condyle	2	-
	3	metapodial	?	distal	condyle fragment	1	1-calcined
	2	metapodial	?	distal	unfused epiphysis (condyle)	0	-
	3	residual metapodial	?	distal	-	0	1-scorched, 1- calcined
	4	residual metapodial	?	nearly complete	-	0	-
	1	residual metapodial	?	proximal	-	0	-
	2	astragalus	left	complete	-	0	-
	1	astragalus	left	distal	-	0	-
	2	astragalus	left	nearly complete	-	0	-
	2	astragalus	right	complete	-	0	-
	1	astragalus	right	nearly complete	-	0	-

Table A.8 (continued). Identified mammal remains from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

Taxon	NISP	Element	Side	Portion	Description	#GBF	Comments
Odocoileus virginianus	2	calcaneus	left	anterior	-	0	-
	2	calcaneus	left	complete	-	0	1-CG
	2	calcaneus	left	nearly complete	-	0	1-CG
	3	calcaneus	left	proximal	-	1	1- burned, 1-RG
	4	calcaneus	right	complete	-	0	-
	1	calcaneus	right	proximal	-	1	-
	1	naviculo-cuboid	left	complete	-	0	-
	1	naviculo-cuboid	left	dorsal	-	0	1-calcined
	1	naviculo-cuboid	right	complete	-	0	-
	2	naviculo-cuboid	right	medial	-	2	-
	1	2nd + 3rd tarsal	left	complete	-	0	-
	1	2nd + 3rd tarsal	right	complete	-	0	-
	4	sesamoid	?	complete	-	0	1-burned, 1-calcined
	1	sesamoid	?	nearly complete	-	0	1-calcined
	1	1st phalanx	?	complete	-	0	1-UE
	1	1st phalanx	?	diaphysis	dorsal fragment	0	-
	1	1st phalanx	?	diaphysis	lateral fragment	0	1-CG
	1	1st phalanx	?	diaphysis	ventral fragment	0	-
	15	1st phalanx	?	distal	epiphysis	12	1-burned, 4-CG
	3	1st phalanx	?	distal	dorsal fragment	3	-
	1	1st phalanx	?	distal	lateral fragment	0	-
	1	1st phalanx	?	distal	medial fragment	1	-
	12	1st phalanx	?	proximal	epiphysis	7	1-calcined, 1- CG
	1	1st phalanx	?	proximal	unfused epiphysis	0	-
	1	2nd phalanx	?	complete	-	0	-
	4	2nd phalanx	?	diaphysis	dorsal fragment	3	-
	1	2nd phalanx	?	diaphysis	medial fragment	0	1-burned
	3	2nd phalanx	?	diaphysis	ventral fragment	3	1-burned
	5	2nd phalanx	?	distal	epiphysis	3	1-ING

Table A.8 (continued). Identified mammal remains from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

Taxon	NISP	Element	Side	Portion	Description	#GBF	Comments
Odocoileus virginianus	3	2nd phalanx	?	distal	dorsal fragment	1	1-burned, 1-calcined
	1	2nd phalanx	?	distal	lateral fragment	1	1-calcined
	2	2nd phalanx	?	distal	ventral fragment	1	1-calcined
	7	2nd phalanx	?	proximal	epiphysis	3	1-burned, 1-calcined, 1-CG
	1	2nd phalanx	?	proximal	unfused epiphysis	0	-
	13	3rd phalanx	?	complete	-	0	2-RG
	5	3rd phalanx	?	distal	-	0	1-CG, 1-cut for projectile point
	1	3rd phalanx	?	nearly complete	-	0	-
	4	3rd phalanx	?	proximal	-	0	1-calcined, 1-CG
	1	residual 1st phalanx	?	complete	-	0	-
	2	residual 2nd phalanx	?	complete	-	0	-
	2	residual 3rd phalanx	?	complete	-	0	-
	3	residual 3rd phalanx	?	nearly complete	-	0	-
cf. *Odocoileus virginianus*	12	vertebra	axial	fragment	-	0	-
	1	scapula	left	dorsal	dorsal border	1	-
	1	humerus	right	diaphysis	anterior fragment	0	-
	1	pubis	left	fragment	-	0	-
	1	tibia	?	proximal	unfused epiphysis (fragment)	0	-
	1	tibia	right	diaphysis	anterior crest	0	1-calcined
Bison bison	1	scapula	?	fragment	-	0	1-RG
	1	scapula	?	fragment	w/ spine	0	1-burned
	1	scapula	right	distal	glenoid cavity	0	1-CG
	1	scapula	right	spine	fragment	1	-
unid. sm. mammal	11	vertebra	axial	nearly complete	-	0	6-burned

Table A.8 (continued). Identified mammal remains from Feature 205 at the Sanford Archaeological District, Locality 32 (47LC394-32).

Taxon	NISP	Element	Side	Portion	Description	#GBF	Comments
unid. med. mammal	1	thoracic vertebra	axial	nearly complete	-	0	-
	1	thoracic vertebra	axial	spinous process	-	0	1-burned
	52	vertebra	axial	fragment	-	0	1-burned, 3-calcined, 1-CG
	46	rib	?	fragment	-	0	3-burned, 2-calcined
unid. lg. mammal	73	vertebra	axial	fragment	-	0	1-scorched, 3-burned, 1-calcined, 3-UE
	46	rib	?	fragment	-	0	1-burned, 1-calcined, 1-RG, 5-CG
unid. mammal	21	rib	?	fragment	-	0	1-burned, 2-CG
	41	vertebra	axial	fragment	-	0	1-calcined, 2-burned
	3352	-	-	-	-	365	45-scorched, 355-burned, 690-calcined

VITA

Jonathan Douglas Baker was born on July 29, 1980 in Hillsboro, Wisconsin. He grew up near the rural village of Wonewoc, Wisconsin and graduated from Wonewoc-Center High School in May, 1998. He received his Bachelor of Science degree from the University of Wisconsin-La Crosse in May, 2003, where he majored in Archaeological Studies, with minors in Anthropology, Geoarchaeology, and University Honors. Following graduation, Jonathan was employed as a Research Intern at the Mississippi Valley Archaeology Center of the University of Wisconsin-La Crosse. While in La Crosse, he participated in numerous excavations and served as the senior Teaching Assistant for three college field schools.

In the fall of 2004, Jonathan entered the University of Tennessee in order to pursue a Master of Arts degree in Anthropology, with a concentration in Zooarchaeology. During his first year of study at Tennessee, Jonathan was supported by a Hilton A. Smith Graduate Fellowship and he subsequently severed as both a Graduate Teaching Associate and Research Assistant/Laboratory Supervisor for the Department of Anthropology's extensive Zooarchaeological Comparative Collection. Following the completion of this thesis and the conferral of the Master's degree, Jonathan continues his education at the University of Tennessee in pursuit of a Ph.D. degree in Anthropology.

Jonathan and his wife, Stephaine Michelle Baker, currently reside in Knoxville, Tennessee. They have a daughter, Anna Elaine Baker, who was born on January 5, 2007.